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 I 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: Storing waveforms in a flash drive and submitting print-outs 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 225 Experiment #1

Introduction to the function generator and the oscilloscope

Purpose: To familiarize yourself with the laboratory equipment
Equipment: Keysight InfiniiVision DSO-X 2012A Oscilloscope, Keysight 33500B Series 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)

      Time Period \( T = 1/f = 2\pi /\omega \) (\( T \) is the time required to complete 1 cycle)

      **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 will be discussed later in the experiment.

II. Learning to use the function generator

1. The function generator controls

Take a look at the Keysight 33500B Series Waveform generator. Locate the sync and output terminals on the right hand side of the front panel. Note the special BNC 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 seven buttons arranged in a vertical line. In the experiments you are going to use the top 3 buttons frequently. The top 3 buttons are “Waveforms”, “Parameters” and “Units”. These are used to select the shape of the waveform and make incremental changes in various numerical quantities (frequency, amplitude, offset, etc.)

On the top right hand corner of the function generator there 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.

Power up the function generator by pressing the power switch located on the bottom left corner. Wait for the system to boot. Now press the “Channel” button located right above the Output. Select “Output Load” by pressing the button right below it. Change the load from 50Ω to “Set to High Z”. This is a very important procedure and needs to be done before starting any experiment for the proper functioning of the function generator.

Now press the “waveforms” button. Locate the 3 options of “sine”, “square” and “Triangle” in the screen. (For locating the “Triangle” option you need to press the “More” button). These buttons will allow you to select the waveshape of the output signal.

Select the “Sine” option by pressing the button right below it. Now you can change various parameters of the waveform like “frequency”, “amplitude”, “offset” and “phase”.
2. Setting the frequency

Press the “sine” button once more. You will find that the bottom row of screen displays “Parameters” and “Frequency” is selected by default. **What is the value of frequency now?**

There are two ways to configure the frequency.

a) Use the number panel located to the left of dial knob. Set the frequency to 50.049 KHz using the number panel. Try to set the frequency to 50MHz. **What do you see on the screen? Find out the range of frequency output of the function generator, i.e. the upper and lower limits.** Set the frequency to 1KHz now.

b) The other way to change a parameter is to use the dial knob and the left and right arrow buttons below it. For example in order to set the frequency as 1.05 KHz you need to press the right arrow button to select the 3rd digit and then rotate the knob to get 5. Press the right arrow button to reach the end. “k” of the kHz is selected now. Rotate the knob now. **How does the frequency change now?** Set the frequency to 21.0095Hz.

Use both the methods described above to set the following frequencies.

- 27.3 KHz
- 351 Hz
- 11.77 MHz
- 73.26 KHz

Set the frequency back to 1 kHz and go on to the next section

3. Setting the AC magnitude

Press the Amplitude button. **What is the value of amplitude now?** The amplitude can be changed in the same ways as the frequency.

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

a) Press 2
b) Press V_{pp} (V_{pp} means peak-to-peak voltage)

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.
a. Press 0.707
b. Press $V_{\text{rms}}$

Record exactly what appears in the display.

What happens when you try to set the amplitude to 22 Vpp?

What happens when you try to set the amplitude to 1 mVpp?

Set the amplitude to 2 volt peak-to-peak and go on to the next section.

2. Setting the DC offset

Press the offset button. What is the default value of the Offset?

Now let's set the DC offset to 1.2 volts

a. Press 1.2
b. Press V

By using the “+/-“ button on the number panel you can set a negative offset too. Set the offset to -1.2 V. Reset the DC offset to zero.

3. 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 $V_{\text{pp}} = 2A$ where $A$ is the amplitude of the sine wave signal $A\sin wt$ volts.)

