# Fourier Analysis

Full appreciation of the power of Fourier analysis requires not only the ability to perform the required mathematical operations, but also some intuitive feeling for the relationship between a waveform and its Fourier spectrum. In this lab you will have the opportunity to obtain the Fourier spectra of various waveforms using several techniques.

<u>Before You Come to Lab:</u>

Review the text's material on Fourier analysis (HL Chapter 13). In particular, look at the spectrum of a square wave, triangle wave, and a repeating spike. You'll be comparing these mathematical ideals to what you measure in the lab.

I) Analysis of electrical waveforms using a tuned filter.

The Wavetek 166 function generator can produce sine, triangle, sawtooth, and square waves, as well as pulses with variable "duty cycle. The HP 302A wave analyzer is a tunable narrow bandpass filter, which passes only those components of the input signal having frequencies close to the frequency setting of the analyzer. When tuned to some frequency, the wave analyzer's meter will show the Fourier amplitude of the input signal at that frequency. Use this arrangement to construct the Fourier spectra for triangle and square waveforms. A frequency meter is available for accurately checking frequencies. *Check both even and odd harmonics and see whether your spectra agree with theory.*

N.B. Tune the HP 302A by sending it a 1 kHz sine wave, setting the pass frequency to 1 kHz, and adjusting the offset until the response is maximized. It s unlikely to be far out of tune, so don t adjust the offset too far or you may tune to -1 kHz and it will act really weird.

II) Analysis of waveforms using the Stanford Research Systems SR770 Network Analyzer.

This part of the experiment is similar to the first, except that the Fourier spectra are generated automatically on a CRT screen. The SR770 is a special-purpose computer that samples the input waveform and calculates its Fourier spectrum using a numerical technique called the "Fast Fourier Transform (FFT)." This computation is carried out very rapidly so the spectrum is displayed in real time. The instrument has an enormous range of capabilities, including control of the scale of the display and a cursor to allow numerical data to be read from the display. The operating manual is available to help you understand the instrument. Use the SR770 to investigate triangle and square waves as well as a variety of others. Include pulses of differing duty cycles. ( Duty cycle refers to how much of the time something is on. A 50% duty cycle would mean a square wave which is high 50% of the time.) Be sure to look at a wave with its duty cycle near zero. Does the result make sense? Try to understand what you observe. A plotter can be directly connected to the SR770 to make plots of the functions and spectra you see on its screen.

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III) Waveform synthesis.

For this part of the lab, use the Pasco synthesizer to generate desired waveforms. From your work with parts I and II, you should know the relative strengths of the harmonics needed to create square and triangle waves. Notice that the synthesizer also has phase controls. You might want to listen to the waveforms on a speaker to find out how the spectrum is related to the sound.

**Warning:** the amplitude controls on the Pasco synthesizer are **not** calibrated, so use the oscilloscope or SR770 to set your amplitudes appropriately.

IV) Computer analysis of hand-drawn waveforms (if time permits).

You can use the program Fourier 1.1 (written by Michael Martin '93) on the Mac to analyze waveforms that you draw on the screen. This gives you a good opportunity to develop an intuitive feel for how Fourier analysis works. To run it, double click on the "Fourier program" folder icon, and then double-click on the Fourier 1.1 icon. You draw the waveform by clicking the mouse button when the cursor is at the location of each point that you wish to specify. The "Waveform" display button should be dark at this point. The positions of existing points can be changed by dragging them vertically; the cursor changes to a double-headed arrow when this option has been activated by placing the cursor on an existing point. To do the analysis, click on the "Analyze" button. The fit to the data is shown, and the amplitudes of the components are displayed. The Fourier spectrum can be displayed by clicking on the "Spectrum" button. The program is set up for a "wave on a string," so the fundamental has nodes only at the ends; it does not correspond to a full cycle of the wave in the drawing window. The waveform can be erased by clicking on the "Zero" button with "Waveform" display selected; the fit can then be erased by clicking on the "Analyze" button. Other features of the program are reasonably self-evident.

V) Other possibilities.

Look at the Fourier spectra of sounds by connecting a microphone to the Fourier analyzer. You will probably have to increase the sensitivity (decrease the input voltage range) of the analyzer to see the small microphone signal.

Investigate the uncertainty principle by using two oscillators to produce tone bursts.

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| R.R.C | 1/21/83 |
| S.J.H. rev. | 1/14/91 |
| R.R.C. rev. | 1/31/94 |
| C.E.C. rev. | 5/19/95 |
| C.E.C. rev. | 1/19/96 |