Notes on Experiment #1

Bring graph paper (cm × cm is best)

From this week on, be sure to print a copy of each experiment and bring it with you to lab. There will not be any experiment copies available in the lab.

The purpose of this experiment is to get familiar with the function generator and the oscilloscope.

During your lab session read very carefully and do everything just as described in the text. For each question that you encounter in the text, write down the question and then answer the question. There is very little calculation required. Please do draw the sketches required at the end of Section III.

Experiment 1 is a bit long and so you may not finish. That's OK. There will be no penalty if you do not finish. But do as much as you can. It will make the next experiment go easier for you.

To prepare for this experiment:

1. Read the entire experiment.
2. Write down all the questions that are asked in the text of the experiment.
3. Prepare a title page, purpose paragraph (no theory or circuit analysis), and the questions (with space for the answers) in advance to coming to lab.

Your report, which is due at the end of the lab session, will include the material above, the answers to the questions (which you will determine from performing the experiment), and a conclusion paragraph.

Note: Taking pictures of the waveforms is also acceptable (instead of plotting on graph paper). In either case, the X and Y axes should be clearly labeled, and the divisions also must be labeled.
ECE 210 Experiment #1

Introduction to the function generator and the oscilloscope

Purpose: To familiarize yourself with the laboratory equipment

Equipment: Agilent 54621A Oscilloscope, Agilent 33120A 15MHz Function/Arbitrary Waveform generator

I. General Introduction
1. The function generator is a voltage source. It is most generally set so that the voltage at the output terminal is

\[ v(t) = B + A \sin \omega t \text{ volts} \]

where

a. \( B \) is the DC component of \( v(t) \) called the DC offset or just the offset
b. \( A \sin \omega t \) is the AC component of \( v(t) \). Note that the AC component is a periodic function of time. There are other periodic waveform shapes available from the function generator.

The AC component has three parts: Shape (\( \sin \) implies a sinusoidal shape); Amplitude (\( A \) is the zero-to-peak amplitude); Frequency (in this example the frequency would be radian frequency. But note that the function generator frequency must be set in Hertz (Hz))

Here are some useful terms:

Radian frequency \( \omega = 2\pi f \) where \( f \) is frequency in Hertz (i.e. cycles/second)

Period \( T = 1/f = 2\pi /\omega \)

Zero-to-Peak Amplitude = \( A \) for a sinusoidal function

Peak-to-Peak Amplitude = \( 2A \) for a sinusoidal function

RMS Amplitude = \( A /\sqrt{2} = 0.707A \) for a sinusoidal function

There are controls on the function generator that allow you to set each of the parts of \( v(t) \) (\( B, A, \) shape, frequency) very accurately.
2. The oscilloscope is a voltmeter. You measure the voltage by observing the graphical image on the display. The parts of the voltage $v(t)$ ($B$, $A$, shape, frequency) above can be determined very easily on the "scope."

The scopes in your lab are digital "dual trace" oscilloscopes. They are capable of measuring two voltages simultaneously. Note that the scope has two sets of input terminals. Each input is called a channel. More about this later in the experiment.

II. Learning to use the function generator
1. The function generator controls

Take a look at the Agilent 33120A 15MHz Function/Arbitrary Waveform generator. Locate the sync and output terminals on the right hand side of the front panel. Note the special "Pomona plug" connector attached to each terminal. The function $v(t)$ would be available at the output terminal. The voltage at the sync terminal is a special waveform that we will take a look at later in this experiment.

Just to the left of the terminals are four arrow buttons. These are used to select menu options and to make incremental changes in various numerical quantities (frequency, amplitude, offset, etc.) So the arrow buttons are multi-purpose in nature. Which arrow button do think is used to select a peak-to-peak voltage setting? Which arrow button do you think is used to select mega-Hertz frequency setting? Which button selects an RMS voltage setting?

Just above the arrow button is a large dial knob. This dial knob can be used to set numerical quantities for frequency, amplitude, offset, etc. You can also use this dial knob to "fine tune" any quantity.

Locate the three buttons under the Function/Modulation heading on the left side of the front panel with the sine wave, square wave, and triangle wave shapes. These buttons allow you to select the wave shape of the AC part of $v(t)$. Just below these three buttons are buttons used to set the frequency, amplitude, and DC offset of $v(t)$.

The buttons described above are the features most frequently used for the experiments in this lab.

Press the power button. Observe the display. Record what is written to the display exactly as you see it. Press the button with the triangle waveform. How does the display change? Press the square waveform button. How does the display change? Press the sine waveform button.

2. Setting the frequency
Press the frequency button labeled **Freq**

There are three methods to set numerical values. These methods apply to all function settings.

i. Using the dial knob and left - right arrow buttons.

