Measuring the Speeds of Sound and Electricity

Goals:

- **Measure the speed of sound in air and the speed of an electric pulse in a wire.**
- **Learn the use of a digital oscilloscope for later, more challenging lab work.**

The time it takes information to travel from source to receiver may have an effect on the way that information should be measured and interpreted. Figure 1 below shows the oscilloscope's record of one measurement of the time it takes for a sound pulse to travel from source to both receivers. We will first describe how to interpret the record, and then how to get your oscilloscope to produce a similar display.

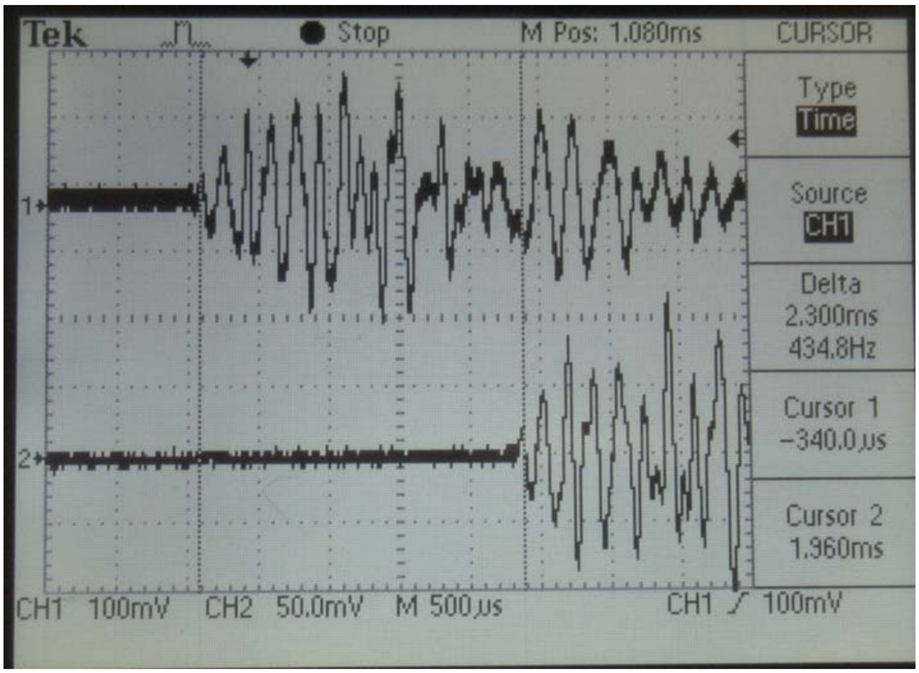

Figure 1: Sound pulses generated by the two sensors

In figure 1 you see two graphs, or traces, on the screen. The top trace is a report of the voltage signal connected to Channel 1 on the oscilloscope, and the bottom trace reports voltage signal connected to Channel 2. The graphing divisions are the light dotted boxes on the screen grid which are 1 cm x 1 cm and have 5 secondary divisions. The units are displayed at the bottom of the screen, following the letter "M" (for "Main time base"). The time scale is "500 μs" or 500 microseconds per division. This means that each (cm) horizontal division on the screen grid represents 500 μs (microseconds) or half of a millisecond. In the lower left of the bottom of the screen the sensitivities of Channels 1 and 2 are displayed. We have set Channel 1 to move one vertical division for every 100 millivolts (0.1 Volts), and Channel 2 to move one division for 50 millivolts .

The sound sensor closest to the source of a loud, brief sound (a clap or a bang) is connected to Channel 1. A second sound sensor that can be placed anywhere from 0.1 meter to 1 meter away from the first sensor is connected to Channel 2. The horizontal distance between the starting points of the two disturbances on the screen indicates the time it took sound to travel from the first to the second sensor (about 5 divisions).

Prelab Question #1: There is a very good reason for making channel 2 more sensitive than Channel 1. What do you think it is?

To get your oscilloscope to make this measurement you must learn how to set the buttons and knobs on the panel to the right of the screen. This is a bit challenging since most of the knobs and buttons have several functions that are chosen by screen menus.

