Fourier Analysis Lab

Introduction:

The goal of this lab is to give students a fuller understanding of Fourier analysis through hands-on experience. You will calculate the Fourier Series of a signal, see how Fourier Analysis can be practically applied to filter design, and see how Fourier Analysis applies to signal processing. In addition, you will experiment with passive RC filters to better understand their design and their effect on signals.

Equipment:

Qty	Equipment
1	Leader LFG-1300S Function Generator
1	BNC to 2 alligator clips cable
1	Hewlett-Packard 54600A Oscilloscope/Spectrum Analyzer
2	HP Oscilloscope Probe
1	Heathkit Circuit Design Trainer
1	1 kΩ Resistor
1	.01µF Capacitor

Note: Use must use the HP 54600A Oscilloscope for this lab. The older HP 54502A Oscilloscopes do not have the FFT capability that is available in the newer 54600A.

Calculation of Fourier Series Coefficients:

A. Calculate the Fourier series coefficients of the repetitive even triangle wave shown in **Figure 1** with a one volt amplitude (A = 1 V) and a DC component of zero volts (DC = 0V). (Do your work on separate sheets of paper and attach them to this handout. For full credit, make sure you show all your work!)

Figure 1
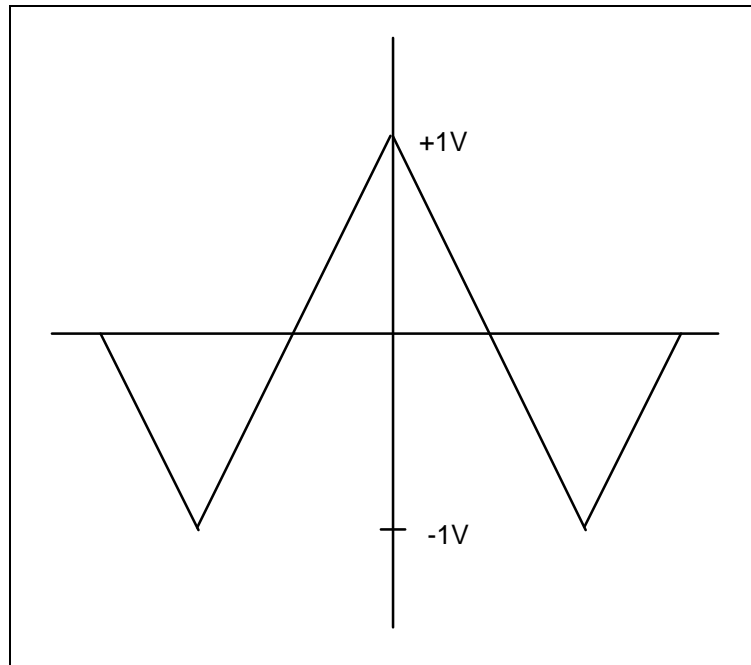
B. A square wave (A = 1V, DC = 0V, T = 10µs) with even symmetry is passed through a passive-RC low-pass filter (R = 1kΩ, C = 0.01µF) as shown in **Figure 2**.

- (B.1) Calculate the Fourier coefficients of the output voltages to the ninth harmonic.
  (Show all of your work on separate sheets of paper and attach to this handout.)

- (B.2) How do they compare to the coefficients found in Step A?

Lab Procedure:

1. Implement the circuit described in **Step B** of the calculation section as shown in **Figure 2**. Place **channel one's oscilloscope probe across the function generator** and place **channel two's probe across the capacitor**. Set the function generator to **produce a square wave with the amplitude knob at the 12 o'clock position**, **all pad buttons in the out position**, and **a period of 10 μsec.** (f = 100kHz)

- Turn on the oscilloscope and **press the autoscale button**. (You should see two waveforms, the input wave, a square wave, above the output wave.) See Step 2 on the next page for troubleshooting tips.

- Using Graph 1, **sketch both waveforms you see on the oscilloscope**. (Graph 1 should show both waveforms just as they appear on the oscilloscope--one above the other.)
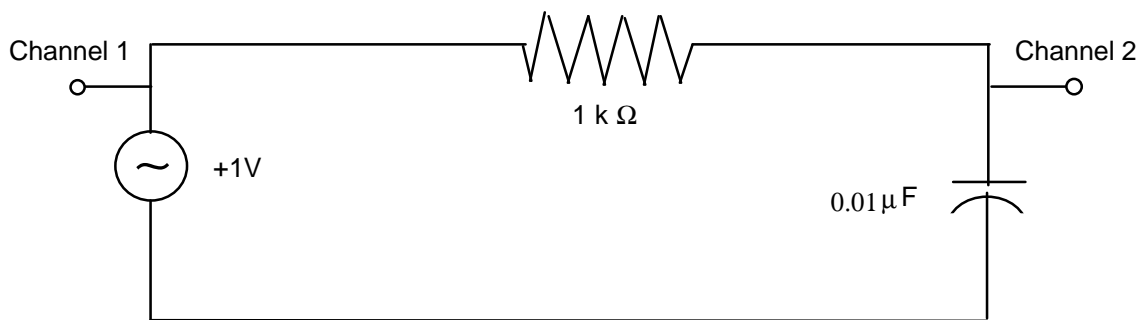

Figure 2

Graph 1: Square Wave Input: T = 10μs.

