

Scilab Textbook Companion for
Microelectronic Circuits
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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

Introduction to Electronics

Scilab code Exa 1.1 Amplifier gain power and efficiency

```
1 // Example1.1: Amplifier gain , power and efficiency
2 // Amplifier operates at +10-V/-10-V power supply.
3 A_v=9/1; // sinusoidal voltage input of 1V peak and
   sinusoidal output voltage of 9V peak
4 I_o=9/1000; // 1 kilo ohms load
5 disp(A_v," Voltage gain (V/V) =")
6 disp(20*log10(A_v)," Voltage gain (dB) =")
7 I_i=0.0001 // sinusoidal current input of 0.1mA peak
8 A_i=I_o/I_i;
9 disp(A_i," Current gain (A/A) =")
10 disp(20*log10(A_i)," Current gain (dB) =")
11 V_orms = 9/sqrt(2);
12 I_orms = 9/sqrt(2);
13 P_L=V_orms*I_orms; // output power in mW
14 V_irms=1/sqrt(2);
15 I_irms=0.1/sqrt(2);
16 P_I=V_irms*I_irms; // input power in mW
17 A_p=P_L/P_I;
18 disp(A_p," Power gain (W/W) =")
19 disp(10*log10(A_p)," Power gain (dB) =")
20 P_dc=10*9.5+10*9.5; // amplifier draws a current of
```



```

    9.5mA from each of its two power supplies
21 disp(P_dc,"Power drawn from the dc supplies (mW) =")
22 P_dissipated=P_dc+P_I-P_L;
23 disp(P_dissipated,"Power dissipated in the amplifier
    (mW)")
24 n=P_L/P_dc*100;
25 disp(n,"Amplifier efficiency in percentage")

```

Scilab code Exa 1.2 Gain of transistor amplifier

```

1 // Example 1.2: Gain of transistor amplifier
2 // Amplifier has transfer characteristics v_o
   =10-(10^-11)*(exp^40*v_1) applies for v_1 is
   greater than or equal 0V and v_o is greater than
   or equal to 0.3V
3 L_l = 0.3; // limit L_-
4 disp(L_l,"The limit L_- (V) =")
5 v_I=1/40*log((10-0.3)/10^-11); // from the transfer
   characteristics and v_o=0.3V
6 disp(v_I,"v_I in volts =")
7 L_u=10-10^-11; // obtained by v_I=0 in transfer
   characteristics
8 disp(L_u,"the limit L_+ (V) =")
9 V_I=1/40*log((10-5)/10^-11); // V_O=5V
10 disp(V_I,"The value of the dc bias voltage that
   results in V_O=5V (V)=")
11 A_v=-10^-11*exp(40*V_I)*40; // A_v=dv_o/dv_I
12 disp(A_v,"Gain at the operating point (V/V) =")
13 disp("NOTE the gain is negative that implies the
   amplifier is an inverting amplifier")

```

Scilab code Exa 1.3 Overall voltage gain of three stage amplifier

```

1 // Example 1.3 : Overall voltage gain of cthree-
   stage amplifier
2 gainloss_in=10^6/(1*10^6+100*10^3); // fraction of
   input signal is obtained using voltage divider
   rule , gainloss_in= v_i1/v_s
3 A_v1=10*100000/(100000+1000); // A_v1 = v_i2/v_i1 is
   the voltage gain at first stage
4 A_v2=100*10000/(10000+1000); // A_v2 = v_i3/v_i2 is
   the voltage gain at second stage
5 A_v3=100/(100+10); // A_v3 = v_L/v_i3 is the voltage
   gain at the output stage
6 A_v=A_v1*A_v2*A_v3; // A_v is the total voltage gain
7 disp(A_v,"The overall voltage gain (V/V) =")
8 disp(20*log10(A_v),"The overall voltage gain (dB) =")
   )
9 gain_src_ld=A_v*gainloss_in;
10 disp(gain_src_ld,"The voltage gain from source to
   gain (V/V) =")
11 disp(20*log10(gain_src_ld),"The voltage gain from
   source to load (dB) =")
12 A_i=10^4*A_v; // A_i=i_o/i_i=(v_L/100)/(v_i1/10^6)
13 disp(A_i,"The current gain (A/A)=")
14 disp(20*log10(A_i),"The current gain (dB) =")
15 A_p=818*818*10^4; // A_p=P_L/P_I=v_L*i_o/v_i1*i_i
16 disp(A_p,"The power gain (W/W) =")
17 disp(10*log10(A_p),"The power gain (dB) =")

```

Scilab code Exa 1.4 Bipolar junction transistor

```

1 // Example1.4 : Bipolar junction transistor
2
3 // 1,4a
4 // using voltage divider rule the fraction of input
   signal v_be=v_s*r_pi/(r_pi+R_s)
5 // output voltage v_o=-g_mv_be(R_L||r_o)

```

```

6 r_pi=2.5*10^3; // (ohm)
7 R_s=5*10^3; // (ohm)
8 R_L=5*10^3 // (ohm)
9 g_m=40*10^-3; // (mho)
10 r_o=100*10^3; // (ohm)
11 gain=-(r_pi*g_m*(R_L*r_o/(R_L+r_o)))/(r_pi+R_s); //
    gain=v_o/v_s
12 disp(gain,"The voltage gain (V/V) =")
13 gain_negl_r_o=-r_pi*g_m*R_L/(r_pi+R_s);
14 disp(gain_negl_r_o,"Gain neglecting the effect of
    r_o (V/V) =")
15
16 // 1.4b
17 // Bi_b=g_m*v_be
18 // B is short circuit gain
19 B=g_m*r_pi;
20 disp(B,"The short circuit gain (A/A) =")

```

Scilab code Exa 1.5 DC gain 3dB frequency and frequency at which gain

```

1 // Example 1.5 : DC gain, 3dB frequency and
    frequency at which gain=0 of voltage amplifier
2
3 // 1.5b
4 R_s =20*10^3; // (ohm)
5 R_i =100*10^3; // (ohm)
6 C_i =60*10^-12; // (ohm)
7 u = 144; // (V/V)
8 R_o = 200; // (ohm)
9 R_L = 1000; // (ohm)
10 K=u/((1+R_s/R_i)*(1+R_o/R_L));
11 disp(K,"The dc gain (V/V)= ")
12 disp(20*log10(K)," The dc gain (dB) =")
13 w_o=1/(C_i*R_s*R_i/(R_s+R_i));
14 disp(w_o,"The 3-dB frequency (rad/s) =")

```

```

15 f_o= w_o/2/%pi;
16 disp(f_o,"Frequency (Hz) =")
17 disp(100*w_o,"unity gain frequency (rad/s)=" ,100*f_o
      ,"Unity gain frequency (Hz)")

```

Scilab code Exa 1.6 Evaluation of t_{PHL}

```

1 // Example 1.6: Time for the output to reach (V_OH+
  V_OL)/2
2 V_DD=5; // (V)
3 R=1000; // (ohm)
4 R_on=100; // (ohm)
5 V_offset=0.1; // (V)
6 C=10*10^-12; // (F)
7 V_OH=5; // (V)
8 V_OL=V_offset+(V_DD-V_offset)*R_on/(R+R_on);
9 T=R*C;
10 v_o_t_PLH=(V_OH+V_OL)/2; //to find t_PLH
11 t_PLH=0.69*T; // t_PLH is low to high propogtion
  delay
12 disp(t_PLH,"time required for he output to reach (
  V_OH+V_OL)/2 (seconds) =")

```

Chapter 2

Operational Amplifiers

Scilab code Exa 2.1 Closed loop and open loop gain

```
1 // Example 2.1 : Closed loop and open loop gain
2 // Consider inverting configuration
3
4 // 2.1 a
5 R_1=1000; // (ohm)
6 R_2=100*10^3; // (ohm)
7 A=10^3; // (V/V)
8 disp(A,"A (V/V)")
9 G=-R_2/R_1/(1+(1+R_2/R_1)/A);
10 disp(-G,"G")
11 e=(-G-(R_2/R_1))/(R_2/R_1)*100;
12 disp(e,"e (%)")
13 v_1=0.1; // (V)
14 v_1=G*v_1/A;
15 disp(v_1,"v_1 (V)")
16 A=10^4; // (V/V)
17 disp(A,"A (V/V)")
18 G=-R_2/R_1/(1+(1+R_2/R_1)/A);
19 disp(-G,"G")
20 e=(-G-(R_2/R_1))/(R_2/R_1)*100;
21 disp(e,"e (%)")
```

```

22 v_1=0.1; // (V)
23 v_1=G*v_1/A;
24 disp(v_1,"v_1 (V)")
25 A=10^5; // (V/V)
26 disp(A,"A (V/V)")
27 G=-R_2/R_1/(1+(1+R_2/R_1)/A);
28 disp(-G,"G")
29 e=(-G-(R_2/R_1))/(R_2/R_1)*100;
30 disp(e,"e (%)")
31 v_1=0.1; // (V)
32 v_1=G*v_1/A;
33 disp(v_1,"v_1 (V)")
34
35 // 2.1b
36 A=50000; // (V/V)
37 disp(A,"A (V/V)")
38 G=-R_2/R_1/(1+(1+R_2/R_1)/A);
39 disp(-G,"G")
40 disp("Thus a -50% change in the open loop gain
      results in only -0.1% in the closed loop gain")

```

Scilab code Exa 2.3 Design instrumentation amplifier

```

1 // Example 2.3 : Design instrumentation amplifier
2 R_2=1-50000-1/1000+50;
3 disp(R_2,"R_2 (ohm)")
4 R_1=2*R_2/999;
5 disp(R_1,"R_1 (ohm)")

```

Chapter 3

Diodes

Scilab code Exa 3.1 Peak value of diode current and maximum reverse vo

```
1 //Example 3.1: Peak value of diode current and
   maximum reverse voltage
2 //v_s is sinusoidal input voltage with peak 24V
3 //battery charges to 12V
4 I_d=(24-12)/100
5 max_v_rev=24+12;
6 disp(I_d,"peak value of diode current (A)",
   max_v_rev,"maximum reverse voltage across the
   diode (V)")
```

Scilab code Exa 3.2 Values of I and V for the circuit given

```
1 //Example 3.2 : Values of I and V for the circuit
   given
2 disp("Consider fig 3.6(a). Assume both diodes are
   conducting")
3 I_D2=(10-0)/10;
4 I=(0-(-10))/5-I_D2; // node equation at B for fig
   3.6(a)
```

```

5 V_B=0;
6 V=0;
7 disp(I,"I (mA)=", v,"V (V)" ,"D_1 is conducting as
    assumed originally")
8 disp("Consider fig 3.6(a). Assume both diodes are
    conducting")
9 I_D2=(10-0)/5;
10 I=(0-(-10))/10-2; // node equation at B for fig 3.6(b
    )
11 disp(I,"I (mA)=", v,("V (V)"))
12 disp("Implies assumption is wrong. lets assume D_1
    is off and D_2 is on")
13 I_D2=(10-(-10))/15;
14 V_B=-10+10*I_D2;
15 I=0;
16 disp(I,"I (mA)", v_B,"V (V)" ,"D_1 is reverse biased
    ")

```

Scilab code Exa 3.3 Evaluating junction scaling constant

```

1 //Example 3.3 : Evaluating junction scaling constant
2 //i-I_S*exp(v/(n*V_T)) implies I_S=i*exp(-v/(n*V_T))
3 n=1;
4 i=10^-3; // (A)
5 v=700; // (V)
6 V_T=25; // (V)
7 I_S=i*exp(-v/(n*V_T))
8 disp(I_S,"I_S (A) for n=1")
9 n=2;
10 I_S=i*exp(-v/(n*V_T))
11 disp(I_S,"I_S (A) for n=2")
12 disp("These values implies I_S is 1000 times greater
    ")

```

Scilab code Exa 3.4 To determine ID and VD

```
1 //Example 3.4: To determine I_D and V_D
2 V_DD=5; // (V)
3 R=1000; // (ohm)
4 I_1=1*10^-3; // (A)
5 V_D=0.7; // (V)
6 V_1=V_D;
7 I_D=(V_DD-V_D)/R;
8 I_2=I_D;
9 V_2=V_1+0.1*log10(I_2/I_1);
10 I_D=(V_DD-V_2)/R;
11 disp(I_D,"The diode current (A)")
12 V_D=V_2+0.1*log10(I_D/I_2)
13 disp(V_D,"The diode volage (V)")
```

Scilab code Exa 3.5 Repeating example 4 using piecewise linear model

```
1 // Example 3.5 : Repeating example 3.4 using
   piecewise linear model
2 V_D0=0.65; // (V)
3 r_D=20; // (ohm)
4 R=1000; // (ohm)
5 V_DD=5; // (V)
6 I_D=(V_DD-V_D0)/(R+r_D);
7 disp(I_D,"I_D (A)")
8 V_D=V_D0+I_D*r_D;
9 disp(V_D,"The diod voltage (V)")
```

Scilab code Exa 3.6 Power supply ripple

```
1 // Example 3.6 : Power supply ripple
2 V_S=10; // V_S=V_+
3 V_D=0.7; // (V)
4 R=10*10^3; // (ohm)
5 n=2;
6 V_T=25*10^-3; // (V)
7 V_s=1; // (V)
8 I_D=(V_S - V_D)/R;
9 r_D=n*V_T/I_D;
10 v_d=V_s*r_D/(R+r_D);
11 disp(v_d,"v_d(peak (V))")
```

Scilab code Exa 3.7 Percentage change in regulated voltage

```
1 // Example 3.7 : Percentage change in regulated
  voltage
2 V_DD=10; // (V)
3 V_D=0.7*3; // string of 3 diodes provide this
  constant voltage
4 R=1*10^3;
5 I_D=(V_DD-V_D)/R;
6 n=2;
7 V_T= 25*10^-3; // (V)
8 r_d=n*V_T/I_D; // incremental resistance
9 r=3*r_d; // total incremental resistance
10 deltav_0=2*r/(r+R); // deltav is peak to peak change
  in output voltage
11 disp(deltav_0,"Percentage change (V) in regulated
  voltage caused by 10% change in power supply")
12 I=2.1*10^-3; // The current drawn from the diode
  string
13 deltav_0=-I*r; // Decrease in voltage across diode
  string
```

```
14 disp(deltav_0,"Decrease in voltage across diode
    string (V)")
```

Scilab code Exa 3.8 line regulation load regulation

```
1 // Example 3.8 : line regulation load regulation
2
3 V_Z=6.8; // (V)
4 I_Z=0.005; // (A)
5 r_Z=20; // (ohm)
6 V=10; // V=V_+
7 R=0.5*10^3; // (ohm)
8
9 // 3.8a
10 V_Z0=V_Z-r_Z*I_Z;
11 I_Z=(V-V_Z0)/(R+r_Z)
12 V_0=V_Z0+I_Z*r_Z;
13 disp(V_0,"V_0 (V)")
14
15 // 3.8b
16 deltaV=1; // change in V is +1 and -1
17 deltaV_0=deltaV*r_Z/(R+r_Z); // corresponding change
    in output voltage
18 disp(deltaV_0,"Line regulation (V/V)")
19
20 // 3.8c
21 I_L=1*10^-3; // load current
22 deltaI_L=1*10^-3;
23 deltaI_Z=-1*10^-3; // change in zener current
24 deltaV_0=r_Z*deltaI_Z;
25 disp(deltaV_0,"Load regulation (V/A)")
26
27 // 3.8d
28 I_L=6.8/2000; // load current with load resistance
    of 2000
```

```

29 deltaI_Z=-I_L;
30 deltaV_0=r_Z*deltaI_Z;
31 disp(deltaV_0,"Corresponding change in zener voltage
      (V) for zener current change of -3.4mA")
32
33 // 3.8e
34 R_L=0.5*10^3; // (ohm)
35 V_0=V*R_L/(R+R_L);
36 disp(V_0,"V_0 (V) for R_L=0.5K ohm")
37
38 // 3.8f
39 I_Z=0.2*10^-3; // Zener t be at the edge of
      breakdown I_Z=I_ZK
40 V_Z=6.7; // V_Z=V_ZK
41 I_Lmin=(9-6.7)/0.5; // Lowest current supplied to R
42 I_L=I_Lmin-I_Z; // load current
43 R_L=V_Z/I_L;
44 disp(R_L,"R_L (ohm)")

