

# EECS 100/43

## Lab 2 – Function Generator and Oscilloscope

### 1. Objective

In this lab you learn how to use the oscilloscope and function generator

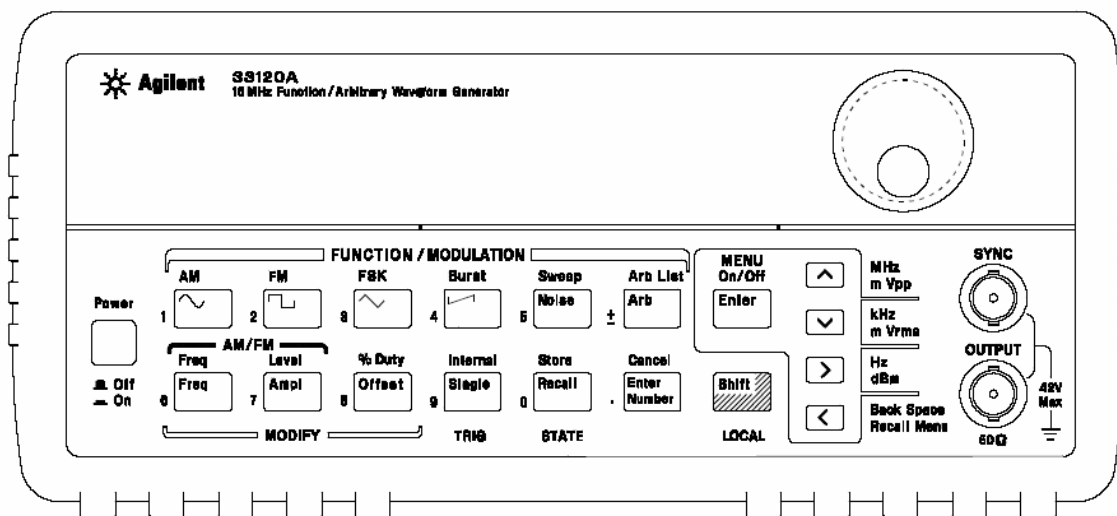
### 2. Equipment

- Breadboard
- Wire cutters
- Wires
- Oscilloscope
- Function Generator
- 1k resistor x 2
- Various connectors (banana plugs-to-alligator clips) for connecting breadboard to power supply and for multimeter connections.

### 3. Theory

#### a. The HP33120A Function Generator

The front panel of your function generator is shown in Figure 1. This instrument outputs a time-varying periodic voltage signal (the **OUTPUT** connector, do not use the sync connector, refer to figure 2). By pushing the appropriate buttons on the front panel, the user can specify various characteristics of the signal.



**Figure 1.** Front panel of your function generator  
(Ref: Agilent Function Generator User's Guide #33120-90006)

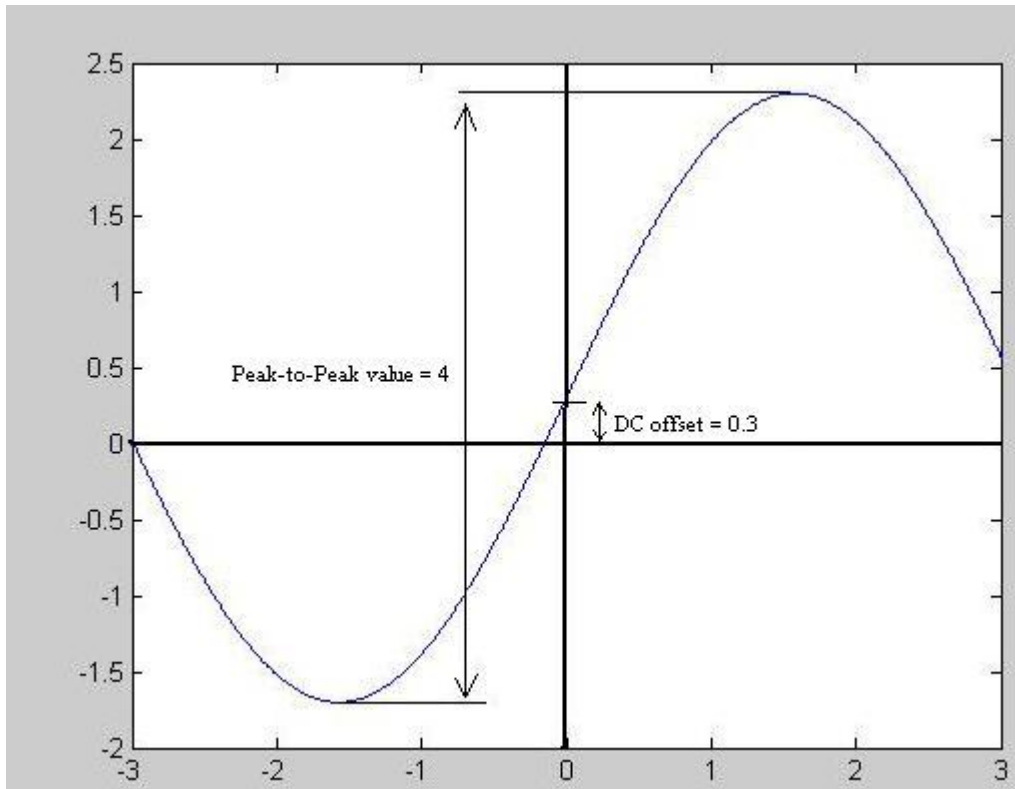


**Figure 2.** Make sure you use **BLACK** BNC input cables. Connect them to the OUTPUT terminal as shown above. Do not use the SYNC connector

The main characteristics that you will be concerned with in this class are:

