

Laboratory Exercise: Introduction to the Oscilloscope

I. Object

In this lab you will be introduced to the Oscilloscope and learn its basic operation.

I. Introduction

The Oscilloscope is an instrument for measuring voltage as a function of time. It starts with a CRT (cathode ray tube). This is similar to the picture tube in a television set or an older computer monitor.

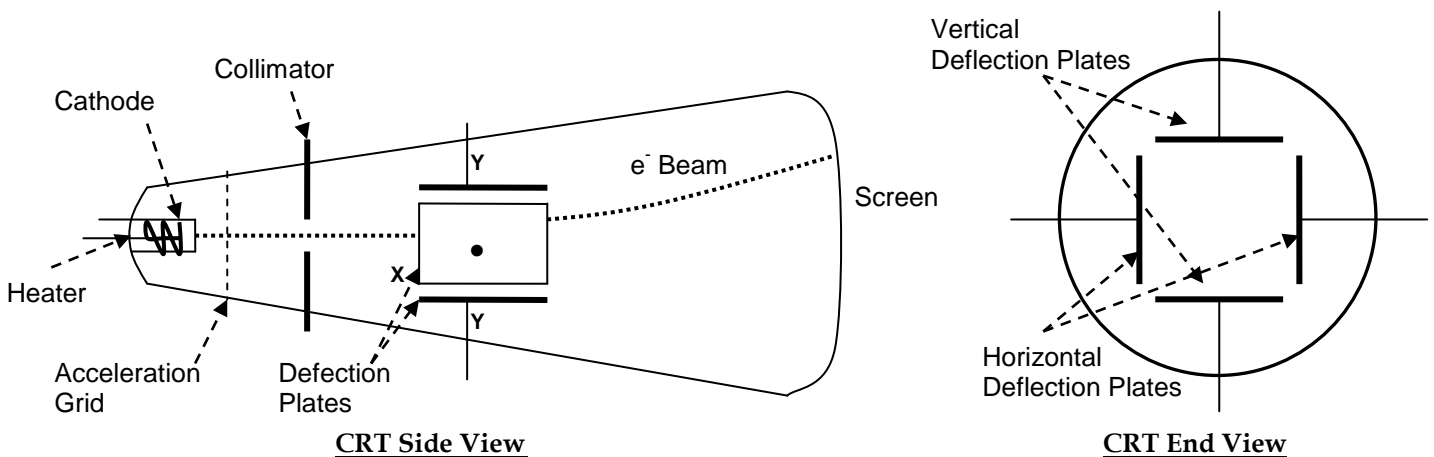


Figure 1

The following is how simple CRT functions using Figure 1 as a reference. A heater filament heats a cathode, which in turn 'boils off' a cloud of electrons at the far left end of the tube. The electrons 'see' a fairly large potential in the acceleration grid (think of a piece of metal window screen) and are accelerated toward it. As the grid is mostly open space, most of the electrons miss the metal wires of the grid and now 'see' larger potential(s) down the tube culminating with the potential of the screen at the far right. As the electrons are now on their way toward the screen they pass a collimator which focus' the electrons into a beam.

At this point, with no further influences, the beam would arrive at the center of the screen. The screen is coated with a phosphorous mixture so that it will give off light when and where an electron hits it and make a dot. Just having a dot at the center of the screen has limited uses so in the next step the beam passes through a set of deflection plates. The set consist of a pair of vertical plates and a pair of horizontal plates (see CRT End View). In our simple CRT the deflection plates have a potential difference between them. This potential sets up an electric field between the plates, and a force on the electron beam that influences its flight path. By having the right combinations of potentials on the vertical and horizontal pairs we can place the dot (end of the beam path) any where we like on the screen.

With the oscilloscope we generally vary the horizontal plates with time and the vertical plates with the voltage that we are measuring. Adding grid lines to the screen gives us a voltage vs. time graph right on the screen!