```

Scilab code Exa 3.9 Value of capacitance C that will result in peak pe

```

1 // Example 3.9 : Value of capacitance C that will
      result in peak-peak ripple of 2V
2 V_P=100; // (V)
3 V_r=2; // (V)
4 f=60; // (Hz)
5 R=10*10^3; // (ohm)
6 I_L=V_P/R;
7 C=V_P/(V_r*f*R);
8 disp(C,"C (V)")
9 wdeltat=sqrt(2*V_r/V_P);
10 disp(wdeltat,"Conduction angle (rad)")
11 i_Dav=I_L*(1+%pi*sqrt(2*V_P/V_r));
12 disp(i_Dav,"i_Dav (A)")
13 i_Dmax=I_L*(1+2*%pi*sqrt(2*V_P/V_r));

```

```
14 disp(i_Dmax,"i_Dmax (A)")
```

Chapter 4

MOS Field Effect Transistors

Scilab code Exa 4.1 To determine operating point parameters

```
1 // Example 4.1 : To determine operating point
  parameters
2 L_min=0.4*10^-6; // (m)
3 t_ox=8*10^-9; // (s)
4 u_n=450*10^-4; // (A/V^2)
5 V_t=0.7; // (V)
6 e_ox=3.45*10^-11;
7
8 // 4.1a
9 C_ox=e_ox/t_ox;
10 disp(C_ox,"C_ox (F/m^2)")
11 k_n=u_n*C_ox;
12 disp(k_n,"k_n (A/V^2)")
13
14 // 4.1b
15 // Operation in saturation region
16 W=8*10^-6; // (m)
17 L=0.8*10^-6; // (m)
18 i_D=100*10^-6; // (A)
19 V_GS=sqrt(2*L*i_D/(k_n*W)) +V_t;
20 disp(V_GS,"V_GS (V)")
```

```

21 V_DSmin=V_GS-V_t;
22 disp(V_DSmin,"V_DSmin (V)")
23
24 // 4.1c
25 // MOSFET in triode region
26 r_DS=1000; // (ohm)
27 V_GS=1/(k_n*(W/L)*r_DS)+V_t;
28 disp(V_GS,"V_GS (V)")

```

Scilab code Exa 4.2 Design of given circuit

```

1 // Example 4.2: Design of given circuit to obtain
  I_D=0.4mA and V_D=0.5V
2 // NMOS transistor is operating in saturation region
3 I_D=0.4*10^-3; // (A)
4 V_D=0.5; // (V)
5 V_t=0.7; // (V)
6 uC_n=100*10^-6; // (A/V^2)
7 L=1*10^-6; // (m)
8 W=32*10^-6; // (m)
9 V_SS=-2.5; // (V)
10 V_DD=2.5; // (V)
11 V_OV=sqrt(I_D*2*L/(uC_n*W));
12 V_GS=V_t+V_OV;
13 disp(V_GS,"V_t (V)")
14 V_S=-1.2; // (V)
15 R_S=(V_S-V_SS)/I_D;
16 disp(R_S,"R_S (ohm)")
17 V_D=0.5; // (V)
18 R_D=(V_DD-V_D)/I_D;
19 disp(R_D,"R_D (ohm)")

```

Scilab code Exa 4.3 Design of given circuit

```

1 // Example 4.3: Design of given circuit to obtain
  I_D=80uA
2 // FET is operating in saturation region
3 I_D=80*10^-6; // (A)
4 V_t=0.6; // (V)
5 uC_n=200*10^-6; // (A/V^2)
6 L=0.8*10^-6; // (m)
7 W=4*10^-6; // (m)
8 V_DD=3; // (V)
9 V_OV=sqrt(2*I_D/(uC_n*(W/L)));
10 V_GS=V_t+V_OV;
11 V_DS=V_GS;
12 V_D=V_DS;
13 disp(V_D,"V_D (V)")
14 R=(V_DD-V_D)/I_D;
15 disp(R,"R (ohm)")

```

Scilab code Exa 4.4 Design of given circuit

```

1 // Example 4.4 : Design of given circuit to obtain
  V_D=0.1V
2 // MOSFET is operating in triode region
3 V_D=0.1; // (V)
4 V_DD=5; // (V)
5 V_t=1; // (V)
6 K=1*10^-3; // K=k' _n (W/L)
7 V_GS=5; // (V)
8 V_DS=0.1; // (V)
9 I_D=K*((V_GS-V_t)*V_DS-(V_DS^2)/2);
10 disp(I_D,"I_D (A)")
11 R_D=(V_DD-V_D)/I_D;
12 disp(R_D,"R_D (ohm)")
13 r_DS=V_DS/I_D;
14 disp(r_DS,"r_DS (ohm)")

```

Scilab code Exa 4.5 To determine all node voltages and currents through

```
1 // Example 4.5: To determine all node voltages and
   currents through all branches
2 V_t=1; // (V)
3 K=1*10^-3; // K=k'_n (W/L)
4 V_DD=10; // (V)
5 R_G1=10*10^6; // (ohm)
6 R_G2=10*10^6; // (ohm)
7 R_D=6*10^3; // (ohm)
8 R_S=6*10^3; // (ohm)
9 p=poly([8 -25 18], 'I_D', 'coeff');
10 I_D=roots(p);
11 // I_D=0.89mA will result in transistor cut off
   hence we take the other root of the equation
12 V_G=V_DD*R_G2/(R_G2+R_G1);
13 I_D=I_D(1)*10^-3;
14 disp(I_D, "I_D (A)")
15 V_S=I_D*R_S;
16 disp(V_S, "V_S (V)")
17 V_GS=V_G-V_S;
18 disp(V_GS, "V_GS (V)")
19 V_D=V_DD-R_D*I_D;
20 disp(V_D, "V_D (V)")
21 // V_D>V_G-V_t the transistor is operating in
   saturation as initially assumed
```

Scilab code Exa 4.6 Design of given circuit

```
1 // Example 4.6; Design of given circuit to obtain
   I_D=0.5mA and V_D=3V
2 // MOSFET is in saturation
```

```

3 V_DD=5; // (V)
4 V_D=3; // (V)
5 I_D=0.5*10^-3; // (A)
6 V_t=-1; // (V)
7 K=1*10^-3; // K=k' _n (W/L)
8 V_OV=sqrt(2*I_D/K);
9 V_GS=V_t+(-V_OV)
10 R_D=V_D/I_D;
11 V_Dmax=V_D-V_t; // - sign as magnitude of V_t is
    considered
12 R_D=V_Dmax/I_D;
13 disp(R_D, "R_D (ohm)")

```

Scilab code Exa 4.7 To determine drain currents and output voltage

```

1 // Example 4.7: To determine drain currents and
    output voltage
2 K_n =1*10^-3; // K_n=k_n*W_n/L_n (A/V^2)
3 K_p = 1*10^-3; // K_p=k_p*W_p/L_p (A/V^2)
4 V_tn= 1; // (V)
5 V_tp= -1; // (V)
6 V_I=-2.5:2.5:2.5; // (V)
7 V_DD=2.5; // (V)
8 R=10; // (kilo ohm)
9 // For V_I=0
10 I_DP=(K_p*(V_DD-V_tn)^2)/2;
11 I_DN=I_DP;
12 disp(I_DP,I_DN,"I_DP (A) and I_DN (A) for V_I=0V")
13 disp(0,"V_O for V_I =0V")
14 // For V_I=2.5V
15 // I_DN=K_N(V_GS-V_tn)V_DS
16 // I_DN=v_O/R
17 // Solving the two equations we get
18 I_DN=0.244*10^-3; // (V)
19 V_O=-2.44; // (V)

```

```

20 disp(I_DN,V_0,"V_O and I_DN for V_I=2.5V")
21 // For V_I=-2.5V Q_N is cut off
22 I_DP=2.44*10^-3; // (A)
23 V_0=2.44; // (V)
24 disp(0,I_DP,V_0,"V_O(V), I_DP (A) and I_DN (A) for
      V_I=-2.5V")

```

Scilab code Exa 4.9 Design of given circuit

```

1 // Example 4.9 : Design of given circuit to obtain
  I_D=0.5mA
2 I_d=0.5*10^-3; // (A)
3 I_S=0.5*10^-3; // (A)
4 V_t=1:0.5:1.5; // (V)
5 K_n=1*10^-3; // K_n=k_n*W/L (A/V^2)
6 V_DD=15; // (V)
7 V_D=10; // (V)
8 V_S=5; // (V)
9 R_D=(V_DD-V_D)/I_d;
10 R_S=V_S/I_S;
11 V_OV=sqrt(I_d*2/K_n);
12 V_GS=V_t+V_OV;
13 V_G=V_S+V_GS;
14 // V_t=1.5V
15 // I_D=K(V_GS-V_t)^2/2
16 // 7=V_GS+10I_D
17 // solving above equations
18 I_D=0.455*10^-3;
19 deltaI_D=I_D-I_d; // Change in I_D (A)
20 change=deltaI_D*100/I_d; // Change in %
21 disp(change,"Change in I_D (%)")

```

Scilab code Exa 4.10 Small signal analysis

```

1 // Example 4.10 : Small signal analysis
2 V_t=1.5; // (V)
3 K=0.00025; //K= k_nW/L (A/V^2)
4 V_A=50; // (V)
5 I_D=1.06*10^-3; // (A)
6 V_D=4.4; // (V)
7 R_D=10000; // (ohm)
8 R_L=10000; // (ohm)
9 V_GS=V_D;
10 g_m=K*(V_GS-V_t);
11 r_o=V_A/I_D;
12 A_v=-g_m*(R_L*R_D*r_o)/(R_D*R_L+R_D*r_o+R_L*r_o);
13 disp(A_v," Voltage gain (V/V)")
14 R_G=10*10^6; //(ohm)
15 // i_i=v_i*(1-A_v)/R_G
16 R_in=R_G/(1-(A_v));
17 disp(R_in," Input resistance (ohm)")
18 // v_DSmin=v_GSmin-V_t
19 v_i=V_t/(1+(-A_v)); // - sign to make A_v positive
20 disp(v_i," Largest allowable input signal (V)")

```

Scilab code Exa 4.11 To determine all parameters of transistor amplifier

```

1 // Example 4.11: To determine all parameters of
  transistor amplifier
2 v_o=90; // (V)
3 v_i=9; // (V)
4 R_sig=100*10^3; // (ohm)
5 R_L=10*10^3; // (ohm)
6 v_sig=10; // (V)
7 A_vo=v_o/v_i;
8 disp(A_vo," A_vo (V/V)")
9 G_vo=v_o/A_vo;
10 disp(G_vo," G_vo (V/V)")
11 R_i=G_vo*R_sig/(A_vo-G_vo)

```

```

12 disp(R_i," R_i")
13 disp(" assume R_L = 10 kilo ohm is connected")
14 v_o=70; // (V)
15 v_i=8; // (V)
16 A_v=v_o/v_i;
17 disp(A_v," A_v (V/V)")
18 G_v=v_o/A_vo;
19 disp(G_v," G_v (V/V)")
20 R_o=R_L*(A_vo-A_v)/A_v;
21 disp(R_o," R_o (ohm)")
22 R_out=R_L*(G_vo-G_v)/G_v;
23 disp(R_out," R_out (ohm)")
24 R_in=(v_i*100)/(v_sig-v_i);
25 disp(R_in," R_in (ohm)")
26 G_m=A_vo/R_o;
27 disp(G_m," G_m (mho)")
28 A_i=A_v*R_in/R_L;
29 disp(A_i," A_i (V/V)")
30 R_inL0=R_sig/((1+R_sig/R_i)*(R_out/R_o)-1); // R_in |
    R_L=0 (ohm)
31 disp(R_inL0," R_in at R_L=0")
32 A_is=A_vo*R_inL0/R_o;
33 disp(A_is," A_is (A/A)")

```

Scilab code Exa 4.12 Midband gain and upper 3dB frequency

```

1 // Example 4.12 : Midband gain and upper 3dB
    frequency
2 R_sig= 100*10^3; // (ohm)
3 R_G=4.7*10^6; // (ohm)
4 R_D=15*10^3; // (ohm)
5 R_l=15*10^3; // (ohm)
6 g_m=1*10^-3; // (mho)
7 r_o=150*10^3; // (ohm)
8 C_gs=1*10^-12; // (F)

```

```

9 C_gd=0.4*10^-12; // (F)
10 R_L= 1/(1/r_o + 1/R_D + 1/R_L)
11 A_M=R_G/(R_G + R_sig)*g_m*R_L;
12 disp(A_M,"midband gain A_M (V/V)")
13 C_eq=(1+g_m*R_L)*C_gd;
14 C_in=C_gs+C_eq;
15 f_H=(R_G+R_sig)/(2*pi*C_in*R_sig*R_G);
16 disp(f_H,"f_H (Hz)")

```

Scilab code Exa 4.13 Coupling capacitor values

```

1 // Example 4.13 : Coupling capacitor values
2 R_G=4.7*10^6; // (ohm)
3 R_D=15*10^3; // (ohm)
4 R_L=15*10^3; // (ohm)
5 R_sig=100*10^3; // (ohm)
6 g_m=1*10^-3; // (mho)
7 f_L=100; // (Hz)
8 C_S=g_m/(2*pi*f_L)
9 disp(C_S,"C_S (F)")
10 f_P2=1/(2*pi*C_S/g_m);
11 f_P1=10; // (Hz)
12 f_P2=10; // (Hz)
13 C_C1=1/(2*pi*(R_G+R_sig)*10)
14 disp(C_C1,"C_C1 (F)")
15 C_C2=1/(2*pi*(R_D+R_L)*10)
16 disp(C_C2,"C_C2 (F)")

```

Chapter 5

Bipolar Junction Transistor

Scilab code Exa 5.1 Design of given circuit with current 2mA

```
1 // Example 5.1 : Design of given circuit with
   current 2mA
2 // BJT will be operating in active mode
3 B=100; // B is beta value
4 a=B/(B+1); // a is alpha value
5 v_BE=0.7; // v_BE (V) at i_C=1mA
6 i_C=1*10^-3:1*10^-3:2*10^-3; // (A)
7 I_C=2*10^-3; // (A)
8 V_T=25*10^-3; // (V)
9 V_C=5; // (V)
10 V_CC=15; // (V)
11 V_B=0; // (V)
12 V_RC=V_CC-V_C; // V_RC is the voltage drop across
   resistor R_C
13 R_C=V_RC/I_C;
14 disp(R_C," Collector Resistance R_C (ohm)")
15 V_BE=v_BE+V_T*log(i_C(2)/i_C(1));
16 disp(V_BE," Base emitter voltage V_BE (V) at i_C=2mA"
   )
17 V_E=V_B-V_BE;
18 disp(V_E," Emitter voltage V_E (V)")
```

```

19 I_E=I_C/a;
20 disp(I_E," Emitter current I_E (A)")
21 R_E=(V_E-(-V_CC))/I_E;
22 disp(R_E," Emitter resistance R_C (ohm)")

```

Scilab code Exa 5.2 Consider a common Emitter circuit

```

1 // Example 5.2 : Consider a common Emitter circuit
2 I_S=10^-15; // (A)
3 R_C=6.8*10^3; // (ohm)
4 V_CC=10; // (V)
5 V_CE=3.2; // (V)
6 V_T=25*10^-3; // (V)
7
8 // 5.2 a
9 I_C=(V_CC-V_CE)/R_C;
10 disp(I_C," Collector current (A)")
11 V_BE=V_T*log(I_C/I_S);
12 disp(V_BE,"V_BE (V)")
13
14 // 5.2 b
15 V_in=5*10^-3; // sinusoidal input of peak amplitude
    5mv
16 A_v=-(V_CC-V_CE)/V_T;
17 disp(A_v," Voltage gain")
18 V_o=-A_v*V_in; // negative sign to make positive
    value of voltage gain
19 disp(V_o," Amplitude of output voltage (V)")
20
21 // 5.2 c
22 v_CE=0.3 // (V)
23 i_C=(V_CC-v_CE)/R_C;
24 disp(i_C," i_C (A)")
25 v_be=V_T*log(i_C/I_C); // v_BE is positive increment
    in v_BE

```



```

26 disp(v_be,"required increment (V)")
27
28 // 5.2d
29 v_0=0.99*V_CC;
30 R_C=6.8*10^3; // (ohm)
31 i_C=(V_CC-v_0)/R_C;
32 I_C=1*10^-3; // (A)
33 disp(i_C,"i_C (A)")
34 v_be=V_T*log(i_C/I_C);
35 disp(v_be,"negative increment in v_BE (V)")

