MAS.836 LABORATORY ONE

February 2019

Assigned: February 12th, 2019 **Due:** February 26th, 2019

1 Learning to Use Test Equipment

The purpose of this laboratory exercise is to familiarize you with the four main pieces of equipment you will use to build sensor signal conditioning electronics (oscilloscope, power supply, multimeter, and function generator). **Labeled pictures of these devices are included at the end of this lab.** You will be using this equipment to complete the four subsequent labs in this class. Although each of the labs are self directed, the TAs will allocate time in recitation throughout the semester for reviewing the necessary concepts. Please keep each space clean when you leave, and make sure all of the equipment stays in the lab area for the next person to use. Resistors for this lab are available in E14-548. For this lab, please turn in a written report that includes answers to all questions below as well as schematics for circuits designed for question 2. there is no need to turn in your physical board for this lab.

Assigned Tasks:

1.1 Power supply and multimeter use

(a) Turn on the power supply

(b) Turn on the multimeter and set it to DC voltage mode

(c) Connect one end of the power leads to the variable voltage output of the power supply

(d) Connect the other end of the power leads to the multimeter probes

(e) Disconnect the multimeter. Obtain an approx. 1kOhm resistor

(f) Adjust the power supply until the multimeter reads 7 volts

(g) Connect the 1kOhm resistor across the power supply's power and ground terminals

(h) Once again, use the multimeter to measure the voltage across the power supply, with the resistor in place

Questions:
How much voltage is across the resistor?

Draw a schematic that includes power, ground, your resistor, and your multimeter.

(i) Set the multimeter to current mode by rotating the dial to either the milliamps (mA) or Amps (A) setting. **Be sure to also move the red probe to the current test point on the meter. If you are not careful about this, you will blow a fuse in the multimeter**

(j) Place the multimeter in series with the resistor and the power supply. *In order to use the multimeter to measure current, you must place the multimeter in series with the circuit so that all the current flows through the multimeter. If you tried to measure current in the same way that you measure voltage, you would not get an accurate current reading!*

(k) Measure the current flowing out of the power supply and through the resistor

Questions:
How much current is flowing through the resistor?

Draw a schematic that includes power, ground, your resistor, and your multimeter.

Why might your current measurement be inaccurate if you tried to measure current using the setup for voltage measurement that you previously used?

(l) Set the multimeter to resistance mode, and be sure to move the probes back to the voltage/resistance test points

(m) Disconnect the power supply from the resistor and shut off the power supply

(n) Use the multimeter to measure the resistance of the resistor

Questions:
How much resistance do you measure? How does this measurement compare to the labeled resistance?

(o) Shut off the multimeter

Questions:
Calculate the expected current and voltage values across the resistor. How do the calculated values compare to the measured values?

What might account for any differences found?

1.2 Function Generator and Oscilloscope Use

For all of these tasks, adjust the oscilloscope such that three or four periods of the waveform are displayed and that the waveform fills up as much of the scale without clipping.

(a) Turn on the function generator and the oscilloscope

(b) Connect oscilloscope probe 1 to the function generator output *To do so, you should connect both signal and ground from the output of the function generator to signal and ground on the oscilloscope probe*

Debugging Tips
If you are having trouble seeing your signal on the oscilloscope, some things to check are:

- Have you scaled your voltage and time intervals reasonably? (turn the volt/div dial for your probe to adjust amplitude, and turn the time dial to adjust width)
- Is the probe signal you are using set to display onscreen? (press the numbered button above the probe input to toggle the signal on and off).

- Is your trigger at the right level? If not, The oscilloscope may not be capturing your waveform (turn the dial under the trigger menu to adjust the trigger level)

(c) Use the amplitude and frequency controls on the function generator to produce a 5 Volt peak to peak (5Vpp) sine wave with 0V offset and 10kHz frequency. If your oscilloscope is connected and scaled properly, you will be able to see this signal on your oscilloscope.