2. Next, **input a triangle wave** to the circuit used in Step 1. **Keep all the remaining function generator settings (amplitude and frequency) the same** as they were in Step 1.

- **Press the autoscale button**. (You should see two waveforms, the input wave, a triangle wave, above the output wave.)

- Using Graph 2, **sketch both waveforms you see on the oscilloscope**. (Graph 2 should show both waveforms just as they appear on the oscilloscope--one above the other.)
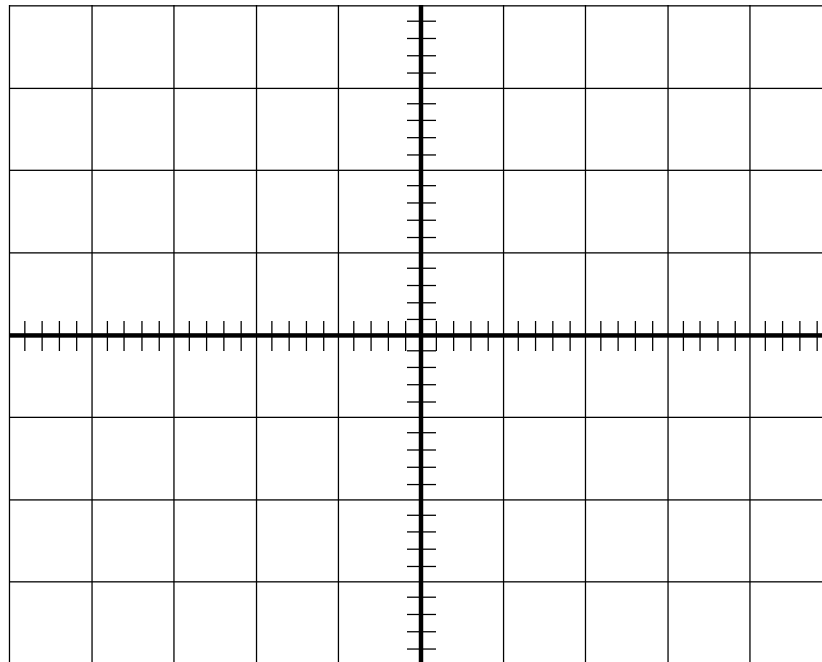
- Troubleshooting Tips:

    The circuit in Figure 2 should already be configured for you. Verify that all the proper circuit connections are correct and that the oscilloscope probes are connected to the proper circuit points. Ask a lab GSA for assistance if you have problems setting up the circuit.

    If the oscilloscope won't display any signals, you may need to reset it. Follow these instructions carefully: Turn the oscilloscope off. Press and hold in the Storage Erase button and while continuing to hold in the Erase button, turn the oscilloscope back on.
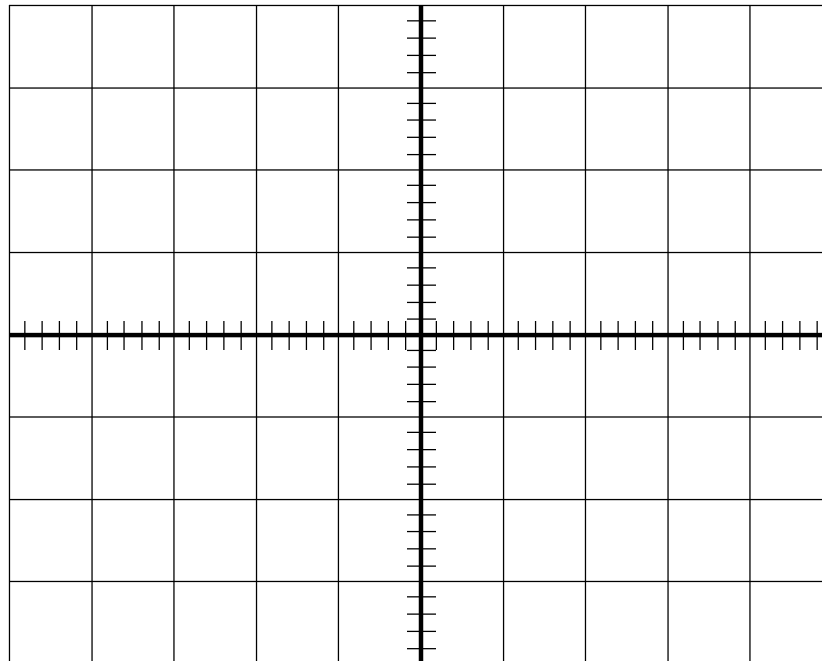
Graph 2: Triangle Wave Input: T = 10μs.

