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.

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Chapter 1

Semiconductor materials and diodes

Scilab code Exa 1.1 Calculate intrinsic carrier concentration in silicon

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

Scilab code Exa 1.2 Calculate thermal equilibrium electron and hole concentrations

13

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

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

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

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

```scilab
1  clear;
2  clc;
```

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

Scilab code Exa 1.5 Determine the diode current in pn junction

```scilab
1  clear;
2  clc;
3  //Example 1.5
4  T=300;//( K )Given Temperature
5  V_T=0.026;//(Volt)terminal voltage
6  Is=10^-11;//(mA)reverse bias saturation current
7  n=1;//emission coefficient
8  v_D=+0.7;//(V)applied voltage
9  //pn junction is forward biased
10 i_D=Is*(exp(v_D/V_T)-1);//diode current
11 printf('\ndiode current=%f mA\n',i_D)
```

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

Scilab code Exa 1.6 Determine the diode voltage and current

```
1  clear;
2  clc;
3  //Example 1.6
4  Is=10^-13;//(A)reverse saturation current
5  V_PS=5;//(V)applied voltage
6  R=2;//(KOhm)Resistance in circuit
7  V_T=0.026;//(Volt)terminal voltage
8  //V_PS=Is*R*(exp(V_D/V_T)-1)+V_D
9  //5=(10^-13)*(2000)*(exp(V_D/V_T)-1)+V_D
10 //let right side of equation be x=(10^-13)*(2000)*(
       exp(V_D/V_T)-1)+V_D
11 V_D=0.6;//(V)
12 x=(10^-13)*(2000)*(exp(V_D/V_T)-1)+V_D
13 //so the equation is not balanced
14 V_D=0.65;//(V)
15 x=(10^-13)*(2000)*(exp(V_D/V_T)-1)+V_D
16 //again equation is not balanced .solution for V_D
       is between 0.6V and 0.65V
17 V_D=0.619;//(V)
18 x=(10^-13)*(2000)*(exp(V_D/V_T)-1)+V_D
19 //essentially equal to the value of the left side of
        the equation i.e 5V
20 printf('\ndiode voltage=%f V',V_D)
21 I_D=(V_PS-V_D)/R;//(A)diode current
22 printf('\nthe diode current=%f mA',I_D)
```

Scilab code Exa 1.7 `Determine the diode voltage and current`

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

Scilab code Exa 1.9 `Analysing the circuit`

```scilab
1  clear;
2  clc;
3  //Example 1.9
4  //circuit and diode parameters
5  V_PS=5;//(V)
6  R=5;//(KOhm)
7  V_Y=0.6;//(V)
8  V_T=0.026;//(Volt) terminal voltage
9  v_i=0.1//*sin(wt) Volt
10 //dc analysis
11 I_DQ=(V_PS-V_Y)/R;
12 printf('\ndc quiescent current=%f mA\n',I_DQ)
13 V_O=I_DQ*R;
14 printf('\ndc output voltage=%f V\n',V_O)
15 //ac analysis
16 V_PS=0;
17 //Kirchhoff voltage law equation becomes
18 //v_i=i_d*r_d+i_d*R
```

```
19  r_d=V_T/I_DQ//(Ohm)small signal diode diffusion
        resistance
20  i_d=v_i/(r_d+R);//ac diode current
21  printf('\nac diode current=%fsin(wt) A\n',i_d)
22
23  v_o=i_d*R;//ac output voltage
24  printf('\nac output voltage=%fsin(wt) V',v_o)
```

Scilab code Exa 1.10 Calculate currents in a circuit

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

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

```
1  clear;
2  clc;
3  //Example 1.11
4  V_Z=5.6;//(V)Zener diode breakdown voltage
5  r_z=0;//(Ohm)Zener resistance
6  I=3;//(mA)current in the diode
```

```
 7  V_PS =10; //(V)
 8  //I=(V_PS−V_Z)/R
 9  R=(V_PS-V_Z)/I;
10  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 w

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

```
      v_Sb )
18  v_S_rms = v_Sb / sqrt (2) ; // for a sinusoidal signal rms
        value of v_S
19  printf ( '\nrms value of v_S=%f V\n' , v_S_rms )
20  // let turns ratio of the primary to secondary
        winding be x=N1/N2
21  x = v_I / v_S_rms ;
22  printf ( '\nturns ratio=%f\n' , x )
23  // for center tapped rectifier
24  PIV =2* v_S - V_Y ;
25  printf ( '\npeak inverse voltage of a diode=%f V\n' ,
        PIV )
26  // for the bridge rectifier peak inverse voltage of a
         diode
27  PIV = v_Sb - V_Y ;
28  printf ( '\npeak inverse voltage of a diode=%.2 f V\n' ,
        PIV )
29  // 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 rippl

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

Scilab code Exa 2.3 `Design a full wave rectifier`

```
1  clear;
2  clc;
3  //Example 2.3
4  V_O=12;//(V)peak output voltage
5  I_L=0.12;//(A)current delivered to the load
6  R=V_O/I_L;
7  printf('\neffective load resistance=%.2f Ohm\n',R)
8  V_Y=0.7;//(V)diode cut in voltage
9  v_S=V_O+2*V_Y;
10 printf('\npeak value of v_S=%.2f V\n',v_S)
11 v_Srms=v_S/sqrt(2);
12 printf('\nrms voltage=%.2f V\n',v_Srms)
13 //let x=N1/N2
14 Vin=120;//(V)input line voltage
15 x=Vin/v_Srms;
16 printf('\nturns ratio=%.2f \n',x)
17 VM=12;//(V)
18 Vr=5/100*VM;
19 printf('\nripple voltage=%.2f V\n',Vr)
20 f=60;//(Hz) input frequency
21 C=VM/(2*R*Vr*f);
22 printf('\nfilter capacitance=%f F\n',C)
23 i_Dmax=(VM/R)*(1+2*%pi*sqrt(VM/(2*Vr)));
24 printf('\npeak diode current=%.2f A\n',i_Dmax)
25 R=0.1;//Kohm
26 i_Davg=(1/(2*%pi))*sqrt(2*Vr/VM)*((VM/R)*(1+%pi*sqrt
      (VM/(2*Vr))));
27 printf('\naverage diode current=%f mA\n',i_Davg)
28 PIV=v_S-V_Y;
29 printf('\npeak inverse voltage=%.2f V\n',PIV)
```

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

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

Scilab code Exa 2.8 Determine the output voltage and diode currents

```scilab
1  clear;
2  clc;
3  //Example 2.8
4  R1=5;R2=10;//(KOhm)
5  V_Y=0.7;//(V)diode cut in voltage
6  V1=5;V2=-5;//(V)
7  vt=0;//(V)
8  //asssuming initially diode D1 is off
9  //iR1=iD2=iR2=V1-V2-V_Y/(R1+R2)
10 iD2=(V1-V2-V_Y)/(R1+R2);
11 printf('\ndiode current=%0.2f mA\n',iD2)
12 iR1=iD2;
13 vo=V1-iR1*R1;
14 printf('\noutput voltage=%0.2f V\n',vo)
15 v=vo-V_Y;//v=v'
16 printf('\nVoltage=%0.1f V\n',v)
17 vt=4;//(V)fig.2.33
18 //both D1 and D2 are on
19 vo==vt;
20 vo=4;
```

```
21  iD2 =( V1 - vo ) / R1 ;
22  printf ( ' \ ndiode  current=%.2 f  mA\n ' , iD2 )
23  iR1 == iD2 ;
24  v = vo - V_Y ;
25  printf ( ' \nV=%.2 f  V\n ' , v )
26  iR2 =( v - V2 ) / R2 ;
27  printf ( ' \niR2=%.2 f  mA\n ' , iR2 )
28  iD1 = iR2 - iD2 ;
29  printf ( ' \ ncurrent  through  D1=%.2 f  mA\n ' , iD1 )
```

Scilab code Exa 2.10 Calculate the photocurrent generated in a photodiode

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

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

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

Chapter 3

The Bipolar Junction Transistor

Scilab code Exa 3.1 Calculate the collector and emitter currents

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

Scilab code Exa 3.2 Calculate the breakdown voltage of a transistor

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

Scilab code Exa 3.3 Calculate the base collector and emitter currents and ce volta

```
1  clear;
2  clc;
3  //Example 3.3
4  Vbb=4;//(V)
5  Rb=220//(KOhm);
6  Rc=2;//(KOhm)
7  Vcc=10;//(V)
8  Vbe=0.7;//(V)
9  b=200;
10 //from fig.3.19(b)
11 Ib=(Vbb-Vbe)/Rb;
12 printf('\nbase current=%.3f mA\n',Ib)
13 Ic=b*Ib;
14 printf('\ncollector current=%.2f mA\n',Ic)
15 Ie=(1+b)*Ib;
16 printf('\nemitter current=%.2f mA\n',Ie)
17 Vce=Vcc-Ic*Rc;
18 printf('\ncollector emitter voltage=%.1f V\n',Vce)
```

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

26

```
1  clear ;
2  clc ;
3  //Example 3.4
4  Vbb =1.5; //(V)
5  Rb =580; //(KOhm)
6  Veb =0.6; //(V)
7  Vcc =5; //(V)
8  b =100;
9  // writing Kirchhoff voltage law equation around E–B
       loop
10 Ib =( Vcc - Veb - Vbb )/ Rb ;
11 printf ( '\ nbase current=%.3 f mA\n ' , Ib )
12 Ic = b * Ib ;
13 printf ( '\ ncollector current=%.2 f mA\n ' , Ic )
14 Ie =(1+ b )* Ib ;
15 printf ( '\ nemitter current=%.3 f mA\n ' , Ie )
16 Vec =(1/2)* Vcc ;
17 printf ( '\ nce voltage=%.2 f V\n ' , Vec )
18 Rc =( Vcc - Vec )/ Ic ;
19 printf ( '\ ncollector resistance=%. f KOhm\n ' , Rc )
```

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

```
1  clear ;
2  clc ;
3  //Example 3.5
4  b =100;
5  Vbe =0.7; //(V)
6  Vce =0.2; //(V)
7  Vbb =8; //(v)
8  Rb =220; //(KOhm)
9  Ib =( Vbb - Vbe )/ Rb
10 printf ( '\ nbase current=%f mA\n ' , Ib )
11 // transistor in active region
12 Ic = b * Ib ;
```

```
13  printf('\ncollector  current=%.3f mA\n',Ic)
14  Vcc=10;//(V)
15  Rc=4;//(KOhm)
16  Vce=Vcc-Ic*Rc;
17  printf('\ncollector  emitter  voltage=%.2f V\n',Vce)
18  //saturation
19  Vce=0.2;//(V)
20  Ic=(Vcc-Vce)/Rc;
21  printf('\nsaturation  collector  current=%.2f mA\n',Ic
        )
22  x=Ic/Ib
23  //which  is  <b
24  Ie=Ic+Ib;
25  printf('\nemitter  current=%f mA\n',Ie)
```

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

```
 1  clear;
 2  clc;
 3  //Example  3.6
 4  Vbe=0.7;
 5  b=75;
 6  //Q point  values::
 7  //using  KVL eq  around  the  B–E loop
 8  //Vbb=Ib*Re+Vbe+Ie*Re
 9  //assuming  transistor  is  in  forward  biased  mode we
        can  write  Ie=(1+b)*Ib
10  Vbb=6;
11  Rb=25;//KOhm
12  Re=0.6;//KOhm
13  Ib=(Vbb-Vbe)/(Rb+(1+b)*Re);
14  printf('\nbase  current=%f mA\n',Ib)
15  Ic=b*Ib;
16  printf('\ncollector  current=%0.2f mA\n',Ic)
17  Ie=(1+b)*Ib;
```

```
18  printf('\nemitter  current=%0.2 f  mA\n',Ie)
19  Vcc =12;
20  Rc =0.4;
21  Vce = Vcc - Ic * Rc - Ie * Re ;
22  printf('\ncollector  emitter  voltage=%0.2 f  V\n',Vce)
23  //load  line ::
24  //using  KVL  law  around  C-E  loop
25  //Vce=Vcc-(Ic*(Rc+((1+B)/B)*Re));
26  Ic =[0 ,12 ,5.63]
27  Vce =12 - Ic *1;
28  xset ('window',1)
29  plot2d (Vce ,Ic , style =3)
30  title ("load  line")
31  xlabel ("Vce")
32  ylabel ("Ic")
```

Scilab code Exa 3.7 Calculate the characteristics of a circuit

```
 1  clear ;
 2  clc ;
 3  // Example  3.7
 4  Vbe =0.65;
 5  Vcc =5;
 6  Rc =0.5; //KOhm
 7  b =100;
 8  V1 = -5;
 9  Re =1; //KOhm
10  //  Q-point  values  ::  writing  KVL  eq  around  B-E  loop
11  Ie =( -V1 - Vbe )/ Re ;
12  printf('\nemitter  current=%.2 f  mA\n',Ie)
13  Ib =( Ie /(1+ b ));
14  printf('\nbase  current=%f  mA\n',Ib)
15  Ic =( b /(1+ b ))* Ie ;
16  printf('\ncollector  current=%0.2 f  mA\n',Ic)
17  Vce = Vcc - Ic * Rc - Ie * Re - V1 ;
```

```
18 printf('\ncollector emitter voltage=%f V\n',Vce)
19 //load line::
20 //Vce=Vcc-V1-(Ic*(Rc+((1+B)/B)*Re));
21 Vce=[0,2,,3.5,4,6,8,10]
22 Ic=(10-Vce)/1.51;
23 xset('window',1)
24 plot2d(Vce,Ic,style=3,rect=[0,0,10,8])
25 title("load line")
26 xlabel("Vce")
27 ylabel("Ic")
```

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

```
 1 clear;
 2 clc;
 3 //Example 3.9
 4 b=100;
 5 Vbe=0.7;
 6 V1=-5;
 7 V2=12;
 8 Rb=10;
 9 Re=5;
10 Rc=5;
11 Rl=5;
12 //Q point values:: using KVL eq around B-E loop
13 Ib=-(V1+Vbe)/(Rb+(1+b)*Re);
14 printf('\nbase current=%f mA\n',Ib)
15 Ic=b*Ib;
16 printf('\ncollector current=%f mA\n',Ic)
17 Ie=(1+b)*Ib;
18 printf('\nemitter current=%f mA\n',Ie)
19 //at collector node we can write Ic=(V2-Vo)/Rc-Vo/Rl
20 Vo=(V2/Rc-Ic)*Rc*Rl/(Rc+Rl);
21 printf('\noutput voltage=%0.3f V\n',Vo)
22 Vce=Vo-Ie*Re-V1;
```

```
23  printf('\ncollector emitter voltage=%f V\n',Vce)
24  //load line::
25  Rth=Rl*Rc/(Rl+Rc);
26  printf('\nThevenin rquivalent resistance=%f KOhm\n',
        Rth)
27  Vth=(Rl/(Rl+Rc))*V2;
28  printf('\nThevenin equivalent voltage=%f V\n',Vth)
29  //fig.3.36(c) KVL law
30  //Vce=6-V1-Ic*Rth-Ie*Re;
31  Vce=[0,2,4.7,3.5,4,6,8,10]
32  Ic=(11-Vce)/7.5;
33  xset('window',1)
34  plot2d(Vce,Ic,style=3,rect=[0,0,12,2])
35  title("load line")
36  xlabel("Vce")
37  ylabel("Ic")
```