These are the important things to control:

	What you want to control	Panel button
A	When the trace starts	Trigger
B	How fast the trace moves horizontally	Sweep Rate
C	How much the trace moves vertically for a specific input voltage	Sensitivity
D	Which Channel controls the trigger	Source

A) Trigger: The start of the trace is set with the controls on the right of the panel under the label "Trigger" in Figure 2. Each of the five boxes down the right side of the screen lines up with one of the five buttons next to them on the panel to the right of the screen. Those buttons will select the choices available.

The top box should read "Edge", meaning the trace will "trigger" when the level of the input voltage crosses a pre-set value or "Edge". The second box ("Slope") lets you choose between starting the trace when the input voltage rises above the preset level, or starting when the voltage falls below that value. Most people visualize the trace starting when the voltage rises above a specified value, so it is set it to read "Rising". (Since we are going to measure a DIFFERENCE between two values, the "Falling" choice would also work.)

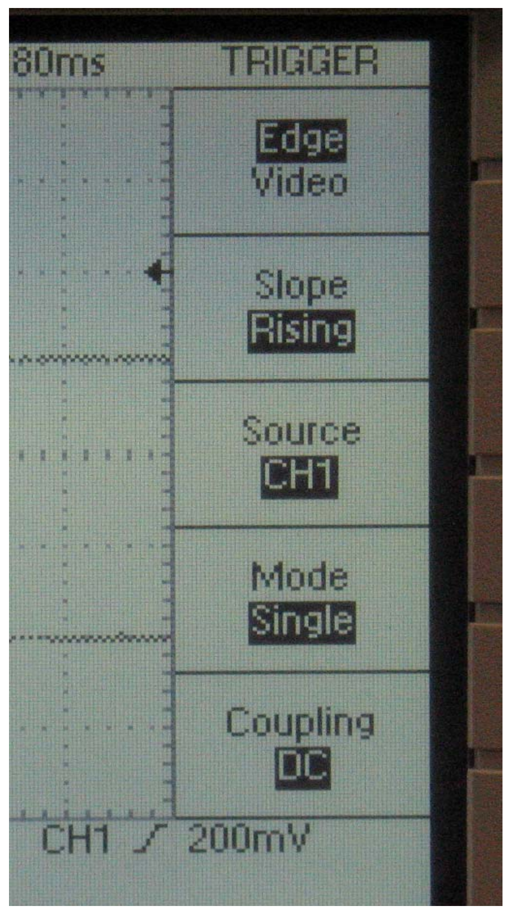

Figure 2: The "Trigger" Menu (A)

The value that the signal must Rise through is set with the knob labeled "Level", found on the panel just below the "Trigger" label (Figure 3).

As you turn the "Level" knob (Figure 3), you will notice a small pointer arrow moving on the right side of the screen (next to the "Slope" box in figure 2). It marks the voltage "level" through which the Channel 1 signal must rise (or fall) to start the trace. The exact value of that trigger level is shown in the lower right hand corner of the screen.

Figure 3: The Control Panel

The third box down, labeled "Source", allows you choose which Channel will control the trigger. Since our first sensor is connected to Channel 1, we will choose CH1 as our triggering Channel. The other choices for "Source" are explained in the Appendix at the end of this document.

The fourth box indicates the "Mode" of the sweep. For this experiment it should be set to "Single". In this mode the sweep starts when the input voltage reaches the trigger level. The trace sweeps across the screen once, recording any signal changes that occur in that brief time, and then freezes that pattern on the screen. This ability to hold a signal is one of the important features of a digital oscilloscope. The single sweep is controlled by the "RUN/STOP" button in the upper right of the panel just above the trigger label, and its status is displayed at the top center of the screen. If that read-out says "Ready" the scope is ready to start a trace as soon as the signal reaches the trigger level. When the input signal reaches the trigger level, the trace sweeps across the screen once and stops. The status read-out changes to "Stop" and the screen holds the displayed pattern. To make a new reading, first make any needed adjustments, then press the "RUN/STOP" button. The status reported at the top of the screen will change to "Ready" and the next time the input signal reaches the trigger level, a new trace will start. In the "Single" mode it may be necessary to try several adjustments of the trigger level to find a value that does not start the sweep on the noise in the room but does respond to the sound being studied.

