Scilab Textbook Companion for Analog Communication by V. Chandrasekar[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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Chapter 2

Signals An Introduction

Scilab code Exa 2.1.A Periodicity

```

clear;
clc;
         //a) periodicity os 5sin(6t-pi/4)
t=0:0.001:1;
w=6;
theta=%pi/4;
T=2*%pi/w;
x=cos(t*w+theta);
y=cos((t+T)*w+theta);
if ceil(x)==ceil(y) then
    disp(' a) cos(6t+pi/4) is periodic with T=2*pi/6
        (sec) ')

else
    disp('nonperiodic')
end


         //b) periodicity of e^(j3t)

```

```
  w=3;
  t=0:0.001:1;
  T=2*%pi/w;
  x=exp(3*%i*t);
  y=exp(3*%i*(t+T));
   if ceil(x)==ceil(y) then
    disp(' b) exp(j3t) is periodic with T=2*pi/3 (sec) ')

else
    disp('nonperiodic')
end


      //c) periodicity of cot(3t+theta)

    t=0:0.001:1;
w=5;
T=%pi/w;

  x=cotg(t*w+theta);
  y=cotg((t+T)*w+theta);
if ceil(x)==ceil(y) then
    disp(' c) cot(3t+Theta) is periodic with T=pi/5 (sec) ')

else
    disp('nonperiodic')
end
```

Scilab code Exa 2.2.A Even and Odd Part of function

```
clc;
clear;
t = 0:1:10;
```

```
for i = 1:length(t)
  x(i) = (t(i)^6) + 2*(t(i)^4)+ 3*(t(i)^2)+4 ;
end

for i = 1:length(t)
  y(i) = ((-t(i))^6)+ 2*((-t(i))^4)+ 3*((-t(i))^2)+4
      ;
end

// checking if the function is even x(t)=x(-t)
if x==y then
    disp("the function is even");
end
//odd part of the signal=0.5(x(t)-x(-t))

z=0.5*(x-y);
if z==0 then
    disp("the odd part is 0")
end
```

Scilab code Exa 2.2 `Real and Imaginary part`

```
clc;
clear;

/// e^j(*2*pi*f*t+theta)

syms pi f0 t theta A
K=2*pi*f0*t+theta;

disp("the given signal is complex");
disp("e^(j*theta) can be written as");
disp("cos(theta)+j*sin(theta)");

```

```
Re=A*cos(K);
Img=A*sin(K);
mag=sqrt(Re^2+Img^2);

disp(Re,"real part is ");
disp(Img,"the imaginary part ");
disp(mag,"Magnitude of signal is |A|=");
disp(K,"phase of the signal ");
```

Scilab code Exa 2.3.A Power and Rms power of Signal

```
clear;
clc;

  //x(t)=5u(t)....
  amp=5; //amplitude is 5
t=0:0.01:1;
x0=0;
x1=0:0.1:10; //  over a time interval of T
disp("the power of the signal (in watts) is");
 X=(integrate('25','x',x0,10)/(2*10)); // power of
    the signal
disp(X);

rms=amp/sqrt(2);
disp(rms,"the rms value of power is (in watts)");
```

Scilab code Exa 2.3 Energy of Signal

```
clc;
clear;

//x(t)=2 over an interval of (-2,2)
```

```
disp("the energy of the signal (in J)is");
 Ex=(integrate('4','x',-2,2)); // energy content of
    the signal
disp(Ex);
```

Scilab code Exa 2.5 Properties of Impulse Signal

```
clc;
clear;


//delta(t)

  for j = 1:1000
        if j==1
        delta(j)=1;
    else
        delta(j)=0;
     end
    end

// a)
figure(1)
 t=-1;
 plot2d4(t,0);
    for j=1:1:10
        t=t+1;
       z(j)=(cosd(j-1)*delta(j));
        plot2d3(t,z(j));
        disp(z(j));

    end


```

```
//b)
figure(2)
 t=1.5;
 plot2d4(t,0);
    for j=3:1:10
        t=t+1;
        z(j)=abs(cosd(2.5)*delta(2*j-5));
        plot2d3(t,z(j));
    end
//c)
syms t;
A=(-1)*exp(-1*t); //property 8
disp(diff(A,t));
disp("when t=3");
A=exp(-3);
disp(A);
```

Scilab code Exa 2.10 `Laplace Transform`

```
//x(t) = del(t)
syms t s;
L =laplace('delta(t)',t,s)
disp(L)
// x(t) = u(t)
L1 =laplace('1',t,s);
disp(L1)
```

```
//x(t) = sin(w0*t)u(t)

L2 =laplace('sin(w0*t)',t,s);
disp(L2)
```

Scilab code Exa 2.11 Z transform

```

clc;
clear;

// a) z-transform of unit impulse function
syms n z;
x=1;
X=symsum(x*(z^-n),n,0,0);
disp(X,'X(z)=');

//b) z-transform of unit step function

y=ones(1);
Y=symsum(y*(z^-n),n,0,%inf);
disp(Y,'Y(z)=');
```

Chapter 3

Amplitude Modulation

Scilab code Exa 3.1.A AM Sidebands

```
clc;
clear;
Fc=500;//carrier frequency in kHz
Fm=1;// message signal frequency in kHz
//a)

USB=Fc+Fm;
LSB=Fc-Fm;
disp(USB,"USBI(in kHZ)=");
disp(LSB,"LSB(in kHz)=");

//b)

Bandwidth=USB-LSB;
disp(Bandwidth,"Bandwidth(in kHZ)=")
//c)

Fm=1.5;//message signal frequency in kHz