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

```
1  clear;
2  clc;
3  //Example 3.10
4  Rb=0.24;
5  Vcc=12;
6  Vbe=0.7;
7  Vce=0.1;
8  b=75;
9  Rc=5;//Ohm
10 //for Vt=0 ,transistor is cut off,Ib=Ic=0,Vo=Vcc=12
        V,power dissipation is zero
11 Vt=12;//(V)
12 Ib=(Vt-Vbe)/Rb;
13 printf('\nbase current=%0.3f mA\n',Ib)
14 Ic=(Vcc-Vce)/Rc;
15 printf('\ncollector current=%0.2f A\n',Ic)
```

```
16  Ib =0.0471; //A
17  x=Ic/Ib
18  //since  Ic/Ib<b transistor is in saturation
19  //Vo==Vcc;
20  Vo =0.1;
21  printf('\noutput voltage=%0.2f V\n',Vo)
22  P=Ic*Vce+Ib*Vbe;
23  printf('\npower dissipation=%0.3f W\n',P)
```

Scilab code Exa 3.13 Design the circuit

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

Scilab code Exa 3.14 Analyze a circuit using voltage divider bias circuit and dete

```
1   clear;
2   clc;
3   //Example 3.14
4   R1 =56;
5   R2 =12.2;
```

```
6   Rc =2;
7   Re =.4;
8   Vcc =10;
9   Vbe =0.7;
10  b =100;
11  // fig .3.53( b)
12  Rth = R2 * R1 /( R1 + R2 ) ;
13  printf ( '\ nThevenin  rquivalent  resistance =%0.1 f KOhm \
         n ' , Rth )
14  Vth =( R2 /( R1 + R2 ) ) * Vcc ;
15  printf ( '\ nThevenin  equivalent  voltage =%0.2 f V \ n ' , Vth
         )
16  Ibq =( Vth - Vbe ) /( Rth +(1+ b ) * Re ) ;
17  printf ( '\ nbase  current =%f mA \ n ' , Ibq )
18  Icq = b * Ibq ;
19  printf ( '\ ncollector  current =%.3 f mA \ n ' , Icq )
20  Ieq =(1+ b ) * Ibq ;
21  printf ( '\ nemitter  current =%.2 f mA \ n ' , Ieq )
22  Vceq = Vcc - Icq * Rc - Ieq * Re ;
23  printf ( '\ ncollector  emitter  voltage =%.3 f V \ n ' , Vceq )
24  b =[50 ,100 ,150]
25  for x = b
26  Ibq =( Vth - Vbe ) /( Rth +(1+ x ) * Re ) ;
27  disp ( " Ibeq , Iceq , Ieq , Vceq " )
28  disp ( Ibq )
29  Icq = x * Ibq ;
30  disp ( Icq )
31  Ieq =(1+ x ) * Ibq ;
32  disp ( Ieq )
33  Vceq = Vcc - Icq * Rc - Ieq * Re ;
34  disp ( Vceq )
35  disp ( " " )
36  end
```

Scilab code Exa 3.15 `Design a bias stable circuit`

```
1  clear;
2  clc;
3  //Example 3.15
4  Vcc=5;
5  Rc=1;//KOhm
6  Vbe=0.7;
7  b=120;
8  Vceq=3;
9  Re=.510;
10 Icq=(Vcc-Vceq)/(Rc+Re);
11 printf('\ncollector current=%.3f mA\n',Icq)
12 Ibq=Icq/b;
13 printf('\nbase current=%0.3f mA\n',Ibq)
14 //for bias stable circuit
15 Rth=0.1*(1+b)*Re;
16 printf('\nThevenin rquivalent resistance=%.1f KOhm\n
       ',Rth)
17 //Ibq=(Vth-Vbe)/(Rth+(1+b)*Re)
18 Vth=Ibq*(Rth+(1+b)*Re)+Vbe;
19 printf('\nThevenin equivalent voltage=%.2f V\n',Vth)
20 //Vth=(R2/(R1+R2))*Vcc
21 //let x=(R2/(R1+R2))
22 x=Vth/Vcc
23 //Rth=6050=R1*x
24 R1=6.05/x;
25 printf('\nR1=%.1f KOhms\n',R1)
26 R2=x*R1/(1-x);
27 printf('\nR2=%.1f KOhms\',R2)
```

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

```
1  clear;
2  clc;
3  //Example 3.16
4  R1=10;
```

```
5  b=50;
6  Vbe=0.7;
7  V1=-5;
8  I1=-(V1+Vbe)/R1;
9  printf('\nreference current=%.3f mA\n',I1)
10 Iq=I1/(1+2/b);
11 printf('\nbias current=%.3f mA\n',Iq)
12 //Ib=Ib1=Ib2
13 Ib=Iq/b;
14 printf('\nbase current=%f mA\n',Ib)
```

Scilab code Exa 3.17 Calculate the dc voltages at each node and the dc currents th

```
1  clear;
2  clc;
3  //Example 3.17
4  Vbe=0.7;
5  Vcc=10;
6  V2=5;
7  b=100;
8  R1=100;
9  R2=50;
10 Re1=2;
11 Rth=R2*R1/(R1+R2);
12 printf('\nThevenin rquivalent resistance=%.1f KOhm\n
       ',Rth)
13 Vth=(R2/(R1+R2))*Vcc-V2;
14 printf('\nThevenin equivalent voltage=%.2f V\n',Vth)
15 //Vth=Ib1*Rth+Vbe+Ie1*Re1-5 and Ie1=(1+b)*Ib1
16 Ib1=(Vth+5-Vbe)/(Rth+(1+b)*Re1);
17 printf('\nIb1=%.3f mA\n',Ib1)
18 Ic1=b*Ib1;
19 printf('\nIc1=%.3f mA\n',Ic1)
20 Ie1=(1+b)*Ib1;
21 printf('\nIe1=%.3f mA\n',Ie1)
```

```
22  //summing the currents at the collector of Q1, Ir1+
        Ib2=Ic1
23  //(5-Vc1)/Rc1+Ib2=Ic1
24  //also  Ib2=Ie2/(1+b)=(5-(Vc1+0.7))/(1+b)*Re2
25  Rc1=5;
26  Re1=2;
27  Re2=2;
28  Rc2=1.5;
29  Vc1=Rc1*(1+b)*Re2*((5/Rc1)+(4.3/((1+b)*Re2))-Ic1)
        /(((1+b)*Re2)+Rc1);
30  printf('\nVc1=%.2f V\n',Vc1)
31  Ir1=(5-Vc1)/Rc1;
32  printf('\nIr1=%.3f mA\n',Ir1)
33  Ve2=Vc1+Vbe;
34  printf('\nVe2=%.2f V\n',Ve2)
35  Ie2=(5-Ve2)/Re1;
36  printf('\nIe2=%.3f mA\n',Ie2)
37  Ic2=Ie2*b/(1+b);
38  printf('\nIc2=%.3f mA\n',Ic2)
39  Ib2=Ie2/(1+b);
40  printf('\nIb2=%f mA\n',Ib2)
41  Ve1=Ie1*Re1-5;
42  printf('\nVe1=%.2f V\n',Ve1)
43  Vc2=Ic2*Rc2-5;
44  printf('\nVc2=%.2f V\n',Vc2)
45  Vce1=Vc1-Ve1;
46  printf('\nVce1=%.2f V\n',Vce1)
47  Vec2=Ve2-Vc2;
48  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 transisto

```
1  clear ;
2  clc ;
3  // Example 4.1
4  b =100;
5  Vcc =12;
6  Vbe =0.7;
7  Rc =6;
8  Rb =50;
9  Vbb =1.2;
10 // dc solution
11 Ibq =( Vbb - Vbe )/ Rb ;
12 printf ( '\ nbase current=%.3 f mA\n ' , Ibq )
13 Icq = b * Ibq ;
14 printf ( '\ ncollector current=%.3 f mA\n ' , Icq )
15 Vceq = Vcc - Icq * Rc ;
16 printf ( '\ ncollector emitter voltage=%.2 f V\n ' , Vceq )
17 // transistor is forward biased
18 // ac solution
19 V_T =0.026; //(V)
20 // small signal hybrid pi parameters
21 r_pi = b * V_T / Icq ;
```

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

Scilab code Exa 4.2 Determine the small signal voltage gain

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

Scilab code Exa 4.4 Determine the small signal voltage gain

```
1   clear;
2   clc;
3   //Example 4.4
4   b=100;
5   Vbe=0.7;
6   Va=100;
7   V_T=0.026;//(V)
```

```
 8  //from dc analysis
 9  Icq=0.95;
10  Vceq=6.31;
11  //ac analysis
12  r_pi=b*V_T/Icq;
13  printf('\nsmall signal resistance=%.2f KOhm\n',r_pi)
14  g_m=Icq/V_T;
15  printf('\ntransconductance=%.3f mA/V\n',g_m)
16  Rs=0.5;
17  Rc=6;
18  ro=Va/Icq;
19  printf('\nro=%.2f KOhm\n',ro)
20  Av=-g_m*(5.9*r_pi/(5.9+r_pi))/((5.9*r_pi/(r_pi+5.9))
       +Rs)*ro*Rc/(ro+Rc);
21  printf('\nsmall signal voltage gain=%.2f \n',Av)
22  Ri=5.9*r_pi/(r_pi+5.9);
23  printf('\ninput resistance=%.3f KOhm\n',Ri)
24  Ro=ro*Rc/(ro+Rc);
25  printf('\noutput resistance=%.2f KOhm\n',Ro)
```

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

```
 1  clear;
 2  clc;
 3  //Example 4.5
 4  b=100;
 5  Vbe=0.7;
 6  Rc=2;
 7  Rs=0.5;
 8  Icq=2.16;
 9  V_T=0.026;//(V)
10  Vceq=4.8
11  //ac solution
12  r_pi=b*V_T/Icq;
13  printf('\nsmall signal resistance=%.2f KOhm\n',r_pi)
```

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

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

```
1   clear ;
2   clc ;
3   // Example 4.7
4   Iq = 0.5 ;
5   b = 120 ;
6   Va = 80 ;
7   V_T = 0.026 ; // (V)
8   rc = 120 ; // small signal collector resistance (KOhm)
9   // Icq=Iq
10  Icq = 0.5 ;
11  g_m = Icq / V_T ;
12  printf ( '\ntransconductance=%.3 f mA/V\n' , g_m )
13  ro = Va / Icq ;
14  printf ( '\nsmall signal output resistance=%.2 f KOhm\n
        ' , ro )
15  Av = - g_m * ro * rc /( ro + rc ) ;
```

```
16  printf ( ' \nsmall signal voltage gain=%.3f \n ' , Av )
```

Scilab code Exa 4.8 Determine the dc and ac load lines

```
 1  clear ;
 2  clc ;
 3  //Example 4.8
 4  b=150; Veb=0.7;
 5  //dc solution
 6  V2=10;
 7  V1=-10;
 8  V_T=0.026; //(V)
 9  Rc=5;
10  Rb=50;
11  Re=10;
12  Ibq=(V2-Veb)/(Rb+(1+b)*Re);
13  printf ( ' \nbase current=%f mA\n ' , Ibq )
14  Icq=b*Ibq;
15  printf ( ' \ncollector current=%.3f mA\n ' , Icq )
16  Ieq=(1+b)*Ibq;
17  printf ( ' \nemitter current=%.3f mA\n ' , Ieq )
18  Vecq=V2-V1-Icq*Rc-Ieq*Re;
19  printf ( ' \nemitter collector voltage=%.2f V\n ' , Vecq )
20  //ac solution
21  r_pi=b*V_T/Icq;
22  printf ( ' \nsmall signal resistance=%.1f KOhm\n ' , r_pi )
23  g_m=Icq/V_T;
24  printf ( ' \ntransconductance =%.3fmA/V\n ' , g_m )
25  //since Va=infinity , ro=Va/Icq is also infinity
```

Scilab code Exa 4.9 Determine the maximum symmetrical swing

```
 1  clear ;
```

41

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

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

```
1 clear;
2 clc;
3 //Example 4.10
4 b=100;
5 Vbe=0.7;
6 V_T=0.026;//(V)
7 Re=2;
8 R1=50;
9 R2=50;
10 Rs=0.5;
11 Va=80;
12 //by dc analysis
13 Icq=0.793;
14 Vceq=3.4;
15 r_pi=b*V_T/Icq;
16 printf('\nsmall signal resistance=%.3f KOhm\n',r_pi)
17 g_m=Icq/V_T;
18 printf('\ntransconductance=%.3f mA/V\n',g_m)
```

```
19  ro = Va / Icq ;
20  printf ( '\nsmall  signal  output  resistance=%.2 f  KOhm\n
        ' ,ro )
21  Rib = r_pi +(1+ b )* Re * ro /( ro + Re );
22  printf ( '\ninput  resistance  to  the  base=%.2 f  KOhm\n ' ,
        Rib )
23  // Ri=R1 || R2 || Rib
24  x = R1 * R2 /( R1 + R2 );
25  Ri = x * Rib /( x + Rib );
26  printf ( '\nRi=%.2 f  KOhm\n ' ,Ri )
27  y = ro * Re /( ro + Re );
28  Av =(1/( r_pi +(1+ b )* y ))*(1+ b )* y * Ri /( Ri + Rs );
29  printf ( '\nsmall  signal  voltage  gain=%.3 f  \n ' ,Av )
```

Chapter 5

The Field Effect Transistor

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

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

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

```scilab
1  clear;
```

```
 2 clc ;
 3 //Example 5.2
 4 Kp =0.2;//(mA/V^2)
 5 Vtp =0.5;
 6 iD =0.5;
 7 Vsg=sqrt(iD/Kp)-Vtp;
 8 printf('\nVgs=%.2f V\n',Vsg)
 9 //to bias in p channel MOSFET
10 Vsd=Vsg+Vtp;
11 printf('\nVsd=%.2f V\n',Vsd)
```

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

```
 1 clear ;
 2 clc ;
 3 //Example 5.3
 4 R1 =30;
 5 R2 =20;
 6 RD =20;
 7 Vdd =5;
 8 Vtn =1;
 9 Kn =0.1;
10 Vgs=R2*Vdd/(R1+R2);
11 printf('\nVgs=%0.2f V\n',Vgs)
12 I_D=Kn*(Vgs-Vtn)^2;
13 printf('\nthe drain current=%0.1f mA\n',I_D)
14 Vds=Vdd-I_D*RD;
15 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 cir

```
 1 clear ;
 2 clc ;
```

```
3  //Example 5.4
4  R1=50;
5  R2=50;
6  RD=7.5;
7  Vdd=5;
8  Vtp=-0.8;
9  Vg=2.5;
10 Kp=0.2;
11 Vo=R2*Vdd/(R1+R2);
12 printf('\nVo=%.2f V\n',Vo)
13 Vsg=Vdd-Vg;
14 printf('\nsource to gate voltage=%.2f V\n',Vsg)
15 I_D=Kp*(Vsg+Vtp)^2;
16 printf('\nthe drain current=%.3f mA\n',I_D)
17 Vsd=Vdd-I_D*RD;
18 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 dr

```
1  clear;
2  clc;
3  //Example 5.6
4  Vtn=2;
5  Kn=80*10^-3;
6  //x=W/L
7  x=4;
8  I_D=0.5;
9  //I_D=Kn*x*((Vgs-Vtn)^2)/2;
10 Vgs=sqrt(I_D*2/(Kn*x))+2;
11 printf('\nVgs=%.2f V\n',Vgs)
12 //y=R1+R2
13 Rs=2;
14 y=10/0.05;
15 printf('\nR1+R2=%.2f Kohm\n',y)
16 //Vgs=Vg-Vs=(R2/(R1+R2)*10-5)-I_D*Rs+5
```

