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SY310 Lab 1

Signals and Spectrum Fundamentals

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Abstract— *For part one of the lab we are introduced to the standard lab bench setup and explore the basic characteristics of a signal. For part two of the lab we plotted a 440 Hz sinusoid in both time and frequency. Then we plotted MATLABS's chirp, gong, and splat for both time and frequency. For part 3 of the lab we plotted a fourier series function, by first solving for the fourier series, then using spectrum we plotted the waveforms.*

Keywords—Generator; Oscilloscope; Frequency; Signals; Bandwidth

INTRODUCTION

For Part 1 of this Lab we first familiarize ourselves with the lab bench and get used to working with the Wave Generator, Oscilloscope, and the Speaker. We generated a Sine Wave using the generator and analyzing it on the Oscilloscope. We first begin our Lab 1 Part 2 to generate a 440 Hz sine wave. Then we use the provided function getSpectrum to determine the frequency content of the sine wave. The next procedure we do is display the spectrum of our signal. The next type of signal frequency we analyze is real-time voice signal analysis. Using the MATLAB included sounds of chirp, gong, and splat we plot the signals as a function of time.We first began Part 3 by discovering one of the given plots functions using fourier series. After we solved for our function we then plotted the sinusoid and the spectrum for the wavelengths of one, five, ten, and one hundred.

Fig 1 FOURIER ANALYSIS

A. *What is Fourier Analysis*

Fourier Analysis is a concept that any signal is made up of components at various frequencies, and each component is sinusoidal. By adding enough signals together, the appropriate frequency, amplitude, and phase of any electromagnetic signal can be constructed.

B. *Part 1: Function Generator Setup*

When we began this lab we first had to set up our lab bench with the appropriate settings for our different equipment. We first had to set up the Generator turning it on at 120 Volts. After powering up the generator we have to select the sinusoidal function on the generator. Then we had to set up the appropriate frequency function to 440Hz, then we set the appropriate amplitude to 2.00 Vpp.

C. *Part 1: Exploring Signal Parameters in Time and Frequency Domains*

The next step in part one is to properly set up our Oscilloscope using the *Autoset* function the scope will automatically calibrate our signal. Using the generator and the *Radioshack Speaker*, we adjust the amplitude and frequency of the sine wave and record our observations (i.e in appendix). The changes that we made impacted both the Oscilloscope display and the speaker output by ___. The lowest frequency we could hear was 1 mHz, and the highest was 19.75 kHz. Our scope also provided the frequency spectrum of the signal which was ____.

D. *Part 1: Exploring a Voice Signal in Time and Frequency*

The next portion of the lab uses a more complex signal, our voice which is observed using the musiclab website. We observed near-real-time frequency content of our voice signals by using the microphone function. We spoke into the microphone and observed the changes that occurred in the spectrum.

E. *Part 2: 440 Hz Sinusoid*

To begin plotting out our 440 Hz sinusoid we input the initial data that is given to us in MATLAB. The next step was to display the 440 Hz Sinusoid signal as a function of time. Using the plot function the sinusoid is displayed. The findings relating to time were from zero to ten milliseconds. The amplitude ranges from negative one to one volts. The 440Hz sinusoid creates the bandwidth of two.

F. *Part 2: 440 Hz Sinusoid Spectrum*

Using the getSpectrum function that was provided we can determine and display the spectrum of our signal. The frequency goes from zero to one thousand, and peeks its amplitude at 440 Hz, reaching a voltage of one. This makes the bandwidth for the spectrum one. The graph of this sinusoid is identical to what is expected and models a perfect sinusoid with no flaws or variation.

G. *Part 2: Spectrum of Signals with Multiple Frequencies*

- For sound clip chirp, the time ranges from zero to one and a half seconds. The frequency domain is from zero to one, making the bandwidth one as well. When using the getSpectrum function the chirp sounds gives a frequency up to 4000 Hz, and the amplitude ranges from zero to 0.0175 with a peak at 2500 Hz..

