

EE2CI5 Lab 1

Part 1

Introduction to Instrumentation

Equipment List: Tektronix TDS210 Oscilloscope
Hewlett Packard HP33120A function generator

It is important that each student get as familiar as possible with the oscilloscope and function generator in this and next week's lab.

Since it will not be possible to explain certain steps, such as function generator programming and setting various control features for the scope in this lab write-up, please help each other with these basic procedures.

The prelab exercise must be completed in your lab books before you show up for the lab. The questions listed at the end of this lab are to be completed and the solutions entered into your lab books during the lab period itself. After you have finished this lab, please hand in your book to be marked.

Prelab exercise: Sketch in your lab books the waveforms that would be displayed on the scope when the input is a sinusoidal source. The frequency of the source and the horizontal scan rate are adjusted so that 1-1/2 periods are displayed in one scan of the scope. Sketch the two cases where triggering has been i) disabled (turned off) and ii) enabled.

LAB DESCRIPTION

1. Objective: In this lab you will learn the basic ideas about function generators and the oscilloscope (otherwise known as a "scope"). The following labs will assume familiarity with these instruments, so please make sure you understand their operation before you finish this lab.

2. Background: The scope operates by causing a spot of light (beam) to travel horizontally across a display. The beam can be deflected in a vertical direction as the beam traverses across the screen, by a voltage connected to the input of the scope. The

magnitude of deflection of the beam corresponds to the instantaneous input voltage at the corresponding time instant. Thus, very basically, the scope is an electronic instrument, which can display a voltage waveform versus time. Accurate voltage and time measurements can be made with the instrument. The voltage source(s) of interest is connected to the channel 1 (Ch1) and/or Ch2 connectors on the front panel. The respective waveforms are then displayed as individual traces on the scope screen. Note that the scope can only display waveforms that are *periodically repeating*, such as square waves, sine waves, saw-tooth waves, etc.

There are three fundamental groups of controls for the scope. The first are the “**vertical**” controls. These set the vertical sensitivity (in Volts per Division) of the displayed waveform, and the position (vertical displacement) of the waveform on the screen. Increasing the vertical sensitivity (i.e., turning the “volts/div” knob counterclockwise) will result in a larger offset of the displayed waveform for the same input voltage level) and vice-versa. The “position” knob translates the displayed waveform (or *trace*) in a vertical direction.

The second group makes up the “**horizontal**” controls. The “sec/div” knob controls the speed of the beam. Turning the knob clockwise makes the beam travel faster in the horizontal direction. The “position” knob translates the entire display in a horizontal direction. Note that when the beam reaches the right-hand end of the display, it immediately resumes a new scan starting from the left-hand end of the display.

The third group controls the so-called “**triggering**” function of the scope. This is the one you will have to think most carefully about.

To explain the need for triggering, consider the following. Recall the beam scans across in such a way that as soon as it reaches the right-hand end of the display, it instantly moves back to the left-hand end, and resumes its trace at the prescribed speed. Now suppose that the input is a sinusoidal waveform whose period does not divide evenly into the total time taken for the beam to scan across the display (i.e., there are a non-integer number of periods of the input waveform in one horizontal scan of the display. This is the usual case).

Now suppose for the sake of example that the beam just happens to start a scan when the input sinusoid is at its peak. (In the case of a sine wave, the initial phase of the waveform is then 90° . Lets say for the sake of argument it finishes its scan when the input sinusoid has a phase of 27° . Then, the beam will start a new scan at the left hand edge of the display, but this time the initial phase is 27° , rather than 90° as it was before. If you think about this for a while, you will realize that the new scan will trace out a different path on the display from the first scan, rather than retrace the same path as the first scan, as desired. Likewise, the third, fourth, etc. scans will also each trace out separate paths from those previous. Since the display remains illuminated for some time after the beam has passed, the result of all these separate scans each tracing out different paths is that the screen will become a “blur”, which is the aggregate of all these scans superimposed together. No meaningful information is conveyed this way.

So, to fix this undesirable situation, we need *triggering*. With triggering, a scan is delayed (i.e., the spot remains at the left-hand edge of the display) until the input voltage waveform reaches a specific voltage level, which is lower than the maximum voltage level of the input waveform. This voltage level that starts the scan is referred to as the “trigger level”. The trigger level can be adjusted, using the “trigger level” control on the trigger control part of the front panel of the scope. The triggering mechanism is sensitive to the slope of the input voltage; i.e., if the triggering is set to positive slope, the scan will not start until the input waveform rises through the trigger level from below. If the triggering is set to negative slope, the input waveform must fall through the trigger level from above.