```
17  R2=(y/10)*(Vgs+I_D*Rs);
18  printf('\nR2=%.2f KOhm\n',R2)
19  R1=y-R2;
20  printf('\nR1=%.2f KOhm\n',R1)
```

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

```
1  clear;
2  clc;
3  //Example 5.7
4  Vtn=0.8;
5  Kn=80;
6  //x=W/L
7  x=3;
8  I_D=250;
9  Vd=2.5;
10  //I_D=Kn/2*x*(Vgs-Vtn)^2
11  Vgs=sqrt(I_D*2/(Kn*x))+Vtn;
12  printf('\nVgs=%.3f V\n',Vgs)
13  Vs=-Vgs
14  //I_D=(5-Vd)/Rd
15  Rd=(5-Vd)/I_D;
16  printf('\nRd=%.2f KOhm\n',Rd)
17  Vds=Vd-Vs;
18  printf('\nVds=%.2f V\n',Vds)
19  Vdssat=Vgs-Vtn
20  //since Vds>Vdssat transistor is biased in
        saturation region
```

Scilab code Exa 5.8 Calculate the characteristics of a circuit containing an enhan

```
1  clear;
2  clc;
```

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

Scilab code Exa 5.10 Calculate the characteristics of a circuit containing a deple

```
1  clear;
2  clc;
3  //Example 5.10
4  Vtn =-2;
5  Kn =0.1;
6  Vdd =5;
7  Rs =5;
8  Vgs =0;
9  I_D=Kn*(Vgs-Vtn)^2;
10 printf('\ndrain current=%.3f mA\n', I_D)
11 Vds=Vdd-I_D*Rs;
12 printf('\ndc drain to source voltage=%.2f V\n', Vds)
13 Vdssat=Vgs-Vtn
14 //since Vds>Vdssat transisyor is biased in
       saturation region
```

Scilab code Exa 5.11 Determine the dc transistor currents and voltages in a circui

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

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

```
1  clear;
2  clc;
3  //Example 5.13
4  Kn1=0.2;
5  Kn2=0.1;
6  Kn3=0.1;
7  Kn4=0.1;
8  Vtn1=1;
9  Vtn2=1;
10 Vtn3=1;
11 Vtn4=1;
```

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```
12  V2=-5;
13  Vgs3=(sqrt(Kn4/Kn3)*(-V2-Vtn4)+Vtn3)/(1+sqrt(Kn4/Kn3
        ));
14  printf('\nVgs3=%.2f V\n',Vgs3)
15  Iq=Kn3*(Vgs3-Vtn3)^2;
16  printf('\nbias current=%.3f mA\n',Iq)
17  Vgs1=sqrt(Iq/Kn1)+Vtn1;
18  printf('\ngate to source voltage on M1=%.2f V\n',
        Vgs1)
19  Vds2=-V2-Vgs1;
20  printf('\ndrain to source voltage on M2=%.2f V\n',
        Vds2)
21  Vgs2=Vgs3;
22  Vdssat=Vgs2-Vtn2
23  //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 o

```
1  clear;
2  clc;
3  //Example 5.14
4  I_D=0.5;
5  Vds=6;
6  Kn=80*10^-6;
7  Vgs=5;
8  Vtn=1;
9  //x=W/L
10  x=I_D*2/(Kn*(Vgs-Vtn)^2);
11  disp(x,"W/L ")
12  //maximum power dissipation in transistor
13  Pmax=Vds*I_D;
14  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

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

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

```
1  clear;
2  clc;
3  //Example 5.17
4  Idss =5; //mA
5  Vp = -4;
6  Vdd =10;
7  I_D=2;
8  Vds =6;
9  //I_D=Idss *(1-Vgs/Vp)^2
10 Vgs =(1-sqrt(I_D/Idss))*Vp;
11 printf('\nVgs=%.2f V\n',Vgs)
12 Rs=-Vgs/I_D;
13 printf('\nRs=%.3f KOhm\n',Rs)
14 Rd=(Vdd -Vds -I_D*Rs)/I_D;
15 printf('\nRd=%.2f KOhm\n',Rd)
16 Vgs -Vp
17 //since Vds>Vgs-Vp JFET is biased in saturation
```

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Scilab code Exa 5.19 Calculate the quiscent current and voltage values

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

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

```
1  clear;
2  clc;
3  //Example 5.20
4  Vtn=0.24;
5  Kn=1.1;
6  //x=R1+R2=50000
7  x=50;
8  Vgs=0.5;
```

```
 9  Vds =2.5;
10  Vdd =4;
11  Rd =6.7;
12  I_D=Kn*(Vgs-Vtn)^2;
13  printf('\ndrain current=%.3f mA\n',I_D)
14  Vd=Vdd-I_D*Rd;
15  printf('\nvoltage at drain=%0.2f V\n',Vd)
16  Vs=Vd-Vds;
17  printf('\nvoltage at source =%0.2fV\n',Vs)
18  Rs=Vs/I_D;
19  printf('\nsource resistance =%.2fKOhm\n',Rs)
20  Vg=Vgs+Vs;
21  printf('\nvoltage at the gate=%.2f V\n',Vg)
22  //Vg=R2*Vdd/(R2+R1)
23  R2=Vg*x/Vdd;
24  printf('\nR2=%0.3f KOhm\n',R2)
25  R1=x-R2;
26  printf('\nR1=%0.3f KOhm\n',R1)
27  Vgs-Vtn
28  //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

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

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

```
1  clear;
2  clc;
```

```
3  //Example 6.2
4  Vgsq=2.12;
5  Vdd=5;
6  Rd=2.5;
7  Vtn=1;
8  Kn=0.8;
9  //let lambda=y
10 y=0.02;//V^-1
11 Idq=Kn*(Vgsq-Vtn)^2;
12 printf('\ndrain current=%.3f mA\n',Idq)
13 Vdsq=Vdd-Idq*Rd;
14 printf('\ndrain to source voltage=%.3f V\n',Vdsq)
15 Vgs=1.82;
16 Vgs-Vtn
17 //since Vdsq>Vgs-Vtn transistor is biased in
       saturation
18 g_m=2*Kn*(Vgsq-Vtn);
19 printf('\ntransconductance=%.3f mA/V\n',g_m)
20 ro=(y*Idq)^-1;
21 printf('\noutput resistance=%.2f KOhm\n',ro)
22 Av=-g_m*ro*Rd/(ro+Rd);
23 printf('\nsmall signal voltage gain=%.2f\n',Av)
```

Scilab code Exa 6.3 Determine the small signal voltage gain and input and output r

```
1  clear;
2  clc;
3  //Example 6.3
4  Vdd=10;
5  R1=70.9;//(Kohm)
6  R2=29.1;//(Kohm)
7  Rd=5;//(Kohm)
8  Vtn=1.5;
9  Kn=0.5;//(mA/V^2)
10 //lambda=y
```

```
11  y=0.01; //V^-1
12  Rsi=4; //(Kohm)
13  Vgsq=Vdd*R2/(R1+R2);
14  printf('\ngate to source voltage=%.2f V\n',Vgsq)
15  Idq=Kn*(Vgsq-Vtn)^2;
16  printf('\ndrain current=%.3f mA\n',Idq)
17  Vdsq=Vdd-Idq*Rd;
18  printf('\ndrain to source voltage=%.2f V\n',Vdsq)
19  g_m=2*Kn*(Vgsq-Vtn);
20  printf('\ntransconductance=%.3f mA/V\n',g_m)
21  ro=(y*Idq)^-1;
22  printf('\noutput resistance=%.2f KOhm\n',ro)
23  Ri=R1*R2/(R1+R2);
24  printf('\namplifier input resistance=%.2f Kohm\n',Ri
       )
25  Av=-g_m*(ro*Rd/(ro+Rd))*Ri/(Ri+Rsi);
26  printf('\nsmall signal voltage gain=%.2f\n',Av)
27  printf('\namplifier input resistance=%.2f Kohm\n',Ri
       )
28  Ro=Rd*ro/(Rd+ro);
29  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 mi

```
1  clear;
2  clc;
3  //Example 6.4
4  Vtn=1;
5  Kn=1; //(mA/V^2)
6  //lambda=y
7  y=0.015; //V^-1
8  Ri=100; //(Kohm)
9  Idq=2; //(mA)
10 Idt=4; //(mA)
```

```
11  //Idt=4=Kn*(Vgst-Vtn)^2
12  Vgst=sqrt(Idt/Kn)+Vtn;
13  printf('\nVgst=%.2f V\n',Vgst)
14  Vdst=Vgst-Vtn;
15  printf('\nVdst=%.2f V\n',Vdst)
16  Vdd=12;
17  Vdsq=7;
18  Rd=(Vdd-Vdsq)/Idq;
19  printf('\nRd =%.2fKOhm\n',Rd)
20  Vgsq=sqrt(Idq/Kn)+Vtn;
21  printf('\nVgsq=%.2f V\n',Vgsq)
22  R1=Ri*Vdd/Vgsq;
23  printf('\nR1=%.2f Kohm\n',R1)
24  R2=Ri*R1/(R1-Ri);
25  printf('\nR2=%.2f Kohm\n',R2)
26  g_m=2*Kn*(Vgsq-Vtn);
27  printf('\ntransconductance=%.3f mA/V\n',g_m)
28  ro=(y*Idq)^-1;
29  printf('\noutput resistance=%.2f KOhm\n',ro)
30  Av=-g_m*(ro*Rd/(ro+Rd));
31  printf('\nsmall signal voltage gain=%.2f\n',Av)
```

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

```
1  clear;
2  clc;
3  //Example 6.6
4  Vtn=0.8;
5  Kn=1;//(mA/V^2)
6  Idq=0.5;
7  Vdd=5;
8  Rd=7;//(Kohm)
9  Vgsq=sqrt(Idq/Kn)+Vtn;
10 printf('\nVgsq=%.2f V\n',Vgsq)
11 Vs=-Vgsq
```

```
12  Vdsq=Vdd-Idq*Rd-Vs;
13  printf('\nVdsq=%.2f V\n',Vdsq)
14  g_m=2*Kn*(Vgsq-Vtn);
15  printf('\ntransconductance=%.3f mA/V\n',g_m)
16  Av=-g_m*Rd;
17  printf('\nsmall signal voltage gain=%.2f\n',Av)
```

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

```
1   clear;
2   clc;
3   //Example 6.7
4   Vdd=12;
5   R1=162;
6   R2=463;
7   Rs=0.75;
8   Kn=4;
9   Vtn=1.5;
10  //lambda=y
11  y=0.01;
12  Rsi=4;
13  Idq=7.97;
14  Vgsq=2.91;
15  g_m=2*Kn*(Vgsq-Vtn);
16  printf('\ntransconductance=%.2f mA/V\n',g_m)
17  ro=(y*Idq)^-1;
18  printf('\noutput resistance=%.2f KOhm\n',ro)
19  Ri=R1*R2/(R1+R2);
20  printf('\namplifier input resistance=%.3f Kohm\n',Ri
        )
21  x=Rs*ro/(Rs+ro);
22  Av=g_m*x*(Ri/(Ri+Rsi))/(1+g_m*x);
23  printf('\nsmall signal voltage gain=%.2f\n',Av)
```

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

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

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

```
1  clear ;
2  clc ;
3  //Example 6.11
4  Vtnd =1;
5  Vtnl =1;
6  Kn =30;
7  // let W/L=x
8  xl =1;
9  Vdd =5;
10 Av =10;
11 // Av=sqrt ( xd / xl )
12 xd =( Av )^2* xl ;
13 printf ( '\ nwidth to length ratio of driver transistor
       =%0.2 f \n ', xd )
14 Knd =xd * Kn *0.001/2;
15 Knl =xl * Kn *0.001/2;
```

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```
16  printf('\nconduction parameter Knd=%.2f mA/V^2\n',
        Knd)
17  printf('\nconduction parameter Knl=%.3f mA/V^2\n',
        Knl)
18  //Vgsd-Vtnd=(Vdd-Vtnl)-sqrt(Knd/Knl)*(Vgsd-Vtnd)
19  y=sqrt(Knd/Knl);
20  Vgsd=(y+5)/(1+y);
21  printf('\nVgsd=%.2f V\n',Vgsd)
22  Vdsd=Vgsd-1;
23  printf('\nVdsd=%.2f V\n',Vdsd)
```

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

```
1   clear;
2   clc;
3   //Example 6.12
4   Vtnd=0.8;
5   Vtnl=-1.5;
6   Knd=1;
7   Knl=0.2;
8   //lambda=y
9   yd=0.01;
10  yl=0.01;
11  Idq=0.2;
12  gmd=2*sqrt(Knd*Idq);
13  printf('\ntransconductance of the driver=%.3f mA/V\n
        ',gmd)
14  roD=1/(yd*Idq);
15  printf('\noutput resistances=%.2f Kohm\n',roD)
16  Av=-gmd*roD/2;
17  printf('\nsmall signal voltage gain=%.2f \n',Av)
```

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

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

Scilab code Exa 6.14 Design the biasing of a multistage MOSFET

```
1  clear ;
2  clc ;
3  //Example 6.14
4  Kn1 =500*10^ -3;
5  Kn2 =200*10^ -3;
6  Vtn1 =1.2;
7  Vtn2 = Vtn1 ;
8  Idq1 =0.2;
9  Idq2 =0.5;
10 Vdsq1 =6;
11 Vdsq2 =6;
```

```
12  Ri =100;
13  Rsi =4;
14  Rs2 =(10 - Vdsq2 )/ Idq2 ;
15  printf ('\nRs2=%.2f KOhm\n',Rs2)
16  Vgs2 =sqrt (Idq2/Kn2)+Vtn2 ;
17  printf ('\ngate to source voltage for M2=%.2f V\n',
        Vgs2)
18  Vs2 = -1;
19  Vg2 =Vs2+Vgs2 ;
20  printf ('\ngate voltage of M2=%.2f V\n',Vg2)
21  Vg1 =Vg2 ;
22  Rd1 =(5 - Vg1 )/ Idq1 ;
23  printf ('\nresistor Rd1=%.2f KOhm\n',Rd1)
24  Vs1 =Vg1 - Vdsq1 ;
25  printf ('\nsource voltage of M1=%.2f KOhm\n',Vs1)
26  Rs1 =( Vs1+5)/ Idq1 ;
27  printf ('\nresistor Rs1=%.2f KOhm\n',Rs1)
28  Vgs1 =sqrt (Idq1/Kn1)+Vtn1 ;
29  printf ('\ngate to source voltage for M1=%.2f V\n',
        Vgs1)
30  R1 =Ri *10/( Vgs1+Idq1*Rs1 );
31  printf ('\nR1=%.2f KOhm\n',R1)
32  //Ri=R1*R2/(R1+R2)
33  R2 =Ri *R1 /(R1 - Ri );
34  printf ('\nR2=%.2f KOhm\n',R2)
```

Scilab code Exa 6.15 Design the biasing of cascade circuit

```
1  clear ;
2  clc ;
3  //Example 6.15
4  Vtn1 =1.2;
5  Vtn2 =1.2;
6  Kn1 =0.8;
7  Kn2 =0.8;
```