```

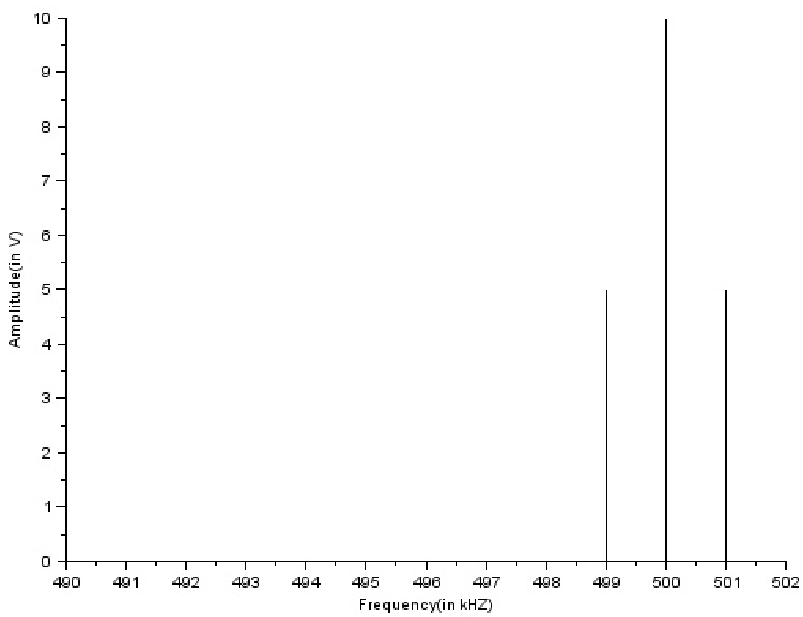

Figure 3.1: AM Sidebands

```
USB1=Fc+Fm;
LSB1=Fc-Fm;
disp(USB1,"USB(in kHz)=");
disp(LSB1,"LSB(in kHZ)=");


//d)

Amplitude=[0 0 0 0 0 0 0 0 0 5 10 5 0]; //sample values as denoted in textbook
frequency=490:1:502;

 plot2d3(frequency,Amplitude);
xlabel("Frequency(in kHZ)");
ylabel("Amplitude(in V)");
```

Scilab code Exa 3.1 `amplitude modulation`

```
clc;
clear;
Vm=3;// amplitude of message signal in V
Vc=5;//amplitude of carrier signal in V
m=Vm/Vc; //modulation index
disp("modulation index");
disp(m,"=");
disp("Upper Sideband Frequency(in MHz)");
Fm=4;//Frequency in KHz
Fc=5;//Frequency in MHz
disp(Fc+(Fm*10^(-3)),"=");
disp("Lower Sideband Frequency(in MHz)");
disp(Fc-(Fm*10^(-3)),"=");
disp("AMplitude of each Sideband(in V)");
disp(m*Vc/2,"=");
```

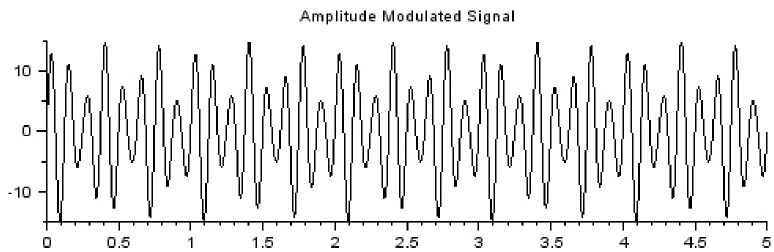

Figure 3.2: Amplitude Modulation

Scilab code Exa 3.2.A `Amplitude Modulation`

```
clear;
clc;


Fm=3; //frequency of message signal
Fc=8; //frequency of carrier signal
Ea=5;
Eb=10;
```

```
m=Ea/Eb; //modulation index
disp(m,"m=");
USf=Fc+Fm*10^(-3);//Upper Sideband frequency
LSf=Fc-Fm*10^(-3);//Lower sideband frequency
disp(USf,"USf(Mhz)=");
disp(LSf,"LSf(Mhz)=");
Amp=m*Eb/2;// amplitude of each sideband
disp(Amp,"amp(v)=");
function[x,Vm,Vc]=ampmod(Ea,Eb,m,Fc,Fm)
    t=0:0.005:5;
    Vm = Ea*sin(2*%pi*Fm*t);
    Vc = Eb*sin(2*%pi*Fc*t);
    x = ((Eb+Ea*sin(2*%pi*Fm*t)).*(sin(2*%pi*Fc*t))
       ;
    subplot(3,1,2);
    plot2d(t,x);
    title('Amplitude Modulated Signal');
endfunction
ampmod(Ea,Eb,m,Fc,Fm)//amplitude modulation
```

Scilab code Exa 3.2 Total power of AM wave

```
clc;
clear;
Pc=300;// Power of the carrier in W
m=0.6// modulation index
Pt=Pc*(1+(m^2)/2); //total power
```

```
disp("Total power in the modulated wave(in W) is");
disp(Pt);
```

Scilab code Exa 3.3.A Efficiency of DSBFC

```
clc;
clear;
disp("efficiency(n)=(useful power/total power)*100%"
   );
disp("        =total sideband power/(total sideband
   power+carrier power)*100%");

syms m Pc
N=[((m^2)*Pc/2)/(Pc*(1+(m^2)/2))];
disp("*100% ",N);

disp("
   ------------------------------------------------------------------------------------
   ");
m=0.7 //modulation index


n=[m^2/(m^2+2)]*100;  //efficiency
disp(n,"the percentage of useful power is ");
```

Scilab code Exa 3.3 Modulation index

```
clc;
clear;
Pt=11.5;//Total power in kW
Pc=10;// Carrier power in kW
//a)

```

```
m_square=2*((Pt/Pc)-1);
m=sqrt(m_square);//modulation index

//b)
m2=0.5;
mt=sqrt(m^2 +m2^2);
Pt=Pc*(1+mt^2/2); //total power in kW

disp(m,"modulation index is ");
disp(Pt,"Total carrier power(in kW) ");
```

Scilab code Exa 3.4.A DSBFC

```
clc;
clear;
Vc=8;// carrier signal voltage in V
m=1;//modulation index
R=8;//resistance in ohms
//a)

Pc=Vc^2/(2*R);
disp(Pc,"power of the carrier(in W) is");
Ps=m^2*Pc/4;
disp(Ps,"Power in each Side-Bands(in W)");

//b)
disp(2*Ps,"Total sideband Power(in W)");

//c)
disp(Pc+2*Ps,"Total Power of Modulated wave(in W)");

//d)
disp(2*Ps/(Pc+2*Ps)*100,"Efficiency Percentage");
```

Scilab code Exa 3.4 `Modulation index and power`

```
clc;
clear;
m1=0.3;
m2=0.4;
m3=0.5;
m4=0.6; //modulation indices
Pc=150;//power of carrier in Watts

mt=sqrt(m1^2+m2^2+m3^2+m4^2); //total modulation index

Pt=Pc*(1+mt^2/2);//Total transmitted power in Watts

Ps=(mt^2)*Pc/4; //Sideband Power in Watts

disp(mt,"Total Modulation index");

disp(Pt,"Total Transmitted Power (in W)");

//change in answer as compared to book ,due to approximation error..
disp(Ps,"Sideband Power(in W)")
```