The last box, "Coupling" should be set to "DC". This setting will put both steady (DC) signals on the screen and changing (AC) signals, and it's the one we use for all the work in this lab.

B) Sweep Rate: This adjustment is made with the knobs and buttons in the third column from the right of the screen, labeled "HORIZONTAL". The most important of these is the large knob near the bottom labeled "SEC/DIV". The current setting of that knob is displayed at the bottom center of the screen, following the letter "M" as earlier described. If it is set too fast, the sweep will end before the sound arrives at sensor 2. If it is set too slow, the blips from the first and second sensors will appear too close together and it will be difficult to determine their time difference. When set correctly, the starting blip on CH1 and the later blip on CH 2 should be more than half a screen width apart.

C) Sensitivity: This determines how much the trace moves vertically for each millivolt of input signal. It is controlled separately for each Channel. The controls that do this are in the two columns closest to the screen, with the heading “VERTICAL” above them. The sensitivity is set with the large lower knobs labeled “VOLTS/DIV”, and its current value is displayed along the bottom edge of the screen, left of center. The “CH1 MENU” and “CH2 MENU” buttons in the middle of those columns select the Channel you are working with.

If repeated pressing of the button does not make the line appear on the screen, it may be because the trace is above or below the screen boundaries. The “POSITION” knobs can raise or lower the trace. When either position knob is turned an information statement briefly appears at the very bottom of the screen to tell you where the trace is (see Figure 4). The zero reference for this is the horizontal middle line of the screen.

In Figure 4 the “CH1 MENU” button has been pushed, and the five boxes on the right of the screen now indicate the choices for Channel 1. The first of these, “Coupling” will usually be set to “DC” which responds to all types of electrical signals.