II. Procedure

Setup

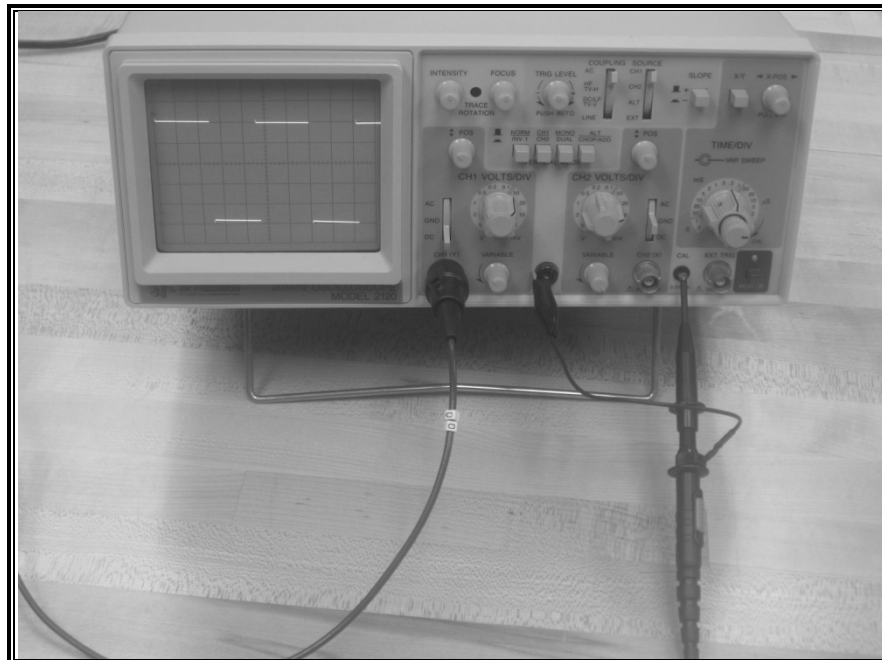
CHECK LIST

1. Check that the oscilloscope is plugged in, but do not turn on.
2. On each of the two voltage channels (vertical) and the time base (horizontal) make sure that the VAR CAL knob is turned to the minimum position.
3. Adjust the INTENSITY and FOCUS knobs to the midway position.
4. Turn on the power.
5. Set the SOURCE to Ch. 1 (Channel 1) and COUPLING to AC.
6. Set the Ch.1 AC-GND-DC lever to the ground (GND) position.

You should now have a bright horizontal line across your screen. You may need to adjust the Ch. 1 POSITION knob to bring it to the center. Once in the center, adjust the INTENSITY and FOCUS knobs to achieve the finest line possible.

Checking Calibration

To the lower right of the Ch. 2 area there is a metal loop. This is a calibration point. It provides a signal that we can use to check the calibration of the oscilloscope. The amplitude and frequency of the signal is printed next to the calibration point. It is typically 0.2v peak-to-peak and 1kHz; verify this by checking the labeling. If we feed this known signal into the oscilloscope, we can check the calibration of the oscilloscope and make any necessary adjustments.



Reading the screen

First though we have to know how to read the screen on the oscilloscope so we know what we are looking at. The screen is designed to look like and be read like a graph with voltage on the vertical and time on the horizontal. It is divided into eight major vertical divisions and ten major horizontal divisions which make up a large grid that covers the screen. The scales on the knobs refer to these major divisions, so by adjusting the vertical voltage/div and horizontal time/div knobs we can set the scale of the 'graph' to fit the signal we are measuring.

If you look closely you will see that the two middle horizontal and vertical lines have four smaller division lines, between each large division line. These each represent a two tenths step (0.2) between the major division. These are to assist you in reading 'between the lines' of the major divisions.

Now we will put the calibration signal on the screen so that we can see what we are talking about and check the calibration of the oscilloscope.

Use the coaxial cable with a BNC connector to probe.

- Connect the BNC connector to the Ch.1 input (at the lower left hand side of the Ch.1 area).
- The probe has a metal hook at the end which retracts. Place the hook on the metal loop of the calibration point so we input the calibration signal to Ch.1.
- Set the Ch.1 AC-GND-DC lever to the DC position.

You should now have a clear, stationary square wave signal displayed on the screen. It should look like Figure 2, but it might not because we have to make sure that we have the scale set correctly and make some other adjustments.

