

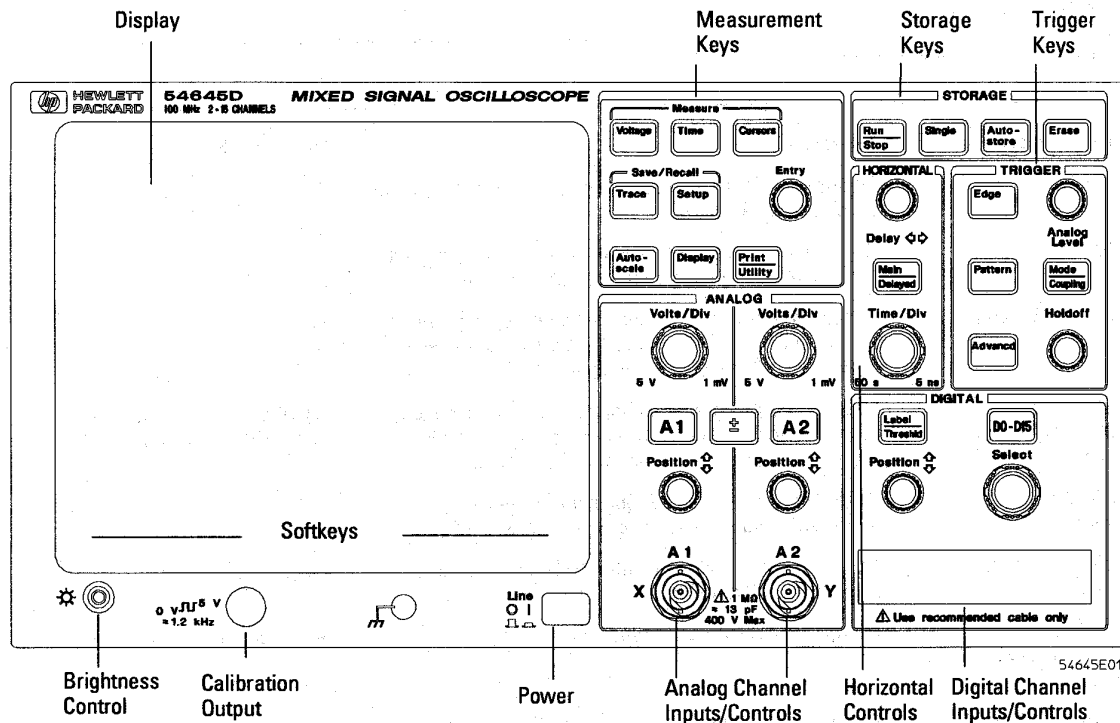
Experiment – The Oscilloscope

I. Introduction

An oscilloscope is a device that graphs voltage versus time. The display shows voltage on the vertical axis and 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 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.

II. The HP33120A Function Generator

The front panel of the function generator is shown in Figure 2. 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
- **DC Offset:** constant voltage added to the signal to increase or decrease its average value
- **Amplitude:** peak value of the time-varying component of the signal
- **Frequency:** inverse of the period of the signal; units are cycles per second (Hz)
- **Modulation:** The amplitude or the frequency of the signal can be made to change with time (modulated) according to another sinusoidal function.
 - For an amplitude-modulated (AM) signal, the amplitude of the periodic signal varies with time.
Example: $v_1(t) = [1 + \sin(2\pi f_m t)] * \sin(2\pi f_c t)$ where $f_c \gg f_m$
 \Rightarrow The amplitude of the sinusoidal signal of frequency f_c varies (between 2 and 0) sinusoidally with time t , at a frequency f_m .
 - For a frequency-modulated (FM) signal, the frequency of the periodic signal varies with time.
Example: $v_2(t) = \sin[2\pi\{10^6 + 10^4 \sin(2\pi f_m t)\}t]$
 \Rightarrow The frequency of the sinusoidal signal varies (between 0.99 MHz and 1.01 MHz) sinusoidally with time t , at a frequency f_m . (The amplitude of the sinusoidal signal is constant.)