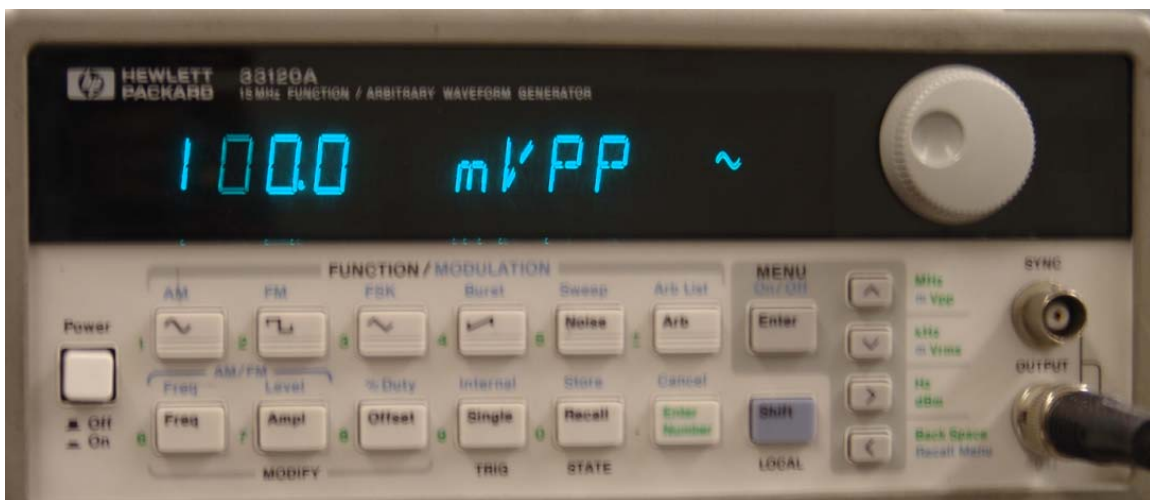
- **Shape:** sine, square, or triangle waves.
- **Frequency:** inverse of the period of the signal; units are cycles per second (Hz)
- **V<sub>pp</sub>:** peak to peak Voltage value of the signal
- **DC Offset:** constant voltage added to the signal to increase or decrease its mean or average level. In a schematic, this would be a DC voltage source in series with the oscillating voltage source.

Figure 3 below illustrates a couple of the parameters above.



**Figure 3.** Sine wave  $V_{pp}$  and DC offset

When the function generator is turned on, it outputs a sine wave at 1 kHz with amplitude of  $100\text{ mV}_{pp}$  (figure 4).



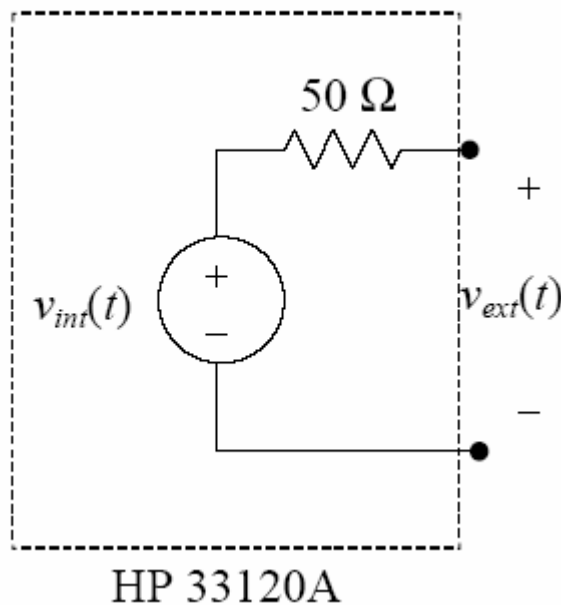
**Figure 4.** Function generator has been turned on

You must specify the characteristics of the signal you need. For example, to set the frequency of the signal:

1. Enable the *frequency modify* mode by pressing the **Freq** button.

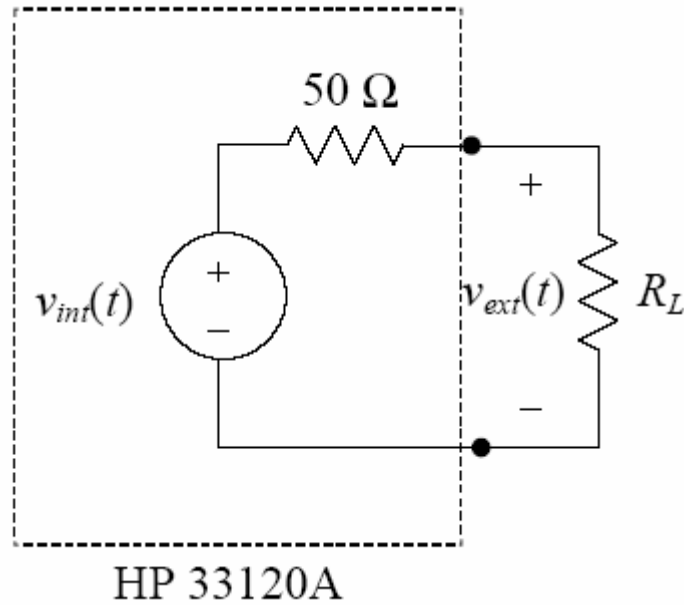
2. Enter the value of the desired frequency by pressing the **Enter Number** button and entering the appropriate numbers on pads labeled with green numbers, or by using the wheel and the left and right arrows to move the tens place.  
(To cancel the number mode, press **Shift** and **Cancel**.)
3. Set the units to the desired value by using the arrow keys (up or down) on the right side of the front panel.

**IMPORTANT NOTE:** There is an internal resistor 50 ohms in series with the oscillating voltage source inside the function generator, refer to figure 5.



**Figure 5.** The internal load resistor in your function generator

Thus, if you connect the function generator to an external resistor  $R_L$ , it will form a voltage divider with the 50 ohms resistor, refer to figure 6.



