Your Name
Fourier Series and Transform Lab
Date Completed

PRELAB

FOURIER SERIES

1. **Derive the Fourier series representation for the square wave shown in Figure A.**
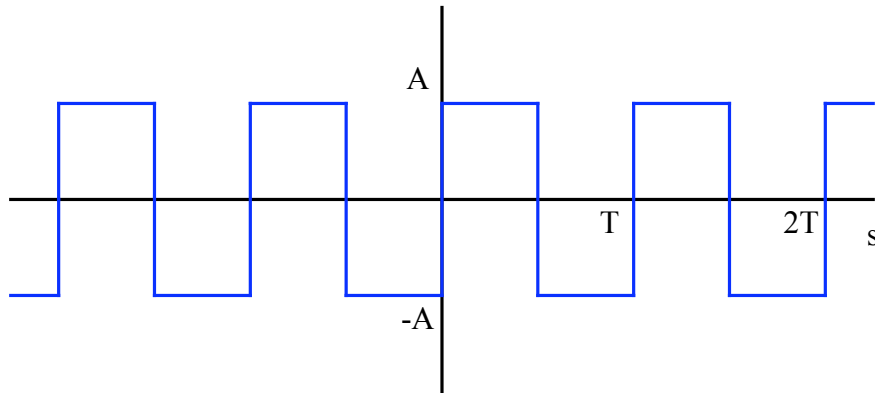

Figure A. Simple Square Wave.

2. **Derive the Fourier series representation for the square wave shown in Figure B. Hint: use your answer from Question 1.**
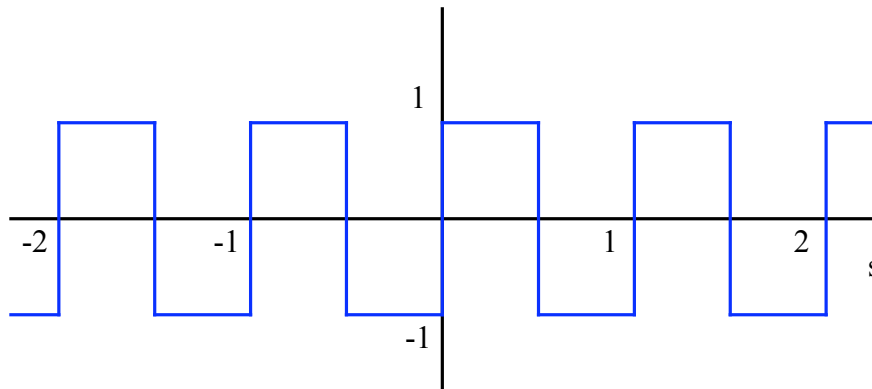

Figure B. Square Wave at 1 Hz.

FOURIER TRANSFORM

3. **Determine the Fourier transform for the square wave in Figure B. Hint: apply the Fourier transform to the Fourier series representation of the signal.**

4. **The following MATLAB script plots the first q = 50 terms of Fourier series representation of a signal. Determine the type of signal represented by the Fourier**

series by running the following sequence of commands. Hint: cut and paste into a MATLAB script file.

```
T = .01;                    %Period of signal
wo = 2 * pi / T;            %Frequency of signal

t = 0:T * 0.001:2 * T;     %Time scale of 2 periods
fs = zeros(size(t));        %Creates vector for Fourier series

%Loop to sum Fourier series

for n = 1:2:100
    fs = fs + 8 / pi^2 * 1 / n^2 * sin(n * pi / 2) * sin(n * t * wo);
end

%Plot Fourier series
plot(t, fs,'r')

xlabel('Time, s');
ylabel('Amplitude, V');
```

5. Using the script from Question 4 as a guide, create five plots in MATLAB of the Fourier series representation of the square wave from Question 2. For the five plots, truncate the series so that it only contains the first q terms in the sum, where q = 1, 3, 5, 10 and 50. Scale each plot to contain two periods of the signal. Label your plots appropriately. Paste all five plots below.

WINDOWING

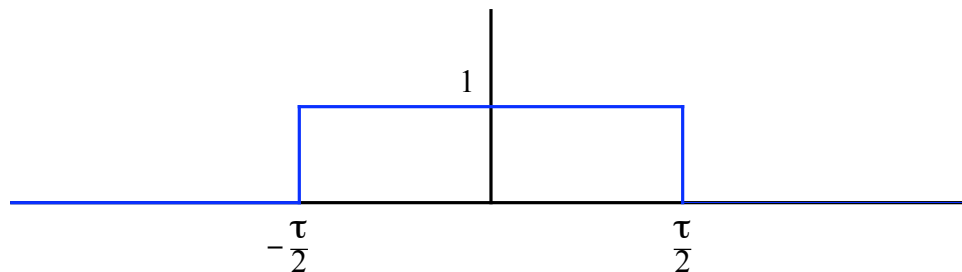6. Determine the Fourier transform for the rectangular window shown in Figure C.

Figure C. Rectangular Window.

