Scilab Textbook Companion for Integrated Circuits by K. R. Botkar[1]

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Book Description

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

Contents

List of Scilab Codes

Chapter 2

Thick Film And Thin Film Hybrid ICs

Scilab code Exa 2.1 Resistance

```
//Chapter 2_Thick Film and Thin Film Hybrid ICs
//Caption : Resistance
//Example2.1: a) A resistor has an aspect ratio of
   20:1 and sheet resistance of 200 ohm/square. Find
    out the value of resistance.
// b) Find out the number of squares contained in a
   2kiloohm resistor whose sheet resistance is 200
   ohm per square.
//Solution: a)
clear;
clc;
function y= myfunction(x,z)//y:resistance, x: sheet
   resistance=200ohm/square, z: aspect ratio=20:1
y = x*z //since,resiatance=sheet resistance
disp('resistance is=")
disp('ohm',y)
endfunction

// Solution: b)
```

```
// we have to find number of square which is to find
    aspect ratio.
function s=myfunction1(r,p)//r:resistor=2kohm(or
   2000ohm), p:sheet resistance=200 Ohm/square, s:
   number of square(aspect ratio)
s=r/p//since, number of square=(resistor/sheet
   resistance)
disp('number of squares are=")// include ";"at the
   time of calling the function
disp('squares',s)
endfunction
//myfunction(200,20/1);myfunction1(2000,200);
```

Scilab code Exa 2.2 Resistance Calculation

```
//Chapter 2_Thick Film and Thin Film Hybrid ICs
//Caption: Resistance calculation
//Example2.2: A thick film resistor is screened with
    a paste off sheet resistivity 10000 ohm/square,
   and the resistor is defined as 0.24 cm long and
   0.06 cm wide. Calculate the resistance R.
// Solution:
clear;
clc;
function R=myfunction3(p,l,w)//r:resistor, p=sheet
   resistance=10000 ohm/square, l:length of resistor
   =0.24cm, w:width of the resistor=0.06cm
    R=p*(l/w)//since, resistance=sheet resistance*(
       length of resistor/width of the resistor)
    disp('resistance of the thick film resistor is='
       )// at the time of calling the function
       include ";" after it
    disp('ohm',R)
endfunction
// myfunction3(10000,0.24,0.06);
```

Scilab code Exa 2.3 Sheet Resistivity

```
//Chapter 2_Thick Film and Thin Film Hybrid ICs
//Caption : Sheet Resistivity
//Example2.3: Calculate the sheet resistivity of a
   square of thick film resistor material with the
   following properties: bulk resistivity=10^-1ohm-
   cm and thick film thickness=10micrometer.
//Solution:
clear;
clc;
function Ps=myfunction4(p,t)// Ps:sheet resistance,
   p:bulk resistivity of thick film=10^-1(or 0.01),
   t:thickness of thick film=10micrometer
   (=10*10^-4=0.001)
    Ps=p/t// since, sheet resistance of the film=
       bulk resistance of the film/thickness of the
       film
    disp('sheet resistivity is=')// include ";" atat
        the time of calling the function
    disp('ohm per square',Ps)
endfunction
//myfunction4(10^-1,10*10^-4);
```

Scilab code Exa 2.4 Design Capacitor

```
//Chapter 2_Thick Film and Thin Film Hybrid ICs
//Caption : Design Capacitor
//Example2.4: Design a circular 100pF capacitor with
    the thick film dielectric having dielectric film
    thickness=0.02mm(or 0.002cm), assume Er=100
```

```
//Solution: We have to find the radius of crcular
   capacitor inorder to design it.
clear;
clc;
function r1= myfunction5(c,t)
    r1=c*t// constant=capacitor * thickness of thick
        film
    Er=100//given relative permeability of thick
       film
    r=sqrt(r1/(Er*%pi*8.85*10^-12))//radius of
       circular capacitor, Eo=8,85*10^-12(dielectric
        constant of free space)
    disp('radius of circular capacitor is=')//
       include ";" at the time of calling the
       function
    disp('meter',r)
endfunction
//myfunction5(100*10^-12,0.002);
```

Scilab code Exa 2.6 Capacitance

```
//Chapter 2_Thick Film and Thin Film Hybrid ICs
//Caption : Capacitance
//Example2.6: Find out the capacitance of a thick
   film capacitor,if the dielectric constant Er=100,
   dielectric film thickness=25micrometer and area A
   =0.0625 cm square.
//Solution:
clear;
clc;
function c=capacitance(Er,A,t)
    c=8.8*10^-12*Er*A/(10^-12*t)// capacitance value
        will be 2.2*10^-10 or 220pF, Eo:dielectric
       constant of free space=8.8*10^-12, Er:
       dielectric constant of thick film= 100(given)
```

```
, A:area of thick film=0.0626 cm square( or 0.0625*10^-4m square), t:thickness of the thick film= 25*10^-6m)
    // capacitance=Eo*Er*A/t
    disp('capacitance is=')// c=2.200D-10(=2.2*10^-10)F, include ";" at last at the time of calling the function
    disp('pF',c)//pF:pico Farad
endfunction
//capacitance(100,0.0625*10^-4,25*10^-6);
```

Scilab code Exa 2.8 Thickness

```
//Chapter 2_Thick Film and Thin Film Hybrid ICs
//Caption : Thickness
//Example2.8: The bulk resistivity of nichrom is 120 uohm-cm. Calculate the thickness T in angstroms of a film with sheet resistivity of 100ohm/square.
// Solution:
function T=thickness(Ps,p)// Ps: sheet resistivity of nichrom=100ohm/square, p:bulk resistivity of nichrom=120uohm-cm
    T=p/(Ps*10^-8)// since Ps=p/T and 1 angstrom=10^-8cm, so dividing by 10^-8 here
    disp('thickness is=')// include ";" at the time of callimg the function
    disp('angstrom',T)
endfunction
//thickness(100,120*10^-6);
```

Scilab code Exa 2.9 Length

```
//Chapter 2_Thick Film and Thin Film Hybrid ICs
//Caption : Length
//Rxample2.9: Calculate the length of a 400ohm thin
   film resistor.Given a sheet resistivity oof 100
   ohm/square and a resistor width of 100um
//Solution:
clear;
clc;
function L=extent(r,w,Ps)// L:length of thin film, r
   :resistance of thin film=400ohm, w:width of
   resistor=100um, Ps:sheet resistance=100ohm/square
  L=r*w/(10^-6*Ps)//since, r=Ps*L/w and length in
     micrometer so dividing by 10^-6.
  disp('length of thin film is=')// include";" at
     the time of calling the function at last
  disp('micrometer',L)
endfunction
//extent(400,100*10^-6,100);
```

Scilab code Exa 2.10 Absolute Coefficient

```
//Chapter 2_Thick Film and Thin Film Hybrid ICs
//Caption : Absolute Coefficient
//Example2.10:A thin film resistor measures 150ohmat
    25degree celcius and 151.5ohm at 100degree
   celcius. Calculate its absolute coefficient of
   resistance in parts per million(ppm) per degre
   celcius.
//Solution:
clear;
clc;
function TCR=absresistor(Rt1,Rt2,T1,T2)// TCR:
   absolute temperature coefficient of resistance,
   Rt1:resistance at 100 degree celcius=150ohm, Rt2:
   resistance at 25degree celcius=151.5ohm, T1:
```

```
temperature=100degree celcius , T2:temperature=25 degree celcius
    TCR=(Rt2-Rt1)*10^6/(Rt1*(T1-T2))
    disp('absolute coefficient of resistance is=")// include ";" at the time of calling the function at last
    disp('ppm/degree Celsius',TCR)// ppm: part per million
endfunction
//absresistor(150,151.5,100,25);
```

