Introduction to basic laboratory instruments

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.

Whenever you are not sure about using equipment (electrical or mechanical), ask the TA or the technician in the lab.

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 reference in future laboratory experiments. 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: HP 33120A 15 MHz Function / Arbitrary Waveform Generator.

c. multimeter: HP 34401A.

d. oscilloscope: Tektronix TDS 340 or TDS 360.

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 the instruments and circuits under test. Connect this 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 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 HP 33120A 15 MHz Function / Arbitrary Waveform Generator. This instrument can provide one signal output to the circuit under test (OUTPUT connector at the lower right corner of the front panel) and a synchronizing output to the oscilloscope (SYNC output immediately above the OUTPUT connector). On most lab benches, the SYNC output is already connected to the oscilloscope EXT TRIG (EXTernal TRIGger input).

The basic signal output may be a sine wave, a square wave, and a ramp signal. The generator is also capable of providing various modulated signals but we will not use them in the EE 233 experiments.

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

5.1 Turn on the instrument

Push **POWER** button (lower left of panel) to ON. At power-on, the instrument automatically sets the signal type to sine wave, frequency to 1 KHz, amplitude to 100 mV peak-to-peak (usually abbreviated as pp), and offset to 0 V.

5.2 Setting signal type

To set the waveform type (sine, square, symmetric ramp, sawtooth), push the appropriate button on the front panel (FUNCTION/MODULATION sub-panel). For this specific exercise, push the **sine wave** button.

5.3 Setting signal frequency

1. Push the **Freq** button in the FUNCTION/MODULATION sub-panel.

2. Push **Enter Number** button (green-lettered button). The display flashes with ENTER NUM message.

3. Use the FUNCTION/MODULATION buttons as numeric entry (green numbers to the left of each button). Note that the **decimal** button is the same as the Enter Number button in this mode. Enter 8.9 for this specific exercise. To cancel any entry in the number mode, push the buttons **Shift Cancel**.

4. Push the **MHz/m Vpp** button (right side of panel): the unit is displayed as MHz. Use the > button to move the flashing digit to MHz segment. Use the button to decrease frequency (by factor of 10 each time) or the button to increase frequency (by factor of 10 each time). Or use the **knob** to change the frequency unit. Set the frequency to KHz unit.

5. To correct an existing digit in the frequency setting, push the > button until the desired digit flashes. Use the or button, or the **knob** to set the digit value.

5.4 Setting signal amplitude

The instrument has an internal 50 Ω output impedance. The power-on value is 100 m Vpp (into 50 Ω termination or load). 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.

1. Push the **Ampl** button.

2. Push the **Enter Number** button. The display flashes with ENTER NUM message.

3. Use the green-lettered numeric buttons to enter 3.0 (see more details above in section 5.3.3 on how to perform numeric entry).

4. Push the **MHz/m Vpp** button: the unit is displayed as Vpp. Use the > to move the flashing digit to **Vpp** segment on the display. Use the button to decrease unit (by factor of 10 each time) or the button to increase unit (by factor of 10 each time). Or use the **knob** to change the value. Set the unit of amplitude to Vpp.

5. Note that the instrument is limited to 100 m Vpp minimum and 20 Vpp maximum. For 50-ohm load, the limits are exactly half.

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 **Offset** button.

2. Push the **Enter Number** button.

3. Push the ± button (above the Enter Number button) to set the polarity.

4. Use the green-lettered numeric buttons to enter 100 (see more details above in section 5.3.3 on how to perform numeric entry).

5. Push the **Shift** blue button.

6. Push button to set mV DC unit. Press > until the unit mV DC flashes on the display.

7. Push or button to change by a factor of 10 at each push. For this exercise, set the unit as mV DC.

8. Note that the display panel shows Offset in the lower right corner. This display is ON whenever the output waveform has a non-zero offset.

