Introduction to basic laboratory instruments

1. Objectives

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

2. Laboratory safety

The lab instructor 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 this 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 BEE 233 are: DC power supply, function generator, multimeter, and oscilloscope. This document describes the procedures to use these instruments available in the UWB 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 UWB are:

- DC power supply Tektronix PWS 4205 single output DC power supply
- Function generator: Tectronix AFG 3022 dual channel, arbitrary/function generator
- Multimeter: Tektronix DMM 4020 multimeter
- Oscilloscope: Tektronix MSO 3012 dual-channel, mixed signal oscilloscope

4. Using a DC power supply

The DC power supply on your bench is the Tektronix PWS 4205 DC power supply. This instrument can provide a single DC power supply voltage from +20V to -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) Enter in your desired DC input voltage to the power supply by using the number pad and pressing **enter** to set the selected value.

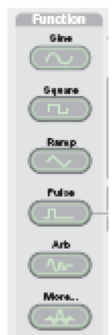
b) Connect the power supply leads as directed in your circuit schematic.

c) To supply voltage to your circuit, press the **output on** button noticing that it is now lit, indicating power is being delivered to the circuit.

5. Using a Function Generator

The function generator on all lab benches is the Tectronix AFG 3022 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):

By default, the instrument automatically sets the signal type to sine wave, frequency to 1MHz, amplitude to 1.000 Vpp (also called voltage peak-to-peak), offset to 0 mV, and output resistance to 50Ω.

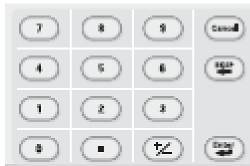
5.2 Setting signal type

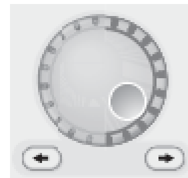
To set the waveform type (sine, square, ramp, pulse, etc), push the appropriate button on the **Function panel**. For this specific exercise, push the sine wave button.

5.3 Setting signal frequency

1. Push the **Frequency/Period button** next to the Function panel: 

2. Use the **number pad** 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 defaults to a 50Ω output impedance. If the generator is connected to a circuit with different impedances, 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 high impedances. Therefore, you will have to do the following to get the desired amplitude when dealing with a high impedance load:

1. Push **Top Menu** located by the top right corner of the screen.
2. Push **Output Menu** on the screen.
3. Push Load impedance on the screen.
4. Push **High Z** on the screen.
5. To exit this menu, push **Top Menu** once more.

Now to set the amplitude:

1. Push the **Amplitude/High button** next to the function generator: 

2. Enter the desired amplitude using the **number pad** 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 **Amplitude/High** button on the screen, enter the desired value with the **number pad** and push the desired units on the screen. If the low level needs to be changed, follow the same procedure, except push the **Offset/Low** 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 **Offset button** on the screen.
2. Push the **± button** on the **number pad** to set the polarity.
3. Use the **number pad** to enter the desired value and select the desired units

5.6 Saving a Screenshot:

Here you will show that you can successfully set the bench function generator to produce a desired output. After setting the FG output, you will learn how to take a screenshot.

To save the display:

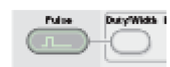
1. Insert USB flash memory into the FG.
2. Simultaneously press the left and right arrow buttons located under the general knob on the right side of the FG.
3. The file will be saved under a new folder named TEK as a .BMP file, ex. TEK00001.BMP.

Turn in:
Produce a sinusoidal wave with voltage of 5.00Vpp at 20kHz and a 1.00V offset.

5.7 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.

In order to change the duty cycle of the square wave, 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 **Pulse button** located in the function section of the FG. 

2. Select **continuous** as the run mode (located at the top-middle of the FG) if not already selected.
3. Press **Duty/Width** (located next to **Pulse**) to adjust the duty cycle.
4. Press **Amplitude/High** twice so that the FG now displays high/low options for the amplitude input.
5. To adjust the amplitude, use the number pad or general knob then select the units on the FG display.
6. To adjust low amplitude, press **Offset/low** once to select low then repeat procedure 5.

Turn in:
Produce a square wave with voltage of 2.00Vpp at 100kHz and 80% duty cycle.

