University of Utah
Electrical & Computer Engineering Department
ECE 2210/2200 Lab 4
Oscilloscope

Objectives
1 Introduce the Oscilloscope and learn some uses.
2 Introduce the Signal Generator (also called a Function Generator).
3 Observe Audio signals.

Parts to be supplied by the student:
● Breadboard and wires
● **Microphone**
● 10 kΩ resistor

Check out from window:
● HP 54654A Self-Paced Training Kit for HP 54600-Series Oscilloscopes. We will adapt this for the Agilent 3000 series scopes. (Check the kit to make sure it contains a battery and a Training Guide booklet.)

Also pick up 2 scope probes, a BNC-to-clip cable, a BNC-to-BNC cable and bannana-to-clip leads from those hanging in the lab. Pick a bench with an HP 3000 series digital oscilloscope similar to the one pictured above.

Oscilloscope
In class we've moved beyond simple DC and have been talking about voltages and currents that are functions of time. These waveforms are AC or at least have an AC component. Simple multimeters are adequate to measure DC voltages and currents but can only give some average or effective (RMS) values for AC. Some will also measure frequency and/or peak values but to *see* the waveform as a function of time you need to use an oscilloscope. Today you will learn to make some basic measurements using the 'scopes found in our lab, but first, familiarize yourself with the scope and its control groups:
1. The screen should be obvious.
2. Right beneath the screen are 6 unlabeled keys. They are "softkeys" and their functions will be shown on the bottom of the screen and will depend on the state of the scope.
3. Under the softkeys is a USB port you may find useful later, and on the left, the power key.
4. The knobs and keys on the right side of the scope are grouped according to function. You will be using controls in the "Vertical", "Horizontal","Trigger", and Measure" areas as well as some of the others.
5. The inputs to the scope are the 4 BNC connectors below all the controls.

Turn on the training board and oscilloscope Step by step:
- ☐ If you have an account in the Engman computer lab, then you can turn on and log onto the computer on your bench (use the same name and password). Look for the Agilent InfiniVision (or Keysite) scope icon on the desktop and open it if you can find it. The user guide may prove very helpful in the rest of the lab (find the User Guide table and click one of the English 3000 X-series versions)
- ☐ Open the Training kit to reveal the Training Guide booklet, the Training board and a battery . Insert the battery in the board.
- ☐ Press the pushbutton near the battery holder next to the red LED. Push once to turn on. The LED will light.
- ☐ Turn on the oscilloscope with the power button under the screen (left side). The scope should "wake up" in its default state.
- ☐ Connect the scope probe to BNC input "1" (the left-most, yellow input). Push it in and twist it clockwise to lock it in place.
- ☐ Find the "1x 10x" switch on the business-end of the probe and switch it to the 1x position.
- ☐ Connect, the probe ground (short clip lead) to a ground test point on the training signal board.
- ☐ Pull back on the sleeve covering the probe tip to reveal the hook at the end and then connect the probe tip to the number 1 test point on the board.
- ☐ Find and press the "Autoscale" key near the upper-right corner of the scope. You should now have a display of the test, point 1 waveform. If not, review the instructions above and ask your TA for help if you still can't get a trace.
- ☐ Press the "1" key in the Vertical area to activate the channel 1 softkeys. Hit the 6th softkey and then the 2nd softkey. Rotate the ↻ knob as needed to let the scope "know" that you're using a 1x probe. Unfortunately this is not automatic for the scope probe we use. You will have to do this every time you connect a new probe or change the 1x -10x switch position on the probe. If you don't, your vertical scope readings may be off by a factor of 10 or 100.
- ☐ Write a line or two in your notebook about how to turn on the scope, use the "Autoscale" and set the scope for the probe. You will be using this scope in later labs, so make sure your notes are adequate for later reference.
- ☐ From here on you will be referring to the Training Guide. You have just performed the "View a signal on the training signal board" in Chapter 1 of the guide. This guide refers to a different scope model and assumes some basic knowledge of oscilloscope controls, functions and terms. I will try to fill you in before you do each section.

