Introduction to Basic Laboratory Instruments

Contents:

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: Tektronix AFG 3021 25MHz/ 250Ms/s Function / Arbitrary Waveform Generator.

c. Multimeter: HP 34401A.

d. Oscilloscope: Tektronix TDS 2004B.

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 Tektronix AFG 3021 25MHz/ 250Ms/s 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 **Frequency/Period** button in the FUNCTION/RUNMODE sub-panel.

2. There are two ways to set the signal frequency, which is as follows:

(a) There is a **general knob** on the right side of the panel. Use the knob to change the frequency.

(b) To set the frequency to the specified one, use the decimal knob on the right corner of the panel.

3. When setting the frequency, select the unit you want to use in the screen by entering the appropriate knob.

4. To correct an existing digit in the frequency setting, push the BKSP button until the desired digit flashes.

5.4 Setting Signal Amplitude

The instrument has internal 50 Ω output impedance. The power-on value is 100 m Vpp (into 50 W termination or load). If the generator is connected to a circuit with 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 **Amplitude** button.

2. There are also two ways to set the amplitude, see more details in the step 2 of 5.3

3. When setting the amplitude, select the unit you want to use in the screen by entering the appropriate knob.

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 +100mV, follow this procedure:

1. Push the **Offset** button.

2. Push the **± button** to set the polarity.

3. Use the method above (see details in the step 2 of 5.3) to set the appropriate value of DC offset.

4. 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

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 **pulse wave** first. To adjust the duty cycle of this square wave, use this procedure:

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

2. Use the **Decimal Number knob** or **General knob** to adjust duty cycle immediately. Otherwise, after 10 seconds of the previous step, the instrument returns to normal 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 W to 100 MW. 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 oscilloscope (or scope) available for EE 233 is the Tektronix TDS 2004B. The scope is the most versatile measuring instrument in the laboratory.

Each scope can display four signals simultaneously on Channel 1 (CH 1), Channel 2 (CH 2), Channel 3 (CH3) and Channel 4 (CH4). 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.

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 **CH1** on the left side of the sub-panel.

3. Push the **CH1 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.

5. Use the VOLT/DIV knob to set the scale (volt per division) for channel 1. The value set is shown on the display.

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 **SEC/DIV** 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. Use the **General Purpose knob** to position the solid vertical marker at point 1.

4. 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.

7.5.2 Measuring voltage difference between two points

1. Push the **MEASURE** button.

2. Push the **CURSOR** button.

3. Use the **General Purpose knob** to position the solid horizontal marker at point 1.

4. 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.

7.5.3 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 Rise Time to measure rise time (10% to 90% points of the signal waveform).

   d) Push Fall Time to measure fall time (90% to 10% points of the signal waveform).

e) Push Mean for the mean value of the signal waveform

There are some other buttons called pk-pk, cyc RMS, Min, Max, which is similar to the button above and will not be talked about any more.

7.5.4 Saving waveforms

The procedure to save waveforms via USB for further data analysis is posted at each lab bench.

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.