Digital Signal Processing Lab

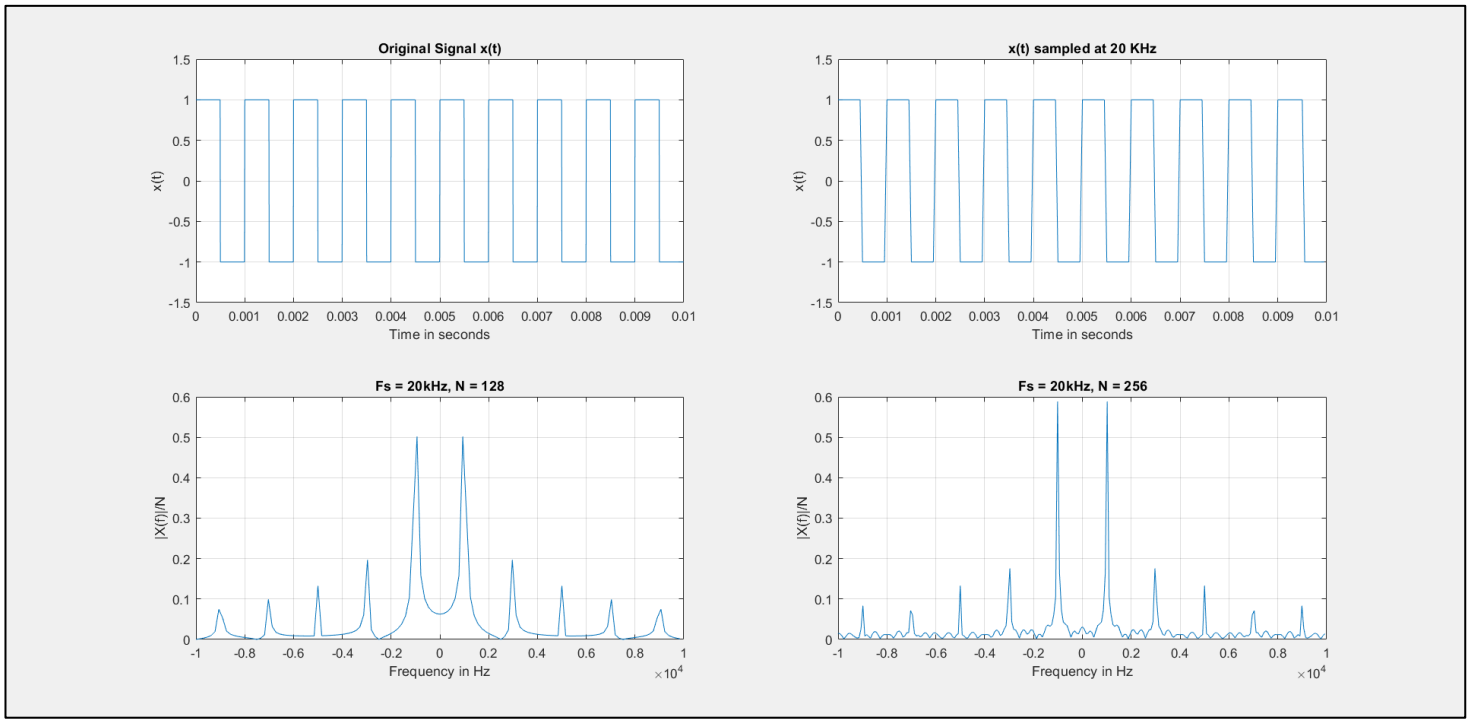
Experiment 1.c & 1.d

By Hardik Tibrewal (18EC10020)

Part C:

To plot the frequency spectrum of a square wave.

Frequency Spectrum of square wave



The original signal in the figure is sampled at 200 kHz to show a distinct effect of sampling at 20 kHz (rise and fall time behaviour is visible).

N-point FFT was done using N=128 and N=256, and peaks were observed at certain frequencies. Reasons will be discussed in the complete lab report.