Scilab code Exa 3.5.A `Amplitude Modulation`

```
clc;
clear;
m1=0.3;
m2=0.4;
m3=0.5;
```

```
m4=0.6; //modulation indices
Pc=80;// Power in carrier signal

mt=sqrt(m1^2+m2^2+m3^2+m4^2);

//a)
disp(mt,"Total Coefficient of Modulation ");

//calculation error in book

//b)
Ps=(mt^2)*Pc/2;
disp(Ps,"Sideband powers(in W) ");

//c)
disp(Pc+2*Ps,"Total Transmitted Power(in W)");

//d)
disp((Ps/(Pc+2*Ps))*100,"Efficiency Percentage");
```

Scilab code Exa 3.5 Peak Envelope Power and average power

```
clc;
clear;
fLSB1=395;
fLSB22=397.5;// Two LSB frequencies in kHz
E1=4;
E2=3;//peak voltages of modulating signal in V
R=60;//resistor in ohms

Et=sqrt(E1^2+E2^2);

Erms=Et*0.707;

PEP=((Et*0.707)^2)/R; //Pak Envelope Power in W
```

```
Avg_Power=PEP/2;

disp(PEP,"Peak Envelope Power(in W)");
disp(Avg_Power,"Average Power(in W)");
```

Scilab code Exa 3.7.A Diagonal Clipping

```
clc;
clear;
Fc=10;//carrier Frequency in kHz
R=15;//Resistance in Kohms
C=660;//Capacitance in pF
a=1/R;
b=2*%pi*Fc*10^(3)*C*10^(-12);
Y=a+%i*b;
Z=1/abs(Y);
//after rounding off
Z=12.83//Impedence in Kohms
m=Z/(R);//modulation index
disp(m,"MAximum modulation index to avoid diagonal clipping is");
```

Scilab code Exa 3.8.A Sideband Frequencies

```
clc;
clear;


syms Ec Fc Fm pi t

Wave=Ec*cos(2*pi*Fm*t)*cos(2*pi*Fc*t)+Ec*sin(2*pi*Fm*t)*sin(2*pi*Fc*t);
```

```
 disp("when the wave is");
 disp(Wave);

f_upper=Ec*cos(2*pi*(Fc+Fm)*t);
disp("We get the upper sideband as");
disp(f_upper);


f_lower=Ec*cos(2*pi*(Fc-Fm)*t);
disp("We get the lower sideband as");
disp(f_lower);
```

Chapter 4

Angle Modulation

Scilab code Exa 4.1.A Frequency Deviation

```

clc;
clear;
Freq_dev=6; //Frequency Deviation in kHz
Vm=3; //Modulating Voltage in V

Dev=Freq_dev*10^(3)/Vm;

// for Vm=6V

Vm=6;
Freq_dev_new=Dev*Vm;

disp(Freq_dev_new,"the new deviation( in Hz)");
```

Scilab code Exa 4.1 phase and frequency deviation

```
clc;
```

```
clear;

t=0:0.01:1;
Freq=2*%pi*10^(5)+3*2*%pi*100*cos(2*%pi*100*(t));//Phase=2*%pi*10^(5)*t+3*sin(2*%pi*100*t);

t1=0.4;// time in ms
Ang_Freq=2*%pi*10^(5)+3*2*%pi*100*cos(2*%pi*100*(t1*10^(-3)));
Freq=Ang_Freq/(2*%pi);

//change in answer due to calculation error in book
disp(Freq,"Instantaneous Frequency(in Hz) at (t=0.4 ms)N =");


Max_pha_Dev=3; //max(3sin(2*%pi*100t))

disp(Max_pha_Dev," Maximum Phase Deviation(in rad) =");

Max_fre_Dev=6*%pi*100;//max(6*pi*100*cos(2*pi*100t))



disp(Max_fre_Dev/(2*%pi),"MAximum Frequency Deiation (in Hz)");
```

Scilab code Exa 4.2.A Power in FM system

```
clc;
clear;
Wc=8*10^(8);// Angular Frequency of Carrier Signal
fc=Wc/(2*%pi);

```

```
Wm=1300;//Angular Frequency of Message Signal
fm=Wm/(2*%pi);

B=3;//Modulation Index
R=12;
Vc_rms=15/sqrt(2);

Max_dev=B*fm;
Power=Vc_rms^(2)/R;

disp(Power,"Power Dissipated (in W) is");
```

Scilab code Exa 4.2 Peak Frequency Deviation

```
clc;
clear;
a=3;//amplitude in volts
Dev_sen=4;// deviation sensitivity in KHz/volts
fm=1.5;// frequency modulating signal in KHz

f=Dev_sen*10^(3)*3;//peak frequency deviation
B=f/(fm*10^3);

disp(f,"Peak Frequency Deviation( in Hz) ");
disp(B,"modulation index ");
```

Scilab code Exa 4.3.A BAndwidth of FM

```
clc;
clear;
fm=3; //Modulating Frequency in kHZ
Max_Dev=18; //MAximum Deviation in kHz

```

```
B=Max_Dev/fm; //modulation index

J=12;//from Bessel Table, for B=6
Bw=fm*J*2*10^(3);

disp(Bw,"The Bandwidth (in Hz) is") ;
```

Scilab code Exa 4.3 Peak Phase Deviation

```
clc;
clear;
Dev_sen=3.5;// Deviation Sensitivity in rad/volt
a=2.5;// amplitude in volts

B=a*Dev_sen; //Peak Phase Deviation

disp(B,"Peak Phase Deviation( in rad)");
```

Scilab code Exa 4.4.A Peak Deviation in FM

```
clc;
clear;
Wm=18850;//Angular Frequency of message signal
fm=Wm/(2*%pi);
a=3;// amplitude of message signal

Dev_sen=6;//Deviation Sensitivity in kHz/V
Max_Freq_Dev=a*Dev_sen*10^(3);

B=Max_Freq_Dev/(fm);

disp(Max_Freq_Dev,"Maximum Frequency Deviation(in Hz
    )");
```

```
disp(B,"Modulation Index");
```

