NOTE: This is a fill-in-the-blanks lab. No notebook is required. You are encouraged to use your notebook for personal notes and comments, but it will not be collected or graded. Instead you will hand in this completed lab handout at the end of your lab period. Read it and do the preliminary problems before coming to lab.

Objectives
This lab is an introduction to the oscilloscope, one of the most common, important, and useful electrical measuring devices. An oscilloscope (scope) is basically a fancy voltmeter that displays voltage as a function of time. You will learn how to use it to take both voltage and time measurements.

Check out from stockroom:
- *The XYZs of Using A Scope*, Tektronix booklet
- Wire kit
- EE 1050 kit, optional, if available.

Parts to be supplied by the student:
This item should be in the EE 1050 kit.
- Small speaker or microphone

Theory
Voltage in an electrical circuit is the "electrical pressure" which makes the current flow. A DC voltmeter can be used to measure this "pressure" between two points in a circuit as long as it doesn't change, or at most, very slowly. An AC voltmeter can give you an average or an RMS (a type of average) reading of a changing voltage but won't give you any indication of how it changes. This means that the majority of important voltages in most circuits cannot be measured with a simple voltmeter. A voltmeter cannot show you the changing voltages (signals) which are often used to convey information like audio, video, or digital data.

What we need is a type of voltmeter that can show, literally show, rapidly changing voltages. No mechanical pointer or pen could possibly move quickly enough to follow the signals that are regularly found in circuits so, a cathode ray tube is used.

A cathode ray tube uses a "beam" of electrons which is generated at the back of the tube and produces a spot of light on the tube's phosphorus screen. It is bent by magnetic or electrostatic means so that the spot of light can be made to move across the face of the screen. A TV picture tube is a cathode ray tube (CRT). Its beam (3 beams in a color tube)
is bent by a magnetic field. A picture is made by "scanning" the spot(s) across the entire screen 30 times each second and modulating the intensity of the electron beam(s). This is called a *raster* scan. Most computer terminals work the same way. In an oscilloscope the electron beam is bent, or deflected, by electric fields and it doesn't scan the whole screen. It simply traces a single spot on the screen. This spot moves up and down in response to an input voltage and left to right at a constant rate. The scope draws on its screen much like you do on a piece of paper-- in continuous lines. A TV draws its picture more like your computer printer does—one horizontal band at a time.

**Beam movement:** The most common way to move the beam of the oscilloscope (scope for short), is to move it from the left side of the screen to the right side at a constant rate. The voltage we are interested in "seeing" or measuring is then used to move the beam up and down on the screen. In this way the screen shows a plot of the voltage as a function of time. When the beam gets to the right side of the screen, it is turned off and then moved back to the left side.

**Triggering:** Before starting a new *sweep* from the left side to the right side of the screen, the scope waits to be "triggered". If the input signal is periodic and the scope triggers on the same point of the waveform each time, then the beam will draw a similar part of the waveform each time and the trace will appear stable. Look at the figures below. The first shows a continuous periodic waveform.

![Waveform](image)

The second shows the pieces that will be seen on the scope screen.

![Scope Screens](image)
Control groups: The profusion of controls on a scope allow you to control the beam movement and triggering as well as some other things we won't cover in this lab.

These controls may be separated into four groups. One group controls the vertical (up and down) movement of the beam. The second group controls the horizontal (side to side) movement of the beam. The third controls the triggering. The remaining group controls everything else—power, beam intensity, beam focus, etc.

Screen divisions: The screen of the scope has a grid pattern printed on it, usually about 1 cm by 1 cm. These are called divisions, and the controls refer to these divisions in ways that let you take measurements from the screen.

Controls
The next page shows the oscilloscope that you will use in this lab. We'll take a look at the controls one at a time and see what they do. The horizontal controls are numbered on the figure as H1, H2, ..., the triggering controls are numbered as T1, T2, ..., and the vertical controls are numbered as V1, V2, ....
H1, SEC/DIV: This is the most important control in the horizontal group. It controls the how fast the beam moves (or sweeps) across the screen from left to right. It is calibrated in seconds, ms ($10^{-3}$ seconds), or µs ($10^{-6}$ seconds) per horizontal division on the scope screen. By knowing how much time it takes the beam to move across one horizontal division, you can get all sorts of timing information from the scope screen.