(d) Use the oscilloscope's vertical cursors to verify that your sine wave frequency is indeed 10KHz. *Cursors are dotted lines that appear on the screen to help you make precise measurements of your signal. To use them, press the 'cursors' button on the oscilloscope, select the 'V1' or 'V2' cursor from the screen's bottom menu, and then use the dial very close to the 'cursors' button to move the selected cursor up and down*

(e) Produce a 3Vpp square wave with 1.5V offset at 1kHz

(f) Produce a 1Vpp triangle wave with .5V offset at 80kHz

(g) Disconnect the function generator and shut it off

(h) Connect a button and a 1kOhm pull-up resistor to the 5V output of the power supply. The pull-up resistor should connect the +5V power supply source to the input of the button, and the output of the button should connect to the ground (black) terminal of the power supply

(i) Connect the oscilloscope across the switch's two terminals. Press the button.

Questions:
What happens to your signal when you press the button?

(j) Now, set the trigger source to the probe that you are using *press 'source' under the trigger menu and then select the appropriate source using the on screen menu*

(k) Set the trigger mode to 'single' *press 'mode' under the trigger menu and then use the on screen menu*

(l) Make sure the trigger threshold is at the level of your signal *use the dial under the trigger menu to move the trigger threshold up and down*

(m) Now that you've set the trigger, the oscilloscope is waiting for a change in your signal. Press the switch and look at the waveform created. This is the waveform at the moment that you press the button

(n) Next, clear the trigger (e.g. switch the trigger mode back to 'auto' and then to 'single' again). This time, look at the waveform created when you release the switch

Questions:
Explain what you are seeing

Some of you may see that the switch waveform oscillates up and down ('switch bounce'). What might cause this? What problems might arise? What could you do to solve this problem?

(o) disconnect the switch assembly and shut off the oscilloscope.

2 Voltage Dividers

Note that you will be asked to use the voltage dividers you design here in lab 2.

Turn on a signal generator and get it generating a sine wave at 5 kHz, 5Vpk-pk. Connect it to the first input of an oscilloscope and change the frequency up and down (what do you see?). Set your scope probe to the 1x setting, and make sure the oscilloscope channel also has this setting. Make sure that when using the oscilloscope, you have the ground of the oscilloscope connected to the ground of the circuit.

1. Design a voltage divider that will convert our 5Vpk-pk sine wave signal to 3.3Vpk-pk. The total resistance of your circuit (sum of all resistors used) should be within 10k and 20k. **Draw a schematic of your circuit.** Using a second probe, show both the 5V signal (on channel 1) and the 3.3V signal (on channel 2) on your oscilloscope at the same time. Make sure that each channel has the same Volts/div scale.

2. Use the oscilloscope's cursors to verify that your signal is indeed approx. 3.3Vpk-pk. To do so, press the 'cursors' button on the oscilloscope, select V1 on the bottom of the screen, and use the dial near the 'cursors' button to adjust the cursor level. Do the same for V2.

   Youll notice that a voltage divider requires a ratio, and that the actual values you pick will only affect how much current and power your circuit consumes, not how successful it is at dividing 5V into 3.3V. Typically, a good rule of thumb is to start in the 1-10k range when picking resistor values- this allows enough current through to keep the voltage stable and avoid noise, but not so much as to consume significant power).

3. Now design a voltage divider that will accomplish the same thing, but this time use MOhm values! (This is a silly idea in real life!) We recommend using approx 1-2 MOhms. Plot the same thing on your oscilloscope. Use the oscilloscope's 'single trigger' feature in order to capture a snapshot of the sinusoid. *To do so, click on the 'Source' button under the trigger menu on the scope, make sure Scope 1 is selected on the screen menu, and then adjust the trigger level to the middle of the signal using the trigger level dial* **Did the magnitude of your output change? Why or why not?**

4. Scope probes, like every other component, are part of a circuit. Model your probe as a 10M resistor to ground, and **draw a schematic that includes the probe as part of your voltage divider circuit. Calculate the new peak voltage** with the probe as part of the circuit for both your first and your second voltage divider designs and a 5V input. How different is it from the original 3.3V you designed for?