Code:

```
clc
close all
```

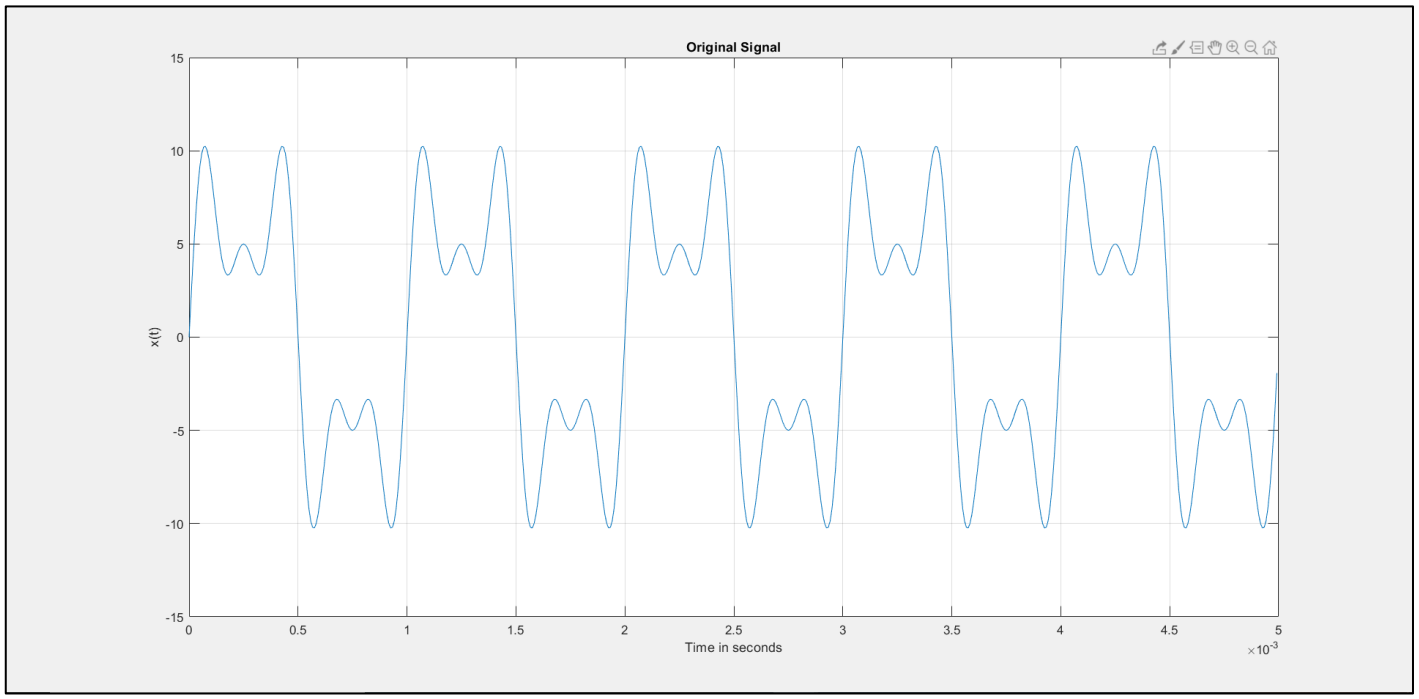
```
f = 1000;
fs = 20000;
t = 0:1/(10*fs):0.1;
ts = 0:1/fs:0.1;
y = square(2*pi*f*t);
subplot(2,2,1);
plot(t(1:2000), y(1:2000));
grid on;
axis([0 0.01 -1.5 1.5]);
xlabel('Time in seconds'); ylabel('x(t)'); title('Original
Signal x(t)');

ys = square(2*pi*f*ts);
subplot(2,2,2);
plot(ts(1:200), ys(1:200));
grid on;
axis([0 0.01 -1.5 1.5]);
xlabel('Time in seconds'); ylabel('x(t)'); title('x(t) sampled
at 20 KHz');

N=128;
Xs = fftshift(fft(ys, N));
mag_s = abs(Xs)/N;
f1 = -fs/2:fs/N:(fs/2 - fs/N);
subplot(2,2,3);
plot(f1, mag_s);
grid on;
xlabel('Frequency in Hz'); ylabel('|X(f)|/N'); title('Fs =
20kHz, N = 128');

N=256;
Xs = fftshift(fft(ys, N));
mag_s = abs(Xs)/N;
f1 = -fs/2:fs/N:(fs/2 - fs/N);
subplot(2,2,4);
plot(f1, mag_s);
grid on;
xlabel('Frequency in Hz'); ylabel('|X(f)|/N'); title('Fs =
20kHz, N = 256');
```

Part D:

