

Scilab Textbook Companion for  
Microelectronic Circuits  
by A. S. Sedra And K. C. Smith<sup>1</sup>

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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  $v_o$ 
   = $10 - (10^{-11}) * (\exp^{40 * v_i})$  applies for  $v_i$  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<sub>PHL</sub>

```

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 // 2.1a
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  $I_D$  and  $V_D$

```
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 amplifie

```

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 V_BE=0.7;
6 R_B=100*10^3; // (ohm)
7 B=100; // beta value
8 I_B=(V_BB-V_BE)/R_B;
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 V_B=V_BE ; // V_B=V_BE
15 disp(V_B," Base voltage (V)")
16 I_E=(B+1)*I_B;
17 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_E=(V_BB-V_BE)/(R_E +(R_BB/(B+1)));
14 disp(I_E,"Emitter current (A)")
15 I_B=I_E/(B+1)
16 disp(I_B,"Base current (A)")
17 V_B=V_BE+I_E*R_E;
18 disp(V_B,"Base voltage (V)")
19 a=B/(B+1); // alpha value
20 I_C=a*I_E
21 disp(I_C,"Collector current (A)")
22 V_C=V_CC-I_C*R_C;
23 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_E1*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_E1
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 B=100;
4 R_C=3000; // (ohm)
5 R_BB=100*10^3; // (ohm)
6 V_BB=3; // (V)
7 V_BE=0.7; // (V)
8 V_T=25*10^-3; // (V)
9 I_B=(V_BB-V_BE)/R_BB;
10 disp(I_B,"Base current (A)")
11 I_C=B*I_B;
12 disp(I_C,"Collector current (A)")
13 V_C=V_CC-I_C*R_C;
14 disp(V_C,"Collector voltage (V)")
15 I_E=B*I_C/(B+1);
16 r_e=V_T/I_E;
17 disp(r_e,"r_e (ohm)")
18 g_m=I_C/V_T;
19 disp(g_m,"g_m (mho)")
20 r_pi=B/g_m;
21 disp(r_pi,"r_pi (ohm)")
22 // v_i is input voltage let us assume it to be 1 V
23 v_i=1;

```

```

24 v_be=v_i*r_pi/(r_pi+R_BB)
25 disp(v_be,"v_be")
26 v_o=-g_m*R_C*v_be;
27 disp(v_o,"Output voltage (V)")
28 A_v=v_o/v_i;
29 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_T=25*10^-3;
5 V_EE=10; // (V)
6 I=0.001; // (A)
7 R_B=100000; // (ohm)
8 R_C=8000; // (ohm)
9 R_sig=5000; //(ohm)
10 R_L=5000; // (ohm)
11 B=100; // beta value
12 V_A=100; // (V)
13 C_u=1*10^-12; // (F)
14 f_T=800*10^6; // (Hz)
15 I_C=0.001; // (A)
16 r_x=50; // (ohm)
17 // Values of hybrid pi model parameters
18 g_m=I_C/V_T;
19 r_pi=B/g_m;
20 r_o=V_A/I_C;
21 w_T=2*%pi*f_T;

```

```

22 CpiplusCu=g_m/w_T; // C_u+C_pi
23 C_pi=CpiplusCu-C_u;
24 R_l=r_o*R_C*R_L/(r_o*R_C+R_C*R_L+R_L*r_o) // R_l=R_L
,
25 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))));
26 disp(A_M,"Midband gain (V/V)")
27 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
28 C_in=C_pi+C_u*(1+R_l*g_m);
29 f_H=1/(2*pi*C_in*R_seff);
30 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 transis

```
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 V_T=0.025;
8 K_n=267*4/0.4*10^-6; // K_n=u_n*C_ox*(W/L) (A/V^2)
9 V_0V=sqrt(2*I_D/K_n);
10 g_m=sqrt(2*K_n*I_D)
11 disp(g_m,"g_m (A/V)")
12 disp("R_in is infinite")
13 r_o=V_a*L/I_D;
14 disp(r_o,"r_o (ohm)")
15 A_0=g_m*r_o;
16 disp(A_0,"A_0 (V/V)")
17 disp("For npn transistor")
18 I_C=0.1*10^-3; // collector current
19 B_o=100; // beta value
20 V_A=35; // (V)
21 g_m=I_C/V_T;
22 disp(g_m,"g_m (A/V)")
23 R_in=B_o/g_m;
24 disp(R_in,"R_in (ohm)")
25 r_o=V_A/I_C;
26 disp(r_o,"r_o (ohm)")
27 A_0=g_m*r_o;
28 disp(A_0,"A_0 (V/V)")
```

---



### Scilab code Exa 6.3 Comparison between NMOS transistor and npn transis

```
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_Omin=V_OV;

```

```

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 amplif

```

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 casc

```

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 inverte

```

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)")

```

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