3. Next, **input a sine wave** to the circuit used in Step 1. **Keep all the remaining function generator settings (amplitude and frequency) the same** as they were in Step 1 and Step 2.

- **Press the autoscale button**. (You should see two waveforms, the input wave, a sine wave, above the output wave.)

- Using Graph 3, **sketch the waveforms you see on the oscilloscope**. (Graph 3 should show both waveforms just as they appear on the oscilloscope.)
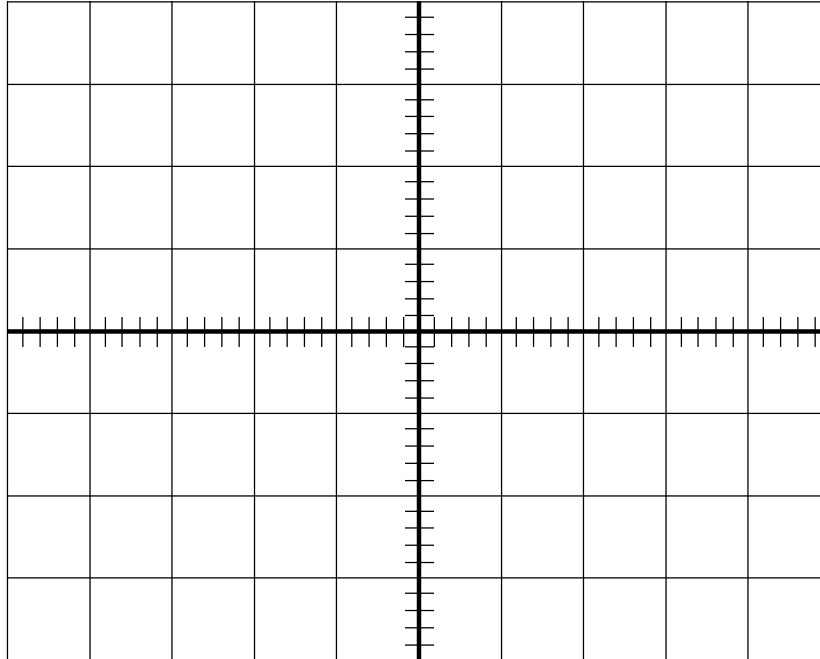
Graph 3: Sine Wave Input: T = 10μs.

4. Return the function generator to the square wave setting. Using the Fast Fourier Transform (FFT) spectrum analyzer function of the oscilloscope, measure the frequency components of the input and output waveforms. The following steps will enable you to easily see and measure these components.

- Press the **Autoscale** Button.
  Press the **1** button **once**. (You are turning Channel 1 ON.)
     Set Coupling to **AC**, Vernier to **ON**, and Probe to **10**.
     Press the **1** button **once**. (You are turning Channel 1 OFF.)
  Press the **2** button **once**. (You are turning Channel 2 ON.)
     Set Coupling to **AC**, Vernier to **ON**, and Probe to **10**.
     Press the **2** button **once**. (You are turning Channel 2 OFF.)

- Press the **Display** Button.
  Set Display Mode to **Average** and Vectors to **ON**.

- Press the **'+/-'**   Button.
  Turn Function 2 (F2) **on** by pushing the **F2** Button.
  Press the **Menu** Button.

- Use the **Soft Keys** (the keys that are labeled under the CRT) to make the following settings. Press the button associated with the setting you want to change, and turn the small white knob near the **Cursors** Button to change the settings:
     Set the **Operand** to **1**.
     Set **Operation** to **FFT**.
     Set the **Scale** to **2.00 dB/div**.
     Set the **Reference Level** to **0.00 dBV**.
        (The top graticule line of the screen now represents al level of 0 dBV.)

- Press the **FFT Menu** Button.
     Press the **Move 0Hz to Left** Button.
     Set the **Window** to **Hanning** for the best frequency resolution.
     Set the **Frequency Span** to **24.41MHz**.
        (A span of 24.41 MHz is displayed from one side of the screen to the other.)

- Use the **Time/Div** Knob to set the Fourier Transform Sampling Rate to **5.00 MSa/s**. (The setting will appear on the CRT as you turn the knob, but will disappear when you stop turning it.)

