Scilab Textbook Companion for Integrated Circuits by P. Raja[1]

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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

Analog Integrated Circuit Design

Scilab code Exa 1.1 Lowest value of VO

```
//Ex 1.1
clc;clear;close;
VDD=1.8;//V
IREF=50;//micro A
IO=IREF;//micro A
L=0.5;//micro m
W=5;//micro m
Vt=0.5;//V
Kn_dash=250;//micro A/V^2
VGS=sqrt(IO/(1/2*Kn_dash*(W/L)))+Vt;//V
disp(VGS,"Value of VGS(V) : ");
R=(VDD-VGS)/(IREF*10^-6);//ohm
disp(R/1000,"Value of R(kohm) : ");
VDS2=VGS-Vt;//V
VO=VDS2;//V
disp(VO,"Lowest value of VO(V) : ");
```

Scilab code Exa 1.3 Design a current source

```
//Ex 1.3
clc;clear;close;
VDD=1.8;//V
Vt=0.6;//V
mpCox=100;//micro A/V^2
IREF=80;//micro A
VOmax=1.6;//V
VSG=VDD-VOmax+Vt;//V
VGS=-VSG;//V
VS=VDD;//V
VG=VGS+VS;//V
R=VG/(IREF*10^-6);//ohm
ID=IREF;//micro A
WbyL=2*ID*10^-6/(mpCox*10^-6)/(VGS+Vt)^2;//unitless
disp(VGS,"Value of VGS(V) : ");
disp(VG,"Value of VG(V) : ");
disp(R/1000,"Value of R(kohm) : ");
disp(WbyL,"W/L ratio : ");
```

Scilab code Exa 1.3.1 Current gain

```
//Ex 1.3 at page no. 20
clc;
clear;
format('v',5);
close;
Beta=20;//unitless
IObyIREF=1/(1+2/Beta);//Current gain
disp(IObyIREF,"Current gain : ");
```

Scilab code Exa 1.4 Current transfer ratio

```
//Ex 1.4
clc;clear;close;
format('v',5);
Beta=80;//unitless
disp("IREF=IC1+IC1/Beta+IO/Beta");
disp("IO/IREF=m implies IC1=IO/m as IC1=IREF");
disp("IREF=IO*(1/m+1/m/Beta+1/Beta");
disp("IO/IREF=m/(1+1/Beta+m/Beta");
disp("IO/IREF=m*(1-5/100);//for large Beta");
m=(1/(1-5/100)-1)*Beta-1;//Current transfer ratio
disp(m,"Largest current transfer ratio : ");
```

Scilab code Exa 1.7 Transistor ratio

```
//Ex 1.7
clc;clear;close;
format('v',5);
Beta=80;//untless
disp("IREF=IC1+IC1/Beta+IO/Beta");
disp("IO/IREF=m implies IC1=IO/m as IC1=IREF");
disp("IREF=IO*(1/m+1/m/Beta+1/Beta");
disp("IO/IREF=m/(1+1/Beta+m/Beta");
disp("IO/IREF=m*(1-5/100);//for large Beta");
m=(1/(1-5/100)-1)*Beta-1;//Current transfer ratio
disp(m,"Largest current transfer ratio : ");
```

Scilab code Exa 1.9 Current gain

```
//Ex 1.9
clc;
clear;
close;
format('v',5);
```

```
Beta=20;//unitless
IObyIREF=1/(1+2/Beta);//Current gain
disp(IObyIREF,"Current gain : ");
```

Scilab code Exa 1.10 Change in IO

```
//Ex 1.10
clc;clear;close;
IREF=2;//mA
IO=IREF;//mA
VA2=90;//V
Vo1=1;//V
Vo2=10;//V
ro2=VA2/IO;//kohm
delVO=Vo2-Vo1;//V
delIO=delVO/ro2;//mA
Change=delIO/IO*100;//%
disp(Change,"Change in Io(%) : ");
```

Scilab code Exa 1.11 Lowest output voltage

```
//Ex 1.11
clc;clear;close;
VBE3=0.7;//V
VBE1=0.7;//V
IREF1=100;//micro A
IC1=IREF1;//micro A
IREF2=1;//mA
IC2=IREF2;//mA
Beta=200;//unitless
//IC2/IC1=(IS*exp(VBE2/VT))/(IS*exp(VBE1/VT))
VT=26;//mV
```

```
deltaVBE=VT*10^-3*log(IC2/IC1);//V(deltaVBE=VBE2-VBE1)
deltaVx=2*deltaVBE;//V
IO=IREF1/(1+2/(Beta^2+Beta));//micro A
delIO=IC1-IO;//micro A
Change=delIO/IO*100;//%
disp(Change,"Change in Io(%) : ");
```

Scilab code Exa 1.12 Design a current mirror circuit

```
//Ex 1.12
clc;clear;close;
format('v',5);
Iout=8;//micro A
VBE=0.7;//V
VCC=20;//V
Beta=80;//unitless
IREF=Iout*(1+2/Beta);//micro A
disp(IREF,"Reference current is(micro A) : ");
R=(VCC-VBE)/(IREF);//Mohm
disp(R,"Resistance is(Mohm) : ");
```

Scilab code Exa 1.13 Design a current mirror circuit

```
//Ex 1.13
clc;clear;close;
format('v',5);
Iout=1;//mA
VBE=0.7;//V
VCC=30;//V
Beta=100;//unitless
IREF=Iout*(1+2/Beta);//mA
disp(IREF,"Reference current is(mA) : ");
```

```
R=(VCC-VBE)/(IREF);//kohm
disp(R,"Resistance is(kohm) : ");
```

Scilab code Exa 1.14 CIrcuit of current source

```
//Ex 1.14
clc;clear;close;
format('v',5);
Iout=0.5;//mA
VBE=0.7;//V
VCC=5;//V
Beta=50;//unitless
IREF=Iout*(1+2/Beta);//mA
disp(IREF,"Reference current is(mA) : ");
R=(VCC-VBE)/(IREF);//kohm
disp(R,"Resistance is(kohm) : ");
```