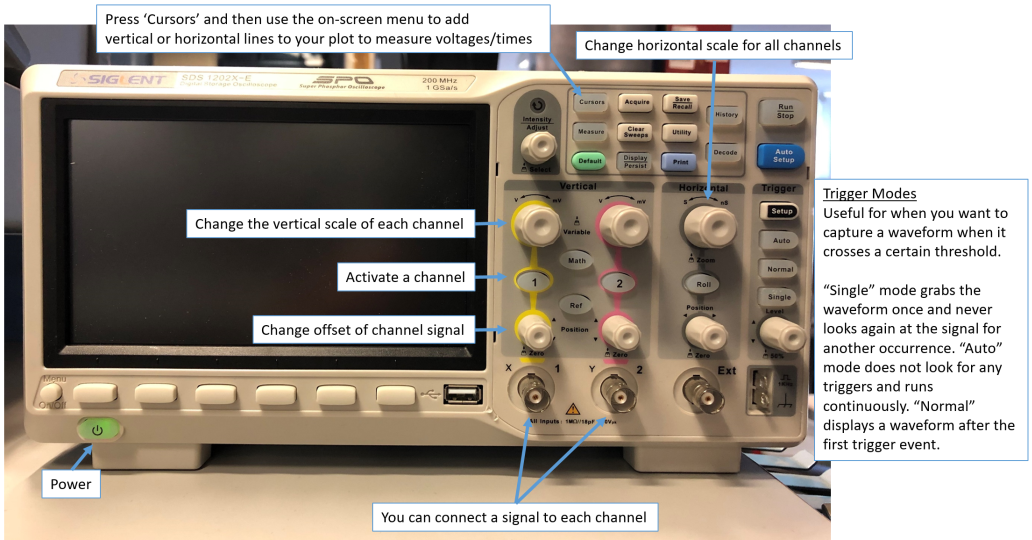
5. Replace the 10M resistor with a 1M resistor and repeat question 4.

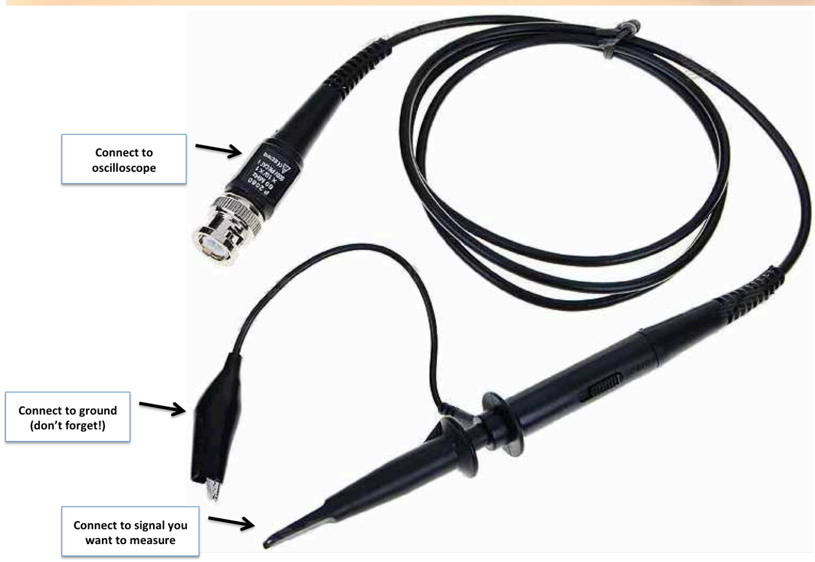
6. Resistive loading like we see here is not usually a concern, but capacitive loading can have a big impact on high frequency measurements. A typical probe will have specs like 1MOhm, 15pF, <300MHz . **What would be the specs of an ideal scope probe?** Additional information on probes may be found here: `web.mit.edu/6.101/www/reference/ABCprobes_s.pdf`

