PC2193 Basic Electronics

Introduction to the Oscilloscope

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Scopes

Two types of scope are used in the PC2193 lab:

- Kenwood Dual Trace Oscilloscope (CS-5130)
- Digital Oscilloscopes (OS-310M)



Fig1. Kenwood Dual Trace Oscilloscope (CS-5130) Digital Oscilloscope (RIGOL DS-1062C)

Introduction

The single most important diagnostic tool used by experimental physicists is the oscilloscope. Certainly *all* scientists and engineers should be familiar with this common instrument, shown in the Fig. 1. An oscilloscope (scope for short) can be used to "see" an electrical signal by displaying a replica of a voltage signal as a function of time. The display is generated by a sweeping electron beam striking a fluorescent screen, the same principle behind common television displays. The purpose of this lab exercise is to introduce the fundamentals of oscilloscope operation and its practical use.

The oscilloscope is used to obtain "voltage versus time" pictures of electrical signals. The display consists of a tube with an electron gun, x and y-deflection plates, and a phosphor screen which glows in response to an internal electron beam. In normal operation the beam is swept continuously from left to right at a uniform speed. (The beam is shut off during its rapid return to the left side.) A triggered ramp generator generates this sweep motion by applying a "saw-tooth" voltage to the x-deflection plates, as indicated in Fig. 2a. The sweep rate and method of triggering can be varied

using controls on the front panel. An external voltage connected to one of the oscilloscope inputs can be internally amplified and applied to the y-deflection plates. The combination of the x and y-motions then causes the beam to trace out a plot of the input voltage as a function of time.



Fig 2a

The four main scope control areas are: 1) display controls, 2) input amplifiers, 3) trigger selection, 4) timebase setting. Another block diagram of an oscilloscope is shown in Fig. 2b.



Fig 2b . Block diagram of oscilloscope operation.



Fig. 3a Front panel of Kenwood Dual Trace Oscilloscope (CS-5130)



Fig. 3b Front panel of Digital Oscilloscope (DS-1062C).

Display Controls

After the scope warms up, with these initial settings, a horizontal line (or possibly two) should appear on the screen. If not, try the positioning knobs explained below or ask the lab instructor for help. Use the INTENSITY knob to adjust the brightness of the so-called trace, but no more intense than necessary as this has a detrimental effect on the phosphor of the display. Use the FOCUS knob to adjust the sharpness of the trace.

Positioning of the trace is accomplished with the knobs labeled with vertical or horizontal arrows. In the upper right hand corner, \Leftrightarrow moves the trace horizontally. The position **1** knobs in the middle of

the front panel move their respective traces vertically. Can the trace be sent completely off the screen in any direction by adjusting the positioning knobs?

Input Amplifiers (OS-310M as example)

The input stage of the oscilloscope is used to couple the signal of interest to the input amplifiers, needed to increase the signal amplitude to a level appropriate to drive the electron beam deflection circuitry. The type of coupling can be selected (dc/ac) as well as the overall gain of the amplifier (VOTLS/DIV) to control the overall vertical "height" of the trace, as discussed further below.

A calibration output, available at the metal tab labeled CAL 0.5 Vpp near the power switch, will be used as the input signal for the course of this exercise. It provides a known, regular waveform by which the oscilloscope may be calibrated to ensure that subsequent readings are accurate. The calibration signal, shown in Fig. 4 is a 0.2 V amplitude square wave, so called because of the appearance that results from the "high" voltage level (0.2 V) lasting for the same duration as the low level (0.0 V). The calibration signal has a frequency of 1000 Hz (period 1.0 ms).



Figure 4. Calibration signal.

Connect the CAL signal to the scope input by attaching a hook-tip scope probe to the channel 1 (CH1) input. Push in the adapter plug and twist until it locks in place (thus the "bayonet" action of the "B"NC) and connect the hook tip of the probe to the BNC signal. In general, both leads of the scope probe would need to be connected to measure a potential *difference*. However, since the signal is derived from the oscilloscope itself, the ground reference is already present and no additional connection is required; generally an additional connection would be made between the black banana clip of the probe and the ground of the circuit being measured. While using the probe in this exercise, please ensure that x1 sensitivity is selected on the probe handle.

To facilitate accurate readings, the ground level for the trace should be checked periodically, Move the slide switch for CH1 marked AC/GND/DC to the GND position. Adjust the vertical position of the trace to an easily remembered position on the display, generally the axis of the reticle.

Now move the slide switch to the DC setting. If the sensitivity is set to 0.2 V/div and the timebase is at 0.5 ms/div, a trace should appear similar to that shown in Fig. 4. If not, see your lab instructor for assistance. Note: the trigger LEVEL may need to be adjusted slightly to obtain a stable trace, discussed at length later in the section on triggering.

Study the effects of changing the sensitivity (VOLTS/DIV). Draw the waveform seen on the display and record the voltage from top to bottom of the square wave. To take a voltage reading: 1) measure the height of the square wave, using the calibrated grid where each square is 1 div x 1 div, and

2) multiply the number of divisions by the sensitivity setting (V/div). Take readings at several sensitivities; discuss which provides the greatest accuracy. Ensure that the outer sensitivity knob, which provides a variable gain if needed, is in the CAL position (fully clockwise and in the detent position) before making the readings.