7. How does the width of the rectangular window spectrum vary as the window length τ increases?

8. As $\tau \rightarrow \infty$, what function does the spectrum become equal to?

9. **Plot the product of the square wave in Figure B and a rectangular window where $-1 \leq \tau \leq 1$ on a time scale of $-5 \leq t \leq 5$. The square wave and rectangular window can be created with the following MATLAB commands:**

```
t = -5:0.1:5;
sqrwave = square(2*pi*t);
window = (t >= -1) & (t <= 1);
```

FOURIER TRANSFORMS ON THE OSCILLOSCOPE

SINUSOIDAL WAVEFORMS GENERATED BY THE FUNCTION GENERATOR

10. **At what frequency do you expect the peak of the bump to occur?**

11. **Using the cursors, determine the exact frequency at the peak of the bump and record this frequency below. How does this compare to what you expected?**

12. **Change the horizontal scale to 1.25 kHz and measure the frequency again. How does this compare to your answer to the previous question? Can you explain the difference?**

13. **Capture an image of the oscilloscope screen with the settings specified in the previous question and paste it below.**

14. **Use MATLAB's subplot command to plot the two FFT spectral estimates in the same figure on different axes. One of the estimates should be generated with a time resolution of 1 ms and the other estimate should be generated with a time resolution of 40 ms. Plot both estimates using the stem command in MATLAB, and terminate the stems with a period. Your plot should look similar to the one in Figure D. Can you explain the difference in the range of the two plots? Which plot has a higher frequency resolution?**

15. **Scale the axis of both plots to 900 < Hz < 1100. Paste a copy of your plots below. Explain the difference in width of the two sinc functions. Hint: consider the duration of the signal (i.e. length of the window) used to generate each estimate.**
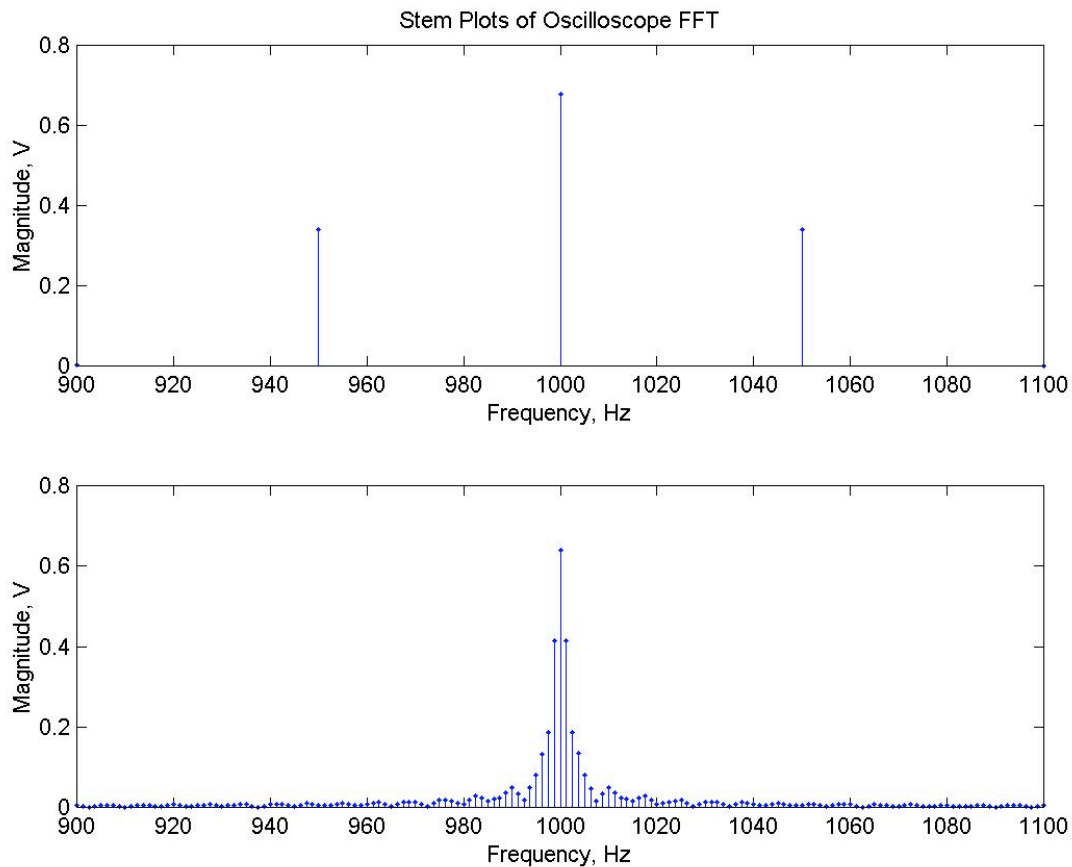
Figure D. MATLAB Stem Plots of FFT from Oscilloscope.

OTHER WAVEFORMS GENERATED BY THE ARBITRARY/FUNCTION GENERATOR

16. Do you see ringing at the edges of the square wave? What do you suspect causes this?

17. Using a frequency of 1 kHz, amplitude of 1 V and a vertical scale of 2.5 kHz, capture screen shots of the spectrums of a square wave, a triangle wave and a sawtooth (ramp) wave. Paste your screen shots below.

18. How do the harmonics of the square wave, triangle wave and sawtooth wave compare (i.e. larger or smaller) to the sine wave at the same frequency and amplitude settings?

19. Use the arbitrary/function generator to create a chirp signal that does a linear sweep from 1 kHz to 1 MHz in 10 s. Examine the spectrum of this signal using the FFT function on the scope. Briefly describe what you observe.

WAVEFORMS GENERATED BY MATLAB

20. Display the 1 kHz sine waves from the sound card and the arbitrary/function generator simultaneously on the oscilloscope. Note that you will need to use the speaker box to connect the output of the sound card to the oscilloscope. Paste a screenshot from the scope below. Is there any qualitative difference between the two signals?

21. Use the FFT function of the oscilloscope to display the spectrum of the sine wave from the sound card. Paste a screen shot of the spectrum below.

22. Do you see any harmonics at 2 kHz? At 3 kHz? Did you expect to see harmonics? What does this tell you about the quality of the sound card?