6. Using a multimeter

The multimeter on all lab benches are the Tektronix 4020. This instrument is used to measure voltages, currents, and resistances.

6.1 Turn on the instrument

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

6.2 Measuring a DC Voltage

1. Push the **DC V** button. The ranges are 200 mV to 1000V, with maximum resolution of 1 µV in the 100 mV range. The instrument automatically selects the range.
2. Connect the two **Input V** (**HI** and **LO**) terminals on the lower 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 **button** (2-wired measurement). The ranges are 200 Ω to 100 MΩ. The instrument automatically selects the range.
2. Connect the two **Input V** (**HI** and **LO**) terminals on the lower 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 **DCI** button. The ranges are 200μA to 10A.
2. Connect the **LO** and **mA/10A** 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 input to the LO input through the branch.

6.6 Measuring AC current (rms value)

1. Push the **ACI**. The ranges are 20mA to 10A .
2. Connect the **LO** and **mA/10A** 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 oscilloscopes available for BEE 233 are the Tektronix MSO 3012. This scope can display two signals simultaneously on Channel 1 (CH1) and Channel 2 (CH2). **Only use oscilloscope probes when connecting to these channels, ask the lab instructor if you are unsure about which cables these are.**

7.1 Turn on the instrument

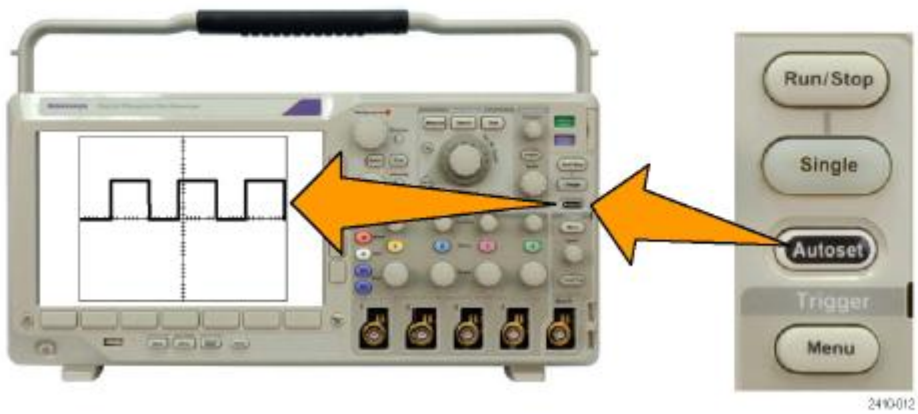
Push the POWER button (bottom left corner of the oscilloscope, white button). It takes a short time for the display to come on.

7.2 Displaying a waveform on CH1: Calibrate Probe

In this section you will be using the square wave that is generated by the oscilloscope to calibrate probes as a test waveform for the following procedures. **Note:** It should not be necessary to calibrate your probes before every use; we use this signal simply to familiarize yourself with the functions of the scope.

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. The screen should now display a square wave, approximately 2.5V at 1kHz:



3. Check to be sure that your probes are properly compensated. If they are not then you may ask for your TA to show you how to go about adjusting your probe to produce the proper waveform, using the calibration tool.

4. Push **Channel 1**, 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.

Coupling	Impedance	Invert	Bandwidth	(1) Label		▲
DC AC	1MΩ 75Ω 50Ω	On Off	Full			More

5. 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.
6. To change the vertical scale of the signal, use the **VOLTS/DIV** knob located below the channel buttons.
7. To move the waveforms horizontally, use the HORIZONTAL POSITION knob located in the upper right corner, or use the pan knob just to the left.
8. To zoom in on the signals, use the SEC/DIV knob below the HORIZONTAL POSITION knob.

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 next to **multipurpose knob a**.

2. Two vertical lines will appear on the screen with a data table appearing on the right. This data table should display both Δt and ΔV. If ΔV is not appearing you may press **Search** located above the pan/zoom knob.

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 **Add Measurement** button then **Measurement Type** menu to find a variety of different measurement options.