H2, Sweep rate fine adjust: With this little center knob you can adjust the beam's horizontal speed more finely. This can be handy when you are interested in relative time measurements, but can also cause problems. You should always check this knob to make sure that it's in its "CAL" (calibrated) position before taking time measurements with the scope. If it isn't, the number from SEC/DIV knob won't be right.

H3, <POSITION>: Horizontal position. Moves the screen display left and right without affecting its scale.

H4, HORIZONTAL MODE: Leave on A.

T1, LEVEL: Remember the earlier discussion of triggering? The scope is usually used to view a periodic waveform over and over. To make the trace (line on the screen) appear stable, the horizontal movement of the beam should start at the same point on the waveform for each sweep. That point is defined by a voltage level and a slope (+ slope means the is voltage increasing). The scope waits for a certain input voltage level and slope before starting the next left-to-right sweep. The LEVEL knob control sets the trigger voltage level.

T2, SLOPE: If the input waveform is periodic, then the input voltage will pass through any level at least twice, once going up and once going down. The SLOPE switch tells the scope which of these two occurrences you wish to trigger on.
**T3, SOURCE:** Selects the source of the voltage the scope uses for triggering. INT means that it will use the same voltage it is using for the vertical display. Leave on INT for now.

**T4, INT trig:** Selects which displayed voltage the scope will trigger on. You can display more than one input, CH1 and CH2. This switch allows you to trigger only on the channel 1 voltage (CH1), only on the channel 2 voltage (CH2), or independently (VERT). Leave on CH1 for now.

**T5, AUTO NORM:** Tells the scope how long to wait for the next trigger. AUTO = wait for a little while, then sweep even without a trigger. NORM = wait as long as it takes. Leave on AUTO for now.

**V1, CH1 BOTH CH2:** There are two complete sets of the vertical controls. That is because you can display two different voltages on the scope at the same time. The first is called channel 1 (CH1), and the second is called channel 2 (CH2). You can display either one by itself or both at the same time.

**V2, ADD ALT CHOP:** If you choose to display both traces, you have some more choices. You can ADD them together, making one trace, or you can display them separately by two methods, ALT or CHOP. Leave in CHOP for now.

**V3, INVERT:** If you push this switch in, the channel 2 voltage will be displayed upside-down. This is sometimes used in conjunction with the ADD switch to subtract two traces.

**V4, VOLTS/DIV CH1:** This is the most important control in the vertical group. It controls how far the beam moves up or down on the screen for a given input voltage. It is calibrated in volts and mV (10^{-3} volts) per vertical division on the scope screen. By knowing how many volts it takes to get the beam to move up or down one vertical division, you can take all sorts of voltage measurements from your scope screen. You can read the volts/div in two places. Upper left if you’re using a 1X probe (a probe is the connection to the voltage you want to measure), upper right if you’re using a 10X probe. For now, our simple BNC-to-clip probes are 1X.

**V5, Vertical gain fine adjust:** With this little knob you can adjust the beam’ s vertical response to input voltage more finely. This can be handy when you are interested in relative voltage measurements, but can also cause problems. You should always check this knob to make sure that it’ s in its "CAL" (calibrated) position before taking voltage measurements with the scope. If it isn’t, the number from VOLTS/DIV knob won’ t be right.

**V6, § POSITION:** Vertical position. Moves the trace up and down. The left knob is for CH1, and the right knob is for CH2.

**V7, AC-GND-DC Switch:** In the AC position, the voltage displayed on the scope is only the changing part of the input voltage, with no average or DC voltage shown. The DC component is filtered out with a capacitor. In the DC position, the voltage displayed on the scope is the input voltage, with no parts missing. In the GND position, there will only be a
zero voltage line displayed on the scope. You can use this to set up the zero baseline on the scope with the POSITION knob. When you switch back to the AC or DC position, voltages can be measured relative to the known zero baseline.

Ok, that pretty well covers what you need to know about the controls. If you didn’t commit all that to memory, then keep this lab as a reference. Next, let’s see how to take some measurements from the screen of the scope. This can best be shown by example.