- For sound gong, the time ranges from zero to five seconds. The frequency domain is from zero to one, making the bandwidth one as well. When using the getSpectrum function the gong sounds give a frequency up to 4000 Hz, and the amplitude ranges from zero to 0.0175 with a peak at 1000 Hz.
- For sound splat, the time ranges from zero to one seconds. The frequency domain is from zero to one, making the bandwidth one as well. When using the getSpectrum function the splat sounds gives a frequency up to 4000 Hz, and the amplitude ranges from zero to 0.006 with a peak at 1000 Hz.
- Unlike the 440 Sinusoid, the plots of the MATLAB signals in both the frequency and time domains have several flaws and deviations from perfect graphs. Thus, showing the difference between modeling a generated signal versus modeling real signals.

H. Part 3: Fourier Series Calculations

For the initial process of this lab we had to choose one of the four signals and using the provided figure, solve for the function using Fourier series. I choose to solve for the second figure that was provided, my calculations can be seen in figure one.

I. Part 3: Plotting in MATLAB

Once we discovered the function for the given figure my group then had to develop code using MATLAB to graph the appropriate figure. Once we developed our initial code that graphed our Fourier series with the wavelength of one, we then had to alter our value of n which was a single line of code for the various wavelengths of five, ten, and one hundred.

J. Part 3: Spectrum of our Signal

For the next step of the lab we had to graph the spectrum of our signal. Using the getSpectrum function that was provided in Part Two, we imputed the data into that function and then got the resulting plots.

K. Part 3: Discoveries

Based on our plots that we created in MATLAB with the various wavelengths it appears to look exactly like what our expected results were supposed to be. The time and frequency domains for each plot were what was expected with the given wavelengths.

L. Appendix

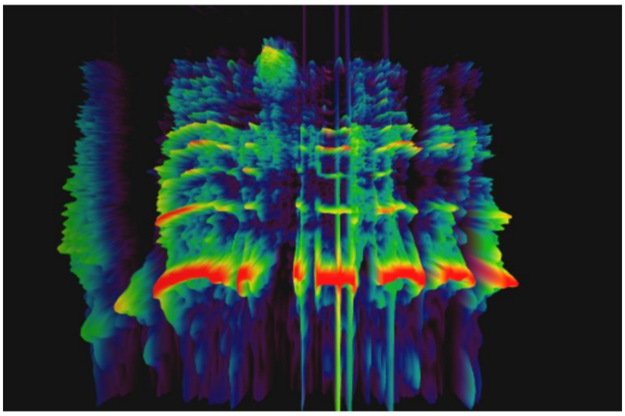

Fig. 1. Part 1: High Frequency Visual

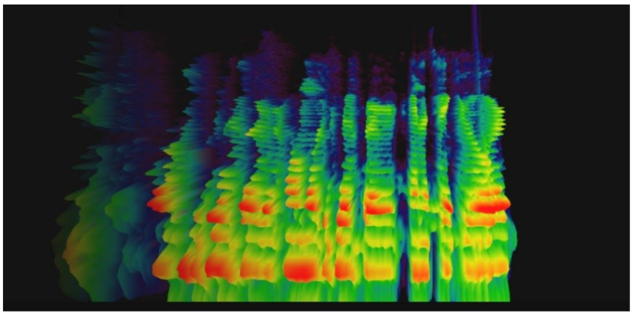

Fig 2 Part 1: Low Frequency Visual

```
fs = 10e5;          % "fs" is sampling frequency
f0 = 440;           % "f0" is the frequency (in Hz) of the sinusoid
A = 1;              % "A" is the amplitude of the sinusoid, 1.0 Volts
Ts = 1/fs;          % "Ts" is the time between samples
dur = 1/f0 * 1e1;   % "dur"ation for 1000 periods of f0
N = fs*dur;         % "N" is the number of samples of the sinusoid for duration
t = 0:Ts:(N-1)*Ts;  % "t" is the time vector (StartTime:StepSize:StopTime)
s1 = A.*sin(2*pi*f0*t) ; % "s1" is our signal vector (a 440 Hz sinusoid)
plot(t,s1,'m-','linewidth',2) % These plot options produce lines of different
% colors/styles, as well as a thicker line that's
% easier to see.
axis([0 10e-3 -1 1]) % Sets the amount of the waveform that's visible
% in the figure window so that you don't get a
% big blue (or pink, in this case) blob. Suggest
% setting xmax to 10 ?s or less.
xlabel("Time (ms)") % All figures should have meaningful titles
ylabel("Voltage (V)") % and axes labels.
title("440 Hz Sinusoid")
grid on;
%[freq, amp] = getSpectrum(A, fs);
```