Scilab code Exa 2.11 Ratio

```
//Chapter 2_Thick Film and Thin Film Hybrid ICs
//Caption : Ratio
//Example2.11: Two thin resistor are measured at 50 degree celcius and 100degree celsius and are found to have the following values:
//Temperatur(degree C)                    Ra(ohm)                    Rb(ohm)
//       50                                    50                         100
//       100                                   51                         102.1
//Calcullate the ratio TCR in ppm/degree celcius.
//Solution:
function TCR= ratio(Rat1,Rbt1,Rat2,Rbt2,T1,T2)
    TCR=(Rat2/Rbt2-Rat1/Rbt1)*10^6/((Rat1/Rbt1)*(T1-T2))
    disp('ratio TCR is=")// iinclude ";" at the time of calling the function at last
    disp('ppm/degree Celsius',TCR)//ppm: part per million
endfunction
//ratio(100,50,102.1,51,100,50);
```

Chapter 3

Semoconductor Devices Fundamentals

Scilab code Exa 3.2 Resistivity

```
//Chapter 3_Semoconductor Devices Fundamentals
//Caption : Resistivity
//Example3.2: A Sample of Si is doped with 10^17
   phosphorus atoms/cubic cm. What is its
   resistivity? Given Un=700square cm/v-sec.
//Solution:
clear;
clc;
function Res=resistivity(u,n)//n:doped concentration
   =10^17 atoms/cubic cm,  u: mobility of electrons
   =700square cm/v-sec.
   q=1.6*10^-19 //q:charge
   Res=1/(q*u*n)// since P is neglegible.
   disp('resistivity of the si doped with     n-
      dopant is:')// include ";" at the time of
      calling
   disp('ohm-cm',Res)
endfunction
// after executing calling resitivity( u=700 and n
```

```
    =10^17)i.e.,                    resistivity
    (10^17,700);
// Result: Resistivity of the Si doped with n-dopant
     is : 0.089 ohm-cm(approx)
```

Scilab code Exa 3.3 Resistivity of Intrinsic Ge

```
//Chapter 3_Semoconductor Devices Fundamentals
//Caption : Resistivity of Intrinsic Ge
//Example3.3: Find the resistivity of intrinsic Ge
    at 300K. Given un=3900, and up=1900 cm^2/N sec.
    and ni=2.5*10^13 cm^-3for intrinsic Ge.
//Solution:
function RES=resistivity(un,up)// un:electron
    concentration , up:hole concentration
  q=1.6*10^-19;//in coulumb
  ni=2.5*10^13;//concentration in cm^-3
  RES=1/(q*ni*(un+up))//since n=p=ni
  disp('resistivity of intrinsic Ge is :')
  disp('ohm-cm',RES)
endfunction
//resistivity(3900,1900);
```

Scilab code Exa 3.4 Hole Concentration

```
//Chapter 3_Semoconductor Devices Fundamentals
//Caption: Hole Concentration
//Example3.4: A semiconductor is doped with a
    concentration of 10^17 atoms/cm^3 of rsenic .
    What is the equilibrium hole concentration p at
    300K. Given ni=1.5*10^10 cm^-3
// Solution:
clear;
```

```
clc;
function p=holeconcentration(ni,Nd)//ni=intrinsiic
    concentration=1.5*10^10 cm^-3, Nd: donar
    concentration; since, Nd>>ni, so Nd=n=10^17 atoms
    /cm^3.
  p=ni^2/Nd
  disp('hole concentrartion at 300K is:')
  disp('per cubic cm',p)
endfunction
//holeconcentration(1.5*10^10,10^17);
```

Scilab code Exa 3.5 Resistivity of Cu

```
//Chapter 3_Semoconductor Devices Fundamentals
//Caption: Resistivity of Cu
//Example3.5:The resistivity of metal is given by p
    =1/nqu, where n is number of electrons per cubic
    meter, u is mobility ,a nd q is electronic charge
    . Determine the resistivit of copper at room
    temperature. Given n=8.5*10^28 per cubic meter, u
    =3.2*10^-3 m^2/V-sec, at room temperature.
//Solution:
q=1.6*10^-19;
n=8.5*10^28;
u=3.2*10^-3;
p=1/(n*q*u);
disp('resistivity of the copper is :')
disp('ohm-meter',p)
//  2.298D-08  means 2.298*10^-8
```

Scilab code Exa 3.6 Bipolar Transistor Parameters

```
//Chapter 3_Semoconductor Devices Fundamentals
```

```
//Caption : Bipolar Transistor Parameters
//Example3.6: Determine Cu,Ccs,Gm,C1,R1,R0 and Ru for a bipolar transisitor. Given : Ic=0.2 mA, Vcb=10V,Vcs=15V,Cuo=0.25pF,Cje=1 pF,Ccso=1.5pF,Bo=2000,Tf=0.3ns, n=2*10^-4 and Vo=0.55V for all junctions.
// Solution:
clear;
clc;
Cuo=0.25;// collector-base depletion region capacitance in pico Farad(pF) for zero bias
Ccso=1.5 ;// collector-substrate junction capacitance in pico Farad(pF) for zero bias
q=1.6*10^-19 ;//electron charge in coulomb
Ic=0.2 ;//collector current in ampere(A)
k=8.6*10^-5;//in eV/K, where 1eV=1.6*10^-19
T=300;//absolute temperature in kelvin(K)
Vcb=10 ;//forward bias on the junction in volt(v)
Vcs=15 ;//collector-substrate bias in volt(V)
Cje=1 ;//depletion region capacitance in pico Farad(pF)
Bo=200;//small signal current gain
Tf=0.3;//transit time in forward direction in nano seconds(nS)
n=2*10^-4;// proportionality constant for Ro and gm
Vo=0.55;// bias voltage in volt(V)
Cu=Cuo/sqrt(1+(Vcb/Vo));// collector-base capacitance
disp('Cu is:')
disp('pF',Cu)
Ccs=Ccso/sqrt(1+(Vcs/Vo));// collector-substrate capacitance
disp('Ccs is:')
disp('pF',Ccs)
gm=q*Ic/(k*T*1.6*10^-19);// since k is in eV so converting it in Coulomb/Kelvin
disp('gm is:')// transconductance of the bipolar transistor here
```

```
disp('mA/V',gm)
Cb=Tf*gm;//diffusion capacitance in pico Farad(pF)
C1=Cb+Cje;//small signal capacitance of bipolar
    transistor
disp("C1 is:")
disp("pF",C1)
R1=Bo/gm;// small signal input resistance of bipolar
     transistor
disp('R1 is:')
disp('kilo Ohm',R1)
Ro=1/(n*gm);//small signal output resistance
disp('R0 is')
disp('kilo Ohm',Ro)
Ru=10*Bo*Ro/10^3;//collector-base resistance
disp('Ru is:')
disp('Mega Ohm',Ru)
```

Chapter 5

Monolithic Components

Scilab code Exa 5.1 Transit Time

```
//Chapter 5_Monolithic Components
//Caption : Transit Time
//Example5.1: A lateral pnp device base width is 8 um and the diffusion cofficient for base region is 10 cm^2/sec. Calculate the base transit time and the unity gain frequency.
//Solution:
function T=transittime(W,D)//W:base width=8um; D:base diffusion cofficient=10 sq cm/sec.
    T= W^2/(2*D);// since f(transit frequency response )=2*D/(W^2)
    disp('base transit time is:')
    disp('ns',T*10^9)// in nanoseconds(ns)
    F=1/(2*%pi*T)// where F=unity gain frequency =1/(2*%pi*transit time)
    disp('unity gain frequency is:')
    disp('MHz',F/10^6)// in Mega Hertz
endfunction
//transittime((8*10^-6),10*10^-4);
```

