A. Introduction

The oscilloscope is one of the most useful and versatile of measurement devices. It is basically a very fast voltmeter. That is, you can use it to measure electrical voltages, even voltages which are changing very rapidly and abruptly. The reason that this is so useful is that most physical quantities can easily be translated into voltage. For example, a microphone converts sound pressure into voltage, so you can use the oscilloscope to “look at” sound. A special form of oscilloscope is used to monitor the electrical signals from the heart during surgery. And, of course, the oscilloscope is an important instrument used in the repair of electronics.

B. How the Oscilloscope Works

The most important component of the oscilloscope is the cathode ray tube (CRT), a vacuum tube in which a filament is heated to “boil off” electrons which are then focused into a beam and “shot” toward the screen with an electron gun. The screen is coated with fluorescent material which glows when it is hit by the electron beam. On its way to the screen, the beam passes between two sets of deflection plates (horizontal and vertical) and a voltage applied to these plates will cause the beam to curve. The sketch illustrates the CRT components with a negative voltage applied only to the vertical plates \( V_y \), causing the beam to bend downward. The amount of deflection \( d \) shown on the screen is proportional to the voltage applied to the plates, so you can measure the voltage by seeing where the beam hits the screen.

The Hitachi oscilloscope you are using has many electronic refinements associated with the CRT to allow electronic signals to be conveniently displayed and measured. This means there are lots of knobs to control its functions. The following sections describe these controls and tell you how to get the oscilloscope ready for the experiment.

C. Getting Started

The last page of this write-up is a summary explanation of the control functions of the scope. Don’t worry if you don’t understand it—you will by the time you work through this lab. Use the summary page as a map as you work. Then you can use it as a quick reference in future labs.
The scope can accept two different inputs at once. (That’s one reason there are so many knobs—many are duplicates.) The first measurements you make will use input channel 2, for reasons that you don’t need to worry about.

On the summary page, each control on the scope has been matched to a circled number which is either light (such as â) or dark (such as ?). As much as possible, controls have been paired. For example, numbers ?, ?, Ç, and ì control the same functions for channel 1 (CH1) as ?, ?, ?, and Ê control for channel 2 (CH2).

- Push the POWER â and turn the TIME/DIV switch ? all the way clockwise to X–Y.

- Turn all three POSITION controls ÏµÊ to 12 o’clock (mark up, like so: Ø). Don’t pull them out because if you do they won’t be position controls anymore. A dot should appear on the screen.

- Play with the INTENSITY, FOCUS, AND ILLUMination controls ?. Use the focus knob to get a sharp, round dot. Use only as much intensity as you need; excessive brightness for prolonged periods can damage the screen. In a lighted room, you will probably find that you prefer to have the scale illumination turned all the way down, but use as much as you like.

- On the screen is a grid to help you
to measure the position of the dot. The grid looks like this.

Some of the knobs on the scope refer to “divisions” (DIV). Each division is marked off by a solid line. Within the divisions are small hatch marks. These marks are not divisions. Since there are five marks per division, each mark is 0.2 divisions.

D. Measuring DC Voltages

The oscilloscope is, fundamentally, a voltmeter. You are provided with a box which produces eight different DC voltages for you to measure. The box has already been connected to a power supply, so you can simply turn on the power supply and you’re ready to go.