   Turn the dial and observe how the display changes. Note also that one of the digits is blinking off and on. Press the left arrow button. What happens? Press the right arrow button. What happens? Use the left and right arrow buttons to select the left most (most significant) digit as the blinking digit. Now turn the dial knob and set this digit to 7. Now press the right arrow key once to select the digit to the right. Again use the dial knob to set this digit to 7. Repeat this for the next two digits to the right. What is the value of the frequency displayed?

ii. Using the arrow buttons

   The up and down arrow buttons can be used to increment and decrement digits in the display. Use the left and right arrow buttons to select the left most digit. Press the down arrow button. What happens? Press the up arrow button what happens? Use the up and down arrow keys to set this digit to 3. Use this method to set the three digits to the right to value 3. What is the value of the frequency now?

iii. Using the Enter Number button

   Note that the twelve keys on the left and center of the panel have green numbers printed to the left of each key. Which key has the number 7? Which key has the +- symbol? Which key has the decimal point?

   You can use these keys for numerical input if you press the **Enter Number** key. Press the **Enter Number** key. Now enter the following key sequence: 6, ., 3, 2, 4 Now press the **ENTER** button. What is the frequency displayed?

   You may change the units to MHz by pressing the MHz (up arrow button) instead of the ENTER button. Set the frequency to 2.701 MHz

iv. Practice

   Use each of the above methods to set these frequencies:
3. Setting the AC magnitude

Press the Amplitude key **Ampl** and record exactly what appears on the display.

To set the amplitude to 2 volts peak-to-peak

a. Press **Enter Number**

b. Press **Vpp** (the up arrow button)

Note that you have created the pure sinusoidal voltage

\[ v(t) = 1\sin(2000\pi t) \text{ volts} \]

This has an RMS value of \(1/(2)^{1/2} = 0.707\) volts. We can set this value directly.

c. Press **Enter Number**

d. Press **0.707**

e. Press **Vrms** (the down arrow button)

Record exactly what appears in the display.

What happens when you try to set the voltage to 12 volts peak-to-peak?

What happens when you try to set the voltage to 0.03 volts peak-to-peak?

Set the amplitude to 1 volt peak-to-peak and go on to the next section.

4. Setting the DC offset

Press the **offset** button and record exactly what you see in the display.

Now let's set the DC offset to 1.2 volts.

a. Press **Enter Number**

b. Press **1.2**
c. Press **ENTER**

Reset the DC offset to zero.

5. **Putting it altogether**

Note that the frequency given below in the argument of the sine function is in radians. You must convert the radian frequency to hertz (Hz, KHz, or MHz) to set the function generator properly. (Recall that \( w = 2\pi f \) so \( f = \frac{w}{2\pi} \)) Note also that it is best to set the AC magnitude before setting the offset. (Recall that \( V_{pp} = 2A \) where \( A \) is the coefficient of the sine wave signal \( Asinwt \) volts.)

Set the **output** voltage \( v(t) \) to:

a. \( 1 + 2\sin2000\pi t \) volts
b. \( -0.5 + 0.7\sin500\pi t \) volts
c. \( 2 + 0.5\sin7000\pi t \) volts

6. **Learning to use the oscilloscope**

1. **The oscilloscope controls**

Take a look at the Agilent 54621A 100MHz Oscilloscope. Locate the two input terminals labeled 1 and 2. Note the special "Pomona plug" connector attached to each terminal. Just above these terminals are the "vertical" presentation controls. The small dial knobs with the up-down arrows along side them are the **vertical position** controls which allow you to move the image on the display up and down. The soft buttons labeled 1 and 2 allow you to access display menus for each channel. The larger dial knobs above the soft buttons are the **vertical scale** controls.

The horizontal scale and position controls are at the very top of the front panel. The small dial knob with the left-right arrows below it is the **horizontal position** control which allow you to move the image on the display left and right. Locate the controls labeled **Quick Meas** and **Auto scale**. These are the buttons you will use most often when measuring voltages with the scope. Locate the **Run/Stop** and **Single** controls. They are used to control the digital "sampling" of the voltages being measured. They will help you to get a stable image on the display. Whenever the image that appears on the display is unstable, just press **Run/Stop** to stabilize the image.
2. Measuring voltages with the scope

   Connect the function generator terminal labeled **output** to the channel 1 input terminal using the red and black cables available in the lab. Now press the power button (at the lower right corner of the display) to turn on the scope. An information page is displayed on the screen for about 15 seconds. Set the function generator to the following voltage:

   \[ 1 + 2\sin(2000\pi t) \text{ volts} \]  
   (Be sure to set the AC part first.)

   Press **Auto scale**
   There should be a sinusoidal image in the center of the display.

   Take a look along the edges of the display. Information about the location of the horizontal and vertical axis (small black arrows with right angle shafts), the vertical scale (in the upper left corner) as well as other values has been displayed along the edges of the display. Of course you also see the voltage image at the center of the display. To what value has the vertical scale been set? Use the vertical scale to determine the peak-to-peak voltage of the sine wave image that appears in the display. Is the value of the peak-to-peak voltage what you expected?