Scilab code Exa 5.2 Unit gain frequency

```
//Chapter 5_Monolithic Components
//Caption : Unit gain frequency
//Example5.2: a) Find Fl(unit gain frequency ) for
   the lateral pnp device. Assume diffusion
   coefficient of holes in the base of 0.5 sq cm/sec
   and base width of 10um.
// b) Find the Fs(unit gain frequency) for the
   substrate pnp device.Assume D=20 sqcm/sec and W=8
   um.
clear;
clc;
//a)Solution: for the lateral pnp device
Wl=10*10^-4;//base width in micro centimeter(ucm)
Dl=0.5;// base diffusion cofficient in sq cm/sec
Fl=2*Dl/(Wl^2);
disp('unit gain frequency for lateral pnp  device is
   ;' )
disp('MHz',Fl/10^6)
//b)Solution: for substrate pnp device
Ws=8*10^-4;// base in ucm
Ds=20;//base diffusion cofficient in sq cm/sec
Fs=Ds/(Ws^2);
disp('unit gain frequency for substrate pnp device
   is;')
disp('MHz',Fs/10^6)
```

Scilab code Exa 5.3 Resistance and Sheet resistance

```
//Chapter 5_Monolithic Components
//Capation : Resistance and Sheet resistance
```

```
//Example5.3: a)A base diffusion layer length is 100 um and it's width is 10um.The sheet resistance of the layer is 100 ohm/square.Calculate its resistance.
//b) Calculate the sheet resistance of a 20um thick ,5 ohm-cm ep-layer.
//a)Solution:
L=100;//base diffusion layer in um
W=10;//base diffusion width in um
Rs=100;//sheet resistance in ohm/square
R=L*Rs/W;
disp('resistance of base diffusion layer is:')
disp('Ohm',R)
//b)Solution:
Pe=5*10^-2;//ep-layer resistivity in ucm
t=20*10^-6;//thickness of the layer in um
Rse=Pe/t;//sheet resitivity of ep-layer
disp('sheet resistance of ep-layer is:')
disp('Ohm',Rse)
```

Scilab code Exa 5.4 Capacitance per unit area

```
//Chapter 5_Monolithic Components
//Caption : Capacitance per unit area
//Example5.4: Determine the capacitance per unit area of the 400 armstrong gate oxide of a MOSFET device relative permittivity of silicon dioxide =3.9.
//Solution:
clear;
clc;
Eo=8.86*10^-14;//permittivity of free space in F/cm
Er=3.9;//relative permittivity of MOSFET device
t=0.4*10^-5;//thickness of the gate oxide in cm
Co=Eo*Er/t;// since capoacitance(C)=permittivity(E)*
```

```
    area(A)/thicknes(t);          so C/A=e/t
disp('capacitance per unit area of gate oxide is:')
disp('F/cm^2',Co)
```

Chapter 7

Operational Amplifier Characteristics

Scilab code Exa 7.1 Bipolar Differential Amplifier Parameter

```
//Chapter 7_Operational Amplifier Characteristics
//Caption : Bipolar Differential Amplifier Parameter
//Example7.1: The following specification are given
    for the dual input,balanced output bipolar
    diferential amplifier:
//Rc=2.2 kOhm,Re=4/7kOhm,Rs=50 ohm,Vcc=10V,Vee=-10V
    and Bf=Bo=100. Assume       Vbe=0.7V.
//Determine
//a)Icq and Vceq
//b)Differential-mode voltage fgain , and
//c)Input and output resistances.
clear;
clc;
//a)Solution:\
Rc=2.2*10^3;// collector resistance in one
    transistor in ohm
Re=4.7*10^3;// emitte resitance of one transistor in
     ohm
Rs=50;//base or source resitance of one transistor
```

```
   in ohm
Vcc=10;// collector power supply in Volt
Vee=-10;// negative emitter power supply
Bf=100;// gain of the transistor
Bo=Bf;
Vbe=0.7;//base emitter voltage of one transiator
Icq=(abs(Vee)-Vbe)/(2*Re+(Rs/Bf));
Vceq=Vcc+Vbe-Rc*Icq;
//b)Solution:
gm=Icq/(25*10^-3);// where transconductance gm=Ic/Vt
   , Vt=25mV at room temperature, so  gm =Ic/25
Ad=-gm*Rc;// differential mode voltage gain Icq here
    will be taken as found above  not approximated
   to as given book
//c)Solution:
r=Bo/gm;// input resistance of one transistor
Ri=2*r;//differential mode input resistance
Ro=Rc;//differential mode output resistance
disp('A',Icq*10^3,'operating point collector current
   ')
disp('V',Vceq,'collector-to-emitter voltage is:')
disp(abs(Ad),'Differential-mode voltage gain')
disp('kilo Ohm',Ri/10^3,'Input Resistance')
disp('kilo Ohm',Ro/10^3,'Output Resistance')
// Note:
//value of  Icq is taken as 0.0009893 A or 0.9893 mA
    not approximated to 0.98 mA
```

Scilab code Exa 7.2 Rc and Re

```
//Chapter 7_Operational Amplifier Characteristics
//Caption : Rc and Re
//Example7.2: A bipolar differentail amplifier uses
   a transistor having Bo=200 and biased at Icq=100
   uA. Determine Rc and Re so that abs(Ad)=500 and
```

```
   CMRR=80 dB.
// Solution:
clear;
clc;
//CMRR in dB is expressed as 20logCMRR, so 80=20
   logCMRR or
CMRR=10^(80/20);
Icq=100*10^-6;//collector current
Vt=25*10^-3;//standard value of threshold voltage at
    room temperature
gm=Icq/Vt;
Re=CMRR/(2*gm);//since CMRR=2*gm*Re(approx)
Ad=500;// absolute value of differential mode
   voltage gain
Rc=-Ad/gm;//Collector resistance
disp('Mega Ohm',Re/10^6,'emitter resitance(Re) of
   bipolar differential amplifier is:')
disp('Kilo Ohm',abs(Rc)/10^3,'collector resistance(
   Rc) of bipolar differential amplifier is:')
```

Scilab code Exa 7.4 Offset Voltage Change

```
//Chapter 7_Operation Amplifier Characteristics
//Caption : Offset Voltage Change
//Example7.4: What is the change in the offset
   voltage of a bipolar transistor amplifier for a
   difference of 10V in the collector-to-emitter
   voltage and Va=250 V. Assume room temperature.
//Solution:
clear;
clc;
Vt=25*10^-3;// threshold voltage at room temperature
    in Volt
Va=250;//early voltage of the bipolar transistor in
   volt
```

```
deltaVce=1;//let us assume 1V of change in Vce(
   collector-to-emitter voltage)
deltaVos1=Vt*(-deltaVce/Va);
disp('mV',abs(deltaVos1)*10^3,'change in offset
   voltage for 1 V change in Vce is:')
for i=1:1,
    if i==1 then
        deltaVce=10;// in volt
        deltaVos=deltaVce*deltaVos1;
        disp('mV',abs(deltaVos)*10^3,'change in
           offset voltage of bipolar transistor for
           10V collector-to-emitter voltage(Vce)
           difference is:')
    end
end
```

Scilab code Exa 7.5 Temperature Coefficient

```
//Chapter 7_Operational Amplifier Characteristics
//Caption : Temperature Coefficient
//Example7.5: Determine the temperature coefficient
   of the input offset voltage for the bipolar
   differential amplifier having Vos=1.5 mV. What is
    the percentage change in the Vos per degree
   temperature change.
//Solution:
clear;
clc;
// temperature cofficient of the input offset
   voltage for the bipolar differential amplifier
   Vos is=dVos/dT=Vos/T;
Vos=1.5*10^-3;//input offset voltage for bipolar
   differential transistor amplifier
T=300;// assuming room temperature
TC=Vos/T;// temperature cofficient of Vos
```

```
//percentage change in the Vos per degree
   temperature change will be given by as follow:
PC=(TC/Vos)*100;// percentage change(PC) in the Vos
   per degree temperature change
disp('%per degree celcius',PC,'percentage change in
   the Vos  per degree temperature change is:')
```

