Lab 0: Introduction to basic laboratory instruments

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1. Objectives

1. To learn safety procedures in the laboratory.
2. To learn how to use basic laboratory instruments: power supply, function generator, multimeter, and oscilloscope.

2. Laboratory safety

The TA will go over safety procedures in the laboratory. Electrical voltages used in the experiments are usually low (e.g. 5V up to 15V) but AC voltages used to operate the instruments themselves are dangerous. Do not cut or interfere with power cords for these equipment, and do not plug your circuits into the 115V outlets. Other utility equipment such as pliers, wire-cutters, etc. is sharp and can cut deeply. When a wire is being stripped of insulators, take extreme precaution that stripped plastic sections or wire segments are not directed at eyes, people's faces, etc.

3. Basic laboratory instruments

The basic instruments used in EE 233 are: DC power supply, function generator, multimeter, and oscilloscope. This document describes the procedures to use these instruments available in the UW laboratory and serves as a reference in future laboratory instruments. If this course is taught at another institution with different instruments than those described below, the instructor needs to provide a document to describe the procedures to use the available instruments.

The instruments available at UW are:

a) DC power supply: HP E3630A triple output DC power supply.
b) Function generator: Tectronix AFG 3021 single channel, arbitrary/function generator
c) Multimeter: HP 34401A Multimeter
d) Oscilloscope: Tektronix TDS 2004B four channel, digital storage oscilloscope

4. Using a DC power supply

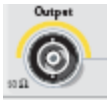
The DC power supply on most lab benches is the HP E3630A triple output DC power supply. This instrument can provide various DC power supply voltages up to +6V, +20V, and -20V. Procedure to set a specific DC power supply value:

1. Turn on the instrument (ON/OFF switch at lower left of front panel).

2. Connecting GROUND: the Ground connection of the instrument is usually connected to the COM connection and is used as the ground for all instruments and circuits under test. Connect the Ground to your circuit Ground.
3. Connecting DC power supply and setting value:
    a) If the power supply is +6V or less, push the +6V button in the METER section of the panel and connect the circuit to the +6V output. Use the +6V knob in the VOLTAGE ADJUST section to set the power supply value, starting from 0V and adjusting upward.
    b) If the power supply is between +6V and +20V, push the +20V button in the METER section of the panel and connect the circuit to the +20V output. Use the ±20V knob in the VOLTAGE ADJUST section to set the power supply value, starting from 0V and adjusting upward.
    c) If the dual balanced power supplies (e.g. +15V and -15V) are needed, push the +20V button in the METER section of the panel and connect the circuit to the +20V and -20V outputs. Use the ±20V knob in the VOLTAGE ADJUST section to set the power supply value. To make sure that the positive and negative supplies are balanced, turn the Tracking ratio knob in the VOLTAGE ADJUST section to the Fixed setting.

If a DC input signal is needed and the DC power supply still has unused outputs, the simplest way is to use one output of the DC power supply to provide a DC signal to the circuit under test.

5. Using a Function Generator

The function generator on most lab benches is the Tectronix AFG 3021 Function generator. This instrument can provide one **signal output** to the circuit under test (bottom of the generator to the right of the display : 

The **Function panel** shows the different output signals that the function generator can provide:

The specific example below shows you how to set the function generator to output a sine wave with frequency 8.9 KHz, amplitude 1.5V (or peak-to-peak value of 3.0V), and offset +100 mV.

5.1 Turn on the instrument

Push the **POWER** button to ON (lower left corner at the bottom of the screen): 

At power-on, the instrument automatically sets the signal type to sine wave, frequency to 1MHz, amplitude to 1.000 Vpp (also called voltage peak-to-peak), and offset to 0 mV.

5.2 Setting signal type

To set the waveform type (sine, square, ramp, pulse, etc), push the appropriate button on the **Function panel**. For this specific exercise, push the sine wave button.