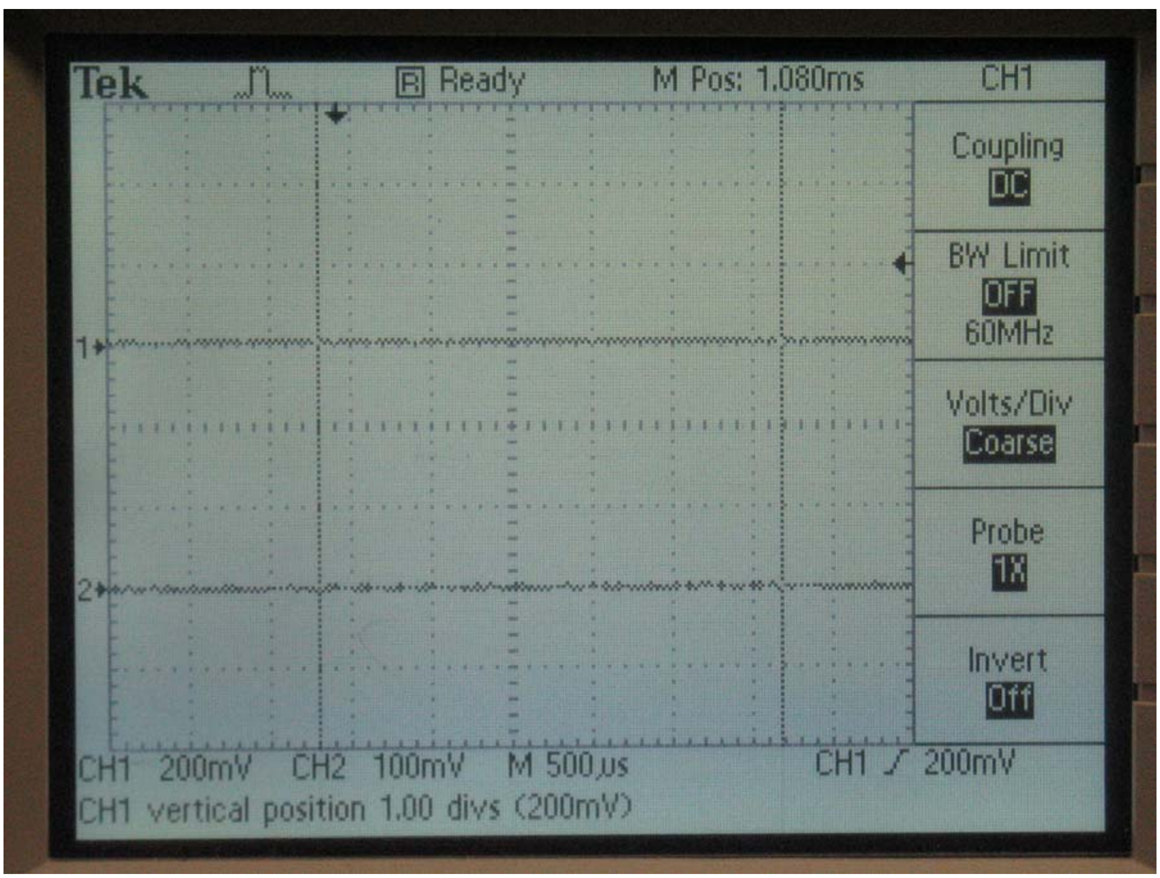

Figure 4: Channel 1 Menu with Position Information shown at bottom of screen

The CH2 menu should be set the same. The "Invert" option in the bottom box will be useful in later labs, however not all the oscilloscopes have and "Invert" button. It flips the displayed pattern, and has the same effect as switching the polarity of the displayed signal.

Measuring the Speed of Sound

Figure 5 shows the equipment set up to measure the speed of sound. You will note that we are using small speakers as our sensors. A device that can convert an electric signal into sound can also convert a sound into an electric signal.

It is important to hold the block as shown, above the table and not too close to the sensor. It is also important to hold the block at least 30 cm from the first sensor, and slightly off to the side to keep the second sensor out of the sound "shadow" of the first sensor.

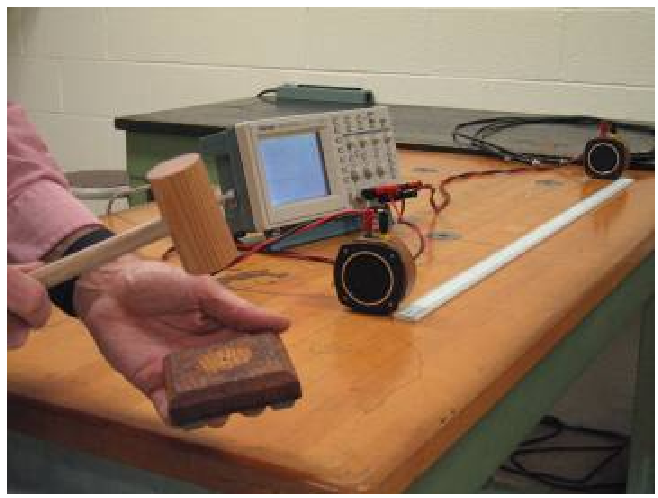

Figure 5: Measuring the Speed of Sound

PreLab Q2: Why is it important to hold the wooden block above the table as shown in Figure 5 when striking the block to generate the sound pulse?

Measuring the time difference

In this experiment the measured times are found as differences between two readings on the horizontal scale. To see the time difference you must access the "Cursor" menu by pressing the "CURSOR" button just above the "VERTICAL" label near the top of the panel. Figure 6 shows both of the sound signals AND the actual time interval between them, "Delta" (2.840 ms)is displayed under the word "Delta" in the third box on the right of the screen.