Scilab code Exa 7.14 Effect on Output Voltage

```
//Chapter 7_Operational Amplifier Characteristics
//Caption : Effect on Output Voltage
//Example7.14: For the noninverting OP-Amp with
   input resistance R1 nad feedback resistance R2
   find the effect on output voltage Vo because of
   the common mode voltage Vcm when the input
   voltage Vs changes by 1V. Given CMRR=70 dB.
//Solution:
clear;
clc;
CMRR=70;//Common Mode Rejection Ratio in dB
// since CMRR=20*log(Vcm/Vdm) dB
//so Vdm=Vcm/10^(CMRR/20)
//since output voltage of OP-Amp is Vo=(R1+R2)*Vdm/
   R1=(R1+R2)*Vcm/(R1*10^(CMRR/20))
R1=100;//assuming input resistance standard value in
    kilo Ohm
R2=900;//assuming feedback resistance standard value
    in kilo Ohm
Vs=1;//change in input voltage given in question
Vcm=Vs;//since change in input voltage is applied to
    noninverting input and through the feedback to
   the inverting iput of the Op-Amp as well.
Vo=(R1+R2)*Vcm/(R1*10^(CMRR/20))
disp('mV',abs(Vo)*10^3,'change in output voltage due
    to common mode Voltage(Vcm) is:')
```

```
//Note:
// CMRR,Vdm,Vo may be of either polarity. Here
   absolute value is calculated
```

Scilab code Exa 7.15 Slew rate and Fmax

```
//Chapter 7_Operational Amplifier Characteristics
//Caption : Slew rate and Fmax
//Example7.15: For type 741 Op-Amp following
   parameter are given.Quiescent collector current
   Ic=9.5 uA, Cc=30 pF. Peak amplitude of input
   voltage Vm=15V.
//a)Determine the slew rate
//b)Determine full power bandwidth Fmax for the slew
    rate as obtained from part (a).
clear;
clc;
//a)Solution:
Ic=9.5*10^-6;// operating collector current in A
Cc=30*10^-12;// parasitic capacitance
SlewRate=2*Ic/Cc;
disp('V/us',SlewRate/10^6,'Slew rate is:')
//b)Solution:
Vm=15;//amplitude of input voltage in Volt
Fmax=SlewRate/(2*%pi*Vm);// full power bandwidth
disp('kHz',Fmax/10^3,'full power bandwidth Fmax for
    the Slew Rate obtained above is:')
```

Scilab code Exa 7.16 Largest Amplitude

```
//Chapter 7_Operational Amplifier Characteristics
//Caption : Largest Amplitude
```

```
//Example7.16: An amplifier has a 10 kHz sinewave input signal. Find the largest amplitude that the output of the amplifier can be,without distortion owing to slew rate limiting. Given slew rate=0.5V/u sec.
//Solution:
clear;
clc;
Fmax=10*10^3;//frequency of sinewave input signal in Hz
SlewRate=0.5*10^6;//given in question in V/sec
Vm=SlewRate/(2*%pi*Fmax);//Since Fmax=slew rate/(2*%pi*Vm)
disp('V(peak)',Vm,'largest amplitude that the output of the amplifier can be without distortion owing to slew rate limitation is:')
//Note:
// calculated amplitude  is 7.9577 V, which can be approximated to 8 V
```

Scilab code Exa 7.17 Maximum allowable frequency

```
//Chapter 7_Operational Amplifier Characteristics
//Caption : Maximum allowable frequency
//Example7.17: When a low frequency sinusoidal waveform is applied to an input of the noninverting Op-Amp the amplifier responds linearly over an output range from -10V to +10V. If R1=R2 and the slew rate of the amplifier is 50 V/u sec,what is the maximum allowable frequency of an input sinusoid if the output signal swing is to be maintained from -10V to +10V without distortion? resistance and R2 is feedback resitance.
//Solution
```

```
clear;
clc;
SlewRate=50/10^-6;//in V/sec
Vo=10-(-10);//from question output is ranging from
    −10V to +10V
Vom=Vo;//where Vom is the maximum value of Vo
//therefore
Fmax=SlewRate/(2*%pi*Vom);
disp('kHz',Fmax/10^3,'maximum allowable frequency of
     an input sinusoidal for output swing maintained
    from −10V to +10v is:')
//Note:
// obtained maximum allowable amplitude is 397.88736
     kHz which can be approximated to 400 kHz
```

Chapter 8

Applications of Operational Amplifier

Scilab code Exa 8.1 Device Temperature

```
//Chapter 8_Applications of Operational Amplifier
//Caption : Device Temperature
//Example8.1:The Heat generated by a linear IC,uA
    741 is 200 mW. If the thermal resistance is 150
    degree Celsius/Watt and the ambient temperature
    is 25 degree celsius.calculate the device
    temperature.
//Solution:
clear;
clc;
Pd=200*10^-3;//heat generated
Rt=150;//thermal resistance
Ta=25;//ambient temperature in degree celsius
//assuming thermal equilibrium conditon
Td=Pd*Rt+Ta;
disp('degree celsius',Td,'The device temperature is:
    ')
```

Scilab code Exa 8.2 Device Temperature

```
//Chapter 8_Applications of Operational Amplifier
//Caption : Device Temperature
//Example8.2: For the device in Example8.1, Pdmax
    =500 mW. Determine the device temperature after
    equilibrium is attained for an ambient
    temperature of 75 degree celsius and if the
    device is subjected to maximum heat generation.
    Maximum allowable device temperature is 150
    degree Celsius.
//Solution:
clear;
clc;
Pmax=500*10^-3;
Pd=Pmax;//since device is subjected to maximum heat
    generation
Rt=150;//thermal resitance
Ta=75;//ambient temperature
Td=Pd*Rt+Ta;
disp('degree celsius',Td,'device temperature is:')
```

Scilab code Exa 8.3 Device Temperature

```
//Chapter 8_Applications of Operational Amplifier
//Caption : Device Temperature
//Example8.3:a)The ambient temperature of the device
     of Example8.2 rises above 90 degree celsius.
    What is the new value of Td if it still generates
     500 mW?
//a)Solution:
clear;
```

```
clc;
Pd=500*10^-3;
Rt=150;//thermal resistance
Ta=90;//ambient temperature
Td=Pd*Rt+Ta;
disp('degree celsius',Td,'New value of device
   temperature is:')
```

Scilab code Exa 8.4 Device Temperature

```
//Chapter 8_Applications of Operational Amplifier
//Caption : Device Temperature
//Example8.4: Forced air cooling provided for the
   device in Example8.3 lowers the ambient
   temperature at 60 degree celsius.What is
   temperature of the device?
//Solution:
clear;
clc;
Pd=500*10^-3;
Rt=150;//thermal resistance
Ta=60;//ambient temperature
Td=Pd*Rt+Ta;
disp('degree celsius',Td,'Temperature of the device
   is:')
```

Scilab code Exa 8.7 Output Voltage

```
//Chapter 8_Applications of Operational Amplifier
//Caption : Output Voltage
//Example8.7: In the summing amplifier(inverting
   mode) the signals to be combined are V1=3V, V2=2v
   , and V3=1V.The input resistor are R1=R2=R3=3
```

```
    kilo ohm.The feeddback resistor Rf=1 kilo ohm.
    Consider ideal Op-Amp,determine Vo.
//Solution:
clear;
clc;
V1=3;//input signal
V2=2;//input signal
V3=1;//input signal
Rf=1*10^3;//feedback resitor
R1=3*10^3;//input resistor in ohm
R2=R1;//input resistor in ohm
R3=R2;//input resistor in ohm
Vo=-(Rf/R1*V1+Rf/R2*V2+Rf/R3*V3);
disp('V',Vo,'Output Voltage of summing amplifier is:
    ')
```