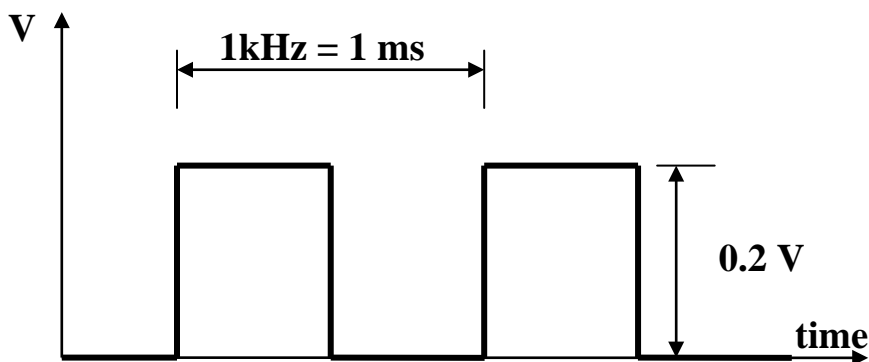


Figure 2

If the scale is too large, then the signal will look very small and we will not be able to measure it accurately. If the scale is too small, then the signal could be off the edges of the screen and again we would not be able to get an accurate measurement, nor would we be able to see the complete signal.

To set the correct scale, we first adjust the vertical (voltage) scale to fit the signal. Using a calibration signal of 0.2 V as an example you need to be able to get at least 0.2 V on the vertical axis. There are eight divisions on the vertical axis of the screen, so

$$0.2 \text{ V} / 8 \text{ Div} = 0.025 \text{ V/Div} = 25 \text{ mV/Div}$$

If we check the Ch.1 VOLTS/DIV knob we see that it has both a 20 mV/Div and a 50 mV/Div position. The 20 mV/Div would not be able to display the whole signal, so we will go with the 50 mV/Div. This will give us some extra room as well. Set the Ch.1 VOLTS/DIV knob to the 50 mV/Div position.

Adjust the CH.1 POSITION knob to set the vertical position of the signal to where it is easy to read.

Now to adjust the horizontal (time) scale to fit the signal. Typically the calibration signal has a frequency of 1kHz, or 1,000 Hz, so you need to know what the period (time per cycle) is. Recall that Hertz (Hz) has units of cycles per second, so to find the period we take the reciprocal of the frequency.

$$T = 1/f = 1/1,000 \text{ Hz} = 1 \times 10^{-3} \text{ s} = 1.0 \text{ ms}$$

So we need to be able to get at least one cycle on the screen, but two would be much better (why?). There are ten divisions on the horizontal axis of the screen, so

$$2 \text{ ms} / 10 \text{ Div} = 0.20 \text{ ms/Div}$$

If we check the Time/Div knob we see that it has a 0.2 ms/Div position, so we will select that. Set the Time/Div knob to the 0.2 ms/Div position.

Adjust the TRIGGER LEVEL knob to be sure that you have a clear, stationary signal.

Adjust the X POSITION knob to set the horizontal position of the signal to where it is easy to read.

Now that you have a stable, clear and well scaled signal try different settings of the time and voltage scales to see how it effects the display of the signal. Remember, you are **not** changing the signal, just how it is displayed.

When you are done exploring, return the settings to the 50 mV/Div, 0.2 ms/Div positions.

When you are satisfied with your settings, draw a picture of what you see on the screen on your data sheet, in Data Figure 1.

Measuring the signal

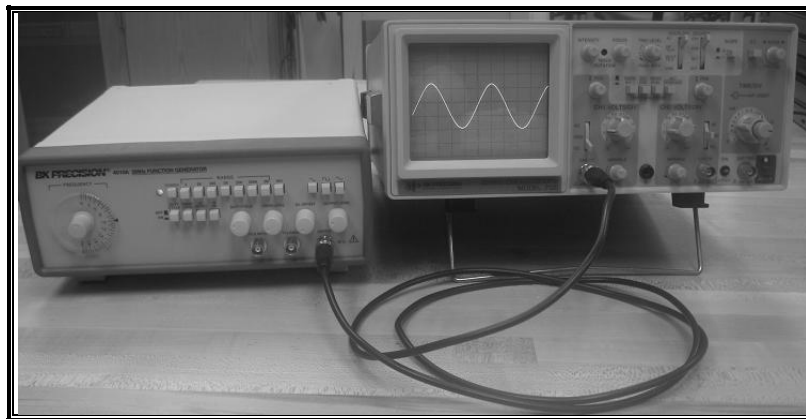
To find the peak-to-peak voltage of the signal, count the number of divisions from the bottom to the top of the signal. Be as precise as possible, use up to a tenth of a division if necessary (recall that the small marks are two tenths). Now multiply the number of divisions by the scale factor that the Ch.1 VOLTS/DIV knob is set on.

