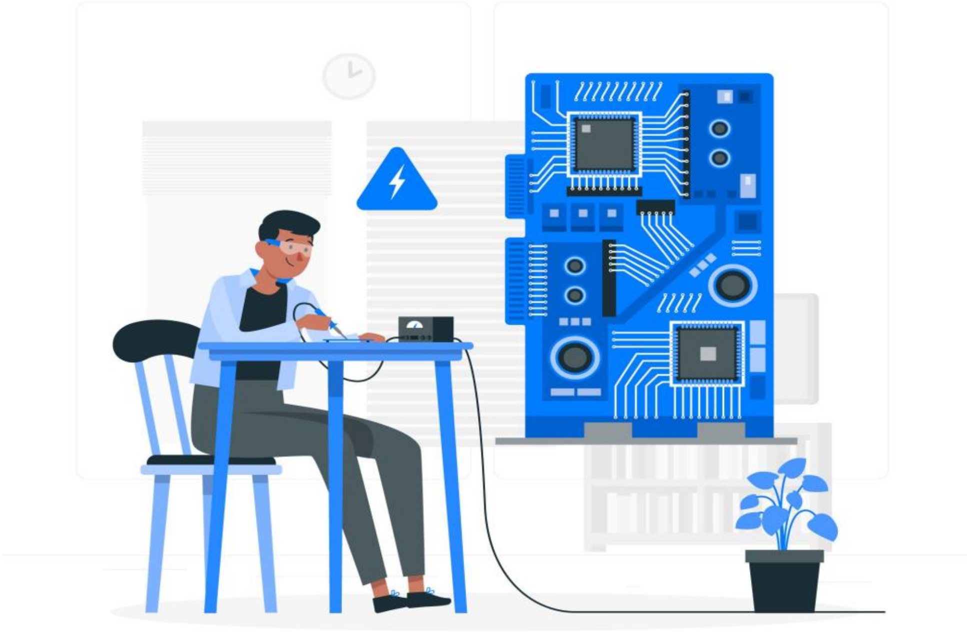

Lab 2: Sampling techniques.

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CT303 Digital Communication
10/8/23

Lab 2: Sampling techniques and matlab code

1. Determine the Nyquist sampling rate and theNyquist sampling interval for the following signals.
   • $x(t) = \mathrm{sinc}(100\pi t) + 3\,\mathrm{sinc}2\,(60\pi t)$
   • $x(t) = 1 + \cos(2000\pi t) + \sin(4000\pi t)$.

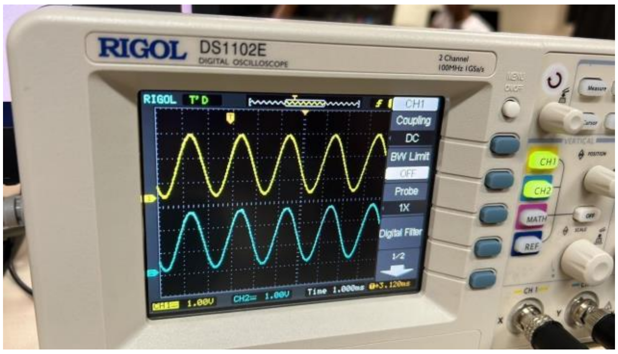
   •$x(t) = \mathrm{sinc}(100\pi t) + 3\,\mathrm{sinc}^2\,(60\pi t)$
   Here, the expression can be expanded as x(t) = sin(100πt)/100πt + 3*(1-cos(120πt))/2/(60πt)^2, so, the maximum frequency component here is 120π Hz. So, f = 120π/2π = 60Hz which implies Nyquist rate = 2*60Hz = 120Hz and Nyquist interval = 1/120s = 0.008333333333s.

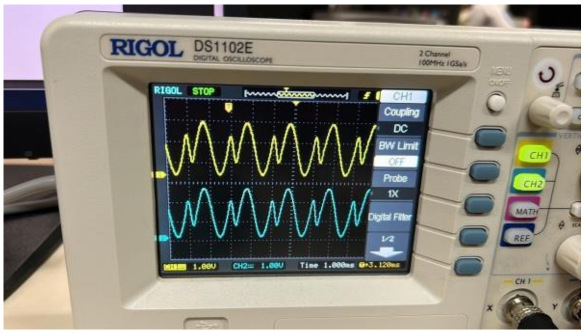
   • $x(t) = 1 + \cos(2000\pi t) + \sin(4000\pi t)$.

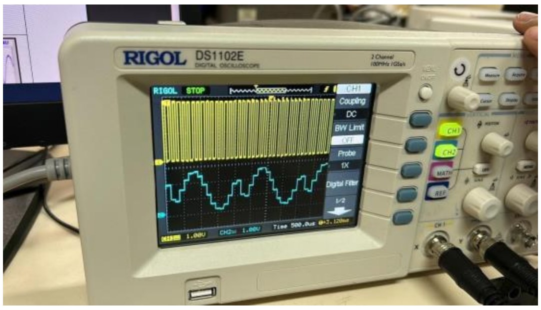
   $x(t) = 1 + \cos(2000\pi t) + \sin(4000\pi t)$.
   Here, the expression has maximum frequency component as 4000π Hz. So, f = 4000π/2π Hz = 2000Hz and Nyquist rate = 2*2000Hz = 4000Hz. The Nyquist interval = 1/4000s = 0.00025s.