7.5.3 Printing the hardcopy of scope display

1. Insert a USB flash drive into the function generator (bottom of the screen).
2. Push the **Menu** button located under the display.
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. Select to save image or waveform.
4. Under **file utilities** you may select the directory of where you will save your files. You may also edit the file name in this menu.
5. Be sure that you save your waveform as a .csv file if you plan on plotting the data on excel. Check to be sure you are saving as .csv by going to the **waveform** menu, then selecting your drive in the **destination** menu, then by selecting **file details**. In this menu you may also rename your file.
6. Now push the **OK SAVE** button, 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.
7. Save a screenshot of the oscilloscope displaying your cursors at the high and low points of a square wave and the table showing both Δt and ΔV. Turn this into by either printing or emailing as required by the lab instructor.

8. Circuits

Figure 1 shows a simple circuit of an arbitrary waveform generator driving a resistive load. This circuit is used to illustrate and measure the internal resistance of an arbitrary waveform generator.

Arbitrary waveform

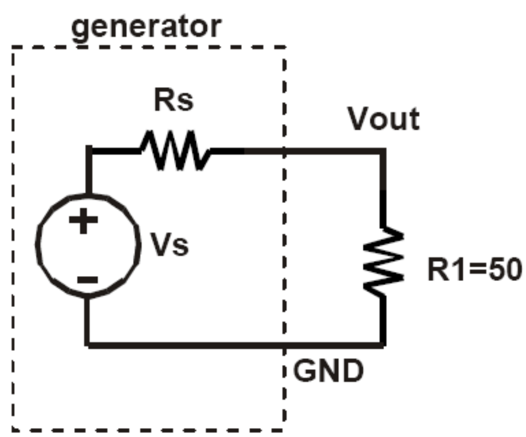


Figure 1. Internal resistance of an arbitrary waveform generator.

9. Components and specifications

Quantity	*Description*	*Comments*
1	50 Ω resistor	
1	27.0 KΩ resistor	

10. Experimental procedures

10.1 Equation for extracting source resistance

1. Derive an equation for V_{out} in Figure 1 in terms of V_s, R_s, and R_1.
2. For the circuit in Figure 1, given that $V_s = 1$ V, compute V_{out} for these two cases: (a) $R_1 = R_s$, and (b) $R_1 \gg R_s$.

10.2 Instruments needed for this experiment

The instruments needed for this experiment are: an arbitrary waveform generator, a multimeter, and an oscilloscope.

10.3 Effect of internal resistance of an arbitrary waveform generator

1. Build the circuit in Figure 1 using a 50 Ω resistor as load. Set the function generator to provide a square wave with amplitude 400 mV, DC offset 0V, frequency 100 Hz and 50 Ω output resistance.
2. Use the scope to display the signal V_{out} on channel 1, using DC coupling and probe gain X1. Do not select “on trigger” under trigger manual. Set the horizontal timebase to display 3 or 4

complete cycles of the signal.

3. Use the cursor to measure the amplitude of V_{out}. Record this value in your report. Is it the same as the amplitude displayed by the arbitrary waveform generator? Explain any difference.
4. Vary the square wave amplitudes from 400 mV to 1 V, using 100 mV step size (e.g. the amplitudes are 400 mV, 500 mV,… up to 1 V). Repeat step 3 to measure the amplitude of V_{out} on the scope for each setting. **Save a screenshot** for the case of 500 mV amplitude only.
5. Remove the 50 Ω resistor and replace it with a 27 KΩ resistor. Repeat the steps 1 through 4 above. Observe and explain any difference in signal amplitudes when the loading on the function generator is changed from 50 Ω to 27 KΩ.
6. Now change the output resistance of FG to high impedance and repeat steps 2 through 5.

Turn in: the measurement results of 50 Ω and 27 KΩ and screenshots.

11. Data analysis

11.1 Extracting internal resistance of an arbitrary waveform generator

1. From the equation for V_{out} and using the amplitude of V_s as 500 mV, compute the amplitude of V_{out} for both cases R_1 = 50.0 Ω and R_1 = 27.0 KΩ. Do these values agree with the recorded data in the lab? Include the screenshot from the display to justify your answers.
2. From the data recorded in section 10.3, explain the effects of different out impedances of functional generator.