So now, let's look at the action of the scope when triggering is in place. As a new example, suppose we are displaying a sinusoidal waveform whose maximum value is one volt. Also suppose the trigger level has been set to 0.5 volts (assume positive slope). This means that the first scan will not start until the input voltage level rises through 0.5 volts. Also assume that the value of the input waveform is zero volts at the end of its first scan. With triggering in effect, the beam remains at the left-hand end of the display, and waits until the input voltage level rises from the zero volts where it was when it finished its last scan, to the 0.5 volt level needed to trigger the new scan. When the input reaches 0.5 volts, the beam starts to scan across the screen again. Assuming the input waveform hasn't changed, the beam will retrace exactly the same waveform as the previous scan! i.e., the new scan overwrites the old, as does each subsequent scan. Thus, with triggering, the waveform appears stationary on the screen, and a meaningful display results.

The trigger level is displayed as a small arrow along the right-hand end of the waveform display area of the scope.

The trigger menu controls the triggering process. Triggering can be set for the input waveform to pass through the trigger level either in the positive or negative direction (+ve or -ve slope). Triggering can also be set to a variety of different sources, as shown on the trigger menu. The most natural source is the waveform itself being displayed. This setting corresponds to either “Ch1” or “Ch2”, respectively. There are also provisions for the scope to be triggered from an *external* source, or from the 60Hz “line” where the line cord plugs into. The “trigger level” knob adjusts the trigger level.

3. Exercises

Turn on the power to the scope and the function generator.

To see the beam scanning across the display, (after disconnecting any input) set the “sec/div” knob to 1 sec/div (this quantity is displayed on the bottom of the screen). You will then see the beam (or maybe two beams) scanning across the display at this rate.

Using its front panel menu, set the function generator to a 2 volt peak-peak sinusoidal waveform, at a frequency of 1 kHz. Ask for help from the TAs if you have trouble doing this. Set the voltage sensitivity to 0.5 volts/div, and the scan rate to 250 microsecs/div. Connect the output of the function generator to the channel 1 input of the scope, using the shielded cable provided. You should see a sinusoidal waveform on the scope. Make sure “Probe” setting is 1X (to select setting push Channel 1 menu). If you have problems, get help.

“Vertical Controls”

Push the “Ch1” menu button on the scope face. The Ch1 menu appears on the right-hand side of the display. You will see that each respective square on the screen is connected to a softkey on the instrument panel. The important keys are “coupling” and “probe”. Push the “coupling” button. The entries correspond to “DC”, “AC” and GND” respectively. The first allows any DC (direct current) component (i.e, any component of the input waveform which is invariant or constant with time) present in the input waveform to be displayed on the scope. The AC (alternating current) entry blocks the DC component from being displayed and hence shows only the AC component of the waveform, by inserting a capacitor in series with the input. The GND setting results in the display showing zero; i.e., the scope input is effectively connected to ground, rather than to the desired source.

Usually, the scope probe attenuates (reduces) the input voltage by a factor of 10. Sometimes, the probe can attenuate by other ratios. The number displayed in the “probe” area indicates the attenuation factor of the probe being used. Set probe to 1X

Experiment with changing the amplitude of the function generator, and the voltage sensitivity setting of the scope. Make sure you understand what you observe. You may need to adjust the trigger level to make the display stand still.

“Horizontal Controls”

Adjust the scan rate knob, or “secs/div” control on the scope. Also, adjust the frequency of the function generator. In each case, explain what you observe. Try experimenting with square waves, triangular waves, and other waves as well.

“Triggering Controls”

For a given input signal, adjust the trigger level control knob, and observe the trigger level arrow. Try adjusting the trigger level to exceed the maximum input voltage level. By pressing the trigger menu button, change from +ve slope to -ve slope triggering. In each case, explain the effect you observe.

4. Report

Write a report on each of the activities you performed above. In addition, perform the following exercises:

1. Set the function generator to produce a sinusoidal waveform at the lowest possible frequency of the function generator. Display the waveform on the scope. Explain the difference between the displayed waveform when the coupling is changed from DC to AC.
2. Set the function generator to produce a sinusoid of 10 kHz frequency, 1 volt peak to peak amplitude and 100 mV. DC offset. Then measure the frequency and amplitude values of the sinusoid using the scope. Use the measure button on the oscilloscope to obtain both peak-to-peak and average values. Compare your measurement with the readings on the signal generator display. Change the peak to peak amplitude to 500 mV and the DC offset to 200 mV. Again measure and compare values. Are the errors constant or are they related to the function generator settings? Repeat the experiment for a frequency of 100 Hz. Are the results different than for the 10 kHz signal? Discuss the sources of error.