Scilab code Exa 1.15 Modified current mirror circuit

```
//Ex 1.15
clc;clear;close;
format('v',5);
Iout=8;//micro A
VBE=0.7;//V
VCC=20;//V
Beta=100;//unitless
IREF=Iout*(1+2/Beta/(Beta+1));//micro A
disp(IREF,"Reference current is(micro A) : ");
R=(VCC-2*VBE)/(IREF);//Mohm
disp(R,"Resistance is(Mohm) : ");
```

Scilab code Exa 1.16 Find Iout

```
//Ex 1.16
clc;clear;close;
format('v',5);
Beta=120;//unitless
VBE=0.7;//V
VCC=10;//V
R=5.6;//kohm
//IREF=IC1+I1;as Beta>>1
//I1=IC2+IB3;as Beta>>1
IREF=(VCC-VBE)/R;//mA
//IREF=IC*(2+1/Beta) or IREF=2*IC;as Beta>>1
IC=IREF/2;//mA
Iout=IC;//mA
disp(Iout,"Iout for the circuit is(mA) : ");
```

Scilab code Exa 1.17 Design a widlar current source

```
//Ex 1.17
clc;clear;close;
format('v',5);
Iout=6;//micro A
IREF=1.2;//mA
VBE2=0.7;//V
VT=26;//mV
VCC=20;//V
Beta=120;//unitless
R=(VCC-VBE2)/IREF;//kohm
IC2=(IREF-Iout/Beta)/(1+1/Beta);//mA
RS=VT/Iout*log(IC2*1000/Iout);//kohm
disp(RS,R,"Value of resistance R & Rs for widlar
    current source design is(kohm) : ");
```

Scilab code Exa 1.18 Design a widlar current source

```
//Ex 1.18
clc;clear;close;
format('v',5);
IREF=1;//mA
IO2=20;//micro A
IO3=40;//micro A
VBE1=0.7;//V
VT=26;//mV
VCC=10;//V
VEE=-VCC;//V
R=(VCC-VBE1-VEE)/IREF;//kohm
RE2=VT*10^-3/(IO2*10^-6)*log((IREF*10^-3)/(IO2
    *10^-6));//ohm
RE2=RE2/1000;//kohm
RE3=VT*10^-3/(IO3*10^-6)*log((IREF*10^-3)/(IO3
    *10^-6));//ohm
RE3=RE3/1000;//kohm
disp(RE3,RE2,R,"Value of resistance R, RE2 & RE3 for
     widlar current source design is(kohm) : ");
VBE2=VBE1-RE2*IO2*10^-3;//V
VBE3=VBE1-RE3*IO3*10^-3;//V
format('v',7);
disp(VBE3,VBE2,"Values of VBE2 & VBE3(V) : ");
```

Scilab code Exa 1.19 Calculate current

```
//Ex 1.19
clc;clear;close;
format('v',5);
Beta=100;//unitless
```

```
VBE=0.715;//V
VEE=10;//V
R=5.6;//kohm
IREF=(VEE-VBE)/R;//mA
IC1=IREF/(1+2/Beta);//mA
disp(IC1,"Collector current in each transistor is
   equal as all are identical. It is(mA) : ");
IRC=3*IC1;//mA
disp(IRC,"Current through resistance Rc is (mA) : ")
   ;
```

Scilab code Exa 1.20 IC1 IC2 and RC

```
//Ex 1.20
clc;clear;close;
format('v',6);
Vout=5;//V
Beta=180;//unitless
VBE=0.7;//V
VEE=10;//V
Vout=5;//V
R1=22;//kohm
R2=2.2;//kohm
IREF=(VEE-VBE)/R1;//mA
IC=(IREF-VBE/R2)/(1+2/Beta);//mA
IC1=IC*1000;//micro A(as VBE1=VBE2 IC1=IC2)
IC2=IC*1000;//micro A
disp(IC2,IC1,"Current IC1 & IC2 (micro A) : ");
RC=(VEE-Vout)/(IC1*10^-3);//kohm
disp(RC,"Value of Rc is (kohm) : ");
//Answer is wrong in the textbook.
```

Scilab code Exa 1.21 IC2 IC3 IC4

```
//Ex 1.21
clc;clear;close;
format('v',6);
AQ2byA1=0.5;
AQ3byA1=0.25;
AQ4byA1=0.125;
VBE=0.7;//V
VCC=15;//V
R=20;//kohm
IC1=(VCC-VBE)/R;//mA
IC2=IC1*AQ2byA1;//mA
IC3=IC1*AQ3byA1;//mA
IC4=IC1*AQ4byA1;//mA
disp(IC4,IC3,IC2,"Value of current IC2, IC3 & IC4 is
    (mA) : ");
//Value of IC4 is displayed wrong in the textbook.
```

Chapter 2

The 741 IC OPamp

Scilab code Exa 2.1 Input reference current

```
//Ex 2.1
clc;clear;close;
format('v',6)
VCC=5;//V
IS=10^-14;//A
RS=39*1000;//ohm
VBE12=0.7;//V(Assumed)
VBE11=0.7;//V(Assumed)
VEE=-5;//V
IREF=(VCC-VBE12-VBE11-VEE)/RS*10^6;//micro A
disp(IREF,"Estimated input reference current , IREF(micro A)");
VT=25*10^-3;//V(Thermal Voltage)
VBE=VT*log(IREF*10^-6/IS);//V
IREF=(VCC-VBE-VBE-VEE)/RS*10^6;//micro A
format('v',5)
disp(IREF,"More precise value of reference current , IREF(micro A)");
//Replacing Vcc by 15 V in the original design
VCC2=15;//V
VEE2=-15;//V
```

```
IREF=(VCC2-VBE-VBE-VEE2)/RS*10^6;//micro A
VBE=VT*log(IREF*10^-6/IS);//V
R5=(VCC-VBE-VBE-VEE)/(IREF*10^-6);//ohm
R5=round(R5/1000);//kohm
disp(R5,"Value of R5(kohm) : ");
```