**Figure 6.** External resistor forming a voltage divider

Hence the voltage seen at the output of the instrument is:

$$v_{ext}(t) = \frac{R_L}{R_L + 50\Omega} \cdot v_{int}(t).$$

The purpose of the internal resistance is to have impedance matching (especially important for high frequency circuits). In RF electronics, resistances of 50 ohms are very common. Therefore if  $R_L = 50\ \text{ohm}$ , we have:

$$v_{ext}(t) = \frac{1}{2} v_{int}(t).$$

**The front panel meter assumes  $R_L = 50\ \text{ohms}$ .** As we saw above, a 50 ohm load leads to a voltage divider with a gain of  $\frac{1}{2}$ , so the instrument compensates for this by raising  $v_{int}$  to twice what the display shows. In other words, if you set the instrument to produce a 5 V sine wave, it actually produces a 10 V sine wave on  $v_{int}$  and relies on the external voltage divider to reduce the signal by a factor of two. We are not going to change the default setting of this instrument, so **just remember that you are getting twice the voltage displayed on the function generator at the output terminal.**

That's all for the function generator. Lets get to the crux of this lab – the oscilloscope.

## **b. Oscilloscope**

Note: This section is mostly a paraphrase of [1]. It might also be useful to go through the Prelab as you read this section.

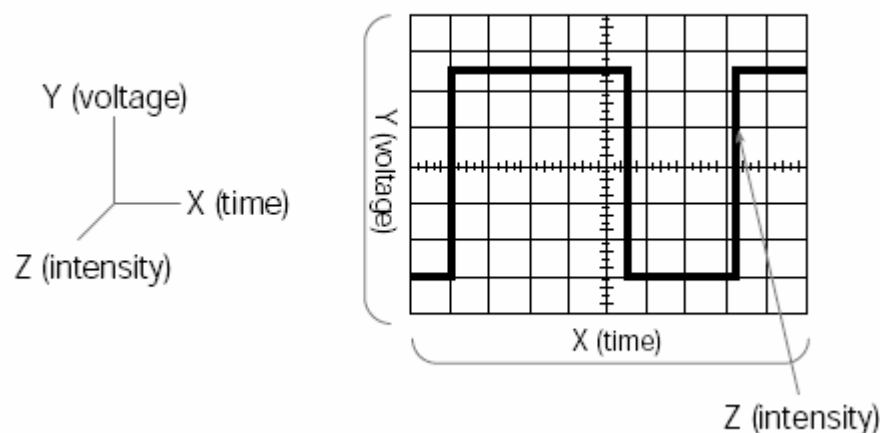
Nature moves in the form of a sine wave, be it an ocean wave, earthquake, sonic boom, explosion, sound through air or the natural frequency of a body in motion. Even light – part particle, part wave – has a fundamental frequency which can be observed as color.

Sensors can convert these forces into electrical signals that you can observe and study with an oscilloscope. You will learn an example of a sensor – the Strain Gauge – in a later lab. For now, we will learn how to use an oscilloscope<sup>1</sup>.

Oscilloscopes enable scientists, engineers, technicians, educators and others to “see” events that change over time. They are indispensable tools for anyone designing, manufacturing or repairing electronic equipment. Oscilloscopes are used by everyone from physicists to television repair technicians. An automotive engineer uses an oscilloscope to measure engine vibrations. A medical researcher uses an oscilloscope to measure brain waves. The possibilities are endless.

### **i. Basic concepts behind an oscilloscope**

What is an oscilloscope? An oscilloscope is basically a graph-displaying device – it draws the graph of an electrical signal. In most applications, the graph shows how signals change over time: the vertical (Y) axis represents voltage and the horizontal (X) axis represents time. The intensity or brightness of the signal is sometimes called the Z-axis (refer to figure 7).



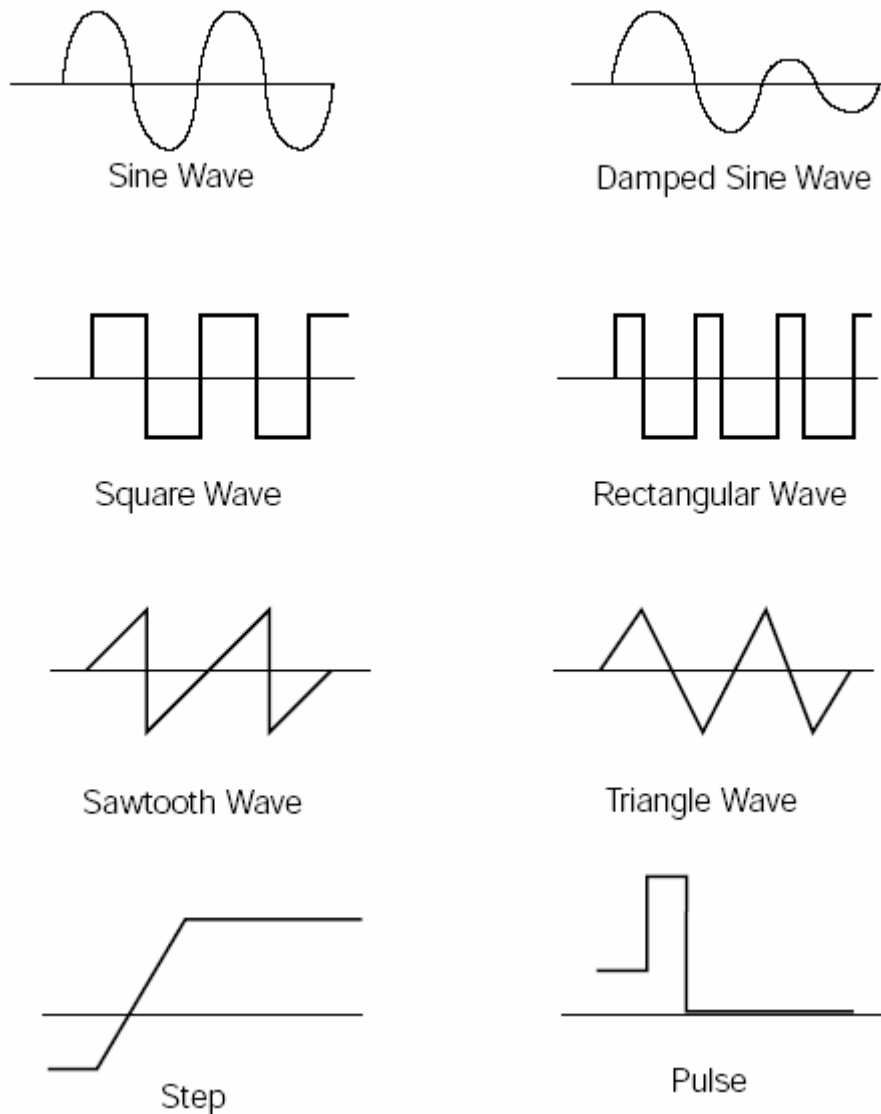
**Figure 7.** X, Y and Z components of a waveform