```
 8  //x=R1+R2+R3=300
 9  x=300;
10  Rs=10;
11  Idq=0.4;
12  Vdsq1=2.5;
13  Vdsq2=2.5;
14  Vs1=Idq*Rs-5;
15  printf('\ndc voltage at source of M1=%.2f V\n',Vs1)
16  Vgs=sqrt(Idq/Kn1)+Vtn1;
17  printf('\ngate to source voltage=%.2f V\n',Vgs)
18  R3=(Vgs+Vs1)*x/5;
19  printf('\nR3=%.2f KOhm\n',R3)
20  Vs2=Vdsq2+Vs1;
21  printf('\nvoltage at source of M2=%.2f V\n',Vs2)
22  //y=R2+R3
23  y=(Vgs+Vs2)*x/5;
24  printf('\nR2+R3=%.2f KOhm\n',y)
25  R2=150;
26  R1=x-y;
27  printf('\nR1=%.2f KOhm\n',R1)
28  R3=y-R2;
29  printf('\nR3=%.2f KOhm\n',R3)
30  Vd2=Vdsq2+Vs2;
31  printf('\nvoltage at drain of M2 =%.2fV\n',Vd2)
32  Rd=(5-Vd2)/Idq;
33  printf('\ndrain resistance=%.2f KOhm\n',Rd)
```

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

```
1  clear;
2  clc;
3  //Example 6.17
4  Kn=0.8;
5  Vtn=1.2;
6  Vgs=1.91;
```

```
 7  Rd =2.5;
 8  gm = 2* Kn *( Vgs - Vtn );
 9  printf ( '\ ntransconductance=%.2 f mA/V\n ', gm )
10  Av = -gm * Rd ;
11  printf ( '\ nsmall  signal  voltage  gain=%.2 f \n ', Av )
```

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

```
 1  clear ;
 2  clc ;
 3  // Example  6.18
 4  // Determine  the  small  signal  voltage  gain  of  a
        circuit  in  fig .6.55
 5  Idss =12;
 6  Vp = -4;
 7  // lambda=y
 8  y =0.008;
 9  Vgsq = poly (0 , ' Vgsq ');
10  p= poly ([26.4  17.2  2.025] , ' Vgsq ' , 'c ')
11  printf ( '\ nroots=%fV\n ', roots ( p ))
12  Vgsq = -2.01
13  Idq = Idss *(1 - Vgsq / Vp )^2;
14  printf ( '\ nquiescent  drain  current=%f mA\n ', Idq )
15  gm =( -2* Idss / Vp )*(1 - Vgsq / Vp );
16  printf ( '\ ntransconductance=%.2 f mA/V\n ', gm )
17  ro =(1/( y * Idq ));
18  printf ( '\ noutput  resistance=%.2 f KOhm\n ', ro )
19  Rd =2.7;
20  Rl =4;
21  x= Rd * Rl /( Rd+Rl );
22  Av = -gm * ro * x /( ro+x );
23  printf ( '\ nsmall  signal  voltage  gain=%.2 f \n ', Av )
```

Scilab code Exa 6.19 Design a JFET source folllower

```
1  clear;
2  clc;
3  //Example 6.19
4  Idss=12;
5  Vp=-4;
6  Rl=10;
7  //lambda=y
8  y=0.01;
9  Av=0.9;
10 //gm=(-2*Idss/Vp)*(1-Vgs/Vp)
11 gm=2;
12 Vgs=(1+gm*Vp/(2*Idss))*Vp;
13 printf('\ngate to source voltage=%.3f V\n',Vgs)
14 Idq=Idss*(1-Vgs/Vp)^2;
15 printf('\nquiescent drain current=%.3f mA\n',Idq)
16 Rs=(-Vgs+10)/Idq;
17 printf('\nRs=%.2f KOhm\n',Rs)
18 ro=(1/(y*Idq));
19 printf('\noutput resistance=%.3f KOhm\n',ro)
20 x=Rl*ro/(Rl+ro);
21 t=x*Rs/(x+Rs);
22 Av=gm*t/(1+gm*t);
23 printf('\nsmall signal voltage gain=%.3f \n',Av)
```

Chapter 7

Frequency Response

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

```scilab
1  clear;
2  clc;
3  //Example 7.1
4  Rs=1000;
5  Rp=10000;
6  Cs=1*10^-6;
7  Cp=3*10^-12;
8  Ts=(Rs+Rp)*Cs;
9  printf('\ntime constant=%.3f s\n',Ts)
10 f=1/(2*%pi*Ts);
11 printf('\ncorner frequency=%.2f Hz\n',f)
12 x=20*log10(Rp/(Rp+Rs));
13 printf('\nmaximum magnitude =%.3fdB\n',x)
14 Rp=10; //KOhm
15 Rs=1; //Kohm
16 Cp=3; //pF
17 Tp=Cp*Rs*Rp/(Rs+Rp);
18 printf('\ntime constant=%.3f ns\n',Tp)
19 Tp=2.73*10^-3; //micro sec
20 f=1/(2*%pi*Tp);
21 printf('\ncorner frequency =%.2fMHz\n',f)
```

Scilab code Exa 7.2 Determine the corner frequencies and bandwidth

```
1  clear;
2  clc;
3  //Example 7.2
4  Rs=1000;
5  Rp=10000;
6  Cs=1*10^-6;
7  Cp=3*10^-12;
8  Ts=(Rs+Rp)*Cs;
9  printf('\nopen circuit time constant=%.3f s\n',Ts)
10 Rs=1;//KOhm
11 Rp=10;//KOhm
12 Cp=3;//pF
13 Tp=Cp*Rs*Rp/(Rs+Rp);
14 printf('\nshort circuit time constant=%.3f ns\n',Tp)
15 fL=1/(2*%pi*Ts);
16 printf('\ncorner frequency fL=%.2f Hz\n',fL)
17 Tp=2.73*10^-3;// microsec
18 fH=1/(2*%pi*Tp);
19 printf('\ncorner frequency fH=%.3f MHz\n',fH)
20 fL=14.5*10^-6;//MHz
21 fbw=fH-fL;
22 printf('\nbandwidth =%.3fMHz\n',fbw)
```

Scilab code Exa 7.3 Determine the corner frequencies and maximum gain

```
1  clear;
2  clc;
3  //Example 7.3
4  R1=51.2;
```

```
5  R2=9.6;
6  Rc=2;
7  Re=.4;
8  Rsi=.1;
9  Vt=0.026;
10 Cc=1;
11 Vcc=10;
12 Vbe=0.7;
13 b=100;
14 Rb=8.08;
15 Icq=1.81;
16 gm=Icq/Vt;
17 printf('\ntransconductance=%.3f mA/V\n',gm)
18 r=b*Vt/Icq;
19 printf('\ndiffusion resistance=%.2f KOhm\n',r)
20 x=r+(1+b)*Re;
21 y=x*R2/(x+R2);
22 Ri=y*R1/(R1+y);
23 printf('\ninput resistance=%.3f KOhm\n',Ri)
24 Ts=(Rsi+Ri)*Cc;
25 printf('\ntime constant=%.3f ms\',Ts)
26 Ts=6.87*10^-3;//Sec
27 fL=1/(2*%pi*Ts);
28 printf('\ncorner frequency fL=%.3f Hz\n',fL)
29 Rib=r+(1+b)*Re;
30 printf('\nRib=%.3f KOhm\n',Rib)
31 Av=(gm*r*Rc/(Rsi+Ri))*Rb/(Rb+Rib);
32 printf('\nsmall signal voltage gain=%.2f\n',Av)
```

Scilab code Exa 7.4 Design the circuit

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

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

Scilab code Exa 7.5 `Determine 3dB frequency`

```
1  clear;
2  clc;
3  //Example 7.5
4  b=100;
5  Vbe=0.7;
6  Rs=500;
7  Rb=100000;
8  Re=10000;
9  Rl=10000;
10 Va=120;
11 Ccc2=1*10^-6;
12 Icq=0.838*0.001;
13 r=3100;//small signal parameter
14 gm=32.2*0.001;
15 ro=143000;
16 x=(r+Rs*Rb/(Rs+Rb))/(1+b);
17 y=ro*x/(ro+x);
18 Ro=Re*y/(Re+y);
19 printf('\noutput resistance of emitter=%.2f Ohm\n',
       Ro)
20 Ts=(Ro+Rl)*Ccc2;
21 printf('\ntime constant=%.2f s\n',Ts)
22 fL=1/(2*%pi*Ts);
23 printf('\n3dB frequency=%.2f Hz\n',fL)
```

Scilab code Exa 7.6 Determine the corner frequencies and maximum gain

```scilab
1  clear;
2  clc;
3  //Example 7.6
4  Rs=3.2;
5  Rd=10;
6  Rl=20;
7  Cl=10;
8  Vtp=-2;
9  Kp=0.25;
10 Idq=0.5;
11 Vsgq=3.41;
12 Vsdq=3.41;
13 gm=2*Kp*(Vsgq+Vtp);
14 printf('\ntransconductance =%.3fmA/V\n',gm)
15 Tp=Cl*Rd*Rl/(Rd+Rl);
16 printf('\ntime constant=%.3f ns\n',Tp)
17 Tp=66.7*10^-3;//micro sec
18 fH=1/(2*%pi*Tp);
19 printf('\ncorner frequency=%.2f MHz\n',fH)
20 Av=(gm*Rd*Rl/(Rd+Rl))/(1+gm*Rs);
21 printf('\nmaximum small signal voltage gain=%.2f\n',
       Av)
```

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

```scilab
1  clear;
2  clc;
3  //Example 7.7
4  Vbe=0.7;
5  b=100;
```

```scilab
 6  Re=.5;
 7  Rc=5;
 8  Rl=10;
 9  R1=40;
10  Cc=10;
11  R2=5.7;
12  Rs=.1;
13  Vt=0.026;
14  Icq=0.99;
15  gm=Icq/Vt;
16  printf('\ntransconductance=%.3f mA/V\n',gm)
17  r=b*Vt/Icq;
18  printf('\ndiffusion resistance=%.2f KOhm\n',r)
19  Ri=r+(1+b)*Re;
20  printf('\ninput resistance=%.2f KOhm\n',Ri)
21  x=Rc*Rl/(Rc+Rl);
22  y=R1*R2/(R1+R2);
23  t=y*Ri/(y+Ri);
24  Av=gm*r*x*(y/(y+Ri))*(1/(Rs+t));
25  printf('\nmaximum small signal voltage gain=%.2f\n',
        Av)
26  Ts=(Rs+t)*Cc;
27  printf('\ntime constant=%.3f ms\n',Ts)
28  Ts=46.6*0.001;//sec
29  Cl=15;
30  Tp=x*Cl;
31  printf('\ntime constant=%.3f ns\n',Tp)
32  fL=1/(2*%pi*Ts);
33  printf('\nlower corner frequency=%.2f Hz\n',fL)
34  Tp=50*10^-3;//micro sec
35  fH=1/(2*%pi*Tp);
36  printf('\nupper corner frequency=%.2f MHz\n',fH)
37  fL=3.4*10^-6;//MHz
38  fbw=fH-fL;
39  printf('\nbandwidth =%.2fMHz\n',fbw)
```

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

```scilab
1  clear;
2  clc;
3  //Example 7.8
4  Re=4;
5  Rc=2;
6  Rs=0.5;
7  Vt=0.026;
8  Ce=1*10^-3;
9  V1=5;
10 Icq=1.06;
11 V2=-5;
12 b=100;
13 Vbe=0.7;
14 gm=Icq/Vt;
15 printf('\ntransconductance =%.2fmA/V\n',gm)
16 r=b*Vt/Icq;
17 printf('\ndiffusion resistance=%.2f KOhm\n',r)
18 Ta=Re*Ce;
19 printf('\ntime constant Ta=%ef s\n',Ta)
20 Tb=(Re*Ce*(Rs+r))/(Rs+r+(1+b)*Re);
21 printf('\ntime constant Tb=%e s\n',Tb)
22 fA=1/(2*%pi*Ta);
23 printf('\ncorner frequency =%.2fHz\n',fA)
24 Tb=2.9*0.01;//msec
25 fB=1/(2*%pi*Tb);
26 printf('\ncorner frequency =%.2fkHz\n',fB)
27 Av=(gm*r*Rc)/(Rs+r+(1+b)*Re);
28 printf('\nlimiting low frequency horizontal
       asymptote=%.2f\n',Av)
29 Av=gm*r*Rc/(Rs+r);
30 printf('\nnlimiting high frequency horizontal
       asymptote=%.2f\n',Av)
```

Scilab code Exa 7.9 `Determine 3dB frequency`

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

Scilab code Exa 7.10 `Calculate bandwidth and capacitance`

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

Scilab code Exa 7.12 Determine the unity gain bandwidth

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

Scilab code Exa 7.13 Determine the Miller capacitance and cutoff frequency

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

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

```scilab
1  clear;
2  clc;
3  //Example 7.14
4  V1=5;
5  V=-5;
6  Rs=0.1;
7  Rb=40;
8  R2=5.72;
9  Re=0.5;
10 Rc=5;
11 Rl=10;
12 b=150;
13 Vbe=0.7;
14 C1=35*10^-3;
15 C2=4;
16 Vt=0.026;
17 Icq=1.02;
18 r=b*Vt/Icq;
19 printf('\nsmall signal parameter=%.2f KOhm\n',r)
20 gm=Icq/Vt;
21 printf('\ntransconductance=%.3f mA/V\n',gm)
22 Cm=C2*(1+gm*Rc*Rl/(Rc+Rl));
23 printf('\nMiller capacitance=%.3f pF\n',Cm)
24 Cm=527*10^-3;
25 x=Rb*Rs/(Rb+Rs);
26 y=r*x/(r+x);
27 fH=1/(2*%pi*y*(C1+Cm));
28 printf('\nupper corner frequency =%.2fMHz\n',fH)
29 t=Rb*r/(Rb+r);
30 p=Rc*Rl/(Rc+Rl);
31 Av=gm*p*t/(t+Rs);
32 printf('\nmidband gain=%.2f\n',Av)
```

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

```
 1  clear;
 2  clc;
 3  //Example 7.15
 4  V1=5;
 5  V=-5;
 6  Rs=0.1;
 7  R1=40;
 8  R2=5.72;
 9  Re=0.5;
10  Rc=5;
11  Rl=10;
12  b=150;
13  Vbe=0.7;
14  C1=35;
15  C2=4;
16  Vt=0.026;
17  Icq=1.02;
18  gm=39.2;
19  r=3.82;
20  x=Re*Rs/(Re+Rs);
21  t=r/(1+b);
22  y=t*x/(t+x);
23  Tp=y*C1;
24  printf('\ntime constant=%.3f ns\n',Tp)
25  Tp=0.679*10^-3;//micro sec
26  f=1/(2*%pi*Tp);
27  printf('\nupper frequency =%.3fMHz\n',f)
28  T=C2*Rc*Rl/(Rc+Rl);
29  printf('\ntime constant=%.3f ns\n',T)
30  T=13.3*10^-3;//micro sec
31  f=1/(2*%pi*T);
32  printf('\nupper frequency=%.2f MHz\n',f)
33  x=Rc*Rl/(Rc+Rl);
34  y=Re*t/(Re+t);
35  Av=gm*x*(y/(y+Rs));
36  printf('\nmidband voltage gain=%.2f \n',Av)
```

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

```
1  clear;
2  clc;
3  //Example 7.16
4  V1=5;
5  V=-5;
6  Rs=0.1;
7  R1=42.5;
8  R2=20.5;
9  R3=28.3;
10 Re=5.4;
11 Rc=5;
12 Rl=10;
13 b=150;
14 Vbe=0.7;
15 C1=35;
16 C2=4;
17 Vt=0.026;
18 Icq=1.02;
19 gm=39.2;
20 r=3.820;
21 Rb=R2*R3/(R2+R3);
22 x=Rb*r/(Rb+r);
23 y=Rs*x/(x+Rs);
24 Tp=y*(C1+2*C2);
25 printf('\ntime constant=%.3f ns\n',Tp)
26 Tp=Tp*10^-3;//micro sec
27 f=1/(2*%pi*Tp);
28 printf('\n3dB frequency =%0.3fMHz\n',f)
29 T=C2*Rc*Rl/(Rc+Rl);
30 printf('\ntime constant=%.2f ns\n',T)
31 T=T*0.001;//micro sec
32 f=1/(2*%pi*T);
```

