

## Experiment – The Oscilloscope

**I. Objective:** Understand how to use the function generator and oscilloscope.

### II. Theory

#### 1. The HP33120A Function Generator

The front panel of the function generator is shown in Figure 1. This instrument outputs a time-varying periodic voltage signal (OUTPUT connector). By pushing the appropriate buttons on the front panel, the user can specify the following characteristics of the signal:

- **Shape:** sinusoidal, square, or triangular waves. These are all mathematical functions of time.
- **Frequency:** inverse of the period of the signal; units are cycles per second (Hz)
- **Amplitude:** peak to peak value of the time-varying component 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.

In terms of math, a sine wave of frequency  $f$ , peak to peak amplitude  $V_{PP}$ , and DC offset  $V_{DC}$ , is written as  $v(t) = (V_{PP}/2) * \sin(2\pi f t) + V_{DC}$

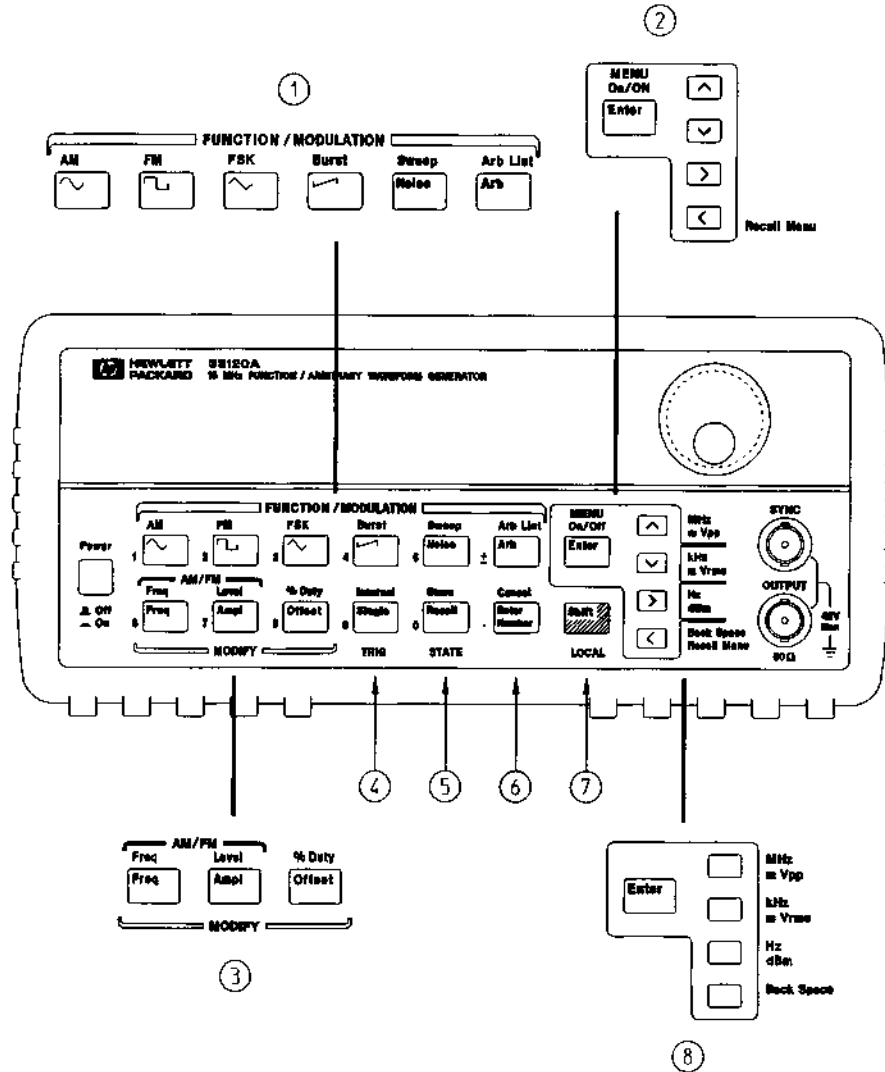
When the function generator is turned on, it outputs a sine wave at 1 kHz with amplitude of 100 mV<sub>PP</sub>. You must specify the characteristics of the signal you need. For example,

- **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 50 ohm resistor  $R_S$  in series with the oscillating voltage source. Thus, if you connect the function generator to an external resistor  $R_L$ , it will form a voltage divider with  $R_S$ . The purpose of  $R_S$  is to have impedance matching especially important for high frequency circuits. **The front panel meter assumes  $R_S = R_L$  and displays  $V_{PP}$  of half the actual voltage source.** You must not assume that the load voltage is equal to the displayed voltage.