<sup>1</sup> An oscilloscope takes sometime to get used to. Just remember a simple rule: oscilloscopes **do not** generate waveforms (except for a simple test signal), they **measure** waveforms.

This simple graph can tell you many things about a signal such as:

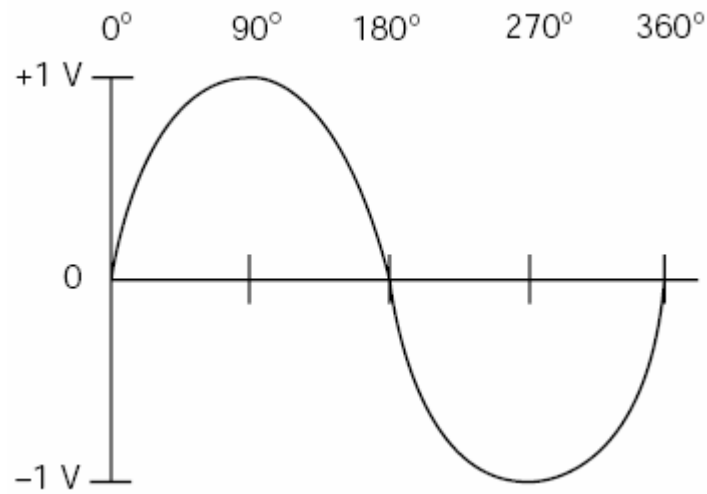
- The time and voltage values of a signal
- The frequency of an oscillating signal
- Whether or not a malfunctioning component is distorting the signal
- How much of a signal is direct current (DC) or alternating current (AC)

What kind of signals can you measure with an oscilloscope? Figure 8 shows some common signals (or waveforms).

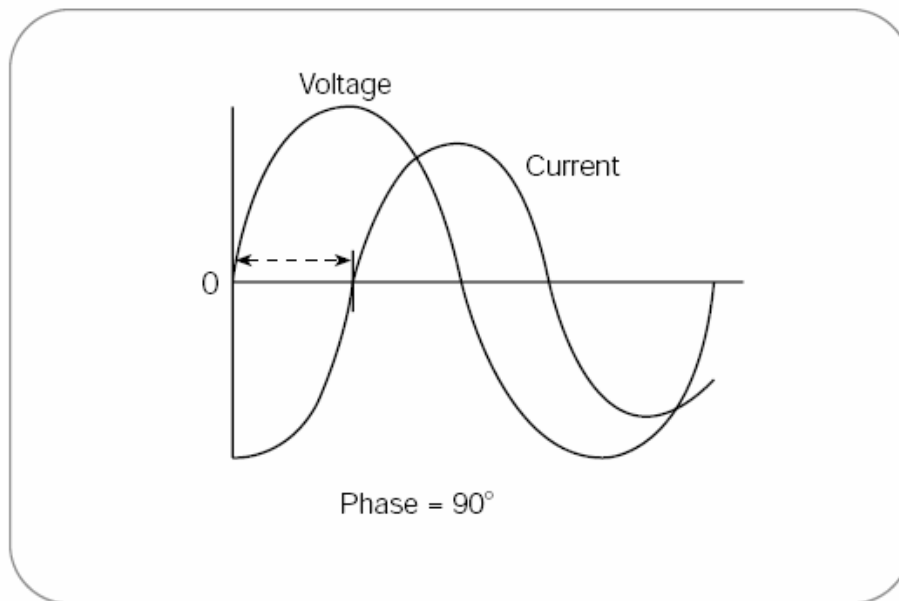


**Figure 8.** Common waveforms

You can measure different characteristics of a waveform with an oscilloscope – amplitude, frequency, DC offset and phase.



**Figure 9.** Degrees of a sine wave



**Figure 10.** Concept of Phase shift

Phase is best explained by looking at sine waves (figure 9). The voltage level of sine waves is based on circular motion. Given that a circle has  $360^\circ$ , one cycle of a sine wave has  $360^\circ$  (as shown in figure 9). Using degrees you can refer to the phase angle of a sine wave when you want to describe how much of the period has elapsed.

Phase shift describes the difference in timing between two otherwise similar signals. The waveform in figure 10 labeled "Current" is said to be  $90^\circ$  out of phase with the waveform labeled "Voltage". This is because the waves reach similar points in their cycles exactly  $\frac{1}{4}$  of a cycle apart ( $360^\circ/4 = 90^\circ$ ). Phase shifts are common in electronics.