Defining Zero

Using one of the leads provided, connect the ground terminal of the scope Ȳ to the black ground terminal of the voltage box, both of which are marked with the ground symbol ¼. All voltages are measured relative to this ground. Now use another lead to connect the CH2 input ?p to the ground. Since ground is defined to be zero, you are now measuring zero volts. Use the CH2 position control Ê to move the dot on the screen up or down to some convenient place. Since all of the voltages you will be measuring in this section will be positive, the best place is the bottom line of the screen grid. This allows you to use the entire screen for measurement. Moving the line to this position when the CH2 input is grounded defines the bottom line of the grid as zero volts. In the left-right direction, you will want to have the dot in the middle of the screen, so that you can take advantage of the hatch marks to help you measure the position of the dot accurately. To move the dot left-and-right, use the horizontal POSITION control ¬.
You can ground the CH2 input in two ways. You can take a wire and connect it from the CH2 input to the ground terminal. But it is easier simply to flip the CH2 input selector switch to the position labeled GND (which is an abbreviation for ground). The dot on the screen will drift around some over time, particularly as the scope warms up, so it is important to check it frequently as you make these measurements. You check it by grounding the input and then looking at the dot to make sure it’s in the correct position. If necessary, use the position controls to move the dot. Then you have to remember to put the input selector switch back on DC to make measurements.

Practicing with Known Voltages

Turn the CH2 VOLTS/DIV knob fully counter-clockwise, to 5 volts/div. When you connect the CH2 input to the largest “Known Voltage” on your box, about 17 volts, you should see the dot jump up about three and a half divisions. To measure the voltage, carefully count the number of divisions above the zero line and multiply by the number on the VOLTS/DIV knob.

\[3.4 \text{ div} \times 5 \text{ volts/div} = 17 \text{ V}\]

Notice that with careful measurement, you can estimate the third significant digit, but only if the scope is well zeroed. Check the zero now to see if it has drifted.

Now connect CH2 to the 3.7 V terminal. The line should be less than one division above zero. You can get a rough measurement now:

\[0.8 \text{ div} \times 5 \text{ volts/div} = 4 \text{ V}\]

However, you can do much better than this with the scope. Slowly turn the VOLTS/DIV knob clockwise, to more sensitive settings. The dot will get higher and higher on the screen and will eventually go off the screen. Turn the knob back to the position which puts the line highest on the screen but not off the screen. (This should be 0.5 V/div.) This is the setting which will allow you to make the most accurate measurement of the voltage.

\[7.4 \text{ div} \times 0.5 \text{ volts/div} = 3.7 \text{ V}\]

Each box also has a known voltage between 80 mV and 120 mV. Check your measuring technique by measuring it as accurately as you can and comparing your measurement to the value written on the box. For this particular voltage, you should use the 20 mV/div setting. Remember that this is 20 millivolts per division, not 20 volts.

Mystery Voltages

Now you are ready for the mystery voltages, labeled A–E. You will measure each one and record it on the data sheet which will be handed out in lab. Then have your instructor check your work. Start by writing the box number on the data sheet.

Your instructor will be looking to see not only that you have measured the correct voltage, but also that you have measured it as accurately as possible by using the optimum VOLTS/DIV setting. To be sure you have the right setting, use the following procedure:

- Turn the VOLTS/DIV knob to the least sensitive setting, 5 volts/div.
- Connect the CH2 input to the mystery voltage.
• Slowly turn the VOLTS/DIV knob and watch the dot, which should rise up on the screen. Keep turning the knob until the dot goes entirely off the screen. Then turn the knob back one notch. This is the best setting.

• Check the zero. Then carefully measure the number of divisions that the dot moves when you switch the input select back to DC. Record the number of divisions and the VOLTS/DIV setting (including units) in the table.

• Multiply to get the voltage.

E. Measuring AC Voltages

The oscilloscope can be used for measuring DC voltages, but so can a simple hand-held voltmeter. The real strength of the oscilloscope is its ability to allow you to look in detail at rapidly alternating (AC) voltages. Your source of alternating voltages for this lab will be the Global Specialties 2002 Function Generator.

Setting Up the Function Generator

To get your function generator ready to go, you need to do the following things:

• Push in the POWER ON button.
• There is a bank of grey buttons labeled FREQUENCY MULTIPLIER–HZ. Push in the button label 1.
• There is a white bank of buttons labeled MODE. Push in the one with the picture above it.
• Make sure both the ATT 30dB and the INVERT buttons are out.
• Make sure the knobs labeled SYMMETRY and D.C. OFFSET are pushed in, which disables them.
• Turn the AMPLITUDE knob to MAX.
• Turn the FREQUENCY dial to 0.2.