Figure 3 illustrates how you can enter numbers (to specify the characteristics of the signal) from the front panel.

When the function generator is turned on, it outputs a sine wave at 1 kHz with an amplitude of 100 mV peak-to-peak.

- **To set the frequency of the signal:**
 1. Enable the *frequency modify* mode by pressing the **Freq** button.
 2. Enter the magnitude of the desired frequency by pressing the **Enter Number** button and entering the appropriate number.
(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.
- **To set the amplitude of the signal:**
 1. Enable the *amplitude modify* mode by pressing the **Ampl** button.
 2. Enter the magnitude of the desired amplitude by pressing the **Enter Number** button and entering the appropriate number.
(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.

- **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.

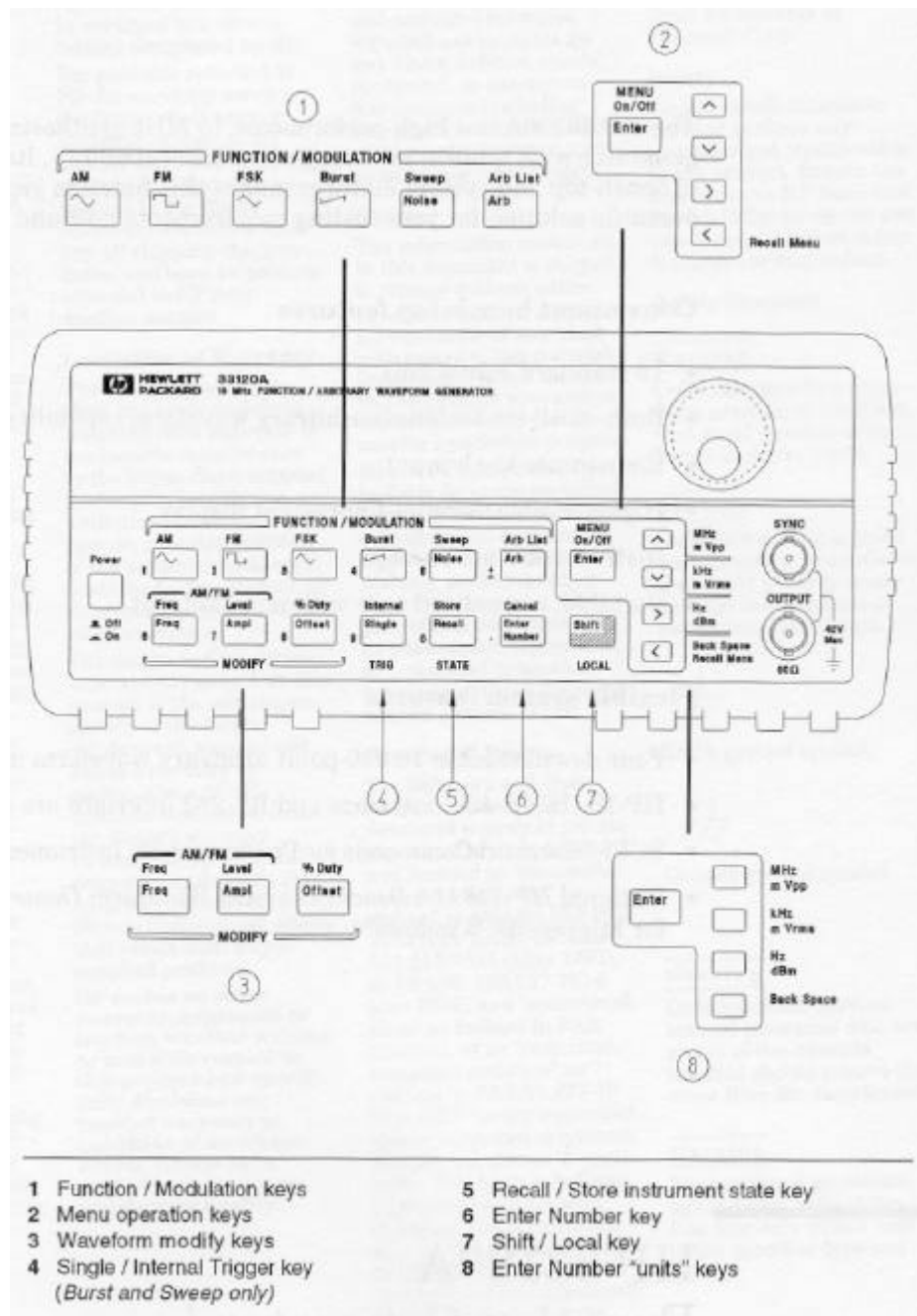


Figure 2: Front panel of function generator.