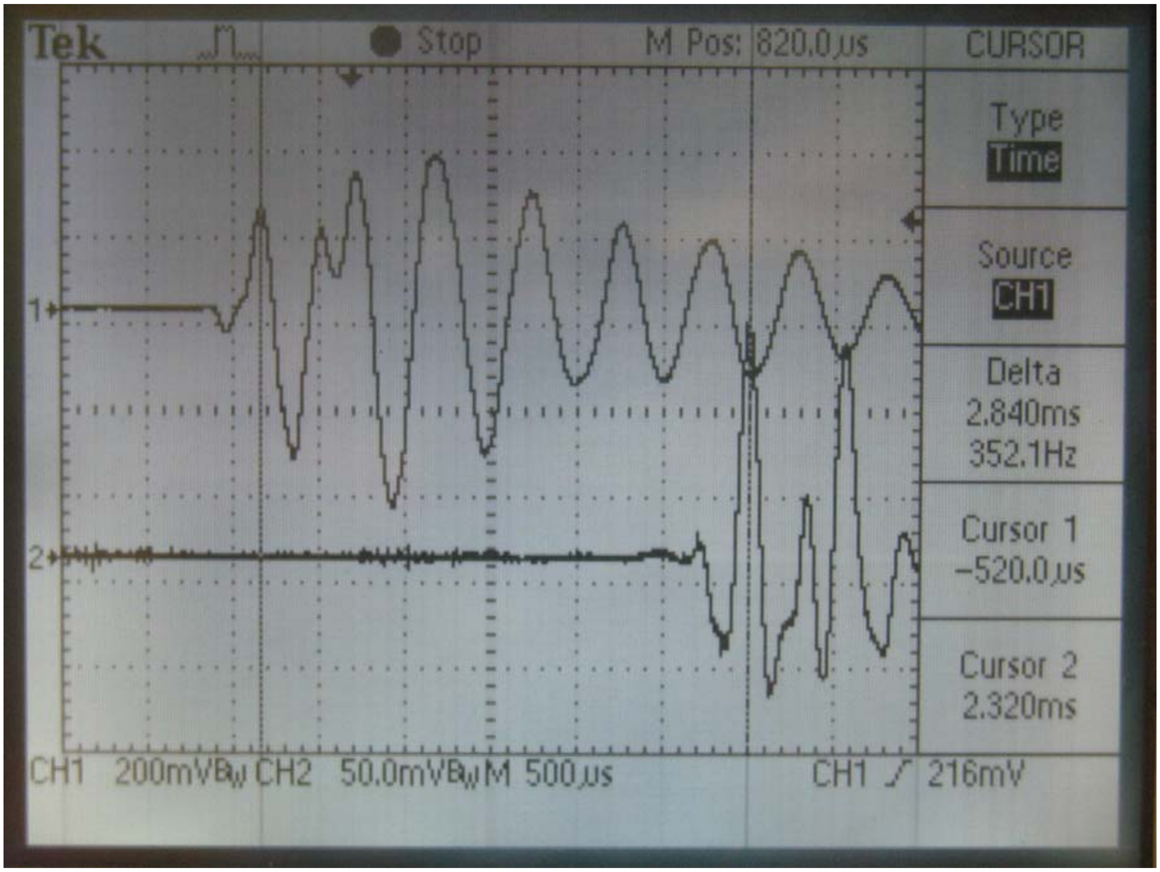

Figure 6: The signals from the two speakers used to measure the travel time of sound

Set "Type" to "Time". That causes two vertical lines to appear on the screen. They are controlled by the two "Position" knobs that usually control Channel 1 and Channel 2. (To regain the original Channel position functions, press the CH1 or CH2 Menu buttons). As you move each of these cursor lines to similar peaks or valleys at the beginning of each signal, the difference between their times is digitally displayed in the third "Delta" box.

To find the time difference, count the horizontal divisions and secondary (0.2 cm) divisions from the start of Channel 1's disturbance to the start of Channel 2's and multiply by the scale factor of 500 μs per division. The actual distance between the sensors is determined with a meter stick.

Measuring the Speed of an Electric Signal

We will now use the oscilloscope to measure how fast an electric pulse moves in a wire similarly to what we did with sound. We will measure how fast a pulse moves, not how fast an individual electron moves. There are several important changes.

First, the source of the pulse will be a small black electronic box connected to the wire and oscilloscope with a "T" connector. Note there are actually two "T" connectors at the Channel 1 input because the pulser does not send out a signal unless a load resistor is included in the circuit. The resistor is in the cap on the left side of the "T" connector in Figure 7 circled in yellow.