```

Scilab code Exa 5.3 Determine RB

```

1 // Example 5.3 :Determine R_B
2 // transistor is specified to have B value in the
   range of 50 to 150
3 V_C=0.2; // V_C=V_CEsat
4 V_CC=10; // (V)
5 R_C=10^3; // (ohm)
6 V_BB=5; // (V)
7 V_BE=0.7; // (V)
8 bmin=50; // range of beteta is 50 to 150
9 I_Csat=(V_CC-V_C)/R_C;
10 I_BEOS=I_Csat/bmin; // I_B(EOS)=I_BEOS
11 I_B=10*I_BEOS; // base current for an overdrive
   factor 10
12 R_B=(V_BB-V_BE)/I_B;
13 disp(R_B,"Value of R_B (ohm)")

```

Scilab code Exa 5.4 Analyse the circuit to find node voltages and bran

```

1 // Example 5.4 : Analyse the circuit to find node
   voltages and branch currents

```

```

2 V_BB= 4; // (V)
3 V_CC=10; // (V)
4 V_BE=0.7; // (V)
5 b=100; // beta = 100
6 R_E=3.3*10^3; // (ohm)
7 R_C=4.7*10^3; // (ohm)
8 V_E=V_BB-V_BE;
9 disp(V_E,"Emitter voltage (V)")
10 I_E=(V_E-0)/R_E;
11 disp(I_E,"Emitter current (A)")
12 a=b/(b+1) // alpha value
13 I_C=I_E*a;
14 disp(I_C,"Collector current (A)")
15 V_C=V_CC-I_C*R_C; // Applying ohm's law
16 disp(V_C,"Collector voltage (V)")
17 I_B=I_E/(b+1);
18 disp(I_B,"Base current (A)")

```

Scilab code Exa 5.5 Analyse the circuit to find node voltages and bran

```

1 // Example 5.5 : Analyse the circuit to find node
   voltages and branch currents
2 disp("Assuming active mode operation")
3 V_CC=10; // (V)
4 R_C=4.7*10^3; // (V)
5 R_E=3.3*10^3; // (ohm)
6 V_BE=0.7; // (V)
7 V_BB=6; // (V)
8 V_CEsat=0.2; // (V)
9 V_E=V_BB-V_BE;
10 disp(V_E,"Emitter voltage (V)")
11 I_E=V_E/R_E;
12 disp(I_E,"Emitter current (A)")
13 V_C=V_CC-I_E*R_C; // I_E=I_C
14 disp(V_C,"Collector voltage (V)")

```

```

15 disp("Since  $V_C < V_B$  our assumption is wrong\n
      Hence its saturation mode operation")
16 V_E=V_BB-V_BE;
17 disp(V_E,"Emitter voltage (V)")
18 I_E=V_E/R_E;
19 disp(I_E,"Emitter current (A)")
20 V_C=V_E+V_CEsat;
21 disp(V_C,"Collector voltage (V)")
22 I_C=(V_CC-V_C)/R_C;
23 disp(I_C,"Collector current (A)")
24 I_B=I_E-I_C;
25 disp(I_B,"Base current (A)")
26 Bforced=I_C/I_B; // transistor is made to operate at
      a forced beta value
27 disp(Bforced,"forced beta")

```

Scilab code Exa 5.7 Analyse the circuit to find node voltages and bran

```

1 // Example 5.7: Analyse the circuit to find node
      voltages and branch currents
2 V_CC=-10; // (V)
3 R_E=2000; // (ohm)
4 R_C=1000; // (ohm)
5 V_EE=10; // (V)
6 V_E=0.7; // (V) emitter base junction will be
      forward biased with  $V_E=V_{EB}=0.7V$ 
7 disp(V_E,"Emitter base junction is forward biased
      with  $V_E$  (V)")
8 I_E=(V_EE-V_E)/R_E;
9 disp(I_E,"Emitter current (A)")
10 B=100; // Assuming beta 100
11 a=B/(B+1);
12 I_C=a*I_E; // Assuming the transistor to operate in
      active mode
13 disp(I_C,"Collector current (A)")

```

```

14 V_C=V_CC+I_C*R_C;
15 disp(V_C," Collector voltage (V)")
16 I_B=I_E/(B+1);
17 disp(I_B," Base current (A)")

```

Scilab code Exa 5.8 Analyse the circuit to find node voltages and bran

```

1 // Example 5.8 : Analyse the circuit to find node
  voltages and branch currents
2 V_CC= 10; // (V)
3 R_C=2000; // (ohm)
4 V_BB=5; // (V)
5 R_B=100*10^3; // (ohm)
6 B=100; // beta value
7 I_B=(V_BB-V_BE)/R_B;
8 disp(I_B," Base current (A)")
9 I_C=B*I_B;
10 disp(I_C," Collector current (A)")
11 V_C=V_CC-I_C*R_C;
12 disp(V_C," Collector voltage (V)")
13 V_B=0.7 ; // V_B=V_BE
14 disp(V_B," Base voltage (V)")
15 I_E=(B+1)*I_B;
16 disp(I_E," Emitter current (A)")

```

Scilab code Exa 5.9 Analyse the circuit to find node voltages and bran

```

1 // Example 5.9 :Analyse the circuit to find node
  voltages and branch currents
2 // assuming that the transistor is saturated
3 V_CC=-5; // (V)
4 V_EE=5; // (V)
5 R_B=10000; // (ohm)

```

```

6 R_C=10000; // (ohm)
7 R_E=1000; // (ohm)
8 V_EB=0.7; // (V)
9 V_ECsat=0.2; // (V)
10 // using the relation I_E=I_C+I_B
11 V_B=3.75/1.2; //(V)
12 disp(V_B,"Base voltage (V)")
13 V_E=V_B+V_EB;
14 disp(V_E,"Emitter voltage (V)")
15 V_C=V_E-V_ECsat;
16 disp(V_C,"Collector voltage (V)")
17 I_E=(V_EE-V_E)/R_E;
18 disp(I_E,"Emitter current (A)")
19 I_B=V_B/R_B;
20 disp(I_B,"Base current (A)")
21 I_C=(V_C-V_CC)/R_C;
22 disp(I_C,"Collector current (A)")
23 Bforced=I_C/I_B; // Value of forced beta
24 disp(Bforced, "Forced Beta value")

```

Scilab code Exa 5.10 Analyse the circuit to find node voltages and bran

```

1 // Exampe 5.10 : Analyse the circuit to find node
   voltages and branch currents
2 V_CC=15; // (V)
3 R_C=5000; // (ohm)
4 R_B1=100*10^3; // (ohm)
5 R_B2=50*10^3; // (ohm)
6 R_E=3000; // (ohm)
7 V_BE=0.7; // (V)
8 B=100; // beta value
9 V_BB=V_CC*R_B2/(R_B1+R_B2);
10 disp(V_BB,"V_BB (V)")
11 R_BB=R_B1*R_B2/(R_B1+R_B2);
12 disp(R_BB,"R_BB (ohm)")

```

```

13 I_B=I_E/(B+1);
14 disp(I_B," Base current (A)")
15 I_E=(V_BB-V_BE)/(R_E +(R_BB/(B+1)))
16 disp(I_E," Emitter current (A)")
17 I_B=I_E/(B+1)
18 disp(I_B," Base current (A)")
19 V_B=V_BE+I_E*R_E;
20 disp(V_B," Base voltage (V)")
21 a=B/(B+1); // alpha value
22 I_C=a*I_E
23 disp(I_C," Collector current (A)")
24 V_C=V_CC-I_C*R_C;
25 disp(V_C," Collector voltage (V)")

```

Scilab code Exa 5.11 Analyse the circuit to find node voltages and bran

```

1 // Example 5.11 :Analyse the circuit to find node
   voltages and branch currents
2 V_CC=15; // (V)
3 R_C1=5000; // (ohm)
4 R_B1=100*10^3; // (ohm)
5 R_B2=50*10^3; // (ohm)
6 R_E=3000; // (ohm)
7 V_BE=0.7; // (V)
8 R_E2=2000; // (ohm)
9 R_C2=2700; // (ohm)
10 V_EB=0.7; // (V)
11 B=100; // beta value
12 V_BB=V_CC*R_B2/(R_B1+R_B2);
13 R_BB=R_B1*R_B2/(R_B1+R_B2);
14 I_E1=(V_BB-V_BE)/(R_E +(R_BB/(B+1)))
15 disp(I_E1," I_E1 (A)")
16 I_B1=I_E1/(B+1)
17 disp(I_B1," I_B1 (A)")
18 V_B1=V_BE+I_E*R_E;

```

```

19 disp(V_B1,"V_B1 (V)")
20 a=B/(B+1); // alpha value
21 // beta and alpha values are same for the two
    transistors
22 I_C1=a*I_E
23 disp(I_C1,"IC1 (A)")
24 V_C1=V_CC-I_C1*R_C1;
25 disp(V_C1,"V_C1 (V)")
26 V_E2=V_C1+V_EB;
27 disp(V_E2,"V_E2(V)")
28 I_E2=(V_CC-V_E2)/R_E2;
29 disp(I_E2,"I_E2 (A)")
30 I_C2=a*I_E2;
31 disp(I_C2,"I_C2 (A)")
32 V_C2=I_C2*R_C2;
33 disp(V_C2,"V_C2 (V)")
34 I_B2=I_E2/(B+1);
35 disp(I_B2,"I_B2 (A)")

```

Scilab code Exa 5.13 Design of bias network of the amplifier

```

1 // Example 5.13 : Design of bias network of the
    amplifier
2 I_E=1*10^-3; // (A)
3 V_CC=12; // (V)
4 B=100; // beta value
5 V_B=4; // (V)
6 V_BE=0.7; // (V)
7 R1=80; // (ohm)
8 R2=40; // (ohm)
9 V_C=8; // (V)
10 V_E=V_B-V_BE;
11 disp(V_E,"Emitter voltage (V)")
12 R_E=V_E/I_E;
13 disp(R_E,"Emitter resistance (ohm)")

```

```

14 I_E=(V_B-V_BE)/(R_E+(R1*R2/(R1+R2)))/(B+1));
15 disp(I_E,"more accurate value for I_E (A) for R1=80
    ohm and R2=40 ohm")
16 R1=8; // (ohm)
17 R2=4; // (ohm)
18 I_E=(V_B-V_BE)/(R_E+(R1*R2/(R1+R2)))/(B+1));
19 disp(I_E,"more accurate value for I_E (A) for R1=8
    ohm and R2=4 ohm")
20 R_C=(V_CC-V_C)/I_E; // I_E=I_C
21 disp(R_C,"Collector resistor (ohm)")

```

Scilab code Exa 5.14 Analysis of transistor amplifier

```

1 // Example 5.14 : Analysis of transistor amplifier
2 V_CC=10; // (V)
3 R_C=3000; // (ohm)
4 R_BB=100*10^3; // (ohm)
5 V_BB=3; // (V)
6 V_BE=0.7; // (V)
7 V_T=25*10^-3; // (V)
8 I_B=(V_BB-V_BE)/R_BB;
9 disp(I_B,"Base current (A)")
10 I_C=B*I_B;
11 disp(I_C,"Collector current (A)")
12 V_C=V_CC-I_C*R_C;
13 disp(V_C,"Collector voltage (V)")
14 I_E=B*I_C/(B+1);
15 r_e=V_T/I_E;
16 disp(r_e,"r_e (ohm)")
17 g_m=I_C/V_T;
18 disp(g_m,"g_m (mho)")
19 r_pi=B/g_m;
20 disp(r_pi,"r_pi (ohm)")
21 // v_i is input voltage let us assume it to be 1 V
22 v_i=1;

```



```

23 v_be=v_i*r_pi/(r_pi+R_BB)
24 disp(v_be,"v_be")
25 v_o=-g_m*R_C*v_be;
26 disp(v_o,"Output voltage (V)")
27 A_v=v_o/v_i;
28 disp(A_v,"Voltage gain")

```

Scilab code Exa 5.17 Amplifier parameters

```

1 // Example 5.17 : Amplifier parameters
2 // Transistor amplifier is having a open circuit
  voltage of v_sig of 10mV
3 v_sig=10*10^-3; // (V)
4 R_L=10*10^3; // (ohm)
5 R_sig=100*10^3; // (ohm)
6 disp("Calculation with R_L infinite")
7 v_i=9; // (V)
8 v_o=90; // (V)
9 A_vo=v_o/v_i;
10 disp(A_vo,"A_vo (V/V)")
11 G_vo=v_o/A_vo;
12 disp(G_vo,"G_vo (V/V)")
13 R_i=G_vo*R_sig/(A_vo-G_vo)
14 disp(R_i,"R_i (ohm)")
15 disp("Calculations with R_L = 10k ohm")
16 v_o=70*10^-3; // (V)
17 v_i=8*10^-3; // (V)
18 A_v=v_o/v_i;
19 disp(A_v,"Voltage gain A_v (V/V)")
20 G_v=v_o*10^3/10;
21 disp(G_v,"G_v (V/V)")
22 R_o=(A_vo-A_v)*R_L/A_v;
23 disp(R_o,"R_o (ohm)")
24 R_out=(G_vo-G_v)*R_L/G_v;
25 disp(R_out,"R_out (ohm)")

```

```

26 R_in=v_i*R_sig/(v_sig-v_i);
27 disp(R_in,"R_in (ohm)")
28 G_m=A_vo/R_o;
29 disp(G_m,"G_m (A/V)")
30 A_i=A_v*R_in/R_L;
31 disp(A_i,"A_i (A/A)")
32 R_ino=R_sig/((1+R_sig/R_i)*(R_out/R_o)-1); // R_ino
    is R_in at R_L=0
33 disp(R_ino,"R_in at R_L =0")
34 A_is=A_vo*R_ino/R_o;
35 disp(A_is,"A_is (A/A)")

```

Scilab code Exa 5.18 Midband gain and 3dB frequency

```

1 //Example 5.18 : Midband gain and 3dB frequency
2 // Transistor is biased at I_C=1mA
3 V_CC=10; // (V)
4 V_EE=10; // (V)
5 I=0.001; // (A)
6 R_B=100000; // (ohm)
7 R_C=8000; // (ohm)
8 R_sig=5000; //(ohm)
9 R_L=5000; // (ohm)
10 B=100; // beta value
11 V_A=100; // (V)
12 C_u=1*10^-12; // (F)
13 f_T=800*10^6; // (Hz)
14 I_C=0.001; // (A)
15 r_x=50; // (ohm)
16 // Values of hybrid pi model parameters
17 g_m=I_C/V_T;
18 r_pi=B/g_m;
19 r_o=V_A/I_C;
20 w_T=2*%pi*f_T;
21 C_piplusCu=g_m/w_T; // C_u+C_pi

```

```

22 C_pi=C_piplusCu-C_u;
23 R_l=r_o*R_C*R_L/(r_o*R_C+R_C*R_L+R_L*r_o) // R_l=R_L
,
24 A_M=R_B*r_pi*g_m*R_l/(((R_B+R_sig)*(r_pi+r_x+(R_B*
R_sig/(R_B+R_sig)))));
25 disp(A_M,"Midband gain (V/V)")
26 R_seff=(r_pi*(r_x+R_B*R_sig/(R_B+R_sig)))/(r_pi+r_x+
R_B*R_sig/(R_B+R_sig)); // Effective source
resistance R_seff=R'_sig
27 C_in=C_pi+C_u*(1+R_l*g_m);
28 f_H=1/(2*pi*C_in*R_seff);
29 disp(f_H,"3dB frequency (Hz)")

```

Scilab code Exa 5.19 To select values of capacitance required

```

1 // Example 5.19 : To select values of capacitance
required
2 R_B=100000; // (ohm)
3 r_pi=2500; // (ohm)
4 R_C=8000; // (ohm)
5 R_L=5000; // (ohm)
6 R_sig=5000; // (ohm)
7 B=100; // beta value
8 g_m=0.04; // (A/V)
9 r_pi=2500; //(ohm)
10 f_L=100; // (Hz)
11 r_e=25; // (ohm)
12 R_C1=R_B*r_pi/(R_B+r_pi)+R_sig; // Resistance seen
by C_C1
13 R_E=r_e+R_B*R_sig/((R_B+R_sig)*(B+1)); // Resistance
seen by C_E
14 R_C2=R_C+R_L; // Resistance seen by C_C2
15 w_L=2*pi*f_L;
16 C_E=1/(R_E*0.8*w_L); //C_E is to contribute only 80%
of the value of w_L