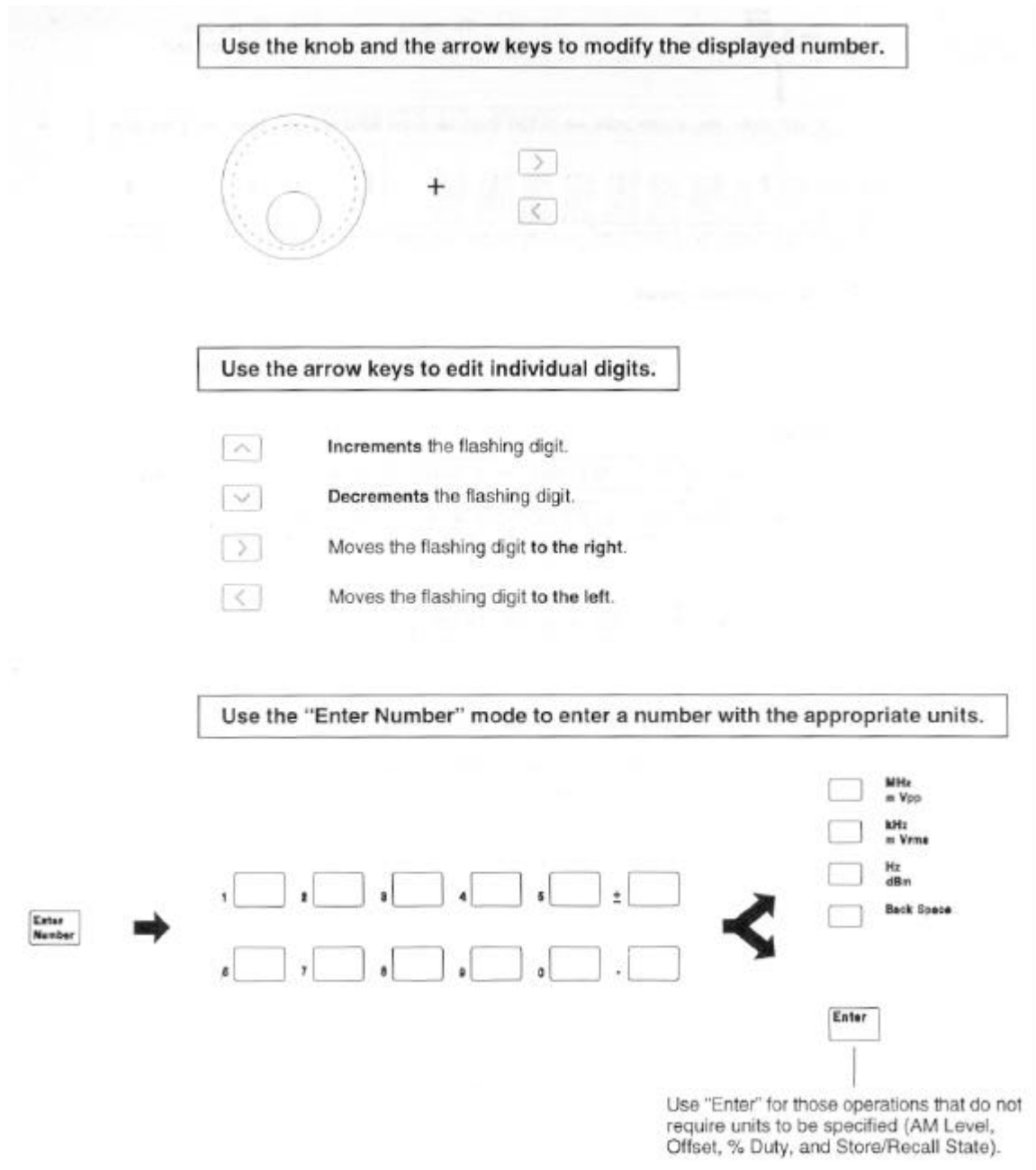


Figure 3: Number entry from the front panel.