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 section 5.2 and set the waveform to **square wave** first. To adjust the duty cycle of this square wave, use this procedure:

1. Push the **Shift** button then the **% Duty** button (marked above the Offset button).

2. Use the **Enter Number** or **knob** to adjust duty cycle immediately. Otherwise, after 10 seconds of the previous step, the instrument returns to normal mode.

3. Push the **Enter** button (above the Shift button) to terminate this mode.

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

6.2 Measuring a DC voltage

1. Push the **DC V** button. The ranges are 100 mV to 1000 V, 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 3 A.

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 3 A.

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.

7. Using an oscilloscope

The two oscilloscopes (or scopes) available for EE 233 are the Tektronix TDS 340 and TDS 360. Their usage is identical, except that the TDS 360 has a floppy drive (the upper right corner of the front panel) for saving files on diskette. The scope is the most versatile measuring instrument in the laboratory.

Each scope can display two signals simultaneously on Channel 1 (CH 1) and Channel 2 (CH 2). In the description below, we will use this terminology:

1. SIDE MENU buttons refer to the column of buttons on the right-hand side of the display.

2. MAIN MENU buttons refer to the row of buttons below the display.

3. The knob without any marking at the highest vertical position on the front panel is the **General Purpose knob**.

7.1 Turn on the instrument

Push **ON/STBY** button (at the lower left corner of the front panel) to turn on the scope. It takes a short time for the display to come on. Push the **CLEAR MENU** button (at the lower right corner of the front panel) to clear the display message.

7.2 Displaying a waveform on CH 1

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

2. Push the button **CH 1** on the left side of the VERTICAL sub-panel.

3. Push the **VERTICAL MENU** button. Use the SIDE MENU 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).

4. Use the **POSITION** knob (above the VERTICAL 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. Use the **SCALE** knob (below the VERTICAL menu button) to set the scale (volt per division) for channel 1. The value set is shown on the display (last line, **Ch1 1V** indicating 1V per vertical division for channel 1).

6. Push the **CLEAR MENU** button to remove the menu from the display if necessary.

The same procedure is be used to display a waveform on Channel 2 (connect the signal to Channel 2 probe in step 1 and push the **CH 2** button in step 2).

7.3 Setting the horizontal time division for both channels

1. Use the **SCALE** knob in the HORIZONTAL sub-panel. The value set is shown on the display (last line, **M 1ms** indicating 1ms per horizontal division). Note that the time axis is common to both channels.

2. To move a signal along a horizontal direction:

   a) Push CH 1 button (or CH2 button as appropriate) in the VERTICAL sub-panel.

   b) Use the **POSITION** knob in the HORIZONTAL sub-panel to move this signal. This move affects only one channel, not both.

7.4 Setting in the TRIGGER MENU

The scope is pre-set to trigger from the **EXT TRIG** signal provided by the Function Generator. If the Function Generator is not used, push the **TRIGGER MENU** button and use the SIDE MENU buttons to set triggering on Ch1 or Ch2 to get a stable display of the waveforms. The key is to get a stable display of the signals. The SIDE MENU button **Ext** corresponds to using external trigger: in this case, an external signal must be connected to the **EXT TRIG** input (the lower right corner of the front panel) of the scope.

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

Most of the buttons and knob mentioned below are near the upper right corner of the front panel of the scope (except of course the SIDE MENU and MAIN MENU buttons, which are along the right side and below the scope display itself).

7.5.1 Measuring time interval between two points

1. Push the **MEASURE** button.

2. Push the **CURSOR** button.

3. Push **V bars** on the SIDE MENU button.

4. Use the **General Purpose knob** to position the solid vertical marker at point 1.

5. Press **SELECT** (on TDS 360) or **TOGGLE** (on TDS 340) to set that marker (it will turn into a dashed marker).

6. Use the **General Purpose knob** to position the second vertical marker (solid line) at point 2.

The time interval between these 2 points is the Δ value appearing on the top right corner of the scope trace display. The **@** value is the current position of the solid line (point 2).