Scilab code Exa 4.4 Frequency Modulation

```
clc;
clear;
a=3; //amplitude in Volts
Dev=4;// Deviation in kHz
fm=1;// modulating frequency in kHz

Dev_sen=Dev*10^(3)/a; //Deviation Sensitivity
B=Dev/fm; // Modulation Index

disp(Dev_sen,"Deviation Sensitivity(in kHz/V)");
disp(B,"Modulation Index");

//a)
a=5;
Dev_sen_1=a*Dev_sen;
B=Dev_sen_1/(fm*10^(3));

disp(Dev_sen_1,"Deviation Sensitivity for 5V (in Hz)
   ");
disp(B,"Modulation index");


//b)
a=10;
fm=400;
Dev_sen_2=a*Dev_sen;
B=Dev_sen_2/fm;


disp(Dev_sen_2,"Deviation Sensitivity for 10V (in Hz
   )");
```

```
disp(B,"Modulation index");
```

Scilab code Exa 4.5.A side frequencies and Aplitudes

```
clc;
clear;
disp("for B=2, The number of significant frequencies are 6");
disp("They are J1,J2,J3,J4,J5 and J6");
disp('Their amplitudes with carriers are');
J0= 0.224*8;
J1= 0.577*8;
J2= 0.353*8;
J3= 0.129*8;
J4= 0.034*8;
J5= 0.007*8;
J6= 0.001*8;
disp(J6, J5,J4,J3,J2,J1,J0,"they are (in V)");
```

Scilab code Exa 4.5 CArson Bandwidth

```
clc;
clear;
fm=3; //Modulating Frequency in kHZ
Max_dev=15;// Maximum Deviatin in kHZ

B=Max_dev/fm;

J=8; // Bessel table,the highest J coefficient
BW=J*fm*10^(3);//Bandwidth in kHz

BW1=2*(fm+Max_dev)*10^(3);//  According to carson rule, BAndwidth
```

```
disp(BW,"Bandwidth required (in Hz)");
disp(BW1,"According to Carsons rule , Bandwidth(in Hz
   )");
```

Scilab code Exa 4.6.A Carson Bandwidth

```
clc;
clear;
Max_Freq_Dev=12; //Maximum Frequency Deviation in
   kHZ
fm=6; //Modulating frquency in kHz

B=Max_Freq_Dev/fm;// Modulation index

J=6;//From Bessel Table , for B=2

Bw=2*J*6*10^(3);
BW_carson=2*(fm + Max_Freq_Dev)*10^(3);

disp(Bw," Minimum Bandwidth (in Hz) is");
disp(BW_carson," Approximate Minimum Bandwidth
   according to carson rule( in Hz) is");
```

Scilab code Exa 4.6 Average Power of signal

```
clc;
clear;
a=10; //Amplitude in V
Pt=a*(0.18^2 +2*(0.33^2
   +0.05^2+0.36^2+0.39^2+0.26^2+0.13^2+0.05^2+0.02^2+0.01^2)
   );

```

```
disp(" For B=5 from the Bessel table,The Bessel Function is taken upto J9");
disp(Pt," Hence the average power of the modulated signal (in W) is");
disp("Hence, the average power of the modulated signal is equal to ");
disp("unmodulated carrier power");
```

Scilab code Exa 4.7.A Unmodulated Carrier Power

```
clc;
clear;
a=8;// amplitude in V
r=30; //resistance in ohms

Pc_unmodulated=a^2/(2*r);
Pt=1.792^2/(2*30)+2*(4.616)^2/(2*30)+2*(2.824^2)/(2*30)+2*(1.032)^2/(2*30)+2*(0.272)^2/(2*30)+2*(0.056)^2/(2*30)+2*(0.008)^2/(2*30);

// change in answer due to approximations in the book

disp(Pc_unmodulated,"Unmodulated Power Carrier(in W)=");
disp(Pt,"Total Power  in modulated wave(in W)=");
disp("Power in the modulated wave is equal to");
disp("power  in the unmodulated wave");
disp("Small error due to rounded off values in Bessel functions");
```

Scilab code Exa 4.7 Phase Modulation

```
clc;
clear;
syms t pi;

Pha_dev=3; //Phase_Deviation constant in rad/V

// Phase Modulation Function

Pha_function=Pha_dev*4*sin(2*pi*1.5*10^(3)*t);
Mod_wave=8*cos(2*pi*10^(4)*t) +Pha_function

disp( Pha_function,"the Phase Modulation Function =
    ");

disp(Mod_wave ,"The Modulated Wave Function = ");
```

Scilab code Exa 4.8.A Balanced Modulator

```
clc;
clear;

initial_Freq_Dev=5; //frequency in kHz
B_initial=0.5; //modulation index
fm_initial=10;// message signal frequency in kHz
fc_initial=800; //carrier frequency in kHz

disp("The outputs of the balanced modulator for
    these parameters");
disp("are same as the inputs");
disp("They remain unaltered");

//at the output of the multiplier

m=12;// multiplication factor

```

```
final_Freq_Dev=initial_Freq_Dev*m;
B_final=0.5*m;
fm_final=10; //modulating signal remains unaltered
fc_final=800*m;

disp("At the output of the Multiplier,");
disp(fc_final,"Fc(in kHz)=",fm_final,"Fm(in kHz)=",
   B_final,"B=");
disp(final_Freq_Dev," Frequency Deviation(in kHz)=")
   ;
```

Scilab code Exa 4.9.A Frequency Deviation

```
clc;
clear;
ft=100.2; //final carrier frequency in MHz
Freq_Dev_ft=60;// Frequency Deviation in KHz at
   power amplifier
fm=10;//modulating frequency in KHz
m=25;//multiplication factor

//a)
fc=ft/25;

//b)
Freq_Dev=Freq_Dev_ft/25;

//c)
B=Freq_Dev/fm;

//d)
Bt=B*m;

disp(fc,"a) MAster Oscillator Centre Frequency(in
   MHz) =");
```

```
disp(Freq_Dev, "b) Frequency Deviation at the output of modulator(in KHz)=");
disp(B,"c)Devaition ratio at the output of modulator");
disp(Bt,"d)deviation ratio at power amplifier");
```

Scilab code Exa 4.10.A Angle Modulation

```
clc;
clear;

//f(t)=5cos(Wc*t+3sin(2000*t)+5sin(2000*pi*t))

fm=2000*%pi/(2*%pi); //bandwidth is the highest frequency component

//a)

Freq_dev=(6000+10000*%pi)/(2*%pi);

//b)

B=Freq_dev/fm;

//c)
Phase_dev=8;//Highest value of[3sin(2000t)+5sin(2000*pi*t)]

//d)
Bw= 2*(fm+Freq_dev);

disp(Freq_dev," a) Frequency Deviation(in Hz)=");
disp(B," b) Devaition Ratio=");
disp(Phase_dev," c) Phase Deviation( in rad)=");
disp(Bw," d) Bandwidth( in Hz)=")
```