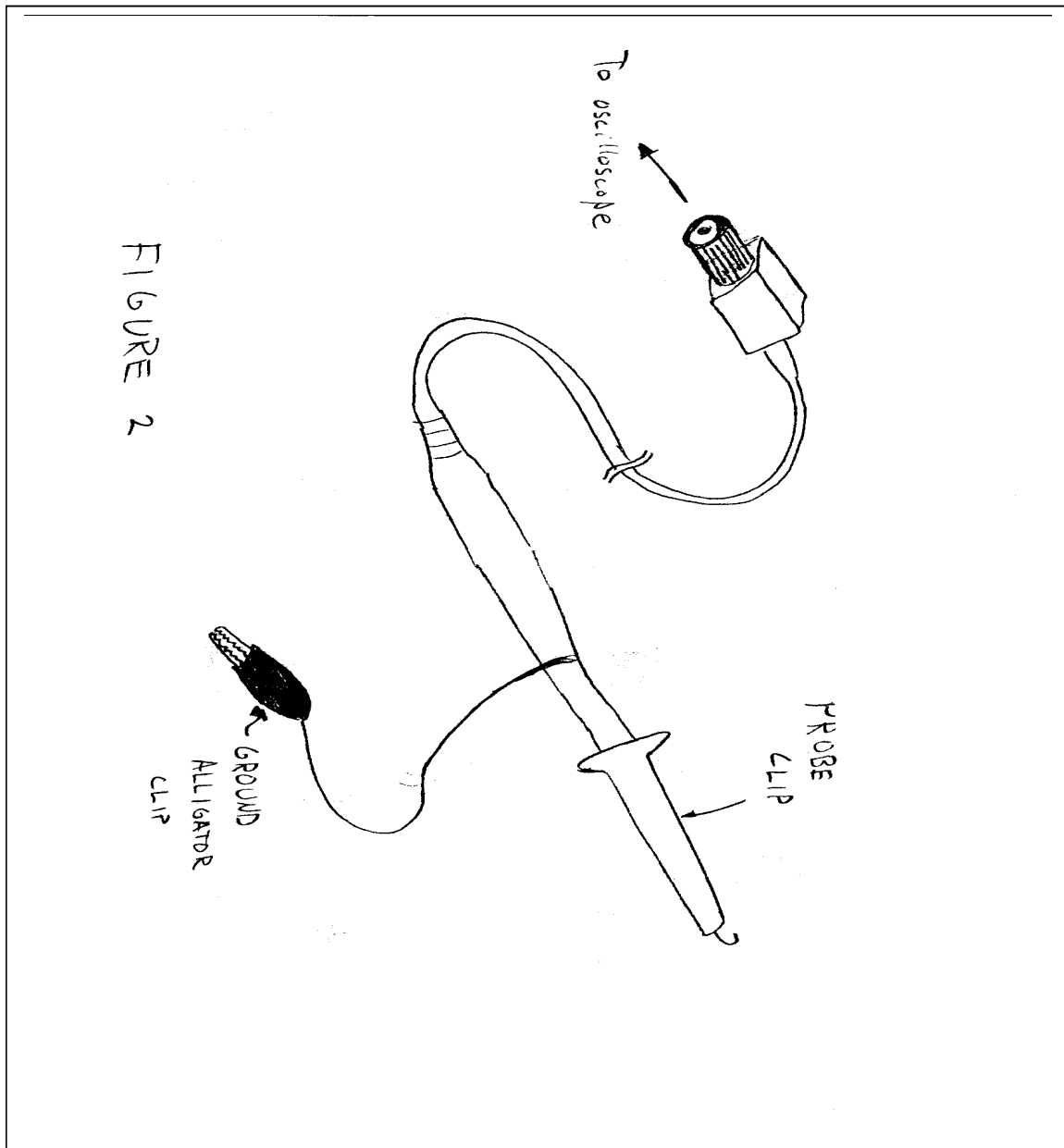


Figure 4: Schematic diagram detailing the components of the oscilloscope probe.

III. Hands On

a. Graphing a signal on the oscilloscope

1. Build the circuit shown in Figure 5.
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

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 200mV per vertical division and 100us per horizontal division. These values represent the scale of the graph and are set when the **Autoscale** button is hit.

4. Adjust the amplitude of the signal being output by the function generator to 100mV pk-pk (don’t touch the oscilloscope! This adjustment is made on the function generator by turning the dial.). As you dial down the voltage, watch the oscilloscope’s display. You can see the amplitude of your signal changing as you turn the dial. Once you get to 100mV pk-pk the signal should be quite flat – the voltage scale needs adjusting.
5. You can adjust the voltage manually by turning the **Volts/Div** knob for the A1 signal. Turn this knob two “clicks” clockwise until the display reads 50.0mv/.
6. Reset the amplitude of the signal to 1V pk-pk (again, this adjustment is made on the function generator, not the oscilloscope!) Hit the **Autoscale** button.
7. Now, change the frequency of the signal from 500 Hz to 5000 Hz (this adjustment is also made on the function generator, by hitting the **Freq** button and turning the dial). As you dial up the frequency, watch the oscilloscope’s display. You can see the period of the sinusoid shrink.
8. You can manually adjust the horizontal (time) scale by turning the **Time/Div** knob four “clicks” clockwise until the display reads 20.0us/.
9. Play with the **Position** and **Delay** knobs. They shift the vertical (voltage) and horizontal (time) scales respectively.