Scilab code Exa 8.8 Vp and Vo

```
//Chapter 8_Applications of Operational Amplifier
//Caption : Vp and Vo
//Example8.8: In the circuit of non-inverting
    summing Op-Amp, V1=+2V, V2=-4V, V3=+5V. input
    resistors for all the three input signal are same
     and are equal to 1 kilo Ohm.The feedback
    resistor Rf is 2 kilo ohm. Determine the voltage
    Vp at the noninverting pin of the Op-Amp and the
    output Vo. Assume ideal Op=Amp.
//Solution:
clear;
clc;
Rf=2*10^3;//feedback resistor
R1=1*10^3;
R2=R1;
R3=R2;
V1=2;
```

```
V2=-4;
V3=5;
n=3;//no of inputs
Vp=(Rf/R1*V1+Rf/R2*V2+Rf/R3*V3)/n;
Vo=(1+Rf/R1)*Vp;
disp('V',Vp,'voltage at noninverting pin is:')
disp('V',Vo,'output voltage voltage of noninverting
   summing Op-Amp is:')
```

Chapter 9

Active Filters

Scilab code Exa 9.6 Determine Q Fl and Fh

```
//Chapter 9_Active Filters
//Caption : Determine Q Fl and Fh
//Example9.6:A certain two-pole band pass filter
    response is required with a centre frequency of 2
     kHz and a 3 dB bandwidth of 400 Hz. Determine Q,
    Fl and Fh.
//Solution:
clear;
clc;
Fo=2*10^3;//centre frequency in Hz
BW=400;//3 dB bandwidth
Q=Fo/BW;// Q-factor of band pass filter
Fl=Fo*sqrt(1+1/(4*Q^2))-Fo/(2*Q);
Fh=Fo*sqrt(1+1/(4*Q^2))+Fo/(2*Q);
disp('Hz',Fl,'lower cutt off frequency is:')
disp('Hz',Fh,'Higher cutt off frequency is:')
```

Scilab code Exa 9.12 Unity gain frequency and Capacitor determination

```
//Chapter 9_Active Filters
//Caption : Unity gain frequency and Capacitor
    determination
//Example9.12: a)Determine the unity gain frequency,
    Fo,of a switched capacitor integrator having
    following specifications:Fclk=1 kHz, C1=1 pF,and
    C2=15.9 pF
//b)What is the value of capacitor for an RC
    integrator having R=1.6 mega Ohm and Fo as
    obtained in part(a).
//a)Solution:
clear;
clc;
C1=1*10^-12;//source capacitor in F
C2=15.9*10^-12;//feedback capacitor
Fclk=1*10^3;//clock frequency or switching frequency
Fo=1*(C1/C2)*Fclk/(2*%pi);
disp('Hz',Fo,'unity gain frequency is:')
//b)Solution:
R=1.6*10^6;//resistor of RC integrator in Ohm
C=1/(2*%pi*Fo*R);
disp('nF',C*10^9,'for Rc integrator value of
    capacitor needed is:')
// Note:
// Obtained results are approximated to nearest
    values,thus Fo=10 Hz and C=10 nF
```

Chapter 10

Special Purpose Amplifiers

Scilab code Exa 10.3 Class B Power Amplifier

```
//Chapter 10_Special Purpose Amplifiers
//Caption : Class B Power Amplifier
//Example10.3: A class-B audio power amplifier has a
    supply voltage of  abs(Vcc)=15V. The closed loop
    gain Av=50 and the amplifier has to deliver 10W
   of power into an 8 ohm load.Find:
//a)the peak output voltage swing
//b)the peak output current swing
//c)the input signal required(rms)
//d)the total power from the power supply
//e)the power dissipated in the amplifier
//f)the power conversion efficiency
clear;
clc;
//a)Solution:
Po=10;//power in Watt
Rl=8;//load resistance in Ohm;
Vorms=sqrt(Po*Rl);// since output power Po=Vorms^2/
   Rl
Vom=sqrt(2)*Vorms;//peak output voltage swing
disp('V',abs(Vom),'The peak output Voltage swing:')
```

```
//b)Solution:
Iom=Vom/Rl;
disp('A',abs(Iom),'The peak output current swing is:
    ')
//c)Solution:
Av=50;//closed loop gain
Vsrms=Vorms/Av;
disp('V',Vsrms,'The input rms signal required is:')
//d)Solution:
Vcc=15;//absolute value of poer supply in volt
Pin=2*Vcc*Iom/%pi;// since Iorms*2^(1/2)=Iom
disp('W',Pin,'The total power from power supply is:'
    )
//e)Solution:
Pd=(2/%pi)*Vcc*sqrt(2*Po/Rl)-Po;
disp('W',Pd,'The power dissipated in the amplifier
    is:')
//f)Solution:
n=(Po/Pin)*100;
disp('%',n,'The power conversion efficiency is:')
//Note:
//Vcc,Vom and Iom can be of either polarity but here
     only absolute value is considered and calculated
```

Scilab code Exa 10.4 Power Output

```
//Chapter 10_Special Purpose Amplifier
//Caption : Power Output
//Example10.4: For the amplifier of Example10.3,
    find the power output level at which the power
    dissipation will bw maximum and the maximum power
     dissipation.
//Solution:
clear;
clc;
```

```
Vcc=15;//power supply in volt
Rl=8;//load resistance in ohm
//since Pd=2*Vcc/%pi*sqrt(2*Po/Rl)-Po
//to determine the value of Po at which Pd is
   maximum we differentiate above equation and
   equate to zero,we find Po as
Po=2*Vcc^2/((%pi)^2*Rl);
// there fore maximum power dissipated is
Pdmax=2*Vcc/%pi*sqrt(2*Po/Rl)-Po;
disp('W',Po,'The power output level for maximum
   power dissipation is:')
disp('W',Pdmax,'Maximum power dissipation for
   corresponding output power level is;')
```

Scilab code Exa 10.8 LM4250 Parameters

```
//Chapter 10_Special Purpose Amplifiers
//Caption : LM4250 Parameters
//Example10.8: The micropower programmable Op-Amp LM
    4250 is supplied by 3 v sourse(absolute value)
   source.Determine the value of set resistor for
   Iset=0.1 uA if Rset is connected to (a)Vee and (b
   )ground. (c)determine the quiescent supply
   current and the quiescent power dissipation.
clear;
clc;
//a)Solution:
Vcc=3;//power supply in Volt
Vee=-Vcc;//negative power supply in Volt
Iset=0.1*10^-6;//bias setting current in A;
Rset=(Vcc+abs(Vee)-0.5)/Iset;
disp('mega Ohm',Rset/10^6,'The bias setting current
   resistor for Vee=-10 V is:')
//b)Solution:
clear Vee;
```

```
Vee=0;//since Rset is connected to ground
Rset=(Vcc+abs(Vee)-0.5)/Iset;
disp('mega Ohm',Rset/10^6,'The bias setting current
    resistor for Vee=0 V is:')
//c)Solution:
Qcurrent=5*Iset;
Qpower=(Vcc+3)*Qcurrent;//where abs(Vee)=3 V
disp('uA',Qcurrent*10^6,'The quiescent current
    supply is:')
disp('uW',Qpower*10^6,'The quiescent power
    dissipated is:')
```