Once again, we have not detailed all the capabilities of your function generator. Please refer to the function generator User's Manual for details.

- **To set a DC offset voltage:**
  1. Enable the *offset modify* mode by pressing the **Offset** button.
  2. Enter the magnitude of the desired DC offset by pressing the **Enter Number** button and entering the appropriate number. Notice that the +/- button toggles the displayed value between + and -.  
 (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.



- |   |                                       |
|---|---------------------------------------|
| 1 Function / Modulation keys                              | 5 Recall / Store instrument state key |
| 2 Menu operation keys                                     | 6 Enter Number key                    |
| 3 Waveform modify keys                                    | 7 Shift / Local key                   |
| 4 Single / Internal Trigger key<br>(Burst and Sweep only) | 8 Enter Number "units" keys           |

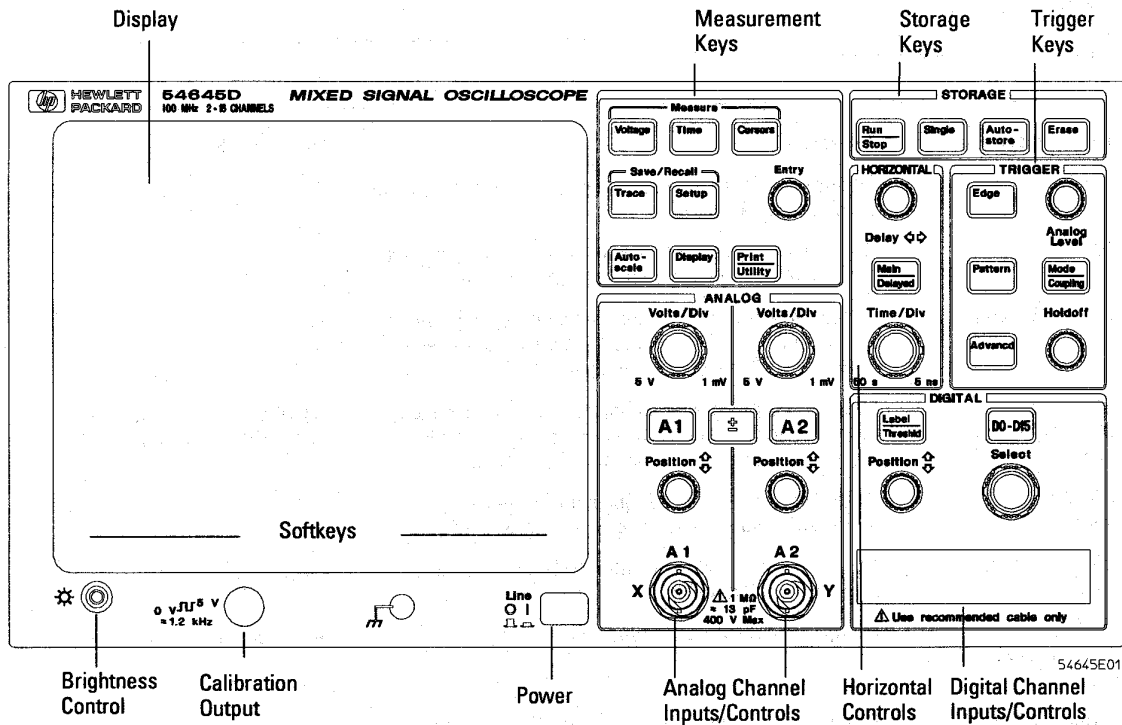
Figure 1: Front panel of function generator.

### 3. The HP54645D Oscilloscope

An oscilloscope is a device that graphs voltage versus time. The display shows voltage on the vertical axis as a function of time on the horizontal axis. The user can control the scale of both the time and the voltage axes.

The HP54645D oscilloscope can accept two voltage-signal inputs (A1 and A2 connectors) and graph them simultaneously. This is useful because it allows us to compare two signals. For example, we can graph the input signal to a circuit and compare it to the output signal.

In this lab, you will use the HP 33120A Function Generator to generate voltage signals and you will use the HP 54645D oscilloscope to graph those signals. You will build a circuit that takes an input signal from the function generator, modifies that signal in some way, and outputs the modified signal. You will use two independent channels to graph both the input signal and the output signal on the oscilloscope.



HP 54645D Mixed-Signal Oscilloscope Front Panel

Figure 1: The face of the HP54645D oscilloscope.