7.5.2 Measuring voltage difference between two points

1. Push the **MEASURE** button.
2. Push the **CURSOR** button.
3. Push **H bars** on the SIDE MENU button.
4. Use the **General Purpose knob** to position the solid horizontal marker at point 1.
5. Press **SELECT** (on TDS 360) or **TOGGLE** (on TDS 340) to set that marker (it will turn into a dashed marker).
6. Use the **General Purpose knob** to position the second horizontal marker (solid line) at point 2.

The voltage difference between these 2 points is the Δ value appearing on the top right corner of the scope trace display. The **@** value is the current position of the solid line (point 2).

7.5.3 Measuring time interval and voltage difference between two points simultaneously

1. Push the **MEASURE** button.
2. Push the **CURSOR** button.
3. Push **Paired** on the SIDE MENU button.
4. Use the **General Purpose knob** to position the solid marker at point 1.
5. Press **SELECT** (on TDS 360) or **TOGGLE** (on TDS 340) to set that marker (it will turn into a dashed marker).
6. Use the **General Purpose knob** to position the second marker (solid line) at point 2.

The two Δ values appearing on the top right corner of the scope trace display show the voltage difference and time interval between these two points. The **@** values are the current position of the solid line (point 2).

7.5.4 Clearing previous measurements

The scope can perform only 4 measurements at one time. If there are too many measurements (the scope will display this warning message), clear them by:

1. Push the **MEASURE** button.
2. Push the **Remove Measrmnt** button on the MAIN MENU buttons at the bottom row of the scope display.
3. Push an appropriate button using the SIDE MENU button to remove a specific measurement or all measurements at once.
4. Push the **CLEAR MENU** button to get rid of the menu on the display.

To perform measurements again after clearing previous measurements,

1. Push the **MEASURE** button.
2. Use the MAIN MENU button at the bottom row of the scope display to **Select Measrmnt** for Ch1.
3. To perform measurements for Channel 2, push the **CH2** button in the VERTICAL sub-panel.

7.5.5 Automatic measurements

1. Push the **CH 1** or **CH 2** button in the VERTICAL sub-panel to perform measurements on a specific signal.
2. Push the **MEASURE** button.
3. Use the SIDE MENU buttons as follows:
   a) Push **Period** to measure period. The display shows the period immediately to the left of the SIDE MENU.
   b) Push **Frequency** to measure frequency.
   c) Push **more 1 of 6** to get to the next side menu.
   d) Push **Rise Time** to measure rise time (10% to 90% points of the signal waveform).
   e) Push **Fall Time** to measure fall time (90% to 10% points of the signal waveform).
   f) For square waves, push **Positive Duty Cycle** to measure duty cycle in %.
   g) Push **more 2 to 6** to get to the next several side menus that provide measurements of peak-to-peak value (Pk-Pk), amplitude (Amplitude), Max, Min, Mean, RMS.

7.5.6 Printing hardcopy of scope display

1. Push the **CLEAR MENU** button if necessary to remove any menu from the scope display.
2. Turn on the DPU-411 thermal printer. Make sure that there is paper in the printer, and that the network cable is connected. Push the **ON LINE** button on the printer unless the printer is already on-line.
3. Push the scope **HARDCOPY** button near the upper right corner of the scope front panel. The printer starts printing. The job takes several minutes to complete.
4. Push the **ON LINE** button on the printer to get the printer off line. Press the **FEED** button to feed paper, then tear it off. Remember to push the **ON LINE** button again to return printer on line.

7.5.7 Saving waveforms as a PC disk file

The procedure to save waveforms as a PC disk file for further data analysis is posted at each lab bench. Bring a pre-formatted PC floppy disk and follow the instructions. Note that only the TDS 360 scope has a floppy drive.

8. Further research

1. There is an excellent guide to using analog and digital oscilloscopes on the web at URL: htttp://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 Hewlett-Packard, Tektronix, Fluke maintain very good web sites for User's Guide of their instruments. Check out their sites especially if you use instruments different than those available in the laboratory.