Fig 3 Part 2: MATLAB Code for to find the spectrum of a 440Hz Sinusoid

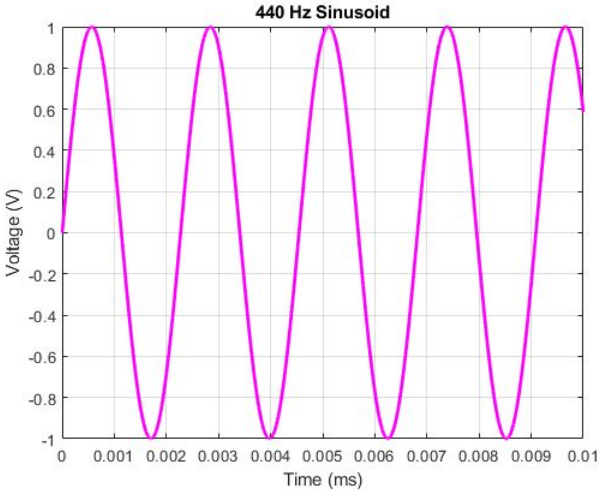

Fig 4   Part 2 : 440Hz Sinusoid plot

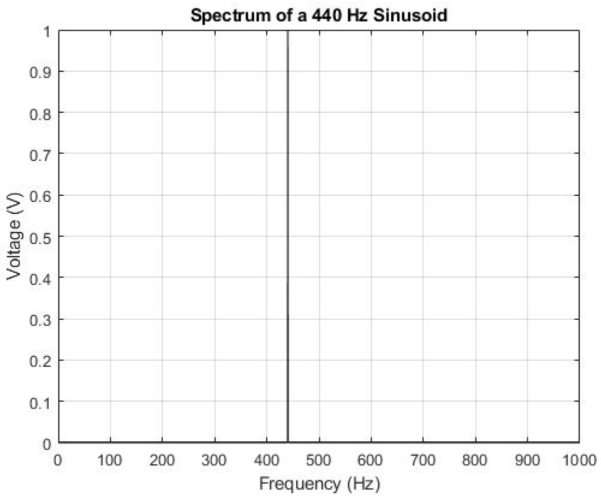

Fig 5   Part 2: Plot of the Spectrum of a 440 Hz Sinusoid

```
fs = 10e5;            % "fs" is sampling frequency
f0 = 440;             % "f0" is the frequency (in Hz) of the sinusoid
A = 1;                % "A" is the amplitude of the sinusoid, 1.0 Volts
Ts = 1/fs;            % "Ts" is the time between samples
dur = 1/f0 * 1e1;     % "dur"ation for 1000 periods of f0
N = fs*dur;           % "N" is the number of samples of the sinusoid for duration
t = 0:Ts:(N-1)*Ts;    % "t" is the time vector (StartTime:StepSize:StopTime)
s1 = A.*sin(2*pi*f0*t);

%%Chirp
figure()
subplot(2,3,1);

load chirp;
Fs_chirp= 8192;
s1_chirp=y;
soundsc(s1_chirp,Fs_chirp);

sizechirp = length(s1_chirp);
xc = linspace(0,1.5,sizechirp);
plot(xc,s1_chirp,"m-","linewidth",1)
axis([0 1.5 -1 1]);
xlabel("Time (seconds)");
ylabel("Amplitude");
title("Signal 1: Chirp");
grid off;

%%Chirp Spectrum
subplot(2,3,4);
[freq, amp] = getSpectrum(s1_chirp, Fs_chirp);
plot(freq,amp, "m-", "linewidth",1);
axis([0 4000 0 0.02]);
xlabel("Frequency (Hz)");
ylabel("Amplitude");
title("Spectrum");

%%GONG
subplot(2,3,2);
load gong;
Fs_gong= 8192;
s1_gong=y;
soundsc(s1_gong,Fs_gong);

sizegong = length(s1_gong);
xg = linspace(0,5,sizegong);
plot(xg,s1_gong,"m-","linewidth",1)
axis([0 5 -1 1]);
xlabel("Time (seconds)");
ylabel("Amplitude");
title("Signal 1: Gong");
grid off;

%Gong Spectrum
subplot(2,3,5);
[freq, amp] = getSpectrum(s1_gong, Fs_gong);
```