## ii. The Systems and Controls of an Oscilloscope

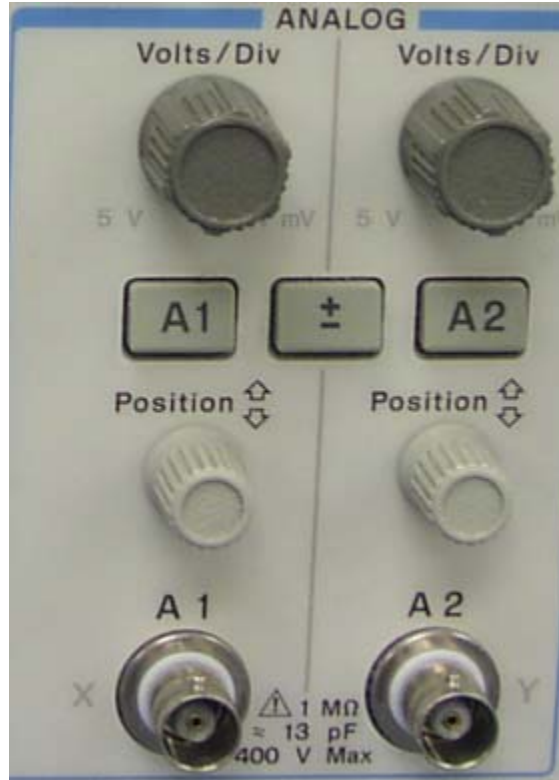
There are different types of oscilloscope on the market – analog, digital, digital storage etc. The oscilloscope that you have costs approximately \$5000 and is a digital storage oscilloscope. Figure 11 is the front view of your scope.



**Figure 11.** Your oscilloscope – the Agilent (or HP) 54645D


Your oscilloscope consists of four main systems – the vertical (ANALOG) system, the horizontal system, the measure system and the trigger system. The different systems are described below. You are not required to use the Logic Analyzer (DIGITAL) system in this course.

**a. The vertical (ANALOG) system**



**Figure 12.** The vertical system controls

You select the channel you want by pressing A1 or A2. You can use the Volts/Div to adjust the vertical scale. The position knobs move the waveform up or down on the

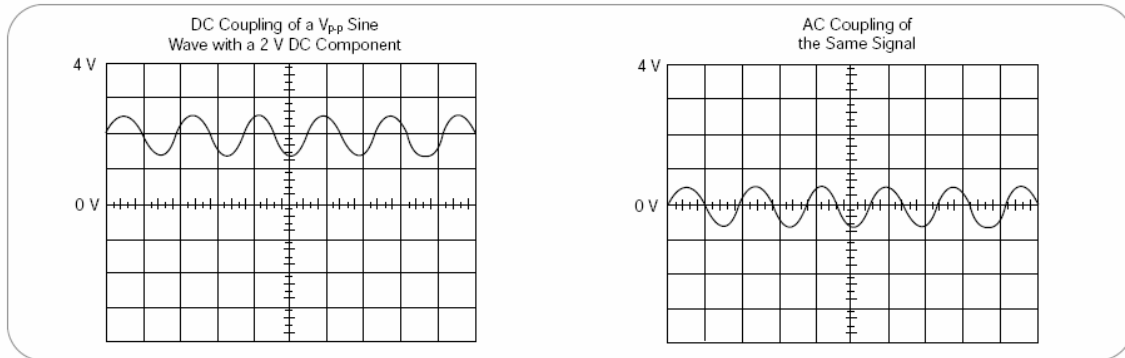
scope screen. The  buttons control mathematical functions (like A1+A2, A1-A2 etc). Once you press this button you can select which function you want by using the soft-keys below the oscilloscope screen (refer to figure 14).



**Figure 13.** Soft-keys for accessing various functions

Also, once you choose the channel you will have various functions to choose from above the soft-keys. One of the most important of these is the coupling function.

Coupling refers to the method used to connect an electrical signal from one circuit to another. In this case, the input coupling is the connection from your test circuit to the oscilloscope. The coupling can be set to DC, AC or ground. DC coupling shows all of an input signal. AC coupling blocks the DC component of a signal so that you see the waveform centered around zero volts. Figure 14 illustrates the difference.



**Figure 14.** AC and DC input coupling

The AC coupling is useful when the entire signal (AC + DC) is too large for the volts/div setting. The ground setting disconnects the input signal from the vertical system, which lets you see where zero volts is located on the screen. Switching from DC coupling to ground and back again is a handy way of measuring signal voltage levels with respect to ground.

### **b. The horizontal system**

An oscilloscope's horizontal system (figure 15) is most closely associated with its acquisition of an input signal. Horizontal controls are used to position and scale the waveform horizontally.

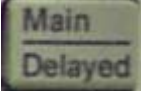


**Figure 15.** The horizontal system controls



The knob moves the waveforms left or right, the



controls the zoom scale on the time axis. The  button controls the format of the display. You can display either the waveforms versus time or enable XY mode. XY mode is mathematically called a “parametric plot” – you plot one varying voltage versus another. This is especially useful for graphing I-V curves (current versus voltage characteristics) for components [2].

### c. The measure system

Even the most advanced instrument can only be as precise as the data that goes into it. A probe functions in conjunction with an oscilloscope as part of the measurement system. Hence we first talk about the probes you use with your oscilloscope. Figure 16 shows a picture of your scope probe.