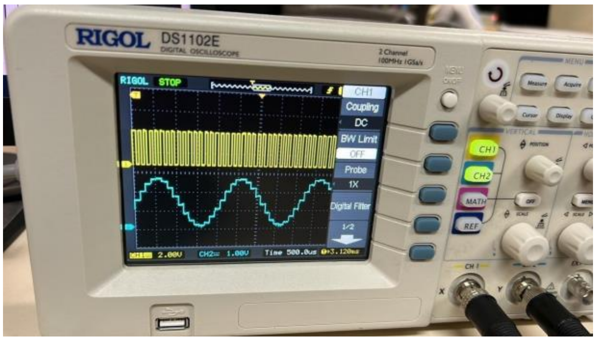
Experiment 1

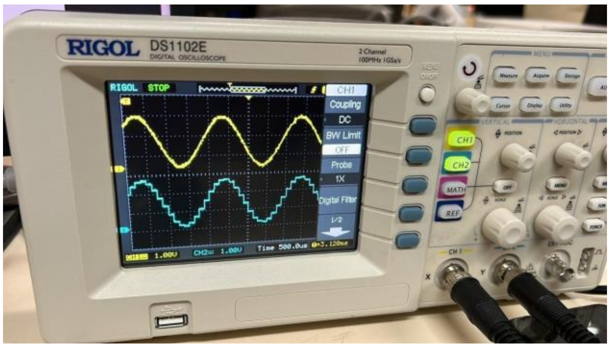
Experiment 1.1 , 1.2 , 1.3 , 1.4 , 1.5 , 1.6 Respectively