Scilab code Exa 2.2 Design a widlar current source

```
//Ex 2.2
clc;clear;close;
format('v',5);
IC10=20*10^-6;//A
IREF=0.5*10^-3;//A
IS=10^-14;//A
VT=25*10^-3;//V(Thermal Voltage)
R4=VT/IC10*log(IREF/IC10);//ohm
disp(R4/1000,"For Widlar current source design, the
    value of R4(kohm) : ");
```

Scilab code Exa 2.3 Slew rate

```
//Ex 2.3
clc;clear;close;
format('v',5)
Gm1=10;//mA/V
Gm1=Gm1/1000;//A/V
Cc=50;//pF
Cc=Cc*10^-12;//F
Rt=10^8;//ohm(Shunting resistance with Cc)
Ao=Gm1*Rt;// unitless
fp=1/(2*%pi*Rt*Cc);//Hz
ft=Gm1/(2*%pi*Cc)/10^6;//MHz
```

```
disp(fp,"Frequency at which gain is maximum, fp in
    Hz");
disp(ft,"Unit gain frequency, ft(MHz)");
//Bode plot can not be plotted with the given data
    in the question by using scilab functions.
```

Scilab code Exa 2.4 Full power Bandwidth

```
//Ex 2.4
clc;clear;close;
format('v',6);
SR=10/10^-6;//V/s
Vout=10;//V(magnitude of output voltage)
fm=SR/(2*%pi*Vout)/1000;//kHz
disp(fm,"Full power bandwidth(kHz)");
VT=25/1000;//V(Thermal voltage)
ft=SR/(2*%pi*4*VT)/10^6;//MHz
disp(ft,"Unity gain bandwidth(MHz)");
```

Scilab code Exa 2.5 Output voltage limits

```
//Ex 2.5
clc;clear;close;
VCC=5;//V
VEE=-5;//V
VBE=0.6;//V
VCE23=0.6;//V
VCE_sat=0.2;//V
Vo_max=VCC-VCE_sat-VBE;//V
Vo_min=VEE+VCE_sat+VBE+VCE23;//V
disp(Vo_max,"Maximum output voltage(V)");
disp(Vo_min,"Minimum output voltage(V)");
```

Chapter 3

Linear Applications of IC OPamp

Scilab code Exa 3.1 Value of Rf

```
//Ex 3.1
clc;clear;close;
R1=2.2;//kohm
G=-100;//Voltage gain
Rf=-G*R1;//kohm
disp(Rf,"Value of Rf(kohm) : ");
```

Scilab code Exa 3.2 Output Voltage

```
//Ex 3.2
clc;clear;close;
Vin=2.5;//mV
R1=2;//kohm
Rf=200;//kohm
G=-Rf/R1;//Gain
Vo=G*Vin/1000;//V
```

```
disp(Vo,"Output Voltage(V) : ");
```

Scilab code Exa 3.3 Design invertin amplifier

```
//Ex 3.3
clc;clear;close;
G=-10;//Gain
Ri=100;//kohm(input resistance)
R1=Ri;//kohm
R2=-G*R1;//kohm
disp(R1,"Value of R1(kohm)");
disp(R2/1000,"Value of R2(Mohm)");
```

Scilab code Exa 3.4 Approximate values of attenuation

```
//Ex 3.4
clc;clear;close;
format('v',6);
FT1=1;//Filter Transmission
FT2=0.99;//Filter Transmission
FT3=0.9;//Filter Transmission
FT4=0.1;//Filter Transmission
A1=-20*log10(FT1);//dB
A2=-20*log10(FT2);//dB
A3=-20*log10(FT3);//dB
A4=-20*log10(FT4);//dB
disp(A1,"For filter transmission=1, Attenuation(dB)"
   );
disp(A2,"For filter transmission=0.99, Attenuation(
   dB)");
disp(A3,"For filter transmission=0.9, Attenuation(dB
   )");
```

```
disp(A4,"For filter transmission=0.1, Attenuation(dB
    )");
//Answer in the book is wrong for 0.99 filter
    transmission.
```

Scilab code Exa 3.5 First order low pass filter

```
//Ex 3.5
clc;clear;close;
format('v',5);
fo=2;//kHz
Ap=10;//Band pass gain
C=0.1;//micro F(have to choose C, 0.01<C<1)
R2=1/(2*%pi*fo*10^3*C*10^-6);//ohm
R1=R2/Ap;//ohm
disp("Design values are :");
disp(C,"Capacitance(micro F)");
disp(R1,"Resistance R1(ohm)");
disp(R2/1000,"Resistance R2(kohm)");
//Answer in the book is wrong.
```

Scilab code Exa 3.6 Second order low pass filter

```
//Ex 3.6
clc;clear;close;
format('v',6);
fo=1;//kHz
Ap=1.586;//Band pass gain
C1=0.005;C2=0.005//micro F(Assumed)
R=1/(2*%pi*fo*10^3*C1*10^-6);//ohm
Rf=10;//kohm(Assumed)
Ri=Rf/(Ap-1);//kohm
disp("Design values are :");
```

```
disp(R/1000,"Resistance in kohm, R1=R2=");
disp(Ri,"Resistance Ri(kohm)");
disp(Rf,"Resistance Rf(kohm)");
disp(C1,"Capacitance(micro F), C1=C2=");
```

Scilab code Exa 3.7 Second order Butterworth filter

```
//Ex 3.7
clc;clear;close;
format('v',6);
fo=3;//kHz
Ap=4;//Band pass gain
alfa=1.414;//for butterworth filter
C1=0.01;//micro F(Assumed)
C2=alfa^2*C1/4;//micro F
R=1/(2*%pi*fo*10^3*sqrt(C1*10^-6*C2*10^-6))/1000;//
    kohm
Rf=2*R;//kohm(Assumed)
disp("Design values are :");
disp(C1,"Capacitance C1(micro F)");
disp(C2,"Capacitance C2(micro F)");
disp(R,"Resistance R(kohm)");
disp(Rf,"For offset minimization, Resistance Rf(kohm
    )");
///For additional pass band gain
Ri=10;//kohm(Assumed)
Rf=(Ap-1)*Ri;//kohm
disp("For additional band pass gain:");
disp(Ri,"Resistance Ri(kohm)");
disp(Rf,"Resistance Rf(kohm)");
//Answer in the book is not accurate.
```