5.3 Setting signal frequency

1. Push the **Frequency/Period/Phase Menu button** shown on the screen. Or, push the **Frequency/Period button** next to the Function panel: 

2. Use the **numberpad** to enter the desired frequency and push the desired units located on the screen. Notice the small line underneath a digit on the frequency line. To correct a digit in the frequency setting, use the **arrows** underneath the **general knob** to move the line underneath the digit you want to change and then change it to the desired digit using the general knob.

5.4 Setting signal amplitude

The instrument has an internal 50 Ω output impedance. If the generator is connected to a circuit with a different input impedance, the amplitude value is different due to the input impedance of the circuit under test. The best way to find out the amplitude value is to use the oscilloscope to measure it.

Note: In this course, the circuits you built will have a high impedance. Therefore, you will have to do the following to get the desired amplitude when dealing with a high impedance load:

1. Push the **Output Menu** on the screen.
2. Push Load impedance on the screen.
3. Push **High Z** on the screen.

Now to set the amplitude:

1. Push the **Amplitude/Level Menu button** the screen. Or, push the **Amplitude/High button** next to the function generator: 
2. Enter the desired amplitude using the **numberpad** and push the desired units located on the screen. Hit enter. You can also use the **general knob** and the **arrows** underneath it to change individual digits as well.
    a. If the high level amplitude and the lower amplitude need to be different do the following: If the high level amplitude needs to be changed, push the **High Level button** on the screen, enter the desired value with the **numberpad** and push the desired units on the screen. If the low level needs to be changed, follow the same procedure, except push the **Low Level button**.

5.5 Setting a DC offset

Most AC signals are referred to ground (the mid-level value is 0 V). Sometimes an AC signal needs to be offset by a DC value, which can be positive or negative. To set the offset of +100 mV, follow this procedure:

1. Push the **Amplitude/Level Menu** or the **Amplitude/High button**.
2. Push the **Offset button** on the screen.
3. Push the **± button** on the **numberpad** to set the polarity.
4. Use the **numberpad** to enter the desired value and select the desired units

5.6 Setting a duty cycle FOR SQUARE WAVES ONLY

A square wave usually has 50% duty cycle: the time interval for HIGH value is the same as the time interval for LOW value. For this specific exercise, refer to 5.2 and set the waveform to **Pulse** first. To adjust the duty cycle of this square wave, use this procedure:

1. Push the **Duty/Width button** next to the **Pulse button**. 
2. Select **Duty** on the screen.
3. Enter the desired value using the **numberpad** or **general knob**. Push Enter.

5. Using a multimeter

The multimeter on most lab benches is the HP 34401A. This instrument is used to measure voltages, currents, and resistances.

6.1 Turn on the instrument

Push the **Power** button (left side of panel) to turn the instrument ON.

6.2 Measuring a DC Voltage

1. Push the **DC V** button. The ranges are 100 mV to 1000V, with maximum resolution of 100 nV in the 100 mV range. The instrument automatically selects the range.
2. Connect the two **Input V** (**HI** and **LO**) terminals on the upper right corner of the panel to the two points whose voltage difference is to be measured. A positive value means the node connected to the **HI** input is positive with respect to the other node.

6.3 Measuring an AC voltage (AC-coupled RMS value)

1. Push the **AC V** button.
2. Connect the two **Input V** (**HI** and **LO**) terminals on the upper right corner of the panel to the two points whose voltage difference is to be measured.

6.4 Measuring resistance

1. Push the Ω **2W** button (2-wired measurement). The ranges are 100 Ω to 100 MΩ. The instrument automatically selects the range.
2. Connect the two **Input V** (**HI** and **LO**) terminals on the upper right corner of the panel to the two points whose resistance is to be measured.

Note: 4-wired (Ω **4W** button) resistance measurement is used only in high-precision measurements and will not be covered in this introductory laboratory.

6.5 Measuring DC current

1. Push the **Shift** button then the **DC V** button for DC current measurement mode (blue **DC I** marking above the DC V button). The ranges are 10 mA to 3A.
2. Connect the **LO** and **I** input terminals (on the lower right corner of the panel) to the two points of a circuit branch whose current is to be measured. Note that the instrument must be

connected **in series** with the branch. A positive value means the branch current flows from the I input to the LO input through the branch.