Chapter 5

Pulse Modulation

Scilab code Exa 1.A Sample and Hold

```
clear;
clc;
//("current through the capacitor is i=C(dv/dt)");

t=15; //acquisition time in us
i=5; //current in mA
v=5; //maximum voltage across capacitor in V


// to satisfy current requirement
disp("to satisfy current requirement");
C_current_req=i*t/v;
disp(C_current_req,"C(nF)=");

//to satisfy accuracy requirement
disp("to satisfy accuracy requirement");

C_accuracy_req=t/(6.9*15)*1000;// to convert into "
    nanoFarad"

disp(C_accuracy_req,"C(nF)=");
```

```

disp("to satisfy both requirements,smaller of the
    two can b taken");
```

Scilab code Exa 5.1 Sampling

```
clear;
clc;
disp("for 8-KHz sampling,the frequencies present are
    ...(in KHz)");

Fs=8; //sampling frequency
Fst=3.5 //single tone frequency

disp(Fst);
disp(-Fst);
disp(Fs-Fst);
disp(-(2*Fs+Fst),(2*Fs+Fst),-(Fs+Fst),(Fs+Fst),(Fs-
    Fst));
disp("...etc...");

disp("in this case, if the LPF is designed with cut-
    off frequency(8/2= 4-KHz)");
disp("then the maximum passable frequency is 3.5-KHz
    ");
disp("for 5-KHz sampling,the frequencies present are
    ...(in KHz)");

Fs=5;//new sampling frequency
disp(Fst);
disp(-Fst);
disp(Fs-Fst);
disp(-(2*Fs+Fst),(2*Fs+Fst),-(Fs+Fst),(Fs+Fst),(Fs-
    Fst));
disp("...etc...");
```

```
disp("in this case, if the LPF is designed with cut-off frequency(5/2=2.5-KHz)");
disp("then the original signal cant be passed");
disp("therefore, the signal cant be reconstructed");
```

Scilab code Exa 5.2.A Aliasing Frequency

```
clc;
clear;
F_audio=5; //Audio input Frequency in kHz

F_sampling=2*F_audio;

disp(F_sampling,"The Minimum Sampling Frequency (in kHz)");

disp("When the audio Frequency of 6 Khz enters the Sample and Hold circuit");
disp("it will overlap the audio spectrum, and the alaising frequency is 4 kHz");
```

Scilab code Exa 5.2 Sampling Rate

```
clc;
clear;

//x(t)=2sin(4000*pi*t)+3sin(5000*pi*t)+4sin(8000*pi*t)

fh=8000/2;
fl=4000/2;

```

```
disp(fh,"a) Highest Frequency component(in Hz)");
disp(fl,"Lowest Frequency component(in Hz)");

fs=2*fh;
disp(fs," Minimum Sampling frequency(in Hz)");

Bw=fh-fl;
disp(Bw," b)Bandwidth(in Hz) is");

n=fh/Bw;
disp(n,"integer factor");

Fs_new=2*fh/n;
disp(Fs_new,"Required Sampling frequency in this
    case(in Hz) is");
```

Scilab code Exa 5.3.A PCM system

```
clc;
clear;
fm=5;// maximum analog frequency in kHz
Min_dyna_range=35;
Vr=3; //Voltage in the receiver in V

//a)
F_sampling=2*fm;

//b)
n=Min_dyna_range/6;
k=(Vr-(-Vr)+1);// inclusive of sign bit

//c)
Resolution=Vr/(2^(7));

//d)
```

```
Max_quant_Error=Resolution/2

disp(F_sampling,"a)Minimum Sampling Rate(in kHz) =")
    ;
disp(n,"b) Minimum dynamic Range is");
disp(" But Closest whole number is 6. Henc,6 bits
    must be used for amplitude" );
disp("But the amplitude range is from -3 to +3 V,
    hence a sign bit also   ");
disp( k,"becomes necessary..Therefore,the total
    number of bits");
disp(Resolution,"c) Resolution(in V) =");
disp(Max_quant_Error," d)MAximum Quantization Error
    (in V) ");
```

Scilab code Exa 5.4.A Bandwidth of PCM system

```
clc;
clear;
n=16;// Number of telephone lines
m=256;//Quantization levels
q=8;// since 2^(q)=256

fs=10;//Sampling frequency in kHz

Bw=[(16*9)+1]*10*10^(3);

disp(Bw,"Bandwidth (in Hz ) is");
```

Chapter 6

Noise

Scilab code Exa 6.A Thermal Noise Power

```
clc;
clear;
T=290;//Temperature in K
B=15; //Bandwidth in KHz
k=1.38*10^(-23); //Boltzman constant
R=60; //resistance in ohms

N=k*T*B*10^(3); //Therman Noise Power in watts
N_dBm=10*log10(N/0.001);//in dBm

Vrms=sqrt(4*R*k*T*B*10^(3));

disp("thermal noise power (in watts) is");
disp(N);
disp("thermal noise power (in dBm) is");
disp(N_dBm);
disp("RMS noise voltage (in Volts) is");
disp(Vrms);
```

Scilab code Exa 6.1 Thermal Noise

```
clear;
clc;
T=290; // temperature in kelvin
k=1.38*10^(-23); // Boltzman constant
B=1;// bandwidth in MHz

P=k*T*B*10^(6); // thermal noise power
disp("the thermal noise power (in watts) is ");
disp(P);
```

Scilab code Exa 6.2.A SNR and Noise Figure

```
clc;
clear;

Inp_sig_pow=1.5*10^(-9); //Input Signal Power in Watts
Inp_noi_pow=1.5*10^(-18); //Input Noise Power in Watts
Pow_gain=10^(6);
int_noi=4*10^(-12); //internal noise in watts

//a)
Inp_SNR=10*log10(Inp_sig_pow/Inp_noi_pow);// input SNR in dB

//b)
Nout=Pow_gain*Inp_noi_pow+int_noi //output output noise power

Pout=Pow_gain*Inp_sig_pow //output signal power

SNR=Pout/Nout;// Signal to Noise ratio
```

```
SNRout=10*log10(SNR);// Output SNR in dB

//c)
F=10^(9)/(273*10^(6)); //Noise factor
NF=10*log10(F);// Noise figure in dB

disp("Input SNR (in dB) is");
disp(Inp_SNR);
disp("Output SNR ( in dB) is");
disp(SNRout);
disp("Noise factor");
disp(F);
disp("Noise Figure(in dB)");
disp(NF);
```