```
33  printf('\nupper frequency=%.3f MHz\n',f)
34  x=Rc*Rl/(Rc+Rl);
35  y=Rb*r/(Rb+r);
36  Av=gm*x*(y/(y+Rs));
37  printf('\nmidband voltage gain=%.f \n',Av)
```

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

```
1   clear;
2   clc;
3   //Example 7.17
4   V1=5;
5   V=-5;
6   Rs=0.1;
7   R1=40;
8   R2=5.720;
9   Re=0.5;
10  Rc=5;
11  Rl=10;
12  b=150;
13  Vbe=0.7;
14  C1=35;
15  C2=4;
16  Vt=0.026;
17  Icq=1.02;
18  gm=39.2;
19  r=3.820;
20  t=r/(1+b);
21  t=t*0.001;
22  f=1/(2*%pi*C1*t);
23  printf('\nthe zero occurs at this frequency=%.2f MHz
        \n',f)
24  x=1+gm*Re*Rl/(Re+Rl);
25  Rb=R1*R2/(R1+R2)
26  d=x*r;
```

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```
27  y=d*Rb/(d+Rb);
28  t=y*Rs/(y+Rs);
29  Tp=t*(C2+C1/x);
30  printf('\ntime constant=%.2f ns\n',Tp)
31  Tp=Tp*10^-3;//micro sec
32  f=1/(2*%pi*Tp);
33  printf('\n3dB frequency=%.f MHz\n',f)
```

Chapter 8

Ouput Stages and Power Amplifier

Scilab code Exa 8.2 Determine the maximum power dissipation

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

Scilab code Exa 8.3 Determine the maximum safe power dissipation

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

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

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

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

Scilab code Exa 8.8 Design a transformer coupled emitter follower amplifier

```
1   clear;
2   clc;
3   //Example  8.8
4   Vcc=24;
5   Rl=8;
6   P=5;
7   Vbe=0.7;
8   b=100;
9   Vp=sqrt(2*Rl*P);
10  printf('\npeak  output  voltage=%.2 f  V\n',Vp)
11  Ip=Vp/Rl;
12  printf('\npeak  output  current  =%.2fA\n',Ip)
13  a=0.9*Vcc/Vp;
14  printf('\na=%.2 f\n',a)
15  Icq=Ip/(0.9*a);
16  printf('\nIcq=%.3 f  A\n',Icq)
17  Pq=Vcc*Icq;
18  printf('\nmaximum  power  dissipated  in  the  transistor
        =%.2 f  W\n',Pq)
19  Ibq=Icq/b;
20  Ibq=Ibq*1000;//mA
21  printf('\nbase  current  Ibq=%.2 f  mA\n',Ibq)
22  Rth=2.500;
23  //Vth=Vcc*Rth/R1  and  Vth=Ibq*Rth+Vbe
```

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

Scilab code Exa 8.9 Design the class AB output stage

```
1 clear;
2 clc;
3 //Example 8.9
4 Iso=3*10^-14;
5 Isq=10^-13;
6 b=75;
7 Vt=0.026;
8 Rl=8;
9 P=5;
10 Vp=sqrt(2*Rl*P);
11 printf('\npeak voltage Vp=%.2f V\n',Vp)
12 Vcc=Vp/0.8;
13 printf('\nsupply voltage=%.2f V\n',Vcc)
14 Ien=Vp/Rl;
15 printf('\nemitter current=%.3f A\n',Ien)
16 Ibn=Ien/(1+b);
17 Ibn=Ibn*1000;//mA
18 printf('\nbase current=%.2f mA\n',Ibn)
19 iD=0.020;
20 Vbb=2*Vt*log(iD/Iso);
21 printf('\nVbb=%.2f V\n',Vbb)
22 Icq=Isq*exp((Vbb/2)/Vt);
23 Icq=Icq*1000;//mA
24 printf('\nquiescent collector current=%.3f mA\n',Icq
     )
25 Ibias=20;//mA
26 iD=Ibias-Ibn;
27 printf('\ndrain current=%.3f mA\n',iD)
```

```
28  iD=iD*0.001;//A
29  Vbb=2*Vt*log(iD/Iso);
30  printf('\nVbb=%.2f V\n',Vbb)
31  Icn=1.12;
32  Vben=Vt*log(Icn/Isq);
33  printf('\nB-E voltage of Qn=%.2f V\n',Vben)
34  Vebp=Vbb-Vben;
35  printf('\nemitter base voltage of Qp=%.2f V\n',Vebp)
36  Icp=Isq*exp(Vebp/Vt);
37  Icp=Icp*1000;//mA
38  printf('\nIcp=%f mA\n',Icp)
```

Scilab code Exa 8.11 Determine the currents and the current gain

```
1   clear;
2   clc;
3   //Example 8.11
4   R1=2;//KOhm
5   R2=R1;
6   Rl=.1;//KOhm
7   b=60;
8   Vbe=0.6;
9   Veb=0.6;
10  V1=15;
11  V2=V1;
12  iR1=(V1-Vbe)/R1;
13  //iR1=iR2=iE1=iE2
14  printf('\niR1=%.2f mA\n',iR1)
15  vo=10;
16  io=vo/Rl;
17  printf('\noutput current=%.3f mA\n',io)
18  iB3=100/61;
19  printf('\niB3=%.3fmA\n',iB3)
20  iR1=(V1-(10+Vbe))/R1;
21  printf('\ncurrent in R1=%.3f mA\n',iR1)
```

```
22  iE1=iR1-iB3;
23  printf('\niE1=%.3f mA\n',iE1)
24  iB1=iE1/(1+b);
25  iB1=iB1*1000;//micro A
26  printf('\niB1=%.3f microA\n',iB1)
27  iE2=(10-0.6+15)/R1;
28  printf('\niE2=%.3f mA\n',iE2)
29  iB2=iE2/(1+b);
30  iB2=iB2*1000;
31  printf('\niB2=%.3f microA\n',iB2)
32  Ii=iB2-iB1;
33  printf('\ninput current=%.3f microA\n',Ii)
34  Ii=Ii*0.001;//mA
35  Ai=io/Ii;
36  printf('\ncurrent gain=%.2f\n',Ai)
37  Ai=(1+b)*R1/(2*Rl);
38  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

```
1  clear;
2  clc;
3  //Example 9.5
4  Zl=0.1;
5  R1=10;
6  R2=1;
7  R3=1;
8  Rf=10;
9  Vt=-5;
10 iL=-Vt/R2;
11 printf('\nload current=%.3f mA\n',iL)
12 vL=iL*Zl;
13 printf('\nvoltage across the load=%.2f V\n',vL)
14 i4=vL/R2;
15 printf('\ni4=%.3f mA\n',i4)
16 i3=i4+iL;
17 printf('\ni3=%.3f mA\n',i3)
18 Vo=i3*R3+vL;
19 printf('\noutput voltage=%.2f V\n',Vo)
```

```
20  i1=Vt/R1;
21  i2=i1;
22  printf('\ni1=%.3f mA\n',i1)
23  printf('\ni2=%.2f mA\n',i2)
```

Scilab code Exa 9.9 Determine the time constant

```
1  clear;
2  clc;
3  //Example 9.9
4  //Vo=(-1/R1*C2)*integrate((-1)dt)
5  x=integrate('(-1)','t',0,1)
6  Vo=10;
7  //let y=R1*C2
8  y=-x/Vo;
9  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

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

Scilab code Exa 10.2 Determine the change in load current

```scilab
1  clear;
```

```
2  clc;
3  //Example 10.2
4  V1=5;
5  V2=-5;
6  R1=9.3;
7  b=50;
8  Vbe=0.7;
9  Va=80;
10 Iref=(V1-Vbe-V2)/R1;
11 printf('\nreference current =%.3fmA\n',Iref)
12 Io=Iref/(1+2/b);
13 printf('\noutput current=%.2fmA\n',Io)
14 ro=Va/Io;
15 printf('\nsmall signal output resistance=%.2f KOhm\n
       ',ro)
16 //dIo=dVce2/ro
17 Vce2=0.7;
18 dIo=(V1-Vce2)/ro;
19 printf('\nchange in load current=%.3f mA\n',dIo)
20 x=dIo/Io;
21 x=x*100;
22 printf('\npercent change in output current=%.2f \n',
       x)
```

Scilab code Exa 10.4 Design a Widlar current source

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

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

Scilab code Exa 10.5 Determine the change in load current

```
1   clear;
2   clc;
3   //Example 10.5
4   V1=5;
5   V2=-5;
6   R1=9.3;
7   Re=9.580;
8   Vt=0.026;
9   b=100;
10  Vbe=0.7;
11  Va=80;
12  Io=12;
13  ro2=Va/Io;
14  printf('\nsmall signal collector resistance=%.2f
        MOhm\n',ro2)
15  Io=12*0.001; //mA
16  gm2=Io/Vt;
17  printf('\ntransconductance=%.3f mA/V\n',gm2)
18  r=b*Vt/Io;
19  printf('\nResistance=%.2f KOhm\n',r)
20  Ro=ro2*(1+gm2*Re*r/(Re+r));
21  printf('\noutput resistance=%.2f MOhm\n',Ro)
22  dVc2=4;
23  dIo=dVc2/Ro;
24  printf('\nchange in load current=%.3f microA\n',dIo)
```

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

Scilab code Exa 10.6 Design a generalized current mirror

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

Scilab code Exa 10.7 Design a MOSFET current source

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

```
 9  Iref =0.25*10^ -3;
10  Io=0.1*10^ -3;
11  Vgs2=1.85;
12  //let y=W/L
13  y2=Io/(x*(Vgs2-Vtn)^2);
14  printf('\nwidth per length 2=%.2 f\n',y2)
15  y1=Iref/(x*(Vgs2-Vtn)^2);
16  printf('\nwidth per length 1=%.2 f\n',y1)
17  Vgs1=Vgs2;
18  Vgs3=V1-V2-Vgs1;
19  printf('\nVgs3=%.2 f V\n',Vgs3)
20  y3=Iref/(x*(Vgs3-Vtn)^2);
21  printf('\nwidth per length 3=%.2 f\n',y3)
```

Scilab code Exa 10.8 Compare the output resistances

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

Scilab code Exa 10.9 Determiine the currents and voltages

```
1  clear;
2  clc;
3  //Example 10.9
4  Idss1=2;
5  Idss2=1;
6  Vp1=-1.5;
7  Vp2=Vp1;
8  //lambda=y
9  y1=0.05;
10 y2=y1;
11 V2=-5;
12 Vds=1.5;
13 Vsmin=Vds+V2;
14 printf('\nminimum value of Vs=%.2f V\n',Vsmin)
15 Io=Idss2*(1+y1*Vds);
16 printf('\noutput current=%.2f mA\n',Io)
17 Vgs1=(1-sqrt(Io/Idss1))*Vp1;
18 printf('\ngate to source voltage of Q1=%.2f V\n',
      Vgs1)
19 V1=Vgs1+Vsmin;
20 printf('\nV1=%.2f V\n',V1)
```

Scilab code Exa 10.10 Calculate the open circuit voltage gain

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

Scilab code Exa 10.11 Calculate the small signal voltage gain

```
1  clear;
2  clc;
3  //Example 10.11
4  Van=120;
5  Vap=80;
6  Vt=0.026;
7  Ico=0.001;
8  //Rl=infinity
9  Av=-(1/Vt)/(1/Van+1/Vap);
10 printf('\nsmall signal open circuit voltage gain=%.2
      f\n',Av)
11 Rl=100;
12 Av1=-(1/Vt)/(1/Van+1/Vap+1/Rl);
13 printf('\nsmall signal open circuit voltage gain=%.2
      f\n',Av1)
14 Rl=10;
15 Av2=-(1/Vt)/(1/Van+1/Vap+1/Rl);
16 printf('\nsmall signal open circuit voltage gain=%.2
      f\n',Av2)
```

Scilab code Exa 10.12 Calculate the small signal voltage gain

```
1  clear;
2  clc;
3  //Example 10.12
4  //lambda=y
5  yn=0.01;
6  yp=0.01;
7  Vtn=1;
8  Kn=1;
```

```
 9  Iref =0.5;
10  gm =2* sqrt ( Kn * Iref );
11  printf ( '\ ntransconductance =%.2 fmA/V\n ', gm )
12  go = yn * Iref ;
13  printf ( '\ nsmall  signal  transistor  conductance=%.4 f
        mA/V\n ', go )
14  go2 = go ;
15  // for  Rl=infinity
16  Av = - gm /( go + go2 );
17  printf ( '\ nvoltage  gain=%.2 f  \n ', Av )
18  Rl =100; // Kohm
19  gl =0.01;
20  Av = - gm /( go + gl + go2 );
21  printf ( '\ nvoltage  gain=%.2 f  \n ', Av )
```

Chapter 11

Differential and Multistage Amplifier

Scilab code Exa 11.1 Determine the quiescent collector current and collector emitt

```
1  clear;
2  clc;
3  //Example 11.1
4  V1=10;
5  V2=-10;
6  Iq=1;
7  Rc=10;
8  Vbe=0.7;
9  iC1=Iq/2;
10 iC2=iC1;
11 printf('\ncollector currents =%.2fmA\n',iC1)
12 Vc1=V1-iC1*Rc;
13 Vc2=Vc1;
14 printf('\ncollector voltages =%.2fV\n',Vc1)
15 Vcm=0;
16 Ve=Vcm-Vbe;
17 Vce1=Vc1-Ve;
18 printf('\ncollector emitter voltage=%.2f V\n',Vce1)
19 Vcm=-5;
```

```
20  Ve=Vcm-Vbe;
21  Vce1=Vc1-Ve;
22  printf('\ncollector emitter voltage =%.2fV\n',Vce1)
23  Vcm=5;
24  Ve=Vcm-Vbe;
25  Vce1=Vc1-Ve;
26  printf('\ncollector emitter voltage=%.2f V\n',Vce1)
```

Scilab code Exa 11.3 Determine the differential and common mode gains

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

Scilab code Exa 11.7 Determine the CMRR of a differential amplifier

```
1  clear;
2  clc;
3  //Example 11.7
4  Ad=92.3;
5  Acm=0.237;//mod of Acm
6  CMRR=Ad/Acm;
```

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

Scilab code Exa 11.8 Design a bipolar source

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

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

```
1  clear;
2  clc;
3  //Example 11.9
4  b=100;
5  Vbe=0.7;
6  Va=100;
7  Vt=0.026;
8  Iref=0.5;
9  Iq=Iref;
10 I1=Iq/2
11 Icq=I1;
12 r=b*Vt/Icq;
13 printf('\nsmall signal parameter=%.2f KOhm\n',r)
```

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```
14  ro=Va/Icq;
15  printf('\nro=%.2f KOhm\n',ro)
16  Ro=Va/Iq;
17  printf('\noutput resistance of Q4=%.2f KOhm\n',Ro)
18  Rid=2*r;
19  printf('\ndifferential mode input resistance =%.2
       fKOhm\n',Rid)
20  Ricm=(1+b)*(Ro*ro/2)/(Ro+ro/2);
21  Ricm=Ricm*0.001;//Mohm
22  printf('\ncommon mode input resistance=%.2f MOhm\n',
       Ricm)
```

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

