Fourier Analysis of a Square Wave

Second Laboratory Report for CENG 3331

Submitted by

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Abstract

The goal of this lab was to analyze the spectrum of a sin wave and square wave using Matlab and MultiSim. The secondary goal was to also learn about frequency domain analysis, bandwidth, and data rate. During this lab we learned how to calculate data rate, bandwidth, and bit rate and viewed that as frequency increased for a square wave, amplitudes increased across the spectral line.

Write-Up

Introduction

A square wave is a wave where the amplitude alternates steadily between a fixed maximum and minimum. This wave is used to visualize how 0s and 1s are sent as a signal in a circuit, which we did using Multisim and Matlab in this experiment.

Task 1:

We began this experiment by using Matlab to simulate a square wave by modifying code given to us. We were tasked to implement a for loop to work with the rest of the code, which we did and plotted the Time Domain and Frequency Domain schematics of the simulation. To view these schematics, they can be found in the appendix under figure 1 and the full modified code can be found below.

```
Fs = 1000; % Sampling frequency

T = 1/Fs; % Sampling period
L = 2000; % Length of signal
t = (0:L-1)*T; % Time vector
S = 0;
for i = (0:1000)
  S = S+(4/pi) * sin(2*pi*1*t*(2*i+1))/(2*i+1);
end
subplot(3,1,2)
% Plot in time domain
plot(1000*t, S)
title('Signal')
xlabel('t (milliseconds)')
ylabel('X(t)')
% Fourier transform
Y = fft(S);
F = Fs*(0:(L/2))/L;
P2 = abs(Y/L);
P1 = P2(1:L/2+1);
P1(2:end-1) = 2*P1(2:end-1);
% Plot in frequency domain
subplot(3,1,1)
plot(F,P1)
title('Single-Sided Amplitude Spectrum of S(t)')
```

```
xlabel('f (Hz)')
ylabel('|P1(f)|')
```

Task 2:

For task 2, we continued the experiment by moving to Multisim and implementing a square wave using four components: a function generator, an oscilloscope, a spectrum analyzer, and a ground. The schematic of this circuit can be seen in the appendix under figure 2. During this task, we tested four different frequencies to see how the amplitudes of the spectral lines would be affected for the wave. The diagram of the 10k Hz test can be found in the appendix under figure 3 and the table of these values can be seen below:

Frequency	Spectral Line 1 (freq, amplitude)	Spectral Line 2 (freq ,amplitude)	S.L. 3 (freq, amplitude)	S. L. 4 (freq, amplitude)	S.L 5 (freq, amplitude)
1k Hz	(1,25.465)	(3.019, 8.331)	(5.037, 4.904)	(6.901,3.277)	(8.919,2.602)
2k Hz	(1.932,23.726)	(5.969,8.227)	(10.006,5.065)	(14.043,3.484)	(18.081,2.606)
5k Hz	(5.037,24.516)	(14.975,8.278)	(24.913,4.651)	(34.851,3.096)	(44.944,2.673)
10k Hz	(10.006,25.307)	(30.037,8.174)	(50.068,4.748)	(69.944,3.439)	(89.820,2.324)

As you can see by the table above, as we increased the frequency of the circuit in the function generator, the amplitude of the circuit increased for similar frequencies on the spectral line.

Task 3:

For task 3, we continued to use the simulation from task 2 and modified the frequency in the function generator to be 2 kHz to answer some questions given. For question 1, if a square wave was used to transmit digital data, the data rate would be 4000 bps because 2 kHz is equal to 2000 Hz and if there are two bits in one period, as seen from figure 4 in the appendix, then the data rate would equal 4000 bps because you would multiply the two values together. For question 2, the corresponding bandwidth would be 8.074k Hz because you would subtract the lowest frequency from the highest frequency of the first three components of the 2k Hz simulation. For question 3, if we had a bandwidth of 3000 Hz and a signal with two levels then the maximum bit rate would be 6000 Hz because you would multiply the two values together.

Task 4:

In this final task, we concluded the experiment by running code given to us in Matlab and guessing what the name of the music that played was. We concluded that the music was Cripple Pachelbel's Canon.

Conclusion

In conclusion, this experiment showed us how to calculate data rate, bandwidth, and bit rate, which we did in task 3, and also showed that as frequency increased for a square wave, amplitudes increased across the spectral line, which we did in task 2. As a fun final experiment in task 4, we concluded that the code given to us played Cripple Pachelbel's Canon in Matlab.