```

```
17 disp(C_E,"C_E (F)")
18 C_C1=1/(R_C1*0.1*w_L); //C_C1 is to contribute only
    10% of the value of f_L
19 disp(C_C1,"C_C1 (F)")
20 C_C2=1/(R_C2*0.1*w_L); //C_C2 should contribute only
    10% of the value of f_L
21 disp(C_C2,"C_C2 (F)")
```

Chapter 6

single stage integrated circuit amplifiers

Scilab code Exa 6.1 To find the operating point of NMOS transistor

```
1 // Example 6.1: To find the operating point of NMOS
  transistor
2 // Consider NMOS transistor
3
4 // 6.1a
5 I_D=100*10^-6; // (A)
6 K_n=387*10^-6*10; // K_n=u_n*C_ox(W/L) (A/V^2)
7 V_th=0.48; // (V)
8 V_OV=sqrt(2*I_D/K_n);
9 disp(V_OV,"V_OV (V)")
10 V_GS=V_th+V_OV;
11 disp(V_GS,"V_GS (V)")
12
13 // 6.1b
14 I_C=100*10^-6; // (A)
15 I_S=6*10^-18 // (A)
16 V_T=0.025; // (V)
17 V_BE=V_T*log(I_C/I_S);
18 disp(V_BE,"V_BE (V)")
```

Scilab code Exa 6.2 Comparison between NMOS transistor and npn transistor

```
1 // Example 6.2 : Comparison between NMOS transistor
  and npn transistor
2
3 disp("For NMOS transistor")
4 I_D=100*10^-6; // (A)
5 V_a=5; // V'_A=V_a (A)
6 L=0.4; // (um)
7 K_n=267*4/0.4*10^-6; // K_n=u_n*C_ox*(W/L) (A/V^2)
8 V_0V=sqrt(2*I_D/K_n);
9 g_m=sqrt(2*K_n*I_D)
10 disp(g_m,"g_m (A/V)")
11 disp("R_in is infinite")
12 r_o=V_a*L/I_D;
13 disp(r_o,"r_o (ohm)")
14 A_0=g_m*r_o;
15 disp(A_0,"A_0 (V/V)")
16 disp("For npn transistor")
17 I_C=0.1*10^-3; // collector current
18 B_o=100; // beta value
19 V_A=35; // (V)
20 g_m=I_C/V_T;
21 disp(g_m,"g_m (A/V)")
22 R_in=B_o/g_m;
23 disp(R_in,"R_in (ohm)")
24 r_o=V_A/I_C;
25 disp(r_o,"r_o (ohm)")
26 A_0=g_m*r_o;
27 disp(A_0,"A_0 (V/V)")
```

Scilab code Exa 6.3 Comparison between NMOS transistor and npn transistor

```
1 // Example 6.3 : Comparison between NMOS transistor
  and npn transistor
2 // For npn transistor
3 disp("For npn transistor")
4 I_C=10*10^-6; // (A)
5 V_T=0.025; // (V)
6 V_A=35; // (V)
7 C_je0=5*10^-15; // (F)
8 C_u0=5*10^-15; // (F)
9 C_L=1*10^-12; // (F)
10 disp("The data calculated for I_C=10uA")
11 g_m=I_C/V_T;
12 disp(g_m,"g_m (A/V)")
13 r_o=V_A/I_C;
14 disp(r_o,"r_o (ohm)")
15 A_0=V_A/V_T;
16 disp(A_0,"A_0 (V/V)")
17 T_F=10*10^-12;
18 C_de=T_F*g_m;
19 disp(C_de,"C_de (F)")
20 C_je=2*C_je0;
21 disp(C_je,"C_je (F)")
22 C_pi=C_de+C_je;
23 disp(C_pi,"C_pi (F)")
24 C_u=C_u0;
25 disp(C_u,"C_u (F)")
26 f_T=g_m/(2*pi*(C_pi+C_u));
27 disp(f_T,"f_T (Hz)")
28 f_t=g_m/(2*pi*C_L);
29 disp(f_t,"f_t (Hz)")
30 disp("The data calculated for I_C=100uA")
31 I_C=100*10^-6;
32 g_m=I_C/V_T;
33 disp(g_m,"g_m (A/V)")
34 r_o=V_A/I_C;
```

```

35 disp(r_o,"r_o (ohm)")
36 A_0=V_A/V_T;
37 disp(A_0,"A_0 (V/V)")
38 T_F=10*10^-12;
39 C_de=T_F*g_m;
40 disp(C_de,"C_de (F)")
41 C_je=2*C_je0;
42 disp(C_je,"C_je (F)")
43 C_pi=C_de+C_je;
44 disp(C_pi,"C_pi (F)")
45 C_u=C_u0;
46 disp(C_u,"C_u (F)")
47 f_T=g_m/(2*pi*(C_pi+C_u));
48 disp(f_T,"f_T (Hz)")
49 f_t=g_m/(2*pi*C_L);
50 disp(f_t,"f_t (Hz)")
51 disp("The data calculated for I_C=1mA")
52 I_C=1*10^-3;
53 g_m=I_C/V_T;
54 disp(g_m,"g_m (A/V)")
55 r_o=V_A/I_C;
56 disp(r_o,"r_o (ohm)")
57 A_0=V_A/V_T;
58 disp(A_0,"A_0 (V/V)")
59 T_F=10*10^-12;
60 C_de=T_F*g_m;
61 disp(C_de,"C_de (F)")
62 C_je=2*C_je0;
63 disp(C_je,"C_je (F)")
64 C_pi=C_de+C_je;
65 disp(C_pi,"C_pi (F)")
66 C_u=C_u0;
67 disp(C_u,"C_u (F)")
68 f_T=g_m/(2*pi*(C_pi+C_u));
69 disp(f_T,"f_T (Hz)")
70 f_t=g_m/(2*pi*C_L);
71 disp(f_t,"f_t (Hz)")
72 // For NMOS transistor

```



```

73 L=0.4*10^-6; // (m)
74 C_L=1*10^-12; // (F)
75 disp("The data calculated for I_D = 10uA")
76 I_D=10*10^-6; // (A)
77 WbyL=0.12*I_D; // WbyL=(W/L)
78 disp(WbyL*10^6,"(W/L)")
79 g_m=8*I_D;
80 disp(g_m,"g_m (A/V)")
81 r_o=2/I_D;
82 disp(r_o,"r_o (ohm)")
83 A_0=g_m*r_o;
84 disp(A_0,"A_0 (V/V)")
85 C_gs=(2/3)*WbyL*0.4*0.4*5.8+0.6*WbyL*0.4;
86 disp(C_gs,"C_gs (fF)")
87 C_gd=0.6*WbyL*0.4;
88 disp(C_gd,"C_gd (fF)")
89 f_T=g_m/(2*pi*(C_gs*10^-15+C_gd*10^-15));
90 disp(f_T,"f_T (Hz)")
91 f_t=g_m/(2*pi*C_L)
92 disp(f_t,"f_t (Hz)")
93 disp("The data calculated for I_D = 100uA")
94 I_D=100*10^-6; // (A)
95 WbyL=0.12*I_D; // WbyL=(W/L)
96 disp(WbyL*10^6,"(W/L)")
97 g_m=8*I_D;
98 disp(g_m,"g_m (A/V)")
99 r_o=2/I_D;
100 disp(r_o,"r_o (ohm)")
101 A_0=g_m*r_o;
102 disp(A_0,"A_0 (V/V)")
103 C_gs=(2/3)*WbyL*0.4*0.4*5.8+0.6*WbyL*0.4;
104 disp(C_gs,"C_gs (fF)")
105 C_gd=0.6*WbyL*0.4;
106 disp(C_gd,"C_gd (fF)")
107 f_T=g_m/(2*pi*(C_gs*10^-15+C_gd*10^-15));
108 disp(f_T,"f_T (Hz)")
109 f_t=g_m/(2*pi*C_L)
110 disp(f_t,"f_t (Hz)")

```

```

111 disp("The data calculated for I_D = 1mA")
112 I_D=1*10^-3; // (A)
113 WbyL=0.12*I_D; // WbyL=(W/L)
114 disp(WbyL*10^6,"(W/L)")
115 g_m=8*I_D;
116 disp(g_m,"g_m (A/V)")
117 r_o=2/I_D;
118 disp(r_o,"r_o (ohm)")
119 A_0=g_m*r_o;
120 disp(A_0,"A_0 (V/V)")
121 C_gs=(2/3)*WbyL*0.4*0.4*5.8+0.6*WbyL*0.4;
122 disp(C_gs,"C_gs (fF)")
123 C_gd=0.6*WbyL*0.4;
124 disp(C_gd,"C_gd (fF)")
125 f_T=g_m/(2*pi*(C_gs*10^-15+C_gd*10^-15));
126 disp(f_T,"f_T (Hz)")
127 f_t=g_m/(2*pi*C_L)
128 disp(f_t,"f_t (Hz)")

```

Scilab code Exa 6.4 Design of the circuit with output current 100uA

```

1 // Example 6.4 : Design of the circuit with output
  current =100uA
2
3 V_DD=3; // (V)
4 I_REF=100*10^-6; // (A)
5 I_D1=100*10^-6; // (A)
6 L=1*10^-6; // (m)
7 W=10*10^-6; // (m)
8 V_t=0.7; // (V)
9 k_n=200*10^-6; // k_n=k'_n (A/V^2)
10 V_A=20; // V_A=V'_A (V)
11 V_OV=sqrt(I_D1*2*L/(k_n*W));
12 V_GS=V_t+V_OV;
13 R=(V_DD-V_GS)/I_REF;

```

```

14 V_0min=V_0V;
15 disp(V_0min,"V_min (V)")
16 r_o2=V_A/I_REF;
17 disp(r_o2,"r_o2 (ohm)")
18 V_0=V_GS;
19 deltaV_0=1; // Change in V_O (V)
20 deltaI_0=deltaV_0/r_o2; // Corresponding change in
    I_O (A)
21 disp(deltaI_0,"The correspondng change in I-O (A)")

```

Scilab code Exa 6.5 Determine 3dB frequency

```

1 // Example 6.5 : Determine 3dB frequency
2 // High frequency response of an amplifier can be
    characterized by th transfer function
3 //  $F_H(s)=(1-s/10^5)/(1+s/10^4)(1+s/4*10^4)$ 
4 w_H=1/sqrt(1/10^8+1/(16*10^8)-2/10^10); // w_H=1/
    sqrt(1/w_P1^2+1/w_P2^2-2/w_Z1^2-2w_Z2^2)
5 disp(w_H,"w_H (rad/s)")

```

Scilab code Exa 6.6 To determine midband gain and upper 3dB frequency

```

1 // Example 6.6 : To determine midband gain and upper
    3dB frequency
2 R_in=420*10^3; // (ohm)
3 R_sig=100*10^3; // (ohm)
4 g_m=4*10^-3; // (mho)
5 R_L=3.33*10^3; // R_L=R'_L (ohm)
6 C_gs=1*10^-12; // F
7 C_gd=C_gs;
8 A_M=-R_in*g_m*R_L/(R_in+R_sig)
9 disp(A_M,"Midband frequency gain A_M (V/V)")
10 R_gs=R_in*R_sig/(R_in+R_sig);

```

```

11 R=R_gs; //R=R'
12 T_gs=C_gs*R_gs; // Oen circuit time constant of C_gs
    (s)
13 R_gd=R+R_L+g_m*R_L*R;
14 T_gd=R_gd*C_gd; // open circuit time constant of
    C_gd (s)
15 w_H=1/(T_gs+T_gd); // upper 3dB frequency w_H
16 f_H=w_H/(2*%pi);
17 disp(f_H,"Upper 3dB frequency f_H (Hz)")

```

Scilab code Exa 6.7 Application of miller theorem

```

1 // Example 6.7 : Application of miller 's theorem
2
3 // 6.7a
4 // By miller 's theorem
5 Z=1000*10^3; // (ohm)
6 K=-100; // (V/V)
7 R_sig=10*10^3; // (ohm)
8 Z_1=Z/(1-K);
9 disp(Z_1,"Z_1 (ohm)")
10 Z_2=Z/(1-(1/K));
11 disp(Z_2,"Z_2 (ohm)")
12 VobyVsig=-100*Z_1/(Z_1+R_sig); // VobyVsig=(V_o/
    V_sig)
13 disp(VobyVsig,"(V_o/V_sig) (V/V)")
14
15 //6.7b
16 // Applying miller 's theorem
17 f_3dB=1/(2*%pi*1.01*10^-6);
18 disp(f_3dB,"f_3dB (Hz)")

```

Scilab code Exa 6.8 Analysis of CMOS CS amplifier

```

1 // Example 6.8 : Analysis of CMOS CS amplifier
2 k_n=200*10^-6; // (A/V^2)
3 W=4*10^-6; // (m)
4 L=0.4*10^-6; // (m)
5 I_REF=100*10^-6; // (A)
6 V_An=20; // (A)
7 I_D1=0.1*10^-3; // (A)
8 V_Ap=10; // (V)
9 V_DD=3; // (V)
10 I_D2=0.1*10^-3; // (A)
11 V_tp=0.6; // (V)
12 V_tn=0.6; // (V)
13 g_m1=sqrt(2*k_n*(W/L)*I_REF);
14 disp(g_m1,"g_m1 (A/V)")
15 r_o1=V_An/I_D1;
16 disp(r_o1,"r_o1 (ohm)")
17 r_o2=V_Ap/I_D2;
18 disp(r_o2,"r_o2 (ohm)")
19 A_v=-g_m1*r_o1*r_o2/(r_o1+r_o2);
20 disp(A_v,"A_v (v/V)")
21 I_D=100*10^-6; // (A)
22 k_n=65*10^-6; // (A/V^2)
23 V_OV3=0.53; // (V)
24 V_SG=V_tp+V_OV3;
25 disp(V_SG,"V_SG (V)")
26 V_OA=V_DD-V_OV3;
27 disp(V_OA,"V_OA (V)")
28 V_IB=0.93; // (V)
29 V_IA=0.88; // (V)
30 disp(V_IA,V_IB,"Coordinates of the extremities of
    the amplifier V_IB and V_IA")
31 deltavI=V_IB-V_IA; // width of amplifier region
32 V_OB=0.33; // (V)
33 deltav0=V_OB-V_OA; // corresponding output range (V)
34 deltav0bydeltavI=-deltav0/deltavI; // Large signal
    voltage gain (V/V)
35 disp(deltav0bydeltavI,"Large signal voltage gain (V/
    V)")

```

Scilab code Exa 6.9 Analysis of CMOS CS amplifier

```
1 // Example 6.9: Analysis of CMOS CS amplifier
2 // Consider CMOS open source amplifier
3 I_D=100*10^-6; // (A)
4 I_REF=I_D;
5 uC_n=387*10^-6; // u_n*C_ox=uC_n (A/V^2)
6 uC_p=86*10^-6; // u_n*C_ox=uC_n (A/V^2)
7 W=7.2*10^-6; // (m)
8 L=0.36*10^-6; // (m)
9 V_An=5*10^-6; // (A)
10 R_sig=10*10^3; // (ohm)
11 V_OV=sqrt(2*I_D*L/(W*uC_n));
12 g_m=I_D/(V_OV/2);
13 disp(g_m,"g_m (A/V)")
14 r_o1=5*0.36/(0.1*10^-3);
15 disp(r_o1,"r_o1 (ohm)")
16 r_o2=6*0.36/(.1*10^-3);
17 disp(r_o2,"r_o2 (ohm)")
18 R_L=r_o1*r_o2/(r_o1+r_o2);
19 disp(R_L,"R_L (ohm)")
20 A_m=-g_m*R_L;
21 disp(A_m,"A_m (V/V)")
22 C_gs=20*10^-15; // (F)
23 C_gd=5*10^-15; // (F)
24 C_in=C_gs+C_gd*(1+g_m*R_L); // using miller
    equivalence
25 disp(C_in,"C_in (F)")
26 f_H=1/(2*pi*C_in*R_sig);
27 disp(f_H,"f_H (Hz)")
28 R_gs=10*10^3; // (ohm) using open circuit time
    constants methods
29 R_L=9.82*10^3; // (ohm)
30 R_gd=R_sig*(1+g_m*R_L) + R_L;
```

```

31 disp(R_gd,"R_gd (ohm)")
32 R_CL=R_L;
33 T_gs=C_gs*R_gs;
34 disp(T_gs,"T_gs (s)")
35 T_gd=C_gd*R_gd;
36 disp(T_gd,"T_gd (s)")
37 C_L=25*10^-15;
38 T_CL=C_L*R_CL;
39 disp(T_CL,"T_CL (s)")
40 T_H=T_gs+T_gd+T_CL;
41 disp(T_H,"T_H (s)")
42 f_H=1/(2*pi*T_H); // 3dB frequency
43 disp(f_H,"f_H (Hz)")
44 f_Z=g_m/(2*pi*C_gd); // frequency of the zero
45 disp(f_Z,"f_Z (Hz)")
46 // Denominator polynomial
47 p=poly([1 1.16*10^-9 0.0712*10^-18], 's', 'coeff')
48 disp(p,"Denominator polynomial")
49 s=roots(p);
50 f_P2=s(2)/(-2*pi);
51 f_P1=s(1)/(-2*pi)
52 disp(f_P2,f_P1,"The frequencies f_P1 (Hz) and f_P2
    (Hz) are found as the roots of the denominator
    frequency")
53 f_H=f_P1;
54 disp(f_H,"Another estimate for f_H (Hz)")