Scilab code Exa 10.9 Common Emitter Amplifier Parameters

```
//Chapter 10_Special Purpose Amplifiers
//Caption : Common Emitter Amplifier Parameters
//Example10.9: A single common emitter amplifier has
     following device and circuit parameters: Rb=60
    Ohm,Rs=40 Ohm,Cu=1.5 pF,Cl=1 pF,ft=1.6 GHz at Ic
    =2.5 mA quiescent current.Determine each of the
    following for two values of Rl: 30 Ohm and 100
    Ohm. a)f1 b)F2 (c)BW (d)Avmid (e)avmid*Bw.
clear;
clc;
Ft=1.6*10^9;//reduced unity gain frequency in Hz
Ic=2.5*10^-3;//collector current in A
Vt=25*10^-3;//threshold voltage at room temperature
gm=Ic/Vt;//transconductance
Cu=1.5*10^-12;
Cl=1*10^-12;
Rs=40;
Rb=60;
C2=gm/(2*%pi*Ft)-Cu
for i=1:2,
    if i==1 then
```

```
        Rl=30;//load resistance
        F1=1/(2*%pi*(Rs+Rb)*(C2+Cu*(1+gm*Rl)));//first break frequency
        F2=1/(2*%pi*Rl*(Cu+Cl));//second break frequency
        BW=F1;//since single common emitter amplifier so n=1 thus BW=F1*sqrt(2^(1/n)-1),i.e.,BW=F1
        Avmid=-gm*Rl;//mid frequency gain
        GBW=Avmid*BW;// gain-bandwidth product
        disp('********For Rl=30 Ohm********')
        disp('MHz',F1/10^6,'first break frequency is:')
        disp('MHz',F2/10^6,'second break frequency is:')
        disp('MHz',BW/10^6,'Bandwidth is:')
        disp(abs(Avmid),'mid frequency gain is:')
        disp('MHz',abs(GBW)/10^6,'gain-bandwidth product is:')
    else
        Rl=100;//load resistance in ohm
        F1=1/(2*%pi*(Rs+Rb)*(C2+Cu*(1+gm*Rl)));//first break frequency
        F2=1/(2*%pi*Rl*(Cu+Cl));//second break frequency
        BW=F1;//since single common emitter amplifier so n=1 thus BW=F1*sqrt(2^(1/n)-1),i.e.,BW=F1
        Avmid=-gm*Rl;//mid frequency gain
        GBW=Avmid*BW;// gain-bandwidth product
        disp('********For Rl=100 Ohm********')
        disp('MHz',F1/10^6,'first break frequency is:')
        disp('MHz',F2/10^6,'second break frequency is:')
        disp('MHz',BW/10^6,'Bandwidth is:')
        disp(abs(Avmid),'mid frequency gain is:')
        disp('MHz',abs(GBW)/10^6,'gain-bandwidth
```

```
            product is:')
    end
end
```

Chapter 11

Nonlinear Circuit Application

Scilab code Exa 11.4 Time taken

```
//Chapter 11_Nonlinear Circuit Application
//Caption :Time taken
//Example11.4: b)Type 741 Op-amp is used as a
   comparator and its slew rate is 0.5V/us.How long
   will it change from +10 V to -10v?
//b)Solution:
clear;
clc;
deltaVo=10-(-10);
SlewRate=0.5*10^-6;
t=deltaVo/SlewRate;
disp('us',t/10^6,'time taken by the output voltage
   to change from +10 V to -10 V is:')
```

Scilab code Exa 11.5 Rise Time

```
//Chapter 11_Nonlinear Circuit Application
//Caption : Rise Time
```

```
//Example11.5: The upper 3-dB frequency of an Op-Amp
    is 1MHz.Calculate the rise time of the output.
   If the upper 3-dB frequency of the Op-Amp is
   increased to 50 MHz by reducing the gain such
   that gain bandwidth product remains constant,then
    find out the new rise time.Discuss the effect of
    increasing bandwidth on accuracy of comparator.
//Solution:
clear;
clc;
F3dB=1*10^6;//upper 3-dB frequency of Op-Amp
Tr=0.35/F3dB;//from definition of rise time
disp('n sec',Tr*10^9,'Rise time of the output is:')
F3dB1=50*10^6;
Tr1=0.35/F3dB1;
disp('n sec',Tr1*10^9,'Rise time of the output is:')
```

Scilab code Exa 11.11 Design Peak Detector

```
//Chapter 11_Nonlinear Circuit Application
//Caption :Design Peak Detector
//Example11.11: Design a positive peak detector
   using type uA 760 comparator that can respond to
   a 100 mV(pp),5 MHz sinusoidal input signal.The
   device has following specifications. Response
   time=25 ns, propagation time=12 ns, and Input
   bias current=8uA.
//Solution:
clear;
clc;
Vp=50*10^-3;//since peak-peak voltage is 100 mV
f=5*10^6;
T=200*10^-9;
t=15*10^-9//since rise time(t) should be greater
   than propagation delay(12ns)
```

```
deltaVc=Vp*(1-cos(4*t/T*90*(%pi)/180));
Ib=8*10^-6;//input bias current
C=Ib/(deltaVc/T);
disp('mV',deltaVc*10^3,'voltage change is:')
disp('pF',C*10^12,'capacitor value is:')
//Note:
// the Exact value as calculated is taken to
   calculate C, so C=293.59555 pF. If approx value
   of deltaVc is taken as 5 mV then C=320 pF
```

Chapter 12

Signal Generators

Scilab code Exa 12.6 555 Timer

```
//Chapter 12_Signal Generators
//Caption : 555 Timer
//Example12.6: Calculate (a)Tc (b)Td, and (c)the
    free running frequency for the timer 555
    connected in astable mode.Given Ra=6.8 kilo Ohm;
    Rb=3.3 kilo Ohm; C=0.1 uF. What is the duty cycle
     ,d,of the circuit?
//Solution:
clear;
clc;
Ra=6.8*10^3;
Rb=3.3*10^3;
C=0.1*10^-6;
// Using equation for astable multivibrator we have
Tc=0.69*(Ra+Rb)*C;//charging time
Td=0.69*Rb*C;//discharging time
f=1.44/((Ra+2*Rb)*C);//free running frequency
d=Rb/(Ra+2*Rb);//duty cycle
disp('ms',Tc*10^3,'charging time of 555 timer in
    astable mode is:')
disp('ms',Td*10^3,'discharging time of 555 timer in
```

```
    astable mode is:')
disp('kHz',f/10^3,'free running frequency of 555
    timer in astable mode is:')
disp(d,'duty cycle of 555 timer in astable mode is:'
    )
```

Scilab code Exa 12.11 Design

```
//Chapter 12_Signal Generators
//Caption : Design
//Example12.11: A 555 one shot circuit with Vcc=16 V
     is to have a 2 ms output pulse width.Design a
    suitable Circuit.Ithres=0.25 uA(max.) from data
    sheet of the device.
//Solution:
clear;
clc;
Ithres=0.25*10^-6;
T=2*10^-3//output pulse width
Vcc=16;//power supply to 555
//The value of minimum capacitor charging current Ic
     should be much greater than the threshold
    Current Ithres
Icmin=1000*Ithres;//since Icmin>>Ithres
Ra=Vcc/(3*Icmin);
C=T/(1.1*Ra);
disp('kilo Ohm',Ra/10^3,'resitance design is:')
disp('uF',C*10^6,'Capacitor design is:')
```

Scilab code Exa 12.12 Generating pulse by 555 timer

```
//Chapter 12_Signal Generators
//Caption : Generating pulse by 555 timer
```

```
//Example12.12:(a)Design a 555 astable multivibrator to generate an output pulse with pulse repetition frequency(PRF)=4 kHz and a duty cycle of 60%.Given Vcc=15V.
//(b)Analyse the circuit designed in part (a) to determine the actual PRF and duty cycle. Given Ithres=25 uA(max.) for timer 555.
clear;
clc;
//a)Solution:
d=60*10^-2;//duty cycle given
PRF=4*10^3;
Vcc=15;//power supply
T=1/PRF;//where T=Tc+Td
Tc=d*T;
Td=T-Tc;
Ithres=25*10^-6;
Icmin=1*10^-3;//since Icmin>>Ithres,so assuming Icmin=1 mA
R=Vcc/(3*Icmin);//where R=Ra+Rb
C=Tc/(0.7*R);
Rb=Td/(0.7*C);
Ra=R-Rb;
disp('kilo Ohm',Ra/10^3,'Designed resistor(Ra) for 555 timer in astable mode is:')
disp('kilo Ohm',Rb/10^3,'Designed resistor(Rb) for 555 timer in astable mode is:')
disp('uF',C*10^6,'Designed Capacitor for 555 timer in astable mode is:')
//b)Solution:
//from equation of charging
Tc1=0.7*R*C;
Td1=0.7*Rb*C;
T1=Tc1+Td1;
PRFa=1/T1;
da=Tc1/(Tc1+Td1)*100;
disp('kHz',PRFa/10^3,'actual Pulse Repetition Frequency is:')
```

```
disp('%',da,'actual duty cycle is:')
```