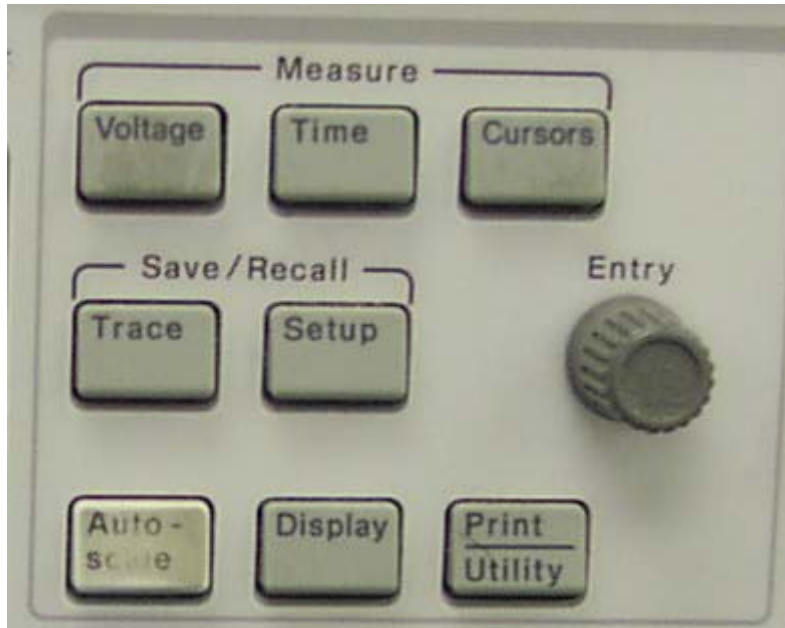
**Figure 16.** Your scope probes. They cost around \$50 each, use them with caution

**Please note: do not interchangeably use your function generator BNC connectors and your scope probes!**

Your scope probes are passive: they don't contain any amplifier circuitry. The main point to know about probes is that probes introduce resistive, capacitive and inductive loading that inevitably alters the measurement. This is quantitatively measured by the attenuation factor of a probe – 10X, 100X and so on. Your scope probes are 10x (or so called 10:1 probe).

The 10X (read as “ten times”) reduces the signal's amplitude at the oscilloscope input by a factor of 10. However, your scope contains auto-detection circuitry that automatically detects the type of probe connected to your input and thus the scope compensates for the 10X attenuation.

Once you connect the probe to your scope and hook it up to the circuit, you can use the measurement system (figure 17) to perform measurements. A note about your scope probe grounds: the two grounds are connected inside the scope to a common ground point. Thus you don't have to connect both the grounds to the same point. If one of the ground alligator clips is connected to a ground point, the other ground alligator clip from the second probe is also connected to the same point.



**Figure 17.** Oscilloscope measurement system

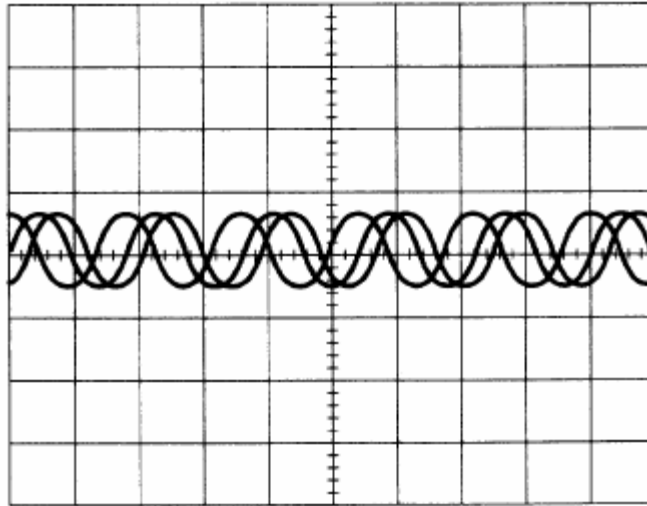
Selecting Voltage, Time or Cursors enables you to perform a variety of measurements.



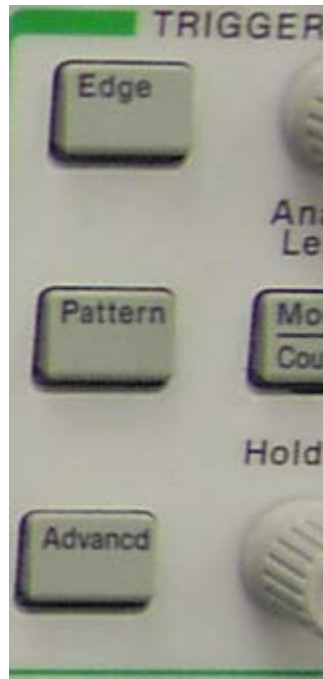
You select the type of measurement using the soft-keys. The knob helps to move the cursor locations on the scope screen.

#### **d. The trigger system**

An oscilloscope's trigger function synchronizes the horizontal sweep at the correct point of the signal, essential for clear signal characterization. Trigger controls allow you to stabilize repetitive waveforms and capture single-shot waveforms. The trigger makes repetitive waveforms appear static on the oscilloscope display by repeatedly displaying the same portion of the input signal. Imagine the jumble on the screen that would result if each sweep started at a different place on the signal, as illustrated in figure 18. Figure 19 shows the trigger system on your scope.