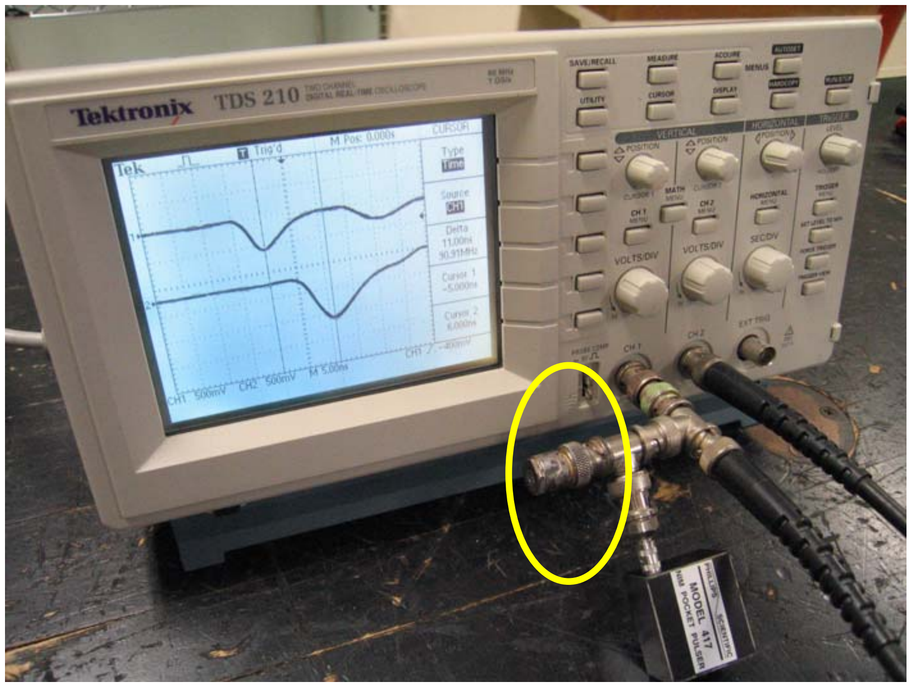

Figure 7: Measuring the speed of pulses in a cable

If you don't see the signal, push the "AutoSet" button to initialize the scope settings. Speeds will be A LOT faster, so you must change the sweep time to the 5 nanosecond (5 ns) per division range. The sensitivity should be about 200 mV per division.

The electronic pulser produces negative pulses, so it may help to change the Trigger Menu scope setting to "Falling" here.

The last important change is that the Trigger Mode must be changed from "Single" to "Normal". This is because the small electronic pulser sends out a repeating signal, and the "Normal" mode repeats the trace every time a new pulse occurs.

In Figure 8, CH 2 is set to 2 V per division because the CH 2 "Probe" menu box is set to "10X". If you have the Probe set at "1X", use the 200 mV sensitivity.