```

Scilab code Exa 6.10 To determine AM ft fZ f3dB

```

1 // Example 6.10 : To determine A_M, f_t, f_Z, f_3dB
2 // Consider the CS amplifier
3 A_M=-12.3; // (V/V) found from Example 6.9
4 C_L=25*10^-15; // (F)
5 C_gd=5*10^-15; // (F)
6 R_L=9.82*10^3; // (F)

```

```

7 g_m=1.25*10^-3; // (mho)
8 f_H=1/(2*pi*(C_L+C_gd)*R_L); // 3dB frequency
9 disp(f_H,"f_H (Hz)")
10 f_t=-A_M*f_H; // Unity-gain frequency – sign to make
    gain positive as only magnitude is considered
11 disp(f_t,"f_t (Hz)")
12 f_Z=g_m/(2*pi*C_gd); // frequency of the zero
13 disp(f_Z,"f_Z (Hz)")
14 I_D=400*10^-6; // I_D must be quadrupled by changing
    I_REF to 400uF
15 V_OV=0.32;
16 g_m=I_D/(V_OV/2);
17 disp(g_m,"g_m (A/V)")
18 r_o1=5*0.36/(0.4*10^-3);
19 disp(r_o1,"r_o1 (ohm)")
20 r_o2=6*0.36/(0.4*10^-3);
21 disp(r_o2,"r_o2 (ohm)")
22 R_L=(r_o1*r_o2)/(r_o1+r_o2);
23 disp(R_L,"R_L (ohm)")
24 A_M=-g_m*R_L;
25 disp(A_M,"A_M (V/V)")
26 f_H=1/(2*pi*(C_L+C_gd)*R_L);
27 disp(f_H,"f_H (Hz)")
28 f_t=f_H*-A_M; // Unity gain frequency
29 disp(f_t,"f_t (Hz)")

```

Scilab code Exa 6.11 Avo Rin Rout Gi Gis Gv fH

```

1 // Example 6.11 : Avo Rin Rout Gi Gis Gv fH
2 // Consider the common gate amplifier
3 g_m=1.25*10^-3; // (A/V)
4 r_o=18000; // (ohm)
5 I_D=100*10^-6; // (A)
6 X=0.2;
7 R_S=10*10^3; // (ohm)

```



```

8 R_L=100*10^3; // (ohm)
9 C_gs=20*10^-15; // (F)
10 C_gd=5*10^-15; // (F)
11 C_L=0; // (F)
12 gmplusgmb=g_m+0.2*g_m; // gmplusgmb=g_m+g_mb
13 A_vo=1+(gmplusgmb)*r_o;
14 disp(A_vo,"A_vo (V/V)")
15 R_in=(r_o+R_L)/A_vo;
16 disp(R_in,"R_in (ohm)")
17 R_out=r_o+A_vo*R_S;
18 disp(R_out,"ohm")
19 G_v=A_vo*R_L/(R_L+R_out);
20 disp(G_v,"G_v (V/V)")
21 G_is=A_vo*R_S/R_out;
22 disp(G_is,"G_is (A/A)")
23 G_i=G_is*R_out/(R_out+R_L)
24 disp(G_i,"G_i (A/A)")
25 R_gs=R_S*R_in/(R_S+R_in);
26 R_gd=R_L*R_out/(R_L+R_out);
27 T_H=C_gs*R_gs+C_gd*R_gd;
28 f_H=1/(2*pi*T_H);
29 disp(f_H,"f_H (Hz)")

```

Scilab code Exa 6.12 Comparison between Cascode amplifier and CS amplifier

```

1 // Example 6.12 : Comparison between Cascode
  // amplifier and CS amplifier
2 // 6.12a
3 // CS amplifier
4 g_m=1.25*10^-3;
5 r_o=20*10^3;
6 R_L=r_o*r_o/(r_o+r_o);
7 C_gs=20*10^-15;
8 R_sig=10000;

```

```

 9 C_gd=5*10^-15;
10 C_L=5*10^-15;
11 C_db=5*10^-15;
12 A_o=g_m*r_o;
13 disp(A_o,"A_o (V/V)")
14 A_v=-A_o/2;
15 disp(A_v,"A_v (V/V)")
16 T_H=C_gs*R_sig+C_gd*[(1+g_m*R_L)*R_sig+R_L]+(C_L+
    C_db)*R_L;
17 disp(T_H,"T_H (s)")
18 f_H=1/(2*pi*T_H);
19 disp(f_H,"f_H (Hz)")
20 f_t=-A_v*f_H;
21 disp(f_t,"f_t (Hz)")
22 // Cascode amplifier
23 g_m1=1.25*10^-3;
24 r_o1=20000;
25 X=0.2;
26 r_o2=20000;
27 R_L=20000;
28 A_o1=g_m1*r_o1;
29 disp(A_o1,"A_o1 (V/V)")
30 gm2plusgmb2=g_m1+X*g_m;
31 A_vo2=1+(gm2plusgmb2)*r_o2;
32 disp(A_vo2,"A_vo2 (V/V)")
33 R_out1=r_o1;
34 R_in2=1/(gm2plusgmb2)+R_L/A_vo2;
35 disp(R_in2,"R_in2 (ohm)")
36 R_d1=R_out1*R_in2/(R_out1+R_in2);
37 disp(R_d1,"R_d1 (ohm)")
38 R_out=r_o2+A_vo2*r_o1;
39 disp(R_out,"R_out (ohm)")
40 vo1byvi=-g_m1*R_d1;
41 disp(vo1byvi,"(v_o1/v_i) (V/V)")
42 A_v=-A_o1*A_vo2*R_L/(R_L+R_out);
43 disp(A_v,"A_v (V/V)")
44 C_gs1=20*10^-15;
45 R_sig=10*10^3;

```

```

46 gm1Rd1=1.5;
47 C_gd1=5*10^-15;
48 C_gs2=20*10^-15;
49 C_db2=5*10^-15;
50 C_gd2=5*10^-15;
51 C_db1=5*10^-15;
52 T_H=R_sig*[C_gs1+C_gd1*(1+gm1Rd1)]+R_d1*(C_gd1+C_db1
      +C_gs2)+((R_L*R_out)/(R_L+R_out))*(C_L+C_db2+
      C_gd2);
53 f_H=1/(2*pi*T_H);
54 disp(T_H,"T_H (s)")
55 disp(f_H,"f_H (Hz)")
56 f_t=-A_v*f_H;
57 disp(f_t,"f_t (Hz)")
58 // 6.12b
59 // CS amplifier
60 A_v=-12.5;
61 R_L=10*10^3;
62 disp(A_v,"A_v (V/V)")
63 T_H=(C_gd+C_L+C_db)*R_L;
64 disp(T_H,"T_H (s)")
65 f_H=1/(2*pi*T_H);
66 disp(f_H,"F_H (Hz)")
67 f_t=-A_v*f_H;
68 disp(f_t,"f_t (Hz)")
69 // Cascode amplifier
70 R_L=640*10^3;
71 R_out=640*10^3;
72 R_out1=20*10^3;
73 A_v=-A_o1*A_vo2*R_L/(R_L+R_out);
74 disp(A_v,"A_v (V/V)")
75 R_in2=1/gm2plusgmb2+R_L/A_vo2;
76 disp(R_in2,"R_in2 (ohm)")
77 R_d1=R_in2*R_out1/(R_in2+R_out1);
78 disp(R_d1,"R_d1 (ohm)")
79 T_H=R_d1*(C_gd1+C_db1+C_gs2)+(R_L*R_out/(R_L+R_out))
      *(C_L+C_gd2+C_db2);
80 disp(T_H,"T_H (s)")

```

```

81 f_H=1/(2*%pi*T_H);
82 disp(f_H,"f_H (Hz)")
83 f_t=-A_v*f_H;
84 disp(f_t,"f_t (Hz)")

```

Scilab code Exa 6.13 Analysis of CC CE amplifier

```

1 // Example 6.13: Analysis of CC-CE amplifier
2 // Consider a CC-CE amplifier
3 // at an emitter bias current of 1mA for Q_1 and Q_2
4 g_m=40*10^-3; // (A/V)
5 r_e=25; // (ohm)
6 B=100; // beta value
7 C_u=2*10^-12; // (F)
8 f_T=400*10^6 // (Hz)
9 r_pi= B/g_m;
10 disp(r_pi,"r_pi (ohm)")
11 C_pi=g_m/(2*%pi*f_T)-C_u;
12 disp(C_pi,"C_pi (F)")
13 R_in2=2500; // (ohm)
14 r_pi2=2500; // (ohm)
15 r_pi1=2500; // (ohm)
16 r_e1=0.025; // (ohm)
17 B_1=100; // beta value
18 R_in=(B_1+1)*(r_e1+R_in2);
19 disp(R_in,"R_in (ohm)")
20 R_sig=4*10^3; // (ohm)
21 R_L=4000; // (ohm)
22 Vb1byVsig=R_in/(R_in+R_sig); // (V_b1/V_sig)
23 disp(Vb1byVsig,"(V_b1/V_sig) (V/V)")
24 Vb2plusVb1=R_in2/(R_in2+r_e1); // (V_b2/V_b1)
25 disp(Vb2plusVb1,"(V_b2/V_b1) (V/V)")
26 VobyVb2=-g_m*R_L; // (V_o/V_b2)
27 disp(VobyVb2,"(V_o/V_b2) (V/V)")
28 A_M=VobyVb2*Vb2plusVb1*Vb2plusVb1;

```

```

29 disp(A_M,"A_M (V/V)")
30 R_u1=R_sig*R_in/(R_sig+R_in);
31 disp(R_u1,"R_u1 (ohm)")
32 R_pi1=(R_sig+R_in2)/(1+(R_sig/r_pi1)+(R_in2/r_e1));
    // C_pi1 sees a resistance R_pi1
33 disp(R_pi1,"R_pi1 (ohm)")
34 R_out1=25+4000/101;
35 R_pi2=R_in2*R_out1/(R_in2+R_out1); // C_pi2 sees a
    resistance R_pi2
36 disp(R_pi2,"R_pi2 (ohm)")
37 R_u2=(1+g_m*R_L)*R_pi2+R_L;
38 disp(R_u2,"R_u2 (ohm)")
39 C_u1=2*10^-12; // (F)
40 R_u1=3940; // (ohm)
41 C_pi1=13.9*10^-12; // (F)
42 C_u2=2*10^-12; // (F)
43 C_pi2=13.9*10^-12; // (F)
44 T_H=C_u1*R_u1+C_pi1*R_pi1+C_u2*R_u2+C_pi2*R_pi2;
45 disp(T_H,"T_H (s)")
46 f_H=1/(2*pi*T_H);
47 disp(f_H,"f_H (Hz)")
48 A_M=r_pi*(-g_m*R_L)/(r_pi+R_sig);
49 disp(A_M,"A_M (V/V)")
50 R_pi=r_pi*R_sig/(r_pi+R_sig);
51 disp(R_pi,"R_pi (ohm)")
52 R_u=(1+g_m*R_L)*R_pi +R_L;
53 disp(R_u,"R_u (ohm)")
54 T_H=C_pi*R_pi+C_u*R_u;
55 disp(T_H,"T_H (s)")
56 f_H=1/(2*pi*T_H);
57 disp(f_H,"f_H (Hz)")

```

Scilab code Exa 6.14 To determine required resistor values

```

1 // Example 6.14 : To determine required resistor
  values
2 // The circuits generate a constant current I_D=10
  uA which operate at a supply of 10V
3 V_BE=0.7; // (V)
4 V_t=0.025; // (V)
5 I_REF=10*10^-6; // (A)
6 V_DD=10; // (V)
7 I=1*10^-3; // (A)
8 V_BE1=V_BE+V_t*log(I_REF/I); // Voltage drop across
  Q_1
9 disp(V_BE1,"V_BE1 (V)")
10 R_1=(V_DD-V_BE1)/(I_REF); // For the Widlar circuit
  we decide I_REF=1mA and V_BE1=0.7V
11 disp(R_1,"R_1 (ohm)")
12 R_2=(V_DD-V_BE)/I;
13 disp(R_2,"R_2 (ohm)")
14 R_3=(V_t/I_REF)*log(I/I_REF);
15 disp(R_3,"R_3 (ohm)")

```

Chapter 7

Differential and multistage amplifier

Scilab code Exa 7.1 Analysis of differential amplifier

```
1 // Example 7.1 Analysis of differential amplifier
2 // Consider the differential amplifier
3 B=100; // beta value
4
5 // 7.1 a
6 V_T=0.025; // (V)
7 I_E=0.0005; // (A)
8 R_E=150; // (ohm)
9 r_e1=V_T/I_E; // emitter resistance (ohm)
10 r_e2=r_e1; // emitter resistance (ohm)
11 r_e=r_e1;
12 R_id=2*(B+1)*(r_e+R_E);
13 disp(R_id,"The input differential resistance R_id (
    ohm)")
14
15 // 7.1 b
16 R_id=40000; // (ohm)
17 R_sig=5000; // (ohm)
18 R_C=10000; // (ohm)
```

```

19 R_E=150; // (ohm)
20 A_v=R_id/(R_id+R_sig); // A_v= v_o/v_sig (V/V)
21 A_V=2*R_C/(2*(r_e+R_E)); // A_V= v_o/v_id (V/v)
22 A_d=A_v*A_V; // A_d=v_o/v_sig (V/V)
23 disp(A_d,"Overall differential voltage gain (V/V)")
24
25 // 7.1c
26 R_EE=200000; // (ohm)
27 deltaR_C=0.02*R_C; // in the worst case
28 A_cm=R_C*deltaR_C/(2*R_EE*R_C)
29 disp(A_cm,"Worst case common mode gain (V/V)")
30
31 // 7.1d
32 CMRR=20*log10(A_d/A_cm)
33 disp(CMRR,"CMRR in dB")
34
35 // 7.1e
36 r_o=200000; //(ohm)
37 R_icm=(B+1)*(R_EE*r_o/2)/(R_EE+r_o/2);
38 disp(R_icm,"Input common mode resistance (ohm)")

```

Scilab code Exa 7.2 Analysis of Active loaded MOS differential amplifi

```

1 // Example 7.2 : Analysis of Active loaded MOS
  differential amplifier
2 W=7.2*10^-6; // (m)
3 L=0.36*10^-6; // (m)
4 C_gs=29*10^-15; // (F)
5 C_gd=5*10^-15; // (F)
6 C_db=5*10^-15; // (F)
7 uC_n=387*10^-6; // uC_n=u_nC_ox (A/V^2)
8 uC_p=86*10^-6; // uC_p=u_pC_ox (A/V^2)
9 V_an=5; // V_an=V'_An (V/um) (V)
10 V_ap=6; // V_ap=V'_Ap (V/um) (V)
11 I=0.2*10^-3; // (A)