Appendix

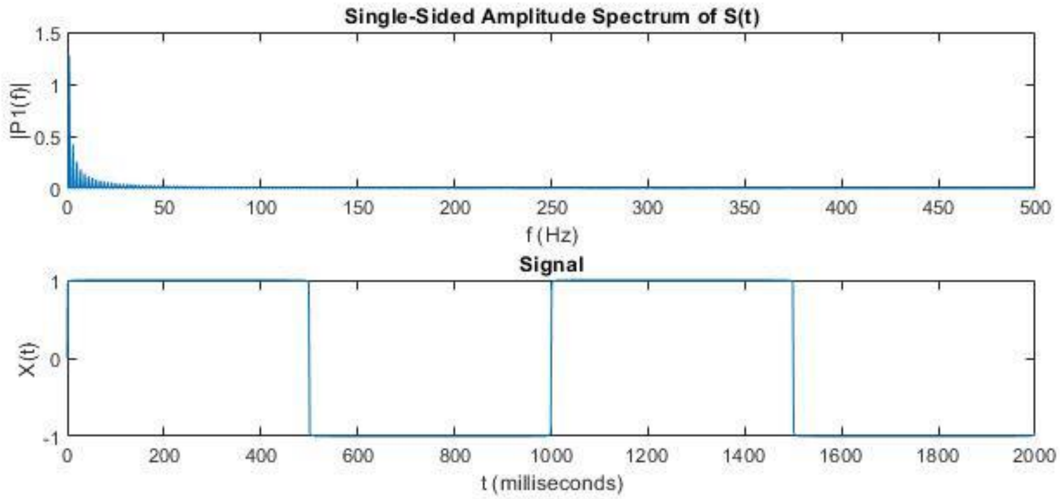

Fig. 1. Time Domain and Frequency Domain Schematics

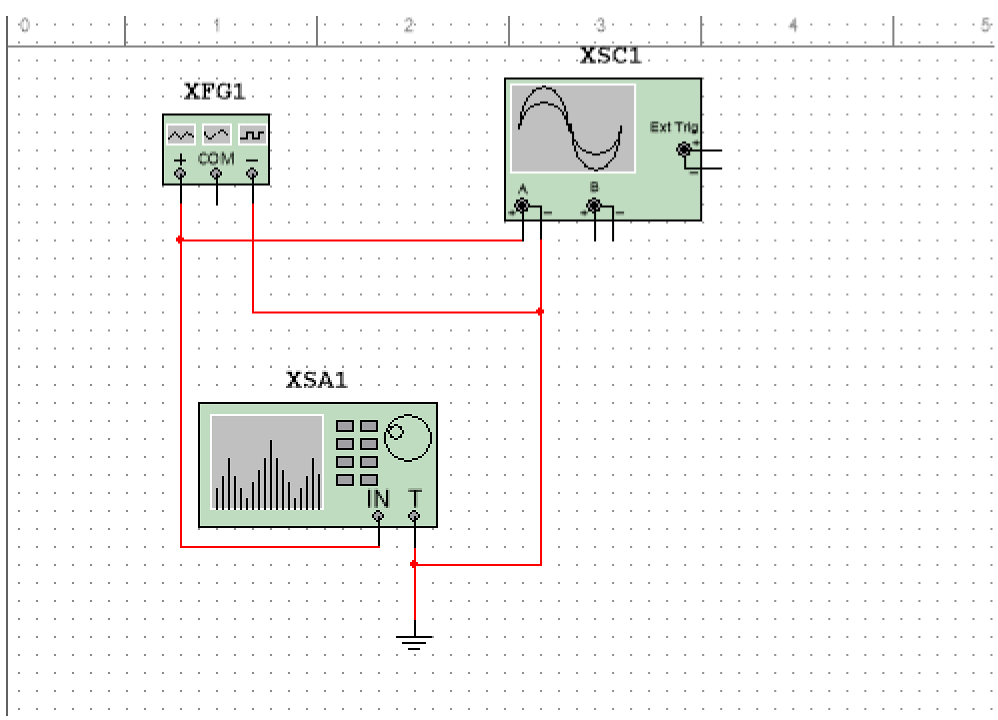

Fig. 2. Circuit diagram

