Scilab Textbook Companion for Electronic Circuit Analysis And Design by D. A. Neamen[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.

Contents

List of Scilab Codes

Chapter 1

Semiconductor materials and diodes

Scilab code Exa 1.1 Calculate intrinsic carrier concentration in silicon

```
clear;
clc;
//Example 1.1
T=300;//(( K )temperature)
//for silicon
B=5.23*10^(15);//Constant (per centimeter cube
    degree kelvin)
Eg=1.1;//bandgap energy in electrovolt(eV)
k=86*10^(-6);//Boltzmann's constant(eV per degree
    kelvin)
n_i=B*T^(3/2)*exp(-Eg/(2*k*T));//intrinsic carrier
    concentration
printf('intrinsic carrier concentration=%f cm^-3',
    n_i);
```

Scilab code Exa 1.2 Calculate thermal equilibrium electron and hole concentrations

```
clear;
clc;
//Example 1.2
T=300;//( K )Given Temperature
Nd=10^16;//(cm^-3)Donor concentration
n_i=1.5*10^10;//(cm^-3)intrinsic carrier
    concentration
//since Nd>>n_i
n_o=10^16;//(cm^-3)electron concentration
//by using formula :: n_i^2=n_o*p_o
p_o=(n_i)^2/Nd;//hole concentration
printf('\nelectron concentration= %.e cm^-3',n_o);
printf('\nhole concentration =%e cm^-3',p_o);
```

Scilab code Exa 1.3 Calculate the built in potential barrier of a pn junction

```
clear;
clc;
//Example1.3
T=300;//( K )Given Temperature
Na=10^16;//(cm^-3)Acceptor concentration in p region
Nd=10^17;//(cm^-3)Donor concentration in n region
n_i=1.5*10^10;//(cm^-3)intrinsic carrier
    concentration
V_T=0.026;//(Volt)terminal voltage
//built-in potential
V_bi=V_T*log(Na*Nd/(n_i)^2);
printf('\nthe built-in potential=%f V',V_bi)
```

Scilab code Exa 1.4 Calculate the junction capacitance of a pn junction

```
clear;
```

```
clc;
//Example 1.4
T=300;//( K )Given Temperature
Na=10^16;//(cm^-3)Acceptor concentration in p region
Nd=10^15;//(cm^-3)Donor concentration in n region
n_i=1.5*10^10;//(cm^-3)intrinsic carrier
    concentration
C_jo=0.5;//(pF)junction capacitance at zero applied
    voltage
V_T=0.026;//(Volt)terminal voltage
//built-in potential
V_bi=V_T*log(Na*Nd/(n_i)^2);
disp(V_bi,"the built-in potential(V)")
//the junction capacitance for
V_R=1;//(V)reverse bias voltage
Cj=C_jo*(1+V_R/V_bi)^(-1/2);
printf('\nthe junction capacitance for V_R=1V=%f pF\
    n',Cj)
V_R=5;//(V)reverse bias voltage
Cj=C_jo*(1+V_R/V_bi)^(-1/2);
printf('\nthe junction capacitance for V_R=5V =%f pF
    ',Cj)
```

Scilab code Exa 1.5 Determine the diode current in pn junction

```
clear;
clc;
//Example 1.5
T=300;//( K )Given Temperature
V_T=0.026;//(Volt)terminal voltage
Is=10^-11;//(mA)reverse bias saturation current
n=1;//emission coefficient
v_D=+0.7;//(V)applied voltage
//pn junction is forward biased
i_D=Is*(exp(v_D/V_T)-1);//diode current
```

```
printf('\ndiode current=%f mA\n',i_D)
v_D=-0.7;//(V)pn junction is reverse biased
Is=10^-14//A;
i_D=Is*(exp(v_D/V_T)-1);//diode current
printf('\ndiode current=%e A',i_D)
```

Scilab code Exa 1.6 Determine the diode voltage and current

```
clear;
clc;
//Example 1.6
Is=10^-13;//(A)reverse saturation current
V_PS=5;//(V)applied voltage
R=2;//(KOhm)Resistance in circuit
V_T=0.026;//(Volt)terminal voltage
//V_PS=Is*R*(exp(V_D/V_T)-1)+V_D
//5=(10^-13)*(2000)*(exp(V_D/V_T)-1)+V_D
//let right side of equation be x=(10^-13)*(2000)*(exp(V_D/V_T)-1)+V_D
V_D=0.6;//(V)
x=(10^-13)*(2000)*(exp(V_D/V_T)-1)+V_D
//so the equation is not balanced
V_D=0.65;//(V)
x=(10^-13)*(2000)*(exp(V_D/V_T)-1)+V_D
//again equation is not balanced .solution for V_D is between 0.6V and 0.65V
V_D=0.619;//(V)
x=(10^-13)*(2000)*(exp(V_D/V_T)-1)+V_D
//essentially equal to the value of the left side of the equation i.e 5V
printf('\ndiode voltage=%f V',V_D)
I_D=(V_PS-V_D)/R;//(A)diode current
printf('\nthe diode current=%f mA',I_D)
```

Scilab code Exa 1.7 Determine the diode voltage and current

```
clear;
clc;
//Example 1.7
//piecewise linear diode parameters
V_Y=0.6;//(V)
r_f=0.010;//(KOhm)
V_PS=5;//(V)applied voltage
R=2;//(KOhm)Resistance in circuit
I_D=(V_PS-V_Y)/(R+r_f);//(A)diode current
printf('\nthe diode current=%f mA\n',I_D)
V_D=V_Y+I_D*r_f;//(V)diode voltage
printf('\ndiode voltage=%f V',V_D)
```

Scilab code Exa 1.9 Analysing the circuit

```
clear;
clc;
//Example 1.9
//circuit and diode parameters
V_PS=5;//(V)
R=5;//(KOhm)
V_Y=0.6;//(V)
V_T=0.026;//(Volt)terminal voltage
v_i=0.1//*sin(wt)Volt
//dc analysis
I_DQ=(V_PS-V_Y)/R;
printf('\ndc quiescent current=%f mA\n',I_DQ)
V_O=I_DQ*R;
printf('\ndc output voltage=%f V\n',V_O)
//ac analysis
```

```
V_PS=0;
//Kirchhoff voltage law equation becomes
//v_i=i_d*r_d+i_d*R
r_d=V_T/I_DQ//(Ohm)small signal diode diffusion resistance
i_d=v_i/(r_d+R);//ac diode current
printf('\nac diode current=%fsin(wt) A\n',i_d)

v_o=i_d*R;//ac output voltage
printf('\nac output voltage=%fsin(wt) V',v_o)
```

Scilab code Exa 1.10 Calculate currents in a circuit

```
clear;
clc;
//Example 1.10
V_Y=0.7;//(V)cut in voltage for pn junction
r_f=0;
V_PS=4;//(V)
R1=4,R2=4//(KOhm) from given circuit
I1=(V_PS-V_Y)/R1;
printf('\ncurrent through pn junction diode=%.3f mA\n',I1)
V_Y=0.3;//(V)cut in voltage for Schottky diode
I2=(V_PS-V_Y)/R2;
printf('\ncurrent through Schottky diode=%.3f mA\n',I2)
```

Scilab code Exa 1.11 Design the value of resistance required to limit the current in given circuit

```
clear;
clc;
```

```
//Example 1.11
V_Z=5.6;//(V)Zener diode breakdown voltage
r_z=0;//(Ohm)Zener resistance
I=3;//(mA)current in the diode
V_PS=10;//(V)
//I=(V_PS-V_Z)/R
R=(V_PS-V_Z)/I;
printf('\nresistance=%.3f KOhm\n',R)
```

Chapter 2

Diode Circuits

Scilab code Exa 2.1 Compare voltages and the transformer turns ratio in two full wave rectifier circuits

```
clear;
clc;
//Example 2.1
v_I=120;//(V)rms primary input
v_o=9;//(V)peak output voltage
V_Y=0.7;//(V)diode cut in voltage
//for center-tapped transformer circuit in fig.2.6(a
    )
v_S=v_o+V_Y//(V)peak value of secondary voltage
printf('\npeak value of secondary voltage=%.2f V\n',
    v_S)
v_S_rms=v_S/sqrt(2)//for a sinusoidal signal rms
    value of v_S
printf('\nrms value of v_S=%.2f V\n',v_S_rms)
//let turns ratio of the primary to secondary
    winding be x=N1/N2
x=v_I/v_S_rms;
printf('\nturns ratio=%f \n',x)
//for the bridge circuit in fig.2.7(a)
v_Sb=v_o+2*V_Y;//(V)peak value of secondary voltage
```

```
printf('\npeak value of secondary voltage=%.2f V\n',v_Sb)
v_S_rms=v_Sb/sqrt(2);//for a sinusoidal signal rms value of v_S
printf('\nrms value of v_S=%f V\n',v_S_rms)
//let turns ratio of the primary to secondary winding be x=N1/N2
x=v_I/v_S_rms;
printf('\nturns ratio=%f\n',x)
//for center tapped rectifier
PIV=2*v_S-V_Y;
printf('\npeak inverse voltage of a diode=%f V\n',PIV)
//for the bridge rectifier peak inverse voltage of a diode
PIV=v_Sb-V_Y;
printf('\npeak inverse voltage of a diode=%.2f V\n',PIV)
//advantage of bridge rectifier over center tapped rectifier is it requies only half of the turns
```

Scilab code Exa 2.2 Determine the capacitance required to yield a particular ripple voltage

```
clear;
clc;
//Example 2.2
//full wave rectifier circuit with 60Hz input signal
V_M=10;//(V)peak output voltage
R=0.01;//(MOhm)output load resistance
f=60;//Hz
V_r=0.2;//(V)ripple voltage
C=V_M/(2*f*R*V_r);//capacitance
printf('\ncapacitance=%f microF\n',C)
```

Scilab code Exa 2.3 Design a full wave rectifier

```
clear;
clc;
//Example 2.3
V_O=12;//(V)peak output voltage
I_L=0.12;//(A)current delivered to the load
R=V_O/I_L;
printf('\neffective load resistance=%.2f Ohm\n',R)
V_Y=0.7;//(V)diode cut in voltage
v_S=V_O+2*V_Y;
printf('\npeak value of v_S=%.2f V\n',v_S)
v_Srms=v_S/sqrt(2);
printf('\nrms voltage=%.2f V\n',v_Srms)
//let x=N1/N2
Vin=120;//(V)input line voltage
x=Vin/v_Srms;
printf('\nturns ratio=%.2f \n',x)
VM=12;//(V)
Vr=5/100*VM;
printf('\nripple voltage=%.2f V\n',Vr)
f=60;//(Hz) input frequency
C=VM/(2*R*Vr*f);
printf('\nfilter capacitance=%f F\n',C)
i_Dmax=(VM/R)*(1+2*%pi*sqrt(VM/(2*Vr)));
printf('\npeak diode current=%.2f A\n',i_Dmax)
R=0.1;//Kohm
i_Davg=(1/(2*%pi))*sqrt(2*Vr/VM)*((VM/R)*(1+%pi*sqrt
    (VM/(2*Vr))));
printf('\naverage diode current=%f mA\n',i_Davg)
PIV=v_S-V_Y;
printf('\npeak inverse voltage=%.2f V\n',PIV)
```

Scilab code Exa 2.5 Determine the percent regulation of a voltage regulator

```
clear;
clc;
//Example 2.5
rZ=4;//(Ohm) Zener resistance
V_Lnom=9;//(V) nominal output voltage
Izmax=0.3;//(A) maximum zener diode current
Izmin=0.03;//(A) minimum zener diode current
V_Lmax=V_Lnom+Izmax*rZ
V_Lmin=V_Lnom+Izmin*rZ
//percent regulation R
R=((V_Lmax-V_Lmin)/V_Lnom)*100;
printf('\npercent regulation=%0.1f \n',R)
```

Scilab code Exa 2.8 Determine the output voltage and diode currents

```
clear;
clc;
//Example 2.8
R1=5;R2=10;//(KOhm)
V_Y=0.7;//(V)diode cut in voltage
V1=5;V2=-5;//(V)
vt=0;//(V)
//asssuming initially diode D1 is off
//iR1=iD2=iR2=V1-V2-V_Y/(R1+R2)
iD2=(V1-V2-V_Y)/(R1+R2);
printf('\ndiode current=%0.2f mA\n',iD2)
iR1=iD2;
vo=V1-iR1*R1;
printf('\noutput voltage=%0.2f V\n',vo)
```

```
v=vo-V_Y;//v=v'
printf('\nVoltage=%0.1f V\n',v)
vt=4;//(V) fig.2.33
//both D1 and D2 are on
vo==vt;
vo=4;
iD2=(V1-vo)/R1;
printf('\ndiode current=%.2f mA\n',iD2)
iR1==iD2;
v=vo-V_Y;
printf('\nV=%.2f V\n',v)
iR2=(v-V2)/R2;
printf('\niR2=%.2f mA\n',iR2)
iD1=iR2-iD2;
printf('\ncurrent through D1=%.2f mA\n',iD1)
```

Scilab code Exa 2.10 Calculate the photocurrent generated in a photodiode

```
clear;
clc;
//Example 2.10
n=1;//quantum efficiency
A=10^-2;//cm^2 junction area
p=5*10^17;//(cm^-2-s^-1) incident photon flux
e=1.6*10^-16;//charge of an electron
Iph=n*e*p*A;
printf('\nphotocurrent=%0.1f mA\n',Iph)
```

Scilab code Exa 2.11 Determine the value of R required to limit the current in circuit

```
clear;
```

```
clc;
//Example 2.11
I=0.01;//(A) diode current
V_Y=1.7;//(V) forward bias voltage drop
Vt=0.2;//(V)
R=(5-V_Y-Vt)/I;
printf('\nresistance=%0.1f Ohm',R)
```

Chapter 3

The Bipolar Junction Transistor

Scilab code Exa 3.1 Calculate the collector and emitter currents

```
clear;
clc;
//Example 3.1
//let beta be "b"
b=150;//common emitter current gain
iB=15*10^-3;//(mA) base current
//assume transistor biased in forward active mode
iC=b*iB;
printf('\ncollector current=%.2f mA\n',iC)
iE=(1+b)*iB;
printf('\nemitter current=%.2f mA\n',iE)
a=b/(1+b);
printf('\ncommon base current gain=%.3f\n',a)
```

Scilab code Exa 3.2 Calculate the breakdown voltage of a transistor

```
clear;
clc;
//Example 3.2
b=100;//common emitter current gain
BVcbo=120;//(V) break down voltage of the B-C junction
n=3;//empirical constant
BVceo=BVcbo/(b)^(1/n);
printf('\nbreakdown voltage=%.2f V\n',BVceo)
```

Scilab code Exa 3.3 Calculate the base collector and emitter currents and ce voltage for common emitter circuit

```
clear;
clc;
//Example 3.3
Vbb=4;//(V)
Rb=220//(KOhm);
Rc=2;//(KOhm)
Vcc=10;//(V)
Vbe=0.7;//(V)
b=200;
//from fig.3.19(b)
Ib=(Vbb-Vbe)/Rb;
printf('\nbase current=%.3f mA\n',Ib)
Ic=b*Ib;
printf('\ncollector current=%.2f mA\n',Ic)
Ie=(1+b)*Ib;
printf('\nemitter current=%.2f mA\n',Ie)
Vce=Vcc-Ic*Rc;
printf('\ncollector emitter voltage=%.1f V\n',Vce)
```

Scilab code Exa 3.4 Analyse the common emitter circuit with pnp transistor

```
clear;
clc;
//Example 3.4
Vbb=1.5;//(V)
Rb=580;//(KOhm)
Veb=0.6;//(V)
Vcc=5;//(V)
b=100;
//writing Kirchhoff voltage law equation around E-B
   loop
Ib=(Vcc-Veb-Vbb)/Rb;
printf('\nbase current=%.3f mA\n',Ib)
Ic=b*Ib;
printf('\ncollector current=%.2f mA\n',Ic)
Ie=(1+b)*Ib;
printf('\nemitter current=%.3f mA\n',Ie)
Vec=(1/2)*Vcc;
printf('\nce voltage=%.2f V\n',Vec)
Rc=(Vcc-Vec)/Ic;
printf('\ncollector resistance=%.f KOhm\n',Rc)
```

Scilab code Exa 3.5 Calculate the currents and voltages in a circuit

```
clear;
clc;
//Example 3.5
b=100;
Vbe=0.7;//(V)
Vce=0.2;//(V)
Vbb=8;//(v)
Rb=220;//(KOhm)
Ib=(Vbb-Vbe)/Rb
```

```
printf('\nbase current=%f mA\n',Ib)
//transistor in active region
Ic=b*Ib;
printf('\ncollector current=%.3f mA\n',Ic)
Vcc=10;//(V)
Rc=4;//(KOhm)
Vce=Vcc-Ic*Rc;
printf('\ncollector emitter voltage=%.2f V\n',Vce)
//saturation
Vce=0.2;//(V)
Ic=(Vcc-Vce)/Rc;
printf('\nsaturation collector current=%.2f mA\n',Ic)
x=Ic/Ib
//which is <b
Ie=Ic+Ib;
printf('\nemitter current=%f mA\n',Ie)
```

Scilab code Exa 3.6 Calculate the characteristics of a circuit containing an emitter resistor

```
clear;
clc;
//Example 3.6
Vbe=0.7;
b=75;
//Q point values::
//using KVL eq around the B-E loop
//Vbb=Ib*Re+Vbe+Ie*Re
//assuming transistor is in forward biased mode we can write Ie=(1+b)*Ib
Vbb=6;
Rb=25;//KOhm
Re=0.6;//KOhm
Ib=(Vbb-Vbe)/(Rb+(1+b)*Re);
```

```
printf('\nbase current=%f mA\n',Ib)
Ic=b*Ib;
printf('\ncollector current=%0.2f mA\n',Ic)
Ie=(1+b)*Ib;
printf('\nemitter current=%0.2f mA\n',Ie)
Vcc=12;
Rc=0.4;
Vce=Vcc-Ic*Rc-Ie*Re;
printf('\ncollector emitter voltage=%0.2f V\n',Vce)
//load line::
//using KVL law around C-E loop
//Vce=Vcc-(Ic*(Rc+((1+B)/B)*Re));
Ic=[0,12,5.63]
Vce=12-Ic*1;
xset('window',1)
plot2d(Vce,Ic,style=3)
title("load line")
xlabel("Vce")
ylabel("Ic")
```