```
1   clear;
2   clc;
3   //Example 11.10
4   Kn1=0.1;
5   Kn2=Kn1;
6   Kn3=0.1;
7   Kn4=Kn3;
8   R1=30;
9   Vtn=1;
10  Rd=16;
11  //I1=(20-Vgs4)/R1 and I1=Kn3*(Vgs4-Vtn)^2
12  Vgs4=poly(0,'Vgs4')
13  p=poly([-1 -17 9],'Vgs4','c')
14  printf('\nroots=%.2fV\n',roots(p))
15  Vgs4=2.40;
16  I1=(20-Vgs4)/R1;
17  printf('\nI1=%.2f mA\n',I1)
18  Iq=I1;
19  Id1=Iq/2;
20  printf('\nId1 and Id2 =%.2fmA\n',Id1)
21  Vgs1=sqrt(Id1/Kn1)+Vtn;
```

```
22  printf('\nVgs1 and Vgs2 =%.2fV\n',Vgs1)
23  vo1 =10 - Id1 * Rd ;
24  printf('\nvo1 and vo2=%.2f V\n',vo1)
25  Vds1 = Vgs1 - Vtn ;
26  printf('\nVds1=Vds2=Vds1(sat)=%.2f V\n',Vds1)
27  Vcm = vo1 - Vds1 + Vgs1 ;
28  printf('\nVcm max=%.2f V\n',Vcm)
29  Vds4 = Vgs4 - Vtn ;
30  printf('\nVds4=%.2f V\n',Vds4)
31  Vcm2 = Vgs1 + Vds4 -10;
32  printf('\nVcm min=%.2fV\n',Vcm2)
```

Scilab code Exa 11.11 Compare the forward transconductance

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

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

```
1  clear ;
2  clc ;
3  //Example 11.12
4  Iq =0.587;
```

```
 5  Kn =1;
 6  Rd =16;
 7  //lambda=y
 8  y =0.01;
 9  Ro =1/( y * Iq ) ;
10  printf ( '\noutput  resistance  =%.2fKOhm\n',Ro)
11  Ad = sqrt ( Kn * Iq /2) * Rd ;
12  printf ( '\ndifferential  mode  voltage  gain=%.2f  \n',Ad
      )
13  Acm =- sqrt (2* Kn * Iq ) * Rd /(1+2* sqrt (2* Kn * Iq ) * Ro ) ;
14  printf ( '\ncommon  mode  voltage  gain=%.2f\n',Acm)
15  CMRR =20* log10 ( - Ad / Acm ) ;
16  printf ( '\ncommon  mode  rejection  ratio=%.2f  dB\n',
      CMRR )
```

Scilab code Exa 11.13 Determine the differential mode voltage gain

```
 1  clear ;
 2  clc ;
 3  //Example  11.13
 4  Iq =0.2;
 5  Va =100;
 6  Va2 = Va ;
 7  Va4 = Va ;
 8  Rl =100;
 9  Vt =0.026;
10  Ad =(1/ Vt ) /(1/ Va2 +1/ Va4 ) ;
11  printf ( '\nopen  circuit  voltage  gain=%.2f\n',Ad)
12  Ad =( Iq /(2* Vt ) ) /( Iq /(2* Va2 ) + Iq /(2* Va4 ) +1/ Rl ) ;
13  printf ( '\nvoltage  gain=%.2f\n',Ad)
```

Scilab code Exa 11.15 Determine the differential mode voltage gain

```
1  clear;
2  clc;
3  //Example 11.15
4  Kn=0.2;
5  Idq=0.1;
6  ro4=1000; //Kohm
7  ro6=1000; //KOhm
8  ro2=ro4;
9  //lambda=y
10 y=0.01;
11 gm=2*sqrt(Kn*Idq);
12 printf('\ntransconductance=%.3f mA/V\n',gm)
13 ro=1/(y*Idq);
14 printf('\noutput resistance=%.2f KOhm\n',ro)
15 Ro=ro4+ro6*(1+gm*ro);
16 Ro=Ro*0.001; //Mohm
17 printf('\noutput resistance of the cascode active
      load=%.2fMohm\n',Ro)
18 Ro=Ro*1000; //KOhm
19 Ad=gm*ro2*Ro/(ro4+Ro);
20 printf('\ndifferential mode voltage gain=%.2f\n',Ad)
```

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

```
1  clear;
2  clc;
3  //Example 11.16
4  Iq=0.2;
5  Ic1=Iq;
6  Icb=1;
7  R4=10;
8  R3=0.2;
9  b=100;
10 Va=100;
11 Vt=0.026;
```

```
12  Ri =2*(1+b)*b*Vt/Iq;
13  Ri=Ri*0.001; //MOhm
14  printf('\ninput resistance=%.2f MOhm\n',Ri)
15  R11=b*Vt/Iq;
16  printf('\nresistance R11=%.2f KOhm\n',R11)
17  Re=R11*R3/(R11+R3);
18  printf('\nRe=%.2f KOhm\n',Re)
19  gm11=Iq/Vt;
20  printf('\ngm11=%.3f mA/V\n',gm11)
21  ro11=Va/Iq;
22  printf('\nro11 =%.2fKOhm\n',ro11)
23  Rc11=ro11*(1+gm11*Re);
24  Rc11=Rc11*0.001; //MOhm
25  printf('\nRc11=%.2f MOhm\n',Rc11)
26  r8=b*Vt/Icb;
27  printf('\nresistance=%.2fKOhm\n',r8)
28  //answer of following given in the book is wrong
29  Rb8=r8+(1+b)*R4;
30  Rb8=Rb8*0.001; //MOhm
31  printf('\nRb8 =%.2fMOhm\n',Rb8)
32  Rl7=Rc11*Rb8/(Rc11+Rb8);
33  printf('\nRl7=%.2f MOhm\n',Rl7)
34  Av=Iq*Rl7/(2*Vt);
35  printf('\nsmall signal voltage gain=%.2f\n',Av)
```

Scilab code Exa 11.17 Calculate the output resistance

```
1  clear;
2  clc;
3  //Example 11.17
4  Va=100;
5  R4=10;
6  b=100;
7  Rc11=1.26*10^3;
8  r8=2.6;
```

```
 9  Iq =0.2;
10  Rc7 = Va / Iq ;
11  printf ('\nRc7=%.2 f KOhm\n',Rc7)
12  Z= Rc11 * Rc7 /( Rc11 + Rc7 );
13  printf ('\nZ=%.2 f KOhm\n',Z)
14  x =( r8 + Z )/(1+ b );
15  Ro = R4 * x /( R4 + x );
16  printf ('\noutput resistance=%.2 f KOhm\n',Ro)
```

Scilab code Exa 11.19 Determine the differential mode voltage gain

```
 1  clear ;
 2  clc ;
 3  //Example 11.19
 4  b =100;
 5  Vt =0.026;
 6  Rc =20;
 7  Ir4 =0.4;
 8  Iq = Ir4 ;
 9  Ir6 = Ir4 ;
10  r4 = b * Vt / Ir4 ;
11  printf ('\nr4=%.2 f KOhm\n',r4)
12  r3 = b ^2* Vt / Ir4 ;
13  printf ('\nr3=%.2 f KOhm\n',r3)
14  Ri2 = r3 +(1+ b )* r4 ;
15  printf ('\ninput resistance=%.2 f KOhm\n',Ri2)
16  gm = Iq /(2* Vt );
17  printf ('\ntransconductance=%.3 f mA/V\n',gm)
18  Ad1 = gm * Rc * Ri2 /(2*( Rc + Ri2 ));
19  printf ('\ngain of differential amplifier stage=%.2 f\
        n',Ad1)
20  r5 = b * Vt / Ir6 ;
21  printf ('\nr5 =%.2fKOhm\n',r5)
22  Ir7 =2;
23  r6 = b * Vt / Ir7 ;
```

```
24  printf('\nr6=%.2f KOhm\n',r6)
25  R6=16.5;
26  R7=5;
27  Ri3=r5+(1+b)*(R6+r6+(1+b)*R7);
28  Ri3=Ri3*0.001;//MOhm
29  printf('\nRi3=%.2f MOhm\n',Ri3)
30  Rs=5;
31  A2=Ir4*Rs/(2*Vt);
32  printf('\nvoltage gain A2=%.2f\n',A2)
33  A3=1;//vo/vo3
34  Ad=Ad1*A2*A3;
35  printf('\nsmall signal voltage gain=%.2f\n',Ad)
```

Scilab code Exa 11.20 Determine the zero and pole frequencies

```
 1  clear;
 2  clc;
 3  //Example 11.20
 4  Ro=10000000;
 5  Co=1*10^-12;
 6  Rb=500;
 7  r=10000;
 8  b=100;
 9  f=1/(2*%pi*Ro*Co);
10  f=f*0.001;//KHz
11  printf('\nfrequency of the zero=%.2f KHz\n',f)
12  Req=Ro*(1+Rb/r)/(1+Rb/r+2*(1+b)*Ro/r);
13  printf('\nReq=%.2f Ohm\n',Req)
14  f=1/(2*%pi*Req*Co);
15  f=f*10^-9;//GHz
16  printf('\nfrequency of the pole=%.2f GHz\n',f)
```

Chapter 12

Feedback and Stability

Scilab code Exa 12.1 Calculate the feedback transfer function

```scilab
1  clear ;
2  clc ;
3  //Example 12.1
4  A =10^5; //open loop gain
5  Af =50; //closed loop gain
6  b=(A/Af -1)/A ;
7  printf ('\nfeedback transfer function=%f\n',b)
8  A = -10^5;
9  Af = -50;
10 b=(A/Af -1)/A ;
11 printf ('\nfeedback transfer function=%f\n',b)
```

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

```scilab
1  clear ;
2  clc ;
3  //Example 12.2
4  A =10^5;
```

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

Scilab code Exa 12.3 Determine the bandwidth of a feedback amplifier

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

Scilab code Exa 12.5 Determine the input resistance and output resistance

```
1  clear;
2  clc;
3  //Example 12.5
4  Av =10^5;
5  Avf =50;
6  Rf =10;//Kohm
7  Ro =20000;//Ohm
```

```
 8  //x=(1+bvAv)
 9  x = Av / Avf ;
10  printf ( '\n(1+bvAv)=%. e \n ' ,x)
11  Rif = Rf * x ;
12  Rif = Rif *0.001; //MOhm
13  printf ( '\ninput  resistance=%.2 f  MOhm\n ' ,Rif )
14  Rof = Ro / x ;
15  printf ( '\noutput  resistance=%.2 f  Ohm\n ' ,Rof )
```

Scilab code Exa 12.6 Determine the input resistance and output resistance

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

Scilab code Exa 12.7 Determine the expected input resistance

```
 1  clear ;
 2  clc ;
 3  //Example  12.7
 4  Ri =50;
```

```
5  R1 =10;
6  R2 =90;
7  Av =10^4;
8  bv =1/(1+ R2 / R1 );
9  printf ('\nfeedback transfer function=%.2f\n',bv)
10 Rif = Ri *(1+ bv * Av );
11 Rif = Rif *0.001; //Mohm
12 printf ('\ninput resistance=%.2f MOhm\n',Rif)
```

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

```
1  clear ;
2  clc ;
3  //Example 12.11
4  hFE =100; // transistor parameter
5  Vbe =0.7;
6  Vcc =10;
7  R1 =55;
8  R2 =12;
9  Re =1;
10 Rc =4;
11 Rl =4;
12 Icq =0.983;
13 Vceq =5.08;
14 Vt =0.026;
15 r= hFE * Vt / Icq ;
16 printf ('\nsmall signal parameter resistance=%.2f
       KOhm\n',r)
17 gm = Icq / Vt ;
18 printf ('\ntransconductance=%.3f mA/V\n',gm)
19 Agf =- gm *( Rc /( Rc + Rl ))/(1+ Re *( gm +1/ r ));
20 printf ('\ntransconductance transfer function=%.3f mA
       /V\n',Agf)
21 //as first approximation
22 Agf2 =-1/ Re ;
```

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```
23  printf('\nAgf=%.2f mA/V\n',Agf2)
24  Avf=Agf*Rl;
25  printf('\nvoltage gain=%.2f\n',Avf)
```

Scilab code Exa 12.16 Determine the loop gain

```
1   clear;
2   clc;
3   //Example 12.15
4   //Determine the loop gain fig12.45(a)
5   hFE=100;
6   Vbe=0.7;
7   Icq=0.492;
8   r=5.28;
9   gm=18.9;
10  Rs=10;
11  R1=51;
12  R2=5.5;
13  Re=0.500;
14  Rc=10;
15  Rf=82;
16  x=r*R2/(r+R2);
17  y=R1*x/(x+R1);
18  t=Rs*y/(y+Rs);
19  Req=t;
20  printf('\nequivalent resistance=%.2f KOhm\n',t)
21  T=gm*Rc*Req/(Rc+Rf+Req);
22  printf('\nthe loop gain=%.2f\n',T)
```

Scilab code Exa 12.19 Determine the stability of an amplifier

```
1   clear;
2   clc;
```

```
3  //Example  12.19
4  //T=b*100/(sqrt(1+(f/10^5)^2)  angle=-3tan^-1(f/10^5)
5  //stable  at  f180  at  which  phase  becomes  -180  degrees
6  //-3*atan(f180/10^5)=-180
7  f180=tand(180/3)*10^5;
8  printf('\nfrequency  at  -180  degree=%ef  Hz\n',f180)
9  b=0.2;
10 T=b*100/(sqrt(1+(f180/10^5)^2))^3;
11 printf('\nmagnitude  of  the  loop  gain=%.2f\n',T)
12 b=0.02;
13 T=b*100/(sqrt(1+(f180/10^5)^2))^3;
14 printf('\nmagnitude  of  the  loop  gain=%.2f\n',T)
```

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

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

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

```
1  clear;
2  clc;
3  //Example  12.23
4  A=10^3;
5  Cf=30*10^-12;//feedback  capacitor  (F)
```

```
 6  R2 =5*10^5;
 7  Cm= Cf *(1+A);
 8  printf('\nMiller  capacitance=%e F\n',Cm)
 9  fp =1/(2* %pi *R2* Cm);
10  printf('\ndominant  pole  frequency =%.2 fHz\n',fp)
```

Chapter 13

Operational Amplifier Circuits

Scilab code Exa 13.1 Calculate the dc currents

```scilab
1  clear;
2  clc;
3  //Example 13.1
4  V1=15;//positive supply voltage
5  V2=-15;//negative supply voltage
6  Veb12=0.6;
7  Vbe11=0.6;
8  Rs=40;
9  Iref=(V1-V2-Veb12-Vbe11)/Rs;
10 printf('\nreference current=%.2f mA\n',Iref)
11 Ic10=19;
12 Ic1=Ic10/2;
13 printf('\nIc1=Ic2=Ic3=Ic4= %.3fmicroA\n',Ic1)
14 Ic1=Ic1*0.001;//mA
15 Vbe7=0.6;
16 Vbe6=0.6;
17 Ic6=Ic1;
18 R2=1;
19 Vc6=Vbe7+Vbe6+Ic6*R2+V2;
20 printf('\nvoltage at collector of Q6=%.2f V\n',Vc6)
```

Scilab code Exa 13.2 Calculate the bias currents

```
1  clear;
2  clc;
3  //Example 13.2
4  Iref=0.72;
5  Ic17=0.75*Iref;
6  printf('\ncollector currents in Q17=%.2f mA\n',Ic17)
7  b=200;
8  Ib17=Ic17/b;
9  Ie17=Ic17;
10 R8=0.100;
11 Vbe17=0.6;
12 R9=50;
13 Ic16=Ib17+(Ie17*R8+Vbe17)/R9;
14 Ic16=Ic16*1000;
15 printf('\ncollector current in Q16=%.2f microA\n',
      Ic16)
```