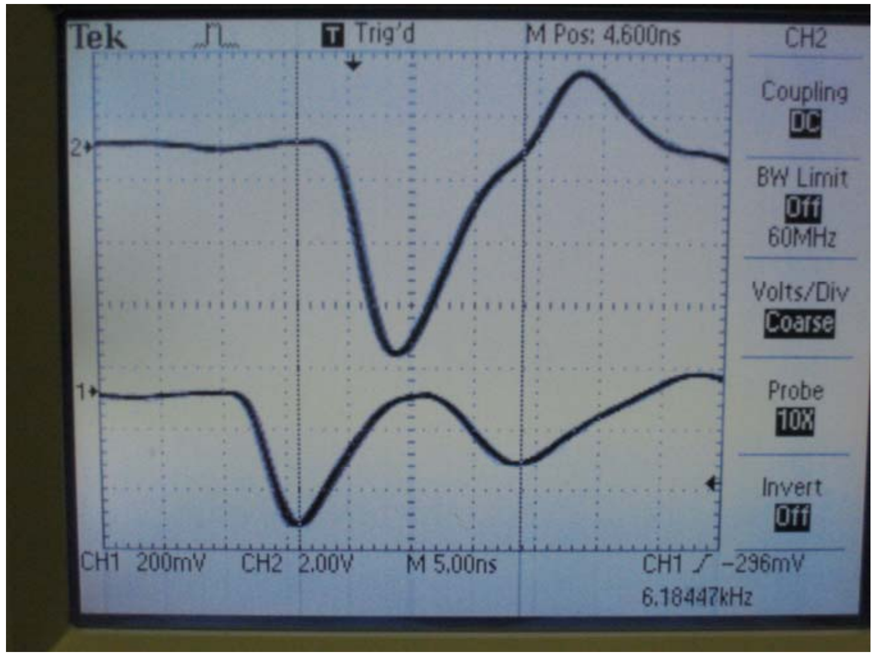

Figure 8: Channel 2 Settings for Measuring the Electric Pulse

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Appendix: Other important scope details not covered above.

Each MENU button cycles through three operations as you repeatedly press it:
a) Display the trace for that Channel on the screen
b) Insert the menu for that Channel on the right of the screen, so that the five pushbuttons can make choices for that Channel.
c) Remove the trace for that Channel from the screen

Trigger settings:

<u>SOURCE</u> "Source", lets you choose which Channel will control the trigger. The choices in that box are:
"CH1" which uses CH1 to trigger
"CH2" which works just like "CH1"
"EXT" which triggers the trace using a separate input signal connected to the "EXT TRIG" jack next to CH 2.
"AC" which will trigger at the same rate as the 60 cycle AC power in our electric outlets.

We will usually trigger on “CH1”, although occasionally an “EXT” connection will eliminate some unwanted electrical noise.

MODE In “Single” mode the sweep starts when the input voltage reaches the trigger level described above. The trace sweeps across the screen once, recording any signal changes that occur in that brief time, and then freezes that pattern on the screen. For most oscilloscope applications the “MODE” setting will be “Normal”. This setting starts a new trace from the left side of the screen as soon as: a) the last trace ends, and b) the signal to CH1 passes the pre-set trigger level again. The human eye can only report visual changes about 30 times a second. If the pattern repeats faster than that, it appears constant to the eye. In this respect the “Normal” mode functions like a strobe light. It synchronizes rapidly repeating electrical changes with the screen sweep so our “slow” vision can see them “sitting still” on the screen. The same outcome can be produced with the “External” mode. It differs in that the sweep triggers on the voltage of a separate signal applied to the right-most input jack labeled “EXT TRIG”. There is also an “Auto” mode setting in which the oscilloscope starts a new trace at the moment the last trace ended, without waiting for the signal to reach the trigger level. This setting does not synchronize with the input changes, and could be termed a “free-run” mode. It is often used to find a “lost” trace on the screen, because the trace is present even if there is no input signal.

COUPLING The “DC” setting will put both steady (DC) signals on the screen as well as changing (AC) signals, and it’s the one we use for all the work in this lab. The “AC” setting only reports changing signals. It ignores steady (DC) signals, and the trace remains at zero for them. There are situations when that is very helpful, but we will not see any of them.

“CH1 MENU” settings:

“Coupling” will usually be set to “DC”. This is for the same reasons that we used DC coupling for the trigger; it responds to all types of electrical signals. “Ground” setting connects the Channel 1 input to the electrical ground of the oscilloscope. In other words, it guarantees a zero volts display of the Channel 1 trace. The zero position can be moved with the “POSITION” knob, and is shown by the small “1” (with an arrow) in the left margin of the screen. Sometimes electrical noise will cause the trace to vibrate, and the ground setting produces a thin, smooth line that can be accurately positioned exactly on one of the screen gridlines. This greatly simplifies converting the position of the line to a voltage or time

“Cursor” menu settings:

The first box, labeled “Type” should be set to “Time. That causes two vertical lines to appear on the screen. They are controlled by the two “Position” knobs that usually control Channel 1 and Channel 2. (To regain the original Channel position functions, press the CH1 or CH2 Menu buttons). The difference between their times is digitally displayed in the “Delta” box.

Figure 9 : The Oscilloscope panel