Set up the vertical
- ☐ Turn to page 2-4 in the Training Guide. The "Volts/Div" knob is the knob just above the "1" key in the "Vertical" area. The "channel 1 position" knob is the knob just below the "1" key with the ▲and ▼ symbols above and below it. The "status line" is the top line of text information on the screen. Follow the directions in the guide on pages 2-4 and 2-5. 3. The "Vernier" soft key is called "Fine" on this scope. The position information is closer to the upper right than the bottom left.
- ☐ After you've finished this section, write the heading of this section ("Set up the vertical") followed by a line or two in your notebook about what you learned. You should write a similar line or two for all that sections that follow.

Set up the main time base

☐ Turn to page 2-6 in the Training Guide. The "Time/Div" knob is the big knob in the Horizontal area and the "Delay" knob is the smaller one.. (Time is the horizontal axis on the scope screen.) This section refers to "triggering" but doesn't explain this very important concept. The scope shows you volts as a function of time, but at what time? When should the scope start a new trace? These are the questions answered by the triggering function of the scope. Triggering refers to starting a new trace (or "sweep"). 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 top shows a continuous periodic waveform.
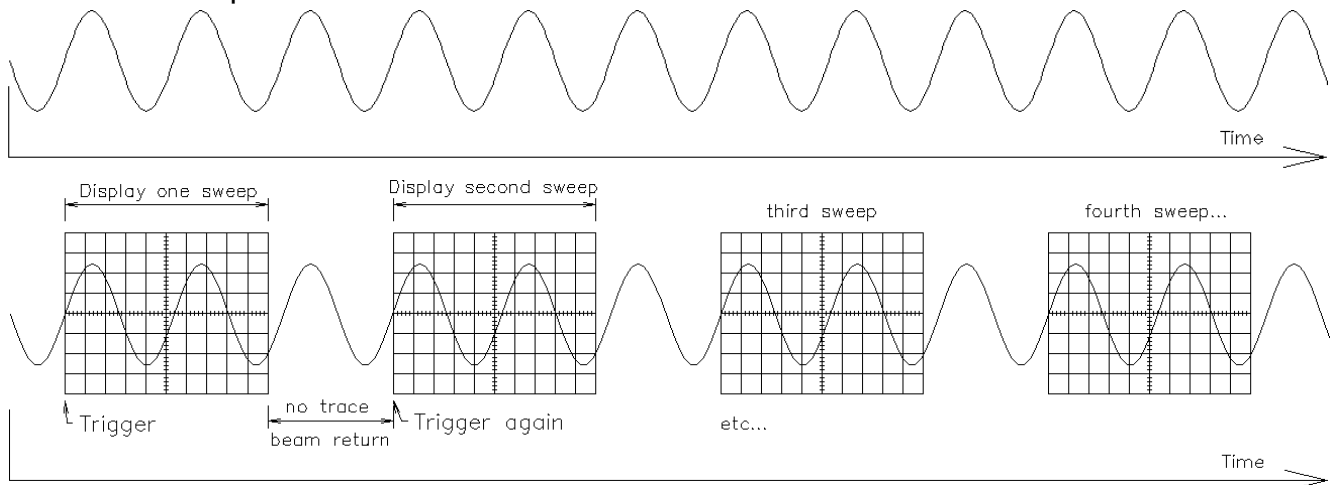
The bottom shows the pieces that will be seen on the scope screen. In this example the scope is triggering at about 0V and a + (upward) slope. How would the trace on the scope screen look different if the scope triggered on the - slope? Explain triggering in you notebook in your own words. If you're not sure, come back and answer this question after you have a trace on the scope and you've had a chance to hit the "Trigger" button followed by hitting the 3rd ("Slope") softkey multiple times to scroll through the slope options.

OK, that's how an old-fashioned analog scope works– it quite literally waits for the correct trigger before starting a new trace. But this scope is digital. It's constantly sampling, digitizing and memorizing the input, which means that it can do something no analog scope can do, it can show what the waveform was *before* the trigger. The trigger event is not at the left side of the screen on this digital scope. Instead it is either at the first vertical division (about 1 cm in from the left) or at the center of the screen, depending on how you set the scope.