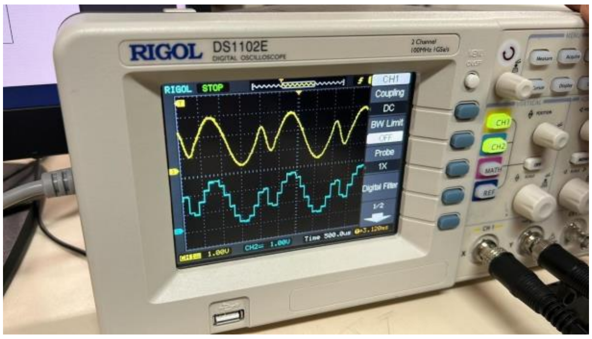






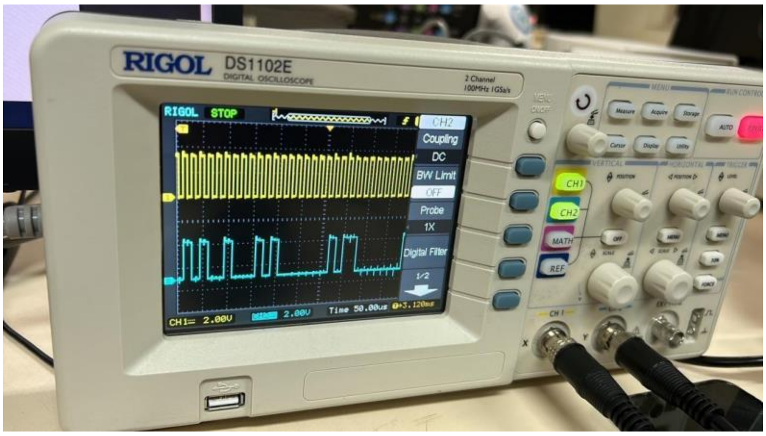


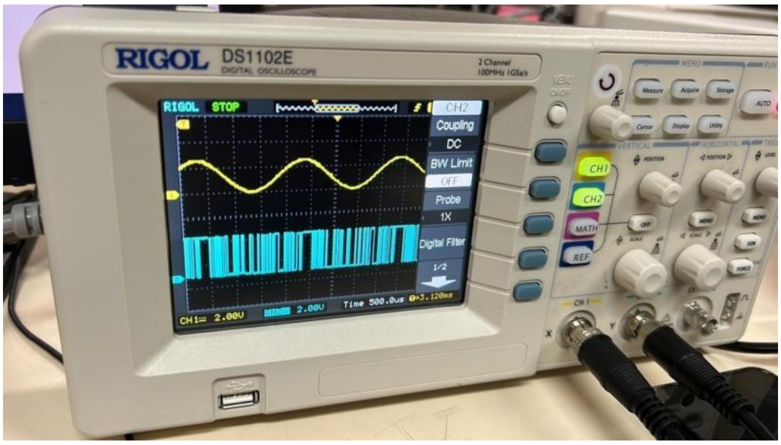


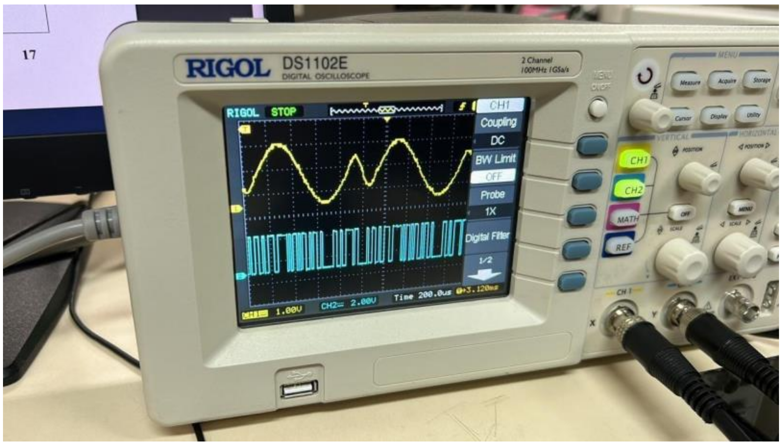


Experiment 2

Experiment 2.1, 2.2, 2.3

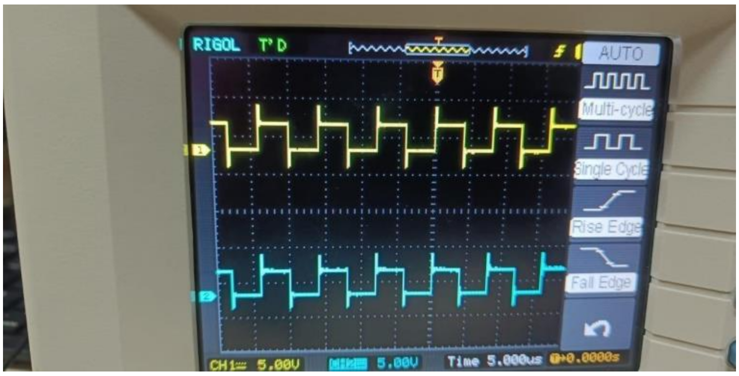






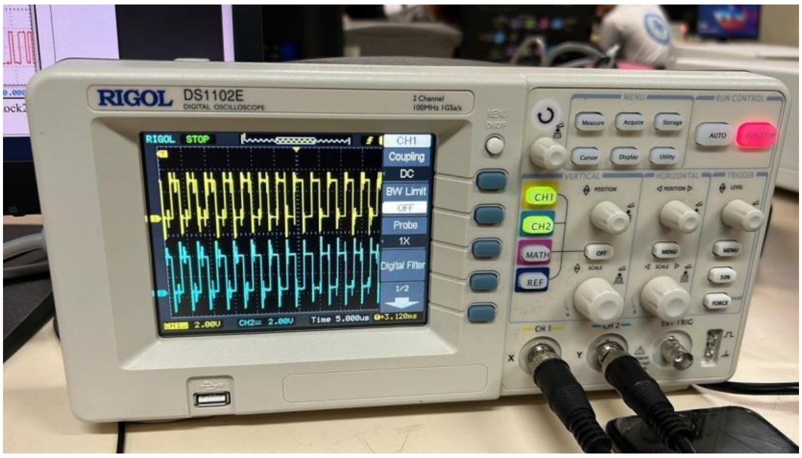
Experiment 3

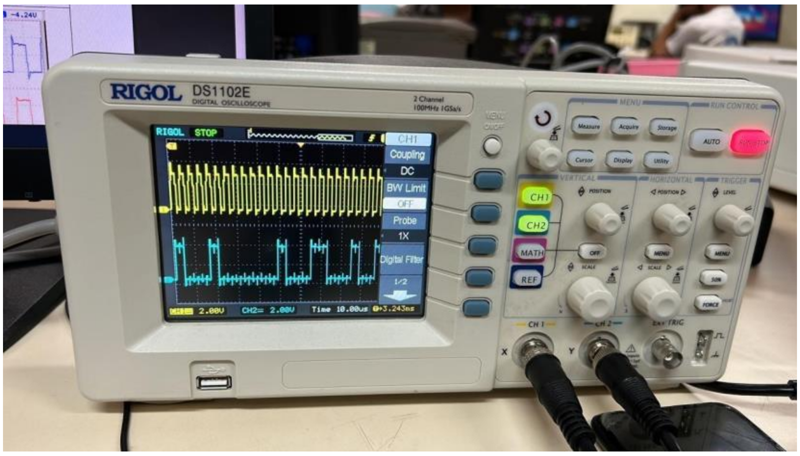
experiment 3.1, 3.2, 3.3 ,3.4 respectively