Scilab code Exa 3.8 Second order low pass filter

```
//Ex 3.8
clc;clear;close;
format('v',6);
fo=2;//kHz
alfa=1.414;//for butterworth filter
Ap=3-alfa;//band pass gain
RfBYRi=(Ap-1);//op-amp gain
C=0.05;//micro F(Assumed)
R=1/(2*%pi*fo*10^3*C*10^-6)/1000;//kohm
//For offset minimization 2*R=Rf||Ri
Rf=2*R*RfBYRi+2*R;//kohm
Ri=Rf/RfBYRi;//kohm
disp("Design values are :");
disp(C,"Capacitance C(micro F)");
disp(R,"Resistance R(kohm)");
disp(Rf,"Resistance Rf(kohm)");
disp(Ri,"Resistance Ri(kohm)");
```

Scilab code Exa 3.9 Second order low pass filter

```
//Ex 3.9
clc;clear;close;
format('v',6);
fo=1.2;//kHz
alfa=1.414;//for butterworth filter
Ap=3-alfa;//band pass gain
RfBYRi=(Ap-1);//op-amp gain
C=0.03;//micro F(have to choose C, 0.01<C<1)
R=1/(2*%pi*fo*10^3*C*10^-6)/1000;//kohm
//For offset minimization 2*R=Rf||Ri
Rf=2*R*RfBYRi+2*R;//kohm
Ri=Rf/RfBYRi;//kohm
disp("Design values are :");
disp(C,"Capacitance(micro F)");
disp(R,"Resistance R(kohm)");
```

```
disp(Rf,"Resistance Rf(kohm)");
disp(Ri,"Resistance Ri(kohm)");
```

Scilab code Exa 3.10 Design a band pass filter

```
//Ex 3.10
clc;clear;close;
format('v',5);
fL=200;//Hz
fH=1*1000;//Hz
Ap=4;//band pass gain
BW=fH-fL;//Hz
f0=sqrt(fH*fL);//Hz
fc=sqrt(fH*fL);//Hz
Q=fc/BW;//Quality factor
disp(Q,"Quality factor");
disp("As Q<12 ; it is wide band filter");
disp(fL,"Design values for high pass section with
    Ap1=2 & fL(Hz) :");
Ap1=2;//band pass gain for high pass section
C=0.033;//micro F(have to choose C, 0.01<C<1)
R=1/(2*%pi*fL*C*10^-6)/1000;//kohm
RfBYRi=(Ap-1);//op-amp gain
Rf=2*R;//kohm
Ri=2*R;//kohm
disp(C,"Capacitance(micro F)");
disp(R,"Resistance R(kohm)");
disp(Rf,"Resistance Rf(kohm)");
disp(Ri,"Resistance Ri(kohm)");
disp(fH,"Design values for low pass section with Ap2
    =2 & fH(Hz) :");
Ap2=2;//band pass gain for low pass section
C=0.033;//micro F(have to choose C, 0.01<C<1)
k=fL/fH;//scaling factor
Rdash=0.2*R;//kohm
```

```
Ri=2*Rdash;//kohm
Rf=Ri;//kohm(for Ap2=2)
disp(C,"Capacitance(micro F)");
disp(Rdash,"Resistance Rdash(kohm)");
disp(Rf,"Resistance Rf(kohm)");
disp(Ri,"Resistance Ri(kohm)");
disp("For design purpose use rounded value 10 kohm for Rf & Ri");
```

Scilab code Exa 3.11 Design a band pass filter

```
//Ex 3.11
clc;clear;close;
format('v',5);
fL=200;//Hz
fH=1*1000;//Hz
Ap=4;//band pass gain
BW=fH-fL;//Hz
f0=sqrt(fH*fL);//Hz
fc=sqrt(fH*fL);//Hz
Q=fc/BW;//Quality factor
disp(Q,"Quality factor");
disp("As Q<10 ; it is wide band filter");
disp(fH,"Design values for low pass section with Ap2=2 & fH(Hz) :");
Ap2=2;//band pass gain for low pass section
C=0.03;//micro F(have to choose C, 0.01<C<1)
Rdash=1/(2*%pi*fH*C*10^-6)/1000;//kohm
disp(C,"Capacitance(micro F)");
disp(Rdash,"Resistance Rdash(kohm)");
disp("Value of Resistance Rf & Ri can be choosen as 10 kohm for filter design.");
disp(fL,"Design values for high pass section with Ap1=2 & fL(Hz) :");
Ap1=2;//band pass gain for high pass section
```

```
C=0.05;//micro F(have to choose C, 0.01<C<1)
R=1/(2*%pi*fL*C*10^-6)/1000;//kohm
RfBYRi=(Ap-1);//op-amp gain
disp(C,"Capacitance(micro F)");
disp(R,"Resistance R(kohm)");
disp("Value of Resistance Rf & Ri can be choosen as
    10 kohm for filter design.");
```

Scilab code Exa 3.12 Design a band pass filter

```
//Ex 3.12
clc;clear;close;
format('v',6);
fo=1.2*1000;//Hz
Q=4;//Quality factor
Ap=10;//band pass gain
C=0.05;//micro F(have to choose C, 0.01<C<1)
R2=2*Q/(2*%pi*fo*C*10^-6)/1000;//kohm
R1=R2/2/Ap;//kohm
R3=R1/(4*%pi^2*R1*1000*R2*1000*(C*10^-6)^2*fo^2-1);
    //kohm
disp("Design values are :");
disp(C,"Capacitance(micro F)");
disp(R1,"Resistance R1(kohm)");
disp(R2,"Resistance R2(kohm)");
disp(R3*1000,"Resistance R3(ohm)");
//Answer in the book is wrong for R3 & value of C is
    0.05 instead of 0.5.
```