Scilab code Exa 3.7 Calculate the characteristics of a circuit

```
clear;
clc;
//Example 3.7
Vbe=0.65;
Vcc=5;
Rc=0.5;//KOhm
b=100;
V1=-5;
Re=1;//KOhm
// Q-point values :: writing KVL eq around B-E loop
Ie=(-V1-Vbe)/Re;
printf('\nemitter current=%.2f mA\n',Ie)
Ib=(Ie/(1+b));
```

```
printf('\nbase current=%f mA\n',Ib)
Ic=(b/(1+b))*Ie;
printf('\ncollector current=%0.2f mA\n',Ic)
Vce=Vcc-Ic*Rc-Ie*Re-V1;
printf('\ncollector emitter voltage=%f V\n',Vce)
//load line::
//Vce=Vcc-V1-(Ic*(Rc+((1+B)/B)*Re));
Vce=[0,2,,3.5,4,6,8,10]
Ic=(10-Vce)/1.51;
xset('window',1)
plot2d(Vce,Ic,style=3,rect=[0,0,10,8])
title("load line")
xlabel("Vce")
ylabel("Ic")
```

Scilab code Exa 3.9 Calculate the characteristics of an npn bipolar circuit

```
clear;
clc;
//Example 3.9
b=100;
Vbe=0.7;
V1=-5;
V2=12;
Rb=10;
Re=5;
Rc=5;
Rl=5;
//Q point values:: using KVL eq around B-E loop
Ib=-(V1+Vbe)/(Rb+(1+b)*Re);
printf('\nbase current=%f mA\n',Ib)
Ic=b*Ib;
printf('\ncollector current=%f mA\n',Ic)
Ie=(1+b)*Ib;
printf('\nemitter current=%f mA\n',Ie)
```

```
//at collector node we can write Ic=(V2-Vo)/Rc-Vo/Rl
Vo=(V2/Rc-Ic)*Rc*Rl/(Rc+Rl);
printf('\noutput voltage=%0.3f V\n',Vo)
Vce=Vo-Ie*Re-V1;
printf('\ncollector emitter voltage=%f V\n',Vce)
//load line::
Rth=Rl*Rc/(Rl+Rc);
printf('\nThevenin rquivalent resistance=%f KOhm\n',
   Rth)
Vth=(Rl/(Rl+Rc))*V2;
printf('\nThevenin equivalent voltage=%f V\n',Vth)
//fig.3.36(c) KVL law
//Vce=6-V1-Ic*Rth-Ie*Re;
Vce=[0,2,4.7,3.5,4,6,8,10]
Ic=(11-Vce)/7.5;
xset('window',1)
plot2d(Vce,Ic,style=3,rect=[0,0,12,2])
title("load line")
xlabel("Vce")
ylabel("Ic")
```

Scilab code Exa 3.10 Calculate the currents output voltage and power dissipation

```
clear;
clc;
//Example 3.10
Rb=0.24;
Vcc=12;
Vbe=0.7;
Vce=0.1;
b=75;
Rc=5;//Ohm
//for Vt=0 ,transistor is cut off,Ib=Ic=0,Vo=Vcc=12
   V,power dissipation is zero
```

```
Vt=12;//(V)
Ib=(Vt-Vbe)/Rb;
printf('\nbase current=%0.3f mA\n',Ib)
Ic=(Vcc-Vce)/Rc;
printf('\ncollector current=%0.2f A\n',Ic)
Ib=0.0471;//A
x=Ic/Ib
//since Ic/Ib<b transistor is in saturation
//Vo==Vcc;
Vo=0.1;
printf('\noutput voltage=%0.2f V\n',Vo)
P=Ic*Vce+Ib*Vbe;
printf('\npower dissipation=%0.3f W\n',P)
```

Scilab code Exa 3.13 Design the circuit

```
clear;
clc;
//Example 3.13
b=100;
Vcc=12;
Vbe=0.7;
Icq=1;//mA
Vceq=6;
Rc=(Vcc-Vceq)/Icq;
printf('\ncollector resistance=%.3f KOhms\n',Rc)
Ibq=Icq/b;
printf('\nbase current=%0.3f mA\n',Ibq)
Rb=(Vcc-Vbe)/Ibq;
printf('\nbase resistance=%.3f KOhms\n',Rb)
```

Scilab code Exa 3.14 Analyze a circuit using voltage divider bias circuit and determine the change in Q point

```
clear;
clc;
//Example 3.14
R1=56;
R2=12.2;
Rc=2;
Re=.4;
Vcc=10;
Vbe=0.7;
b=100;
//fig.3.53(b)
Rth=R2*R1/(R1+R2);
printf('\nThevenin rquivalent resistance=%0.1f KOhm\n',Rth)
Vth=(R2/(R1+R2))*Vcc;
printf('\nThevenin equivalent voltage=%0.2f V\n',Vth)
Ibq=(Vth-Vbe)/(Rth+(1+b)*Re);
printf('\nbase current=%f mA\n',Ibq)
Icq=b*Ibq;
printf('\ncollector current=%.3f mA\n',Icq)
Ieq=(1+b)*Ibq;
printf('\nemitter current=%.2f mA\n',Ieq)
Vceq=Vcc-Icq*Rc-Ieq*Re;
printf('\ncollector emitter voltage=%.3f V\n',Vceq)
b=[50,100,150]
for x=b
Ibq=(Vth-Vbe)/(Rth+(1+x)*Re);
disp("Ibeq,Iceq,Ieq,Vceq")
disp(Ibq)
Icq=x*Ibq;
disp(Icq)
Ieq=(1+x)*Ibq;
disp(Ieq)
Vceq=Vcc-Icq*Rc-Ieq*Re;
disp(Vceq)
disp("")
end
```

Scilab code Exa 3.15 Design a bias stable circuit

```
clear;
clc;
//Example 3.15
Vcc=5;
Rc=1;//KOhm
Vbe=0.7;
b=120;
Vceq=3;
Re=.510;
Icq=(Vcc-Vceq)/(Rc+Re);
printf('\ncollector current=%.3f mA\n',Icq)
Ibq=Icq/b;
printf('\nbase current=%0.3f mA\n',Ibq)
//for bias stable circuit
Rth=0.1*(1+b)*Re;
printf('\nThevenin rquivalent resistance=%.1f KOhm\n',Rth)
//Ibq=(Vth-Vbe)/(Rth+(1+b)*Re)
Vth=Ibq*(Rth+(1+b)*Re)+Vbe;
printf('\nThevenin equivalent voltage=%.2f V\n',Vth)
//Vth=(R2/(R1+R2))*Vcc
//let x=(R2/(R1+R2))
x=Vth/Vcc
//Rth=6050=R1*x
R1=6.05/x;
printf('\nR1=%.1f KOhms\n',R1)
R2=x*R1/(1-x);
printf('\nR2=%.1f KOhms\',R2)
```

Scilab code Exa 3.16 Determine the currents in a two transistor current source

```
clear;
clc;
//Example 3.16
R1=10;
b=50;
Vbe=0.7;
V1=-5;
I1=-(V1+Vbe)/R1;
printf('\nreference current=%.3f mA\n',I1)
Iq=I1/(1+2/b);
printf('\nbias current=%.3f mA\n',Iq)
//Ib=Ib1=Ib2
Ib=Iq/b;
printf('\nbase current=%f mA\n',Ib)
```

Scilab code Exa 3.17 Calculate the dc voltages at each node and the dc currents through the elements in mulststage circuit

```
clear;
clc;
//Example 3.17
Vbe=0.7;
Vcc=10;
V2=5;
b=100;
R1=100;
R2=50;
Re1=2;
Rth=R2*R1/(R1+R2);
printf('\nThevenin rquivalent resistance=%.1f KOhm\n
    ',Rth)
Vth=(R2/(R1+R2))*Vcc-V2;
```

```
printf('\nThevenin equivalent voltage=%.2f V\n',Vth)
//Vth=Ib1*Rth+Vbe+Ie1*Re1-5 and Ie1=(1+b)*Ib1
Ib1=(Vth+5-Vbe)/(Rth+(1+b)*Re1);
printf('\nIb1=%.3f mA\n',Ib1)
Ic1=b*Ib1;
printf('\nIc1=%.3f mA\n',Ic1)
Ie1=(1+b)*Ib1;
printf('\nIe1=%.3f mA\n',Ie1)
//summing the currents at the collector of Q1,Ir1+Ib2=Ic1
//(5-Vc1)/Rc1+Ib2=Ic1
//also Ib2=Ie2/(1+b)=(5-(Vc1+0.7))/(1+b)*Re2
Rc1=5;
Re1=2;
Re2=2;
Rc2=1.5;
Vc1=Rc1*(1+b)*Re2*((5/Rc1)+(4.3/((1+b)*Re2))-Ic1)/((((1+b)*Re2)+Rc1);
printf('\nVc1=%.2f V\n',Vc1)
Ir1=(5-Vc1)/Rc1;
printf('\nIr1=%.3f mA\n',Ir1)
Ve2=Vc1+Vbe;
printf('\nVe2=%.2f V\n',Ve2)
Ie2=(5-Ve2)/Re1;
printf('\nIe2=%.3f mA\n',Ie2)
Ic2=Ie2*b/(1+b);
printf('\nIc2=%.3f mA\n',Ic2)
Ib2=Ie2/(1+b);
printf('\nIb2=%f mA\n',Ib2)
Ve1=Ie1*Re1-5;
printf('\nVe1=%.2f V\n',Ve1)
Vc2=Ic2*Rc2-5;
printf('\nVc2=%.2f V\n',Vc2)
Vce1=Vc1-Ve1;
printf('\nVce1=%.2f V\n',Vce1)
Vec2=Ve2-Vc2;
printf('\nVec2=%.2f V\n',Vec2)
```

Chapter 4

Basic BJT Amplifiers

Scilab code Exa 4.1 Calculate the small signal voltage gain of a bipolar transistor

```
clear;
clc;
//Example 4.1
b=100;
Vcc=12;
Vbe=0.7;
Rc=6;
Rb=50;
Vbb=1.2;
//dc solution
Ibq=(Vbb-Vbe)/Rb;
printf('\nbase current=%.3f mA\n',Ibq)
Icq=b*Ibq;
printf('\ncollector current=%.3f mA\n',Icq)
Vceq=Vcc-Icq*Rc;
printf('\ncollector emitter voltage=%.2f V\n',Vceq)
//transistor is forward biased
//ac solution
V_T=0.026;//(V)
//small signal hybrid pi parameters
```

```
r_pi=b*V_T/Icq;
printf('\nsmall signal resistance=%.1f KOhm\n',r_pi)
g_m=Icq/V_T;
printf('\ntransconductance=%.3f mA/V\n',g_m)
//Av=Vo/Vs=-(g_m*Rc)*r_pi/(r_pi+Rb)
Av=-(g_m*Rc)*r_pi/(r_pi+Rb);
printf('\nsmall signal voltage gain=%.3f\n',Av)
```

Scilab code Exa 4.2 Determine the small signal voltage gain

```
clear;
clc;
//Example 4.2
V_pi=50;//(V)
Icq=1;//(mA)
ro=V_pi/Icq;
printf('\nsmall signal output resistance=%.1f KOhm\n',ro)
Rc=6;
g_m=38.5;
r_pi=2.6;
Rb=50;
Av=-(g_m)*(Rc*ro/(Rc+ro))*r_pi/(r_pi+Rb);
printf('\nsmall signal voltage gain=%.2f \n',Av)
```

Scilab code Exa 4.4 Determine the small signal voltage gain

```
clear;
clc;
//Example 4.4
b=100;
Vbe=0.7;
Va=100;
```

```
V_T=0.026;//(V)
//from dc analysis
Icq=0.95;
Vceq=6.31;
//ac analysis
r_pi=b*V_T/Icq;
printf('\nsmall signal resistance=%.2f KOhm\n',r_pi)
g_m=Icq/V_T;
printf('\ntransconductance=%.3f mA/V\n',g_m)
Rs=0.5;
Rc=6;
ro=Va/Icq;
printf('\nro=%.2f KOhm\n',ro)
Av=-g_m*(5.9*r_pi/(5.9+r_pi))/((5.9*r_pi/(r_pi+5.9))
    +Rs)*ro*Rc/(ro+Rc);
printf('\nsmall signal voltage gain=%.2f \n',Av)
Ri=5.9*r_pi/(r_pi+5.9);
printf('\ninput resistance=%.3f KOhm\n',Ri)
Ro=ro*Rc/(ro+Rc);
printf('\noutput resistance=%.2f KOhm\n',Ro)
```

Scilab code Exa 4.5 Determine the small signal voltage gain of a common emitter circuit

```
clear;
clc;
//Example 4.5
b=100;
Vbe=0.7;
Rc=2;
Rs=0.5;
Icq=2.16;
V_T=0.026;//(V)
Vceq=4.8
//ac solution
```

```
r_pi=b*V_T/Icq;
printf('\nsmall signal resistance=%.2f KOhm\n',r_pi)
g_m=Icq/V_T;
printf('\ntransconductance=%3f mA/V\n',g_m)
//since Va=infinity,ro=Va/Icq is also infinity
Re=0.4;
Rib=r_pi+(1+b)*Re;
printf('\ninput resistance to the base=%.2f KOhm\n',Rib)
//Ri=R1||R2||Rib
Ri=10*Rib/(10+Rib);
printf('\ninput resistance to the amplifier=%.3f KOhm\n',Ri)
Av=-(1/(r_pi+(1+b)*Re))*b*Rc*Ri/(Ri+Rs);
printf('\nsmall signal voltage gain=%.2f \n',Av)
//by approximate expression
Av=-Rc/Re;
printf('\nsmall signal voltage gain=%.3f \n',Av)
```

Scilab code Exa 4.7 Determine the small signal voltage gain of a common emitter circuit

```
clear;
clc;
//Example 4.7
Iq=0.5;
b=120;
Va=80;
V_T=0.026;//(V)
rc=120;//small signal collector resistance (KOhm)
//Icq=Iq
Icq=0.5;
g_m=Icq/V_T;
printf('\ntransconductance=%.3f mA/V\n',g_m)
ro=Va/Icq;
```

```
printf('\nsmall signal output resistance=%.2f KOhm\n',ro)
Av=-g_m*ro*rc/(ro+rc);
printf('\nsmall signal voltage gain=%.3f \n',Av)
```

Scilab code Exa 4.8 Determine the dc and ac load lines

```
clear;
clc;
//Example 4.8
b=150;Veb=0.7;
//dc solution
V2=10;
V1=-10;
V_T=0.026;//(V)
Rc=5;
Rb=50;
Re=10;
Ibq=(V2-Veb)/(Rb+(1+b)*Re);
printf('\nbase current=%f mA\n',Ibq)
Icq=b*Ibq;
printf('\ncollector current=%.3f mA\n',Icq)
Ieq=(1+b)*Ibq;
printf('\nemitter current=%.3f mA\n',Ieq)
Vecq=V2-V1-Icq*Rc-Ieq*Re;
printf('\nemitter collector voltage=%.2f V\n',Vecq)
//ac solution
r_pi=b*V_T/Icq;
printf('\nsmall signal resistance=%.1f KOhm\n',r_pi)
g_m=Icq/V_T;
printf('\ntransconductance =%.3fmA/V\n',g_m)
//since Va=infinity,ro=Va/Icq is also infinity
```

Scilab code Exa 4.9 Determine the maximum symmetrical swing

```
clear;
clc;
//Example 4.9
Ic=0.894;
i_C=2*Ic;
printf('\nmaximum possible symmetrical peak to peak
    ac collector current=%.3f mA\n',i_C)
Rc=5;
Rl=2;
vo=i_C*Rc*Rl/(Rc+Rl);
printf('\nmaximum possible symmetrical peak to peak
    output voltage=%.2f V\n',vo)
iC=Ic+i_C*1/2;
printf('\nmaximum instantaneous collector current=%
    .3f mA\n',iC)
```

Scilab code Exa 4.10 Calculate the small signal voltage gain of an emitter circuit

```
clear;
clc;
//Example 4.10
b=100;
Vbe=0.7;
V_T=0.026;//(V)
Re=2;
R1=50;
R2=50;
Rs=0.5;
Va=80;
//by dc analysis
Icq=0.793;
Vceq=3.4;
```

```
r_pi=b*V_T/Icq;
printf('\nsmall signal resistance=%.3f KOhm\n',r_pi)
g_m=Icq/V_T;
printf('\ntransconductance=%.3f mA/V\n',g_m)
ro=Va/Icq;
printf('\nsmall signal output resistance=%.2f KOhm\n',ro)
Rib=r_pi+(1+b)*Re*ro/(ro+Re);
printf('\ninput resistance to the base=%.2f KOhm\n',Rib)
//Ri=R1||R2||Rib
x=R1*R2/(R1+R2);
Ri=x*Rib/(x+Rib);
printf('\nRi=%.2f KOhm\n',Ri)
y=ro*Re/(ro+Re);
Av=(1/(r_pi+(1+b)*y))*(1+b)*y*Ri/(Ri+Rs);
printf('\nsmall signal voltage gain=%.3f \n',Av)
```