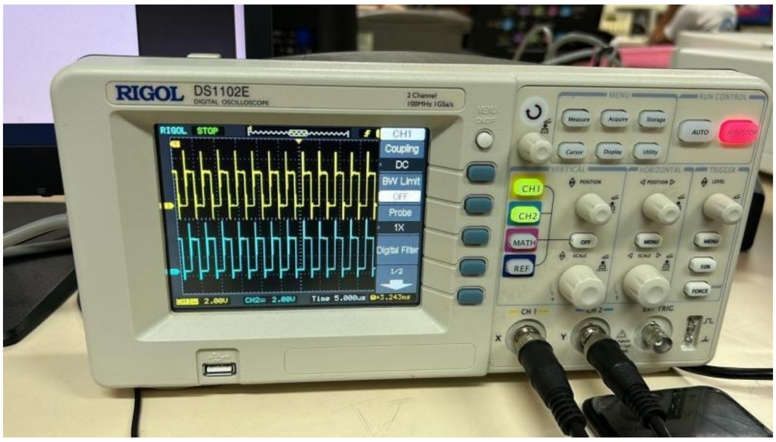


Experiment 4

experiment 4.1, 4.2, 4.3 respectively

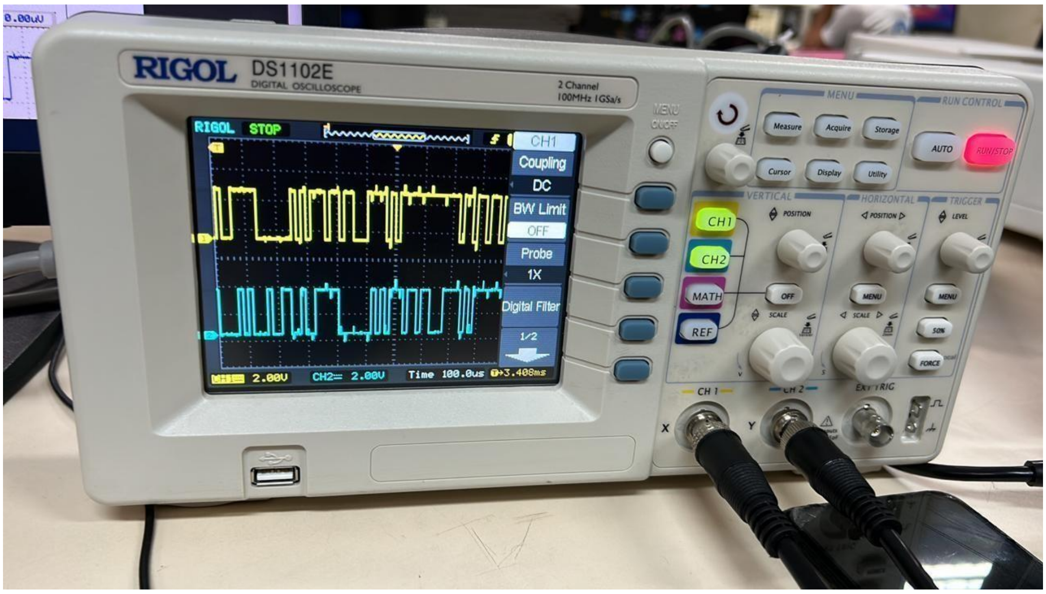


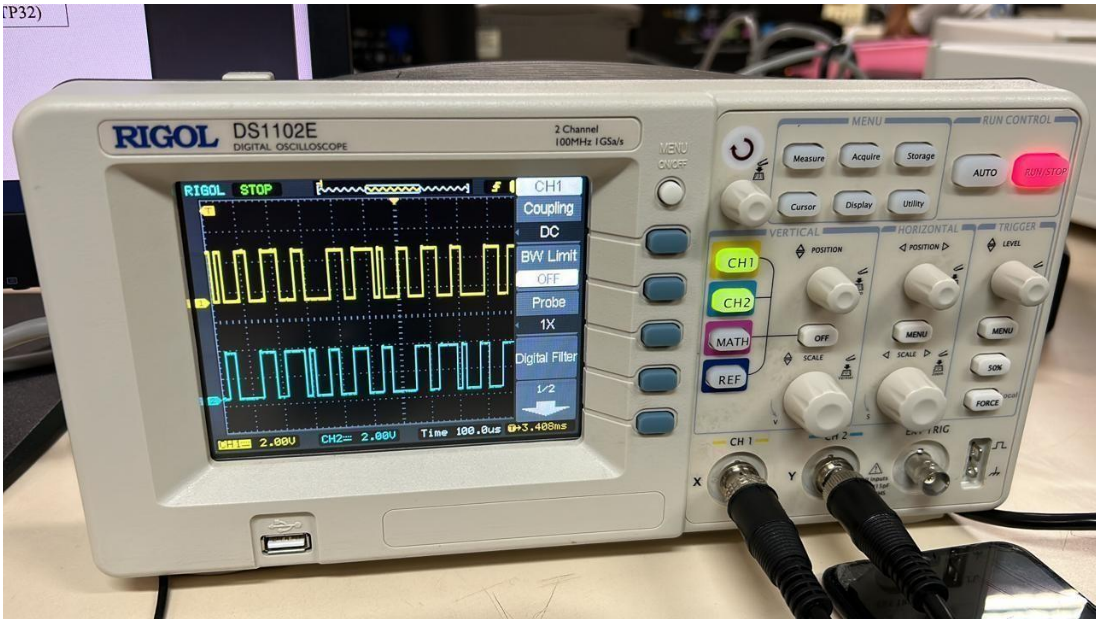




Experiment 5

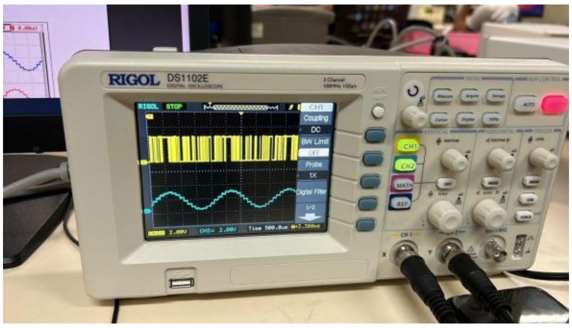
Experiment 5.1, 5.2

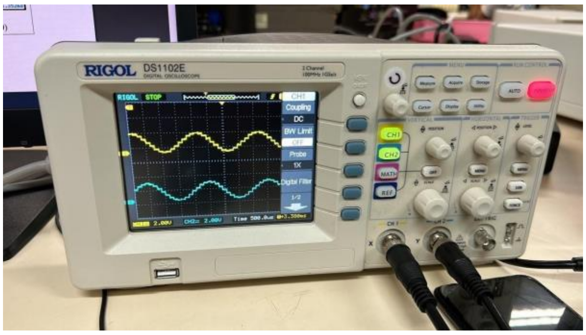


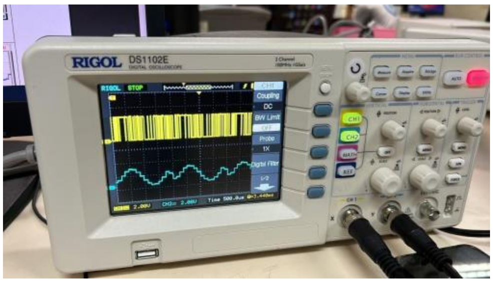


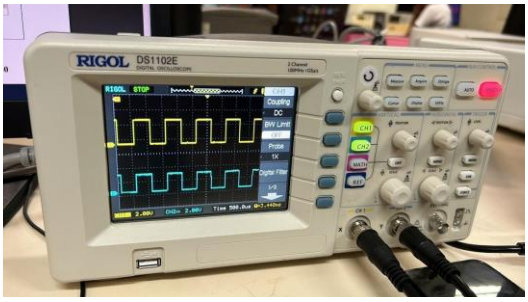
Experiment 6