- You should now see the **fundamental** and 10 or more **harmonics**.
  Press the **Stop** Button.
  Note: Ignore the component at 0Hz; it is an artifact of the FFT process.

- Press the **Cursors** Button.
  Set the **Active Cursor** to **f1**.
  Move the cursor to the first component, the **fundamental**.

- (4.1) What is the frequency of the fundamental? _____ ___ Hz

- Set the **Active Cursor** to **f2**.

- (4.2) Using cursor **f2**, **measure each** of the other components, the **harmonics**.
     (List at least eight harmonic frequencies.)

- Press the **'+/-'** Button.
  Press the **Previous Menu** Button **one or two** times until you see the function/operand menu.
  Set the **Operand** to **2**.
  Set the **Reference Level** to **-16.00 dBV**.
     You are now looking at the FFT of the output waveform.

- Press the **Run** Button.
  Wait **ten seconds**.
  Press the **Stop** Button

- Press the **Cursors** Button.
  Set the **Active Cursor** to **f1**.
  Move the cursor to the first component, the **fundamental**.

- (4.3) What was the shape of the output wave you drew in Graph 1? _____

- (4.4) What is the frequency of its fundamental? _____ ____ Hz

- Set the **Active Cursor** to **f2**.

- (4.5) Measure each of the other components, the **harmonics**.
     (You may only see one or two components.)

- (4.6) Do you see fewer, the same, or more frequency components in the FFT of the output waveform, the triangle wave? Why did you or why did you not see any changes?

5. Repeat Step 4; replacing the square wave input with a triangle wave input. (Leave the other settings unchanged.

- (5.1) What is the frequency of the fundamental? _____ ___ Hz

- (5.2) Measure each of the other components, the **harmonics**.

- (5.3) What was the shape of the output wave you drew in Graph 2? _____

- (5.4) What is the frequency of the fundamental? _____ ___ Hz

- Set the **Active Cursor** to **f2**.

- (5.5) Measure each of the other components, the **harmonics**.

- (5.6) Do you see fewer, the same, or more frequency components in the FFT of the output waveform, the triangle wave? Why did you or why did you not see any changes?

6. Run the filters program on the PC in the lab. The program is in the `c:\filters` directory. The program calculates the output of a filter. Configure the system with the square wave and the filter described in Step B of the calculation section. (A = 1V, T = 100kHz, R = 1kΩ, C = .01µF)

- (6.1) Using Graph 4, sketch the waveform output by the filters program.

- (6.2) Do the amplitudes of the first five harmonics of the output match your calculations?

- (6.3) Does the resultant waveform resemble the signal you observed in Step 1?
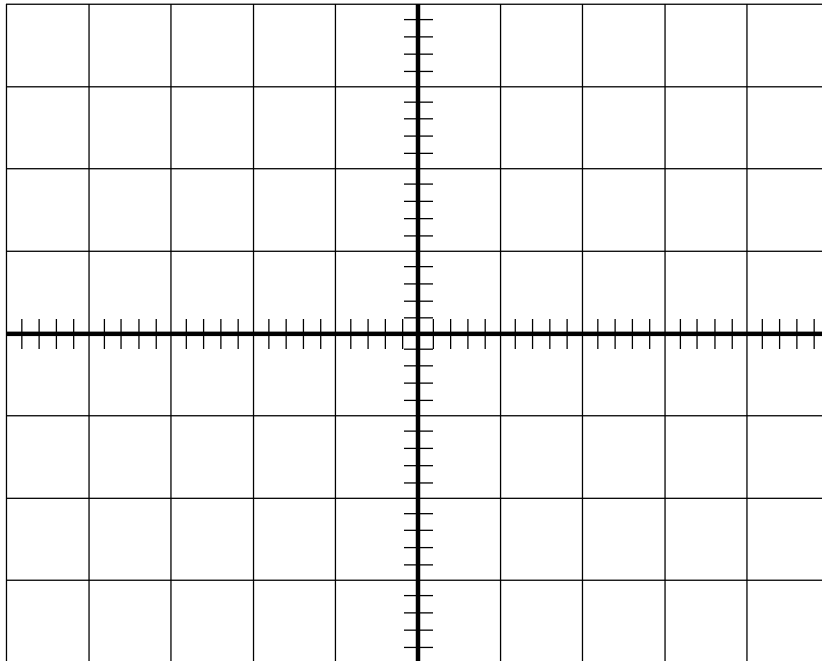
Graph 4: Output of Filters Program.

Observations:

(Use separate sheets of paper for your answers in this section. Remember to show your work!)

1. The filter constructed above could be called an integrator for the frequencies examined. Show that the output signal is the integral of the input signal.

2. Does this property hold true at all frequencies?

3. If discrepancies exist, discuss the reasons for them.