$$V = (\# \text{ of Div}) (\text{scale factor}) = (\# \text{ Div}) (\# \text{ Volts/Div}) = \# \text{ of Volts}$$

When you determine the voltage, record it on your Data Figure 1. **Each person in your group must make an independent measurement** so that you can estimate the error by comparing multiple measurements - plus, then you each get some practice in reading the oscilloscope!

To measure the period, follow the same concept. Count the number of divisions for one full period of the signal, then multiply the number of divisions by the scale factor that the Time/Div knob is set on. Use the period to find the frequency. Record the period and frequency on your Data Figure 1 also. Do your measured values of the peak-to-peak voltage and frequency agree with the stated values of the calibration point? Note any discrepancy as a percent.

Function Generator Signals



The function generator is a type of power supply. It has the ability to supply various periodic signals that can be specified from its front panel. From the front panel of the function generator we can select three different waveforms (square wave, sine wave and saw-tooth wave), we can set the frequency from 0.2 Hz to 2 MHz, and we can set the amplitude voltage from 0 to 10 V_{p-p}. When the function generator signal is displayed on the oscilloscope, the oscilloscope setting will have to be adjusted to properly display the particular signal from the function generator. Remember that when you adjust the oscilloscope, you are not changing the signal. You are only changing the graph as it were that is displaying the signal.

With the power off, connect the function generator to the oscilloscope with a BNC to BNC cable. Turn on the power and explore the different settings on the function generator. When you are satisfied that you understand the capabilities of the function generator do the following:

1. Set the waveform to square wave.
2. Set the frequency to 10 kHz.
3. Adjust the amplitude to $4 V_{p-p}$. Use a multi-meter if necessary.
4. Adjust the oscilloscope settings so you can measure the waveform as precisely as possible.
5. Measure the voltage and period, and calculate the frequency.
6. Record these in Data Figure 2.
7. Do your measured values of the peak-to-peak voltage and frequency agree with the stated values of the function generator (and multi-meter)? Note any discrepancy as a percent.
8. Record a sketch of what you see on the screen on your data sheet, in Data Figure 2.

Repeat 1 – 8 for a sine wave (Data Figure 3) and a saw-tooth wave (Data Figure 4).