Chapter 5

The Field Effect Transistor

Scilab code Exa 5.1 Calculate the current in an n channel MOSFET

```
clear;
clc;
//Example 5.1
Vtn=0.75;//(V)
W=40*10^-6;//(cm)
L=4*10^-6;//(cm)
u=650;//(cm)
Iox=450*10^-11;
e=3.9*8.86*10^-14;
Kn=W*u*e/(2*L*Iox);
printf('\nconduction parameter=%f mA/V^2\n',Kn)
Vgs=2*Vtn;
i_D=Kn*(Vgs-Vtn)^2;
printf('\ndrain current=%f mA\n',i_D)
```

Scilab code Exa 5.2 Determine the source to drain voltage required to bias p channel MOSFET

```
clear;
clc;
//Example 5.2
Kp=0.2;//(mA/V^2)
Vtp=0.5;
iD=0.5;
Vsg=sqrt(iD/Kp)-Vtp;
printf('\nVgs=%.2f V\n',Vsg)
//to bias in p channel MOSFET
Vsd=Vsg+Vtp;
printf('\nVsd=%.2f V\n',Vsd)
```

Scilab code Exa 5.3 Calculate the drain current and drain to source voltage of circuit

```
clear;
clc;
//Example 5.3
R1=30;
R2=20;
RD=20;
Vdd=5;
Vtn=1;
Kn=0.1;
Vgs=R2*Vdd/(R1+R2);
printf('\nVgs=%0.2f V\n',Vgs)
I_D=Kn*(Vgs-Vtn)^2;
printf('\nthe drain current=%0.1f mA\n',I_D)
Vds=Vdd-I_D*RD;
printf('\ndrain to source voltage=%0.1f V\n',Vds)
```

Scilab code Exa 5.4 Calculate the drain current and drain to source voltage of circuit

```
clear;
clc;
//Example 5.4
R1=50;
R2=50;
RD=7.5;
Vdd=5;
Vtp=-0.8;
Vg=2.5;
Kp=0.2;
Vo=R2*Vdd/(R1+R2);
printf('\nVo=%.2f V\n',Vo)
Vsg=Vdd-Vg;
printf('\nsource to gate voltage=%.2f V\n',Vsg)
I_D=Kp*(Vsg+Vtp)^2;
printf('\nthe drain current=%.3f mA\n',I_D)
Vsd=Vdd-I_D*RD;
printf('\nsource to drain voltage=%.3f V\n',Vsd)
```

Scilab code Exa 5.6 Design the dc bias of a MOSFET circuit to produce specified drain current

```
clear;
clc;
//Example 5.6
Vtn=2;
Kn=80*10^-3;
//x=W/L
x=4;
I_D=0.5;
//I_D=Kn*x*((Vgs-Vtn)^2)/2;
Vgs=sqrt(I_D*2/(Kn*x))+2;
printf('\nVgs=%.2f V\n',Vgs)
//y=R1+R2
Rs=2;
```

```
y=10/0.05;
printf('\nR1+R2=%.2f Kohm\n',y)
//Vgs=Vg-Vs=(R2/(R1+R2)*10-5)-I_D*Rs+5
R2=(y/10)*(Vgs+I_D*Rs);
printf('\nR2=%.2f KOhm\n',R2)
R1=y-R2;
printf('\nR1=%.2f KOhm\n',R1)
```

Scilab code Exa 5.7 Design a MOSFET circuit biased with a constant current source

```
clear;
clc;
//Example 5.7
Vtn=0.8;
Kn=80;
//x=W/L
x=3;
I_D=250;
Vd=2.5;
//I_D=Kn/2*x*(Vgs-Vtn)^2
Vgs=sqrt(I_D*2/(Kn*x))+Vtn;
printf('\nVgs=%.3f V\n',Vgs)
Vs=-Vgs
//I_D=(5-Vd)/Rd
Rd=(5-Vd)/I_D;
printf('\nRd=%.2f KOhm\n',Rd)
Vds=Vd-Vs;
printf('\nVds=%.2f V\n',Vds)
Vdssat=Vgs-Vtn
//since Vds>Vdssat transistor is biased in
   saturation region
```

Scilab code Exa 5.8 Calculate the characteristics of a circuit containing an enhancement load device

```
clear;
clc;
//Example 5.8
Vtn=0.8;
Kn=0.05;
//I_D=Kn*(Vgs-Vtn)^2
//Vds=Vgs=5-I_D*Rs
//combining these two equations we obtain 0.5(Vgs)
    ^2+0.2Vgs-4.68
Vgs=poly(0,'Vgs')
p=poly([-4.68 0.2 0.5],'Vgs','c')
printf('\npossible solutions ::%.3f V\n',roots(p))
//assuming transistor is conducting ,Vgs must be
    greater than threshold voltage
Vgs=2.87;
I_D=Kn*(Vgs-Vtn)^2;
printf('\ndrain current=%.3f mA\n',I_D)
```

Scilab code Exa 5.10 Calculate the characteristics of a circuit containing a depletion load device

```
clear;
clc;
//Example 5.10
Vtn=-2;
Kn=0.1;
Vdd=5;
Rs=5;
Vgs=0;
I_D=Kn*(Vgs-Vtn)^2;
printf('\ndrain current=%.3f mA\n',I_D)
Vds=Vdd-I_D*Rs;
```

```
printf('\ndc drain to source voltage=%.2f V\n',Vds)
Vdssat=Vgs-Vtn
//since Vds>Vdssat transisyor is biased in saturation region
```

Scilab code Exa 5.11 Determine the dc transistor currents and voltages in a circuit containing a depletion load device

```
clear;
clc;
//Example 5.11
Vtnd=1;
Vtnl=-2;
Knd=50;
Knl=10;
Vt=5;
Vo=poly(0,'Vo')
p=poly([4 -40 5],'Vo','c')
printf('\npossible solutions ::%.2f V\n',roots(p))
//since output voltage cannot be greater than supply voltage 5V
Vo=0.1;//(V)
I_D=Knl*(-Vtnl)^2;
printf('\ndrain current=%.3f microA\n',I_D)
```

Scilab code Exa 5.13 Determine the currents and voltages in a MOSFET constant current source

```
clear;
clc;
//Example 5.13
Kn1=0.2;
Kn2=0.1;
```

```
Kn3=0.1;
Kn4=0.1;
Vtn1=1;
Vtn2=1;
Vtn3=1;
Vtn4=1;
V2=-5;
Vgs3=(sqrt(Kn4/Kn3)*(-V2-Vtn4)+Vtn3)/(1+sqrt(Kn4/Kn3));
printf('\nVgs3=%.2f V\n',Vgs3)
Iq=Kn3*(Vgs3-Vtn3)^2;
printf('\nbias current=%.3f mA\n',Iq)
Vgs1=sqrt(Iq/Kn1)+Vtn1;
printf('\ngate to source voltage on M1=%.2f V\n',Vgs1)
Vds2=-V2-Vgs1;
printf('\ndrain to source voltage on M2=%.2f V\n',Vds2)
Vgs2=Vgs3;
Vdssat=Vgs2-Vtn2
//since Vds2>Vdssat M2 is biased in saturation region
```

Scilab code Exa 5.14 Design the size of a power MOSFET to meet the specification of particular switch application

```
clear;
clc;
//Example 5.14
I_D=0.5;
Vds=6;
Kn=80*10^-6;
Vgs=5;
Vtn=1;
//x=W/L
```

```
x=I_D*2/(Kn*(Vgs-Vtn)^2);
disp(x,"W/L ")
//maximum power dissipation in transistor
Pmax=Vds*I_D;
printf('\nmaximum power dissipation in transistor=%
    .3f W\n',Pmax)
```

Scilab code Exa 5.16 Calculate Id and Vds in an n channel pn JFET

```
clear;
clc;
//Example 5.16
Idss=2;//(mA) saturation current
Vp=-3.5;//(V) pinch off voltage
Vgs=[0 Vp/4 Vp/2]
I_D=Idss*(1-Vgs/Vp)^2;
disp(I_D,"I_D (A)")
Vds=Vgs-Vp;
disp(Vds,"Vdssat (V)")
```

Scilab code Exa 5.17 Design the dc bias of a JFET circuit

```
clear;
clc;
//Example 5.17
Idss=5;//mA
Vp=-4;
Vdd=10;
I_D=2;
Vds=6;
//I_D=Idss*(1-Vgs/Vp)^2
Vgs=(1-sqrt(I_D/Idss))*Vp;
printf('\nVgs=%.2f V\n',Vgs)
```

```
Rs=-Vgs/I_D;
printf('\nRs=%.3f KOhm\n',Rs)
Rd=(Vdd-Vds-I_D*Rs)/I_D;
printf('\nRd=%.2f KOhm\n',Rd)
Vgs-Vp
//since Vds>Vgs-Vp JFET is biased in saturation
```

Scilab code Exa 5.19 Calculate the quiscent current and voltage values

```
clear;
clc;
//Example 5.19
Idss=2.5;
Vp=2.5;
I_D=0.8;
//I_D=Iq=0.8*10^-3=(Vd-(-9))/Rd
Vd=0.8*4-9;
printf('\nVd =%.2fV\n',Vd)
//I_D=Idss*(1-Vgs/Vp)^2;
Vgs=(1-sqrt(I_D/Idss))*Vp;
printf('\nVgs =%.2fV\n',Vgs)
Vs=1-Vgs;
printf('\nVs=%.2f V\n',Vs)
Vsd=Vs-Vd;
printf('\nVsd=%.2f V\n',Vsd)
Vp-Vgs
//since Vsd>Vp-Vgs JFET is biased in saturation
```

Scilab code Exa 5.20 Design a circuit with an enhancement mode MESFET

```
clear;
clc;
```

```
//Example 5.20
Vtn=0.24;
Kn=1.1;
//x=R1+R2=50000
x=50;
Vgs=0.5;
Vds=2.5;
Vdd=4;
Rd=6.7;
I_D=Kn*(Vgs-Vtn)^2;
printf('\ndrain current=%.3f mA\n',I_D)
Vd=Vdd-I_D*Rd;
printf('\nvoltage at drain=%0.2f V\n',Vd)
Vs=Vd-Vds;
printf('\nvoltage at source =%0.2fV\n',Vs)
Rs=Vs/I_D;
printf('\nsource resistance =%.2fKOhm\n',Rs)
Vg=Vgs+Vs;
printf('\nvoltage at the gate=%.2f V\n',Vg)
//Vg=R2*Vdd/(R2+R1)
R2=Vg*x/Vdd;
printf('\nR2=%0.3f KOhm\n',R2)
R1=x-R2;
printf('\nR1=%0.3f KOhm\n',R1)
Vgs-Vtn
//since Vds>Vgs-Vtn transistor is biased in saturation
```

Chapter 6

Basic FET Amplifier

Scilab code Exa 6.1 Calculate the transconductance of an n chennel MOSFET

```
clear;
clc;
//Example 6.1
Vtn=1;
//let x= u_n*Cox*1/2
x=20*10^-3;
//let y=W/L
y=40;
I_D=1;
Kn=x*y;
printf('\nconduction parameter=%.3f mA/V^2\n',Kn)
g_m=2*sqrt(Kn*I_D);
printf('\ntransconductance=%.3f mA/V\n',g_m)
```

Scilab code Exa 6.2 Determine the small signal voltage gain of a MOSFET

```
clear;
clc;
//Example 6.2
Vgsq=2.12;
Vdd=5;
Rd=2.5;
Vtn=1;
Kn=0.8;
//let lambda=y
y=0.02;//V^-1
Idq=Kn*(Vgsq-Vtn)^2;
printf('\ndrain current=%.3f mA\n',Idq)
Vdsq=Vdd-Idq*Rd;
printf('\ndrain to source voltage=%.3f V\n',Vdsq)
Vgs=1.82;
Vgs-Vtn
//since Vdsq>Vgs-Vtn transistor is biased in saturation
g_m=2*Kn*(Vgsq-Vtn);
printf('\ntransconductance=%.3f mA/V\n',g_m)
ro=(y*Idq)^-1;
printf('\noutput resistance=%.2f KOhm\n',ro)
Av=-g_m*ro*Rd/(ro+Rd);
printf('\nsmall signal voltage gain=%.2f\n',Av)
```

Scilab code Exa 6.3 Determine the small signal voltage gain and input and output resistance of a commoon source amplifier

```
clear;
clc;
//Example 6.3
Vdd=10;
R1=70.9;//(Kohm)
R2=29.1;//(Kohm)
Rd=5;//(Kohm)
```

```
Vtn=1.5;
Kn=0.5;//(mA/V^2)
//lambda=y
y=0.01;//V^-1
Rsi=4;//(Kohm)
Vgsq=Vdd*R2/(R1+R2);
printf('\ngate to source voltage=%.2f V\n',Vgsq)
Idq=Kn*(Vgsq-Vtn)^2;
printf('\ndrain current=%.3f mA\n',Idq)
Vdsq=Vdd-Idq*Rd;
printf('\ndrain to source voltage=%.2f V\n',Vdsq)
g_m=2*Kn*(Vgsq-Vtn);
printf('\ntransconductance=%.3f mA/V\n',g_m)
ro=(y*Idq)^-1;
printf('\noutput resistance=%.2f KOhm\n',ro)
Ri=R1*R2/(R1+R2);
printf('\namplifier input resistance=%.2f Kohm\n',Ri)
Av=-g_m*(ro*Rd/(ro+Rd))*Ri/(Ri+Rsi);
printf('\nsmall signal voltage gain=%.2f\n',Av)
printf('\namplifier input resistance=%.2f Kohm\n',Ri)
Ro=Rd*ro/(Rd+ro);
printf('\namplifier output resistance=%.2f Kohm\n',Ro)
```

Scilab code Exa 6.4 Design the bias of a MOSFET such that the Q point is in the middle of saturation

```
clear;
clc;
//Example 6.4
Vtn=1;
Kn=1;//(mA/V^2)
//lambda=y
```

```
y=0.015;//V^-1
Ri=100;//(Kohm)
Idq=2;//(mA)
Idt=4;//(mA)
//Idt=4=Kn*(Vgst-Vtn)^2
Vgst=sqrt(Idt/Kn)+Vtn;
printf('\nVgst=%.2f V\n',Vgst)
Vdst=Vgst-Vtn;
printf('\nVdst=%.2f V\n',Vdst)
Vdd=12;
Vdsq=7;
Rd=(Vdd-Vdsq)/Idq;
printf('\nRd =%.2fKOhm\n',Rd)
Vgsq=sqrt(Idq/Kn)+Vtn;
printf('\nVgsq=%.2f V\n',Vgsq)
R1=Ri*Vdd/Vgsq;
printf('\nR1=%.2f Kohm\n',R1)
R2=Ri*R1/(R1-Ri);
printf('\nR2=%.2f Kohm\n',R2)
g_m=2*Kn*(Vgsq-Vtn);
printf('\ntransconductance=%.3f mA/V\n',g_m)
ro=(y*Idq)^-1;
printf('\noutput resistance=%.2f KOhm\n',ro)
Av=-g_m*(ro*Rd/(ro+Rd));
printf('\nsmall signal voltage gain=%.2f\n',Av)
```

Scilab code Exa 6.6 Determine the small signal voltage gain of a circuit

```
clear;
clc;
//Example 6.6
Vtn=0.8;
Kn=1;//(mA/V^2)
Idq=0.5;
Vdd=5;
```

```
Rd=7;//(Kohm)
Vgsq=sqrt(Idq/Kn)+Vtn;
printf('\nVgsq=%.2f V\n',Vgsq)
Vs=-Vgsq
Vdsq=Vdd-Idq*Rd-Vs;
printf('\nVdsq=%.2f V\n',Vdsq)
g_m=2*Kn*(Vgsq-Vtn);
printf('\ntransconductance=%.3f mA/V\n',g_m)
Av=-g_m*Rd;
printf('\nsmall signal voltage gain=%.2f\n',Av)
```

Scilab code Exa 6.7 Determine the small signal voltage gain of a circuit

```
clear;
clc;
//Example 6.7
Vdd=12;
R1=162;
R2=463;
Rs=0.75;
Kn=4;
Vtn=1.5;
//lambda=y
y=0.01;
Rsi=4;
Idq=7.97;
Vgsq=2.91;
g_m=2*Kn*(Vgsq-Vtn);
printf('\ntransconductance=%.2f mA/V\n',g_m)
ro=(y*Idq)^-1;
printf('\noutput resistance=%.2f KOhm\n',ro)
Ri=R1*R2/(R1+R2);
printf('\namplifier input resistance=%.3f Kohm\n',Ri
    )
x=Rs*ro/(Rs+ro);
```

```
Av=g_m*x*(Ri/(Ri+Rsi))/(1+g_m*x);
printf('\nsmall signal voltage gain=%.2f\n',Av)
```

Scilab code Exa 6.9 Calculate the output resistance of a source follower circuit

```
clear;
clc;
//Example 6.9
Rs=750;//Ohm
ro=12500;
g_m=11.3*10^-3;
x=1/g_m;
y=x*Rs/(x+Rs);
Ro=y*ro/(y+ro);
printf('\noutput resistance=%.3f ohm\n',Ro)
```

Scilab code Exa 6.11 Design the small signal voltage gain of an NMOS amplifier

```
clear;
clc;
//Example 6.11
Vtnd=1;
Vtnl=1;
Kn=30;
//let W/L=x
xl=1;
Vdd=5;
Av=10;
//Av=sqrt(xd/xl)
xd=(Av)^2*xl;
```

```
printf('\nwidth to length ratio of driver transistor=%0.2f\n',xd)
Knd=xd*Kn*0.001/2;
Knl=xl*Kn*0.001/2;
printf('\nconduction parameter Knd=%.2f mA/V^2\n',Knd)
printf('\nconduction parameter Knl=%.3f mA/V^2\n',Knl)
//Vgsd-Vtnd=(Vdd-Vtnl)-sqrt(Knd/Knl)*(Vgsd-Vtnd)
y=sqrt(Knd/Knl);
Vgsd=(y+5)/(1+y);
printf('\nVgsd=%.2f V\n',Vgsd)
Vdsd=Vgsd-1;
printf('\nVdsd=%.2f V\n',Vdsd)
```