EXAMPLE: The drawing at right shows the screen of an oscilloscope. The zero baseline (ground) for channel 1 is the center line of the screen and the zero baseline for channel 2 is the bottom of the screen. The scope is set as follows:

CH1 VOLTS/DIV: 0.5V/div
CH2 VOLTS/DIV: 2v/div
SEC/DIV: 0.2mS/div
INT trig: CH1.

a) Find the amplitude of the channel 1 waveform.

\[
(3.1\text{div} - 0.1\text{div}) \times 0.5\text{V/div} = 1.5\text{Vpp} \quad 0.75\text{V amplitude}
\]

b) Find the maximum of the channel 2 voltage.

\[
4.6\text{div} \times 2\text{V/div} = 9.2\text{V}
\]

c) Find the minimum of the channel 2 voltage.

\[
0.2\text{div} \times 2\text{V/div} = 0.4\text{V}
\]

d) Find the average, or DC value of each voltage.

\[
\text{CH1:} \frac{3.1\text{div} + 0.1\text{div}}{2} \times 0.5\text{V/div} = 0.8\text{Vpp} \quad \text{CH2:} \frac{9.2\text{V} + 0.4\text{V}}{2} = 4.8\text{V}
\]

e) Find the period and the frequency of the channel 1 waveform.

\[
T = 3\text{div} \times 0.2\text{ms/div} = 0.6\text{ms} \quad f = 1/T = 1/0.6\text{ms} = 1.67\text{Hz}
\]

f) Find the period and the frequency of the channel 2 waveform.

\[
T = (6.9\text{div} 	imes 0.2\text{ms/div}) / 3\text{cycles} = 0.46\text{ms} \quad f = 1/T = 1/0.46\text{ms} = 2.17\text{Hz}
\]

g) What is the scope’s trigger LEVEL set to?

Triggering on CH1, CH1 starts at about 2.6 div \times 0.5V/div = 1.3V

h) What is the setting of the SLOPE switch? CH1 starts on downward (-) slope

Note: While the drawing above is OK for this example, it would be almost impossible to actually get these traces stable in real life unless \( f_{\text{CH2}} \) were an integer multiple of \( f_{\text{CH1}} \). Can you see why?

Preliminary Problem

Refer to the screen at right. The zero baseline for channel 1 is the center line of the screen and the zero baseline for channel 2 is the bottom of the screen. The knobs are set as follows:

CH1 VOLTS/DIV: 50mV/div
CH2 VOLTS/DIV: 0.2V/div
SEC/DIV: 0.5ms/div
INT trig: CH1
a) Find the amplitude of the channel 1 waveform.

b) Find the peak-to-peak voltage of the channel 2 waveform.

c) Find the maximum of the channel 2 voltage.

d) Find the minimum of the channel 2 voltage.

e) Find the average, or DC value of the each voltage.

f) Find the period and frequency of the channel 1 waveform.

g) Find the period and frequency of the channel 2 waveform.

h) What is the scope’s trigger LEVEL set to?

i) What is the setting of the SLOPE switch?

**Experiment**

This lab does not lend itself well to the standard lab notebook format, so no notebook will be required. Simply fill in the blanks in this handout and hand it in. To make up for not keeping a notebook, *everyone will have to work individually!* If there are not enough scopes, take turns with the same equipment. It is important that everyone turns the knobs and takes their own measurements from the screen. The point is to get everyone familiar with the scope.

**Booklet:** I’ve asked you to check out a Tektronix booklet on the scope. Look it over now if you still have questions that my earlier explanations did not answer or if you were confused by those explanations. Keep the booklet handy as a reference during this lab.

**DC measurements:** Set up the oscilloscope as shown. Adjust the CH1 vertical position knob so that the horizontal line is centered half-way up the screen. If you have any trouble getting a trace across the center of your screen, call your TA over for help. Turn the AUTO INTENSITY knob so that your trace is not too bright. A trace that is too bright will not be sharp and can burn the phosphor of the CRT. Turn the FOCUS knob to focus the beam.

Connect a BNC-to-Clip cable to the CH1 input of the scope (use a push and twist motion), and the alligator clips to the B&K as shown. Turn on the B&K and set it to 3V.
How many vertical divisions did the trace move up? ___________________________
Determine the B&K voltage from the scope trace. ________________________________
Change the VOLTS/DIV knob to 2V/div, what happened to the trace? ________________

Determine the B&K voltage again. ____________________________________________
Return the VOLTS/DIV knob to 1V/div. Reverse the leads at the B&K. How did the trace change? ____________________________________________
Switch the AC GND DC switch to AC. What happened to the trace? ______________

Reverse the leads again to the red-red, blk-blk configuration and switch the AC GND DC switch back to DC. Play with the voltage knob on the power supply while you watch the scope screen. Adjust the VOLTS/DIV and POSITION knobs as needed to keep the trace on the screen. The point I want you to get here is that the scope is just a voltmeter and it can show DC as well as AC.