### III. Hands On

#### a. Graphing a signal on the oscilloscope

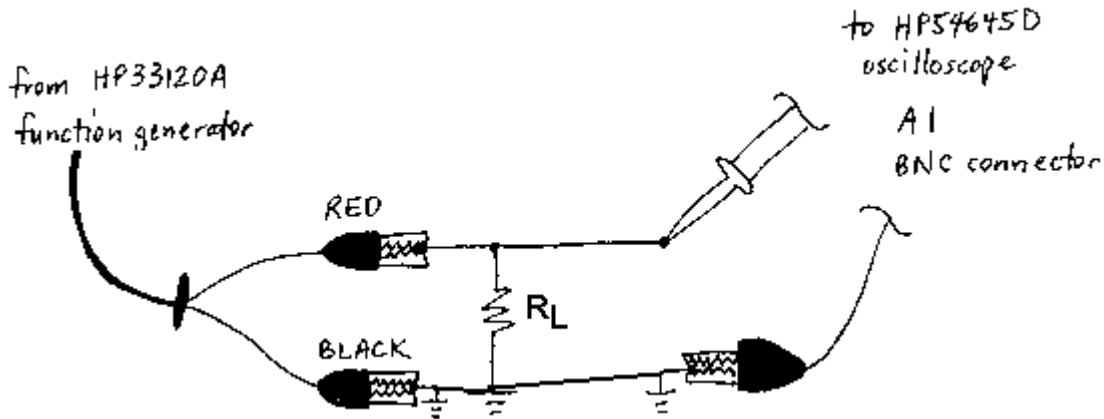
1. Build the circuit of Figure 5.  $R_L=200$  Ohms. Make sure the signal across the resistor is 1.0Vpp, 500 Hz. The HP function generator may end up saying 640 mVpp to achieve this.
2. Turn on the oscilloscope. Hit the **Autoscale** button. You should see the signal on the display.  
*The Autoscale button automatically scales the time and voltage axes for the user. It senses the input signal, determines its maximum and minimum voltage values and measures the frequency of the signal if it is periodic. Based on this information, it adjusts the scales of the voltage and time axes so that the signal is comfortably displayed on the display.*
3. Verify the frequency and amplitude of the displayed signal. At the top of the display you should see something similar to:

A1 500mv/                      500us/

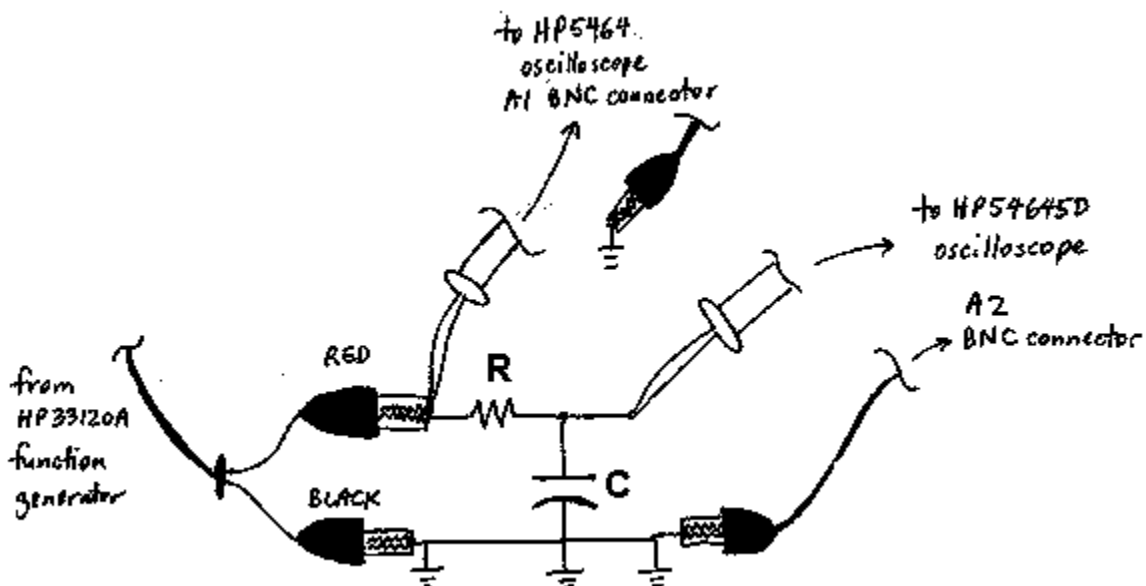
These numbers indicate the scale of the voltage (vertical) and time (horizontal) axes. Note that the grid is divided into “divisions”. Observe that there are 10 divisions in the horizontal direction (time axis) and 8 divisions in the vertical direction (voltage axis). In this case, we have 500mV per vertical division and 500us per horizontal division. These values represent the scale of the graph and are set when the **Autoscale** button is hit.