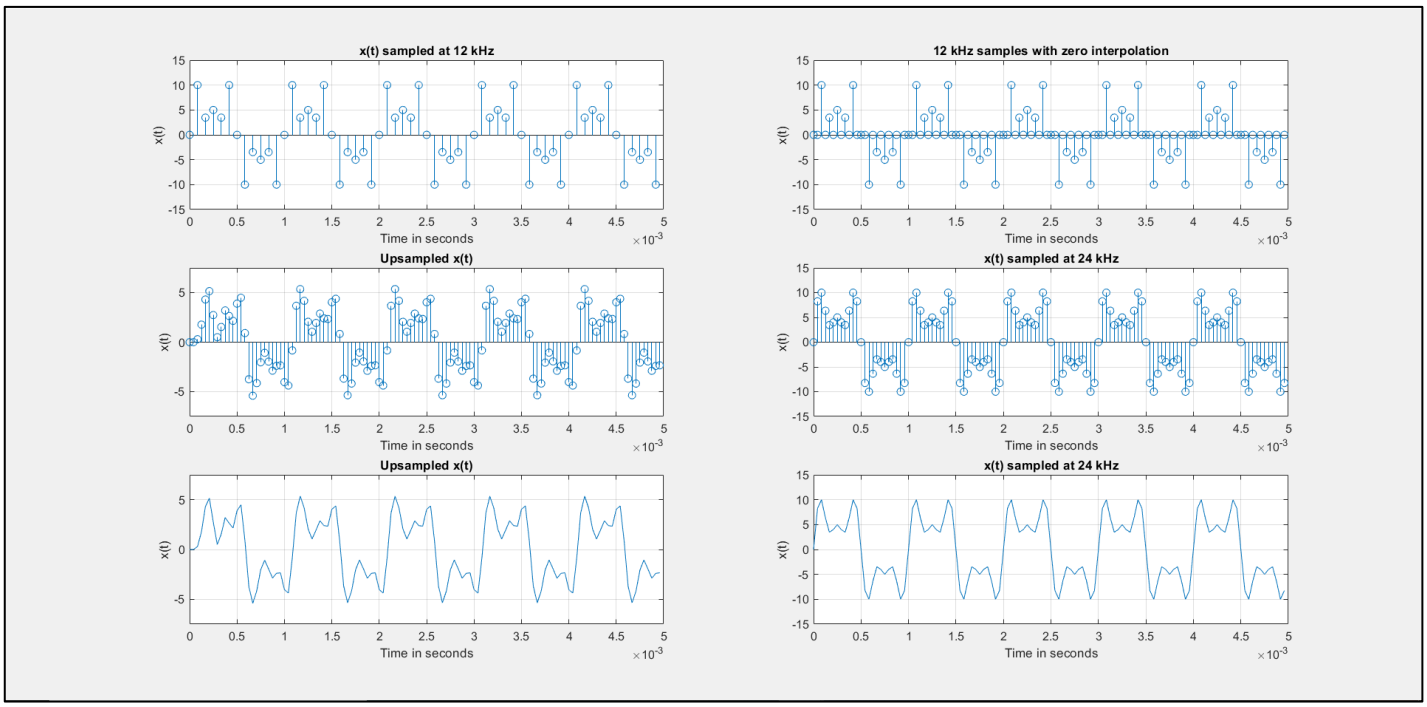
To interpolate (or upsample) a signal originally sampled at 12 kHz to twice the frequency (24 kHz) by zero interpolation and lowpass filtering.

Original signal (actually sampled at 120 kHz)

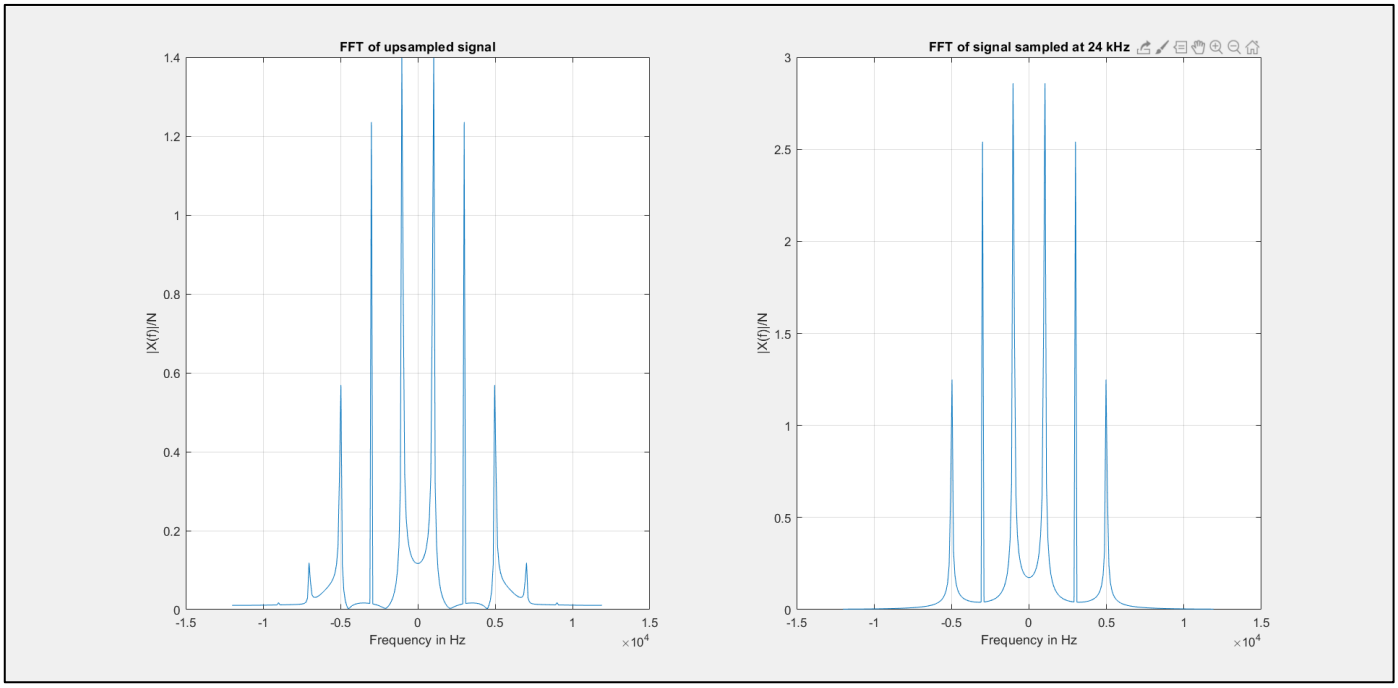
Equation: 3sin(2π*5000t)+5sin(2π*3000t)+7sin(2π*1000t)