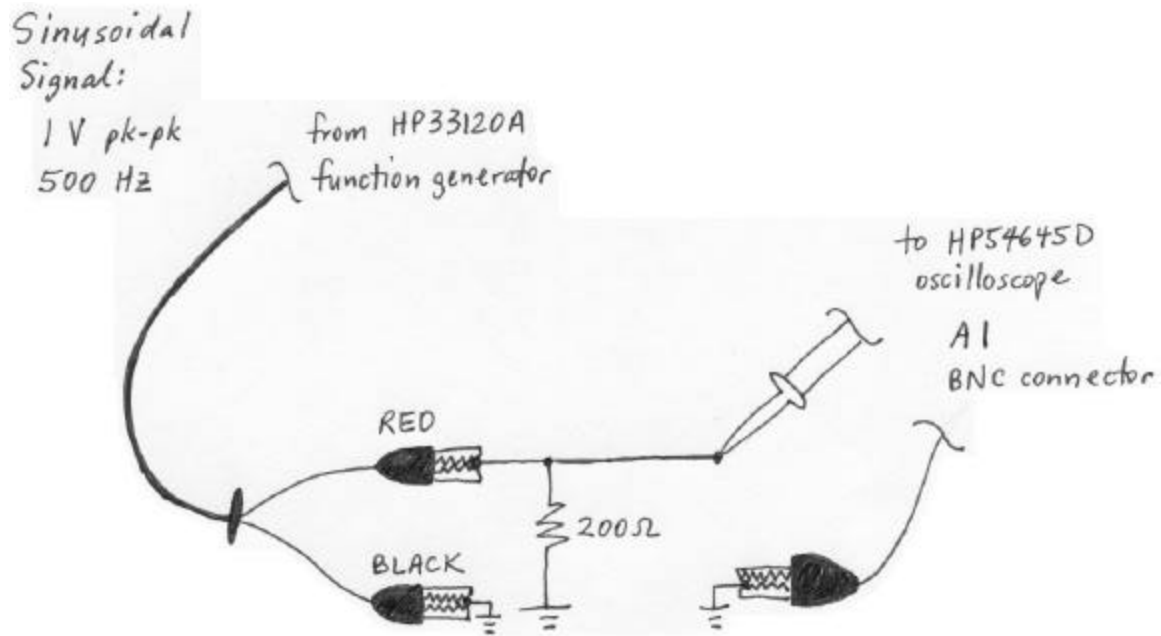


Figure 5: Set-up to graph a signal on the oscilloscope.

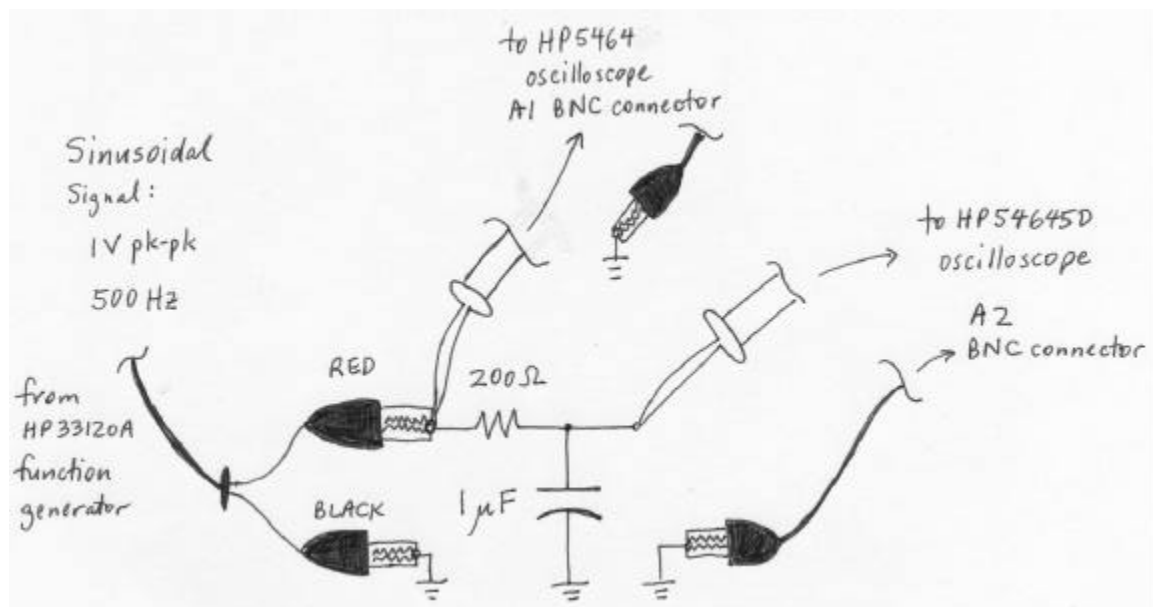


Figure 6: Set-up to graph the input & output signals of an RC circuit on the oscilloscope.

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 shown in Figure 6.
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 (3rd soft-key from the left), the coupling is set to DC (4th 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 (2nd 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 (5th and 6th 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?

c. More fun stuff

1. Disconnect the ground from your oscilloscope probe, remove the probe clip if there is one and touch the tip of the probe to your finger (be careful – the probe tip is sharp like a tack). With your finger touching the probe tip, hit the **Autoscale** button. What kind of waveform do you see? What's the frequency of this waveform? Where is it coming from? (Hint: In Europe, the frequency of the signal you see would be 5/6 of what you see here in North America.)
2. Set the trigger mode to **Auto**, set the **Volts/div** to 10.0mV/div, set the **Time/Div** to 2ms/div. Connect the A1 probe (both the ground alligator clip and the probe tip) to a speaker or a microphone or a piezo-buzzer. Speak into the speaker/microphone/buzzer and watch the display. You're looking at the voltage signal created from sound by the speaker/microphone/buzzer!