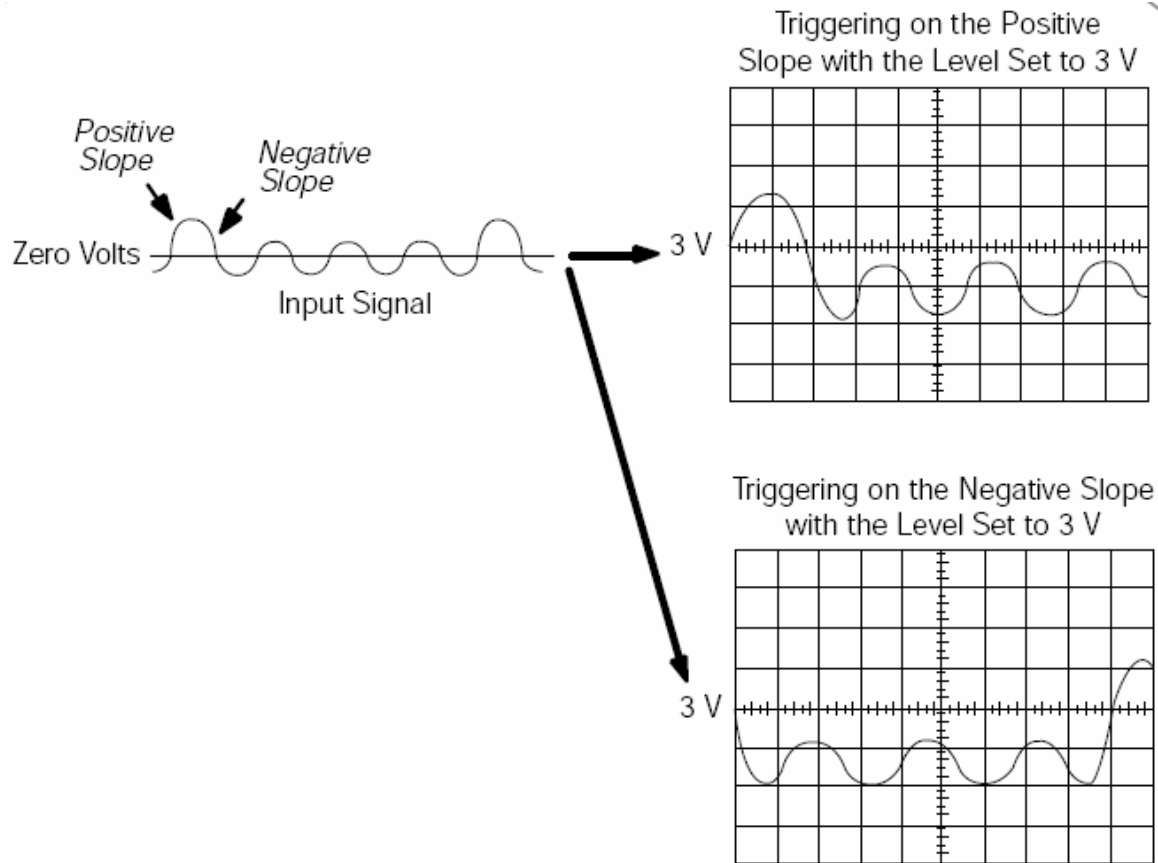
**Figure 18.** Untriggered display



**Figure 19.** Agilent 54645D trigger system



The Analog level and slope controls (press the  button to access slope functionality) provide the basic trigger point definition and determine how a waveform is displayed, as illustrated in figure 20.



**Figure 20.** Trigger level and slope functionality

The oscilloscope does not necessarily need to trigger on the signal being displayed (again



press the button and then use the soft-keys to select a source). Several sources can trigger the sweep - any input channel, an external source other than the signal applied to an input channel, the power source signal and a signal internally defined by the oscilloscope, from one or more input channels. Most of the time, you can leave the oscilloscope set to trigger on the channel displayed. Some oscilloscopes provide a trigger output that delivers the trigger signal to another instrument. The oscilloscope can use an alternate trigger source, whether or not it is displayed, so you should be careful not to unwittingly trigger on channel 1 while displaying channel 2, for example.

The trigger mode determines whether or not the oscilloscope draws a waveform based on a signal condition. Common trigger modes include normal and auto. In normal mode the oscilloscope only sweeps if the input signal reaches the set trigger point; otherwise (on an analog oscilloscope) the screen is blank or (on a digital oscilloscope) frozen on the last

acquired waveform. Normal mode can be disorienting since you may not see the signal at first if the level control is not adjusted correctly.

Auto mode causes the oscilloscope to sweep, even without a trigger. If no signal is present, a timer in the oscilloscope triggers the sweep. This ensures that the display will not disappear if the signal does not cause a trigger. However when the trigger mode is Auto and the trigger level magnitude is greater than the peak-to-peak signal voltage, then your oscilloscope will continue to sweep. Hence your scope screen will become jumbled.

Thus, your scope includes a third trigger mode called Auto Level. Here your scope senses when the magnitude of your trigger level goes beyond your peak-to-peak signal voltage and then automatically resets your trigger level to zero. It is best to leave the trigger mode to Auto Level during the first couple of weeks.

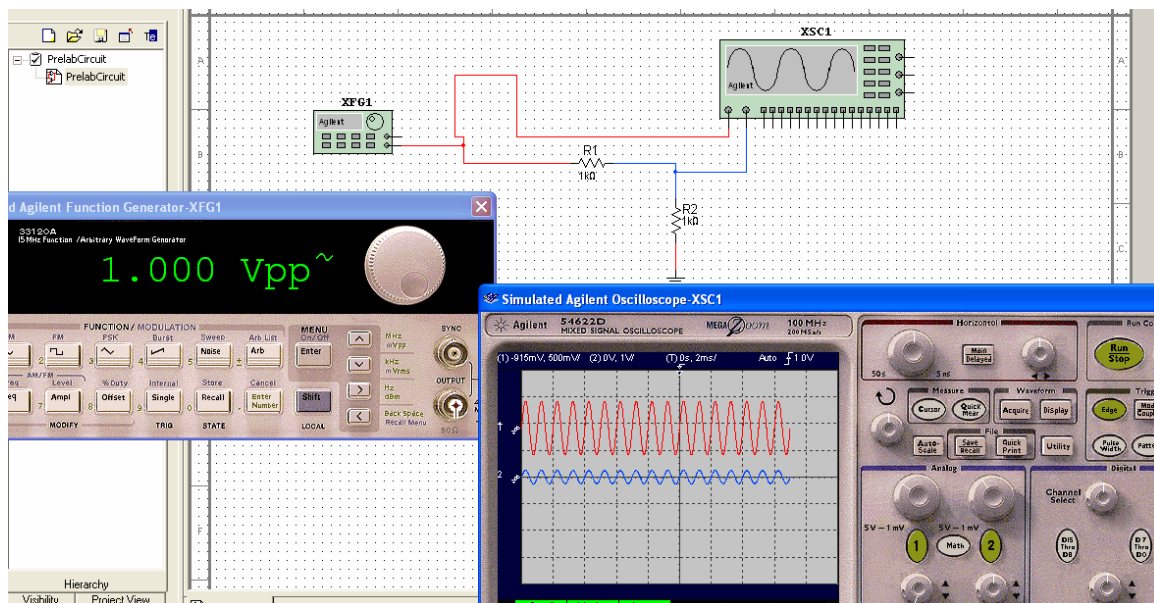
There are a few other advanced features in your scope that we will not cover in this lab. However the best way for you to learn how to use the oscilloscope is to continually use it! Do not get scared by its myriad of features – there is a reason for the \$5000 price tag! Experiment!