Scilab code Exa 6.12 Determine the small signal voltage gain of a circuit

```
clear;
clc;
//Example 6.12
Vtnd=0.8;
Vtnl=-1.5;
Knd=1;
Knl=0.2;
//lambda=y
yd=0.01;
yl=0.01;
Idq=0.2;
gmd=2*sqrt(Knd*Idq);
printf('\ntransconductance of the driver=%.3f mA/V\n',gmd)
roD=1/(yd*Idq);
printf('\noutput resistances=%.2f Kohm\n',roD)
Av=-gmd*roD/2;
printf('\nsmall signal voltage gain=%.2f \n',Av)
```

Scilab code Exa 6.13 Determine the small signal voltage gain of a circuit

```
clear;
clc;
//Example 6.13
Vtn=0.8;
Vtp=-0.8;
Kn=80*10^-3;
Kp=40*10^-3;
//x=W/L
xn=15;
xp=10;
//lambda=y
yn=0.01;
yp=0.01;
Ibias=0.2;
gm=2*sqrt(Kn*xn*Ibias/2);
printf('\ntransconductance of the NMOS driver=%.3f
    mA/V^2\n',gm)
ron=1/(yn*Ibias);
printf('\noutput resistances=%.2f Kohm\n',ron)
Av=-gm*ron/2;
printf('\nsmall signal voltage gain=%.2f \n',Av)
```

Scilab code Exa 6.14 Design the biasing of a multistage MOSFET

```
clear;
clc;
//Example 6.14
Kn1=500*10^-3;
Kn2=200*10^-3;
```

```
Vtn1=1.2;
Vtn2=Vtn1;
Idq1=0.2;
Idq2=0.5;
Vdsq1=6;
Vdsq2=6;
Ri=100;
Rsi=4;
Rs2=(10-Vdsq2)/Idq2;
printf('\nRs2=%.2f KOhm\n',Rs2)
Vgs2=sqrt(Idq2/Kn2)+Vtn2;
printf('\ngate to source voltage for M2=%.2f V\n',
    Vgs2)
Vs2=-1;
Vg2=Vs2+Vgs2;
printf('\ngate voltage of M2=%.2f V\n',Vg2)
Vg1=Vg2;
Rd1=(5-Vg1)/Idq1;
printf('\nresistor Rd1=%.2f KOhm\n',Rd1)
Vs1=Vg1-Vdsq1;
printf('\nsource voltage of M1=%.2f KOhm\n',Vs1)
Rs1=(Vs1+5)/Idq1;
printf('\nresistor Rs1=%.2f KOhm\n',Rs1)
Vgs1=sqrt(Idq1/Kn1)+Vtn1;
printf('\ngate to source voltage for M1=%.2f V\n',
    Vgs1)
R1=Ri*10/(Vgs1+Idq1*Rs1);
printf('\nR1=%.2f KOhm\n',R1)
//Ri=R1*R2/(R1+R2)
R2=Ri*R1/(R1-Ri);
printf('\nR2=%.2f KOhm\n',R2)
```

Scilab code Exa 6.15 Design the biasing of cascade circuit

```
clear;
```

```
clc;
//Example 6.15
Vtn1=1.2;
Vtn2=1.2;
Kn1=0.8;
Kn2=0.8;
//x=R1+R2+R3=300
x=300;
Rs=10;
Idq=0.4;
Vdsq1=2.5;
Vdsq2=2.5;
Vs1=Idq*Rs-5;
printf('\ndc voltage at source of M1=%.2f V\n',Vs1)
Vgs=sqrt(Idq/Kn1)+Vtn1;
printf('\ngate to source voltage=%.2f V\n',Vgs)
R3=(Vgs+Vs1)*x/5;
printf('\nR3=%.2f KOhm\n',R3)
Vs2=Vdsq2+Vs1;
printf('\nvoltage at source of M2=%.2f V\n',Vs2)
//y=R2+R3
y=(Vgs+Vs2)*x/5;
printf('\nR2+R3=%.2f KOhm\n',y)
R2=150;
R1=x-y;
printf('\nR1=%.2f KOhm\n',R1)
R3=y-R2;
printf('\nR3=%.2f KOhm\n',R3)
Vd2=Vdsq2+Vs2;
printf('\nvoltage at drain of M2 =%.2fV\n',Vd2)
Rd=(5-Vd2)/Idq;
printf('\ndrain resistance=%.2f KOhm\n',Rd)
```

Scilab code Exa 6.17 Determine the small signal voltage gain of a circuit

```
clear;
clc;
//Example 6.17
Kn=0.8;
Vtn=1.2;
Vgs=1.91;
Rd=2.5;
gm=2*Kn*(Vgs-Vtn);
printf('\ntransconductance=%.2f mA/V\n',gm)
Av=-gm*Rd;
printf('\nsmall signal voltage gain=%.2f \n',Av)
```

Scilab code Exa 6.18 Determine the small signal voltage gain of a circuit

```
clear;
clc;
//Example 6.18
//Determine the small signal voltage gain of a
   circuit in fig.6.55
Idss=12;
Vp=-4;
//lambda=y
y=0.008;
Vgsq=poly(0,'Vgsq');
p=poly([26.4 17.2 2.025],'Vgsq','c')
printf('\nroots=%fV\n',roots(p))
Vgsq=-2.01
Idq=Idss*(1-Vgsq/Vp)^2;
printf('\nquiescent drain current=%f mA\n',Idq)
gm=(-2*Idss/Vp)*(1-Vgsq/Vp);
printf('\ntransconductance=%.2f mA/V\n',gm)
ro=(1/(y*Idq));
printf('\noutput resistance=%.2f KOhm\n',ro)
Rd=2.7;
Rl=4;
```

```
x=Rd*Rl/(Rd+Rl);
Av=-gm*ro*x/(ro+x);
printf('\nsmall signal voltage gain=%.2f \n',Av)
```

Scilab code Exa 6.19 Design a JFET source folllower

```
clear;
clc;
//Example 6.19
Idss=12;
Vp=-4;
Rl=10;
//lambda=y
y=0.01;
Av=0.9;
//gm=(-2*Idss/Vp)*(1-Vgs/Vp)
gm=2;
Vgs=(1+gm*Vp/(2*Idss))*Vp;
printf('\ngate to source voltage=%.3f V\n',Vgs)
Idq=Idss*(1-Vgs/Vp)^2;
printf('\nquiescent drain current=%.3f mA\n',Idq)
Rs=(-Vgs+10)/Idq;
printf('\nRs=%.2f KOhm\n',Rs)
ro=(1/(y*Idq));
printf('\noutput resistance=%.3f KOhm\n',ro)
x=Rl*ro/(Rl+ro);
t=x*Rs/(x+Rs);
Av=gm*t/(1+gm*t);
printf('\nsmall signal voltage gain=%.3f \n',Av)
```

Chapter 7

Frequency Response

Scilab code Exa 7.1 Determine the corner frequencies and maximum magnitude asymptotes

```
clear;
clc;
//Example 7.1
Rs=1000;
Rp=10000;
Cs=1*10^-6;
Cp=3*10^-12;
Ts=(Rs+Rp)*Cs;
printf('\ntime constant=%.3f s\n',Ts)
f=1/(2*%pi*Ts);
printf('\ncorner frequency=%.2f Hz\n',f)
x=20*log10(Rp/(Rp+Rs));
printf('\nmaximum magnitude =%.3fdB\n',x)
Rp=10;//KOhm
Rs=1;//Kohm
Cp=3;//pF
Tp=Cp*Rs*Rp/(Rs+Rp);
printf('\ntime constant=%.3f ns\n',Tp)
Tp=2.73*10^-3;//micro sec
f=1/(2*%pi*Tp);
```

```
printf('\ncorner frequency =%.2fMHz\n',f)
```

Scilab code Exa 7.2 Determine the corner frequencies and bandwidth

```
clear;
clc;
//Example 7.2
Rs=1000;
Rp=10000;
Cs=1*10^-6;
Cp=3*10^-12;
Ts=(Rs+Rp)*Cs;
printf('\nopen circuit time constant=%.3f s\n',Ts)
Rs=1;//KOhm
Rp=10;//KOhm
Cp=3;//pF
Tp=Cp*Rs*Rp/(Rs+Rp);
printf('\nshort circuit time constant=%.3f ns\n',Tp)
fL=1/(2*%pi*Ts);
printf('\ncorner frequency fL=%.2f Hz\n',fL)
Tp=2.73*10^-3;//microsec
fH=1/(2*%pi*Tp);
printf('\ncorner frequency fH=%.3f MHz\n',fH)
fL=14.5*10^-6;//MHz
fbw=fH-fL;
printf('\nbandwidth =%.3fMHz\n',fbw)
```

Scilab code Exa 7.3 Determine the corner frequencies and maximum gain

```
clear;
clc;
//Example 7.3
R1=51.2;
```

```
R2=9.6;
Rc=2;
Re=.4;
Rsi=.1;
Vt=0.026;
Cc=1;
Vcc=10;
Vbe=0.7;
b=100;
Rb=8.08;
Icq=1.81;
gm=Icq/Vt;
printf('\ntransconductance=%.3f mA/V\n',gm)
r=b*Vt/Icq;
printf('\ndiffusion resistance=%.2f KOhm\n',r)
x=r+(1+b)*Re;
y=x*R2/(x+R2);
Ri=y*R1/(R1+y);
printf('\ninput resistance=%.3f KOhm\n',Ri)
Ts=(Rsi+Ri)*Cc;
printf('\ntime constant=%.3f ms\',Ts)
Ts=6.87*10^-3;//Sec
fL=1/(2*%pi*Ts);
printf('\ncorner frequency fL=%.3f Hz\n',fL)
Rib=r+(1+b)*Re;
printf('\nRib=%.3f KOhm\n',Rib)
Av=(gm*r*Rc/(Rsi+Ri))*Rb/(Rb+Rib);
printf('\nsmall signal voltage gain=%.2f\n',Av)
```

Scilab code Exa 7.4 Design the circuit

```
clear;
clc;
//Example 7.4
fL=20*10^-3;//KHz
```

```
Rd=6.7;
Rl=10;
Ts=1/(2*%pi*fL);
printf('\ntime constant=%.3f ms\n',Ts)
Cc=Ts/(Rd+Rl);
printf('\ncoupling capacitance=%.3f microF\n',Cc)
```

Scilab code Exa 7.5 Determine 3dB frequency

```
clear;
clc;
//Example 7.5
b=100;
Vbe=0.7;
Rs=500;
Rb=100000;
Re=10000;
Rl=10000;
Va=120;
Ccc2=1*10^-6;
Icq=0.838*0.001;
r=3100;//small signal parameter
gm=32.2*0.001;
ro=143000;
x=(r+Rs*Rb/(Rs+Rb))/(1+b);
y=ro*x/(ro+x);
Ro=Re*y/(Re+y);
printf('\noutput resistance of emitter=%.2f Ohm\n',
   Ro)
Ts=(Ro+Rl)*Ccc2;
printf('\ntime constant=%.2f s\n',Ts)
fL=1/(2*%pi*Ts);
printf('\n3dB frequency=%.2f Hz\n',fL)
```

Scilab code Exa 7.6 Determine the corner frequencies and maximum gain

```
clear;
clc;
//Example 7.6
Rs=3.2;
Rd=10;
Rl=20;
Cl=10;
Vtp=-2;
Kp=0.25;
Idq=0.5;
Vsgq=3.41;
Vsdq=3.41;
gm=2*Kp*(Vsgq+Vtp);
printf('\ntransconductance =%.3fmA/V\n',gm)
Tp=Cl*Rd*Rl/(Rd+Rl);
printf('\ntime constant=%.3f ns\n',Tp)
Tp=66.7*10^-3;//micro sec
fH=1/(2*%pi*Tp);
printf('\ncorner frequency=%.2f MHz\n',fH)
Av=(gm*Rd*Rl/(Rd+Rl))/(1+gm*Rs);
printf('\nmaximum small signal voltage gain=%.2f\n',
    Av)
```

Scilab code Exa 7.7 Determine the mid gain corner frequencies and bandwidth of a circuit

```
clear;
clc;
//Example 7.7
Vbe=0.7;
```

```
b=100;
Re=.5;
Rc=5;
Rl=10;
R1=40;
Cc=10;
R2=5.7;
Rs=.1;
Vt=0.026;
Icq=0.99;
gm=Icq/Vt;
printf('\ntransconductance=%.3f mA/V\n',gm)
r=b*Vt/Icq;
printf('\ndiffusion resistance=%.2f KOhm\n',r)
Ri=r+(1+b)*Re;
printf('\ninput resistance=%.2f KOhm\n',Ri)
x=Rc*Rl/(Rc+Rl);
y=R1*R2/(R1+R2);
t=y*Ri/(y+Ri);
Av=gm*r*x*(y/(y+Ri))*(1/(Rs+t));
printf('\nmaximum small signal voltage gain=%.2f\n',Av)
Ts=(Rs+t)*Cc;
printf('\ntime constant=%.3f ms\n',Ts)
Ts=46.6*0.001;//sec
Cl=15;
Tp=x*Cl;
printf('\ntime constant=%.3f ns\n',Tp)
fL=1/(2*%pi*Ts);
printf('\nlower corner frequency=%.2f Hz\n',fL)
Tp=50*10^-3;//micro sec
fH=1/(2*%pi*Tp);
printf('\nupper corner frequency=%.2f MHz\n',fH)
fL=3.4*10^-6;//MHz
fbw=fH-fL;
printf('\nbandwidth =%.2fMHz\n',fbw)
```

Scilab code Exa 7.8 Determine the corner frequencies and limiting horizontal asymptotes

```
clear;
clc;
//Example 7.8
Re=4;
Rc=2;
Rs=0.5;
Vt=0.026;
Ce=1*10^-3;
V1=5;
Icq=1.06;
V2=-5;
b=100;
Vbe=0.7;
gm=Icq/Vt;
printf('\ntransconductance =%.2fmA/V\n',gm)
r=b*Vt/Icq;
printf('\ndiffusion resistance=%.2f KOhm\n',r)
Ta=Re*Ce;
printf('\ntime constant Ta=%ef s\n',Ta)
Tb=(Re*Ce*(Rs+r))/(Rs+r+(1+b)*Re);
printf('\ntime constant Tb=%e s\n',Tb)
fA=1/(2*%pi*Ta);
printf('\ncorner frequency =%.2fHz\n',fA)
Tb=2.9*0.01;//msec
fB=1/(2*%pi*Tb);
printf('\ncorner frequency =%.2fkHz\n',fB)
Av=(gm*r*Rc)/(Rs+r+(1+b)*Re);
printf('\nlimiting low frequency horizontal
    asymptote=%.2f\n',Av)
Av=gm*r*Rc/(Rs+r);
printf('\nnlimiting high frequency horizontal
```

```
asymptote=%.2f\n',Av)
```

Scilab code Exa 7.9 Determine 3dB frequency

```
clear;
clc;
//Example 7.9
r=2600;
C1=2*10^-6;
C2=0.1*10^-6;
fB=1/(2*%pi*r*(C1+C2));
printf('\n3dB frequency=%.2f MHz\n',fB)
```

Scilab code Exa 7.10 Calculate bandwidth and capacitance

```
clear;
clc;
//Example 7.10
fT=500;
Ic=1;
b=100;
Vt=0.026;
C2=0.3*10^-12;
fB=fT/b;
printf('\nbandwidth=%.3f MHz\n',fB)
gm=Ic/Vt;
printf('\ntransconductance=%.3f mA/V\n',gm)
fT=500000000;
gm=38.5*0.001;
C1=gm/(fT*2*%pi)-C2;
printf('\ncapacitance =%3.2eF\n',C1)
```

Scilab code Exa 7.12 Determine the unity gain bandwidth

```
clear;
clc;
//Example 7.12
Kn=0.25;
Vtn=1;
Cgd=0.04*10^-3;
Cgs=0.2*10^-3;
Vgs=3;
gm=2*Kn*(Vgs-Vtn);
printf('\ntransconductance =%.3fmA/V\n',gm)
fT=gm/(2*%pi*(Cgd+Cgs));
printf('\nunity gain bandwidth=%.f MHz\n',fT)
```

Scilab code Exa 7.13 Determine the Miller capacitance and cutoff frequency

```
clear;
clc;
//Example 7.13
gm=1;
Cgd=0.04;
Rl=10;
Cgs=0.2;
Cm=Cgd*(1+gm*Rl);
printf('\nMiller capacitance=%.3f pF\n',Cm)
Cm=0.44*0.001;//nF
Cgs=0.2*0.001;//nF
fT=gm/(2*%pi*(Cgs+Cm));
printf('\ncutoff frequency=%.3f MHz\n',fT)
```

Scilab code Exa 7.14 Determine the upper corner frequency and midband gain

```
clear;
clc;
//Example 7.14
V1=5;
V=-5;
Rs=0.1;
Rb=40;
R2=5.72;
Re=0.5;
Rc=5;
Rl=10;
b=150;
Vbe=0.7;
C1=35*10^-3;
C2=4;
Vt=0.026;
Icq=1.02;
r=b*Vt/Icq;
printf('\nsmall signal parameter=%.2f KOhm\n',r)
gm=Icq/Vt;
printf('\ntransconductance=%.3f mA/V\n',gm)
Cm=C2*(1+gm*Rc*Rl/(Rc+Rl));
printf('\nMiller capacitance=%.3f pF\n',Cm)
Cm=527*10^-3;
x=Rb*Rs/(Rb+Rs);
y=r*x/(r+x);
fH=1/(2*%pi*y*(C1+Cm));
printf('\nupper corner frequency =%.2fMHz\n',fH)
t=Rb*r/(Rb+r);
p=Rc*Rl/(Rc+Rl);
Av=gm*p*t/(t+Rs);
```

```
printf('\nmidband gain=%.2f\n',Av)
```