Set the output voltage $v(t)$ to:

a. $1 + 2\sin 2000\pi t$ volts
b. $-0.5 + 0.7\sin 500\pi t$ volts
c. $2 + 0.5\sin 7000\pi t$ volts

4. Using the Units feature

Press the Units button. This feature gives you some useful information about the waveform. Once you have set the frequency, amplitude and offset of the waveform you can press this button and find out the time period and high and low levels of the waveform.
Set the output voltage $v(t)$ to $2 + 0.5\sin7000\pi t$ volts. **What is the theoretical time period of this waveform?** **What are the theoretical high and low levels of this waveform?** **Do they match with the data that you see on the screen after using the Units feature?**

II. **Learning to use the oscilloscope**

1. **The oscilloscope controls**

   Take a look at the Keysight Infiniivision DSO-X 2012A 100MHz Oscilloscope. The instrument has a screen and a control panel where many buttons are located. Locate the two input terminals labeled 1 and 2. Note the special BNC connector attached to each terminal. The small dial knobs with the up-down arrows alongside 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 allows you to move the image on the display left and right. Locate the controls labeled **Meas** and **Auto scale**. These are the buttons you will use most often when measuring voltages with the scope. Locate the **Run/Stop**, and **Trigger** controls. They will help you to get a stable image on the display.

2. **Measuring voltages with the scope**

   Connect the red and black terminals of the function generator output terminal to red and black terminals of the channel 1 input terminal of the scope. Now press the power button (at the lower left corner of the display) to turn on the scope and wait for the system to boot. Set the function generator to the following voltage:

   $$1 + 2\sin2000\pi t$$

   (Be sure to set the AC part first.)

   Press **Channel** button on the function generator and select **Output On**.

   Press **Auto scale** on the oscilloscope.

   There should be a sinusoidal image in the center of the display.

   Take a look along the edges of the display. The position of horizontal axis or the X-axis is indicated by a small yellow arrow marked 1. This is the reference line. The vertical scale is displayed in the top-left corner of the screen. It should be reading 1.00V. This means that one big division in the Y-axis or the vertical axis is 1V. **Use the vertical scale to determine the peak-to-peak voltage of the sine wave image that appears in the display.** **Does the value of the peak-to-peak voltage match with your expectation?**
Play with the small dial knob with the up-down arrows alongside it (the **vertical position** control to move the image on the display up and down. **Push the knob and record your observation.**

Play with the small dial knob with the left-right arrows below it (the **horizontal position** control located at the top central part of the panel) 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 screen that makes it easier for you to make measurements. The horizontal axis scale value is displayed at the central top position of the screen. It should be reading $200\text{us}$/ which means that one big division on the X-axis is $200\text{us}$. You can change the X-axis scale by turning the dial labeled **Horizontal** at the top left corner of the panel.

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 select the **Probe 1.00:1** option. **Now turn the dial knob below the circular arrow. What happens?** Set the probe setting to **1.0:1**. This ensures that the scope is correctly calibrated for the probes (which in this case are just the wire cables.) Remember to set the **probe** option to **1.0:1** every time you use the scope in this lab.
   
   iii. Press the Channel 1 soft button. Note that the **coupling** option is set to DC (direct coupling). This means the image on the display contains **both the DC offset and AC components** of the voltage signal. Select this option and change the coupling to AC (alternate coupling). **How has the image on the display changed?** **What is the mathematical expression of the signal now?** In this setting only the AC component of the signal is displayed. The DC offset 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?** In case the signal has exceeded the screen size, get the signal back on the display use the vertical 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. 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 $2.0\text{V}/$. **How does the image in the display change?** Now set the scale to $5.0\text{V}$/ and then to $200\text{mV}/$. Note how the image changes as the
scale changes. 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?** Push the scale dial for fine tuning. Turn the dial now. **Do you notice something different?** Push the dial once more to switch off the fine tuning feature.

vi. Press the **Meas** button
The scope will now do all of your measurements for you!

You will see that Frequency and Pk-Pk (peak to peak) are being measured by default on the right hand side of the screen. To get more measurements select the **Type** feature and then use the dial knob below the circular arrow to navigate through the options. Add any measurement to the right hand side of the screen by pressing the **Add Measurement** button. Record the following and compare with theoretical counterparts.

1. Frequency
2. Pk-Pk
3. DC RMS – Cyc
4. AC RMS - Cyc
5. Maximum
6. Minimum
7. Average (is the DC value of the signal)
8. Time Period

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: \(0 + 2\sin4000\pi t\)

With the **output** terminal of the function generator still connected to the channel 1 input of the scope, connect 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 or you can save the waveform in your flash drive and print it out.