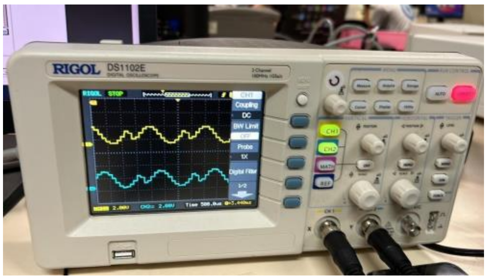
Experiment 6.1, 6.2, 6.3, 6.4 , 6.5, 6.6 respectively

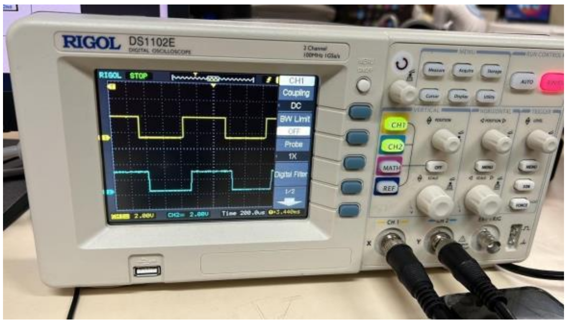






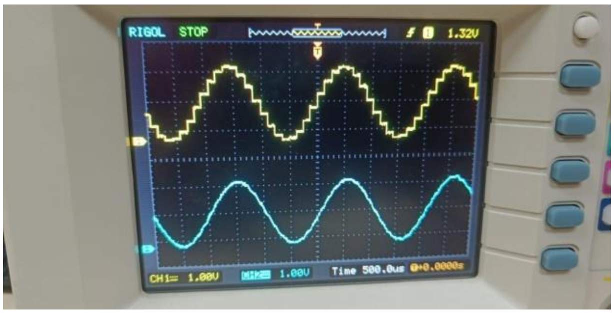


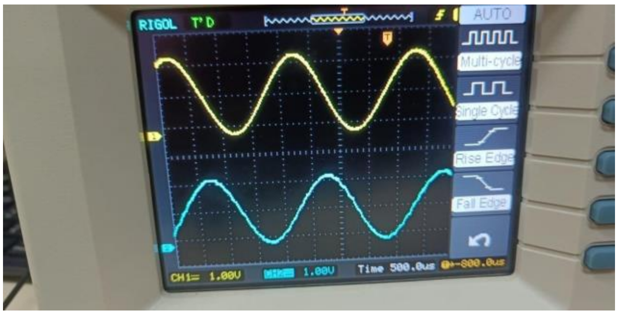


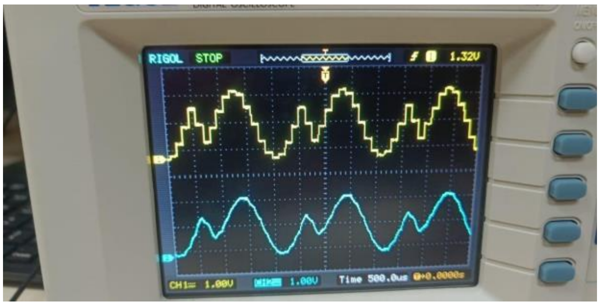


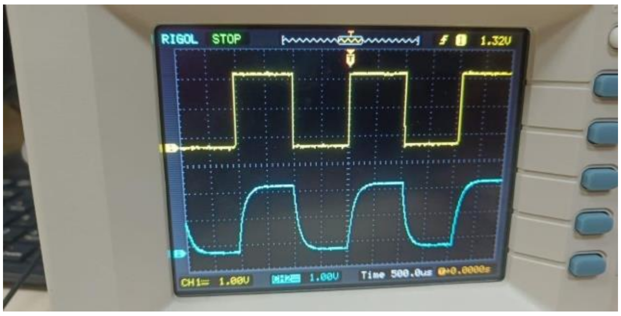
Experiment 7

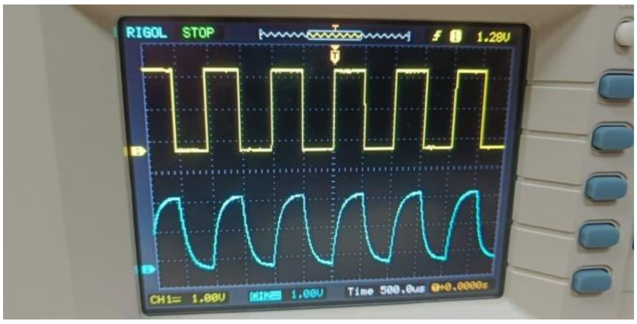
Experiment 7.1, 7.2, 7.3, 7.4 , 7.5, 7.6,7.7, 7.8, 7.9 respectively