```



```

12 R_SS=25000; // (ohm)
13 C_SS=0.2*10^-12; // (F)
14 C_S=25*10^-15; // (F)
15 K_n=uC_n*W/L;
16 I_D=100*10^-6; // bias current (A)
17 V_OV=sqrt(2*I_D/K_n);
18 g_m=I/V_OV;
19 g_m1=g_m;
20 g_m2=g_m;
21 r_o1=V_an*0.36/(0.1*10^-3);
22 r_o2=r_o1;
23 K_p=uC_p*W/L;
24 V_OV34=sqrt(2*I_D/K_p); // V_OV3,4
25 g_m3=2*0.1*10^-3/V_OV34;
26 g_m4=g_m3;
27 r_o3=V_ap*0.36/(0.1*10^-3);
28 r_o4=r_o3;
29 A_d=g_m*(r_o2*r_o4)/(r_o2+r_o4);
30 disp(A_d,"A_d (V/V)")
31 A_cm=-1/(2*g_m3*R_SS);
32 disp(A_cm,"A_cm (V/V)")
33 CMRR=20*log10(-A_d/A_cm); // negative sign to make
    A_cm positive
34 disp(CMRR,"CMRR in dB")
35 C_gd1=5*10^-15; // (F)
36 C_db1=5*10^-15; // (F)
37 C_db3=5*10^-15; // (F)
38 C_gs3=20*10^-15; // (F)
39 C_gs4=20*10^-15; // (F)
40 C_m=C_gd1+C_db1+C_db3+C_gs3+C_gs4;
41 C_gd2=5*10^-15; // (F)
42 C_db2=5*10^-15; // (F)
43 C_gd4=5*10^-15; // (F)
44 C_db4=5*10^-15; // (F)
45 C_x=25*10^-15; // (F)
46 C_L=C_gd2+C_db2+C_gd4+C_db4+C_x;
47 disp("poles and zeroes of A_d")
48 R_o=r_o2*r_o4/(r_o2+r_o4)

```

```

49 f_p1=1/(2*%pi*C_L*R_o);
50 disp(f_p1,"f_p1 (Hz)")
51 f_p2=g_m3/(2*%pi*C_m);
52 disp(f_p2,"f_p2 (Hz)")
53 f_Z=2*f_p2;
54 disp(f_Z,"f_Z (Hz)")
55 disp("Dominant pole of CMRR is at location of common
      -mode gain zero")
56 f_Z=1/(2*%pi*C_SS*R_SS);
57 disp(f_Z,"f_Z (Hz)")

```

Scilab code Exa 7.3 To determine all parameters for different transistor

```

1 // Example 7.3 : To determine all parameters for
  different transistor
2 I_REF=90*10^-6; // (A)
3 V_tn=0.7; // (V)
4 V_tp=0.8; // Magnitude is considered
5 uC_n=160*10^-6; // uC_n=u_n*C_ox
6 uC_p=40*10^-6; // uC_p=u_p*C_ox
7 V_A=10; // (V)
8 V_DD=2.5; // (V)
9 V_SS=2.5; // (V)
10 L=0.8*10^-6; // (m)
11 r_o2=222; // (ohm)
12 r_o4=222; // (ohm)
13 g_m1=0.3; // (mho)
14 A_1=-g_m1*r_o2*r_o4/(r_o2+r_o4);
15 disp(A_1,"A_1 (V/V)")
16 r_o6=111; // (ohm)
17 r_o7=111; // (ohm)
18 g_m6=0.6; // (mho)
19 A_2=-g_m6*r_o6*r_o7/(r_o6+r_o7);
20 disp(A_2,"A_2 (V/V)")
21 disp("For Q_1")

```

```

22 W=20*10^-6; // (m)
23 I_D=I_REF/2; // (A)
24 disp(I_D,"I_D (A)")
25 K_p=uC_p*W/L;
26 V_OV=sqrt(2*I_D/K_p);
27 disp(V_OV,"V_OV (V)")
28 V_GS=V_tp+V_OV;
29 disp(V_GS,"V_GS (V)")
30 g_m=2*I_D/V_OV;
31 disp(g_m,"g_m (A/V)")
32 r_o=V_A/I_D;
33 disp(r_o,"r_o (ohm)")
34 disp("For Q_2")
35 W=20*10^-6; // (m)
36 I_D=I_REF/2; // (A)
37 disp(I_D,"I_D (A)")
38 K_p=uC_p*W/L;
39 V_OV=sqrt(2*I_D/K_p);
40 disp(V_OV,"V_OV (V)")
41 V_GS=V_tp+V_OV;
42 disp(V_GS,"V_GS (V)")
43 g_m=2*I_D/V_OV;
44 disp(g_m,"g_m (A/V)")
45 r_o=V_A/I_D;
46 disp(r_o,"r_o (ohm)")
47 disp("For Q_3")
48 W=5*10^-6; // (m)
49 I_D=I_REF/2; // (A)
50 disp(I_D,"I_D (A)")
51 K_n=uC_n*W/L;
52 V_OV=sqrt(2*I_D/K_n);
53 disp(V_OV,"V_OV (V)")
54 V_GS=V_tn+V_OV;
55 disp(V_GS,"V_GS (V)")
56 g_m=2*I_D/V_OV;
57 disp(g_m,"g_m (A/V)")
58 r_o=V_A/I_D;
59 disp(r_o,"r_o (ohm)")

```

```

60 disp(" For Q_4")
61 W=5*10^-6; // (m)
62 I_D=I_REF/2; // (A)
63 disp(I_D," I_D (A)")
64 K_n=uC_n*W/L;
65 V_OV=sqrt(2*I_D/K_n);
66 disp(V_OV," V_OV (V)")
67 V_GS=V_tn+V_OV;
68 disp(V_GS," V_GS (V)")
69 g_m=2*I_D/V_OV;
70 disp(g_m," g_m (A/V)")
71 r_o=V_A/I_D;
72 disp(r_o," r_o (ohm)")
73 disp(" For Q_5")
74 W=40*10^-6; // (m)
75 I_D=I_REF; // (A)
76 disp(I_D," I_D (A)")
77 K_p=uC_p*W/L;
78 V_OV=sqrt(2*I_D/K_p);
79 disp(V_OV," V_OV (V)")
80 V_GS=V_tp+V_OV;
81 disp(V_GS," V_GS (V)")
82 g_m=2*I_D/V_OV;
83 disp(g_m," g_m (A/V)")
84 r_o=V_A/I_D;
85 disp(r_o," r_o (ohm)")
86 disp(" For Q_6")
87 W=10*10^-6; // (m)
88 I_D=I_REF;
89 disp(I_D," I_D (A)")
90 K_n=uC_n*W/L;
91 V_OV=sqrt(2*I_D/K_n);
92 disp(V_OV," V_OV (V)")
93 V_GS=V_tn+V_OV;
94 disp(V_GS," V_GS (V)")
95 g_m=2*I_D/V_OV;
96 disp(g_m," g_m (A/V)")
97 r_o=V_A/I_D;

```

```

98 disp(r_o,"r_o (ohm)")
99 disp("For Q_7")
100 W=40*10^-6; // (m)
101 I_D=I_REF;
102 disp(I_D,"I_D (A)")
103 K_p=uC_p*W/L;
104 V_OV=sqrt(2*I_D/K_p);
105 disp(V_OV,"V_OV (V)")
106 V_GS=V_tp+V_OV;
107 disp(V_GS,"V_GS (V)")
108 g_m=2*I_D/V_OV;
109 disp(g_m,"g_m (A/V)")
110 r_o=V_A/I_D;
111 disp(r_o,"r_o (ohm)")
112 disp("For Q_8")
113 W=40*10^-6; // (m)
114 I_D=I_REF;
115 disp(I_D,"I_D (A)")
116 K_p=uC_p*W/L;
117 V_OV=sqrt(2*I_D/K_p);
118 disp(V_OV,"V_OV (V)")
119 V_GS=V_tp+V_OV;
120 disp(V_GS,"V_GS (V)")
121 g_m=2*I_D/V_OV;
122 disp(g_m,"g_m (A/V)")
123 r_o=V_A/I_D;
124 disp(r_o,"r_o (ohm)")
125 A_0=A_1*A_2;
126 disp(20*log10(A_0),"The dc open loop gain in dB")
127 v_ICMmin=-2.5+1;
128 disp(v_ICMmin,"Lower limit of input common-mode (V)"
)
129 v_ICMmax=2.2-1.1;
130 disp(v_ICMmax,"Upper limit of input common-mode (V)"
)
131 v_Omax=V_DD-V_OV;
132 disp(v_Omax,"Highest allowable output voltage (V)")
133 v_Omin=-V_SS+V_OV;

```

134 `disp(v_0min,"Lowest allowable output voltage (V)")`

Scilab code Exa 7.5 Analysis of given circuit

```
1 // Example 7.5 : Analysis of given circuit
2 B=100; // beta value
3 I_E=0.2510^-3; // (A)
4 R_1=20000; // (ohm)
5 R_2=20000; // (ohm)
6 R_3=3000; // (ohm)
7 R_4=2300; // (ohm)
8 R_5=15700; // (ohm)
9 R_6=3000; // (ohm)
10 r_e1=25/0.25; // (ohm)
11 r_e2=r_e1; // (ohm)
12 r_pi1=(B+1)*r_e1;
13 r_pi2=(B+1)*r_e2;
14 R_id=r_pi1+r_pi2;
15 disp(R_id,"Input differential resistance (ohm)")
16 I_E=1*10^-3;
17 r_e4=25/1;
18 r_e5=r_e4;
19 r_pi4=(B+1)*r_e4;
20 r_pi5=(B+1)*r_e5;
21 R_i2=r_pi4+r_pi5;
22 disp(R_i2,"Input resistance of the second stage R_i2
    (ohm)")
23 A_1=(R_i2*(R_1+R_2)/((R_i2+R_1+R_2)*(r_e1+r_e2)))
24 disp(A_1,"Voltage gain of the first stage (V/V)")
25 r_e7=25/1;
26 R_i3=(B+1)*(R_4+r_e7);
27 disp(R_i3,"Input resistance of the third stage R_i3
    (ohm)")
28 A_2=(-R_3*R_i3)/((R_3+R_i3)*(r_e4+r_e5));
29 disp(A_2,"Voltage gain of the second stage (V/V)")
```

```

30 r_e8=25/5;
31 R_i4=(B+1)*(r_e8+R_6);
32 disp(R_i4,"Input resistance of the third stage R_i2
    (ohm)")
33 A_3=(-R_5*R_i4)/((R_5+R_i4)*(r_e7+R_4));
34 disp(A_3,"Voltage gain of the third stage (V/V)")
35 A_4=R_6/(R_6+r_e8);
36 disp(A_4,"Voltage gain of the fourth stage (V/V)")
37 A=A_1*A_2*A_3*A_4 ; // A=v_o/v_id (V/V)
38 disp(A,"Overall output gain (V/V)")
39 disp(20*log10(A),"Overall output gain in dB")
40 R_o=R_6*(r_e8+R_5/(B+1))/(R_6+r_e8+R_5/(B+1))
41 disp(R_o,"Output resistance (ohm)")

```

Chapter 8

Feedback

Scilab code Exa 8.1 Analysis of op amp connected in an inverting conf

```
1 // Example 8.1: Analysis of op amp connected in an
  inverting configuration
2 // By inspection we can write down the expressions
  for A, B , closed loop gain , the input
  resistance and the output resistance
3 u=10^4; // (ohm)
4 R_id=100*10^3; // (ohm)
5 r_o=1000; // (ohm)
6 R_L=2000; // (ohm)
7 R_1=1000; // (ohm)
8 R_2=10^6; // (ohm)
9 R_S=10000; // (ohm)
10 A=u*(R_L*(R_1+R_2)/(R_L+R_1+R_2))*R_id/(((R_L*(R_1+
  R_2))/(R_L+R_1+R_2)+r_o)*(R_id+R_S+(R_1*R_2)/(R_1
  +R_2)))
11 disp(A,"Voltage gain without feedback (V/V)")
12 B=R_1/(R_1+R_2); // Beta value
13 disp(B, "Beta value ")
14 A_f=A/(1+A*B);
15 disp(A_f,"Voltage gain with feedback (V/V)")
16 R_i=R_S+R_id+(R_1*R_2/(R_1+R_2))// Input resistance
```



```

    of the A circuit in fig 8.12a of textbook
17 R_if=R_i*7;
18 R_in=R_if-R_S;
19 disp(R_in,"Input resistance (ohm)")
20 R_o=1/(1/r_o+1/R_L+1/(R_1+R_2));
21 R_of=R_o/(1+A*B);
22 R_out=R_of*R_L/(R_L-R_of);
23 disp(R_out,"the output resistance (ohm)")

```

Scilab code Exa 8.2 Feedback triple

```

1 // Example 8.2: Feedback triple
2 // Consider the given three stage series-series
  feedback
3 h_fe=100;
4 g_m2=40*10^-3; // (A/V)
5 r_e1=41.7; // (ohm)
6 a_1=0.99; // alpha value
7 R_C1=9000; // (ohm)
8 R_E1=100; //(ohm)
9 R_F=640; // (ohm)
10 R_E2=100; //(ohm)
11 r_pi2=h_fe/g_m2;
12 R_C2=5000; // (ohm)
13 r_e3=6.25; // (ohm)
14 R_C3=800; //(ohm)
15 // First stage gain A_1=V_c1/V_i
16 A_1=-a_1*R_C1*r_pi2/((R_C1+r_pi2)*(r_e1+((R_E1*(R_F+
  R_E2))/(R_E1+R_F+R_E2))))
17 disp(A_1,"The voltage gain of the first stage (V/V)"
  )
18 // Gain of the second stage A_2=Vc2/V_c1
19 A_2=-g_m2*{(R_C2*(h_fe+1)/(R_C2+h_fe+1)}*[r_e3+(R_E2
  *(R_F+R_E1))/(R_E2+R_F+R_E1)]}
20 disp(A_2,"The second stage gain (V/V)")

```

```

21 // Third stage gain A_3 I_O/V_i
22 A_3=1/(r_e3+(R_E2*(R_F+R_E1)/(R_E2+R_F+R_E1)));
23 disp(A_3,"The third stage gain (V/V)")
24 A=A_1*A_2*A_3; // combined gain
25 disp(A,"Combined gain (V/V)")
26 B=R_E1*R_E2/(R_E2+R_F+R_E1);
27 disp(B,"Beta value")
28 A_f=A/(1+A*B);
29 disp(A_f,"Closed loop gain (A/V)")
30 A_v=-A_f*R_C3; // Voltage gain
31 disp(A_v,"Voltage gain (V/V)")
32 R_i=(h_fe+1)*(r_e1+(R_E1*(R_F+R_E2))/(R_E1+R_F+R_E2)
    );
33 R_if=R_i*(1+A*B);
34 disp(R_if,"Input resistance (ohm)")
35 R_o=(R_E2*(R_F+R_E1)/(R_F+R_E1+R_E2))+r_e3+R_C2/(
    h_fe+1);
36 R_of=R_o*(1+A*B);
37 disp(R_of,"Output voltage (ohm)")
38 r_o=25000; // (ohm)
39 g_m3=160*10^-3; // (mho)
40 r_pi3=625; // (ohm)
41 R_out=r_o+(1+g_m3*r_o)*R_of*r_pi3/(R_of+r_pi3);
42 disp(R_out,"R_out (ohm)")

```

Scilab code Exa 8.3 Small signal analysis

```

1 // Example 8.3 : Small signal analysis
2 B=100; // beta value
3 I_B=0.015*10^-3; // (A)
4 I_C=1.5*10^-3; // (A)
5 V_C=4.7; // (V)
6 g_m=40*10^-3;
7 R_f=47000;
8 R_S=10000;

```

```

9 R_C=4700;
10 r_pi=B/g_m;
11 A=-358.7*10^3; // V_o/I_i= -g_m(R_f||R_C)(R_S||R_F||
    r_pi)
12 R_i=1400; // R_i=R_S||R_f||r_pi (ohm)
13 R_o=R_C*R_f/(R_C+R_f);
14 B=-1/R_f;
15 A_f=A/(1+A*B); // V_o/I_s
16 A_v=A_f/R_S; // V_o/V_s
17 disp(A_v,"The gain (V/V)")
18 R_if=R_i/(1+A*B);
19 disp(R_if,"R_if (ohm)")
20 R_of=R_o/(1+A*B);
21 disp(R_of,"R_of (ohm)")

```

Scilab code Exa 8.4 Small signal analysis

```

1 // Example 8.4: Small signal analysis
2 R_S=10*10^3; // (ohm)
3 R_B1=100*10^3; // (ohm)
4 R_B2=15*10^3; // (ohm)
5 R_C1=10*10^3; // (ohm)
6 R_E1=870; // (ohm)
7 R_E2=3400; // (ohm)
8 R_C2=8000; // (ohm)
9 R_L=1000; // (ohm)
10 R_f=10000; // (ohm)
11 B=100; // beta value
12 V_A=75; // (V)
13 A=-201.45 // I_o/I_i (A/A)
14 R_i=1535; // (ohm)
15 R_o=2690; // (ohm)
16 B=-R_E2/(R_E2+R_f);
17 R_if=R_i/(1+A*B);
18 disp(R_if)