Fig 4b AC coupling

The difference between dc and ac coupling can be understood by examining Figs. 4a & b. As you will see, the capacitor shown in the ac stage prevents the average dc voltage from reaching the CH1 amplifier. Determine the average dc level associated with the CAL signal by switching between ac and dc coupling and observing the change in the vertical level of the trace.

The real utility of ac coupling becomes apparent when trying to measure small variations "riding" on a sizable dc level. As an example, consider the relatively small "ripple" (~0.01V) on the output

of a typical dc power supply (say 5 V). With dc coupling, increasing the input sensitivity in an attempt to see the small variation will send the trace off the top of the screen. With ac coupling however, the 5 V level will be suppressed and the sensitivity can be greatly increased while retaining the trace on the display.

Trigger Control

The triggering circuitry is the means by which the oscilloscope is able to provide repeated "snapshots" of a repetitive signal. By controlling the threshold voltage of triggering and slope polarity, the user is provided with great flexibility in the appearance of the display and the utility of the scope for capturing elusive signals. Some further details of scope operation are required to understand the concept of triggering.

The horizontal sweep of the electron beam is controlled by the timebase circuitry to be discussed in the next section. The beam sweep is driven by the application of a ramp voltage to the horizontal deflection plates, which serves to move the beam across the face a distance proportional to the elapsed time from a trigger event. The occurrence of the trigger event marks the start of the linear ramp. By slowing the timebase to about 0.1 sec/div, the actual deflection of the beam can be slowed to the point where the resulting luminous "dot" can be observed crossing the display from left to right.



Fig 5. Effects of slope and threshold on triggering.

To examine the effects of the trigger settings on the triggering of the display, use the signal generator as the signal for CH1 and increase the sensitivity to 5 V/div. In addition, select 2 ms/div as the sweep speed. With the trigger SOURCE set for CH1, the LEVEL set to the midrange, and SLOPE set as +, a stable trace showing the sinusoidal wave should appear. Adjust the \leftrightarrow horizontal position of the trace until its starting position is seen on the display. Adjust the LEVEL control to the right (positive threshold voltage) and to the left (negative threshold voltage), noting the change in the starting point of the trace. As the threshold for the trigger in increased, the starting point comes later at a higher voltage. Refer to Fig. 5 for a pictorial representation of the various triggering combinations. Setting the trigger level too low or too high (outside the bounds of the signal amplitude) results in loss of triggering and an unstable "running" waveform.

Switch the trigger SOURCE control to CH1 and observe the change. The +/- of the SLOPE selector chooses whether the trigger event will occur on moving through the threshold from high voltage to low (negative slope, thus -) or from low to high (positive slope). Refer again to Fig. 5.

Time-base Setting

The sweep speed of the electron beam is controlled with the time-base setting (TIME/DIV). Using the signal generator at 1000Hz, 100mV again at the time-base to larger settings (slower sweeps) -- a longer "snapshot" of the signal is displayed but with less detail. Remember that the 1000 Hz signal has not changed; the beam sweeps more slowly, so more transitions are displayed. Moving to much smaller time-base settings (faster sweeps), more detail can be seen at the expense of the "big picture". Notice the decrease in intensity of the trace as the electron beam moves more swiftly over the screen at faster time-base settings.

Returning to a time-base around 1 ms/div, confirm that the period of the ac signal is that of a 1000 Hz oscillation. Adjust the trigger level if necessary to achieve a stable display. Measure the horizontal distance between the two closest points where the waveform crosses the baseline (zero volt level) with the same slope. (Note that there are two zero crossings per cycle, each with different slope.) Multiply this number of divisions by the time-base setting (time/div); the resulting time T is known as the period. Repeat for the scope's CAL signal.

How short a time can be read by this oscilloscope? This can be estimated by the smallest time-base setting. In practice, this setting may result in a trace to weak to be seen; thus the so-called writing speed of the oscilloscope may also limit the shortest time that can be accurately determined, as will the bandwidth of the input amplifiers.

Dual Trace Operation

The availability of two independent input channels greatly facilitates comparison of two signals. This is implemented by depressing the button marked MONO/DUAL in the vertical mode section of the front panel. While displaying the 1000 Hz signal on CH1, using it as a trigger source, observe the signal from a loose lead on CH2. You will probably observe "spikes" and other types of electrical noise. You should attempt to explain why this noise is "locked" to the signal on CH1. For a more dramatic effect, touch your finger to the CH2 input jack. The noise probably has much higher amplitude and is still locked to the calibration signal. Finally, while holding the bare lead in one hand, touch the metal frame of the table and observe the noise signal on CH2. Attempt to explain your observations.

There are two modes of dual-trace operation available on most oscilloscopes. The *CHOPPED* mode is the more useful one at low frequencies. In this mode, the beam alternately displays the two signals. The switching occurs at a relatively fast rate with *blanking* in between, so that all that should be seen on the screen are the two separate traces. The other dual-trace display mode is called the *alternating* mode. In this mode the output of CH1 is displayed for a full sweep, then the output of CH2 is displayed for a full sweep, and so on. When the two inputs are repetitive and synchronized this leads to a stable display. You can observe the difference between the chopped and alternate modes by looking again at the 1k Hz ac signal, first with a slow time-base setting of 1 ms/div and then with a much faster setting, while switching between the ALT and CHOP positions.