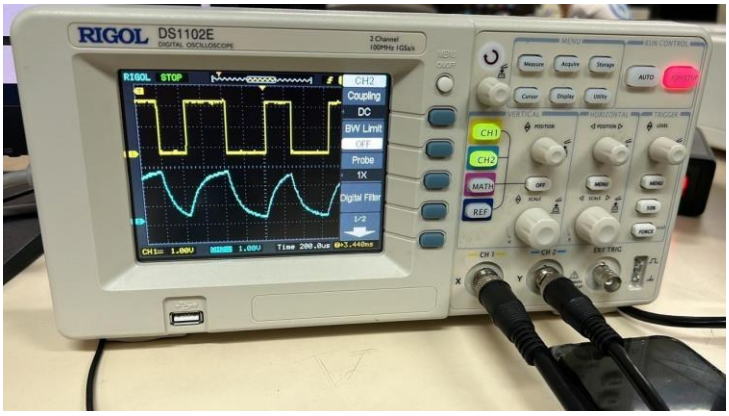


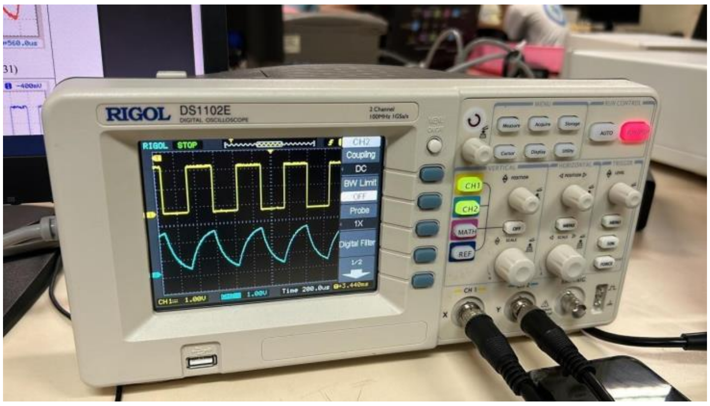









RIGOL
DS1102E
CH2
Coupling
DC
BW Limit
Probe
1X
Digital Filter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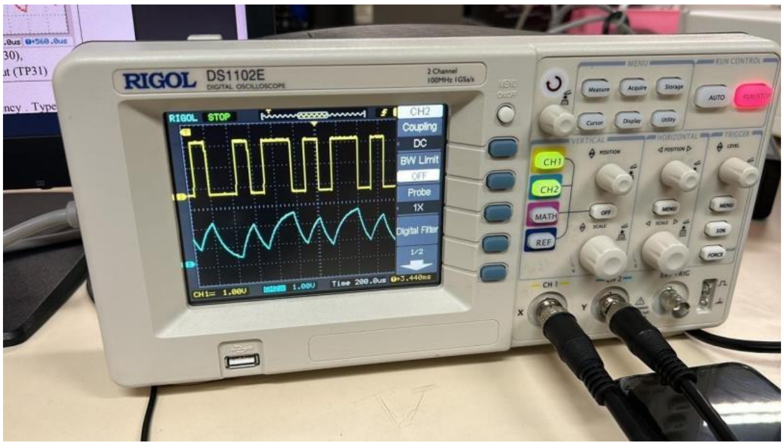
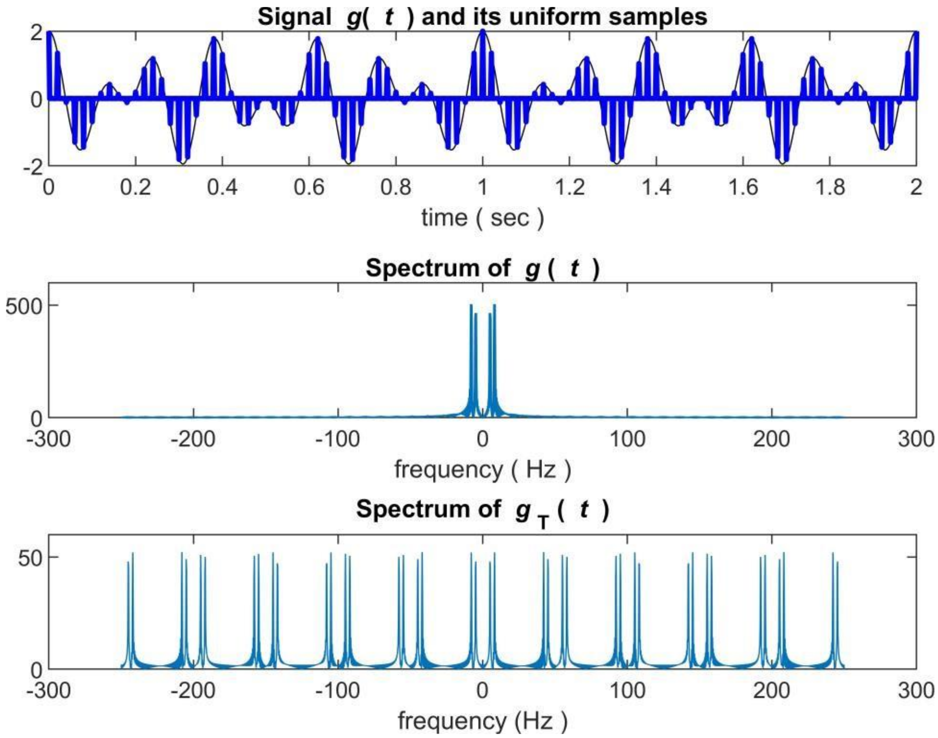