4. You can adjust the voltage manually by turning the **Volts/Div** knob for the A1 signal. Turn this knob clockwise until the display reads 200.0mv/.
5. Now, change the frequency of the signal from 500 Hz to 5000 Hz. This adjustment is made **ONLY** the function generator, by hitting the **Freq** button and turning the dial. **DO NOT CHANGE THE OSCILLOSCOPE**. As you dial up the frequency, watch the oscilloscope’s display. You can see the period of the sinusoid shrink.
6. You can manually adjust the horizontal (time) scale by turning the **Time/Div**.
7. Play with the **Position** and **Delay** knobs. They shift the vertical (voltage) and horizontal (time) scales respectively.

**NOTE ABOUT OSCILLOSCOPE GROUND:** The building earth ground is connected to the outside ring of each of the BNC probe connectors. This ground is also common to the ground wires of both input probes. If you put the ground clips of probe A1 and probe A2 on two different nodes, the ground will short both nodes together.



**Figure 5:** Set-up to graph a signal on the oscilloscope.  $R_L=200$  Ohms



**Figure 6:** Set-up to graph the input & output signals of an RC circuit on the oscilloscope.

### b. Triggering

The display on the oscilloscope can only graph the voltage for a finite time interval. The oscilloscope needs to know what time interval to graph. “Triggering” determines the starting point of the interval. A voltage signal (usually one of the input signals A1 or A2) serves as the “trigger source”. The “trigger condition” is usually some sort of level-crossing condition of the “trigger source”. For example, the oscilloscope can be set up to “trigger off the positive edge of A1” which means that a new time interval will be graphed when the voltage on the A1 input crosses the “trigger level” and is increasing.

After triggering and drawing the graph of voltage for a single time interval, the oscilloscope can do one of the following: stop; wait for another trigger condition and then

draw a new graph; or automatically re-trigger without waiting for a new trigger. The action taken is determined by the “trigger mode”. Three trigger modes are described below:

Normal: In the normal triggering mode, the oscilloscope waits for the trigger condition and then graphs one time interval. It freezes (doesn't graph anything more) until it receives another trigger. When a new trigger is received, it erases the graph, and draws a new one. In this mode, if the trigger source is periodic, triggering will occur regularly and the oscilloscope will continuously graph the input signal for multiple time-intervals.

Auto: This mode is the same as Normal mode except that in the absence of any triggers, the oscilloscope will automatically trigger after some small amount of time after having graphed the signal for a time interval.

Single or One-Shot: The oscilloscope will wait for a trigger, graph a single time interval, and then freeze. This mode is useful for capturing signals that are not periodic and that occur only once.

1. Build the circuit of Figure 6.  $R_L = 200$  Ohms,  $C = 1$  uF. Apply 5 Vpp, 500 Hz.
2. Hit **Autoscale**. Use the **Position** knobs to adjust the height of each of the traces so that the grounds are in the center of the vertical (voltage) axis. Hit the **Main/Delayed** button, ensure that the **Time Ref** is set to **Center** (rightmost soft-key at the bottom of the display)
3. Hit the **Edge** button. Ensure the **Trigger Source** is set to **A1** and that the **Edge** is set to the up edge (soft-keys)
4. Hit the **Mode/Coupling** button. Ensure that the **Trigger Mode** is set to **Normal** (3<sup>rd</sup> soft-key from the left), the **coupling** is set to **DC** (4<sup>th</sup> soft-key)
5. Adjust the **Analog Level** knob which changes the trigger level. What happens when the trigger level is beyond that of the signal?
6. Set the trigger mode to **Auto** (2<sup>nd</sup> soft-key). Now adjust the **Analog Level** knob. What happens now when the level is beyond the voltage signals?
7. Hit the **Edge** button and change the edge from up to down (5<sup>th</sup> and 6<sup>th</sup> soft-keys)
8. Change the **Trigger Source** from **A1** to **A2**. Explain what's going on.
9. Turn the **Delay** knob back and forth.
10. Measure the amplitudes and phase shift between the input (**A1**) and the output (**A2**) sinusoids. Adjust the **Time/Div** knob and use the **Measure Cursors**, **Time** and **Voltage** buttons as necessary.
11. Turn the frequency of the sinusoid back to 500 Hz and then up to 5000Hz. Measure the amplitude and phase difference between the input and output voltage signals. Does the RC circuit pass low-frequency signals, or does it pass high-frequency signals?