Scilab code Exa 7.15 Determine the upper corner frequency and midband gain

```
clear;
clc;
//Example 7.15
V1=5;
V=-5;
Rs=0.1;
R1=40;
R2=5.72;
Re=0.5;
Rc=5;
Rl=10;
b=150;
Vbe=0.7;
C1=35;
C2=4;
Vt=0.026;
Icq=1.02;
gm=39.2;
r=3.82;
x=Re*Rs/(Re+Rs);
t=r/(1+b);
y=t*x/(t+x);
Tp=y*C1;
printf('\ntime constant=%.3f ns\n',Tp)
Tp=0.679*10^-3;//micro sec
f=1/(2*%pi*Tp);
printf('\nupper frequency =%.3fMHz\n',f)
T=C2*Rc*Rl/(Rc+Rl);
printf('\ntime constant=%.3f ns\n',T)
T=13.3*10^-3;//micro sec
```

```
f=1/(2*%pi*T);
printf('\nupper frequency=%.2f MHz\n',f)
x=Rc*Rl/(Rc+Rl);
y=Re*t/(Re+t);
Av=gm*x*(y/(y+Rs));
printf('\nmidband voltage gain=%.2f \n',Av)
```

Scilab code Exa 7.16 Determine the upper corner frequency and midband gain

```
clear;
clc;
//Example 7.16
V1=5;
V=-5;
Rs=0.1;
R1=42.5;
R2=20.5;
R3=28.3;
Re=5.4;
Rc=5;
Rl=10;
b=150;
Vbe=0.7;
C1=35;
C2=4;
Vt=0.026;
Icq=1.02;
gm=39.2;
r=3.820;
Rb=R2*R3/(R2+R3);
x=Rb*r/(Rb+r);
y=Rs*x/(x+Rs);
Tp=y*(C1+2*C2);
printf('\ntime constant=%.3f ns\n',Tp)
```

```
Tp=Tp*10^-3;//micro sec
f=1/(2*%pi*Tp);
printf('\n3dB frequency =%0.3fMHz\n',f)
T=C2*Rc*Rl/(Rc+Rl);
printf('\ntime constant=%.2f ns\n',T)
T=T*0.001;//micro sec
f=1/(2*%pi*T);
printf('\nupper frequency=%.3f MHz\n',f)
x=Rc*Rl/(Rc+Rl);
y=Rb*r/(Rb+r);
Av=gm*x*(y/(y+Rs));
printf('\nmidband voltage gain=%.f \n',Av)
```

Scilab code Exa 7.17 Determine the frequency of a zero and a pole

```
clear;
clc;
//Example 7.17
V1=5;
V=-5;
Rs=0.1;
R1=40;
R2=5.720;
Re=0.5;
Rc=5;
Rl=10;
b=150;
Vbe=0.7;
C1=35;
C2=4;
Vt=0.026;
Icq=1.02;
gm=39.2;
r=3.820;
t=r/(1+b);
```

```
t=t*0.001;
f=1/(2*%pi*C1*t);
printf('\nthe zero occurs at this frequency=%.2f MHz\n',f)
x=1+gm*Re*Rl/(Re+Rl);
Rb=R1*R2/(R1+R2)
d=x*r;
y=d*Rb/(d+Rb);
t=y*Rs/(y+Rs);
Tp=t*(C2+C1/x);
printf('\ntime constant=%.2f ns\n',Tp)
Tp=Tp*10^-3;//micro sec
f=1/(2*%pi*Tp);
printf('\n3dB frequency=%.f MHz\n',f)
```

Chapter 8

Ouput Stages and Power Amplifier

Scilab code Exa 8.2 Determine the maximum power dissipation

```
clear;
clc;
//Example 8.1
//let thermal resistance parameters be R
Rdcase=1.75;//degree celsius per watt
Rcsnk=1;//degree celsius per watt
Rsamb=5;//degree celsius per watt
Rcamb=50;//degree celsius per watt
Tamb=30;//ambient temperature
Tjmax=150;//maximum junction temperature
Tdev=150;//device temperature
//when no heat sink is used
P=(Tjmax-Tamb)/(Rdcase+Rcamb);
printf('\nmaximum power dissipation=%.2f W\n',P)
//when heat sink is used
P=(Tjmax-Tamb)/(Rdcase+Rcsnk+Rsamb);
printf('\nmaximum power dissipation=%.2f W\n',P)
```

Scilab code Exa 8.3 Determine the maximum safe power dissipation

```
clear;
clc;
//Example 8.3
Rcsnk=1;//degree celsius per watt
Rsamb=5;//degree celsius per watt
Tjmax=175;//maximum junction temperature
Toc=25;
Tamb=25;
Pr=20;//rated power W
Rdcase=(Tjmax-Toc)/Pr;
printf('\ndevice to case thermal resistance=%.2f  C
   /W\n',Rdcase)
P=(Tjmax-Tamb)/(Rdcase+Rcsnk+Rsamb);
printf('\nmaximum power dissipation=%.2f W\n',P)
```

Scilab code Exa 8.7 Determine the required biasing in MOSFET class AB

```
clear;
clc;
//Example 8.7
Vdd=10;
Rl=20;
K=0.2;
Vt=1;
vo=5;
iL=vo/20;
printf('\niL=%.2f A\n',iL)
Idq=0.05;
//Idq=K*(Vbb/2-Vt)
Vbb=(sqrt(Idq/K)+1)*2;
```

```
printf('\nVbb=%.2f V\n',Vbb)
iD=iL;
Vgsn=sqrt(iD/K)+Vt;
printf('\nVgsn=%.2f V\n',Vgsn)
Vsgp=Vbb-Vgsn;
printf('\nVsgp=%.2f V\n',Vsgp)
vi=vo+Vgsn-Vbb/2;
printf('\ninput voltage=%.2f V\n',vi)
```

Scilab code Exa 8.8 Design a transformer coupled emitter follower amplifier

```
clear;
clc;
//Example 8.8
Vcc=24;
Rl=8;
P=5;
Vbe=0.7;
b=100;
Vp=sqrt(2*Rl*P);
printf('\npeak output voltage=%.2f V\n',Vp)
Ip=Vp/Rl;
printf('\npeak output current =%.2fA\n',Ip)
a=0.9*Vcc/Vp;
printf('\na=%.2f\n',a)
Icq=Ip/(0.9*a);
printf('\nIcq=%.3f A\n',Icq)
Pq=Vcc*Icq;
printf('\nmaximum power dissipated in the transistor
   =%.2f W\n',Pq)
Ibq=Icq/b;
Ibq=Ibq*1000;//mA
printf('\nbase current Ibq=%.2f mA\n',Ibq)
Rth=2.500;
```

```
//Vth=Vcc*Rth/R1 and Vth=Ibq*Rth+Vbe
R1=Vcc*Rth/(Ibq*Rth+Vbe);
printf('\nR1=%.2f KOhm\n',R1)
R2=Rth*R1/(R1-Rth);
printf('\nR2=%.2f KOhm\n',R2)
```

Scilab code Exa 8.9 Design the class AB output stage

```
clear;
clc;
//Example 8.9
Iso=3*10^-14;
Isq=10^-13;
b=75;
Vt=0.026;
Rl=8;
P=5;
Vp=sqrt(2*Rl*P);
printf('\npeak voltage Vp=%.2f V\n',Vp)
Vcc=Vp/0.8;
printf('\nsupply voltage=%.2f V\n',Vcc)
Ien=Vp/Rl;
printf('\nemitter current=%.3f A\n',Ien)
Ibn=Ien/(1+b);
Ibn=Ibn*1000;//mA
printf('\nbase current=%.2f mA\n',Ibn)
iD=0.020;
Vbb=2*Vt*log(iD/Iso);
printf('\nVbb=%.2f V\n',Vbb)
Icq=Isq*exp((Vbb/2)/Vt);
Icq=Icq*1000;//mA
printf('\nquiescent collector current=%.3f mA\n',Icq)
Ibias=20;//mA
iD=Ibias-Ibn;
```

```
printf('\ndrain current=%.3f mA\n',iD)
iD=iD*0.001;//A
Vbb=2*Vt*log(iD/Iso);
printf('\nVbb=%.2f V\n',Vbb)
Icn=1.12;
Vben=Vt*log(Icn/Isq);
printf('\nB-E voltage of Qn=%.2f V\n',Vben)
Vebp=Vbb-Vben;
printf('\nemitter base voltage of Qp=%.2f V\n',Vebp)
Icp=Isq*exp(Vebp/Vt);
Icp=Icp*1000;//mA
printf('\nIcp=%f mA\n',Icp)
```

Scilab code Exa 8.11 Determine the currents and the current gain

```
clear;
clc;
//Example 8.11
R1=2;//KOhm
R2=R1;
Rl=.1;//KOhm
b=60;
Vbe=0.6;
Veb=0.6;
V1=15;
V2=V1;
iR1=(V1-Vbe)/R1;
//iR1=iR2=iE1=iE2
printf('\niR1=%.2f mA\n',iR1)
vo=10;
io=vo/Rl;
printf('\noutput current=%.3f mA\n',io)
iB3=100/61;
printf('\niB3=%.3fmA\n',iB3)
iR1=(V1-(10+Vbe))/R1;
```

```
printf('\ncurrent in R1=%.3f mA\n',iR1)
iE1=iR1-iB3;
printf('\niE1=%.3f mA\n',iE1)
iB1=iE1/(1+b);
iB1=iB1*1000;//micro A
printf('\niB1=%.3f microA\n',iB1)
iE2=(10-0.6+15)/R1;
printf('\niE2=%.3f mA\n',iE2)
iB2=iE2/(1+b);
iB2=iB2*1000;
printf('\niB2=%.3f microA\n',iB2)
Ii=iB2-iB1;
printf('\ninput current=%.3f microA\n',Ii)
Ii=Ii*0.001;//mA
Ai=io/Ii;
printf('\ncurrent gain=%.2f\n',Ai)
Ai=(1+b)*R1/(2*Rl);
printf('\npredicted current gain=%.2f\n',Ai)
```

Chapter 9

The Ideal Operational Amplifier

Scilab code Exa 9.5 Determine a load current in a voltage to current converter

```
clear;
clc;
//Example 9.5
Zl=0.1;
R1=10;
R2=1;
R3=1;
Rf=10;
Vt=-5;
iL=-Vt/R2;
printf('\nload current=%.3f mA\n',iL)
vL=iL*Zl;
printf('\nvoltage across the load=%.2f V\n',vL)
i4=vL/R2;
printf('\ni4=%.3f mA\n',i4)
i3=i4+iL;
printf('\ni3=%.3f mA\n',i3)
Vo=i3*R3+vL;
```

```
printf('\noutput voltage=%.2f V\n',Vo)
i1=Vt/R1;
i2=i1;
printf('\ni1=%.3f mA\n',i1)
printf('\ni2=%.2f mA\n',i2)
```

Scilab code Exa 9.9 Determine the time constant

```
clear;
clc;
//Example 9.9
//Vo=(-1/R1*C2)*integrate((-1)dt)
x=integrate('(-1)','t',0,1)
Vo=10;
//let y=R1*C2
y=-x/Vo;
printf('\nR1C2=%.2f ms\n',y)
```

Chapter 10

Integrated Circuit Biasing and Active Loads

Scilab code Exa 10.1 Design a two transistor current source

```
clear;
clc;
//Example 10.1
Vbe=0.6;//(V)
b=100;
V1=5;
Io=200;//micro A
Iref=Io*(1+2/b);
printf('\nreference current=%.2f microA\n',Iref)
Iref=Iref*0.001;//mA
R1=(V1-Vbe)/Iref;
printf('\nR1=%.2f KOhm\n',R1)
```

Scilab code Exa 10.2 Determine the change in load current

```
clear;
```

```
clc;
//Example 10.2
V1=5;
V2=-5;
R1=9.3;
b=50;
Vbe=0.7;
Va=80;
Iref=(V1-Vbe-V2)/R1;
printf('\nreference current =%.3fmA\n',Iref)
Io=Iref/(1+2/b);
printf('\noutput current=%.2fmA\n',Io)
ro=Va/Io;
printf('\nsmall signal output resistance=%.2f KOhm\n
    ',ro)
//dIo=dVce2/ro
Vce2=0.7;
dIo=(V1-Vce2)/ro;
printf('\nchange in load current=%.3f mA\n',dIo)
x=dIo/Io;
x=x*100;
printf('\npercent change in output current=%.2f \n',
    x)
```

Scilab code Exa 10.4 Design a Widlar current source

```
clear;
clc;
//Example 10.4
Iref=1;
Io=12*10^-3;
V1=5;
V2=-5;
Vt=0.026;
Vbe=0.7;
```

```
R1=(V1-Vbe-V2)/Iref;
printf('\nResistance R1 =%.2fKOhm\n',R1)
Re=(Vt/Io)*log(Iref/Io);
printf('\nResistance Re =%.2fKOhm\n',Re)
Vbe=Io*Re;
printf('\ndifference between two B–E voltages=%.2f V\n',Vbe)
```

Scilab code Exa 10.5 Determine the change in load current

```
clear;
clc;
//Example 10.5
V1=5;
V2=-5;
R1=9.3;
Re=9.580;
Vt=0.026;
b=100;
Vbe=0.7;
Va=80;
Io=12;
ro2=Va/Io;
printf('\nsmall signal collector resistance=%.2f MOhm\n',ro2)
Io=12*0.001;//mA
gm2=Io/Vt;
printf('\ntransconductance=%.3f mA/V\n',gm2)
r=b*Vt/Io;
printf('\nResistance=%.2f KOhm\n',r)
Ro=ro2*(1+gm2*Re*r/(Re+r));
printf('\noutput resistance=%.2f MOhm\n',Ro)
dVc2=4;
dIo=dVc2/Ro;
printf('\nchange in load current=%.3f microA\n',dIo)
```

```
Io=12;//micro A
x=dIo/Io;
x=x*100;
printf('\npercent change in output current =%.4f\n',
   x)
```

Scilab code Exa 10.6 Design a generalized current mirror

```
clear;
clc;
//Example 10.6
V1=5;
V2=-5;
Vbe=0.6;
Veb=0.6;
Iq2=400*10^-3;//mA
Iref=200*10^-3;//mA
Iq1=Iref;
Iq3=Iq1;
Iq4=600*10^-6;
R1=(V1-Veb-Vbe-V2)/Iref;
printf('\nResistance R1=%.f KOhm\n',R1)
```

Scilab code Exa 10.7 Design a MOSFET current source

```
clear;
clc;
//Example 10.7
//uox*Cox/2=x
x=20*10^-6;//A/V^2
Vtn=1;
V1=5;
V2=0;
```

```
Iref=0.25*10^-3;
Io=0.1*10^-3;
Vgs2=1.85;
//let y=W/L
y2=Io/(x*(Vgs2-Vtn)^2);
printf('\nwidth per length 2=%.2f\n',y2)
y1=Iref/(x*(Vgs2-Vtn)^2);
printf('\nwidth per length 1=%.2f\n',y1)
Vgs1=Vgs2;
Vgs3=V1-V2-Vgs1;
printf('\nVgs3=%.2f V\n',Vgs3)
y3=Iref/(x*(Vgs3-Vtn)^2);
printf('\nwidth per length 3=%.2f\n',y3)
```

Scilab code Exa 10.8 Compare the output resistances

```
clear;
clc;
//Example 10.8
Iref=100;
Io=Iref;
//lambda=y
y=0.01;
gm=0.5*10^+3;
ro=1/(y*Iref);
printf('\noutput resistance=%.2f MOhm\n',ro)
ro2=1;
ro4=1;
Ro=ro4+ro2*(1+gm*ro4);
printf('\noutput resistance of cascode circuit=%.2f MOhm\n',Ro)
```

Scilab code Exa 10.9 Determiine the currents and voltages

```
clear;
clc;
//Example 10.9
Idss1=2;
Idss2=1;
Vp1=-1.5;
Vp2=Vp1;
//lambda=y
y1=0.05;
y2=y1;
V2=-5;
Vds=1.5;
Vsmin=Vds+V2;
printf('\nminimum value of Vs=%.2f V\n',Vsmin)
Io=Idss2*(1+y1*Vds);
printf('\noutput current=%.2f mA\n',Io)
Vgs1=(1-sqrt(Io/Idss1))*Vp1;
printf('\ngate to source voltage of Q1=%.2f V\n',
    Vgs1)
V1=Vgs1+Vsmin;
printf('\nV1=%.2f V\n',V1)
```

Scilab code Exa 10.10 Calculate the open circuit voltage gain

```
clear;
clc;
//Example 10.10
Vt=0.026;
Van=120;
Vap=80;
Av=-(1/Vt)/(1/Van+1/Vap);
printf('\nsmall signal open circuit voltage gain=%.2
    f\n',Av)
```

Scilab code Exa 10.11 Calculate the small signal voltage gain

```
clear;
clc;
//Example 10.11
Van=120;
Vap=80;
Vt=0.026;
Ico=0.001;
//Rl=infinity
Av=-(1/Vt)/(1/Van+1/Vap);
printf('\nsmall signal open circuit voltage gain=%.2
    f\n',Av)
Rl=100;
Av1=-(1/Vt)/(1/Van+1/Vap+1/Rl);
printf('\nsmall signal open circuit voltage gain=%.2
    f\n',Av1)
Rl=10;
Av2=-(1/Vt)/(1/Van+1/Vap+1/Rl);
printf('\nsmall signal open circuit voltage gain=%.2
    f\n',Av2)
```

Scilab code Exa 10.12 Calculate the small signal voltage gain

```
clear;
clc;
//Example 10.12
//lambda=y
yn=0.01;
yp=0.01;
Vtn=1;
Kn=1;
```

```
Iref=0.5;
gm=2*sqrt(Kn*Iref);
printf('\ntransconductance =%.2fmA/V\n',gm)
go=yn*Iref;
printf('\nsmall signal transistor conductance=%.4f
   mA/V\n',go)
go2=go;
//for Rl=infinity
Av=-gm/(go+go2);
printf('\nvoltage gain=%.2f \n',Av)
Rl=100;//Kohm
gl=0.01;
Av=-gm/(go+gl+go2);
printf('\nvoltage gain=%.2f \n',Av)
```