RIGOL
DS1102E
CH2
Coupling
DC
BW Limit
Probe
1X
Digital Filter

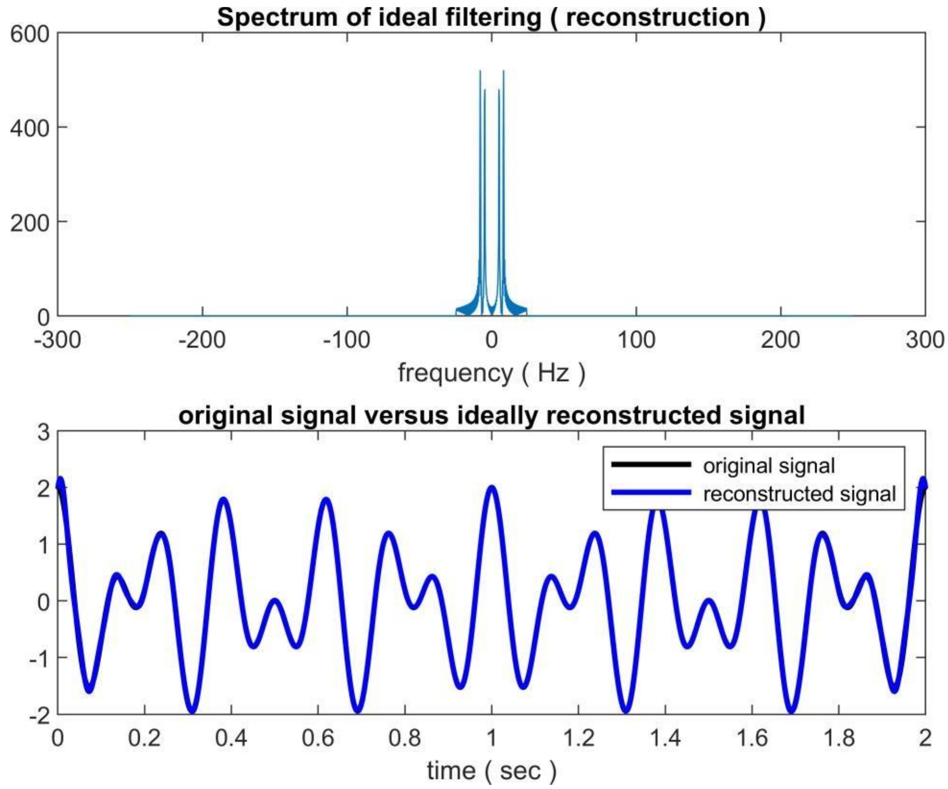
D

```
clear;clf;
td=  0.002  ;
t = [0:td:2];
xsig=cos (10*pi*t) +cos(16*pi*t);
Lsig=length(xsig);
ts=0.02;
Nfactor=ts / td;
[ s_out , sq_out , sqh_out , Delta , SQNR ] = sampandquant (xsig,16,td,ts) ;
Lfft= 2.^ceil(log2(Lsig)+1)  ;
Fmax= 1/ (2*td ) ;
Faxis=linspace(-Fmax ,Fmax , Lfft ) ;
Xsig=fftshift ( fft ( xsig , Lfft ) );
S_out=fftshift ( fft ( s_out ,Lfft ) );
figure (1) ;
subplot (311) ; sfig1a=plot(t,xsig , ' k ');
hold on ; sfig1b=plot(t,s_out(1:Lsig) ,' b ' ) ; hold off ;
set(sfig1b , 'LineWidth' , 2);
xlabel( ' time ( sec ) ');
title( ' Signal {\it g}({ \it t } ) and its uniform samples ' ) ;
subplot(312); sfig1c=plot(Faxis , abs(Xsig));
xlabel( ' frequency ( Hz ) ');
axis([ - 300 300 0 600])
set(sfig1c , 'LineWidth' , 1 ) ; title ( ' Spectrum of {\it g} ( {\it t } ) ');
subplot(313) ; sfig1d=plot(Faxis , abs( S_out ) );
xlabel ( ' frequency (Hz ) ');
axis ( [ - 300 300 0 600 /Nfactor ] )
set(sfig1c , 'LineWidth' , 1 ); title ( ' Spectrum of {\it g }_T ( {\it t } ) ');
```