Fig 6   MATLAB Code for Spectrum of Signals with Multiple Frequencies

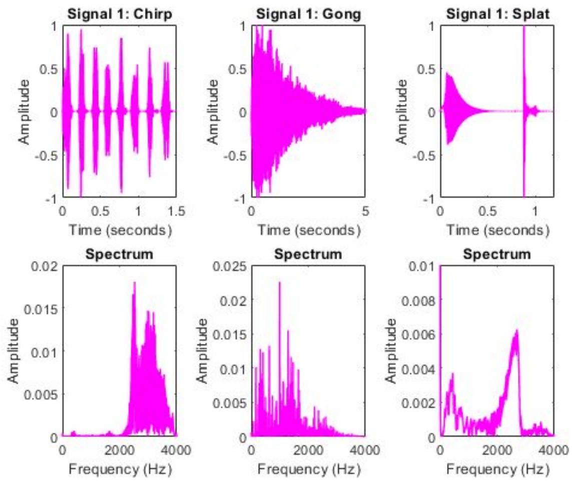

Fig 7   Plots for Spectrum of Signals with Multiple Frequencies

```
fs = 1000;
f0= 0.5;
Ts= 1/fs;
dur = 1/f0 *1e3;
N= fs*dur;
t=0:Ts:(N-1)*Ts;
s1=0;
n=1;
for n = 1:1:n
    Aa=((1-(-1)^n)/((pi*n).^2));
    Ab=((((-1)^n)-2)/(pi*n));
    an= Aa.*cos(pi.*t*n);
    bn= Ab.*sin(pi.*t*n);
    s1=s1+an+bn;
end
a0 = -0.25;
s1=s1+a0;
xmin = 0;
xmax = 4;
ymin = -2;
ymax = 2;
figure
subplot(2,4,1);
plot(t,s1,'b-','linewidth',2)
axis([xmin xmax ymin ymax])
xlabel("Time(Ms)")
ylabel('Voltage (V)')
title("Time Domain Representation of Recreated Wave with n = 1")
grid on;
[freq, amp] = getSpectrum(s1,fs);
xmin = 0;
xmax = 7;
ymin = 0;
ymax = 1.5;
subplot(2,4,5);
plot(freq, amp,'b-','linewidth',2)
axis([xmin xmax ymin ymax])
xlabel("Frequency (kHz)")
ylabel("Voltage (V)")
title("Frequency Domain Representation of Recreated wave with n = 1")
grid on;
s1 = 0;
%subplot(2,4,2);
%plot(t,s1,'b-','linewidth',2);
```