Chapter 11

Differential and Multistage Amplifier

Scilab code Exa 11.1 Determine the quiescent collector current and collector emitter voltage

```
clear;
clc;
//Example 11.1
V1=10;
V2=-10;
Iq=1;
Rc=10;
Vbe=0.7;
iC1=Iq/2;
iC2=iC1;
printf('\ncollector currents =%.2fmA\n',iC1)
Vc1=V1-iC1*Rc;
Vc2=Vc1;
printf('\ncollector voltages =%.2fV\n',Vc1)
Vcm=0;
Ve=Vcm-Vbe;
Vce1=Vc1-Ve;
printf('\ncollector emitter voltage=%.2f V\n',Vce1)
```

```
Vcm=-5;
Ve=Vcm-Vbe;
Vce1=Vc1-Ve;
printf('\ncollector emitter voltage =%.2fV\n',Vce1)
Vcm=5;
Ve=Vcm-Vbe;
Vce1=Vc1-Ve;
printf('\ncollector emitter voltage=%.2f V\n',Vce1)
```

Scilab code Exa 11.3 Determine the differential and common mode gains

```
clear;
clc;
//Example 11.3
V1=10;
V2=-10;
Iq=0.8*10^-3;
Rc=12000;
Ro=25000;
b=100;
Vt=0.026;
Ad=Iq*Rc/(4*Vt);
printf('\ndifferential gain=%.3f\n',Ad)
Acm=-(Iq*Rc/(2*Vt))/(1+(1+b)*Iq*Ro/(Vt*b));
printf('\ncommon mode gain=%.3f\n',Acm)
```

Scilab code Exa 11.7 Determine the CMRR of a differential amplifier

```
clear;
clc;
//Example 11.7
Ad=92.3;
Acm=0.237;//mod of Acm
```

```
CMRR=Ad/Acm;
printf('\ncommon mode rejection ratio=%.2f\n',CMRR)
CMRRdB=20*log10(CMRR);
printf('\nCMRR in decibels=%.2f dB\n',CMRRdB)
```

Scilab code Exa 11.8 Design a bipolar source

```
clear;
clc;
//Example 11.8
CMRRdB=90;//dB
CMRR=3.16*10^4;
b=100;
Vt=0.026;
Iq=0.8;
Ro=(2*CMRR-1)*Vt*b/((1+b)*Iq);
Ro=Ro*10^-3;//Mohm
disp(Ro,"output resistance (MOhm)")
```

Scilab code Exa 11.9 Determine the differential and common mode input resistance

```
clear;
clc;
//Example 11.9
b=100;
Vbe=0.7;
Va=100;
Vt=0.026;
Iref=0.5;
Iq=Iref;
I1=Iq/2
Icq=I1;
```

```
r=b*Vt/Icq;
printf('\nsmall signal parameter=%.2f KOhm\n',r)
ro=Va/Icq;
printf('\nro=%.2f KOhm\n',ro)
Ro=Va/Iq;
printf('\noutput resistance of Q4=%.2f KOhm\n',Ro)
Rid=2*r;
printf('\ndifferential mode input resistance =%.2fKOhm\n',Rid)
Ricm=(1+b)*(Ro*ro/2)/(Ro+ro/2);
Ricm=Ricm*0.001;//Mohm
printf('\ncommon mode input resistance=%.2f MOhm\n',Ricm)
```

Scilab code Exa 11.10 Calculate the dc characteristics of a MOSFET diff amp

```
clear;
clc;
//Example 11.10
Kn1=0.1;
Kn2=Kn1;
Kn3=0.1;
Kn4=Kn3;
R1=30;
Vtn=1;
Rd=16;
//I1=(20-Vgs4)/R1 and I1=Kn3*(Vgs4-Vtn)^2
Vgs4=poly(0,'Vgs4')
p=poly([-1 -17 9],'Vgs4','c')
printf('\nroots=%.2fV\n',roots(p))
Vgs4=2.40;
I1=(20-Vgs4)/R1;
printf('\nI1=%.2f mA\n',I1)
Iq=I1;
```

```
Id1=Iq/2;
printf('\nId1 and Id2 =%.2fmA\n',Id1)
Vgs1=sqrt(Id1/Kn1)+Vtn;
printf('\nVgs1 and Vgs2 =%.2fV\n',Vgs1)
vo1=10-Id1*Rd;
printf('\nvo1 and vo2=%.2f V\n',vo1)
Vds1=Vgs1-Vtn;
printf('\nVds1=Vds2=Vds1(sat)=%.2f V\n',Vds1)
Vcm=vo1-Vds1+Vgs1;
printf('\nVcm max=%.2f V\n',Vcm)
Vds4=Vgs4-Vtn;
printf('\nVds4=%.2f V\n',Vds4)
Vcm2=Vgs1+Vds4-10;
printf('\nVcm min=%.2fV\n',Vcm2)
```

Scilab code Exa 11.11 Compare the forward transconductance

```
clear;
clc;
//Example 11.11
Kn=0.5;
Iq=1;
Vt=0.026;
//transconductance of the MOSFET
gm=2*sqrt(Kn*Iq/2);
printf('\ntransconductance=%.3f mA/V\n',gm)
//transconductance of the bipolar transistor
gm=Iq/(2*Vt);
printf('\ntransconductance=%.3f mA/V\n',gm)
```

Scilab code Exa 11.12 Determine the differential mode voltage gain common mode voltage gain CMRR

```
clear;
clc;
//Example 11.12
Iq=0.587;
Kn=1;
Rd=16;
//lambda=y
y=0.01;
Ro=1/(y*Iq);
printf('\noutput resistance =%.2fKOhm\n',Ro)
Ad=sqrt(Kn*Iq/2)*Rd;
printf('\ndifferential mode voltage gain=%.2f \n',Ad
   )
Acm=-sqrt(2*Kn*Iq)*Rd/(1+2*sqrt(2*Kn*Iq)*Ro);
printf('\ncommon mode voltage gain=%.2f\n',Acm)
CMRR=20*log10(-Ad/Acm);
printf('\ncommon mode rejection ratio=%.2f dB\n',
   CMRR)
```

Scilab code Exa 11.13 Determine the differential mode voltage gain

```
clear;
clc;
//Example 11.13
Iq=0.2;
Va=100;
Va2=Va;
Va4=Va;
Rl=100;
Vt=0.026;
Ad=(1/Vt)/(1/Va2+1/Va4);
printf('\nopen circuit voltage gain=%.2f\n',Ad)
Ad=(Iq/(2*Vt))/(Iq/(2*Va2)+Iq/(2*Va4)+1/Rl);
printf('\nvoltage gain=%.2f\n',Ad)
```

Scilab code Exa 11.15 Determine the differential mode voltage gain

```
clear;
clc;
//Example 11.15
Kn=0.2;
Idq=0.1;
ro4=1000;//Kohm
ro6=1000;//KOhm
ro2=ro4;
//lambda=y
y=0.01;
gm=2*sqrt(Kn*Idq);
printf('\ntransconductance=%.3f mA/V\n',gm)
ro=1/(y*Idq);
printf('\noutput resistance=%.2f KOhm\n',ro)
Ro=ro4+ro6*(1+gm*ro);
Ro=Ro*0.001;//Mohm
printf('\noutput resistance of the cascode active
    load=%.2fMohm\n',Ro)
Ro=Ro*1000;//KOhm
Ad=gm*ro2*Ro/(ro4+Ro);
printf('\ndifferential mode voltage gain=%.2f\n',Ad)
```

Scilab code Exa 11.16 Calculate the input resistance and the small signal voltage gain

```
clear;
clc;
//Example 11.16
Iq=0.2;
Ic1=Iq;
```

```
Icb=1;
R4=10;
R3=0.2;
b=100;
Va=100;
Vt=0.026;
Ri=2*(1+b)*b*Vt/Iq;
Ri=Ri*0.001; //MOhm
printf('\ninput resistance=%.2f MOhm\n',Ri)
R11=b*Vt/Iq;
printf('\nresistance R11=%.2f KOhm\n',R11)
Re=R11*R3/(R11+R3);
printf('\nRe=%.2f KOhm\n',Re)
gm11=Iq/Vt;
printf('\ngm11=%.3f mA/V\n',gm11)
ro11=Va/Iq;
printf('\nro11 =%.2fKOhm\n',ro11)
Rc11=ro11*(1+gm11*Re);
Rc11=Rc11*0.001; //MOhm
printf('\nRc11=%.2f MOhm\n',Rc11)
r8=b*Vt/Icb;
printf('\nresistance=%.2fKOhm\n',r8)
//answer of following given in the book is wrong
Rb8=r8+(1+b)*R4;
Rb8=Rb8*0.001; //MOhm
printf('\nRb8 =%.2fMOhm\n',Rb8)
R17=Rc11*Rb8/(Rc11+Rb8);
printf('\nR17=%.2f MOhm\n',R17)
Av=Iq*R17/(2*Vt);
printf('\nsmall signal voltage gain=%.2f\n',Av)
```

Scilab code Exa 11.17 Calculate the output resistance

```
clear;
clc;
```

```
//Example 11.17
Va=100;
R4=10;
b=100;
Rc11=1.26*10^3;
r8=2.6;
Iq=0.2;
Rc7=Va/Iq;
printf('\nRc7=%.2f KOhm\n',Rc7)
Z=Rc11*Rc7/(Rc11+Rc7);
printf('\nZ=%.2f KOhm\n',Z)
x=(r8+Z)/(1+b);
Ro=R4*x/(R4+x);
printf('\noutput resistance=%.2f KOhm\n',Ro)
```

Scilab code Exa 11.19 Determine the differential mode voltage gain

```
clear;
clc;
//Example 11.19
b=100;
Vt=0.026;
Rc=20;
Ir4=0.4;
Iq=Ir4;
Ir6=Ir4;
r4=b*Vt/Ir4;
printf('\nr4=%.2f KOhm\n',r4)
r3=b^2*Vt/Ir4;
printf('\nr3=%.2f KOhm\n',r3)
Ri2=r3+(1+b)*r4;
printf('\ninput resistance=%.2f KOhm\n',Ri2)
gm=Iq/(2*Vt);
printf('\ntransconductance=%.3f mA/V\n',gm)
Ad1=gm*Rc*Ri2/(2*(Rc+Ri2));
```

```
printf('\ngain of differential amplifier stage=%.2f\n',Ad1)
r5=b*Vt/Ir6;
printf('\nr5 =%.2fKOhm\n',r5)
Ir7=2;
r6=b*Vt/Ir7;
printf('\nr6=%.2f KOhm\n',r6)
R6=16.5;
R7=5;
Ri3=r5+(1+b)*(R6+r6+(1+b)*R7);
Ri3=Ri3*0.001;//MOhm
printf('\nRi3=%.2f MOhm\n',Ri3)
Rs=5;
A2=Ir4*Rs/(2*Vt);
printf('\nvoltage gain A2=%.2f\n',A2)
A3=1;//vo/vo3
Ad=Ad1*A2*A3;
printf('\nsmall signal voltage gain=%.2f\n',Ad)
```

Scilab code Exa 11.20 Determine the zero and pole frequencies

```
clear;
clc;
//Example 11.20
Ro=10000000;
Co=1*10^-12;
Rb=500;
r=10000;
b=100;
f=1/(2*%pi*Ro*Co);
f=f*0.001;//KHz
printf('\nfrequency of the zero=%.2f KHz\n',f)
Req=Ro*(1+Rb/r)/(1+Rb/r+2*(1+b)*Ro/r);
printf('\nReq=%.2f Ohm\n',Req)
f=1/(2*%pi*Req*Co);
```

```
f=f*10^-9;//GHz
printf('\nfrequency of the pole=%.2f GHz\n',f)
```

Chapter 12

Feedback and Stability

Scilab code Exa 12.1 Calculate the feedback transfer function

```
clear;
clc;
//Example 12.1
A=10^5;//open loop gain
Af=50;//closed loop gain
b=(A/Af-1)/A;
printf('\nfeedback transfer function=%f\n',b)
A=-10^5;
Af=-50;
b=(A/Af-1)/A;
printf('\nfeedback transfer function=%f\n',b)
```

Scilab code Exa 12.2 Calculate the percent change in the closed loop gain Af

```
clear;
clc;
//Example 12.2
```

```
A=10^5;
Af=50;
b=0.019999;
dA=10^4;
dAf=Af*dA/(A*(1+b*A));
printf('\ndAf=%e\n',dAf)
//x=dAf/Af
x=dAf/Af;
x=x*100;
printf('\npercent change dAf/Af=%f\n',x)
```

Scilab code Exa 12.3 Determine the bandwidth of a feedback amplifier

```
clear;
clc;
//Example 12.3
Ao=10^4;
wh=2*%pi*100;//rad/s
Af=50;
//x=(1+bAo)
x=Ao/Af;
printf('\n(1+bAo)=%f\n',x)
wfh=wh*x;
printf('\nclosed loop bandwidth=%f\n',wfh)
```

Scilab code Exa 12.5 Determine the input resistance and output resistance

```
clear;
clc;
//Example 12.5
Av=10^5;
Avf=50;
```

```
Rf=10; //Kohm
Ro=20000; //Ohm
//x=(1+bvAv)
x=Av/Avf;
printf('\n(1+bvAv)=%.e\n',x)
Rif=Rf*x;
Rif=Rif*0.001; //MOhm
printf('\ninput resistance=%.2f MOhm\n',Rif)
Rof=Ro/x;
printf('\noutput resistance=%.2f Ohm\n',Rof)
```

Scilab code Exa 12.6 Determine the input resistance and output resistance

```
clear;
clc;
//Example 12.6
Af=10^5;
Aif=50;
Rf=10000;
Ro=20;
//x=(1+biAi)
x=Af/Aif;
printf('\n(1+biAi)=%.e\n',x)
Rif=Rf/x;
printf('\ninput resistance =%.2fOhm\n',Rif)
Rof=Ro*x;
Rof=Rof*0.001; //Mohm
printf('\noutput resistance=%.2f MOhm\n',Rof)
```

Scilab code Exa 12.7 Determine the expected input resistance

```
clear;
```

```
clc;
//Example 12.7
Ri=50;
R1=10;
R2=90;
Av=10^4;
bv=1/(1+R2/R1);
printf('\nfeedback transfer function=%.2f\n',bv)
Rif=Ri*(1+bv*Av);
Rif=Rif*0.001;//Mohm
printf('\ninput resistance=%.2f MOhm\n',Rif)
```

Scilab code Exa 12.11 Determine the transconductance gain of a transistor feedback circuit

```
clear;
clc;
//Example 12.11
hFE=100;//transistor parameter
Vbe=0.7;
Vcc=10;
R1=55;
R2=12;
Re=1;
Rc=4;
Rl=4;
Icq=0.983;
Vceq=5.08;
Vt=0.026;
r=hFE*Vt/Icq;
printf('\nsmall signal parameter resistance=%.2f
    KOhm\n',r)
gm=Icq/Vt;
printf('\ntransconductance=%.3f mA/V\n',gm)
Agf=-gm*(Rc/(Rc+Rl))/(1+Re*(gm+1/r));
```

```
printf('\ntransconductance transfer function=%.3f mA/V\n',Agf)
//as first approximation
Agf2=-1/Re;
printf('\nAgf=%.2f mA/V\n',Agf2)
Avf=Agf*Rl;
printf('\nvoltage gain=%.2f\n',Avf)
```

Scilab code Exa 12.16 Determine the loop gain

```
clear;
clc;
//Example 12.15
//Determine the loop gain fig12.45(a)
hFE=100;
Vbe=0.7;
Icq=0.492;
r=5.28;
gm=18.9;
Rs=10;
R1=51;
R2=5.5;
Re=0.500;
Rc=10;
Rf=82;
x=r*R2/(r+R2);
y=R1*x/(x+R1);
t=Rs*y/(y+Rs);
Req=t;
printf('\nequivalent resistance=%.2f KOhm\n',t)
T=gm*Rc*Req/(Rc+Rf+Req);
printf('\nthe loop gain=%.2f\n',T)
```

Scilab code Exa 12.19 Determine the stability of an amplifier

```
clear;
clc;
//Example 12.19
//T=b*100/(sqrt(1+(f/10^5)^2) angle=-3tan^-1(f/10^5)
//stable at f180 at which phase becomes -180 degrees
//-3*atan(f180/10^5)=-180
f180=tand(180/3)*10^5;
printf('\nfrequency at -180 degree=%ef Hz\n',f180)
b=0.2;
T=b*100/(sqrt(1+(f180/10^5)^2))^3;
printf('\nmagnitude of the loop gain=%.2f\n',T)
b=0.02;
T=b*100/(sqrt(1+(f180/10^5)^2))^3;
printf('\nmagnitude of the loop gain=%.2f\n',T)
```

Scilab code Exa 12.22 Determine the shift in the 3dB frequency

```
clear;
clc;
//Example 12.22
Ao=10^6;
fPD=0.010;//KHz
b=0.01;
Af=Ao/(1+b*Ao);
printf('\nlow frequency closed loop gain=%.2f\n',Af)
fc=fPD*(1+b*Ao);
printf('\nclosed loop 3dB frequency=%.2f KHz\n',fc)
```

Scilab code Exa 12.23 Determine the shift in the 3dB frequency

```
clear;
```

```
clc;
//Example 12.23
A=10^3;
Cf=30*10^-12;//feedback capacitor (F)
R2=5*10^5;
Cm=Cf*(1+A);
printf('\nMiller capacitance=%e F\n',Cm)
fp=1/(2*%pi*R2*Cm);
printf('\ndominant pole frequency =%.2fHz\n',fp)
```