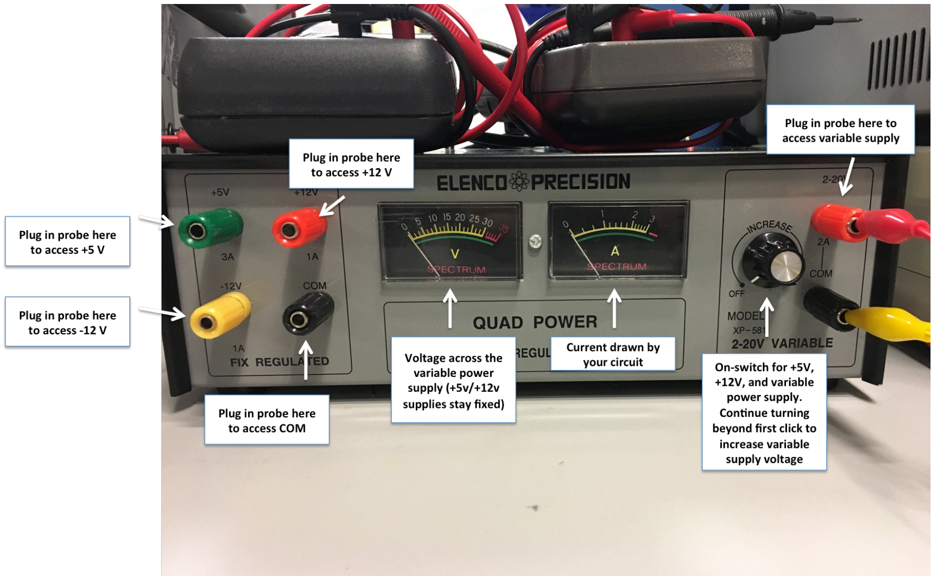
7. Set your probe to 10x now (both on the probe and on the scope) and re-measure your voltage divider. **What changed and why?**

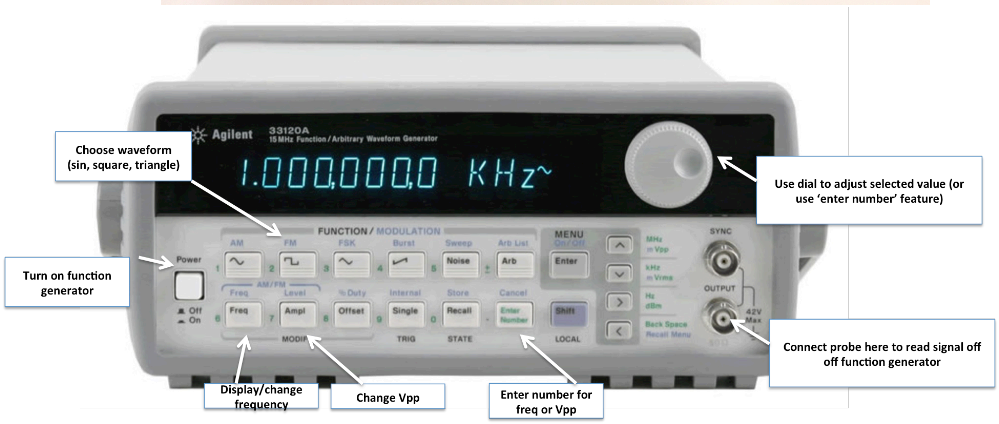
8. Like the oscilloscope probe, the signal generator is not an ideal instrument. Build a voltage divider using the signal generators output impedance (which we can also think of as its series resistance) as part of a voltage divider circuit. For the second resistance, use a 50 Ohm resistor. Measure the signal. **What is the output impedance (resistance) of the signal generator?**

3 Appendix: Labeled Pictures of Devices

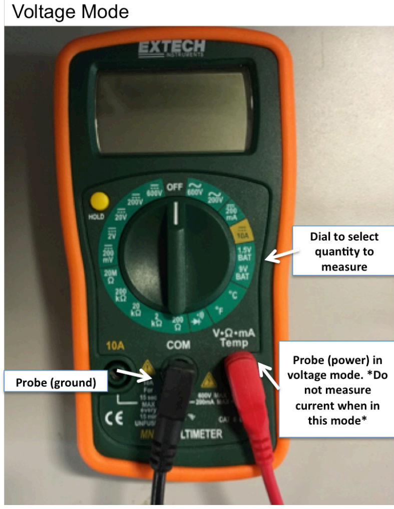








Voltage Mode



Current Mode