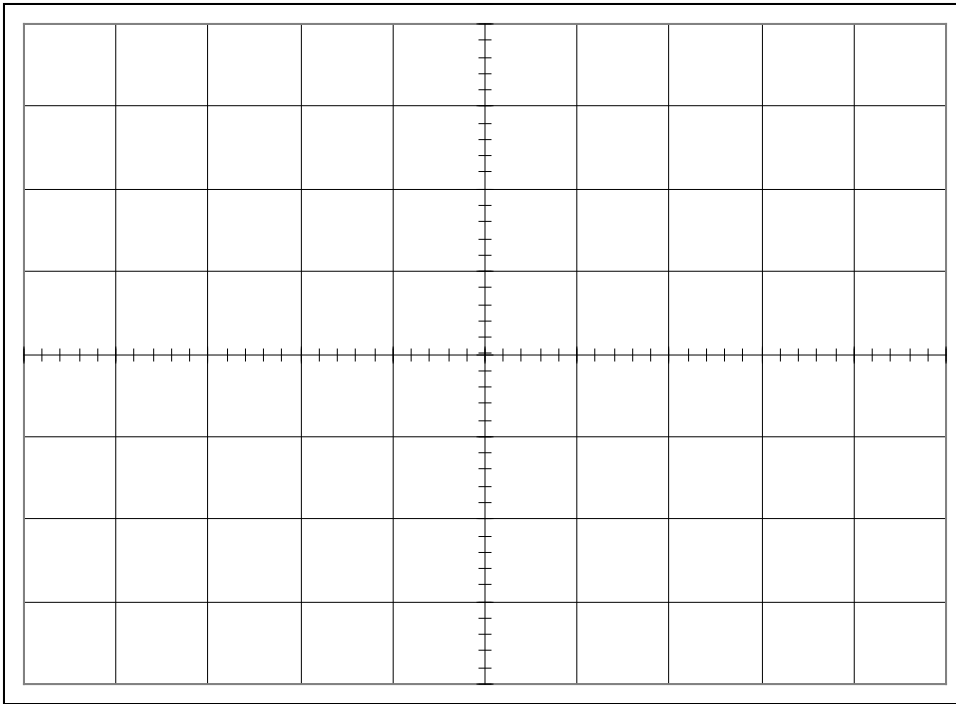
Equipment

- Oscilloscope
- Function Generator
- DMM
- BNC to probe cable
- BNC to BNC cable

