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Section: Phys 233 - Thursday
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Lab 2: Combining Waves

1 Purpose

For this lab, we experimented with the combination of waves of different frequencies, and the properties of that resulting wave. The lab was split in to three exercises. First of these was the introduction to the FFT (Fast Fourier Transform) spectrum analyzer, where we recorded the FFT of an input wave generated by a function generator with sine, square, and sawtooth waves. Next, in exercise two, our goal was to synthesize (construct) a compound wave by combining individual waves of different frequencies and phase shifts (cosine vs. sine.) Finally, in the third exercise, we were tasked with simply observing different sound waves created by ourselves or various devices made available to us.

2 Procedure

Here, I will describe the procedure of each exercise separately. Note: some details of each experiment may appear in the data section which is needed to clarify what the data represents.

2.1 Exercise 1

For this exercise, we used: a function generator, voltage sensor, and the Data Studio software configured both as an oscilloscope and FFT analyzer.

Once the hardware and sensors were set up, our first task was to set the function generator to create a sine wave with frequency set at 220 Hz. To verify that are sensors were calibrated correctly, we were to measure the period of the captured wave and verify that this was indeed a 220 Hz wave. We also measured the relative amplitudes and frequencies of the peaks.

Next, we worked with a square wave. Configuring the function generator to create a square wave is as simple as pressing the square wave button. Again, we took the same measurements on the FFT output: relative amplitude and frequency of the peaks.

Finally, we repeated the measurements with a sawtooth wave, which like the square wave, is a matter of pressing the sawtooth button on the function generator.

2.2 Exercise 2

In exercise 1 we analyzed waves created by a function generator, and here we created our own waves by adjusting the relative amplitudes of the fundamental harmonics of a basic sine wave (at 440 Hz.) Our equipment in this exercise was: an oscilloscope and fourier synthesizer.

Our first task was to create a sawtooth wave. We used the first five harmonics with the following relative amplitudes and phase shifts:

Harmonic:	1	2	3	4	5
Amplitude:	1.0	0.5	0.333	0.25	0.2
Phase Shift:	0	180°	0	180°	0

First, we reset all the settings on the synthesizer to their default values according to the instructions listed in the lab, and switched off the SUMMING AMPLIFIER for each fundamental frequency. Now, one-by-one, we went through the first five fundamental frequencies and adjusted their relative amplitude according to the above table. Once all the harmonics were added, we turned up the volume on the synthesizer to hear the resulting sound wave and observed the summed output on the oscilloscope.

For the second part of this exercise, we were giving the following expression for the n^{th} amplitudes of a square wave:

$$A_n = \frac{1}{T}\int_0^T y(t)sin(\frac{n\pi t}{T})dt$$

Given that $y(t)$ is constant for a square wave, we were asked to find the relative amplitudes of the first five terms. With these relative amplitudes, we set the synthesizer accordingly and observed a square wave in the oscilloscope.

2.3 Exercise 3

The instructions for this exercise were quite vague, but it involved setting up a microphone to the input of an oscilloscope and observing what types of waves different sounds produced. Second, we hooked up another microphone to the Data Studio software to see the FFT output of those same sounds.

From here we just explored different sounds that we could make, such as monotone sounds, beeps from phones, etc.

3 Data

3.1 Exercise 1

As described in the procedure section, we measured the period of the displayed wave from Data Studio, as well as the relative amplitudes and frequencies of the peaks. The function generator was set at 220 Hz, and we measured a period of 0.005 ± 0.0005 units, when scaled appropriatel, is equal to 250 Hz. So our measurement was entirely accurate, but fairly close.

Here are the measurements of the peaks for the sine wave:

Frequency	Relative Amplitude
221 ± 2 Hz	1.0
442 ± 2 Hz	0.375 ± 0.01
661 ± 2 Hz	0.225 ± 0.01
881 ± 2 Hz	0.16 ± 0.01
1101 ± 2 Hz	0.12 ± 0.01
1183 ± 2 Hz	0.08 ± 0.01

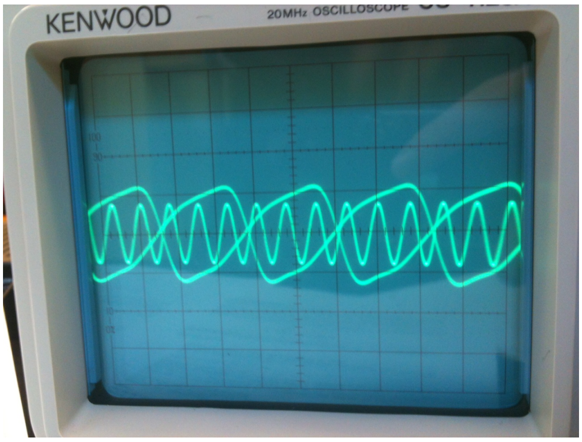
Next we set the function generator to a square wave and recorded the same types of measurements:

Frequency	Relative Amplitude
229 ± 2 Hz	1.0 ± 0.01
676 ± 2 Hz	0.25 ± 0.01
1118 ± 2 Hz	0.19 ± 0.01
1566 ± 2 Hz	0.15 ± 0.01
2018 ± 2 Hz	0.08 ± 0.01

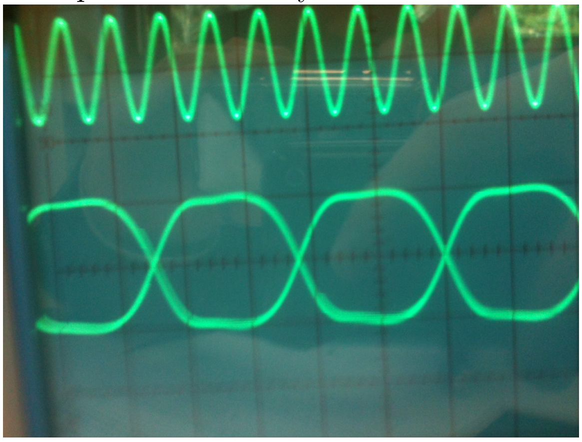
Finally, for the sawtooth wave:

Frequency	Relative Amplitude
73 ± 2 Hz	1.0 ± 0.01
132 ± 2 Hz	0.63 ± 0.01
201 ± 2 Hz	0.42 ± 0.01
258 ± 2 Hz	0.23 ± 0.01
327 ± 2 Hz	0.25 ± 0.01

3.2 Exercise 2



The above photo is of the synthesized sawtooth wave.



The above photo is the synthesized square wave.

Solving for A_n:

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

$\mathrm{A}_1 = \frac{2}{\pi} = 1$
$A_2 = 0$
$A_3 = \frac{2}{3\pi} = \frac{1}{3}$
$A_4 = 0$
$A_5 = \frac{2}{5\pi} = \frac{1}{5}$

3.3 Exercise 3

Frequency — Relative Amplitude	
126 Hz	0.8
253 Hz	0.5
603 Hz	0.5
628 Hz	0.8
714 Hz	0.5
761 Hz	1.0
831 Hz	0.6
882 Hz	0.6

(Note, frequencies are ± 2 Hz and amplitudes are ± 0.01)