Scilab code Exa 12.20 Waveform Generator

```
//Chapter 12_Signal Generators
//Caption : Waveform Generator
//Example12.20: Design a waveform generator using
   type 8038 IC.The frequency of Oscillation is 5
   kHz and the duty cycles is 50%.From data sheet,
   typical values for the device at Vcc=5 V are as
   follws:
//Voh=3.6 V; Vol=0.2 V; Ill=-1.6 mA and Ilh=40 uA.
//Solution:
clear;
clc;
Fo=5*10^3;
//for 50% duty cycle Tp=Tn
Vcc=5;//in volt
Vol=0.2;//in Volt
Voh=3.6;//in volt
Ill=-1.6*10^-3;
Ilh=40*10^-6;
Tp=1/(2*Fo);
C=0.01;//assuming the Capacitor value in uF for
   optimum design
Ra=Tp/(1.66*C);
Rb=2*Ra*Tp/(1.66*Ra*C+Tp);
R2min=(Vcc-Vol)/(2*10^-3-abs(Ill));//since Ill is
   negative
R2max=(Vcc-Voh)/(1*10^-6+Ilh);//since Ilh is
   positive
disp('kilo Ohm',Ra*10^3,'designed value of Ra is:')
disp('kilo Ohm',Rb*10^3,'designed value of Rb is:')
disp('kilo Ohm',R2min/10^3,'minimum pull-up resistor
    is:')
```

```
disp('kilo Ohm',R2max/10^3,'maximum pull-up resistor
    is:')
```

Chapter 13

Voltage Regulators

Scilab code Exa 13.3 Maximum Efficiency and Power

```
//Chapter 13_Voltage Regulators
//Caption : Maximum Efficiency and Power
//Example13.3: Calculate the maximum efficiency and
   associated power dissipation for the 5 V MC7805
   series regulator.The input ripple is 10 V and the
    load current is 1 A. The output is between 4.75
   to 5.25 for &v<=Vin<=20 V.
//Solution:
clear;
clc;
Vo=5;
Vin=17;//since for MC7805 a maximum of 7.5 V is
   added to the ripple.Since 10 V ropple is given so
    Vin=10+7=17 V
Il=1;//load current in ampere
n=Vo/Vin*100;//series pass reguator overall
   efficiency
Pd=(Vin-Vo)*Il;
disp('%',n,'maximum efficiency for 5V MC7805 series
   regulator is:')
disp('W',Pd,'power dissipation for the 5V MC7805
```

```
series regulator is:')
```

Scilab code Exa 13.14 Inductor and Capacitor

```
//Chapter 13_Voltage Regulators
//Caption : Inductor and Capacitor
//Example13.14: A switching voltage regulator
   operates at a switching frequency of 30kHz and is
    to supply a load current Io of 1 A at a dc
   output voltage Vo of +10V.The dc input voltage is
    Vin=20V and the output(peak-peak) ripple factor
   is not to exceed 0.05%. Assume Rl=10 Ohm.
//a)Find the value of the filter inductor L such
   that the maximum change or ripple in the current
   through the inductor will not exceed 40% of the
   average or dc current.
//b)Find the value of the outpur capacitor CL for L1
   =100 uH and for L2=500 uH.
clear;
clc;
//a)Solution:
Rl=10;
D=0.5;
T=2.5;
fs=30*10^3;
L=Rl*T*(1-D)/fs;
disp('uH',L/10^-6,'filter inductor L to ensure
   maximum ripple in the current through the
   inductor will not exceed 40% of the dc current is
   :')
//b)Solution:
L1=100*10^-6;
RF=0.05*10^2;//output (peak-peak)ripple factor
   maximum limit
//for ripple factor condition we have
```

```
CL1=1/(15*fs^2*L1*RF);
disp('********For L=100 uH********')
disp('uF',CL1*10^10,'output capacitor is:')
disp('********For L=500 uH********')
L2=500*10^-6;
CL2=1/(15*fs^2*L2*RF);
disp('uF',CL2*10^10,'output capacitor is:')
```

Chapter 15

Phase Locked Loops

Scilab code Exa 15.2 Output Signal Frequency

```
//Chapter 15_Phase Locked Loops
//Caption : Output Signal Frequency
//Example 15.2: A PLL has a Ko of 2*%pi(1kHz)/V, a Kv of 500 per sec, and a free running frequency of 500Hz.
//a) For a constant input signal frequency of 250 Hz and 1kHz.find vf.
clear;
clc;
//a)Solution:
Ko=2*%pi*10^3;// VCO gain in kHz/V
Kv=500;//loop bandwith in per second
Wc=500;//Free running frequency of VCO in PLL or 2*%pi*500
//Wi=angular input signal  frequency in Hz
//Wo=angular output signal frequency in Hz
//since vf=(Wo(t)-Wc)/Ko
//under locked condition Wo=Wi, so vf=(Wo-Wc)/Ko
for i=1:2,
    if i==1 then
        Wo=250;
```

```
        //or
        Fo=2*%pi*Wo;//in Hz
vf=(Fo-2*%pi*500)/Ko;
disp('********For input signal frequency W=250 Hz
   ********')
disp('V',vf,'output signal voltage of PLL for  Wo
   =250 Hz is:')
else
    Wo=1000;
    Fo=2*%pi*Wo;//in Hz
    vf=(Fo-2*%pi*500)/Ko;
    disp('********For input signal frequency Wo=1
       kHz********')
    disp('V',vf,'output signal voltage of PLL for
       Wo=1kHz is:')
end
end
```

Scilab code Exa 15.3 VCO and Phase detector

```
//Chapter 15_Phase Locked Loops
//Caption : VCO and Phase detector
//Example15.3: A PLL has free running frequency Wc
   =500 kHz,bandwith of low pass filter=10kHz.
   Suppose an input signal of frequency 600kHz is
   applied.Will the loop acquire lock? What is VCO
   output frequency? The phase detector produces sum
    and difference frequency components.
//Solution:
clear;
clc;
BW=10;//bandwidth of low pass filter in kHz
Fi=600;//input frequency in kHz
Fc=500;//free running frequency in kHz
// Output from phase detector is
```

```
Sum=Fi+Fc;
Difference=Fi-Fc;
disp('kHz',Sum,'sum frequency component of phase
    detector in kHz')
disp('kHz',Difference,'difference frequency
    component of phase detector in kHz')
if Sum>BW then
    if Difference>BW then
    disp('Both Sum and Difference frequency
        components are outside the passbandof low-
        pass filter')
    disp('Loop will not acquire lock')
    disp('VCO frequency will be its free running
        frequency')
end
end
```

Scilab code Exa 15.4 Second Order Butterworth Filter

```
//Chapter 15_Phase Locked Loops
//Caption : Second Order Butterworth Filter
//Example 15.4: A Synthesizer using PLL has Kv=5*%pi
    rad/s. What value of low-pass filter bandwidth
    should be used so that the closed-loop system
    approximates a second-order Butterworth filter?
//Solution:
clear;
clc;
//For Butterworth filter the damping ratio(Dr) is
Dr=0.707;
Kv=5*%pi;
Wl=Kv*(2*Dr)^2;//since (Wl/Kv)^2=2*Dr
disp('rad/sec',Wl,'low pass filter bandwidth')
// BW for closed loop system is
BW=sqrt(Kv*Wl);// since BW=Wn, where Wn=natural
```

```
frequency ,BW=bandwidth of closed loop system
Wn=real(BW);
t=2.2/Wn;
disp('rad/sec',BW,'bandwidth of closed loop system is:')
disp('sec',t,'corresponding system rise time is:')
```