DATA SHEET

NAME _____

Oscilloscope



$V_{p-p} =$ _____

% Discrepancy = _____

Agree / Disagree

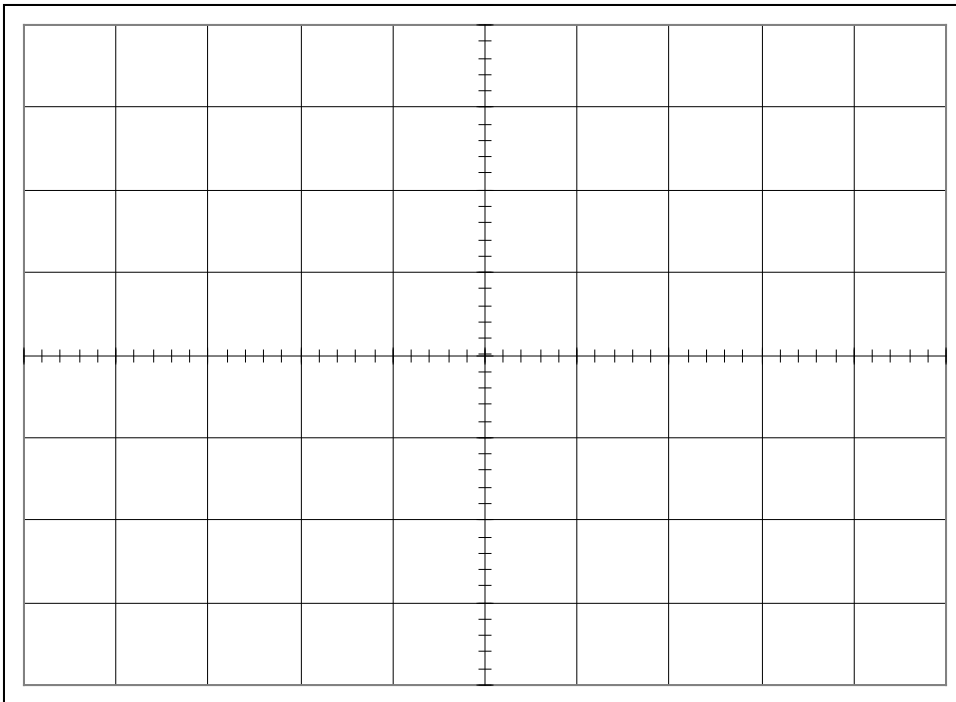
Period = _____

Frequency = _____

% Discrepancy = _____

Agree / Disagree

Data Figure 1



$V_{p-p} =$ _____

% Discrepancy = _____

Agree / Disagree

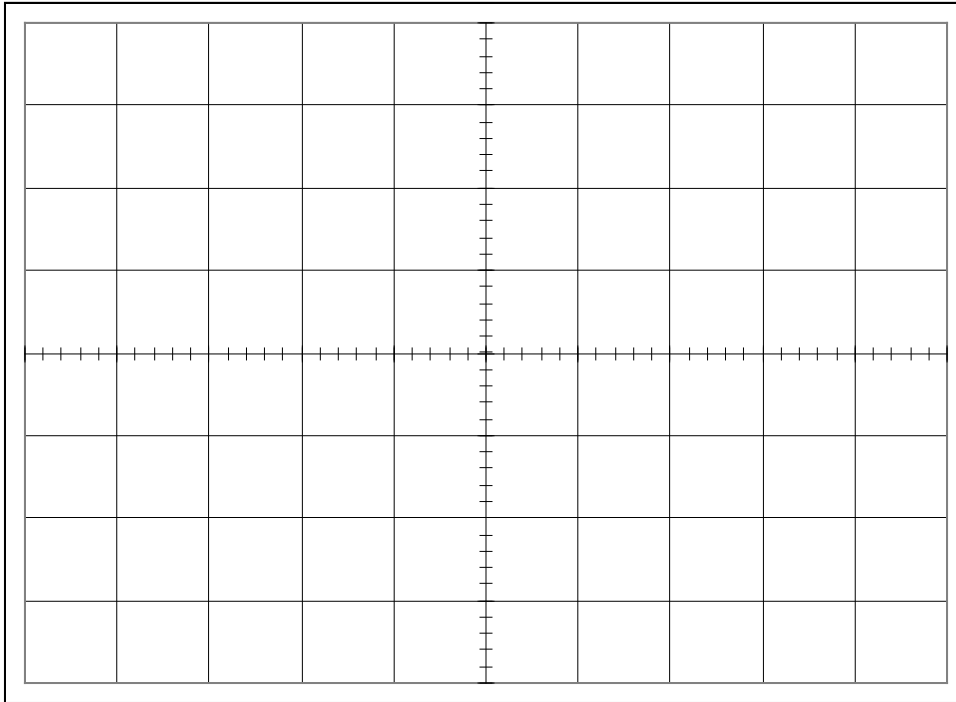
Period = _____

Frequency = _____

% Discrepancy = _____

Agree / Disagree

Data Figure 2



Data Figure 3

$V_{p-p} =$ _____

% Discrepancy = _____

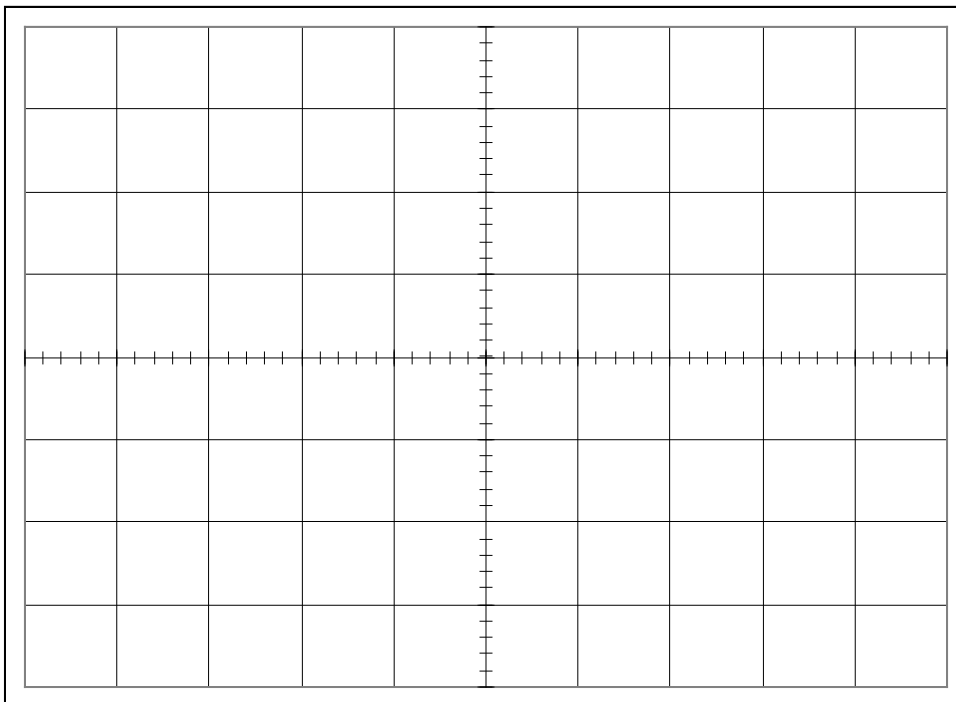
Agree / Disagree

Period = _____

Frequency = _____

% Discrepancy = _____

Agree / Disagree



Data Figure 4

$V_{p-p} =$ _____

% Discrepancy = _____

Agree / Disagree

Period = _____

Frequency = _____

% Discrepancy = _____

Agree / Disagree