Scilab code Exa 3.13 Wide band stop filter

```
//Ex 3.13
clc;clear;close;
```

```
format('v',6);
fH=100;//Hz
fL=1*1000;//Hz
disp("This filter is a combination of -:");
disp("High pass filter having fH=100 Hz");
disp("Low pass filter having fL=1 kHz");
disp("And a summing amplifier");
//High pass filter
disp("Design values for high pass section :");
C=0.05;//micro F(have to choose C, 0.01<C<1)
R=1/(2*%pi*fL*C*10^-6)/1000;//kohm
Ap=2;//assumed
//Rf=Ri;//for gain=2
Rf=10;//kohm(assumed)
Ri=10;//kohm(assumed)
disp(C,"Capacitance(micro F)");
disp(R,"Resistance R(kohm)");
disp("Value of Resistance Rf & Ri can be choosen as
    10 kohm for filter design.");
//Low pass filter
disp("Design values for low pass section :");
C=0.1;//micro F(have to choose C, 0.01<C<1)
Rdash=1/(2*%pi*fH*C*10^-6)/1000;//kohm
Ap=2;//assumed
//Rfdash=Ridash;//for gain=2
Rf_dash=10;//kohm(assumed)
Ri_dash=10;//kohm(assumed)
disp(C,"Capacitance(micro F)");
disp(Rdash,"Resistance Rdash(kohm)");
disp("Value of Resistance Rf_dash & Ri_dash can be
    choosen as 10 kohm for filter design.");
```

Scilab code Exa 3.14 Active notch filter

```
//Ex 3.14
```

```
clc;clear;close;
format('v',6);
fN=50;//Hz
C=0.5;//micro F(have to choose C, 0.01<C<1)
R=1/(2*%pi*fN*C*10^-6)/1000;//kohm
disp("Design values are :");
disp(C,"Capacitance(micro F)");
disp(R,"Resistance R(kohm)");
```

Scilab code Exa 3.15 Low pass filter

```
//Ex 3.15
clc;clear;close;
format('v',6);
fo=1*1000;//Hz
fo_dash=1.5*1000;//Hz
C=0.01;//micro F(have to choose C, 0.01<C<1)
R=1/(2*%pi*fo*C*10^-6)/1000;//kohm
K=1.2*1000/fo_dash;//scaling factor
Rdash=K*R;///kohm
disp("Design values are :");
disp(C,"Capacitance(micro F)");
disp(R,"Resistance R(kohm)");
disp(Rdash,"Resistance Rdash(kohm)");
```

Scilab code Exa 3.16 Minimum Gain

```
//Ex 3.16
clc;clear;close;
Vf=0.0125;//V
Vo=0.5;//V
Beta=Vf/Vo;//unitless
//A*Beta=1 for oscillation
```

```
A=1/Beta;//gain
disp(A,"Minimum Gain");
```

Scilab code Exa 3.17 Frequency of oscillation

```
//Ex 3.17
clc;clear;close;
format('v',6);
R=50;//kohm(R1=R2=R3=R)
C=60;//pF(C1=C2=C3=C)
f=1/(2*%pi*R*1000*C*10^-12*sqrt(6));//Hz
disp(f/1000,"Frequency of oscillation(kHz)");
```

Scilab code Exa 3.18 Wein Bridge Oscillator

```
//Ex 3.18
clc;clear;close;
format('v',5);
f=2*1000;//Hz
R=10;//kohm(Assumed)(R1=R2=R)
C=1/(2*%pi*R*1000*f);//F
disp("Value of resistance R1=R2 can be choosen as 10
    kohm")
disp(C*10^9,"Cpacitance(nF)");
disp("Value of resistance R4 can be choosen as 10
    kohm & R3=2*R4=20 kohm for Beta to be 1/3");
```

Scilab code Exa 3.19 Frequency of oscillation

```
//Ex 3.19
```

```
clc;clear;close;
format('v',6);
R=200;//kohm(R1=R2=R)
C=200;//pF(C1=C2=C)
f=1/(2*%pi*R*1000*C*10^-12);//Hz
disp(f*10^-3,"Frequency of oscillation(kHz)");
//Answer in the book is wrong
```

Scilab code Exa 3.20 First order low pass filter

```
//Ex 3.20
clc;clear;close;
format('v',6);
omegaBYomega0=[0 0.5 1 5 10 100];
//T=omega0/sqrt(omega0^2+omega^2);//Gain
for i=1:6
T(i)=1/sqrt(1^2+omegaBYomega0(i)^2);//Gain
end
G=20*log10(T);//dB
A=-20*log10(T);//dB
fi=-atand(omegaBYomega0);//degree
disp("omega/omega0            T(j*omega)              (G(dB))
            A(dB)             fi")
table=[omegaBYomega0' T G A fi'];
disp(table);
```

Scilab code Exa 3.21 Value of T and FI

```
//Ex 3.21
clc;clear;close;
format('v',6);
omega1=0.1;//rad/s
omega2=1;//rad/s
```

```
omega3=10;//rad/s
T1=1/sqrt(1+omega1^6);//Transfer function
T2=1/sqrt(1+omega2^6);//Transfer function
T3=1/sqrt(1+omega3^6);//Transfer function
fi1=-atand((2*omega1-omega1^3)/real(1-2*omega1^2));
    //degree
fi2=-atand((2*omega2-omega2^3)/real(1-2*omega2^2));
    //degree
fi3=-atand((2*omega3-omega3^3)/real(1-2*omega3^2));
    //degree
disp(fi1,T1,"Value of T & fi for 0.1 rad/s: ");
disp(fi2-180,T2,"Value of T & fi for 1 rad/s: ");
disp(fi3,T3,"Value of T & fi for 10 rad/s: ");
```

Scilab code Exa 3.22 First order opamp RC low pass filter

```
//Ex 3.22
clc;clear;close;
format('v',6);
f0=10*1000;//Hz(3-dB frequency)
DCgain=10;
R1=10;//kohm
R2=DCgain*R1;//kohm
C=1/(2*%pi*f0*R2*1000)*10^9;//nF
disp("Design values are :");
disp(R2,"Resistance R2(kohm): ");
disp(C,"Capacitance C(nF): ");
```