6.6 Measuring AC current (rms value)

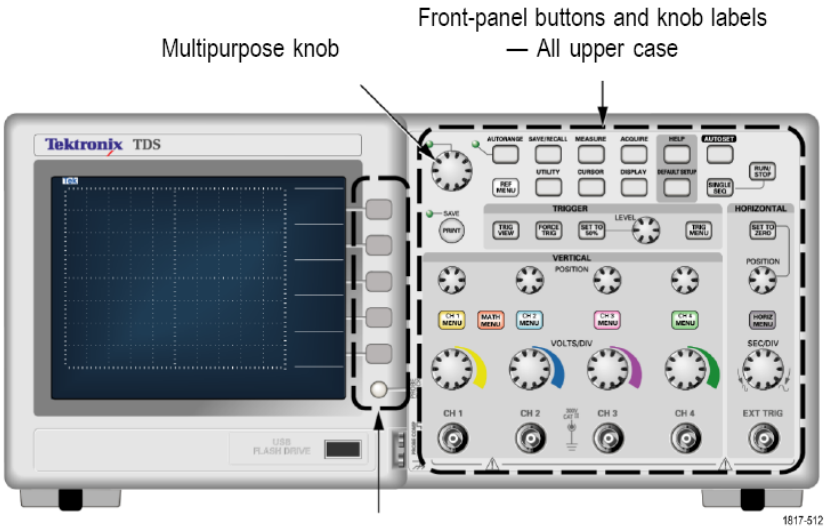
1. Push the **Shift** button then the **AC V** button for DC current measurement mode (blue **AC I** marking above the AC V button). The ranges are 1 A to 3A
2. Connect the **LO** and **I** input terminals (on the lower right corner of the panel) to the two points of a circuit branch whose current is to be measured. Note that the measurement must be connected **in series** with the branch.

7. Using an oscilloscope

The oscilloscope available for EE 233 are the Tektronix TDS 2004B. The scope can display four signals simultaneously on Channel 1 (CH1), Channel 2 (CH2), Channel 3 (CH3), and Channel 4 (CH4).

7.1 Turn on the instrument

Push the POWER button (top left corner of the oscilloscope, white button). It takes a short time for the display to come on.



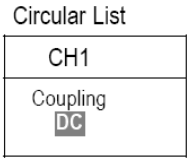
Option buttons — First letter of each word on screen is upper case

7.2 Displaying a waveform on CH1

1. Connect the Channel 1 scope probe to the signal to be displayed from the circuit and the ground of the probe (attached to the side of the probe) to the ground of the circuit.

2. Push the **Autoset** button (top right corner of function generator). This produces a stable signal for the display:

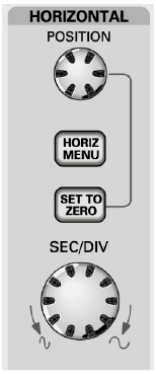
3. Use the Options buttons to select **DC coupling** (direct connection of the signal to the scope) or **AC coupling** (connection of the signal to the scope, ignoring any DC offset in the signal). To know more about what all the stuff on the screen means, look at the end of this lab.



4. Use the **Position knob** (located above the **Ch1 Menu** button) to place the signal trace at the vertical position you want on the display. The marker on the left side of the screen (1→) shows the ground level of the signal.

5. To change the vertical scale of the signal, use the **VOLTS/DIV** knob:

6. To move the waveforms horizontally, use the HORIZONTAL POSITION knob:



7. To zoom in on the signals, use the SEC/DIV knob below the HORIZONTAL POSITION knob.

The same procedure is used to display a waveform on Channel 2, 3, or 4.

7.4 Setting in the TRIGGER MENU

Triggering is a difficult concept to explain. See the document in the section on Further Research below. This concept will be re-visited in later laboratories.