Fig 8 Part 3: MATLAB Code for a signal with the wavelength of one

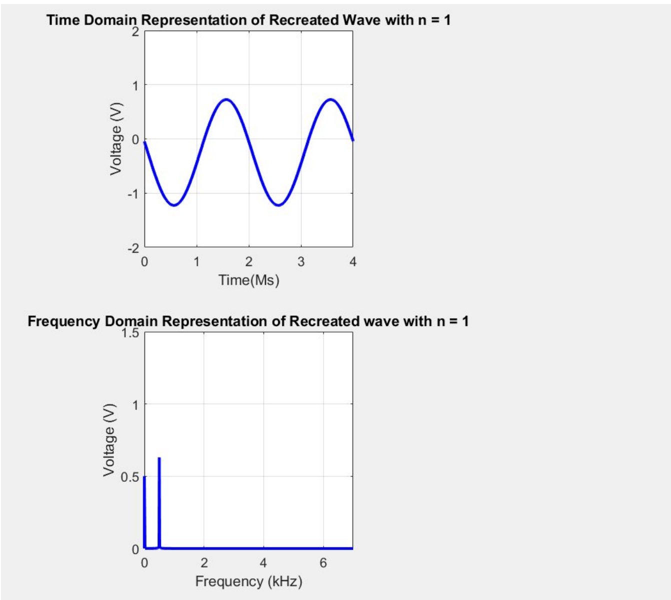

Fig 9 Time and Frequency Plots for wavelength of one

```
fs = 1000;
f0= 0.5;
Ts= 1/fs;
dur = 1/f0 *1e3;
N= fs*dur;
t=0:Ts:(N-1)*Ts;
s1=0;
n=5;
for n = 1:1:n
    Aa=((1-(-1)^n)/((pi*n).^2));
    Ab=((((-1)^n)-2)/(pi*n));
    an= Aa.*cos(pi.*t*n);
    bn= Ab.*sin(pi.*t*n);
    s1=s1+an+bn;
end
a0 = -0.25;
s1=s1+a0;
xmin = 0;
xmax = 4;
ymin = -2;
ymax = 2;
figure
subplot(2,4,1);
plot(t,s1,'b-','linewidth',2)
axis([xmin xmax ymin ymax])
xlabel("Time(Ms)")
ylabel('Voltage (V)')
title("Time Domain Representation of Recreated Wave with n = 1")
grid on;
[freq, amp] = getSpectrum(s1,fs);
xmin = 0;
xmax = 7;
ymin = 0;
ymax = 1.5;
subplot(2,4,5);
plot(freq, amp,'b-','linewidth',2)
axis([xmin xmax ymin ymax])
xlabel("Frequency (kHz)")
ylabel("Voltage (V)")
title("Frequency Domain Representation of Recreated wave with n = 1")
grid on;
s1 = 0;
%subplot(2,4,2);
%plot(t,s1,'b-','linewidth',2);
```

Fig 10 Part 3: MATLAB Code for a signal with the wavelength of five

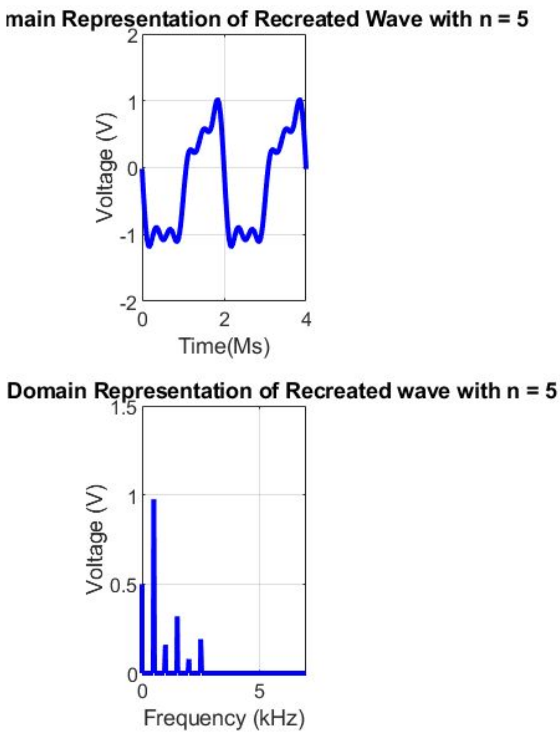

Fig 11 Part 3: Time and Frequency plots for a wavelength of five

```matlab
fs = 1000;
f0= 0.5;
Ts= 1/fs;
dur = 1/f0 *1e3;
N= fs*dur;
t=0:Ts:(N-1)*Ts;
s1=0;
n=10;
for n = 1:1:n
    Aa=((1-(-1)^n)/((pi*n).^2));
    Ab=((((-1)^n)-2)/(pi*n));
    an= Aa.*cos(pi.*t*n);
    bn= Ab.*sin(pi.*t*n);
    s1=s1+an+bn;
end
a0 = -0.25;
s1=s1+a0;
xmin = 0;
xmax = 4;
ymin = -2;
ymax = 2;
figure
subplot(2,4,1);
plot(t,s1,'b-','linewidth',2)
axis([xmin xmax ymin ymax])
xlabel("Time(Ms)")
ylabel('Voltage (V)')
title("Time Domain Representation of Recreated Wave with n = 1")
grid on;
[freq, amp] = getSpectrum(s1,fs);
xmin = 0;
xmax = 7;
ymin = 0;
ymax = 1.5;
subplot(2,4,5);
plot(freq, amp,'b-','linewidth',2)
axis([xmin xmax ymin ymax])
xlabel("Frequency (kHz)")
ylabel("Voltage (V)")
title("Frequency Domain Representation of Recreated wave with n = 1")
grid on;
s1 = 0;
%subplot(2,4,2);
%plot(t,s1,'b-','linewidth',2);
```