Scilab code Exa 15.5 Lock Range

```
//Chapter 15_Phase Locked Loops
//Caption : Lock Range
//Example15.5: A PLL has a VCO with Ko=25kHz/V and Fc=50kHz.The amplifier gain is A=2 and the phase detector has a maximum output voltage swing of +0.7V and -0.7V. Find the lock range of the PLL. Assume filter gain equal to unity.
//Solution:
clear;
clc;
k1=2*0.7/%pi;//positive maximum gain value of phase detector
k2=-k1;//negative maximum gain value of phase detector
A=2;// amplifier gain
Ko=25;// VCO gain in kHz
//positive maximum output voltage swing of phase detector is
V1=k1*%pi/2;
//Negative maximum output voltage swing of phase detector is
V2=k2*%pi/2;
Vf1=k1*A*%pi/2;//Positive maximum control voltage available to drive VCO
Vf2=k2*A*%pi/2;//negative maximum control voltage available to drive VCO
```

```
//maximum VCO frequency swing that can be obtained is
Fh=Ko*Vf1;//positive maximum VCO frequency swing
Fl=Ko*Vf2;// Negative maximum VCO frequency swing
// so lock range of PLL is
f=Fh-Fl;
disp('kHz',f,'The lock range of the PLL is:')
```

Chapter 16

Bipolar and MOS Digital Gate Circuits

Scilab code Exa 16.2 Noise Margin

```
//Chapter 16_Bipolar and MOS Digital Gate Circuits
//Caption : Noise Margin
//Example 16.2: An RTL gate has the worst case
   voltages listed below:
// Temp(degree C)              Voh(V)           Vih(V)
           Vil(V)          Vol(V)
//      -55                    1.014             1.01
            0.718           0.710
//       25                    0.844             0.815
           0.565           0.300
//       125                   0.673             0.67
            0.325           0.320
//Calculte the worst case NMl and NMh noise margins.
//Solution:
clear;
clc;
T=[-55;25;125];// temperatures in degree celsius
   given in table
for j=1:3,
```

```
if j==1 then
    disp('Noise margins for T=-55 degree celsius are:')
    NMl=0.718-0.710;// since NMl=Vil-Vol
    NMh=1.014-1.01;// since NMh=Vih-Voh
    disp('Volt',NMl,'lower limit of noise margin at -55 degree celsius is:')
    disp('volt',NMh,'upper limit of noise limit at -55 degree celsius is:')
elseif j==2 then
    disp('Noise margin for T=25 degree celsius are:')
    NMl=0.565-0.300;
    NMh=0.844-0.815;
    disp('Volt',NMl,'lower limit of noise margin at 25 degree celsius is:')
    disp('Volt',NMh,'upper limit of noise margin at 25 degree celsius is:')
elseif j==3 then
    disp('Noise margin for T=125 degree celsius are:')
    NMl=0.325-0.320;
    NMh=0.673-0.670;
    disp('Volt',NMl,'lower limit of noise margin at 125 degree celsius is:')
    disp('Volt',NMh,'uppwr limit of noise margin at 125 degree celsius is:')
end
end
```

Scilab code Exa 16.3 Fanouts

```
//Chapter 16_Bipolar and MOS Digital Gate Circuits
//Caption : Fanouts
//Example 16.3: A TTL gate is guartnteed to sink 10
```

```
mA without exceeding ann output voltage Vol=0.4V and to source 5mA without dropping below Voh=2.4V. If Tih=100uA at 2.4V and Iil=1mA at 0.4V, calculate the low-state and high-state fan-outs.
// Solution:
clear;
clc;
// for TTL gate
// fanout at low output is= collector saturation current of output transitor/load current of the driven gate.
// fanout for high output is=source current in driving gatte/input current of load gate
// from question given
Ic3=10*10^-3;// collector saturatioon current at output transistor
Ie=1*10^-3;// load current of driven gate
Ie4=5*10^-3;// source current in driving gate
Ic1=100*10^-6;// input current of load gate
Fl=Ic3/Ie;
disp(Fl,'fan out at low output state is:')
Fh=Ie4/Ic1;
disp(Fh,'fan out at high output state is:')
```

Scilab code Exa 16.12 NMOS operating region

```
//Chapter 16_Bipolar and MOS Digital Gate Circuits
//Caption : NMOS operating region
//Example 16.12: A NMOS transistor with K=20uA/V^2 and Vth=1.5V is operated at Vgs=5V and Ids=100uA. Determine the region of the operation on I-V characteristics and find Vds.
//Solution:
clear;
clc;
```

```
K=20*10^-6;
Vgs=5;
Vth=1.5;
Ids=100*10^-6;
Id=(K/2)*(Vgs-Vth)^2;
disp('uA',Id/10^-6,'drain current in saturation
   region')
if Id>Ids then
    disp('region of operation of NMOS transistor on
       I-V characteristics is LINEAR REGION')
end
//since NMOS lies in LINEAR REGION so Ids=(K/2)*(2*(
   Vgs-Vth)*Vds-Vds^2); thus substituting the values
    we have
//100*10^-6==(20*10^-6/2)*(2*(5-1.5)*Vds-Vds^2);
//so Vds^2-7*Vds+10=0; equivalent to quadrattic
   equation of form aX^2+b*X+c=0
Vds=poly(0,'Vds');
p=Vds^2-7*Vds+10;//equation whose roots has to be
   found
z=roots(p);
z=real(z)
  if (z(1)<(Vgs-Vth)) then
    disp('Volt',z(1),'drain to source voltage(Vds)
       in this Linear Region is:')
elseif (z(2)<(Vgs-Vth)) then
    disp('Volt',z(2),'drain to source voltage(Vds)
       in this Linear Region is:')
end
```

Scilab code Exa 16.13 Power Dissipation

```
//Chapter 16_Bipolar and MOS Digital Gate Circuits
//Caption : Power Dissipation
// Example16.13: Calculate the maximum power
```

```
    dissipated by saturated load NMOS inverter for
    following given values: Vdd=5V;Vth=1.5V; device
    transconductance parameter for load device Kl
    =23.34*10^-6 A/V^2.Assume Vo=0V in low state.
// Solution:
clear;
clc;
Vdd=5;// drain voltage of NMOS inverter in Volt
Vth=1.5;// threshold voltage of NMOS inverter in
    Volt
Kl=23.34*10^-6;// transconductance Parameter for
    load device
// since maximum power can be obtained if maximum
    device current flows whish is when Vo=low i.e.,0
    V. So,for saturation region of operation we have
    Id=Kl*(Vgs-Vth)^2/2;
// for saturated load inverter Vgs=Vds  and
//Vds=Vdd in low output condition,so Id=Kl*(Vdd-Vth)
    ^2/2
Id=23.34*10^-6*(Vdd-Vth)^2/2;
Pmax=Id*Vdd;
disp('mW',Pmax/10^-3,'maximum power dissipated by
    saturated load NMOS inverter is:')
```

Scilab code Exa 16.14 AC Power

```
//Chapter 16_Bipolar and MOS Digital Gate Circuits
//Caption : AC Power
//Example16.14: Calculate the ac power dissipated by
     a CMOS inverter which drives a 20pF load.Given f
    =1MHz and Vdd=10V.
//Solution:
clear;
clc;
Ct=20*10^-12;// load capacitor in Farad
```

```
Vdd=10;//drain voltage supply in Volt
f=1*10^6;//frequency at which output voltage changes
//since P=Ct*Vdd^2*f
P=20*10^-12*(10)^2*10^6;
disp('W',P,'ac power dissipated  by a CMOS inverter
   is:')
```

Chapter 17

Light Emitting Diodes and Liquid Crystal Displays

Scilab code Exa 17.2 Viewing distance

```
//Chapter 17_Light Emitting Diodes and Liquid
   Crystal Displays
//Caption :Viewing distance
//Example17.2: Find out the viewinng distance d for
   a seven segmant LED display for a character
   height of 1cm and a height angle of 3 meters.
//Solution:
clear;
clc;
//d:viewing distance
h=1*10^-2;//height of character in cm
O=3;//height angle in meters
// equivaqlent to height angle of 3 meters
d=h/tan(0.167*%pi/180);//where 3 meters height angle
    is equivalent to 0.167 degrees.
disp('meters',d,'viewing distance is:')
```