Scilab code Exa 3.23 First order opamp high pass filter

```
//Ex 3.23
clc;clear;close;
format('v',6);
```

```
f0=100;//Hz(3-dB frequency)
Ri_inf=100;//kohm(High frequency input resistance)
Tinf=1;//high frequency gain
R1=Ri_inf;//kohm
R2=Tinf*R1;//kohm
C=1/(2*%pi*f0*R2*1000)*10^9;//nF
disp("Design values are :");
disp(R2,"Resistance R1=R2 in kohm : ");
disp(C,"Capacitance C(nF): ");
```

Scilab code Exa 3.24 Cascading components

```
//Ex 3.24
clc;clear;close;
format('v',6);
Ap=12;//dB(Pass band gain)
G=round(10^(Ap/20));//gain(unitless)
Ri=100;//kohm(as high input impedence required)
R1=Ri;//kohm
//Low pass filter design
ALP=-1;AHP=-4;//(to satisfy R2<=100;//kohm)
R2=-ALP*R1;//kohm
f0=10*1000;//Hz(3-dB frequency)
C=1/(2*%pi*f0*R2*1000)*10^9;//nF
disp("Design values for low pass filter :");
disp(R2,"Resistance R1=R2 in kohm : ");
disp(C,"Capacitance C(nF): ");
//High pass filter design
R3=25;//kohm(Assumed)
R4=-AHP*R3;//kohm
f0=100;//Hz(3-dB frequency)
C=1/(2*%pi*f0*R3*1000)*10^9;//nF
disp("Design values for high pass filter :");
disp(R4,R3,"Resistance R3 & R4 in kohm : ");
disp(C,"Capacitance C(nF): ");
```

Scilab code Exa 3.25 Value of R

```
//Ex 3.25
clc;clear;close;
format('v',6);
omega=10^4;//rad/s
C=10;//nF
fi1=-30;fi2=-90;fi3=-120;fi4=-150;//degree
R1=tand(-fi1/2)/(C*10^-9*omega)/1000;//kohm
R2=tand(-fi2/2)/(C*10^-9*omega)/1000;//kohm
R3=tand(-fi3/2)/(C*10^-9*omega)/1000;//kohm
R4=tand(-fi4/2)/(C*10^-9*omega)/1000;//kohm
disp(R1,"For phase shift=-30 degree, Resistance(kohm
    ) : ");
disp(R2,"For phase shift=-90 degree, Resistance(kohm
    ) : ");
disp(R3,"For phase shift=-120 degree, Resistance(
    kohm) : ");
disp(R4,"For phase shift=-150 degree, Resistance(
    kohm) : ");
```

Scilab code Exa 3.26 Resulting shift

```
//Ex 3.26
clc;clear;close;
omega1=0;//rad/s
omega2=%inf;//rad/s
omega0=10^4;//rad/s(Assumed)
fi1=atand(omega2/omega0)-atand(omega2/-omega0);//
    degree
fi2=atand(omega1/omega0)-atand(omega1/-omega0);//
    degree
```

```
disp(fi1,"For omega=0, phase shift(degree)");
disp(fi2,"For omega=infinity , phase shift(degree)");
```

Scilab code Exa 3.28 Design the KHN circuit

```
//Ex 3.28
clc;clear;close;
f0=1*1000;//Hz
BW=2*%pi*50;//Hz
C=10;//nF
Q=2*%pi*f0/BW;//quality factor
R=1/(2*%pi*f0*C*10^-9)/1000;//kohm
R1=10;//kohm(Assumed)
RF=10;//kohm(Assumed)
R3BYR2=2*Q-1;
R2=10;//kohm(Assumed)
R3=R3BYR2*R2;//kohm
disp("Design values for KHN circuit :");
disp(RF,R1,"Use Resistance R1 & RF in kohm : ");
disp(R2,"Use Resistance R2 in kohm : ");
disp(R3,"Resistance R3 in kohm : ");
K=2-1/Q;//scaling factor
CenterFrequency=K*Q;
disp(CenterFrequency,"CenterFrequency ");
```

Chapter 4

Digital Integrated Circuit Design

Scilab code Exa 4.3 Gain in transition region

```
//Ex 4.3
clc;clear;close;
VDD=3;//V(Supply Voltage)
VOH=VDD;//V
VOL=0;//V
Vth=VDD/2;//V
VIL=VDD/2;//V
VIH=VDD/2;//V
NMH=VOH-VIH;//V
NML=VIL-VOL;//V
disp(Vth,"Vth(V)");
disp(VIL,"VIL(V)");
disp(VIH,"VIH(V)");
disp(VOL,"VOL(V)");
disp(VOH,"VOH(V)");
disp(NML,"NML(V)");
disp(NMH,"NMH(V)");
//Gain=(VOH-VOL)/(VIH-VIL)=infinity as VIH=VIL;//
   Gain in the transition region
```

```
Gain=%inf;//
disp(Gain,"Gain in the transition region");
//Answer in the book is wrong for the gain.
```

Chapter 5

Non Linear Applications of IC OPamps

Scilab code Exa 5.1 Find VUT and VLT

```
//Ex 5.1
clc;clear;close;
format('v',5);
R1=100;//kohm
R2=86;//kohm
Vsat=15;//V
VUT=R2/(R1+R2)*Vsat;//V
VLT=R2/(R1+R2)*-Vsat;//V
disp(VUT,"VUT(V) : ");
disp(VLT,"VLT(V) : ");
```

Scilab code Exa 5.2 Period of multivbator and frequency

```
//Ex 5.2
clc;clear;close;
Rf=100;//kohm
```

```
C=0.1;//micro F
T=2*Rf*1000*C*10^-6;//s
disp(T*10^3,"Time period(ms)");
f=1/T;//Hz
disp(f,"Frequency(Hz) : ");
```

Scilab code Exa 5.3 Frequency of oscillation

```
//Ex 5.3
clc;clear;close;
R=100;//kohm
C=0.01;//micro F
f=1/(2*R*10^3*C*10^-6);//Hz
disp(f,"Frequency(Hz) : ");
```