Fig 12 Part 3: MATLAB Code for a signal with the wavelength ten

```matlab
fs = 1000;
f0= 0.5;
Ts= 1/fs;
dur = 1/f0 *1e3;
N= fs*dur;
t=0:Ts:(N-1)*Ts;
s1=0;
n=100;
for n = 1:1:n
    Aa=((1-(-1)^n)/((pi*n).^2));
    Ab=((((-1)^n)-2)/(pi*n));
    an= Aa.*cos(pi.*t*n);
    bn= Ab.*sin(pi.*t*n);
    s1=s1+an+bn;
end
a0 = -0.25;
s1=s1+a0;
xmin = 0;
xmax = 4;
ymin = -2;
ymax = 2;
figure
subplot(2,4,1);
plot(t,s1,'b-','linewidth',2)
axis([xmin xmax ymin ymax])
xlabel("Time(Ms)")
ylabel('Voltage (V)')
title("Time Domain Representation of Recreated Wave with n = 1")
grid on;
[freq, amp] = getSpectrum(s1,fs);
xmin = 0;
xmax = 7;
ymin = 0;
ymax = 1.5;
subplot(2,4,5);
plot(freq, amp,'b-','linewidth',2)
axis([xmin xmax ymin ymax])
xlabel("Frequency (kHz)")
ylabel("Voltage (V)")
title("Frequency Domain Representation of Recreated wave with n = 1")
grid on;
s1 = 0;
%subplot(2,4,2);
%plot(t,s1,'b-','linewidth',2);
```

