A. Introduction

Some weeks you synthesized (put together) complex periodic signals with harmonic components. It is also possible to analyze (take apart) a complex signal into its component harmonics. You will do this two ways:

(1) using a new piece of equipment: the band pass filter, or
(2) Fourier Analysis (next lab).

We'll try both methods in this lab.

B. Band Pass Filter

For the purpose of analysis, the ideal band pass filter would allow only one frequency at a time to pass from the input to the output. Real band pass filters, however, cannot be so precise. They always allow some range, or "band" of frequencies through. A band pass filter is a filter which allows a BAND of frequencies to PASS through it, while filtering out all the others.

1. Measuring band pass filter characteristics

It is important to know just how wide the band of frequencies is for the filter you will be using. To find out, use the following procedure:

a. Connect the 50 Ohm output of your function generator to the filter and to one input on the scope. Connect the TTL output of the function generator to accurately measure the input frequency.

b. Connect the filter's scope output to the other scope input. Set the scope to dual trace operation (MODE: switch to either ALT or CHOP, whichever looks best) so you can see both the input to and output from the filter. The "stepped" appearance of the output is normal and is due to the particular electronics used.
c. Set the function generator to a sine wave of 500 Hz with a medium amplitude.

d. Tune the filter to 500 Hz so that its output is maximized. From now through step h, DO NOT ADJUST THE FILTER SETTING.

e. Construct a data table to record input frequency and output amplitude. Put the volts/div, the number to divisions, and the amplitude (in volts) in separate columns.

<table>
<thead>
<tr>
<th>frequency (Hz)</th>
<th>volts/div</th>
<th>nb divisions</th>
<th>amplitude (volts)</th>
</tr>
</thead>
</table>

f. The function generator is now set on the center frequency \( f \) of the filter. Measure the amplitude. You want to measure the amplitude of frequencies near \( f \). Now change the function generator (NOT the filter!) to 490 Hz. Measure the new output amplitude.

g. Repeat this for other frequencies nearby, like 450, 510, 550 Hz, etc. Be sure to measure enough of a frequency range to determine where the output amplitude approaches background noise.

h. Repeat steps e-g for a center frequency of 5000 Hz. Notice that to get a change in output amplitude comparable to the change from 500 Hz to 520 Hz you have to change the frequency from 5000 Hz to 5200 Hz. The absolute number of Hz is much greater, but the percentage is the same.
2. Graph your Results

Plot the results for both frequencies on one piece of two cycle log paper immediately as they are measured. The frequency is plotted on the horizontal axis, and the output voltage on the vertical axis. Fill in additional necessary frequency points in order to obtain a smooth curve.

3. Analysis of a Square Wave

Use the band pass filter (BPF), scope, and frequency counter to analyze a 440 Hz square voltage from the function generator. Measure the amplitude of the harmonics. Their frequency estimate either from the scope or the position of the BPF frequency dial

<table>
<thead>
<tr>
<th>frequency (Hz)</th>
<th>amplitude (volts)</th>
<th>A / A1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>
Plot your amplitudes in the form of a bar graph (a typical way to represent a harmonic spectrum). Do your results agree with the accepted values (recall that the square wave contains odd harmonics with amplitude ratios 1, 1/3, 1/5, ...)?

C. Analysis of a musical sound

1. The Infinite Oboe

The distinctive sound of musical instruments is largely due to the harmonic structure they produce. To facilitate the analysis of the tone of an acoustic instrument we have made a tape loop of an oboe playing a steady 440 Hz tone and recorded it onto cassette tape.

2. Measuring the spectrum

a. Use your BPF to find the harmonic composition of the steady-state oboe tone. Record your results (frequency and amplitude). Show them to your instructor, who can compare your results to his findings.

<table>
<thead>
<tr>
<th>frequency (Hz)</th>
<th>amplitude (volts)</th>
<th>( A / A_0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

9: Filters - 4