Scilab code Exa 5.4 Design a square wave oscillator

```
//Ex 5.4
clc;clear;close;
f=1*1000;//HZ
Vs=15;//V
C=0.1;//micro F(Assumed)
R=1/(2*f*C*10^-6);//Hz
disp(R/1000,"For the required design value of R(kohm) : ");
disp("R1 & R2 can be choosen as 10 kohm");
///Answer in the book is wrong
```

Scilab code Exa 5.5 Maximum diode current

```
//Ex 5.5
clc;clear;close;
Vo=0.7;//V
Vsat=12;//V
R1=10;//kohm
R2=60;//kohm
Vth=R1/(R1+R2)*Vo;//V
iDmax=(Vsat-Vo)/R1-Vo/(R1+R2);//mA
disp(iDmax,"Maximum current(mA) : ");
```

Scilab code Exa 5.7 Frequency of oscillation

```
//Ex 5.7
clc;clear;close;
format('v',6);
R1=10;//kohm
R2=16;//kohm
C=10;//nF
R=62;//kohm
Beta=R1/(R1+R2);//unitless
T=2*R*1000*C*10^-9*log((1+Beta)/(1-Beta));//seconds
f=1/T;//Hz
disp(f,"Frequency of oscillations(Hz) : ");
```

Scilab code Exa 5.8 Average output voltage

```
//Ex 5.8
clc;clear;close;
format('v',5);
//vo/v1=1+R2/R1;//
//For v2/v1 i.e. gain=2, R1 & R2 should be equal
Vpp=10;//V
R1=10;//kohm
```

```
R2=10; //kohm
//Avg=1/T*integrate('Vpp*sin(2*%pi*t/T)','t',0,T/2);
Avg=-Vpp/(2*%pi)*[cos(%pi)-cos(0)];
disp(Avg,"Average output voltage(V) : ");
```

Scilab code Exa 5.9 Design of rectifier

```
//Ex 5.9
clc;clear;close;
format('v',5);
//vo/v1=-2;//Gain for -ve inputs
voBYvi=-2;//Gain for -ve inputs
//vo/v1=0;//Gain for non -ve inputs
Rin=100;//kohm
R1=100;//kohm(R1=Rin)
R2=-R1*voBYvi;//kohm
disp(R2,R1,"Values of R1 & R2(kohm) are : ");
```

Scilab code Exa 5.11 Triangular wave generator

```
//Ex 5.11
clc;clear;close;
format('v',5);
f0=1.5;//kHz
Vopp=6;//V
Vsat=13.5;//V
//Let R2=10kohm
R2=10;//kohm
R3=R2*2*Vsat/Vopp;//kohm
//Let C1=0.05 micro F
C1=0.05;//micro F
R1=R3/(4*f0*1000*R2*1000*C1*10^-6);//kohm
disp(R3,R2,R1,"Values of R1, R2 & R3(kohm) are : ");
```

```
disp(C1,"Value of C1(micro F)");
```

Scilab code Exa 5.12 Frequency of oscillation

```
//Ex 5.12
clc;clear;close;
format('v',4);
tau=1;//ms
//R1/R2=1.8:9;given range
//Let R1/R2=1.8
R1BYR2=1.8;//ratio
Beta1=1/(R1BYR2+1);
R1BYR2=9;//ratio
Beta2=1/(R1BYR2+1);//unitless
Beta=Beta1:Beta2;//Range of Beta
//For fmin
Tmax=2*log((1+Beta1)/(1-Beta1));//ms
fmin=1000/Tmax;//Hz
//For fmax
Tmin=2*log((1+Beta2)/(1-Beta2));//ms
fmax=1/Tmin;//kHz
disp("Frequency range is "+string(fmin)+" Hz to "+
   string(fmax)+" kHz");
```

Chapter 6

Integrated circuit timer and phase locked loops

Scilab code Exa 6.1 Output change per bit Full scale output

```
//Ex 6.1
clc;clear;close;
n=8;//no. of bits
V1=0;//V
V2=5.12;//V
Res=2^n;//resolution
disp(Res,"(a) Resolution=");
delVo=(V2-V1)/Res*1000;//mV/bit
disp(delVo,"(b) Output change per bit(mV/bit)");
VFS=V2*(1-1/2^n);//V
disp(VFS,"(c) Full scale Output voltage(V)");
```

Scilab code Exa 6.2 Produced output

```
//Ex 6.2
clc;clear;close;
```

```
format('v',5);
step=10.3;//mV
reading='101101111';//reading
Vo=step*bin2dec(reading)/1000;//V
disp(Vo,"Output voltage(V)");
```

Scilab code Exa 6.3 LSB MSB and full scale output

```
//Ex 6.3
clc;clear;close;
format('v',5)
n=8;//no. of bits
Range=0:10;//range
LSB=max(Range)/2^n;//V
MSB=max(Range)/2^0;//V
VFS=MSB-LSB;//V
disp(LSB*1000,"LSB(mV)");
disp(MSB,"MSB(V)");
disp(VFS,"VFS(V)");
```

Scilab code Exa 6.4 Produced output

```
//Ex 6.4
clc;clear;close;
format('v',5);
Range=0:10;//range
//(i)2-bit DAC
n=2;//no. of bits
step=max(Range)/2^n;//V
reading='10';//input in binary
Vo=step*bin2dec(reading);//V
disp(Vo,"(i) Output Voltage(V)");
//(ii)4-bit DAC
```

```
n=4;//no. of bits
step=max(Range)/2^n;//V
reading='0110';//input in binary
Vo=step*bin2dec(reading);//V
disp(Vo,"(ii) Output Voltage(V)");
//(i)8-bit DAC
n=8;//no. of bits
step=max(Range)/2^n;//V
reading='10111100';//input in binary
Vo=step*bin2dec(reading);//V
disp(Vo,"(iii) Output Voltage(V)");
```

Scilab code Exa 6.5 Analog output voltage

```
//Ex 6.5
clc;clear;close;
n=8;//no. of bits
Res=20;//mV/bit(Resolution)
reading='00010110';//input in binary
Vo=Res*bin2dec(reading);//V
disp(Vo/1000,"(a) Output Voltage(V)");
reading='10000000';//input in binary
Vo=Res*bin2dec(reading);//V
disp(Vo/1000,"(b) Output Voltage(V)");
```