**Horizontal beam movement:** Disconnect the input from the power supply and adjust the POSITION if necessary to get a trace. Turn the SEC/DIV knob to 0.2s/div. Does the spot of light move across the screen at a constant speed? __________________________
Does it take about two seconds? ____________________________________________
Turn the SEC/DIV knob to 0.1s/div. Does the spot of light now move twice as fast? ______
Does it take about one second? ____________________________________________
At what setting of the SEC/DIV knob does the display look more like a line than a moving spot? __________________________

**AC low frequency:** Set up the oscilloscope as shown. Adjust the CH1 vertical position knob so that the horizontal line is centered half-way up the screen.

Turn the Krone Hite function generator AMPLITUDE knob fully CCW. Connect the function generator to the Simpson meter and the scope as shown. The function

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generators come in two styles, one has more knobs and buttons than the other. The extras are shown dotted on my drawing. Set up the function generator and meter as shown. Adjust the AMPLITUDE knob of the generator so the meter needle swings about half way up and back. Notice that the needle would like to swing down as well but it’s physically unable to show the negative part of the waveform. The function generator should produce a sine wave of about 1 Hz (cycle per second). Do you see the spot on the scope moving in sync with the meter needle? __________ Both are responding to voltage. At very low frequencies the voltmeter can be used to see the relationship of the input voltage and time. Turn the frequency knob (on the function generator) to a higher number. At what frequency is the voltmeter no longer able to keep up? __________ Adjust the SEC/DIV knob of the scope and make some astute observation about the capability of the scope as verses the voltmeter. ________________________________

**AC measurements:** Disconnect the voltmeter from your circuit, and connect the output of the function generator directly to the scope with a BNC-to-BNC cable. Turn the frequency knob on the function generator to 10, and push the M UL T 1 button. Turn the SEC/DIV and VOLT/DIV knobs on the scope until you get a good trace (a good trace shows about 1 to 2 periods of the waveform and isn’t too small vertically). Adjust the frequency knob throughout its range. Repeat this for each of the frequency multiplier buttons (1, 100, & 10k) on the function generator. Can you find a frequency that the scope is no longer able to display? ________________________________

Push the M UL T 100 button on the function generator and get a good trace on the scope. Turn the amplitude knob (on generator) up so that the trace almost fills the scope screen grid from top to bottom. What is the amplitude of the voltage? ________________________________

Turn the VOLTS/DIV knob to the next higher number. Measure the amplitude again. ________________________________

Which measurement do you think is most accurate? ________________________________
Find the period of the waveform from your scope. ________________________________

What is the waveform’s frequency? ________________________________

Change the settings on the function generator to whatever you want. Find the amplitude and frequency of the waveform. Repeat. Change amplitude and frequency settings each time.
Amplitude ________________________________ Frequency ________________________________
Amplitude ________________________________ Frequency ________________________________

Try the other "FUNCTION" buttons.
Amplitude ________________________________ Frequency ________________________________
Amplitude ________________________________ Frequency ________________________________

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**Dual Trace:** Hook another cable from the TTL OUT of the function generator to the CH2 input of the scope. Switch the CH1 BOTH CH2 switch to BOTH. Get a good trace for channel two by adjusting the CH2 VOLTS/DIV and POSITION knobs. Describe what you see.

**Trigger adjustments:** Push the button below the sine wave or triangle wave symbol on the function generator. Adjust the trigger LEVEL knob on the scope. What happens to the trace? ____________________________

Why? ____________________________

Change the position of the SLOPE switch on the scope. What happens to the trace?

Why? ____________________________

Turn off channel two and disconnect both cables.

**Audio signal:** Connect the scope (CH1) to a speaker the little speaker. Turn the VOLTS/DIV knob to the most sensitive position (fully clockwise). The trace may be a little fuzzy, this is caused by electrical noise and may be lessened if you don’t hold the speaker in your hand, try to ignore it. A speaker can also function as a microphone, and that is how we will use it here.

Speak into the speaker. Can you "see" your voice on the scope? Try different settings of the SEC/DIV knob to see how the trace is affected. Notice that each sweep starts at the same level and slope, even though the waveform isn’t periodic. That’s just the scope triggering on what ever it can.

**Conclusion**
This should give you a quick overview of the most important features of the oscilloscope. The booklet will help you explore further if you want. Throughout the rest of this semester you will use the scope for many of your measurements and will become much handier with it.

The speaker should (hopefully) have been in a plastic bag when you got it. Please return it in that bag.