There are two outputs on the function generator, each of which has an adaptor on it with a red and a black jack. To look at the output of the function generator on the scope you need to hook up the left output to the scope input (which is labeled 50•, but the adaptors make it difficult to see the labels).

• Connect the black jack to the ground terminal of the scope.
• Connect the red jack to the CH2 input of the scope. Never connect this red output to ground on the scope or on anything else.
• On the scope, set the CH2 VOLTS/DIV knob to 5 volts/div.

You should see the dot moving slowly up and down. Notice that it goes below the zero line. This indicates that the function generator alternates between positive and negative voltages. To deal with this, you will need to redefine zero volts to be in the center of the screen. Ground the CH2 input and use the position controls to move the dot to the center of the screen. Then look at the dot moving up and down.

Slowly turn the frequency dial up to 2.0. As you do so you will notice that the dot moves up and down more rapidly. Now switch the FREQUENCY MULTIPLIER to 10. The dot is now going up and down 20 times per second (2 on the dial • 10 multiplier) which is too fast to follow with your eye. Now push the multiplier to 100. With the dot now oscillating 200 times per second, you see a solid line on the screen. (You may need to turn up the intensity.)

To see this kind of rapidly oscillating voltage, you need to make use of another feature of the scope called the sweep.

Before going on, be sure the scope and function generator are in this configuration:
CH2 VOLTS/DIV: 5 volts/div  
Function Generator FREQUENCY: 2.0 • 100 Hz = 200 Hz  
Function Generator MODE: sine, ATT 30dB button pushed out.

You should see a solid vertical line in the center of your screen.

Sweep Rate
You will now spend some time with the sweep controls (?¬Á?). But first a word about the controls ‡, ¿, and ?. In general, you will want to leave these controls alone.

• The SWP VAR (sweep variation) control ‡ should be turned fully clockwise until it clicks. If this control is not in this position, the little red light that says UNCAL will come on, telling you that the sweep rate is not exactly what is listed on the TIME/DIV knob.
• The ALT MAG knob ¿ should always be left out.
• The MODE switch ? should be set to AUTO unless you are specifically told set it otherwise.

To make sure things got smoothly, also make the following settings:

• Set the trigger SOURCE switch ? to INT.
• Set the trigger LEVEL knob Â to 12 o’clock.
• Set the channel MODE knob ± to CH2.
• Set the INT TRIG switch ε to CH2.

Now you are ready to vary the sweep rate using the TIME/DIV knob ?. This knob is currently set on the X–Y setting, which disables the sweep. To get the line to sweep across the screen, turn the TIME/DIV knob fully counter-clockwise, to the 0.2 sec/div setting. You should now see the vertical line from before sweeping slowly across the screen.

How long does it take to get across the screen grid? Since there are 10 divisions in the horizontal direction, it should take

\[ 10 \text{ div} \times 0.2 \text{ sec/div} = 2.0 \text{ seconds}. \]

Try timing the sweep to see if this is correct. (Use a wrist stopwatch, or just count “one-1000, two-1000,...”)

Now increase sweep rate by setting the TIME/DIV setting to 50 ms/div. How long should it take the line to get across the screen grid? Does this seem to be correct?

While you watch the screen, slowly increase the sweep rate to 2 ms/div. This sweep rate is fast enough for you to see the oscillations spread out across the screen. (You may need to turn the intensity up again at this point.)

The picture which you now have on your screen is basically a graph of the voltage produced by the generator (plotted vertically) versus time (plotted on the horizontal axis). The scale of each axis is determined by the settings of the TIME/DIV and VOLTS/DIV controls.