Scilab code Exa 6.6 Offset voltage

```
//Ex 6.6
clc;clear;close;
n=12;//no. of bits
Eoff=0.05;//%//maximum offset error
Vref=10.24;//V
Voffset=Eoff/100*Vref;//V
```

```
disp(round(Voffset*1000),"(a) Offset voltage(mV)");
delVo=Vref/2^n;//V/bit
Voff_dash=Voffset/delVo;//in terms of LSB
disp(round(Voff_dash),"(b) Offset voltage in terms
    of LSB");
```

Scilab code Exa 6.7 Minimum output voltage

```
//Ex 6.7
clc;clear;close;
format('v',4);
n=8;//no. of bits
E=0.2;//%//maximum gain error
Vref=5.1;//V
V11=(100-E)*Vref/100;//V
disp(V11,"Minimum output voltage(V)");
```

Scilab code Exa 6.8 Input voltage and digital output

```
//Ex 6.8
clc;clear;close;
format('v',5);
n=8;//no. of bits
Range=0:10;//V
Vin=5.2;//V
oneLSB=max(Range)/2^n;//V
disp(oneLSB*1000,"(a) Minimum voltage for 1 LSB in
    mV");
Vifs=max(Range)-oneLSB;//V
disp(Vifs,"(b) For all ones input voltage should be
    (V)");
D=Vin/oneLSB;//Digital output in decimal
D=dec2bin(round(D));//Digital output in binary
```

```
disp(D,"(c) Digital Output");
```

Scilab code Exa 6.9 Conversion time

```
//Ex 6.9
clc;clear;close;
n=8;//no. of bits
f=1*10^6;//Hz(Clock frequency)
TC=1/f*(n+1);//seconds
disp(TC*10^6,"Conversion time in micro seconds");
```

Chapter 7

Integrated circuit timer and phase locked loops

Scilab code Exa 7.1 tHIGH tLOW and free running frequency

```
//Ex 7.1
clc;clear;close;
RA=6.8;//kohm
RB=3.3;//kohm
C=0.1;//micro F
VCC=5;//V
t_high=0.695*(RA+RB)*C;//ms
disp(t_high,"(a) t_high(ms)");
t_low=0.695*RB*C;//ms
disp(t_low,"(b) t_low(ms)");
f=1.44/(RA+2*RB)/(C);//kHz
disp(f,"(c) Frequency of oscillation(kHz)");
```

Scilab code Exa 7.2 Calculate timing interval

```
//Ex 7.2
```

```
clc;clear;close;
RA=10;//kohm
C=0.1;//micro F
t=1.1*RA*C;//ms
disp(t,"Timing interval(ms)");
```

Scilab code Exa 7.3 Loop lock

```
//Ex 7.3
clc;clear;close;
fc=500;//kHz(Free running frequency)
fi=600;//kHz(Input signal frequency)
BW=10;//kHz
out1=fi+fc;//kHz(Phase detector output)
out2=fi-fc;//kHz(Phase detector output)
disp(out2,out1,"Output of phase detector will be(kHz
    )");
disp("Both components are not lying in the passband(
    i.e. 10 kHz). Hence loop will not acquire lock.")
    ;
//fi+fc is calculated wrong in the book.
```

Scilab code Exa 7.4 Capture range

```
//Ex 7.4
clc;clear;close;
format('v',6);
fo=10;//kHz
V=12;//V
fL=8*fo/(V-(-V));//kHz(both +ve & -ve value)
C=10;//micro F(Assumed)
fC=sqrt(fL*10^3/(2*%pi*3.6*10^3*C*10^-6));//Fz(both
    +ve & -ve value)
```

```
disp(fC,fL,"Frequency fL & fC in kHz");
LR=2*fL;//kHz(Lock Range)
disp(LR,"Lock Range(kHz)");
CR=2*fC;//kHz(Capture rage)
disp(CR,"Capture Range(Hz)");
```

Scilab code Exa 7.5 Design components of PLL

```
//Ex 7.5
clc;clear;close;
format('v',5);
fo=100;//kHz(Free running frequency)
V=6;//V(both +ve & -ve value)
C=1;//micro F(Demodulation capacitor)
fL=8*fo/(V-(-V));//Hz(both +ve & -ve value)
fC=sqrt(fL*1000/(2*%pi*3.6*10^3*C*10^-6));//kHzz(both +ve & -ve value)
LR=2*fL;//kHz(Lock range)
disp(LR,"Lock Range(kHz)");
CR=2*fC/1000;//kHz(Capture range)
disp(CR,"Capture Range(kHz)");
RT=10;//kohm(Assumed)
CT=1.2/(4*RT*1000*fo*10^3);//F
disp("Design values are : ");
disp("Resistance RT can be chooosen as 10 kohm.");
format('v',9);
disp(CT,"Capacitance CT(F)");
```

Scilab code Exa 7.7 Value of R and Vth

```
//Ex 7.7
clc;clear;close;
C=1;//nF
```

```
T=10;//micro seconds(Output pulse duration)
R=T*10^-6/(C*10^-9*log(3))/1000;//kohm
disp(R,"(a) Value of R(kohm)");
VCC=15;//V
T=20;//micro seconds(Output pulse duration)
VTH=VCC*(1-exp(-T*10^-6/(R*1000*C*10^-9)));//V
disp(VTH,"(b) Value of VTH(V)");
```

Scilab code Exa 7.8 Design astable circuit

```
//Ex 7.8
clc;clear;close;
format('v',6);
C=680;//pF
f=50;//kHz(Square wave frequency)
D=75/100;//duty cycle
T=1/f*1000;//micro seconds
tHIGH=D*T;//micro seconds
tLOW=T-tHIGH;//micro seconds
RB=(tLOW*10^-6)/(0.69*C*10^-12);//ohm
RA=(tHIGH*10^-6)/(0.695*C*10^-12)-RB;//ohm
disp(RA/1000,"Value of RA(kohm)");
disp(RB/1000,"Value of RB(kohm)");
```