```

```
19 R_in=1/((1/R_if)-(1/R_S));
20 disp(R_in, "R_in (ohm)")
21 A_f=A/(1+A*B); // I_o/I_S
22 gain=R_C2*A_f/(R_C2+R_L); // I_o/I_S
23 disp(gain, "I_o/I_S (A/A)")
24 R_of=R_o*(1+A*B); // (ohm)
25 r_o2=75/0.0004; // (ohm)
26 g_m2=0.016; // (A/V)
27 r_pi2=6250; // (ohm)
28 R_out=r_o2*[1+g_m2*(r_pi2*R_of/(r_pi2+R_of))]
29 disp(R_out, "R_out (ohm)")
```

Chapter 9

Operational amplifier and data converter circuits

Scilab code Exa 9.1 Design of two stage CMOS op amp

```
1 // Example 9.1 Design of two-stage CMOS op-amp
2 A_v=4000; // (V/V)
3 V_A=20; // (V)
4 k_p=80*10^-6; // k'_n=k_n (A/V^2)
5 k_n=200*10^-6; // k'_p=k_P (A/V^2)
6 V_SS=1.65; // (V)
7 V_DD=1.65; // (V)
8 V_tn=0.5; // (V)
9 V_tp=0.5; // (V)
10 C_1=0.2*10^-12; // (F)
11 C_2=0.8*10^-12; // (F)
12 I_D=100*10^-6; // (A)
13 V_0V=sqrt(V_A^2/A_v);
14 WbyL_1=I_D*2/(V_0V^2*k_p); // WbyL_1=(W/L)_1
15 disp(WbyL_1,"Required (W/L) ratio for Q_1")
16 WbyL_2=WbyL_1; // WbyL_2=(W/L)_2
17 disp(WbyL_2,"Required (W/L) ratio for Q_2")
18 WbyL_3=I_D*2/(V_0V^2*k_n); // WbyL_3=(W/L)_3
19 disp(WbyL_3,"Required (W/L) ratio for Q_3")
```

```

20 WbyL_4=WbyL_3; // WbyL_4=(W/L) _4
21 disp(WbyL_4," Required (W/L) ratio for Q_4")
22 I_D=200*10^-6;
23 WbyL_5=I_D*2/(V_0V^2*k_p); // WbyL_5=(W/L) _5
24 disp(WbyL_5," Required (W/L) ratio for Q_5")
25 I_D=500*10^-6;
26 WbyL_7=2.5*WbyL_5; // WbyL_7=(W/L) _7
27 disp(WbyL_7," Required (W/L) ratio for Q_7")
28 WbyL_6=I_D*2/(V_0V^2*k_n); // WbyL_6=(W/L) _6
29 disp(WbyL_6," Required (W/L) ratio for Q_6")
30 WbyL_8=0.1*WbyL_5; // WbyL_8=(W/L) _8
31 disp(WbyL_8," Required (W/L) ratio for Q_8")
32 V_ICMmin=-V_SS+V_0V+V_tn-V_tp;
33 disp(V_ICMmin,"The lowest value of input common mode
    voltage")
34 V_ICMmax=V_DD-V_0V-V_0V-V_tp;
35 disp(V_ICMmax,"The highest value of input common
    mode voltage")
36 v_omin=-V_SS+V_0V;
37 disp(v_omin,"The lowest value of output swing
    allowable")
38 v_omax=V_DD-V_0V;
39 disp(v_omax,"The highest value of output swing
    allowable")
40 R_o=20/(2*0.5);
41 disp(R_o,"Input resistance is practically infinite
    and output reistance is (ohm)")
42 G_m2=2*I_D/V_0V;
43 disp(G_m2,"G_m2 (A/V)")
44 f_P2=3.2*10^-3/(2*pi*C_2);
45 disp(f_P2,"f_P2 (Hz)")
46 R=1/G_m2;
47 disp(R,"To move the transmission zero to s=infinite
    , r value selected as (ohm)")
48 f_t=f_P2*tand(15); // Phase margin of 75 degrees ,
    thus phase shift due to second pole must be 15
    degrees
49 disp(f_t,"f_t (Hz)")

```

```

50 G_m1=2*100*10^-6/V_OV; // I_D = 100uA
51 C_C1=G_m1/(2*%pi*f_t);
52 disp(C_C1,"C_C1 (F)")
53 SR=2*%pi*f_t*V_OV;
54 disp(SR,"SR (V/s)")

```

Scilab code Exa 9.2 To determine A_v , f_t , f_P , SR and PD of folded cascode

```

1 // Example 9.2 : To determine  $A_v$ ,  $f_t$ ,  $f_P$ ,  $SR$  and  $P_D$ 
  of folded cascode amplifier
2 // Consider a design of the folded-cascode op amp
3 I=200*10^-6; // (A)
4 I_B=250*10^-6; // (A)
5 V_OV=0.25; // (V)
6 k_n=100*10^-6; //  $k_n=k'_n$  (A/V^2)
7 k_p=40*10^-6; //  $k_p=k'_p$  (A/V^2)
8 V_A=20; //  $V_A=V'_A$  (V/um)
9 V_DD=2.5; // (V)
10 V_SS=2.5; // (V)
11 V_t=0.75; // (V)
12 L=1*10^-6; // (m)
13 C_L=5*10^-12; // (F)
14 disp("Data calculated for Q1")
15 I_D=I/2;
16 disp(I_D,"I_D (A)")
17 g_m=2*I_D/V_OV;
18 disp(g_m,"g_m (A/V)")
19 r_o=V_A/I_D;
20 disp(r_o,"r_o (ohm)")
21 WbyL=2*I_D/(k_n*V_OV^2); //  $WbyL = W/L$ 
22 disp(WbyL,"W/L")
23 disp("Data calculated for Q2")
24 I_D=I/2;
25 disp(I_D,"I_D (A)")
26 g_m=2*I_D/V_OV;

```

```

27 disp(g_m,"g_m (A/V)")
28 r_o=V_A/I_D;
29 disp(r_o,"r_o (ohm)")
30 WbyL=2*I_D/(k_n*V_0V^2); // WbyL =W/L
31 disp(WbyL,"W/L")
32 disp("Data calculated for Q3")
33 I_D=I_B-I/2;
34 disp(I_D,"I_D (A)")
35 g_m=2*I_D/V_0V;
36 disp(g_m,"g_m (A/V)")
37 r_o=V_A/I_D;
38 disp(r_o,"r_o (ohm)")
39 WbyL=2*I_D/(k_p*V_0V^2); // WbyL =W/L
40 disp(WbyL,"W/L")
41 disp("Data calculated for Q4")
42 I_D=I_B-I/2;
43 disp(I_D,"I_D (A)")
44 g_m=2*I_D/V_0V;
45 disp(g_m,"g_m (A/V)")
46 r_o=V_A/I_D;
47 disp(r_o,"r_o (ohm)")
48 WbyL=2*I_D/(k_p*V_0V^2); // WbyL =W/L
49 disp(WbyL,"W/L")
50 disp("Data calculated for Q5")
51 I_D=I_B-I/2;
52 disp(I_D,"I_D (A)")
53 g_m=2*I_D/V_0V;
54 disp(g_m,"g_m (A/V)")
55 r_o=V_A/I_D;
56 disp(r_o,"r_o (ohm)")
57 WbyL=2*I_D/(k_n*V_0V^2); // WbyL =W/L
58 disp(WbyL,"W/L")
59 disp("Data calculated for Q6")
60 I_D=I_B-I/2;
61 disp(I_D,"I_D (A)")
62 g_m=2*I_D/V_0V;
63 disp(g_m,"g_m (A/V)")
64 r_o=V_A/I_D;

```



```

65 disp(r_o,"r_o (ohm)")
66 WbyL=2*I_D/(k_n*V_0V^2); // WbyL =W/L
67 disp(WbyL,"W/L")
68 disp("Data calculated for Q7")
69 I_D=I_B-I/2;
70 disp(I_D,"I_D (A)")
71 g_m=2*I_D/V_0V;
72 disp(g_m,"g_m (A/V)")
73 r_o=V_A/I_D;
74 disp(r_o,"r_o (ohm)")
75 WbyL=2*I_D/(k_n*V_0V^2); // WbyL =W/L
76 disp(WbyL,"W/L")
77 disp("Data calculated for Q8")
78 I_D=I_B-I/2;
79 disp(I_D,"I_D (A)")
80 g_m=2*I_D/V_0V;
81 disp(g_m,"g_m (A/V)")
82 r_o=V_A/I_D;
83 disp(r_o,"r_o (ohm)")
84 WbyL=2*I_D/(k_n*V_0V^2); // WbyL =W/L
85 disp(WbyL,"W/L")
86 disp("Data calculated for Q9")
87 I_D=I_B;
88 disp(I_D,"I_D (A)")
89 g_m=2*I_D/V_0V;
90 disp(g_m,"g_m (A/V)")
91 r_o=V_A/I_D;
92 disp(r_o,"r_o (ohm)")
93 WbyL=2*I_D/(k_p*V_0V^2); // WbyL =W/L
94 disp(WbyL,"W/L")
95 disp("Data calculated for Q10")
96 I_D=I_B;
97 disp(I_D,"I_D (A)")
98 g_m=2*I_D/V_0V;
99 disp(g_m,"g_m (A/V)")
100 r_o=V_A/I_D;
101 disp(r_o,"r_o (ohm)")
102 WbyL=2*I_D/(k_p*V_0V^2); // WbyL =W/L

```

```

103 disp(WbyL,"W/L")
104 disp("Data calculated for Q11")
105 I_D=I;
106 disp(I_D,"I_D (A)")
107 g_m=2*I_D/V_OV;
108 disp(g_m,"g_m (A/V)")
109 r_o=V_A/I_D;
110 disp(r_o,"r_o (ohm)")
111 WbyL=2*I_D/(k_n*V_OV^2); // WbyL =W/L
112 disp(WbyL,"W/L")
113 gmro=160; // gmro=g_m*r_o
114 disp(gmro,"g_m*r_o for all transistors is (V/V)")
115 V_GS=1;
116 disp(V_GS,"V_GS for all transistors is (V)")
117 V_ICMmin=-V_SS+V_OV+V_OV+V_t;
118 disp(V_ICMmin,"The lowest value of input common mode
    voltage (V)")
119 V_ICMmax=V_DD-V_OV+V_t;
120 disp(V_ICMmax,"The highest value of input common
    mode voltage (V)")
121 v_omin=-V_SS+V_OV+V_OV+V_t;
122 disp(v_omin,"The lowest value of output swing
    allowable (V)")
123 v_omax=V_DD-V_OV-V_OV;
124 disp(v_omax,"The highest value of output swing
    allowable (V)")
125 r_o2=200*10^3; // r_o calculated for Q2
126 r_o10=80*10^3; // r_o calculated for Q10
127 R_o4=gmro*(r_o2*r_o10)/(r_o2+r_o10);
128 r_o8=133333; // r_o calculated for Q8
129 R_o6=gmro*r_o8;
130 R_o=R_o4*R_o6/(R_o4+R_o6);
131 disp(R_o,"Output resistance (ohm)")
132 G_M=0.0008;
133 A_v=G_M*R_o;
134 disp(A_v,"Voltage gain (V/V)")
135 f_t=G_M/(2*%pi*C_L);
136 disp(f_t,"Unity gain bandwidth (Hz)")

```

```

137 f_P=f_t/A_v;
138 disp(f_P,"Dominant pole frequency (Hz)")
139 SR=I/C_L;
140 disp(SR,"Slew Rate (V/s)")
141 I_t=0.5*10^-3; // total current
142 V_S=5; // Supply voltage
143 P_D=I_t*V_S;
144 disp(P_D,"Power dissipated (W)")

```

Scilab code Exa 9.3 To determine input offset voltage

```

1 // Example 9.3 : To determine input offset voltage
2 r_e=2.63*10^3; // (ohm)
3 R=1000; // (ohm)
4 I=9.5*10^-6; // (A)
5 deltaRbyR=0.02; // 2% mismatch between R_1 and R_2
6 G_m1=10^-3/5.26; // (A/V)
7 deltaI=deltaRbyR/(1+deltaRbyR + r_e/R); // Change of
   deltaI in I_E (A)
8 V_OS=deltaI/G_m1;
9 disp(V_OS,"Offset voltage (V)")

```

Chapter 10

Digital CMOS logic circuits

Scilab code Exa 10.1 To determine t_{PHL} t_{PLH} and t_P

```
1 // Example 10.1 : To determine t_PHL, t_PLH and t_P
2 // Consider CMOS inverter
3 C_ox=6*10^-15; // (F/um^2)
4 uC_n=115*10^-6; //uC_n=u_n*C_ox (A/V^2)
5 uC_p=30*10^-6; //uC_p=u_p*C_ox (A/V^2)
6 V_tn=0.4; // (V)
7 V_tp=-0.4; // (V)
8 V_DD=2.5; // (V)
9 W_n=0.375*10^-6; // W for Q_N
10 L_n=0.25*10^-6; // L for Q_N
11 W_p=1.125*10^-6; // W for Q_P
12 L_p=0.25*10^-6; // L for Q_P
13 C_gd1=0.3*W_n*10^-9; // (F)
14 C_gd2=0.3*W_p*10^-9; // (F)
15 C_db1=10^-15; // (F)
16 C_db2=10^-15; // (F)
17 C_g3= 0.375*0.25*6*10^-15+2*0.3*0.375*10^-15; // (F)
18 C_g4=1.125*0.25*6*10^-15+2*0.3*1.125*10^-15; // (F)
19 C_w=0.2*10^-15; // (F)
20 C=2*C_gd1+2*C_gd2+C_db1+C_db2+C_g3+C_g4+C_w; // (F)
21 i_DN0=uC_n*W_n*(V_DD-V_tn)^2/(2*L_n); // i_DN0 =
```

```

    i_DN(0) (A)
22 i_DNtPHL=uC_n*W_n*((V_DD-V_tn)*V_DD/2-((V_DD/2)^2)
    /2)/L_n; // i_DNtPHL = i_DN(t_PHL) (A)
23 i_DNav=(i_DN0+i_DNtPHL)/2; // i_DN|av (A)
24 t_PHL=C*(V_DD/2)/i_DNav;
25 disp(t_PHL,"t_PHL (s)")
26 t_PLH=1.3*t_PHL; // Since W_p/W_n=3 and u_n/u_p=3.83
    thus t_PLH is greater than t_PHL by 3.83/3
27 disp(t_PLH,"t_PLH (s)")
28 t_P=(t_PHL+t_PLH)/2;
29 disp(t_P,"t_P (s)")

```

Scilab code Exa 10.2 WbyL ratios for the logic circuit

```

1 // Example 10.2 : W/L ratios for the logic circuit
2 //For basic inverter
3 n=1.5;
4 p=5;
5 L=0.25*10^-6; // (m)
6 WbyL=2*n; // W/L for Q_NB , Q_NC , Q_ND
7 disp(WbyL,"W/L ratio for Q_NB")
8 disp(WbyL,"W/L ratio for Q_NC")
9 disp(WbyL,"W/L ratio for Q_ND")
10 WbyL=n; // W/L ratio for Q_NA
11 disp(WbyL,"W/L ratio for Q_NA")
12 WbyL=3*p; // W/L for Q_PA, Q_PC , Q_PD
13 disp(WbyL,"W/L ratio for Q_PA")
14 disp(WbyL,"W/L ratio for Q_PC")
15 disp(WbyL,"W/L ratio for Q_PD")

```

Scilab code Exa 10.3 To determine the parameters of pseudo NMOS in-
verte

```

1 // Example 10.3 : To determine the parameters of
  pseudo NMOS inverter
2 // Consider a pseudo NMOS inverter
3 uC_n=115*10^-6; //uC_n=u_n*C_ox (A/V^2)
4 uC_p=30*10^-6; //uC_p=u_p*C_ox (A/V^2)
5 V_tn=0.4; // (V)
6 V_tp=-0.4; // (V)
7 V_DD=2.5; // (V)
8 W_n=0.375*10^-6; // W for Q_N (m)
9 L_n=0.25*10^-6; // L for Q_N (m)
10 r=9;
11
12 // 10.3a
13 V_OH=V_DD;
14 disp(V_OH,"V_OH (V)")
15 V_OL=(V_DD-V_tn)*(1-sqrt(1-1/r));
16 disp(V_OL,"V_OL (V)")
17 V_IL=V_tn+(V_DD-V_tn)/sqrt(r*(r+1));
18 disp(V_IL,"V_IL (V)")
19 V_IH=V_tn+2*(V_DD-V_tn)/(sqrt(3*r));
20 disp(V_IH,"V_IH (V)")
21 V_M=V_tn+(V_DD-V_tn)/sqrt(r+1);
22 disp(V_M,"V_M (V)")
23 NM_H=V_OH-V_IH;
24 NM_L=V_IL-V_OL;
25 disp(NM_L,NM_H,"The highest and the lowest values of
  allowable noise margin (V)")
26
27 // 10.3b
28 WbyL_p=uC_n*(W_n/L_n)/(uC_p*r); // WbyL_p=(W/L)_p
29 disp(WbyL_p,"(W/L)_p")
30
31 //10.3c
32 I_stat=(uC_p*WbyL_p*(V_DD-V_tn)^2)/2;
33 disp(I_stat,"I_stat (A)")
34 P_D=I_stat*V_DD;
35 disp(P_D,"Static power dissipation P_D (W)")
36