7.5 Measuring signal parameters using the scope

7.5.1 Measuring time interval and voltage difference between two points

1. Push the **CURSOR** button.

2. Select the **Source** to pick the desired channel to be measured and turn **Type** (located on the screen) to ON.

3. Keep pushing the **Type** button until you come to **Time**.

4. Use the **multipurpose knob** (Knob at the top) to position Cursor 1.

5. Now select Cursor 2 on the screen and use the multipurpose knob **multipurpose knob** to position Cursor 2.

6. The time interval can be found on the right side of the screen. The time interval between these 2 points is the Δt value. The voltage difference is the ΔV value.

Note: If you notice that your voltage difference is wrong (ie. You're ΔV value is much greater or smaller than what the function generator is inputting,), try switching the attenuation on your oscilloscope probe.

7.5.2 Automatic measurements

1. Push the **CH1 Menu button** to perform measurements connected to Ch1.
2. Push the **MEASURE** button.
3. Use the buttons next to the screen and select CH1.
4. Push the **Type** button the screen to find the following:
    a. Frequency
    b. Period
    c. Mean voltage value
    d. Voltage from peak-to-peak
    e. Cyc RMS
    f. Minimum Voltage value
    g. Maximum voltage value
    h. Rise time (10% to 90% points of the signal waveform)
    i. Fall time (90% to 10% points of the signal waveform)
    j. Pos Width
    k. Neg Width

7.5.3 Printing the hardcopy of scope display

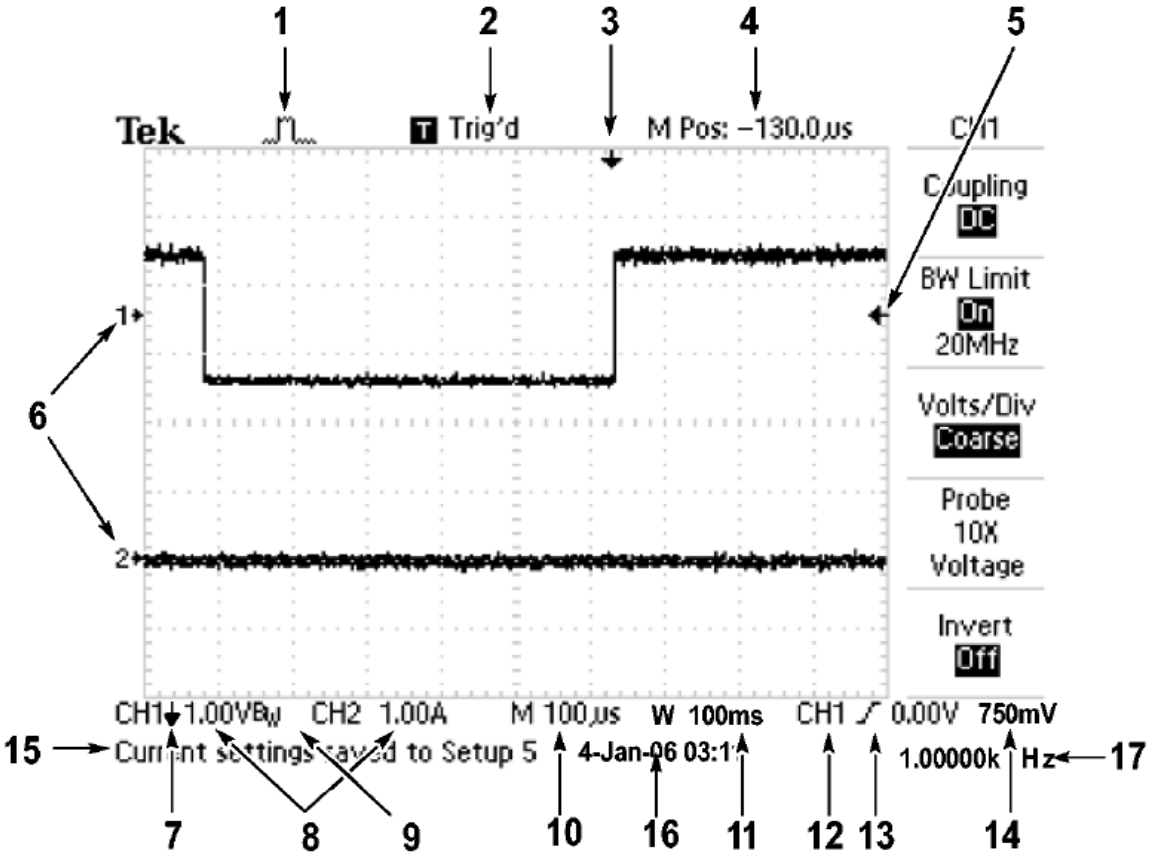
1. Insert a USB flash drive into the function generator (bottom of the screen). It will take some time to load.
2. Once the clock on the right hand side disappears, push the **SAVE/RECALL** button.
3. It is a good idea to save everything about your waveform. Saving everything will save the waveform image and produces Excel sheets containing data points of your waveform. Under **Action** on the screen, push the button until it goes to "Save all".
4. Under **PRINT Button**, select "Save all to Files". There should be a green light shining above the PRINT button.