Scilab code Exa 13.3 Calculate the bias currents

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

```
11  R10 =50;
12  Ir1o=Vbe19/R10;
13  printf('\ncurrent in Ro=%.3f mA\n',Ir1o)
14  Ic19=Ic13a-Ir1o;
15  printf('\ncurrent in Q19 =%.3fmA\n',Ic19)
16  Ic19=Ic19*0.001;//A
17  Vbe19=Vt*log(Ic19/Is1);
18  printf('\nB-E voltage of Q19=%.2f V\n',Vbe19)
19  b=200;
20  Ic19=Ic19*10^6;//micro A
21  Iv19=Ic19*1000;
22  Ib18=Ic19/b;
23  Ir1o=Ir1o*1000;
24  printf('\nbase current in Q18=%.3f microA\n',Ib18)
25  Ic18=Ir1o+Ib18;
26  printf('\ncurrents in Q18=%.3f microA\n',Ic18)
27  Ic18=Ic18*10^-6;
28  Vbe18=Vt*log(Ic18/Is1);
29  printf('\nB-E voltage of Q18=%.2f V\n',Vbe18)
30  Vbb=Vbe18+Vbe19;
31  printf('\nvoltage difference Vbb=%.2f V\n',Vbb)
32  Ic14=Is2*exp(Vbb/(2*Vt));
33  Ic14=Ic14*10^6;//micro A
34  printf('\nquiescent currents in Q14 and Q20 =%.
        fmicroA\n',Ic14)
```

Scilab code Exa 13.4 Determine the small signal differential voltage gain

```
1  clear;
2  clc;
3  //Example 13.4
4  b=200;
5  Va=50
6  Vt=0.026;
7  R2=1;
```

```
 8  Ic6 =0.0095;
 9  Ic4 =Ic6;
10  Ic16 =0.0158;
11  Ic17 =0.54;
12  r17=b*Vt/Ic17;
13  printf('\ninput resistance to gain stage=%.2f KOhm\n
       ',r17)
14  R9=50;
15  R8=0.100;
16  x=r17+(1+b)*R8;
17  Re=x*R9/(x+R9);
18  printf('\nRe=%.3f KOhm\n',Re)
19  r16=b*Vt/Ic16;
20  printf('\nr16=%.2f KOhm\n',r16)
21  Ri2=r16+(1+b)*Re;
22  Ri2=Ri2*0.001; //MOhm
23  printf('\nRi2=%.2f KOhm\n',Ri2)
24  r6=b*Vt/Ic6;
25  printf('\nresistance of the active load=%.2f KOhm\n'
       ,r6)
26  gm=Ic6/Vt;
27  printf('\ntransconductance =%.3fmA/V\n',gm)
28  ro6=Va/Ic6;
29  ro6=ro6*0.001; //MOhm
30  printf('\nro6=%.2f MOhm\n',ro6)
31  R=ro6*(1+gm*R2*r6/(R2+r6));
32  printf('\neffective resistance of active load=%.2f
       MOhm\n',R)
33  ro4=Va/Ic4;
34  ro4=ro4*0.001; //Mohm
35  printf('\nResistance ro4=%.2f KOhm\n',ro4)
36  Icq=9.5;
37  x=Ri2*R/(R+Ri2);
38  y=ro4*x/(ro4+x);
39  Ad=-y*Icq/Vt;
40  printf('\nsmall signal differential voltage gain=%.2
       f\n',Ad)
```

Scilab code Exa 13.5 Determine the small signal voltage gain

```
1  clear;
2  clc;
3  //Example 13.5
4  bp=50;
5  bn=200;
6  Va=50;
7  R9=50;
8  R8=0.100;
9  Rl=2;
10 Vt=0.026;
11 Ri2=4070;
12 Ic20=0.138;
13 r20=bp*Vt/Ic20;
14 printf('\nr20=%.2f KOhm\n',r20)
15 R20=r20+(1+bp)*Rl;
16 printf('\nR20=%.2f KOhm\n',R20)
17 Ic13A=0.18;
18 R19=Va/Ic13A;
19 printf('\nR19=%.2f KOhm\n',R19)
20 r22=bp*Vt/Ic13A;
21 printf('\nr22=%.2f KOhm\n',r22)
22 Ri3=r22+(1+bp)*R19*R20/(R19+R20);
23 Ri3=Ri3*0.001;//MOhm
24 printf('\ninput resistance to the output stage=%.2f
      MOhm\n',Ri3)
25 Ic13B=0.54;
26 R=Va/Ic13B;
27 printf('\neffective resistance of the active load=%
      .2f KOhm\n',R)
28 Ic17=Ic13B;
29 R17=Va/Ic17;
30 printf('\noutput resistance Ro17 =%.2fKOhm\n',R17)
```

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

Scilab code Exa 13.6 Calculate the output resistance

```
 1  clear;
 2  clc;
 3  //Example 13.6
 4  Ic20=2;
 5  bn=200;
 6  bp=50;
 7  Va=50;
 8  r17=9.63;
 9  r22=7.22;
10  R20=0.260;
11  gm17=20.8;
12  ro17=92.6;
13  Ro13B=92.6;
14  R8=0.100;
15  Rc17=ro17*(1+gm17*R8*r17/(R8+r17));
16  printf('\nRc17=%.2f KOhm\n',Rc17)
17  Rc22=(r22+Rc17*Ro13B/(Rc17+Ro13B))/(1+bp);
18  printf('\nRc22=%.2f KOhm\n',Rc22)
19  Ic13A=0.18;
20  Rc19=Va/Ic13A;
21  printf('\nRc19=%.2f KOhm\n',Rc19)
22  Rc20=(R20+Rc22*Rc19/(Rc22+Rc19))/(1+bp);
23  printf('\nRc20=%.5f KOhm\n',Rc20)
24  Rc20=Rc20*1000;//Ohm
25  R3=22;
26  Ro=R3+Rc20;
```

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

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

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

Scilab code Exa 13.9 Determine the small signal voltage gain

```
1  clear;
2  clc;
3  //Example 13.9
4  //lambda=y
5  y=0.02;
6  //W/L=x and u*Cox/2=t
7  x=12.5;
```

```
8  t=10;
9  Kp1=x*t;
10 printf('\nconduction  parameters  of M1 and M2=%.
      fmicroA/V^2\n',Kp1)
11 Kp1=Kp1*0.001;//mA/V^2
12 Id=0.0199;
13 ro2=1/(y*Id);
14 ro2=ro2*0.001;//Mohm
15 printf('\noutput  resistance=%.2f MOhm\n',ro2)
16 Iq=0.0397;
17 ro2=ro2*1000;//Kohm
18 ro4=ro2;
19 Ad=sqrt(2*Kp1*Iq)*ro2*ro4/(ro2+ro4);
20 printf('\nthe  gain  of  input  stage=%.2f  \n',Ad)
21 Kn7=0.250;
22 Id7=Iq;
23 gm7=2*sqrt(Kn7*Id7)
24 printf('\ntransconductance  of M7=%.2f mA/V\n',gm7)
25 ro7=1/(y*Id7);
26 ro7=ro7*0.001;
27 printf('\noutput  resistance  of M7 and M8 =%.2fMOhm\n
      ',ro7)
28 ro7=ro7*1000;//Kohm
29 ro8=ro7;
30 Av2=gm7*ro7*ro8/(ro7+ro8);
31 printf('\ngain  of  the  second  stage=%.2f\n',Av2)
32 Av=Ad*Av2;
33 printf('\noverall  voltage  gain=%.2f\n',Av)
```

Scilab code Exa 13.10 Determine the differential mode voltage gain

```
1 clear;
2 clc;
3 //Example  13.10
4 Iref=100;
```

```
5   Kn=80;
6   Kp=40;
7   //W/L=x
8   x=25;
9   //lambda=y
10  y=0.02;
11  Id=Iref/2;
12  gm1=2*sqrt(Kp*x*Id/2);
13  printf('\ntransconductance gm1=gm8=%.3f microA/V\n',
        gm1)
14  gm6=2*sqrt(Kn*x*Id/2);
15  printf('\ntransconductance=%.3f microA/V\n',gm6)
16  ro1=1/(y*Id);
17  ro8=ro1;
18  ro6=ro1;
19  ro10=ro1;
20  printf('\noutput resistance ro1=ro8=ro6=ro10=%.3f
        MOhm\n',ro1)
21  Id4=Iref;
22  ro4=1/(y*Id4);
23  printf('\nro4=%.3f MOhm\n',ro4)
24  Ro8=gm1*ro8*ro10;
25  printf('\ncomposite output resistances =%.2f MOhm\n'
        ,Ro8)
26  Ro6=gm6*ro6*ro4*ro1/(ro4+ro1);
27  printf('\ncomposite output resistances=%.2f MOhm\n',
        Ro6)
28  Ad=gm1*Ro6*Ro8/(Ro6+Ro8);
29  printf('\ndifferential voltage gain=%.2f\n',Ad)
```

Scilab code Exa 13.12 Determine the small signal voltage gain

```
1   clear;
2   clc;
3   //Example 13.12
```

```
4   Kp =0.6;
5   bn =200;
6   Va =50;
7   Vt =0.026;
8   Ic13 =0.20;
9   Ri2 = bn * Vt / Ic13 ;
10  printf ( '\ ninput  resistance  to  the  gain  stage=%.2 f
       KOhm\n ', Ri2 )
11  Iq5 = Ic13 ;
12  Ad = sqrt (2* Kp * Iq5 )* Ri2 ;
13  printf ( '\ nsmall  signal  voltage  gain=%.2 f\n ', Ad )
```

Scilab code Exa 13.13 Determine the small signal voltage gain

```
1   clear ;
2   clc ;
3   // Example  13.13
4   Va =150;
5   Vt =0.026;
6   Ic13 =0.2;
7   gm13 = Ic13 / Vt ;
8   printf ( '\ ntransconductance=%.2 f  mA/V\n ', gm13 )
9   ro13 = Va / Ic13 ;
10  printf ( '\ noutput  resistance=%.2 f  KOhm\n ', ro13 )
11  Av2 = gm13 * ro13 ;
12  printf ( '\ nvoltage  gain=%.2 f  \n ', Av2 )
```

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

```
1   clear ;
2   clc ;
3   // Example  13.14
4   Av2 =5768;
```

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

Chapter 14

Nonideal Effects in Operational Amplifier Circuits

Scilab code Exa 14.2 Determine the closed loop input resistance

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

Scilab code Exa 14.3 Determine the closed loop input resistance

```
1 clear ;
2 clc ;
3 //Example 14.3
4 Aol =10^5;
```

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

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

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

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

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

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

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

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

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

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

```
1  clear ;
2  clc ;
3  // Example 14.10
4  Kn1 =105;
5  Kn2 =100;
```

```
6  Iq =200;
7  dKn = Kn1 - Kn2 ;
8  printf ( '\ ndifference in conduction parameter=%.2 f
      microA /V ^2\ n ' , dKn )
9  Kn =( Kn1 + Kn2 ) /2;
10 printf ( '\ naverage of the conduction parameter=%.2 f
      microA /V ^2\ n ' , Kn )
11 Vos = sqrt ( Iq /(2* Kn ) ) * dKn /(2* Kn ) ;
12 printf ( '\ noffset voltage=%f V\ n ' , Vos )
```

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

```
1  clear ;
2  clc ;
3  // Example 14.11
4  Rs =100;
5  R4 =100000;
6  R3 =100000;
7  V1 =15;
8  V2 = -15;
9  Vy = Rs * V1 /( Rs + R4 ) ;
10 Vy = Vy *1000; // mV
11 printf ( '\ nVoltage Vy =%.2 fmV \ n ' , Vy )
```

Scilab code Exa 14.13 Determine the bias current effect

```
1  clear ;
2  clc ;
3  // Example 14.13
4  R1 =10;
5  R2 =100;
6  Ib1 =1.1*10^ -3;
7  Ib2 =1*10^ -3;
```

```matlab
 8  vo=Ib1*R2;
 9  printf('\noutput voltage =%.2fV\n',vo)
10  R3=R1*R2/(R1+R2);
11  printf('\nR3=%.2f KOhm\n',R3)
12  vo=R2*(Ib1-Ib2);
13  printf('\noutput voltage=%.2f V\n',vo)
```

Chapter 15

Applications and Design of Integrated Circuits

Scilab code Exa 15.2 Determine the clock frequency

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

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

```
1 clear;
2 clc;
3 //Example 15.3
4 fC=10000;
5 f3dB=1000;
6 //x=C2/C1
```

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

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

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

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

```
1  clear;
2  clc;
3  //Example  15.6
4  R1=10000;
5  R2=90000;
6  Vh=10;
7  Vl=-10;
8  Vth=R1*Vh/(R1+R2);
9  printf('\nupper  crossover  voltage=%.f  V\n',Vth)
10  Vtl=R1*Vl/(R1+R2);
11  printf('\nlower  crossover  voltage=%.f  V\n',Vtl)
12  x=Vth-Vtl;
13  printf('\nhysteresis  width  =%.fV\n',x)
```

Scilab code Exa 15.7 Design a Schmitt trigger circuit

```scilab
1  clear;
2  clc;
3  //Example 15.7
4  Vs=2;
5  Vh=15;
6  Vl=-15;
7  //hysteresis width=x
8  x=60*0.001;//(V)
9  //Vth-Vtl=(R1/(R1+R2))*(Vh-Vl)
10 //R2/R=y
11 y=(Vh-Vl)/x-1;
12 printf('\nR2/R1=%.2f \n',y)
13 Vref=(1+1/y)*Vs;
14 printf('\nreference voltage=%.4f V\n',Vref)
```

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

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

Scilab code Exa 15.13 Design the supply voltage

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

Scilab code Exa 15.14 Determine the output resistance and load regulation

```
1  clear;
2  clc;
3  //Example 15.14
4  Vonl=5;
5  Vofl=4.96;
6  I1=0.005;
7  I2=1.5;
8  dVo=Vonl-Vofl;
9  dIo=I1-I2;
10 Rvf=-dVo/dIo;
11 printf('\noutput resistance=%f Ohm\n',Rvf)
12 LR=100*(Vonl-Vofl)/Vonl;
13 printf('\nload regulation =%.2f\n',LR)
```

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

```
1  clear;
2  clc;
```

```
3  //Example 15.15
4  Aol=1000;
5  Vref=5;
6  Vo=10;
7  Io=0.1*0.001;
8  Vt=0.026;
9  Rof=2*Vt*Vo/(Io*Vref*Aol);
10 printf('\noutput resistance=%.2f mOhm\n',Rof)
11 //dVo/Vo=V   and dIo/Io=I
12 //V=-I*2*Vt/(Vref*Aol)
13 //V/I=x
14 x=-2*Vt/(Vref*Aol);
15 printf('\npercent change=%.2e\n',x)
```

Scilab code Exa 15.16 Determine the bias current temperature compensated reference

```
1  clear;
2  clc;
3  //Example 15.16
4  Vz=6.3;
5  Vbe=0.6;
6  Veb=0.6;
7  Vo=8;
8  R1=3.9;
9  R2=3.4;
10 R3=0.576;
11 Ic3=(Vz-3*Vbe)/(R1+R2+R3);
12 printf('\nbias current =%.3f mA\n',Ic3)
13 Vb7=Ic3*R1+2*Vbe;
14 printf('\ntemperature compensated reference voltage=
       %.2f V\n',Vb7)
15 R13=2.23;
16 R12=R13*Vo/Vb7-R13;
17 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