Now that you understand triggering this section may make some sense. Follow the directions in the guide on pages 2-6 and 2-7.   3. Main/Delayed = Horiz

Use the delayed time base

☐ The delayed time base allows you to look at a smaller portion of the main trace in greater detail. It is accessed by zoom (magnifying glass) button in the "Horizontal" section. Turn to page 2-8 in the Training Guide. Do this section starting at step 3. Hit the zoom button again to turn the delayed time base off.

Set up the normal trigger

☐ Turn to page 2-9 in the Training Guide. In step 4, use the "Trigger" key and try the different softkey options to see what they do.

Use time and voltage cursors

☐ Do the next two sections. Note that the "Cursors" key gives you a "Cursors" softkey to select X1 an X2 instead of t1 and t2 and Y1 and Y2 instead of V1 an V2. Once you've hit the "Cursors" softkey once, use the ↻ knob and the "Cursors" knob together to change the cursors quickly and make measurements fast.

Make voltage and time measurements

☐ Notice the status line at the top of the screen. It shows the volts per division setting for both channels. Use these values and the division lines on the scope screen to determine the peak-to-peak voltage of each waveform. The status line also shows the time per division setting. Use that to determine the period of either waveform and from that the frequency.

☐ Now turn to page 2-13 in the Training Guide. Follow the directions there to see how you can let the scope make these measurements for you. Note: your scope has just one "Meas" key instead of individual "Voltage" and "Time " keys.

Using Trigger Holdoff

☐ Trigger holdoff is a softkey under the "Mode/Coupling" key. When asked in step 5, use the ↻ knob as needed to get the desired trigger holdoff.

☐ Turning to page 2-15 and doing the next two sections will give you a much better idea of what triggering is all about and why it is needed to get stable trace. Record the holdoff needed to achieve a stable trace.

**Observe the phase differences between signals**

☐ Turn to page 2-33 and do that section. Note: use the "Trigger" key and the softkeys to change the trigger source to Ch1.

☐ Turn both knobs on the trainer fully clockwise. Use a combination of the cursors and the "Meas" key to find the phase lag of the lower waveform

☐ Make sure that you've made some comments in your notebook for each section.

Ok, that's enough for the training board, let's measure something else with the scope. But first, turn off the training board and disconnect the scope probes from the board. Return the training board now, it may be in demand by other students.

Function Generator

☐ Find the HP or Agilent function generator on your bench. Connect the scope to the output of the function generator. You can do this with the BNC-to-clip cable and a scope probe, or connect then directly with a BNC-to-BNC cable.
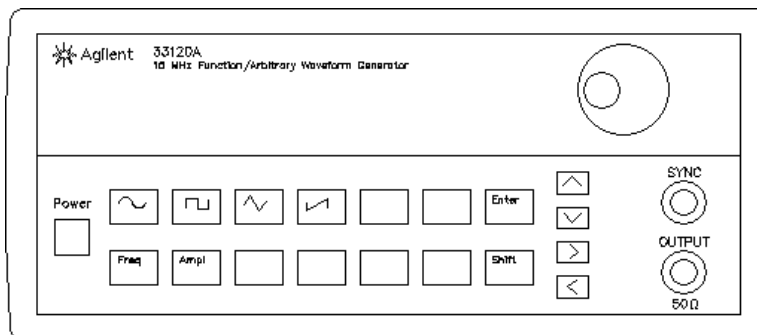
☐ Turn on the function generator and let it begin operating. Adjust the scope to look at the trace. Determine the frequency and amplitude (or peak-to-peak) of the signal. Find the frequency and amplitude (or peak-to-peak) values shown by the function generator (you may have to push the "Freq" and/or the "Ampl" buttons to change the display on the function generator). Compare your two sets of values. You should find something strange about the amplitude (or peak-to-peak) values. For reasons I can only describe as "ding-a-ling design", the function generator actually outputs twice the amplitude it shows, hence, 100 mVpp is actually 200 mVpp. (The ding-a-ling designers made the idiotic assumption that you would always hook their function generator to a 50 Ω load. Since the output resistance (R_S) is also 50 Ω that would result halving the output. Given that you almost never *actually* hook the function generator to a 50 Ω load, that was an incredibly stupid assumption on their part.) Please, when you become an engineer and designer, please try to imagine how all the end users will actually use your device and try to anticipate their expectations. If you can't do this, then please become an "end user" yourself for as long as you can before you finalize your design. Maybe that way you can catch the "ding-a-ling" mistakes before you inflict them on your customers. For example, examine and compare how Apple products operate vs. Microsoft products... you'll get the idea. Design for the convenience and expectations of the end user– not for the producer. Keysite function generators do not have this problem.