Chapter 13

Operational Amplifier Circuits

Scilab code Exa 13.1 Calculate the dc currents

```
clear;
clc;
//Example 13.1
V1=15;//positive supply voltage
V2=-15;//negative supply voltage
Veb12=0.6;
Vbe11=0.6;
Rs=40;
Iref=(V1-V2-Veb12-Vbe11)/Rs;
printf('\nreference current=%.2f mA\n',Iref)
Ic10=19;
Ic1=Ic10/2;
printf('\nIc1=Ic2=Ic3=Ic4= %.3fmicroA\n',Ic1)
Ic1=Ic1*0.001;//mA
Vbe7=0.6;
Vbe6=0.6;
Ic6=Ic1;
R2=1;
Vc6=Vbe7+Vbe6+Ic6*R2+V2;
printf('\nvoltage at collector of Q6=%.2f V\n',Vc6)
```

Scilab code Exa 13.2 Calculate the bias currents

```
clear;
clc;
//Example 13.2
Iref=0.72;
Ic17=0.75*Iref;
printf('\ncollector currents in Q17=%.2f mA\n',Ic17)
b=200;
Ib17=Ic17/b;
Ie17=Ic17;
R8=0.100;
Vbe17=0.6;
R9=50;
Ic16=Ib17+(Ie17*R8+Vbe17)/R9;
Ic16=Ic16*1000;
printf('\ncollector current in Q16=%.2f microA\n',Ic16)
```

Scilab code Exa 13.3 Calculate the bias currents

```
clear;
clc;
//Example 13.3
Is1=10^-14;//reverse saturation currents for Q18 Q19
Is2=3*10^-14;//reverse saturation currents for Q14 Q20
Iref=0.72;
Vt=0.026;
Ic13a=0.25*Iref;
printf('\nIc13a=%.2f mA\n',Ic13a)
Vbe19=0.6;
```

```
R10=50;
Ir1o=Vbe19/R10;
printf('\ncurrent in Ro=%.3f mA\n',Ir1o)
Ic19=Ic13a-Ir1o;
printf('\ncurrent in Q19 =%.3fmA\n',Ic19)
Ic19=Ic19*0.001;//A
Vbe19=Vt*log(Ic19/Is1);
printf('\nB-E voltage of Q19=%.2f V\n',Vbe19)
b=200;
Ic19=Ic19*10^6;//micro A
Iv19=Ic19*1000;
Ib18=Ic19/b;
Ir1o=Ir1o*1000;
printf('\nbase current in Q18=%.3f microA\n',Ib18)
Ic18=Ir1o+Ib18;
printf('\ncurrents in Q18=%.3f microA\n',Ic18)
Ic18=Ic18*10^-6;
Vbe18=Vt*log(Ic18/Is1);
printf('\nB-E voltage of Q18=%.2f V\n',Vbe18)
Vbb=Vbe18+Vbe19;
printf('\nvoltage difference Vbb=%.2f V\n',Vbb)
Ic14=Is2*exp(Vbb/(2*Vt));
Ic14=Ic14*10^6;//micro A
printf('\nquiescent currents in Q14 and Q20 =%.fmicroA\n',Ic14)
```

Scilab code Exa 13.4 Determine the small signal differential voltage gain

```
clear;
clc;
//Example 13.4
b=200;
Va=50
Vt=0.026;
R2=1;
```

```
Ic6=0.0095;
Ic4=Ic6;
Ic16=0.0158;
Ic17=0.54;
r17=b*Vt/Ic17;
printf('\ninput resistance to gain stage=%.2f KOhm\n',r17)
R9=50;
R8=0.100;
x=r17+(1+b)*R8;
Re=x*R9/(x+R9);
printf('\nRe=%.3f KOhm\n',Re)
r16=b*Vt/Ic16;
printf('\nr16=%.2f KOhm\n',r16)
Ri2=r16+(1+b)*Re;
Ri2=Ri2*0.001;//MOhm
printf('\nRi2=%.2f KOhm\n',Ri2)
r6=b*Vt/Ic6;
printf('\nresistance of the active load=%.2f KOhm\n',r6)
gm=Ic6/Vt;
printf('\ntransconductance =%.3fmA/V\n',gm)
ro6=Va/Ic6;
ro6=ro6*0.001;//MOhm
printf('\nro6=%.2f MOhm\n',ro6)
R=ro6*(1+gm*R2*r6/(R2+r6));
printf('\neffective resistance of active load=%.2f MOhm\n',R)
ro4=Va/Ic4;
ro4=ro4*0.001;//Mohm
printf('\nResistance ro4=%.2f KOhm\n',ro4)
Icq=9.5;
x=Ri2*R/(R+Ri2);
y=ro4*x/(ro4+x);
Ad=-y*Icq/Vt;
printf('\nsmall signal differential voltage gain=%.2f\n',Ad)
```

Scilab code Exa 13.5 Determine the small signal voltage gain

```
clear;
clc;
//Example 13.5
bp=50;
bn=200;
Va=50;
R9=50;
R8=0.100;
Rl=2;
Vt=0.026;
Ri2=4070;
Ic20=0.138;
r20=bp*Vt/Ic20;
printf('\nr20=%.2f KOhm\n',r20)
R20=r20+(1+bp)*Rl;
printf('\nR20=%.2f KOhm\n',R20)
Ic13A=0.18;
R19=Va/Ic13A;
printf('\nR19=%.2f KOhm\n',R19)
r22=bp*Vt/Ic13A;
printf('\nr22=%.2f KOhm\n',r22)
Ri3=r22+(1+bp)*R19*R20/(R19+R20);
Ri3=Ri3*0.001;//MOhm
printf('\ninput resistance to the output stage=%.2f
    MOhm\n',Ri3)
Ic13B=0.54;
R=Va/Ic13B;
printf('\neffective resistance of the active load=%
    .2f KOhm\n',R)
Ic17=Ic13B;
R17=Va/Ic17;
printf('\noutput resistance Ro17 =%.2fKOhm\n',R17)
```

```
Ri3=Ri3*1000; //KOhm
r17=9.63;
x=R17*Ri3/(Ri3+R17);
y=x*R/(R+x);
A=-bn*R9*(1+bn)*y/(Ri2*(R9+r17+(1+bn)*R8));
printf('\nsmall signal voltage gain=%.2f\n',A)
```

Scilab code Exa 13.6 Calculate the output resistance

```
clear;
clc;
//Example 13.6
Ic20=2;
bn=200;
bp=50;
Va=50;
r17=9.63;
r22=7.22;
R20=0.260;
gm17=20.8;
ro17=92.6;
Ro13B=92.6;
R8=0.100;
Rc17=ro17*(1+gm17*R8*r17/(R8+r17));
printf('\nRc17=%.2f KOhm\n',Rc17)
Rc22=(r22+Rc17*Ro13B/(Rc17+Ro13B))/(1+bp);
printf('\nRc22=%.2f KOhm\n',Rc22)
Ic13A=0.18;
Rc19=Va/Ic13A;
printf('\nRc19=%.2f KOhm\n',Rc19)
Rc20=(R20+Rc22*Rc19/(Rc22+Rc19))/(1+bp);
printf('\nRc20=%.5f KOhm\n',Rc20)
Rc20=Rc20*1000; //Ohm
R3=22;
Ro=R3+Rc20;
```

```
printf('\noutput resistance=%.2f Ohm\n',Ro)
```

Scilab code Exa 13.7 Determine the dominant pole frequency of the 741 op amp

```
clear;
clc;
//Example 13.7
Av2=285;
C1=30;
Ci=C1*(1+Av2);
printf('\ninput capacitance=%.2f pF\n',Ci)
Ri2=4.07;
Ract=7.18;
ro4=5.26;
Ro1=Ract*ro4/(Ract+ro4);
printf('\ngate stage input resistance=%.2fMOhm \n',
    Ro1)
Req=Ro1*Ri2/(Ri2+Ro1);
printf('\nequivalent resistance=%.2f MOhm\n',Req)
Req=Req*10^6;//Ohm
Ci=Ci*10^-12;//F
fPD=1/(2*%pi*Req*Ci);
printf('\ndominant pole frequency =%.2fHz\n',fPD)
```

Scilab code Exa 13.9 Determine the small signal voltage gain

```
clear;
clc;
//Example 13.9
//lambda=y
y=0.02;
//W/L=x and u*Cox/2=t
```

```
x=12.5;
t=10;
Kp1=x*t;
printf('\nconduction parameters of M1 and M2=%.fmicroA/V^2\n',Kp1)
Kp1=Kp1*0.001;//mA/V^2
Id=0.0199;
ro2=1/(y*Id);
ro2=ro2*0.001;//Mohm
printf('\noutput resistance=%.2f MOhm\n',ro2)
Iq=0.0397;
ro2=ro2*1000;//Kohm
ro4=ro2;
Ad=sqrt(2*Kp1*Iq)*ro2*ro4/(ro2+ro4);
printf('\nthe gain of input stage=%.2f \n',Ad)
Kn7=0.250;
Id7=Iq;
gm7=2*sqrt(Kn7*Id7)
printf('\ntransconductance of M7=%.2f mA/V\n',gm7)
ro7=1/(y*Id7);
ro7=ro7*0.001;
printf('\noutput resistance of M7 and M8 =%.2fMOhm\n',ro7)
ro7=ro7*1000;//Kohm
ro8=ro7;
Av2=gm7*ro7*ro8/(ro7+ro8);
printf('\ngain of the second stage=%.2f\n',Av2)
Av=Ad*Av2;
printf('\noverall voltage gain=%.2f\n',Av)
```

Scilab code Exa 13.10 Determine the differential mode voltage gain

```
clear;
clc;
//Example 13.10
```

```
Iref=100;
Kn=80;
Kp=40;
//W/L=x
x=25;
//lambda=y
y=0.02;
Id=Iref/2;
gm1=2*sqrt(Kp*x*Id/2);
printf('\ntransconductance gm1=gm8=%.3f microA/V\n',gm1)
gm6=2*sqrt(Kn*x*Id/2);
printf('\ntransconductance=%.3f microA/V\n',gm6)
ro1=1/(y*Id);
ro8=ro1;
ro6=ro1;
ro10=ro1;
printf('\noutput resistance ro1=ro8=ro6=ro10=%.3f MOhm\n',ro1)
Id4=Iref;
ro4=1/(y*Id4);
printf('\nro4=%.3f MOhm\n',ro4)
Ro8=gm1*ro8*ro10;
printf('\ncomposite output resistances =%.2f MOhm\n',Ro8)
Ro6=gm6*ro6*ro4*ro1/(ro4+ro1);
printf('\ncomposite output resistances=%.2f MOhm\n',Ro6)
Ad=gm1*Ro6*Ro8/(Ro6+Ro8);
printf('\ndifferential voltage gain=%.2f\n',Ad)
```

Scilab code Exa 13.12 Determine the small signal voltage gain

```
clear;
clc;
```

```
//Example 13.12
Kp=0.6;
bn=200;
Va=50;
Vt=0.026;
Ic13=0.20;
Ri2=bn*Vt/Ic13;
printf('\ninput resistance to the gain stage=%.2f
   KOhm\n',Ri2)
Iq5=Ic13;
Ad=sqrt(2*Kp*Iq5)*Ri2;
printf('\nsmall signal voltage gain=%.2f\n',Ad)
```

Scilab code Exa 13.13 Determine the small signal voltage gain

```
clear;
clc;
//Example 13.13
Va=150;
Vt=0.026;
Ic13=0.2;
gm13=Ic13/Vt;
printf('\ntransconductance=%.2f mA/V\n',gm13)
ro13=Va/Ic13;
printf('\noutput resistance=%.2f KOhm\n',ro13)
Av2=gm13*ro13;
printf('\nvoltage gain=%.2f \n',Av2)
```

Scilab code Exa 13.14 Determine the dominant pole frequency and unity gain bandwidth

```
clear;
clc;
```

```
//Example 13.14
Av2=5768;
C1=12;
Ci=C1*(1+Av2);
printf('\neffective input capacitance=%.2f pF\n',Ci)
Ri2=26000;//gain stage input resistance (Ohm)
Ci=Ci*10^-12;//F
fPD=1/(2*%pi*Ri2*Ci);
printf('\ndominant pole frequency=%.f Hz\n',fPD)
Av=73254;
fT=fPD*Av;
fT=fT*10^-6;//MHz
printf('\nunity gain bandwidth=%.2f MHz\n',fT)
```

Chapter 14

Nonideal Effects in Operational Amplifier Circuits

Scilab code Exa 14.2 Determine the closed loop input resistance

```
clear;
clc;
//Example 14.2
R2=10000;
Ri=10000;
Aol=10^5;
Rif=1/(1/Ri+(1+Aol)/R2);
printf('\nclosed loop input resistance =%.2fOhm\n',
   Rif)
```

Scilab code Exa 14.3 Determine the closed loop input resistance

```
clear;
clc;
//Example 14.3
Aol=10^5;
```

```
Ri=10;
R1=10;
R2=R1;
Rif=(Ri*(1+Aol)+R2*(1+Ri/R1))/(1+R2/R1);
Rif=Rif*0.001;//Mohm
printf('\ninput resistance =%.fMOhm\n',Rif)
```

Scilab code Exa 14.5 Determine the unity gain bandwidth and the closed loop gain

```
clear;
clc;
//Example 14.5
Ao=2*10^5;
fPD=5;
fT=fPD*Ao;
printf('\nunity gain bandwidth=%.e Hz\n',fT)
f3dB=20*10^3;
Acl=fT/f3dB;
printf('\nclosed loop gain=%.2f\n',Acl)
```

Scilab code Exa 14.6 Calculate the slew rate of the 741 op amp

```
clear;
clc;
//Example 14.6
Iq=19*10^-6;
C1=30*10^-12;
SR=Iq/C1;
SR=SR*10^-6;
printf('\nslew rate=%.2f V/micros\n',SR)
```

Scilab code Exa 14.7 Determine the small signal bandwidth of an amplifier and full power bandwidth

```
clear;
clc;
//Example 14.7
fT=1000;//KHz
Aclo=10;
SR=1*10^3;
Vpo=10;
f3dB=fT/Aclo;
printf('\nsmall signal closed loop bandwidth=%.2f
   KHz\n',f3dB)
fmax=SR/(2*%pi*Vpo);
printf('\nfull power bandwidth=%.2f KHz\n',fmax)
```

Scilab code Exa 14.8 Calculate the offset voltage in bipolar diff amp

```
clear;
clc;
//Example 14.8
Is1=10^-14;
Is2=1.05*10^-14;
Vt=0.026;
Vos=Vt*log(Is2/Is1);
printf('\nthe offset voltage =%fV\n',Vos)
```

Scilab code Exa 14.10 Calculate the offset voltage in MOSFET diff amp

```
clear;
clc;
//Example 14.10
Kn1=105;
Kn2=100;
Iq=200;
dKn=Kn1-Kn2;
printf('\ndifference in conduction parameter=%.2f
    microA/V^2\n',dKn)
Kn=(Kn1+Kn2)/2;
printf('\naverage of the conduction parameter=%.2f
    microA/V^2\n',Kn)
Vos=sqrt(Iq/(2*Kn))*dKn/(2*Kn);
printf('\noffset voltage=%f V\n',Vos)
```

Scilab code Exa 14.11 Determine the range of voltage produced by an offset voltage compensation network

```
clear;
clc;
//Example 14.11
Rs=100;
R4=100000;
R3=100000;
V1=15;
V2=-15;
Vy=Rs*V1/(Rs+R4);
Vy=Vy*1000;//mV
printf('\nVoltage Vy =%.2fmV\n',Vy)
```

Scilab code Exa 14.13 Determine the bias current effect

```
clear;
```

```
clc;
//Example 14.13
R1=10;
R2=100;
Ib1=1.1*10^-3;
Ib2=1*10^-3;
vo=Ib1*R2;
printf('\noutput voltage =%.2fV\n',vo)
R3=R1*R2/(R1+R2);
printf('\nR3=%.2f KOhm\n',R3)
vo=R2*(Ib1-Ib2);
printf('\noutput voltage=%.2f V\n',vo)
```

Chapter 15

Applications and Design of Integrated Circuits

Scilab code Exa 15.2 Determine the clock frequency

```
clear;
clc;
//Example 15.2
C=20*10^-6;
Req=1000;
fC=1/(C*Req);
printf('\nclock frequency =%.2fKHz\n',fC)
```

Scilab code Exa 15.3 Design a one pole low pass switched capacitor filter

```
clear;
clc;
//Example 15.3
fC=10000;
f3dB=1000;
//x=C2/C1
```

```
x=2*%pi*f3dB/fC;
printf('\ncapacitances C2/C1=%.3f \n',x)
```

Scilab code Exa 15.4 Determine the oscillation frequency and required amplifier gain

```
clear;
clc;
//Example 15.4
C=0.1*10^-6;
R=1000;
fo=1/(2*%pi*R*C*sqrt(3));
printf('\nthe oscillation frequency =%.2fHz\n',fo)
//minimum amplifier gain=8
R=1;//KOhm
R2=8*R;
printf('\nR2=%.f KOhm\n',R2)
```

Scilab code Exa 15.6 Determine the hysteresis width of a particular Schmitt trigger

```
clear;
clc;
//Example 15.6
R1=10000;
R2=90000;
Vh=10;
Vl=-10;
Vth=R1*Vh/(R1+R2);
printf('\nupper crossover voltage=%.f V\n',Vth)
Vtl=R1*Vl/(R1+R2);
printf('\nlower crossover voltage=%.f V\n',Vtl)
x=Vth-Vtl;
```

```
printf('\nhysteresis width =%.fV\n',x)
```

Scilab code Exa 15.7 Design a Schmitt trigger circuit

```
clear;
clc;
//Example 15.7
Vs=2;
Vh=15;
Vl=-15;
//hysteresis width=x
x=60*0.001;//(V)
//Vth-Vtl=(R1/(R1+R2))*(Vh-Vl)
//R2/R=y
y=(Vh-Vl)/x-1;
printf('\nR2/R1=%.2f \n',y)
Vref=(1+1/y)*Vs;
printf('\nreference voltage=%.4f V\n',Vref)
```