```

```

37 // 10.3d
38 C=7*10^-15;
39 t_PLH=1.7*C/(uC_p*WbyL_p*V_DD);
40 disp(t_PLH,"t_PLH (s)")
41 t_PHL=1.7*C/(uC_n*(W_n/L_n)*sqrt(1-0.46/r)*V_DD);
42 disp(t_PHL,("t_PHL (s)"))
43 t_p=(t_PHL+t_PLH)/2;
44 disp(t_p,"t_p (s)")

```

Scilab code Exa 10.4 To determine parameters for NMOS transistor

```

1 // Example 10.4 : To determine parameters for NMOS
  transistor
2 // Consider NMOS transistor switch
3 uC_n=50*10^-6; //uC_n=u_n*C_ox (A/V^2)
4 uC_p=20*10^-6; //uC_px      '=u_p*C_ox (A/V^2)
5 V_t0=1; // (V)
6 y=0.5; // (V^1/2)
7 fie_f=0.6/2; // (V)
8 V_DD=5; // (V)
9 W_n=4*10^-6; // (m)
10 L_n=2*10^-6; // (m)
11 C=50*10^-15; // (F)
12
13 // 10.4a
14 V_t=1.6; // (V)
15 V_OH=V_DD-V_t; // V_OH is the value of v_O at which
  Q stops conducting (V)
16 disp(V_OH,"V_OH (V)")
17
18 // 10.4b
19 W_p=10*10^-6; // (m)
20 L_p=2*10^-6; // (m)
21 i_DP=uC_p*W_p*((V_DD-V_OH-V_t0)^2)/(2*L_p);
22 disp(i_DP,"Static current of the inverter (A)")

```

```

23 P_D=V_DD*i_DP;
24 disp(P_D,"Power dissipated (W)")
25 V_0=0.08; // Output voltage (V) found by equating
           the current of Q_N=18uA
26 disp(V_0," The output voltage of the inverter (V) ")
27
28 // 10.4c
29 i_D0=uC_n*W_n*((V_DD-V_t0)^2)/(2*2*10^-6); // i_D0=
           i_D(0) (A) current i_D at t=0
30 v_0=2.5; // (V)
31 V_t=V_t0+0.5*(sqrt(v_0+2*fie_f)-sqrt(2*fie_f)); //
           at v_O=2.5V
32 i_DtPLH=(uC_n*W_n*(V_DD-v_0-V_t)^2)/(2*L_n); //
           i_DtPLH=i_D(t_PLH) (A) current i_D at t=t_PLH
33 i_Dav=(i_D0+i_DtPLH)/2; // i_Dav=i_D|av (A) average
           discharge current
34 t_PLH=C*(V_DD/2)/i_Dav;
35 disp(t_PLH,"t_PHL (s)")
36
37 // 10.4d
38 // Case with v_t going low
39 i_D0=uC_n*W_n*((V_DD-V_t0)^2)/(2*2*10^-6); // i_D0=
           i_D(0) (A) current i_D at t=0
40 i_DtPHL=uC_n*W_n*((V_DD-V_t0)*v_0-(v_0^2)/2)/(L_n);
           // i_DtPHL=i_D(t_PHL) (A) current i_D at t=T_PHL
41 i_Dav=(i_D0+i_DtPHL)/2; // i_Dav=i_D|av (A) average
           discharge current
42 t_PHL=C*(V_DD/2)/i_Dav;
43 disp(t_PHL,"t_PHL (s)")
44
45 // 10.4e
46 t_P=(t_PHL+t_PLH)/2;
47 disp(t_P,"t_P (s)")

```

Chapter 11

Memory and advanced digital circuits

Scilab code Exa 11.1 Min WbyL ratio to ensure flip flop will switch

```
1 // Example 10.1 : To determine t_PHL, t_PLH and t_P
2 // Consider CMOS inverter
3 C_ox=6*10^-15; // (F/um^2)
4 uC_n=115*10^-6; //uC_n=u_n*C_ox (A/V^2)
5 uC_p=30*10^-6; //uC_p=u_p*C_ox (A/V^2)
6 V_tn=0.4; // (V)
7 V_tp=-0.4; // (V)
8 V_DD=2.5; // (V)
9 W_n=0.375*10^-6; // W for Q_N
10 L_n=0.25*10^-6; // L for Q_N
11 W_p=1.125*10^-6; // W for Q_P
12 L_p=0.25*10^-6; // L for Q_P
13 C_gd1=0.3*W_n*10^-9; // (F)
14 C_gd2=0.3*W_p*10^-9; // (F)
15 C_db1=10^-15; // (F)
16 C_db2=10^-15; // (F)
17 C_g3= 0.375*0.25*6*10^-15+2*0.3*0.375*10^-15; // (F)
18 C_g4=1.125*0.25*6*10^-15+2*0.3*1.125*10^-15; // (F)
19 C_w=0.2*10^-15; // (F)
```

```

20 C=2*C_gd1+2*C_gd2+C_db1+C_db2+C_g3+C_g4+C_w; // (F)
21 i_DN0=uC_n*W_n*(V_DD-V_tn)^2/(2*L_n); // i_DN0 =
    i_DN(0) (A)
22 i_DNtPHL=uC_n*W_n*((V_DD-V_tn)*V_DD/2-((V_DD/2)^2)
    /2)/L_n; // i_DNtPHL = i_DN(t_PHL) (A)
23 i_DNav=(i_DN0+i_DNtPHL)/2; // i_DN|av (A)
24 t_PHL=C*(V_DD/2)/i_DNav;
25 disp(t_PHL,"t_PHL (s)")
26 t_PLH=1.3*t_PHL; // Since W_p/W_n=3 and u_n/u_p=3.83
    thus t_PLH is greater than t_PHL by 3.83/3
27 disp(t_PLH,"t_PLH (s)")
28 t_P=(t_PHL+t_PLH)/2;
29 disp(t_P,"t_P (s)")

```

Scilab code Exa 11.2 Design of two stage CMOS op amp

```

1 // Example 11.2 Design of two-stage CMOS op-amp
2
3 uC_n=50*10^-6; // u_n*C_ox (A/V^2)
4 uC_p=20*10^-6; // u_p*C_ox (A/V^2)
5 V_tn0=1; // (V)
6 V_tp0=-1; // (V)
7 fie_f=0.6/2; // (V)
8 y=0.5; // (V^1/2)
9 V_DD=5; // (V)
10 W_n=4*10^-6; // (m)
11 L_n=2*10^-6; // (m)
12 W_p=10*10^-6; // (m)
13 L_p=2*10^-6; // (m)
14 W=10*10^-6; // (m)
15 L=10*10^-6; // (m)
16 C_B=1*10^-12; // bit line capacitance (F)
17 deltaV=0.2; // 0.2 V decrement
18 WbyL_eq=1/(L_p/W_p+L_n/W_n); // WbyL_eq=(W/L)_eq
19 // Equivalent transistor will operate in saturation

```

```

20 I=(uC_n*WbyL_eq*(V_DD-V_tn0)^2)/2
21 r_DS=1/(uC_n*(W_n/L_n)*(V_DD-V_tn0));
22 v_Q=r_DS*I; // v_Q=r_DS*I
23 I_5=0.5*10^-3; // (A)
24 deltat=C_B*deltaV/I_5;
25 disp(deltat, "The time (s) required to develop an
    output voltage of 0.2V")

```

Scilab code Exa 11.3 Time required

```

1 // Example 11.3 : Time required for v_B to reach 4.5
  V
2 // Consider sense-amplifier circuit
3 uC_n=50*10^-6; //uC_n=u_n*C_ox (A/V^2)
4 uC_p=20*10^-6; //uC_p=u_p*C_ox (A/V^2)
5 W_n=12*10^-6; // (m)
6 L_n=4*10^-6; // (m)
7 W_p=30*10^-6; // (m)
8 L_p=4*10^-6; // (m)
9 v_B=4.5; // (V)
10 C_B=1*10^-12; // (F)
11 V_GS=2.5; // (V)
12 V_t=1; // (V)
13 deltaV=0.1; // (V)
14 g_mn=uC_n*(W_n/L_n)*(V_GS-V_t); // (A/V)
15 g_mp=uC_p*(W_p/L_p)*(V_GS-V_t); // (A/V)
16 G_m=g_mn+g_mp; // (A/V)
17 T=C_B/G_m; // (s)
18 deltat=T*(log(v_B/V_GS)-log(deltaV));
19 disp(deltat, "The time for v_B to reach 4.5V (s)")

```

Chapter 12

Filters and tuned amplifiers

Scilab code Exa 12.4 To design tuned amplifier

```
1 // Example 12.4 To design tuned amplifier
2
3 cfg=-10; // Center frequency gain (V/V)
4 g_m=0.005; // (A/V)
5 r_o=10000; // (ohm)
6 f_o=1*10^6; // (Hz)
7 B=2*%pi*10^4; // Bandwidth
8 R=-cfg/g_m;
9 R_L=R*r_o/(r_o-R);
10 disp(R_L,"R_L (ohm)")
11 C=1/(R*B)
12 disp(C,"C (F)")
13 w_o=2*%pi*f_o;
14 L=1/(w_o^2*C);
15 disp(L,"L (H)")
```

Chapter 14

Output Stages and amplifier

Scilab code Exa 14.1 To design a Class B Output Amplifier

```
1 // Example 14.1 To design a Class B Output Amplifier
2
3 P_L=20; // Average power (W)
4 R_L=8; // Load resistance (ohm)
5 V_o=sqrt(2*P_L*R_L);
6 disp(V_o,"Supply voltage required (V)")
7 V_CC=23; // We select this voltage (V)
8 I_o=V_o/R_L;
9 disp(I_o,"Peak current drawn from each supply (A)")
10 P_Sav=V_CC*I_o/%pi; // P_S+ = P_S- = P_Sav
11 P_S=P_Sav+P_Sav; // Total supply power
12 disp(P_S,"The total power supply (W)")
13 n=P_L/P_S; // n is power conversion efficiency
14 disp(n*100,"Power conversion efficiency %")
15 P_DPmax=V_CC^2/(%pi^2*R_L);
16 P_DNmax=P_DPmax;
17 disp(P_DPmax,"Maximun power dissipated in each
    transistor (W)")
```

Scilab code Exa 14.2 To determine quiescent current and power

```
1 // Example 14.2 To determine quiescent current and
  power
2 // Consider Class AB Amplifier
3 V_CC=15; // (V)
4 R_L=100; // (ohm)
5 v_0=-10:10:10; // Amplitude of sinusoidal output
  voltage (V)
6 I_S=10^-13; // (A)
7 V_T=25*10^-3; // (V)
8 B=50; // Beta value
9 i_Lmax=10/(0.1*10^3); // Maximum current through Q_N
  (A)
10 // Implies max base current in Q_N is approximately
  2mA
11 I_BIAS=3*10^-3; // We select I_BIAS=3mA in order to
  maintain a minimum of 1mA through the diodes
12 I_Q=9*10^-3; // The area ratio of 3 yeilds quiescent
  current of 9mA
13 P_DQ=2*V_CC*I_Q;
14 disp(P_DQ,"Quiescent power dissipation (W)")
15 //For v_O=0V base current of Q_N is 9/51=0.18 mA
16 // Leaves a current of 3-0.18=2.83mA to flow through
  the diodes
17 I_S= (10^-13)/3; // Diodes have I_S = (1*10^-13)/3
18 V_BB=2*V_T*log((2.83*10^-3)/I_S);
19 disp(V_BB,"V_BB (V) for v_O = 0V")
20 // For v_O=+10V, current through the diodes will
  decrease to 1mA
21 V_BB=2*V_T*log((1*10^-3)/I_S);
22 disp(V_BB,"V_BB (V) for v_O = +10V")
23 // For v_O=-10V , Q_N will conduct very small
  current thus base current is negligible
24 // All of the I_BIAS(3mA) flows through the diodes
25 V_BB=2*V_T*log((3*10^-3)/I_S);
26 disp(V_BB,"V_BB (V) for v_O = -10V")
```

Scilab code Exa 14.3 Redesign the output stage of Example 2

```
1 // Example 14.3 Redesign the output stage of Example
   14.2
2 V_T=25*10^-3; // (V)
3 I_S=10^-14; // (A)
4 I_Q=2*10^-3; // Required quiescent current (A)
5 // We select I_BIAS=3mA which is divided between I_R
   and I_C1
6 // Thus we select I_R=0.5mA and I_C1=2.5mA
7 V_BB=2*V_T*log(I_Q/10^-13);
8 disp(V_BB,"V_BB (V)")
9 I_R=0.5*10^-3;
10 R1plusR2=V_BB/I_R; // R1plusR2 = R_1+R_2
11 I_C1=2.5*10^-3;
12 V_BE1=V_T*log(I_C1/I_S);
13 disp(V_BE1,"V_BE1 (V)")
14 R_1=V_BE1/I_R;
15 disp(R_1,"R_1 (ohm)")
16 R_2=R1plusR2-R_1;
17 disp(R_2,"R_2 (ohm)")
```

Scilab code Exa 14.4 To determine thermal resistance junction temperat

```
1 // Example 14.4 To determine thermal resistance ,
   junction temperature
2 // Consider BJT with following specifications
3 P_D0=2; // Maximum power dissipation (W)
4 T_A0=25; // Ambient temperature (degree celcius)
5 T_Jmax=150; // maximum junction temperature (degree
   celcius)
6
```

```

7 // 14.4a
8 theta_JA=(T_Jmax-T_A0)/P_D0; // Thermal resistance
9 disp(theta_JA,"The thermal resistance (degree
    celsius/W)")
10
11 // 14.4b
12 T_A=50; // (degree celcius)
13 P_Dmax=(T_Jmax-T_A)/theta_JA;
14 disp(P_Dmax,"Maximum power that can be dissipated at
    an ambient temperature of 50 degree celcius (W)"
    )
15
16 // 14.4c
17 T_A=25; // (degree celcius)
18 P_D=1; // (W)
19 T_J=T_A+theta_JA*P_D;
20 disp(T_J," Junction temperature (degree celcius) if
    the device is operating at T_A=25 degree celcius
    and is dissipating 1W")

```

Scilab code Exa 14.5 To determine the maximum power dissipated

```

1 // Example 14.5 To determine the maximum power
    dissipated
2 // Consider a BJT with following specifications
3 T_Jmax=150; // (degree celcius)
4 T_A=50; // (degree celcius)
5
6 // 14.5a
7 theta_JA=62.5; // (degree celcius/W)
8 P_Dmax=(T_Jmax-T_A)/theta_JA;
9 disp(P_Dmax,"The maximum power (W) that can be
    dissipated safely by the transistor when operated
    in free air")
10

```



```

11 //14.5b
12 theta_CS=0.5; // (degree celcius/W)
13 theta_SA=4; // (degree celcius/W)
14 theta_JC=3.12; // (degree celcius/W)
15 theta_JA=theta_JC+theta_CS+theta_SA;
16 P_Dmax=(T_Jmax-T_A)/theta_JA
17 disp(P_Dmax,"The maximum power (W) that can be
    dissipated safely by the transistor when operated
    at an ambient temperature of 50 degree celcius
    but with a heat sink for which theta_CS= 0.5 (
    degree celcius/W) and theta_SA = 4 (degree
    celcius/W) (W)")

18
19 // 14.5c
20 theta_CA=0 // since infinite heat sink
21 P_Dmax=(T_Jmax-T_A)/theta_JC;
22 disp(P_Dmax,"The maximum power (W) that can be
    dissipated safely if an infinite heat sink is
    used and T_A=50 (degree celcius)")

```