   If the value is not what you expect, don't worry, we will learn to fix this a bit later in the experiment.

   Play with the small dial knobs with the up-down arrows along side them (the **vertical position** controls) to move the image on the display up and down.

   Play with the small dial knob with the left-right arrows below it (the **horizontal position** control) to move the image on the display left and right. You can use the position controls to move an image to a location on the display that may make it easier for you to make more accurate visual measurements.

3. The channel 1 menu
   i. Press the soft **1** button one time.
      Notice the menu options at the bottom of the display.
   ii. Select the **probe** option by pressing the key below the word **probe**. Now turn the dial knob next to the circular arrow. What happens? Set the probe setting to **1.0:1**. This will ensure that the scope is correctly calibrated for the probes (which in this case are just the wire cables.)
You should try to remember to set the **probe** option to **1.0:1** every time you use the scope in this lab.

iii. Note that the **coupling** option is set to DC. This means the image on the display contains **both the DC and AC components** of the voltage signal. Select this option and change the coupling to AC. How has the image on the display changed? In this setting only the AC component of the signal is displayed. The DC has been removed. Change the coupling back to DC.

iv. Select the **invert** option. This changes the sign of the signal. What happened to the image on the display? To get the signal back on the display use the position control dial knob just below the soft 1 button. Adjust this control until the horizontal axis is at the second grid line from the top of the display. You may now need to press **Run/Stop** a couple of times to get a "clean" image. Select the invert option again and reposition the image so that the horizontal axis is at the second grid line from the bottom.

v. Turn the vertical scale dial knob (just above the soft 1 button) Note that the scale value is changing (upper left corner edge of the display) Set the scale to 1.0V/ How does the image in the display change? Now set the scale to 2.0V/ and then to 200mV/ Note how the image changes as the scale changes. Remember, if the image is unstable press the **Run/Stop** button a few times. Note that the "best" scale is the scale that makes the image as large as possible but no part of the image goes beyond the top and bottom of the display. Find the "best" scale for the image. What is the scale setting for the "best" image?

vi. Press the **Quick Measure** button
The scope will now do all of your measurement for you!

Press each of the following menu options and record the values given on the display: (Use the arrow option to access more options)

1. Frequency
2. Peak-Peak
3. RMS
4. Maximum
5. Minimum
6. Average (is the DC value of the signal)

Have you noticed that the image on the display is twice as big as it should be? Have you noticed that the measured
values of the peak-to-peak voltage and the average value are twice as big as they should be?

The problem is in the function generator. Here is the fix. On the function generator:

7. Press **Shift** (the blue button)
8. Press **Menu**
9. Repeatedly press **Right Arrow** until the display shows
   D: SYS MENU
10. Press **Down Arrow** two times so that the display shows
     50 Ohms
11. Press **Right Arrow** one time so that the display shows
    High Z
12. Press **Enter**

Now reset the function generator for $1 + 2\sin(2000\pi t)$

Go back to the scope and measure the peak-to-peak and average values. They should now be correct.

Please note: The scope will always give the correct measurement. When in doubt, use the scope measurement and not the function generator display to determine the actual voltage at the output of the function generator.

vii. Measuring two signals at one time.

Here we will be displaying two very different images (a sine wave from the output connection of the function generator and the SYNC signal - a pulse wave from the SYNC connection of the function generator) at the same time.

Set the function generator to: $0 + 2\sin(4000\pi t)$

With the output terminal of the function generator still connected to the channel 1 input of the scope, connect a set of cables from the SYNC terminal to the channel 2 input of the scope. Now press **Auto scale**. There should be two images on the scope. Make a sketch of all that is on the scope display. You can turn off either channel by pressing the channel soft button two times. Turn off channel 1 now.
Use the channel 2 **vertical position control** knob to adjust the position of the channel 2 horizontal axis (remember the black arrow with the right angle shaft?) so that it is at the center of the display. Turn on channel 1 and turn off channel 2. Move the channel 1 axis to the center of the display. Turn channel 2 back on. The two images overlap. Sketch what is on the display. Let's do some math! Press the **math** soft button and select the menu option **1-2**. There are three images on the display now. Turn off channels 1 and 2. The remaining image is the difference between the voltages input to the two channels. To set the vertical scale of the math mode image press the **settings** option (accessed by pressing the **math** soft button once) and then turn the indicated control knob so that the vertical scale is **2.00V**. Sketch this image. Repeat the above procedures using the triangle waveform and then the square waveform from the function generator.

You should now be familiar with the operation of the function generator and the oscilloscope.

Bring this experiment with you each time you come to the lab. It will be a useful reference for future experiments.