With the scope set up like this you can see in detail the way the voltage changes in time. For example, you can see why this type of oscillation is labeled ꚯ. Try changing to the ꚯ and ꙋ shapes. Then go back to the ꚯ shape.

In addition, you can measure the amplitude and period of the oscillation, as described below.
Before going on, be sure your scope and generator are in this configuration:

**CH2 VOLTS/DIV:** 5 volts/div
**TIME/DIV:** 2 ms
**Function Generator FREQUENCY:** 2.0 • 100 Hz = 200 Hz
**Function Generator MODE:** (sine), ATT 30dB button out
**Function Generator AMPLITUDE:** MAX

You should see a sine function displayed on the screen.

**Measuring Amplitude**

The amplitude of a voltage oscillation is measured in exactly the same way as any other voltage: Measure the number of divisions vertically and multiply by the VOLTS/DIV setting.

It is traditional to measure the *peak-to-peak* amplitude with the scope, which is the voltage difference from the top of the signal to the bottom. Be sure to use the most sensitive setting you can to get the most accurate measurement.

Use the position controls to make the measurement easier. For example, you can line up the lowest part of the voltage trace with one of the division lines.

For practice, measure some amplitudes and record them on the data sheet. Measure the amplitude for the following settings:

- The amplitude knob is turned fully clockwise, to MAX.
- The amplitude knob points to 12 o’clock.
- The amplitude knob is set to MAX but the ATT 30dB button is pushed in.

Record these amplitudes on the data sheet.

**Measuring Period and Frequency**

You can also measure the period of the oscillation by measuring the time it takes for the voltage to make one complete oscillation. You can then calculate the frequency by taking the reciprocal of the period.

To measure the period of an oscillation, count the number of horizontal divisions it takes for the voltage to complete one full cycle, and then multiply by the time/div. This measurement will be most accurate if you first adjust the TIME/DIV control until there are as few complete periods on the screen as possible.

Go to the label *Measuring Period and Frequency* on the Data Sheet handout and follow the instructions there for practice in measuring periods and frequencies.

**F. Triggering**

Before going on, put your scope and generator in this configuration:

**CH2 VOLTS/DIV:** 5
**TIME/DIV:** 2 ms
**FUNCTION GENERATOR FREQUENCY:** 1.0 • 1k Hz = 1000 Hz
The triggering system allows the trace to “stand still” on the screen. In order to see how it works, first you need to use the horizontal position knob to put the left edge of the trace exactly at the left edge of the scale grid. Now turn the frequency dial of the function generator back and forth as you watch the sine signal on the screen. (Don’t turn the frequency dial below 0.2 or the oscillation will be too slow to trigger on.) The picture is stretched out and compressed, but notice that it always starts from the same position on the left side of the screen. This happens because the sweep circuitry is “triggered.” That is, after the beam sweeps from left to right it jumps back to the left and waits in this “cocked” position until the appropriate signal releases it to sweep again. There are three controls that regulate the trigger:

1. The trigger signal is selected by the SOURCE switch which has three positions:
   - INTernal: The most common position for these labs. The scope triggers on the signal being fed into CH1 or CH2, depending on the position of the INTernal TRIGger switch.
   - LINE: The scope triggers on the line frequency, 60 Hz. You won’t need this.
   - EXTernal: The scope triggers on the signal fed into the TRIGger INput in the very upper right-hand corner of the scope.

2. The MODE switch can usually be used in the AUTO position in these labs. The NORMal position is useful if you want to look at a single trace, but it is harder to use for periodic signals, since the trace will disappear if the triggering level is set too low or too high.

The other two settings are used only to look at television signals.

3. The trigger LEVEL control is one you will use quite often, so play with it until you understand how it works. It sets the voltage level at which sweep begins, either on positive slope (push in) or negative slope (pull out) of the triggering signal.

Notice how synchronization is lost if you set the trigger level too high or too low. Whenever you see that rambling pattern of multiple waves, reach for the LEVEL control.