Fig 14 Part 3: MATLAB Code for a signal with the wavelength of one hundred

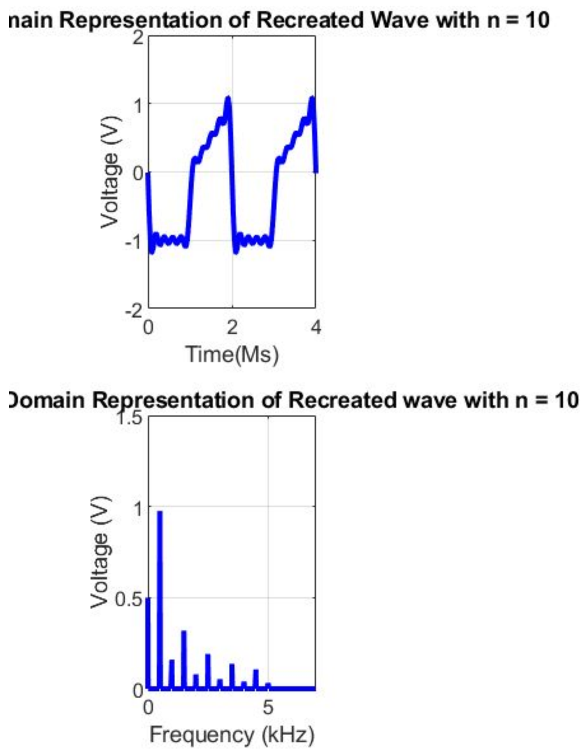

Fig 13 Part 3: Time and Frequency plots for a wavelength of ten

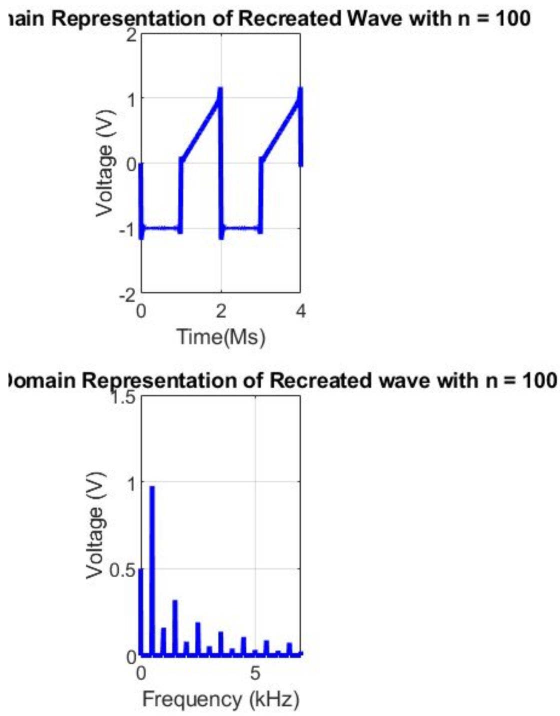

Fig 15 Part 3: Time and Frequency plots for a wavelength of one hundred

Lab 1 Part 3

Signal 2

$T = 2 \qquad f = 1/2$

$$x(t) = \begin{cases} -t & 0 \le t \le 1 \\ 1 & 1 \le t \le 2 \end{cases}$$

$$A_0 = \frac{2}{2}\int_0^1 (-t)\,dt + \int_1^2 (1)\,dt \qquad -\frac{t^2}{2} \qquad t$$

$$= -\frac{1}{2}t^2\Big|_0^1 + t\Big|_1^2$$

$$= -\frac{1}{2} + \underbrace{(2)-1}_{1} = -0.25$$

$$A_n = \frac{2}{T}\int_0^1 (-t)\cos(2\pi n f_0 t)\,dt + \int_1^2 (1)\cos(2\pi n f_0 t)\,dt$$

$$= \int_0^1 (-t)\cos(\pi n t)\,dt + \int_1^2 (1)\cos(\pi n t)\,dt$$

$$= -\left\{\frac{1}{(\pi n)^2}\underbrace{\cos(\pi n t)}_{(-1)^n} + \frac{1}{\pi n}\underbrace{\sin(\pi n)}_{0} - \left(\frac{1}{(\pi n)^2}\underbrace{\cos 0}_{1} + \underbrace{0}_{0}\right)\right\} + \frac{1}{\pi n}\left(\underbrace{\sin 2\pi n}_{0} - \underbrace{\sin \pi n}_{0}\right)$$

$$-\frac{1}{(\pi n)^2}\left[(-1)^n - 1\right] + \frac{1}{\pi n}\sin(2\pi n)$$

$$A_n = \frac{(1-(-1)^n)}{\pi n^2}$$

$$\frac{-\cos(2\pi n) - 2}{\pi n}$$

$$\boxed{-1^n \cdot \frac{1}{\pi n}} \qquad \frac{1}{\pi n}\left(-\cos(2\pi n) + (-1)^n\right)$$

$$B_n = \frac{2}{T}\int_0^1 (-t)\sin \pi n t\,dt + \int_1^2 (1)\sin \pi n t\,dt$$

$$= (-1)\left[\frac{1}{(\pi n)^2}\sin \pi n t - \frac{t}{\pi n}\cos \pi n t\right]_0^1 + \left(\frac{-1}{\pi n}\cos \pi n t\right)\Big|_1^2$$

$$= (-1)\left[\cancel{\frac{1}{(\pi n)^2}\sin \pi n} - \frac{1}{\pi n}\underbrace{\cos \pi n}_{-1^n}\right) - \left(\cancel{\frac{1}{\pi n^2}\underbrace{\sin 0}_{0}} - \underbrace{0}_{0}\right)\Big] + \left(\left(\frac{-1}{\pi n}\right)\underbrace{\cos 2\pi n}_{1} - \underbrace{\cos \pi n}_{(-1)^n}\right)$$

$$B_n = \frac{(-1^n) - 2}{\pi n} \qquad \left(\frac{-1}{\pi n}\right)\left(-1^n\right) + \left(\frac{-1}{\pi n}\right)\left(1 - (-1)^n\right) \qquad \frac{-1}{\pi n}\left(-1^n + 1 - (-1)^n\right)$$

$$X(t) = \frac{-0.25}{2} + \sum_{n=1}^{\infty}\left[\frac{(1-(-1)^n}{\pi n^2}\right]\cos(\pi n t) + \left[\frac{(-1)^n - 2}{\pi n}\right]\sin(\pi n t)$$

Fig 16 Part 3: Calculations of Fourier Series Signal