**How to stabilize the image on the screen?**
There are 2 ways to stabilize the image on the screen.

a) Turn the dial knob called **Level** just beside the **Trigger** button. You will see that once the trigger level exceeds the limits of the sine wave in Channel 1, the waveforms become unstable. Once the trigger level is within the limits of the sinusoidal waveform, both the channel images are stable.

b) Another way to stabilize the image is to press the **Run/Stop** button. In normal mode of operation the button will glow green indicating that the scope is running and continuously recording the waveforms. Press that button once. You will see that the color changes to red indicating that the scope has stopped recording and the image on the screen is the snapshot of the waveforms right at the instant you pressed Stop.

*How to save the screen image on your flash drive?*

Stabilize the image on the screen. Insert the flash drive in the slot located below the screen. Press the button **Save/Recall** on the control panel. Select the **Save** option on the screen. You can save in a format of your choice. You can also change the name of the file by selecting **File Name** and then using the **Push to Select** dial. At any stage you can press the **Back** button to go back to the previous stage. Finally you can press the **Press to Save** button to save the file in your flash drive.

You can turn off either channel by pressing the channel soft button twice. Turn off channel 1 now. Push the channel 2 **vertical position control** knob to set the position of the channel 2 horizontal axis at the center of the display. Note that on the screen everything related to Channel 2 is green while the same for Channel 1 is yellow. Turn on channel 1 and turn off channel 2. Push the Channel 1 **vertical position control** knob to set the Channel 1 horizontal axis at the center of the display. Turn channel 2 back on. The two images overlap. Sketch or print out what is on the display.

*Zooming the waveform*

Increase the time scale to 20ms/div. You can see that the image on the screen is not a clear one and looks jumbled up. You can get a clear picture by zooming in using the **Zoom** feature of the scope. Press the **Zoom** button just to the right of the time scale dial. You can see that the screen got divided into 2 segments. The upper segment contains the blurred waveform with a zoom window and the lower segment contains the image of the signal inside the zoom window. You can see two time scale values in the screen now. The one on the right is the time scale of original waveform while the other one is the time scale of the zoomed waveform.
You can resize the zoom window by turning the Horizontal scale dial. You can also play with the play and stop buttons after stopping the signal.

Turn off the zoom feature by pressing the Zoom button once more. Set the time scale to 200us. Let's do some math! Press the **math** soft button located on the right hand side of the control panel. By default the scope will add the 2 channels and there are three images on the display now. Turn off channels 1 and 2 by pressing the channel soft buttons. The remaining image is the sum of the voltage inputs to the two channels. To set the vertical scale of the math mode image turn the dial knob to the right of **Serial** button. Set the scale to 2V/div and sketch or print 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.
General Lab Instructions

The Lab Policy is here just to remind you of your responsibilities.

Lab meets in room 3250 SEL. Be sure to find that room BEFORE your first lab meeting. You don't want to be late for your first (or any) lab session, do you? Arrive on time for all lab sessions.

You must attend the lab section in which you are registered. You can not make up a missed lab session! So, be sure to attend each lab session.

REMEMBER: You must get a score of 60% or greater to pass lab.

It is very important that you prepare in advance for every experiment. The Title page and the first four parts of your report (Purpose, Theory, Circuit Analysis, and Procedure) should be written up BEFORE you arrive to your lab session. You should also prepare data tables and bring graph paper when necessary. To insure that you get into the habit of doing the above, your lab instructor MAY be collecting your preliminary work at the beginning of your lab session. Up to four points will be deducted if this work is not prepared or is prepared poorly. This work will be returned to you while you are setting up the experiment.

NOTE: No report writing (other than data recording) will be allowed until after you have completed the experiment. This will insure that you will have enough time to complete the experiment. If your preliminary work has also been done then you should easily finish your report before the lab session ends. Lab reports must be submitted by the end of the lab session. (DEFINE END OF LAB SESSION = XX:50, where XX:50 is the time your lab session officially ends according to the UIC SCHEDULE OF CLASSES.) Each student should submit one lab report on the experiment at the end of each lab session. If your report is not complete then you must submit your incomplete report. If you prepare in advance you should always have enough time to complete your experiment and report by the end of the lab session.
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