Scilab code Exa 6.2 Noise voltage

```
clc;
clear;
T=290;// temperature in kelvin
R=60;//resistance in ohms
k=1.38*10^(-23);

Esquare=4*R*T*k;
E=sqrt(Esquare); //noise voltage

disp("the noise voltage( in volts) is")
disp(E);
```

Scilab code Exa 6.3.A Noise Voltage

```
clc;
clear;
```

```
q=1.6*10^(-19);// electron charge
Ieq=5;//equivalent shot noise current in uA
Bn=8;//bandwidth in MHz
Rn=200;
Rs=100;//resistance in ohms
k=1.38*10^(-23);// boltzman constant
T=290;//temperature in K
Vs=10// RMS signal source volatage in uV

In=sqrt(2*Ieq*q*Bn);

Vni=Rs*In;//shot noise voltage

Vns=sqrt(4*Rs*k*T*Bn*10^(6));//thermal noise volatge from source

//change in answer due to calculation error in book
Vne=sqrt(4*Rn*k*T*Bn*10^(6));//noise voltage by equivalent noise resistance

Vn=sqrt(Vni^2+Vns^2+Vne^2);// total noise voltage

SNR=20*log10(Vs*10^(-6)/Vn);

disp("shot noise voltage(in V) is ");
disp(Vni);
disp("thermal noise voltage from source(in V) is");
disp(Vns);
disp("noise voltage by equivalent noise resistance(in V) is");
disp(Vne);
disp("total noise voltage at the input(in V) is");
disp(Vn);
disp("SNR (in dB) is");
disp(SNR);
```

Scilab code Exa 6.3 Thermal Noise Voltage

```
clear;
clc;
B=150;// bandwidth in KHz
R1=30;
R2=60;// both resistors R1 and R2 in K-ohms
k=1.38*10^(-23);// boltzman constant
T=290; //temperature in Kelvin

Esquare=4*R1*10^(3)*k*B*10^(3)*T;
E=sqrt(Esquare);

disp("series combination Rseries(in K-ohms)=");
disp(R1+R2);
Eseries=E*sqrt(3);
disp("the thermal noise voltage (in volts) is");
disp(Eseries);

disp("series combination Rseries(in K-ohms)=");
disp(R1*R2/(R1+R2));
Eparallel=E*sqrt(2/3);
disp("the thermal noise voltage (in volts) is");
disp(Eparallel);
```

Scilab code Exa 6.4.A Output SNR

```
clc;
clear;
S=4;//number of stages
SNR_input=55;//input Signal to Noise ratio in dB

```

```
SNR_output=SNR_input-10*log10(S);

disp("Output SNR( in dB) is");
disp(SNR_output);
```

Scilab code Exa 6.4 Shot Noise

```
clc;
clear;

Idc=2; //direct current in mA
q=1.6*10^(-19); // electron charge
B=3; //bandwidth in MHz

Isquare=2*Idc*10^(-3)*q*B*10^6;
I=sqrt(Isquare); //shot noise component

disp("the shot noise component(in amperes) is");
disp(I);
```

Scilab code Exa 6.5.A Output SNR

```
clc;
clear;
F=5; //noise figure in dB
SNR_input=55;//Input Signal to noise ratio in dB
SNR_output=SNR_input-F;
disp("Output SNR (in dB) is");
disp(SNR_output);
```

Scilab code Exa 6.5 Output SNR

```
clc;
clear;
Np1=60; // Noise-Power ratio of first system in dB
Np2=40; // Noise-Power ratio of second system in dB
Np3=30; // Noise-Power ratio of third system in dB
Np4=50; // Noise-Power ratio of fourth system in dB

 P1=10^(-6); //power ratio of first system
 P2=10^(-4); //power ratio of second system
 P3=10^(-3); //power ratio of third system
 P4=10^(-5);//power ratio of fourth system

 SNR=(P1+P2+P3+P4); // Overall Signal to Noise ratio
  disp("SNR ratio is");
  disp(SNR);

  N_final=30; //since SNR is 10^(-3)

 disp("overall SNR (in dB)is");
 disp(N_final);

 disp("the overall SNR is equal to that of the worst
     system")
```

Scilab code Exa 6.6.A Noise Figure

```
clc;
clear;
F=16;// Power ratio in dB
k=1.38*10^(-23) ;// boltzman constant
T=290; //temperature in K
B=5; //Bandwidth in MHz

```

```
P=(F-1)*k*T*B*10^(6);
disp(" Amplifier Inout noise power (in watts) is");
disp(P);
```

Scilab code Exa 6.6 Output SNR

```
clc;
clear;
N_figure=8 ;//Noise figure in dB
SNR_in=45; //Signal to  Noise ratio in dB

SNR_out=SNR_in-N_figure //output Signal to Noise
   ratio

disp("the Output SNR(in dB) is ");
disp(SNR_out);
```

Scilab code Exa 6.7.A Overall noise figure

```
clc;
clear;
Nf1=7; //Noise figure of first stage in dB
F1=5.01; //first power ratio
Nf2=25; //Noise figure of second stage in dB
F2=316.22; //second power ratio
pG=15; //power gain in dB
G1=31.62; //power ratio

F=F1+(F2-1)/G1;

disp("overall noise factor");
disp(F);
disp("Overall noise factor in dB")
```

```
disp(10*log10(F));
```

Scilab code Exa 6.8.A Noise Temperature

```
clc;
clear;
Nf=15; //noise figure in dB
F=31.62;//power ratio
T=290; //Temperature in K
T_em=(F-1)*T

G1=10^(6); //power ratio
N_t=80; //Noise temperature in K
T_e=N_t+T_em/G1;

disp("Noise temperature of receiver (in K)");
disp(T_em);

// change in answer....the calculation in the book is wrong

disp("Overall Noise temperature of receiving system(in K) is");
disp(T_e);
```

Scilab code Exa 6.9.A Noise Temperature

```
clc;
clear;
ENR=31.62; //10^(1.5);
Y=6.30; //10^(0.8)
T=290;//temperature in K
T_h=T*(ENR+1);
```

```
T_e=(T_h-Y*(T))/(Y-1);
disp("Equivalent Noise Temperature (in K) is");
disp(T_e);
```