Upsampling and comparison with sampling at 24 kHz



FFTs of upsampled signal and signal sampled at 24 kHz



The interpolation process and the sampling at 24 kHz is compared. There are slight differences such as delay and degradation of magnitude. Reasons for the same will be discussed in the complete lab report.

Code:

```
clc
close all

f = 1000;
fs1 = 12000;
fs2 = 24000;

t = 0:1/(10*fs1):0.1;
ts1 = 0:1/fs1:0.1;
ts2 = 0:1/fs2:0.1;

x = 3*sin(2*pi*5*f*t)+5*sin(2*pi*3*f*t)+7*sin(2*pi*f*t);
figure();
len = (length(t)-1)/20;
plot(t(1:len), x(1:len));
grid on;
axis([0, 0.005 -15 15]);
```

```
xlabel('Time in seconds'); ylabel('x(t)'); title('Original
Signal');

figure();

xs1 =
3*sin(2*pi*5*f*ts1)+5*sin(2*pi*3*f*ts1)+7*sin(2*pi*f*ts1);
subplot(321);
len = (length(ts1)-1)/20;
stem(ts1(1:len), xs1(1:len));
grid on;
axis([0, 0.005 -15 15]);
xlabel('Time in seconds'); ylabel('x(t)'); title('x(t) sampled
at 12 kHz');

z = zeros(1,length(ts1));
xs2 = [xs1(:) z(:)]';
xs2 = xs2(:);

subplot(322);
len = (length(ts2)-1)/20;
stem(ts2(1:len), xs2(1:len));
grid on;
axis([0, 0.005 -15 15]);
xlabel('Time in seconds'); ylabel('x(t)'); title('12 kHz
samples with zero interpolation');

[b,a] = butter(6,(6*f)/(fs2/2));
data = filter(b,a,xs2);

up_xs1 = data(1:length(data)-1);
len = (length(ts2)-1)/20;
subplot(323);
stem(ts2(1:len), up_xs1(1:len));
grid on;
axis([0, 0.005 -7.5 7.5]);
xlabel('Time in seconds'); ylabel('x(t)'); title('Upsampled
x(t)');

len = (length(ts2)-1)/20;
subplot(325);
plot(ts2(1:len), up_xs1(1:len));
grid on;
axis([0, 0.005 -7.5 7.5]);
xlabel('Time in seconds'); ylabel('x(t)'); title('Upsampled
x(t)');
```

```
xs2 =
3*sin(2*pi*5*f*ts2)+5*sin(2*pi*3*f*ts2)+7*sin(2*pi*f*ts2);
subplot(324);
len = (length(ts2)-1)/20;
stem(ts2(1:len), xs2(1:len));
grid on;
axis([0, 0.005 -15 15]);
xlabel('Time in seconds'); ylabel('x(t)'); title('x(t) sampled
at 24 kHz');

subplot(326);
len = (length(ts2)-1)/20;
plot(ts2(1:len), xs2(1:len));
grid on;
axis([0, 0.005 -15 15]);
xlabel('Time in seconds'); ylabel('x(t)'); title('x(t) sampled
at 24 kHz');

figure();
N = 256;
up_ys1 = fftshift(fft(up_xs1, N));
mag_ys1 = abs(up_ys1)/N;
f1 = -fs2/2:fs2/N:(fs2/2 - fs2/N);
subplot(1,2,1);
plot(f1, mag_ys1);
grid on;
xlabel('Frequency in Hz'); ylabel('|X(f)|/N'); title('FFT of
upsampled signal');

ys2 = fftshift(fft(xs2, N));
mag_ys2 = abs(ys2)/N;
f1 = -fs2/2:fs2/N:(fs2/2 - fs2/N);
subplot(1,2,2);
plot(f1, mag_ys2);
grid on;
xlabel('Frequency in Hz'); ylabel('|X(f)|/N'); title('FFT of
signal sampled at 24 kHz');
```