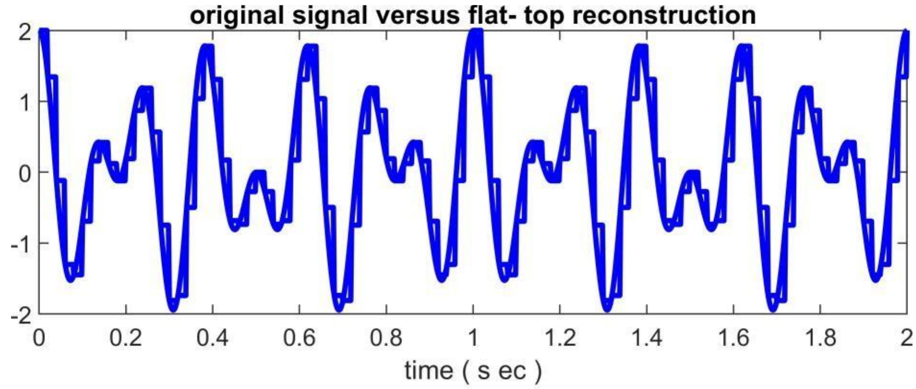


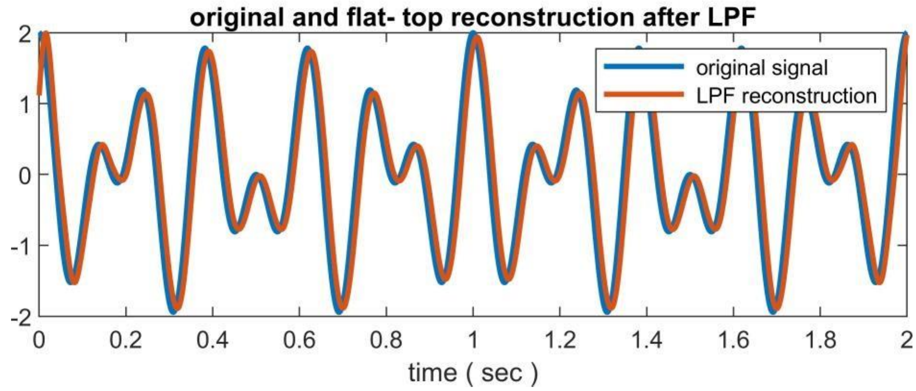

```
% calculate the recons tructed signal from ideal sampl ing and
BW=100 ;
H_lpf= zeros(1, Lfft); H_lpf(Lfft/2-BW : Lfft/2+BW-1) = 1 ;
S_recv=Nfactor* S_out .* H_lpf ;
s_recv=real(ifft(fftshift(S_recv))) ;
s_recv= s_recv(1:Lsig) ;

figure(2)
subplot (211) ; sfig2a=plot(Faxis , abs(S_recv) );
xlabel ( ' frequency ( Hz ) ');
axis ( [ -300 300 0 600] );
title ( ' Spectrum of ideal filtering ( reconstruction ) ');
subplot(212 ) ; sfig2b=plot(t,xsig , ' k- . ' , t , s_recv(1 : Lsig) , ' b ');
legend( ' original signal ', ' reconstructed signal ');
xlabel( ' time ( sec ) ');
title( ' original signal versus ideally reconstructed signal ');
set( sfig2b, 'LineWidth' ,2) ;
```




```
% non-ideal reconstruction
ZOH=ones(1, Nfactor ) ;
s_ni =kron( downsample( s_out , Nfactor ),ZOH) ;
S_ni = fftshift( fft( s_ni , Lfft ) );
S_recv2 =S_ni .*H_lpf; % ideal filtering
s_recv2 =real(ifft( fftshift( S_recv2 ))); % reconstructed f-domain
s_recv2 =s_recv2 (1:Lsig) ; % reconstructed t-domain
figure (3)
subplot(211); sfig3a=plot(t,xsig , 'b' , t , s_ni (1:Lsig) , ' b ');
xlabel( ' time ( s ec ) ');
title ( ' original signal versus flat- top reconstruction ');
subplot(212); sfig3b=plot(t,xsig  , t , s_recv2 (1:Lsig)   ) ;
legend( ' original signal ', ' LPF reconstruction ');
xlabel ( ' time ( sec ) ');
set( sfig3a, 'LineWidth' ,2) ; set(sfig3b , 'LineWidth' ,2) ;
title ( ' original and flat- top reconstruction after LPF ' );
```






```
function [ q_out ,Delta , SQNR]=uniquan( sig_in , L )



sig_pmax=max( sig_in ) ;

sig_nmax=min( sig_in ) ;

Delta= ( sig_pmax- sig_nmax ) /L;

q_level=sig_nmax+Delta/2 : Delta : sig_pmax-Delta / 2 ; L_sig=length( sig_in ) ;

sigp=(sig_in- sig_nmax ) / Delta+1/2 ;

qindex=round( sigp ) ;

qindex=min ( qindex , L ) ;

q_out =q_level(qindex) ;

SQNR=20.*log10(norm(sig_in)/norm( sig_in-q_out ));

end

function [ s_out , sq_out , sqh_out , Delta , SQNR] = sampandquant ( sig_in , L , td , ts)

if ( rem(ts/td , 1 ) ==0 )
 nfac=round( ts/td ) ;
```

```
else
warning( 'Error ! ts / td is not an integer ! ');
s_out= [] ; sq_out= [] ; sqh_out= [] ; Delta= [] ; SQNR= [] ;
end
end
```