The way this scope works, you lose synchronization whenever the voltage of the displayed signal is less than the trigger level. If it falls below the trigger level for any reason, including change of the volts/div control, you will have to re-adjust the level to get it back. For example, set the amplitude on the function generator to 9 o’clock. Set the VOLT/DIV to make the display as large as is can be and still fit completely on the screen. Set the level so it triggers near the top of the trace. Now flip the volts/div switch to a less sensitive setting for a smaller picture. How do you get the display back in synch?

Triggering is one of the most important features of a scope because it makes the pattern stand still so you can examine it.

**G. Dual Trace Feature**

This scope has two separate inputs, channel 1 and channel 2, and can display both signals at the same time. It’s easy to do—the only tricky part is (guess what) triggering.

The generator has two outputs. The one on the left is currently displayed on CH2. The other output, labeled TTL, always puts out a square voltage which jumps from 0 to 5 V. Use two more banana leads to connect the TTL output to CH1 of the scope. (Remember, don’t ground the red output terminal!) Flip the display MODE switch ±
to CH1 to see this signal. You may need to adjust the CH1 VOLTS/DIV knob, and you will need to set the CH1 mode select to DC. Then switch to ALTernate to see both signals. Use the position controls to put CH1 above CH2 on the screen so they are easily distinguished. Adjust the sensitivity of each channel so the signals don’t overlap.

You can also use the CHOP mode to see both signals—use ALT or CHOP, whichever looks best. Chop tends to look best at low frequencies, ALT at higher frequencies.

The scope can also ADD the two signals and display the sum, often with interesting results.

Set the mode switch back to ALT so you can look at triggering in dual trace operation. So far you have triggered off of CH2, which you can see by looking at the INTernal TRIGger switch. Now pull the test lead out of the CH2 input. Not only does the CH2 display become a straight line at zero volts (since there is no signal coming into that channel), but the CH1 display is not stationary. That’s because the scope is trying to trigger off channel 2, but there is no signal there anymore. To synchronize it with the sweep, flip the INT TRIG switch to CH1 so it triggers on that signal. If it still isn’t stationary, adjust the LEVEL control.

H. Conclusion

By now you should understand the basic operation of the scope. Congratulations! As you use the scope in other experiments, it will become easier to use each time.

To be sure you know what’s going on, let your instructor look over the blanks you have filled on the Data Sheet, and then give you a “mystery frequency” or two for you to figure out.
OSCILLOSCOPE DATA SHEET

Name

Measuring DC Voltages

Put your data for the mystery voltages here:

<table>
<thead>
<tr>
<th>Box #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>E</td>
</tr>
</tbody>
</table>

When you are done, have your instructor check your work. Then turn off the power supply and disconnect the leads from the scope. The dot on the oscilloscope should still be at the bottom of the screen.

Now return to the lab write-up at the section entitled Measuring AC Voltages.

Measuring AC Voltages

Measuring Amplitudes

<table>
<thead>
<tr>
<th>Setting</th>
<th>number of divisions</th>
<th>volts/div</th>
<th>Amplitude (p-p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 o’clock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 o’clock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum ATT 30dB button in</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Let the ATT 30dB button back out. Then return to the lab write-up at the section called Measuring Period and Frequency.
Measuring Period and Frequency

Set the frequency multiplier to 1000 and study the accuracy of the frequency dial at the low end (250 Hz) in the middle (1000 Hz) and at the high end of the dial (1900 Hz).

<table>
<thead>
<tr>
<th>Function Generator Setting</th>
<th>number of divisions for one period</th>
<th>time/div</th>
<th>Period</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1900 Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How accurate is the dial on the function generator? Is it consistently high or low?

For a little more practice, try measuring some very high and very low frequencies:

<table>
<thead>
<tr>
<th>Function Generator Setting</th>
<th>number of divisions for one period</th>
<th>time/div</th>
<th>Period</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400 kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>