Scilab code Exa 15.10 Design the 555IC as a monostable multivibrator

```
clear;
clc;
//Example 15.10
C=15*10^-9;
T=100*10^-6;//(s) time
R=T/(1.1*C);
R=R*0.001;//Kohm
printf('\nResistance R=%.2f KOhm\n',R)
```

Scilab code Exa 15.13 Design the supply voltage

```
clear;
clc;
//Example 15.13
Rl=10;//load resistance
Pl=20;//power delivered to the load
Ps=20;// (W)
Vp=sqrt(2*Rl*Pl);
printf('\npeak output voltage=%.2f V\n',Vp)
Ip=Vp/Rl;
printf('\npeak load current =%.2fA\n',Ip)
Vs=%pi*Rl*Ps/Vp;
printf('\nrequired supply voltage=%.2f V\n',Vs)
```

Scilab code Exa 15.14 Determine the output resistance and load regulation

```
clear;
clc;
//Example 15.14
Vonl=5;
Vofl=4.96;
I1=0.005;
I2=1.5;
dVo=Vonl-Vofl;
dIo=I1-I2;
Rvf=-dVo/dIo;
printf('\noutput resistance=%f Ohm\n',Rvf)
LR=100*(Vonl-Vofl)/Vonl;
printf('\nload regulation =%.2f\n',LR)
```

Scilab code Exa 15.15 Determine the output resistance and variation in output voltage

```
clear;
clc;
//Example 15.15
Aol=1000;
Vref=5;
Vo=10;
Io=0.1*0.001;
Vt=0.026;
Rof=2*Vt*Vo/(Io*Vref*Aol);
printf('\noutput resistance=%.2f mOhm\n',Rof)
//dVo/Vo=V  and dIo/Io=I
//V=-I*2*Vt/(Vref*Aol)
//V/I=x
x=-2*Vt/(Vref*Aol);
printf('\npercent change=%.2e\n',x)
```

Scilab code Exa 15.16 Determine the bias current temperature compensated reference voltage and required resistor

```
clear;
clc;
//Example 15.16
Vz=6.3;
Vbe=0.6;
Veb=0.6;
Vo=8;
R1=3.9;
R2=3.4;
R3=0.576;
Ic3=(Vz-3*Vbe)/(R1+R2+R3);
printf('\nbias current =%.3f mA\n',Ic3)
Vb7=Ic3*R1+2*Vbe;
```

```
printf('\ntemperature compensated reference voltage=
    %.2f V\n',Vb7)
R13=2.23;
R12=R13*Vo/Vb7-R13;
printf('\nR12=%.2f KOhm\n',R12)
```

Chapter 16

MOSFET Digital Circuits

Scilab code Exa 16.3 Design the aspect ratio and determine the power dissipation

```
clear;
clc;
//Example 16.3
Vdd=5;
Vtnd=0.8;
Vtnl=0.8;
Kn=35;
Vo=0.1;
Vi=4.2;
//W/L=Y
yl=0.5;
//Kd/Kl=x
x=(Vdd-Vo-Vtnl)^2/(2*Vo*(Vi-Vtnd)-Vo^2);
printf('\nKd/Kl=%.2f\n',x)
//Kd/Kl=yd/yl
yd=12.6
yl=0.5
iD=Kn*yl*(Vdd-Vo-Vtnl)^2/2;
printf('\ndrain current =%.2f microA\n',iD)
P=iD*Vdd;
```

```
printf('\npower dissipation=%.2f microW\n',P)
```

Scilab code Exa 16.4 Design the aspect ratio and determine the power dissipation

```
clear;
clc;
//Example 16.4
Vdd=5;
Vtnd=0.8;
Vtnl=-2;
Kn=35;
Vo=0.1;
Vi=5;
//W/L=Y
yl=0.5;
//Kd/Kl=x
x=(-Vtnl)^2/(2*Vo*(Vi-Vtnd)-Vo^2);
printf('\nKd/Kl=%.2f\n',x)
//Kd/Kl=yd/yl
yd=2.41
yl=0.5
iD=Kn*yl*(-Vtnl)^2/2;
printf('\ndrain current=%.2f microA\n',iD)
P=iD*Vdd;
printf('\npower dissipation =%.2f microW\n',P)
```

Scilab code Exa 16.5 Determine the noise margin of an inverter with enhancement load

```
clear;
clc;
//Example 16.5
```

```
Voh=4.2;
Vol=0.1;
//x=Kd/Kl
x=25.1;
Vdd=5;
Vtnl=0.8;
Vohu=4.2;
Vil=0.8;
Vtnd=0.8;
Vih=Vtnd+(Vdd-Vtnl)/x*((1+2*x)/sqrt(1+3*x)-1);
printf('\nVih=%.2f V\n',Vih)
Volu=(Vdd-Vtnl+x*(Vih-Vtnd))/(1+2*x);
printf('\noutput voltage corresponding to Vih=%.3f V\n',Volu)
NMl=Vil-Volu;
printf('\nnoise margin=%0.3f V\n',NMl)
NMh=Vohu-Vih;
printf('\nnoise margin=%.3f V\n',NMh)
```

Scilab code Exa 16.9 Determine the critical voltage on the voltage transfer curve of a CMOS inverter

```
clear;
clc;
//Example 16.9
Vdd=5;
Vtn=1;
Vtp=-1;
//Kn=Kp hence Kn/Kp=x=1;
x=1;
Vit=(Vdd+Vtp+sqrt(x)*Vtn)/(1+sqrt(x));
printf('\ninput voltage=%.2f V\n',Vit)
Vipt=Vit;
Vopt=Vipt-Vtp;
printf('\noutput voltage at the transition point for
```

```
    PMOS =%.2fV\n',Vopt)
Vint=Vit;
Vont=Vint-Vtn;
printf('\noutput voltage at the transition point for
    NMOS=%.2f V\n',Vont)
Vdd=10;
Vit=(Vdd+Vtp+sqrt(x)*Vtn)/(1+sqrt(x));
printf('\ninput voltage =%.2fV\n',Vit)
Vipt=Vit;
Vint=Vit;
Vopt=Vipt-Vtp;
printf('\noutput voltage at the transition point for
    PMOS =%.2fV\n',Vopt)
Vont=Vint-Vtn;
printf('\noutput voltage at the transition point for
    NMOS =%.2fV\n',Vont)
```

Scilab code Exa 16.10 Calculate the power dissipation in CMOS inverter

```
clear;
clc;
//Example 16.10
Cl=2*10^-6;
Vdd=5;
f=100000;
P=f*Cl*Vdd^2;
printf('\npower dissipation in the CMOS inverter=%.3
    f microW\n',P)
```

Scilab code Exa 16.11 Determine the noise margins of a CMOS inverter

```
clear;
clc;
```

```
//Example 16.11
Vtn=1;
Vtp=-1;
Vdd=5;
Vth=1;
Vil=Vtn+3*(Vdd+Vtp-Vth)/8;
printf('\ninput voltage at the transition points Vil
    =%.3f V\n',Vil)
Vih=Vtn+5*(Vdd+Vtp-Vtn)/8;
printf('\ninput voltage at the transition points Vih
    =%.3fV\n',Vih)
Vohu=1*(2*Vil+Vdd-Vtn-Vtp)/2;
printf('\noutput voltage =%.3f V\n',Vohu)
Volu=1*(2*Vih-Vdd-Vtn-Vtp)/2;
printf('\noutput voltage =%.2f V\n',Volu)
NML=Vil-Volu;
printf('\nnoise margin =%.3f V\n',NML)
NMH=Vohu-Vih;
printf('\nnoise margin=%.3f V\n',NML)
```

Scilab code Exa 16.15 Determine the currents voltages and power dissipation in two NMOS SPAM cells

```
clear;
clc;
//Example 16.15
Vdd=3;
Kn=60;
Vtnd=0.5;
//W/L=x
xd=2;
Vtnl=-1;
xl=0.5;
R=2;//(MOhm)
Vgsl=0;
```

```
//solution with Depletion load
iD=Kn*xl*(Vgsl-Vtnl)^2/2;
printf('\nfrain currents in M1 and M3 =%.fmicroA\n',iD)
P=iD*Vdd;
printf('\npower dissipation in the circuit=%.f microW\n',P)
//iD=Kn/2*x*(2*Vgsd-Vtnd)Vdsd-Vdsd^2
Q=poly(0,'Q');
p=poly([0.25 -5 1],'Q','c');
roots(p)
disp("Q=50.5 (mV)")
//solution with Resistor load
//(Vdd-Q)/R=Kn/2*xd*(2*Vgsd-Vtnd)Q-Q^2
Q=poly(0,'Q');
p=poly([3 -599 120],'Q','c');
roots(p)
Q=0.005;
disp("Q=5 (mV)")
iD=(Vdd-Q)/R;
printf('\ndrain current =%.2f microA\n',iD)
P=iD*Vdd;
printf('\npower dissipation in the circuit =%.2f microW\n',P)
```

Chapter 17

Bipolar Digital Circuits

Scilab code Exa 17.1 Calculate the currents and voltages in the basic differential amplifier circuit used as digital circuit

```
clear;
clc;
//Example 17.1
V1=5;
V2=-5;
Rc1=1;
Rc2=Rc1;
Rc=Rc1;
Re=2.150;
v2=0;
//for v1=0
vE=-0.7;
iE=(vE-V2)/Re;
printf('\nemitter current=%.3f mA\n',iE)
iC=1;
Vcc=5;
vo1=Vcc-iC*Rc;
printf('\nvo1=vo2=%.f V\n',vo1)
//for v2=-1
vE=-0.7;
```

```
iE=2;
iC2=2;
vo1=5;
vo2=Vcc-iC2*Rc;
printf('\nvo2=%.2f V\n',vo2)
v1=1;
Vbe=0.7;
vE=v1-Vbe;
iE=(vE-V2)/Re;
printf('\nemitter current =%.3fmA\n',iE)
iC1=iE;
vo1=Vcc-iC1*Rc;
printf('\nvo1=%.2f V\n',vo1)
vo2=Vcc
```

Scilab code Exa 17.2 Calculate the currents resistors and logic 0 values in the basic ECL logic gate

```
clear;
clc;
//Example 17.2
Vx=-0.7;
Vy=Vx;
Vbe=0.7;
V2=-5.2;
Re=1.180;
vE=Vx-Vbe;
printf('\nemitter voltage =%.2fV\n',vE)
iE=(vE-V2)/Re;
printf('\nemitter current=%.2f mA\n',iE)
Icxy=iE;
vo1=-0.7;
Rc1=-vo1/Icxy;
printf('\nRc1=%.2f KOhm\n',Rc1)
Vnor=vo1-Vbe;
```

```
printf('\nNOR output logic 0 value=%.2f V\n',Vnor)
Vr=(vo1+Vnor)/2;
vE=Vr-Vbe;
printf('\nvE=%.2f V\n',vE)
iE=(vE-V2)/Re;
printf('\niE=%.2f mA\n',iE)
vo2=-0.7;
iC2=iE;
Rc2=-vo2/iC2;
printf('\nRc2=%.2f KOhm\n',Rc2)
Vor=vo2-Vbe;
printf('\nOR logic 0 value is=%.2f V\n',Vor)
```

Scilab code Exa 17.3 Design the reference position of the ECL circuit

```
clear;
clc;
//Example 17.3
Vr=-1.05;
Vbe=0.7;
Vb5=Vr+Vbe;
printf('\nVb5 =%.2fV\n',Vb5)
R1=0.250;
i1=-Vb5/R1;
printf('\ni1=%.3f mA\n',i1)
Vy=0.7;
V2=-5.2;
//let R1+R2=x
x=(-2*Vy-V2)/i1;
R2=x-R1;
printf('\nR2=%.3f KOhm\n',R2)
iS=i1;
Rs=(Vr-V2)/iS;
printf('\nRs=%.3f KOhm\n',Rs)
```

Scilab code Exa 17.4 Calculate the power dissipated in the ECL logic circuit

```
clear;
clc;
//Example 17.4
Vx=-0.7;
Vy=-0.7;
iCxy=3.22;//(mA)
iCR=0;
i5=1.40;
i1=1.40;
Vor=-0.7;
R4=1.500;
Vnor=-1.4;
V2=-5.2;
R3=1.500;
i3=(Vor-V2)/R3;
printf('\ncurrent i3=%.2f mA\n',i3)
i4=(Vnor-V2)/R4;
printf('\ncurrent i4 =%.2fmA\',i4)
P=(iCxy+iCR+i5+i1+i3+i4)*(0-V2);
printf('\npower dissipation=%.2f mW\n',P)
```

Scilab code Exa 17.5 Calculate minimum fanout of ECL logic gate

```
clear;
clc;
//Example 17.5
b=50;
V2=-5.2;
Vbe=0.7;
```

```
Rc2=0.240;
Vor=-0.75;
Re=1.180;
iE=(Vor-Vbe-V2)/Re;
printf('\nemitter current=%.2f mA\n',iE)
iB=iE/(1+b);
iB=iB*1000;//micro A
printf('\ninput base current=%.2f microA\n',iB)
R3=1.500;
i3=(Vor-V2)/R3;
printf('\ni3=%.2f mA\n',i3)
iB=iB*0.001;//mA
N=(-(Vor+Vbe)*(1+b)/(Rc2)-i3)/iB;
printf('\nN=%.f\n',N)
```

Scilab code Exa 17.7 Analyze the modified ECL logic gate

```
clear;
clc;
//Example 17.7
Vcc=1.7;
Re=0.008;//mohm
Rc=0.008;//mohm
Vy=0.4;
Vbe=0.7;
Vor=Vcc//logic 1
Vor=Vcc-Vy//logic 0
Vr=1.5;
iE=(Vr-Vbe)/Re;
printf('\nemitter current=%.2f microA\n',iE)
iR=Vy/Rc;
printf('\nmaximum current in Rc =%.2fmicroA\n',iR)
iD=iE-iR;
printf('\ncurrent through the diode=%.2f microA\n',
   iD)
```

```
P=iE*Vcc;
printf('\npower dissipation=%.2f microW\n',P)
Vv=1.7;
iE=(Vv-Vbe)/Re;
printf('\niE =%.2fmicroA\n',iE)
P=iE*Vcc;
printf('\npower dissipation =%.2fmicroW\n',P)
```

Scilab code Exa 17.9 Calculate the currents and voltages for the basic TTL NAND circuit

```
clear;
clc;
//Example 17.9
bf=25;
b=bf;
br=0.1;
Vcc=5;
R1=4;
Vbc=0.7;
Vy=0.1;
Vx=0.1;
R2=1.6;
Vbe=0.8;
Rc=4;
Vce=0.1;
vB2=Vx+Vce;
printf('\nvB2=%.2f V\n',vB2)
vB1=Vx+Vbe;
printf('\nbase voltage=%.2f V\n',vB1)
i1=(Vcc-vB1)/R1;
printf('\ncurrent i1=%.2f mA\n',i1)
vB1=Vbe+Vbe+Vbc;
printf('\nvB1=%.2f V\n',vB1)
vC2=Vbe+Vce;
```

```
printf('\ncollector voltage=%.2f V\n',vC2)
i1=(Vcc-vB1)/R1;
printf('\ncurrent i1 =%.2fmA\n',i1)
iB2=(1+2*br)*i1;
printf('\niB2=%.2f mA\n',iB2)
i2=(Vcc-vC2)/R2;
printf('\ni2 =%.2fmA\n',i2)
iE2=i2+iB2;
printf('\niE2=%.2f mA\n',iE2)
Rb=1;
i4=Vbe/Rb;
printf('\ncurrent in the pull down resistor=%.2f mA\
   n',i4)
iBo=iE2-i4;
printf('\nbase drive to the output transistor=%.2f
   mA\n',iBo)
i1=(Vcc-Vce)/Rc;
printf('\ni1=%.2f mA\n',i1)
```

Scilab code Exa 17.11 Determine the currents in a Schottky transistor

```
clear;
clc;
//Example 17.11
b=25;
iB=1;
iC=2;
ic=(iB+iC)/(1+1/b);
printf('\ninternal collector current=%.3f mA\n',ic)
ib=ic/b;
printf('\ninternal base current =%.3fmA\n',ib)
iD=iB-ib;
printf('\nSchottky diode current=%.3f mA\n',iD)
iC=20;
ic=(iB+iC)/(1+1/b);
```

```
printf('\ninternal collector current=%.3f mA\n',ic)
ib=ic/b;
printf('\ninternal base current =%.3fmA\n',ib)
iD=iB-ib;
printf('\nSchottky diode current=%.3f mA\n',iD)
```

Scilab code Exa 17.12 Calculate the power dissipation in a low power Schottky TTL circuit

```
clear;
clc;
//Example 17.12
Vy=0.3;
Vbe=0.7;
vx=0.4;
R2=8;
Vce=0.4;
Vcc=5;
b=25;
Vce=0.4;
Vbe1=0.7;
Vbe2=0.7;
Vcc=5;
R1=20;
v1=Vce+Vy;
i1=(Vcc-v1)/R1;
printf('\ni1=%.3f mA\n',i1)
Pl=i1*(Vcc-vx);
printf('\npower dissipation=%.3f mW\n',Pl)
v1=Vbe1+Vbe2;
printf('\nv1=%.3f V\n',v1)
vC2=Vbe1+Vce;
printf('\nvoltage vC2 =%.2fV\n',vC2)
i1=(Vcc-v1)/R1;
printf('\ncurrent i1 =%.3fmA\n',i1)
```

```
i2=(Vcc-vC2)/R2;
printf('\ncurrent i2 =%.3fmA\n',i2)
P=(i1+i2)*Vcc;
printf('\npower dissipation for high input condition
    =%.3f mW\n',P)
```