☐ Hit the ⎍ button and observe the effect on the scope. Try the other two waveform shapes as well. Go back to the sinusoid.

☐ Hit the "Freq" button and change the frequency to 25 Hz. You will need to use a combination of the knob and the ▷ and ◁ buttons. Readjust the scope, measure and compare the frequency.

☐ Repeat for 12.345 MHz.

☐ Hit the "Ampl" button and change the displayed Vpp to 240 mVpp. Again, you will need to use a combination of the knob and the ▷ and ◁ buttons. Readjust the scope, measure and compare the Vpp.

☐ Repeat for 9.5 Vpp.

☐ Play some more with this combination of instruments and finally turn off the function generator.

Audio signal

☐ The microphone in your parts requires some power to function. Set the power supply that you've used in previous labs to get +6V.
Connect the +6V to the "+ & output pin" through a 10kΩ resistor and the "COM" (or "-" on some supplies) to microphone ground. The scope should be hooked to the "+ & output pin" (V_O on the schematic) and ground.
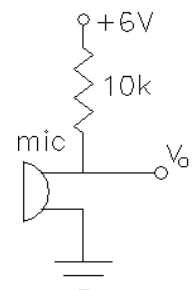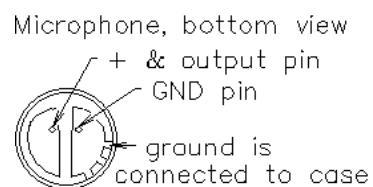
☐ Hit the Autoscale button. Change the input coupling from DC to AC (1st softkey after hitting the number button for the channel you're using, most likely "1"). Adjust the vertical position to the center of the screen. Don't hit Autoscale again or the coupling will revert back to DC and the DC will swamp out the much smaller audio signal.

☐ Play with the scope adjustments (suggestions: vertical ~2 mV/div, horizontal ~ 10 ms/div). Try some different sounds and noises. Does a true audio signal look like the sine waves that we normally use as "signals" in the lab? Comment about the randomness and unpredictability of this signal. see if you can make a sound that

produces something like a sine wave. Note: the triggering will work better if you reject the high frequencies and noise. You can do this with softkeys after you hit the "Mode/Coupling" button in the "Trigger" area.

☐ Speak into the microphone. Notice that each sweep triggers at the same level and slope, even though the waveform isn't periodic (each trace is different from the last one). The scope is triggering normally, it can't help it that the traces don't overlap nicely after the trigger.

Frequencies of different sounds

☐ Make vowel sounds; ahhh, aye, eeee, oooo, eww, etc.. Notice the different frequencies of the different sounds. Try some consonant sounds, like ssssss, shhhh, fffff, or zzzzz. What kinds of sounds are generally higher in frequency?

☐ Now try to capture some more transient sounds, like t, k, ch, or g. These will be difficult to see, especially with all the noise in the lab. Try "Run/Stop" and "Single" to freeze a single trace that you can look at. Try to freeze and look at the t, k, ch, or g sounds again.

☐ You should find that the vowel sounds are generally louder and lower in frequency than the consonant sounds. Comment in your notebook. Unfortunately, the consonant sounds are the most important when it comes to understanding speech, so a common complaint of someone who's lost some of their hearing at higher frequency is, "I can hear, but I can't understand."

Conclusion

This should give you a quick overview of the most important features of the oscilloscope and the function generator as well as give you some practical experience with the microphone. The trainer 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.

Write a conclusion in your notebook like you've done before. Call your lab instructor over to check you off. Be prepared to discuss your measurements, and conclusions and to show off your notebook.

| How the customer explained it | How the Project Leader understood it | How the Analyst designed it | How the Programmer wrote it | How the Business Consultant described it |
| How the project was documented | What operations installed | How the customer was billed | How it was supported | What the customer really needed |