5. Select the folder you want to save to. If you have no preference, the oscilloscope will create a new folder in your flash drive and store all the data there. The oscilloscope will name the folder to something like "ALL0000".
6. After selecting the folder, display the image you would like to save onto the screen.

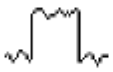
7. Now push the **PRINT button**. It will take some time before a clock in the bottom right corner to appear. Once the clock disappears, your files have been safely stored in your flash drive. Be sure to use the computer to check that you have the correct images and data before taking your circuit apart.

8. Further Research

1. There is an excellent guide to using analog and digital oscilloscopes on the web at URL: http://www.tek.com/Measurement/App_Notes/XYZs/. The guide covers much more than the specific scope we have in the laboratory. If you want to understand more about scopes, spend some time studying this guide.
2. Play around with the capabilities of the instruments, especially the scope. Try as many options as possible and learn more about using these instruments.
3. Equipment manufacturers such as Hewlett-Packard, Tektronix, Fluke maintain very good websites for User's Guide of their instruments. Check out their sites especially if you use instruments different than those available in the laboratory.



1. Icon display shows acquisition mode.



Sample mode

Peak detect mode

Average mode

2. Trigger status indicates the following:

☐ Armed.	The oscilloscope is acquiring pretrigger data. All triggers are ignored in this state.
R Ready.	All pretrigger data has been acquired and the oscilloscope is ready to accept a trigger.
T Trig'd.	The oscilloscope has seen a trigger and is acquiring the posttrigger data.
● Stop.	The oscilloscope has stopped acquiring waveform data.
● Acq. Complete	The oscilloscope has completed a Single Sequence acquisition.
R Auto.	The oscilloscope is in auto mode and is acquiring waveforms in the absence of triggers.
☐ Scan.	The oscilloscope is acquiring and displaying waveform data continuously in scan mode.

3. Marker shows horizontal trigger position. Turn the HORIZONTAL POSITION knob to adjust the position of the marker.

4. Readout shows the time at the center graticule. The trigger time is zero.

5. Marker shows Edge or Pulse Width trigger level.

6. On-screen markers show the ground reference points of the displayed waveforms. If there is no marker, the channel is not displayed.

7. An arrow icon indicates that the waveform is inverted.

8. Readouts show the vertical scale factors of the channels.

9. A B_W icon indicates that the channel is bandwidth limited.

10. Readout shows main time base setting.

11. Readout shows window time base setting if it is in use.

12. Readout shows trigger source used for triggering.

13. Icon shows selected trigger type as follows:

Edge trigger for the rising edge.

Edge trigger for the falling edge.

Video trigger for line sync.

Video trigger for field sync.

Pulse Width trigger, positive polarity.

Pulse Width trigger, negative polarity.

14. Readout shows Edge or Pulse Width trigger level.

15. Display area shows helpful messages; some messages display for only three seconds.

If you recall a saved waveform, readout shows information about the reference waveform, such as RefA 1.00V 500µs.

16. Readout shows date and time.

17. Readout shows trigger frequency.