**4. PRELAB**      **NAME:** \_\_\_\_\_ **/SECTION:** \_\_\_\_\_

Please turn in **INDIVIDUAL COPIES** of the prelab. They are due **10 MINUTES** after start of lab, **NO EXCEPTIONS!**

**a. TASK 1:** Thoroughly read the Theory section.

**b. TASK 2:** Build and simulate the circuit below in MultiSim. **Note: Unfortunately, MultiSim does not have an instrument model of your oscilloscope – the Agilent 54645D. However, it does have the model of a very similar oscilloscope – the Agilent 54622D.** This scope has the same functionality as your scope on your lab-bench. So if you understand how to use the MultiSim scope, you will be able to use the scope on the bench – the functions will be located under different menus.



**Figure 21.** Prelab circuit

Basically you are building a simple voltage divider. Function generator settings: 1.00 Vpp, 1.00 KHz sine wave.

**PRELAB COMPLETE:** \_\_\_\_\_ **(TA CHECKOFF)**

5. REPORT NAME(S): \_\_\_\_\_/SECTION: \_\_\_\_\_

**a. TASK 1:** Wire the circuit from task 2 of your prelab on the breadboard (**WIRE NEATLY!**) The circuit is repeated below for convenience, along with your function generator and scope connections.

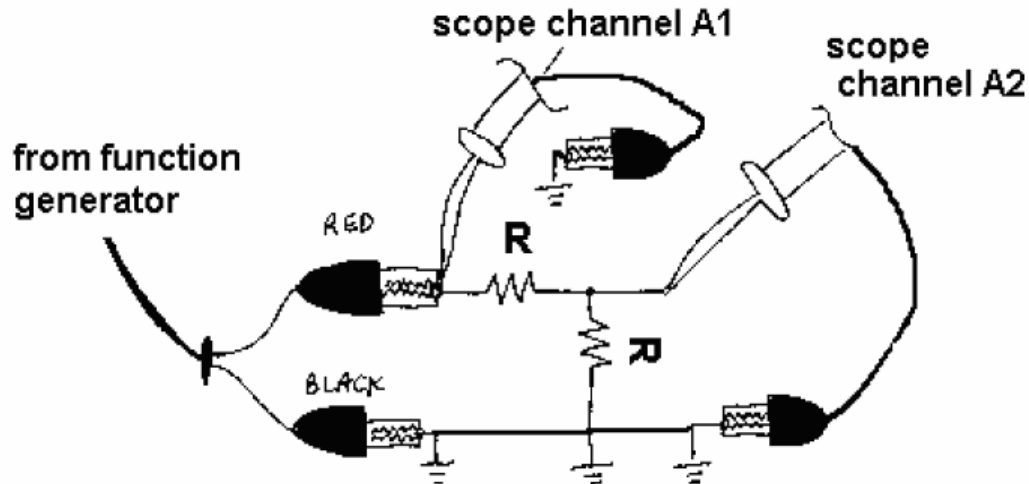


Figure 21. Lab circuit

$R = 1k$  in the circuit above. Set your function generator to: 1.00 V<sub>pp</sub>, 1.00 KHz sine wave. Tune your oscilloscope (**DO NOT MODIFY THE FUNCTION GENERATOR SETTINGS!**) till your oscilloscope screen looks like figure 21.

Now, what happens when you reverse<sup>2</sup> the terminals of your function generator? That is, do the waveforms on the oscilloscope screen change? Before you actually perform the experiment, think what would happen. Write your guess, the experimental observation and a **brief** explanation below:

<sup>2</sup> Switch the red and black connectors

**b. TASK 2:** Touch the oscilloscope probe tip to your index finger. What is the frequency of the waveform? Ask your lab partner to repeat the experiment. Are the frequencies approximately equal? Briefly explain your observations.

**TURN IN ONE REPORT PER GROUP AT THE END OF YOUR LAB SESSION.  
THERE IS NO TAKE HOME REPORT.**

## 6. REFERENCES

[1] Tektronix XYZs of Oscilloscopes.

Online: [http://www.tek.com/Measurement/App\\_Notes/XYZs/03W\\_8605\\_2.pdf](http://www.tek.com/Measurement/App_Notes/XYZs/03W_8605_2.pdf).

Last accessed: May 27<sup>th</sup> 2007

[2] Osilloscope Wikipedia.

Online: [http://en.wikipedia.org/wiki/Oscilloscope#X-Y\\_mode](http://en.wikipedia.org/wiki/Oscilloscope#X-Y_mode)

Last accessed: June 9<sup>th</sup> 2007

## 7. REVISION HISTORY

Date/Author	Revision Comments
Spring 2002/Konrad Aschenbach	Initial documentation
Spring 2007/Bharathwaj Muthuswamy	Typed up source documentation, organized lab report, typed up solutions.