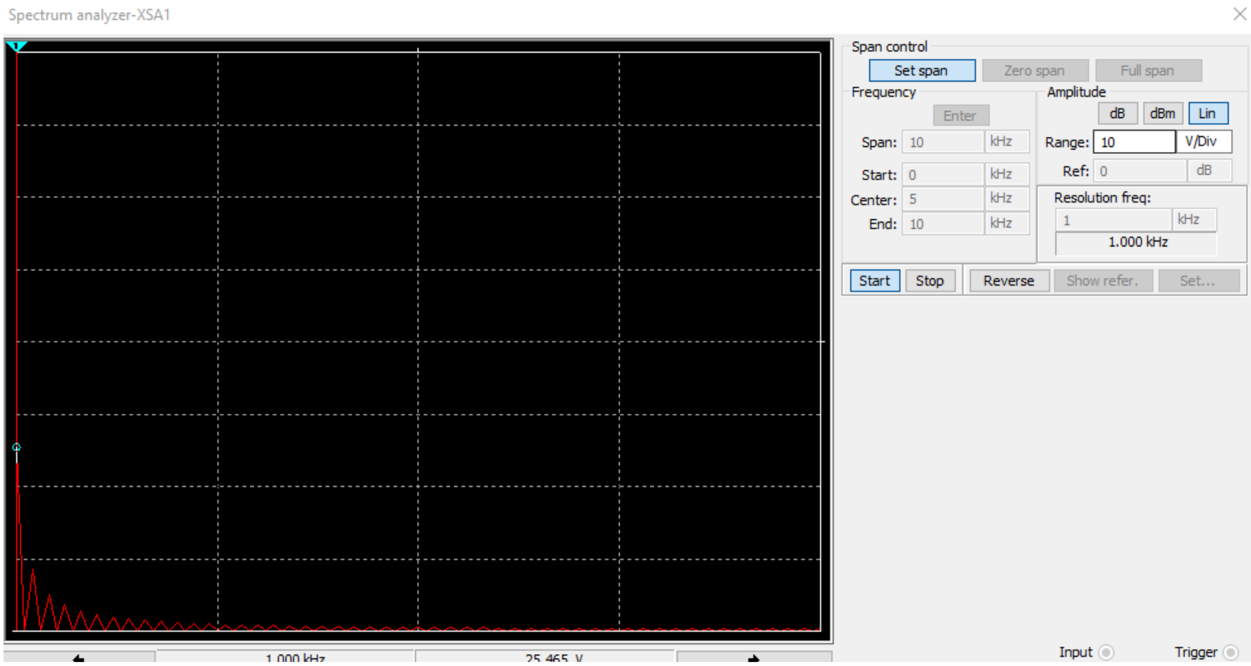

Fig. 3. Spectrum Analyzer Diagram

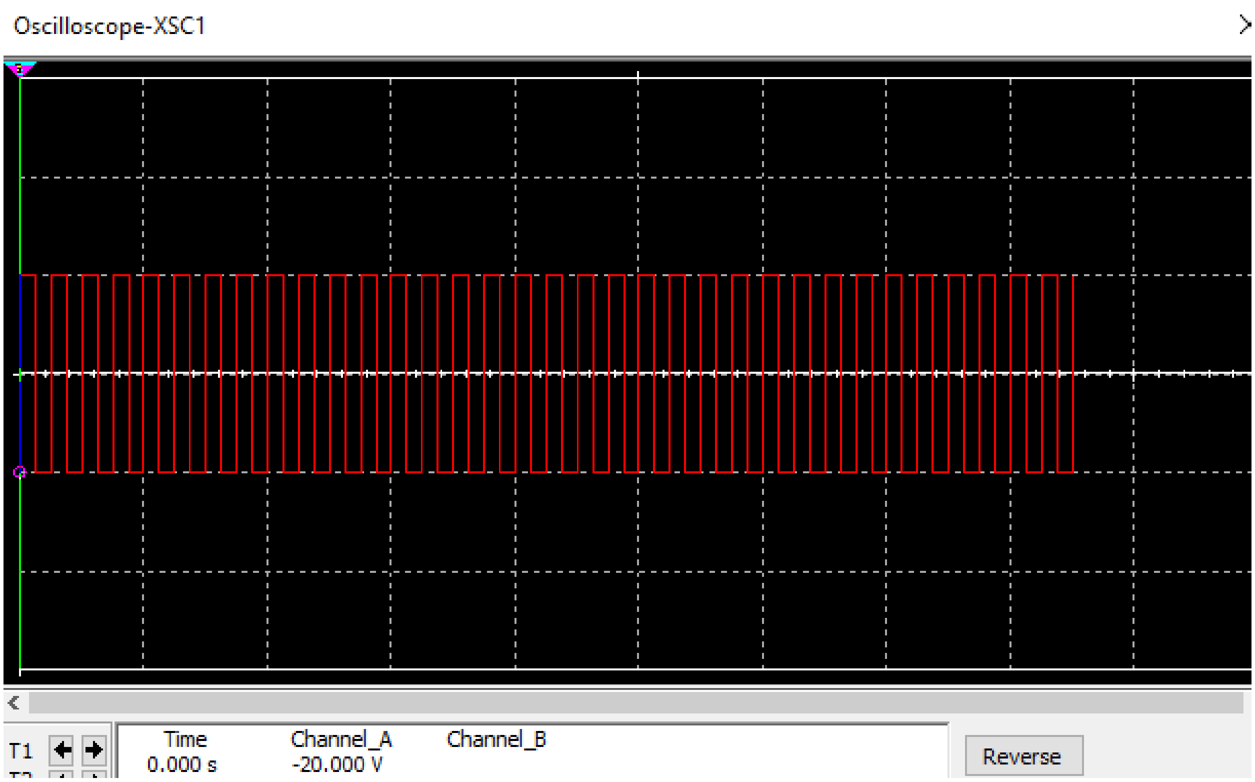

Fig. 4. Square Wave Timing Diagram