Chapter 7

Introduction to Digital Communication

Scilab code Exa 7.1.A Baud Rate and Bandwidth

```
clc;
clear;
bin_signal=20; //binary signal in kbps
N=1;//since ASK

Bw=bin_signal*10^(3);
Baud=bin_signal*10^(3);

disp(Bw,"Bandwidth(in Hz)=");
disp(Baud,"Baud rate=");
```

Scilab code Exa 7.1 Baud Rate

```
clc;
clear;
N=1;// since ASK
```

```
Bin_Sig=15;//Binary signal in kbps

BW=Bin_Sig*10^(3)/N;
Baud=Bin_Sig*10^(3)/N;
disp(BW,"Bw=");
disp(Baud,"Baud=");
```

Scilab code Exa 7.2.A Bandwidth and Baud Rate

```
clc;
clear;
mark_f=59;//MArk Frequency in Hz
space_f=61; //space frequency in Hz
input_rate=5;//input rate in kbps

Peak_Frq_Dev=abs((mark_f-space_f)/2);
Bw=2*(Peak_Frq_Dev+input_rate)*10^(3);
baud=input_rate*10^(3);

disp(Peak_Frq_Dev,"Peak Frequency Deviation (in KHz)=");
disp(Bw,"Minimum BW (in Hz)=");
disp(baud,"Baud=");
```

Scilab code Exa 7.2 Baud Rate and Bandwidth

```
clc;
clear;
mark_f=60;//Mark Frequency in KHz
space_f=63;//Space Frequency in KHz
input_bit_rate=3;// input bit rate

Peak_Frq_Dev=abs((mark_f-space_f)/2);
```

```
B=2*(Peak_Frq_Dev+input_bit_rate);
Baud=input_bit_rate*10^(3);

disp(Peak_Frq_Dev,"Peak Frequency Deviation(in KHz)=
   ");
disp(B,"Minimum Bandwidth(in KHz)=");
disp(Baud,"Baud rate=");
```

Scilab code Exa 7.3.A Bandwidth and Baud Rate

```
clc;
clear;
N=3;// since 8-PSK
bit_rate=36;// in kbps

Bw=bit_rate*10^(3)/N;
baud=bit_rate*10^(3)/N;
n=bit_rate*10^(3)/Bw;

disp(Bw," Minimum Bandwidth(in Hz)=");
disp(baud,"Baud rate=");
disp(n,"Bandwidth efficiency(in bits per second per
   cycle of bandwidth)=");
```

Scilab code Exa 7.3 Baud Rate and Bandwidth

```
clc;
clear;
bit_rate=36;// information bit rate in Kbps
m=3;// since 8-PSK

Baud=bit_rate*10^(3)/m;
Bw=36*10^(3)/m;
```

```
n=36000/12000;

disp(Baud,"Baud=");
disp(Bw,"BW=");
disp(n,"Bandwidth efficiency(in bits/cycle)=");
```

Scilab code Exa 7.4.A Nyquist Bandwidth

```
clc;
clear;

Input_bit=5; //Input bit rate in Mbps

//bit rate in I,Q,C channels is one-third of input
   bit rate

fbI=Input_bit/3;//bit rate in I channel
fbC=Input_bit/3;//bit rate in C  channel
fbQ=Input_bit/3;////bit rate in I channel

Baud=fbI;//Baud in Mbps

fa=fbC/2;

//Output from Modulator is
//  0.5cos(2*pi*49.17MHz)-0.5cos(2*pi*50.83MHz)

Nyquist=50.83-49.17;

disp(Nyquist,"Minimum Nyquist Bandwidth(in MHz)=");
```

Chapter 8

Information theory

Scilab code Exa 8.1.A `Information Rate`

```
clc;
clear;
p1=1/8;
p2=1/8;
p3=5/8;
p4=1/8; //Quantization Levels
//B is the Bandwidth of the signal

H=p1*log2(1/p1)+p2*log2(1/p2)+p3*log2(1/p3)+p4*log2(1/p4);

disp(H,"The average Information (in bits/message)=");
disp("The Information Rate R=rH  =2*B(1.55)  =3.1B bits/s");
```

Scilab code Exa 8.2.A `ShannonFano and Huffman coding`

```
clc;
clear;
m1=0.2;
m2=0.3;
m3=0.2;
m4=0.15;
m5=0.15; // probability of 5 source messages

H=m1*log2(1/m1)+m2*log2(1/m2)+m3*log2(1/m3)+m4*log2
    (1/m4)+m5*log2(1/m5);//Average information in
    bits

//a) Shannon-fano coding
                            //coding
// m1   0.2   0 0           00
// m2   0.3   0 1           01
// m3   0.2   1 0           10
// m4   0.15  1 1 0         110
// m5   0.15  1 1 1         111

L=(0.2*2)+(.3*2)+(0.2*2)+(2*0.15*3) //Average code
    word length(in bits)=probability *coding length

n=H/L;

disp(n*100,"Coding efficiency for Shannon Fano
    coding is");

//b)  Huffman coding

// m1 0.2       01
// m2 0.3       00
// m3 0.2       11
// m4 0.15      010
// m5 0.15      110

L=(0.2*2)+(.3*2)+(0.2*2)+(2*0.15*3) //Average code
    word length(in bits)=probability *coding length
```

```

n=H/L;

disp(n*100,"Coding efficiency for Huffman coding is");

//change in answer due to rounded off value in text-book
```

Scilab code Exa 8.3.A Gaussian Channel

```
clc;
clear;

PSD=10^(-9); //noise PSD in W/Hz
Bw=4000;//Wandwidth in Hz

//a)
E=0.1 //Energy in Joules
C=Bw*log2(1+E/(2*PSD*Bw));
disp(C,"a) Capacity of the gaussian channel(in bits/s) when E is 0.1J=");

//b)
E=0.001 //Energy in Joules
C=Bw*log2(1+E/(2*PSD*Bw));
disp(C,"b) Capacity of the gaussian channel(in bits/s) when E is 0.001J=");

//c)
Bw=10000;
C=Bw*log2(1+E/(2*PSD*Bw));
disp(C,"d) Capacity of the gaussian channel(in bits/s) when Bw is 10Khz=");

```

```
disp("100 times fall in Energy when the BW is increased by 2.5 times");
```