```
1  clear;
2  clc;
3  //Example 16.3
4  Vdd=5;
5  Vtnd=0.8;
6  Vtnl=0.8;
7  Kn=35;
8  Vo=0.1;
9  Vi=4.2;
10 //W/L=Y
11 yl=0.5;
12 //Kd/Kl=x
13 x=(Vdd-Vo-Vtnl)^2/(2*Vo*(Vi-Vtnd)-Vo^2);
14 printf('\nKd/Kl=%.2f\n',x)
15 //Kd/Kl=yd/yl
16 yd=12.6
17 yl=0.5
18 iD=Kn*yl*(Vdd-Vo-Vtnl)^2/2;
19 printf('\ndrain current =%.2f microA\n',iD)
20 P=iD*Vdd;
21 printf('\npower dissipation=%.2f microW\n',P)
```

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

```
1  clear;
2  clc;
3  //Example  16.4
4  Vdd =5;
5  Vtnd =0.8;
6  Vtnl =-2;
7  Kn =35;
8  Vo =0.1;
9  Vi =5;
10 //W/L=Y
11 yl =0.5;
12 //Kd/Kl=x
13 x =( -Vtnl )^2/(2* Vo *( Vi -Vtnd )-Vo^2);
14 printf ('\nKd/Kl=%.2 f\n',x)
15 //Kd/Kl=yd/ yl
16 yd =2.41
17 yl =0.5
18 iD = Kn * yl *( -Vtnl )^2/2;
19 printf ('\ndrain  current=%.2 f  microA \n',iD)
20 P = iD * Vdd ;
21 printf ('\npower  dissipation  =%.2 f  microW \n',P)
```

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

```
1  clear;
2  clc;
3  //Example  16.5
4  Voh =4.2;
5  Vol =0.1;
```

```
6  //x=Kd/Kl
7  x=25.1;
8  Vdd=5;
9  Vtnl=0.8;
10 Vohu=4.2;
11 Vil=0.8;
12 Vtnd=0.8;
13 Vih=Vtnd+(Vdd-Vtnl)/x*((1+2*x)/sqrt(1+3*x)-1);
14 printf('\nVih=%.2f V\n',Vih)
15 Volu=(Vdd-Vtnl+x*(Vih-Vtnd))/(1+2*x);
16 printf('\noutput voltage corresponding to Vih=%.3f V
       \n',Volu)
17 NMl=Vil-Volu;
18 printf('\nnoise margin=%0.3f V\n',NMl)
19 NMh=Vohu-Vih;
20 printf('\nnoise margin=%.3f V\n',NMh)
```

Scilab code Exa 16.9 Determine the critical voltage on the voltage transfer curve

```
1  clear;
2  clc;
3  //Example 16.9
4  Vdd=5;
5  Vtn=1;
6  Vtp=-1;
7  //Kn=Kp hence Kn/Kp=x=1;
8  x=1;
9  Vit=(Vdd+Vtp+sqrt(x)*Vtn)/(1+sqrt(x));
10 printf('\ninput voltage=%.2f V\n',Vit)
11 Vipt=Vit;
12 Vopt=Vipt-Vtp;
13 printf('\noutput voltage at the transition point for
       PMOS =%.2fV\n',Vopt)
14 Vint=Vit;
15 Vont=Vint-Vtn;
```

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

Scilab code Exa 16.10 Calculate the power dissipation in CMOS inverter

```
1  clear;
2  clc;
3  //Example 16.10
4  Cl=2*10^-6;
5  Vdd=5;
6  f=100000;
7  P=f*Cl*Vdd^2;
8  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

```
1  clear;
2  clc;
3  //Example 16.11
4  Vtn=1;
5  Vtp=-1;
```

```
6   Vdd=5;
7   Vth=1;
8   Vil=Vtn+3*(Vdd+Vtp-Vth)/8;
9   printf('\ninput voltage at the transition points Vil
        =%.3f V\n',Vil)
10  Vih=Vtn+5*(Vdd+Vtp-Vtn)/8;
11  printf('\ninput voltage at the transition points Vih
        =%.3fV\n',Vih)
12  Vohu=1*(2*Vil+Vdd-Vtn-Vtp)/2;
13  printf('\noutput voltage =%.3f V\n',Vohu)
14  Volu=1*(2*Vih-Vdd-Vtn-Vtp)/2;
15  printf('\noutput voltage =%.2f V\n',Volu)
16  NML=Vil-Volu;
17  printf('\nnoise margin =%.3f V\n',NML)
18  NMH=Vohu-Vih;
19  printf('\nnoise margin=%.3f V\n',NML)
```

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

```
1   clear;
2   clc;
3   //Example 16.15
4   Vdd=3;
5   Kn=60;
6   Vtnd=0.5;
7   //W/L=x
8   xd=2;
9   Vtnl=-1;
10  xl=0.5;
11  R=2;//(MOhm)
12  Vgsl=0;
13  //solution with Depletion load
14  iD=Kn*xl*(Vgsl-Vtnl)^2/2;
15  printf('\nfrain currents in M1 and M3 =%.fmicroA\n',
        iD)
```

```
16  P=iD*Vdd;
17  printf('\npower dissipation in the circuit=%.f
        microW\n',P)
18  //iD=Kn/2*x*(2*Vgsd-Vtnd)Vdsd-Vdsd^2
19  Q=poly(0,'Q');
20  p=poly([0.25 -5 1],'Q','c');
21  roots(p)
22  disp("Q=50.5 (mV)")
23  //solution with Resistor load
24  //(Vdd-Q)/R=Kn/2*xd*(2*Vgsd-Vtnd)Q-Q^2
25  Q=poly(0,'Q');
26  p=poly([3 -599 120],'Q','c');
27  roots(p)
28  Q=0.005;
29  disp("Q=5 (mV)")
30  iD=(Vdd-Q)/R;
31  printf('\ndrain current =%.2f microA\n',iD)
32  P=iD*Vdd;
33  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

```
1  clear;
2  clc;
3  //Example 17.1
4  V1=5;
5  V2=-5;
6  Rc1=1;
7  Rc2=Rc1;
8  Rc=Rc1;
9  Re=2.150;
10 v2=0;
11 //for v1=0
12 vE=-0.7;
13 iE=(vE-V2)/Re;
14 printf('\nemitter current=%.3f mA\n',iE)
15 iC=1;
16 Vcc=5;
17 vo1=Vcc-iC*Rc;
18 printf('\nvo1=vo2=%.f V\n',vo1)
19 //for v2=-1
20 vE=-0.7;
21 iE=2;
```

```
22  iC2 =2;
23  vo1 =5;
24  vo2=Vcc-iC2*Rc;
25  printf('\nvo2=%.2f V\n',vo2)
26  v1=1;
27  Vbe =0.7;
28  vE=v1-Vbe;
29  iE=(vE-V2)/Re;
30  printf('\nemitter current =%.3fmA\n',iE)
31  iC1=iE;
32  vo1=Vcc-iC1*Rc;
33  printf('\nvo1=%.2f V\n',vo1)
34  vo2=Vcc
```

Scilab code Exa 17.2 Calculate the currents resistors and logic 0 values in the ba

```
1  clear;
2  clc;
3  //Example 17.2
4  Vx=-0.7;
5  Vy=Vx;
6  Vbe =0.7;
7  V2=-5.2;
8  Re =1.180;
9  vE=Vx-Vbe;
10  printf('\nemitter voltage =%.2fV\n',vE)
11  iE=(vE-V2)/Re;
12  printf('\nemitter current=%.2f mA\n',iE)
13  Icxy=iE;
14  vo1=-0.7;
15  Rc1=-vo1/Icxy;
16  printf('\nRc1=%.2f KOhm\n',Rc1)
17  Vnor=vo1-Vbe;
18  printf('\nNOR output logic 0 value=%.2f V\n',Vnor)
19  Vr=(vo1+Vnor)/2;
```

```
20  vE=Vr-Vbe;
21  printf('\nvE=%.2f V\n',vE)
22  iE=(vE-V2)/Re;
23  printf('\niE=%.2f mA\n',iE)
24  vo2=-0.7;
25  iC2=iE;
26  Rc2=-vo2/iC2;
27  printf('\nRc2=%.2f KOhm\n',Rc2)
28  Vor=vo2-Vbe;
29  printf('\nOR logic 0 value is=%.2f V\n',Vor)
```

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

```
 1  clear;
 2  clc;
 3  //Example 17.3
 4  Vr=-1.05;
 5  Vbe=0.7;
 6  Vb5=Vr+Vbe;
 7  printf('\nVb5 =%.2fV\n',Vb5)
 8  R1=0.250;
 9  i1=-Vb5/R1;
10  printf('\ni1=%.3f mA\n',i1)
11  Vy=0.7;
12  V2=-5.2;
13  //let R1+R2=x
14  x=(-2*Vy-V2)/i1;
15  R2=x-R1;
16  printf('\nR2=%.3f KOhm\n',R2)
17  iS=i1;
18  Rs=(Vr-V2)/iS;
19  printf('\nRs=%.3f KOhm\n',Rs)
```

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

```
1  clear;
2  clc;
3  //Example 17.4
4  Vx=-0.7;
5  Vy=-0.7;
6  iCxy=3.22;//(mA)
7  iCR=0;
8  i5=1.40;
9  i1=1.40;
10 Vor=-0.7;
11 R4=1.500;
12 Vnor=-1.4;
13 V2=-5.2;
14 R3=1.500;
15 i3=(Vor-V2)/R3;
16 printf('\ncurrent i3=%.2f mA\n',i3)
17 i4=(Vnor-V2)/R4;
18 printf('\ncurrent i4 =%.2fmA\',i4)
19 P=(iCxy+iCR+i5+i1+i3+i4)*(0-V2);
20 printf('\npower dissipation=%.2f mW\n',P)
```

Scilab code Exa 17.5 Calculate minimum fanout of ECL logic gate

```
1  clear;
2  clc;
3  //Example 17.5
4  b=50;
5  V2=-5.2;
6  Vbe=0.7;
7  Rc2=0.240;
8  Vor=-0.75;
9  Re=1.180;
10 iE=(Vor-Vbe-V2)/Re;
```

```
11  printf('\nemitter current=%.2f mA\n',iE)
12  iB=iE/(1+b);
13  iB=iB*1000;//micro A
14  printf('\ninput base current=%.2f microA\n',iB)
15  R3=1.500;
16  i3=(Vor-V2)/R3;
17  printf('\ni3=%.2f mA\n',i3)
18  iB=iB*0.001;//mA
19  N=(-(Vor+Vbe)*(1+b)/(Rc2)-i3)/iB;
20  printf('\nN=%.f\n',N)
```

Scilab code Exa 17.7 Analyze the modified ECL logic gate

```
1   clear;
2   clc;
3   //Example 17.7
4   Vcc=1.7;
5   Re=0.008;//mohm
6   Rc=0.008;//mohm
7   Vy=0.4;
8   Vbe=0.7;
9   Vor=Vcc//logic 1
10  Vor=Vcc-Vy//logic 0
11  Vr=1.5;
12  iE=(Vr-Vbe)/Re;
13  printf('\nemitter current=%.2f microA\n',iE)
14  iR=Vy/Rc;
15  printf('\nmaximum current in Rc =%.2fmicroA\n',iR)
16  iD=iE-iR;
17  printf('\ncurrent through the diode=%.2f microA\n',
        iD)
18  P=iE*Vcc;
19  printf('\npower dissipation=%.2f microW\n',P)
20  Vv=1.7;
21  iE=(Vv-Vbe)/Re;
```

```
22 printf('\niE =%.2 fmicroA\n',iE)
23 P=iE*Vcc;
24 printf('\npower dissipation =%.2fmicroW\n',P)
```

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

```
1  clear;
2  clc;
3  //Example 17.9
4  bf =25;
5  b=bf;
6  br =0.1;
7  Vcc =5;
8  R1=4;
9  Vbc =0.7;
10 Vy =0.1;
11 Vx =0.1;
12 R2 =1.6;
13 Vbe =0.8;
14 Rc =4;
15 Vce =0.1;
16 vB2 =Vx+Vce;
17 printf('\nvB2=%.2f V\n',vB2)
18 vB1 =Vx+Vbe;
19 printf('\nbase voltage=%.2f V\n',vB1)
20 i1 =(Vcc -vB1)/R1;
21 printf('\ncurrent i1=%.2f mA\n',i1)
22 vB1 =Vbe+Vbe+Vbc;
23 printf('\nvB1=%.2f V\n',vB1)
24 vC2 =Vbe+Vce;
25 printf('\ncollector voltage=%.2f V\n',vC2)
26 i1 =(Vcc -vB1)/R1;
27 printf('\ncurrent i1 =%.2fmA\n',i1)
28 iB2 =(1+2*br)*i1;
29 printf('\niB2=%.2f mA\n',iB2)
```

```
30  i2=(Vcc-vC2)/R2;
31  printf('\ni2 =%.2fmA\n',i2)
32  iE2=i2+iB2;
33  printf('\niE2=%.2f mA\n',iE2)
34  Rb=1;
35  i4=Vbe/Rb;
36  printf('\ncurrent in the pull down resistor=%.2f mA\
        n',i4)
37  iBo=iE2-i4;
38  printf('\nbase drive to the output transistor=%.2f
        mA\n',iBo)
39  i1=(Vcc-Vce)/Rc;
40  printf('\ni1=%.2f mA\n',i1)
```

Scilab code Exa 17.11 Determine the currents in a Schottky transistor

```
1  clear;
2  clc;
3  //Example 17.11
4  b=25;
5  iB=1;
6  iC=2;
7  ic=(iB+iC)/(1+1/b);
8  printf('\ninternal collector current=%.3f mA\n',ic)
9  ib=ic/b;
10  printf('\ninternal base current =%.3fmA\n',ib)
11  iD=iB-ib;
12  printf('\nSchottky diode current=%.3f mA\n',iD)
13  iC=20;
14  ic=(iB+iC)/(1+1/b);
15  printf('\ninternal collector current=%.3f mA\n',ic)
16  ib=ic/b;
17  printf('\ninternal base current =%.3fmA\n',ib)
18  iD=iB-ib;
19  printf('\nSchottky diode current=%.3f mA\n',iD)
```

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

```
1  clear;
2  clc;
3  //Example 17.12
4  Vy=0.3;
5  Vbe=0.7;
6  vx=0.4;
7  R2=8;
8  Vce=0.4;
9  Vcc=5;
10 b=25;
11 Vce=0.4;
12 Vbe1=0.7;
13 Vbe2=0.7;
14 Vcc=5;
15 R1=20;
16 v1=Vce+Vy;
17 i1=(Vcc-v1)/R1;
18 printf('\ni1=%.3f mA\n',i1)
19 Pl=i1*(Vcc-vx);
20 printf('\npower dissipation=%.3f mW\n',Pl)
21 v1=Vbe1+Vbe2;
22 printf('\nv1=%.3f V\n',v1)
23 vC2=Vbe1+Vce;
24 printf('\nvoltage vC2 =%.2fV\n',vC2)
25 i1=(Vcc-v1)/R1;
26 printf('\ncurrent i1 =%.3fmA\n',i1)
27 i2=(Vcc-vC2)/R2;
28 printf('\ncurrent i2 =%.3fmA\n',i2)
29 P=(i1+i2)*Vcc;
30 printf('\npower dissipation for high input condition
       =%.3f mW\n',P)
```