Scilab code Exa 8.5.A `Throughput efficiency`

```
clc;
clear;
k=973;
n=1023;
Pa=0.99;
Tw=10*10^(-6);
Tl=40*10^(-6);
N=4;

N_sw=(k/n)*(Pa/(1+Tl/Tw));// efficiency of stop and wait algorithm
N_sgpull=(k/n)*(1/(1+N*(1-Pa)/Pa));//efficiency of go-back-N algorithm
Nsr=(k/n)*Pa;// efficiency of selective repeat algorithm

disp(N_sw,"N s&w");
disp(N_sgpull,"Nsgpull");
disp(Nsr,"Nsr");
```

Scilab code Exa 8.6.A `Rate of source`

```
clc;
clear;
p1=1/2;
p2=1/4;
p3=1/8;
p4=1/16;
```

```
p5=1/16;// probabilities

H=p1*log2(1/p1)+p2*log2(1/p2)+p3*log2(1/p3)+p4*log2
   (1/p4)+p5*log2(1/p5);
Bw=4000; //Bandwidth in Hz
R=2*H*Bw ;

disp(R,"Rate of the source ( in bits/s) is");
```

Scilab code Exa 8.7.A entropy of equiprobable source

```
clc;
clear;

// probability of all the events are same
syms N;

H_X=N*[(-1/N)*log(1/N)]; //H(X)=(-1/N)log(1/N)+(-1/N
   )log(1/N)+....N times

disp(H_X,"H(X)=");
```

Scilab code Exa 8.8.A Self Information

```
clc;
clear;
P0=2/3; //P(X=0)
P1=2/3; //P(Y=0)
H_x=0.919;
H_y=0.919;
H_b=0.919; //Hb(2/3)

```

```
//since X,Y pair is uniformly distributed on  three
    values
H_xy=log2(3); // H(X,Y)

H_xdivy=H_xy-H_y; //H(X/Y)=H(X,Y)-H(Y)
I_xdivy=H_x-H_xdivy; //I(X,Y)=H(X)-H(X/Y)

disp(I_xdivy,"I(X,Y)=");
```

Scilab code Exa 8.10.A SNR

```
clc;
clear;
W=3000;
SNR_db=39;// 10log (SNR_ratio)=SRN_db
SNR_ratio=7943; //10^(3.9)

C=W*log2(1+SNR_ratio);

disp(C,"Capacity (in bits/s) =");
```

Chapter 9

Introduction to Probability Random variable and Random processes

Scilab code Exa 9.1.A `Multiplication Theoram`

```
clc;
clear;

P_white=5/8; //P(ball is white)

//white ball is removed,the remaining balls are four
    white and three green

P_green=3/7; //P(ball is green)

P_tot=P_white*P_green;

disp(P_tot," Desired Probability using
   multiplication theoram=")
```

Scilab code Exa 9.1 `Conditional Probability`

```
clear;
clc;
// f2 be the event that " a two occurs"


tot=6; //total number of possible outcomes
f_2=1; // number of desired outcomes
M=3; // number of even outcomes

///// a)

P_A=f_2/tot; //P(A)

///// b)
P_M=M/tot; //P(M)

////// c)
P_AintersectionM=P_A/P_M; //P(A intersection M)

disp(P_A,"a) P(A)= ");
disp(P_M,"b) P(M)=");
disp(P_AintersectionM=P_A/P_M,"c) P(A intersection M)=");
```

Scilab code Exa 9.2.A `Theoram of Total Probability`

```
clc;
clear;
P_box1=0.25; //P(box1)
P_box2=0.25; //P(box2)
P_box3=0.25; //P(box3)
P_box4=0.25; //P(box4)

```

```
Pdef_1=0.05;  //P(defective/box1)
Pdef_2=0.3;  //P(defective/box2)
Pdef_3=0.10;  //P(defective/box3)
Pdef_4=0.20;  //P(defective/box4)


Pcomp_def=(P_box1*Pdef_1)+(P_box2*Pdef_2)+(P_box3*
    Pdef_3)+(P_box4*Pdef_4); //Theoram of total
    probability

disp(Pcomp_def," P(component is defective)=");
```

Scilab code Exa 9.2 Conditional Probability

```
clc;
clear;

white_ball=3;
red_ball=2;
total=white_ball+red_ball;
P_W=white_ball/total;

P_SRFW=1/2; //Prob. of second red given  first white

P_FWSR=P_W *P_SRFW// prob. of first  white and
    second red

disp(P_FWSR," P(First Ball is White and second is
    red)=");
```

Scilab code Exa 9.3.A Error Probability

```
clc;
```

```
clear;

P_1=0.3; //P( 1 is transmitted)
Pe_1=10^(-3); //P(detecting an error when 1 is
   transmitted)
P_0=0.7;//P( 0 is transmitted)
Pe_0=10^(-7); //P(detecting an error when 0 is
   transmitted)

error_prob=P_1*Pe_1+P_0*Pe_0;

disp(error_prob,"Error Probabillity of the channel")
   ;
```

Scilab code Exa 9.3 Bayes Theoram

```
clc;
clear;
P_box1=0.25; //P(box1)
P_box2=0.25; //P(box2)
P_box3=0.25; //P(box3)
P_box4=0.25; //P(box4)

Pdef_1=0.05;  //P(defective/box1)
Pdef_2=0.4;  //P(defective/box2)
Pdef_3=0.10;  //P(defective/box3)
Pdef_4=0.10;  //P(defective/box4)

//a)

Pcomp_def=(P_box1*Pdef_1)+(P_box2*Pdef_2)+(P_box3*
   Pdef_3)+(P_box4*Pdef_4); //Theoram of total
   probability

//b)
```

```
Pbox2_def=(P_box2*Pdef_2)/((P_box1*Pdef_1)+(P_box2*Pdef_2)+(P_box3*Pdef_3)+(P_box4*Pdef_4)); //Bayes theoram

disp(Pcomp_def," a) P(component is defective)=");

disp(Pbox2_def," b) P(box2|defective)=");
```

Scilab code Exa 9.4.A Density Function

```
clc;
clear;
//Y is a Gaussian Random Variable

syms y;

x=5;
m=-3*(x)+5; //mean
disp(m,"mean");

var=4*7; //variance
disp(var,"variance");

Y=exp(-{(y+10)^2}/56)/sqrt(56*%pi);

disp("Y is an N{-10,28} random variable");
disp(Y,"density function f(y)= ");
```