

Lab 1: Instrumentation and Measurements

Prelab

Remember that there will be a quiz and the best way to prepare is to do the prelab.

Read the section *7.1.1 Lecture on Safety* in your textbook.

We will only be using line voltage in a few labs and we will review safety procedures when we do. There is no need to be scared of electricity, but you should have a healthy respect.

Watch this YouTube video about voltage: <https://youtu.be/TBt-kxYfync>

Voltage is always a DIFFERENCE in electrical potential but in everyday usage there are two ways we talk about it.

- Voltage “across a component”, that is, the DIFFERENCE between one side and the other.
- Voltage “at a point”, but what we mean is the DIFFERENCE between that point and the “reference potential”. The reference potential is generally called “ground” or “zero volts” since the difference in voltage between the reference potential and itself is zero. Usually the negative side of a power source is chosen for this reference potential, often marked COM on equipment (see your multimeter and DC power supply).

Q. What is the definition of voltage given in the video? Write down both the definition and a few sentences explaining it as if you were trying to explain it to a freshman physics student.

We will be using oscilloscopes in every lab and we should understand how our test equipment can affect the circuit that is being measured. Read section *7.5.6 Oscilloscope Probes* in your textbook.

Q. What does it mean to compensate your probe?

Q. What does 10X mode do?

Q. What are the benefits of this mode?

Your textbook will be a useful reference during labs, be sure to bring it with you.

Supplies

- Multimeter (x2)
- DC Power Supply
- Function Generator (x2)
- Oscilloscope (and probes)
- Breadboard
- Minigrabber probes w/ adapters
- 220 Ω , 1k Ω , 3.3k Ω , 2.2k Ω resistors
- Misc Components to identify

Part I: Learning to use the equipment

1.1 Digital Multimeter

You should have two multimeters at your desk. This will allow you to measure voltage and current at the same time. If there are any modes you don't recognize, look them up in the manual.

- Q. Make a list of the measurements each multimeter is capable of performing.
- Q. What is the maximum current that can be measured without blowing the fuse when using the mA settings? (Look at what is written on the meter.)
 - To test that the fuse is good in each meter, set one to the mA range and the other to measure resistance.
 - Connect a banana-to-bnc adapter to each multimeter (tab side to the COM port). Connect minigrabber cables to this adapter.
 - Connect the minigrabbers together and you should read a very small resistance value if the fuse is good. If you read infinite resistance, then talk to the instructor.
 - Switch settings on the meters and test the other fuse.

The meter measures current by converting the voltage drop across that small resistor via Ohm's law.

- Q. What resistance value did you measure for the each meter in mA mode?

Never switch directly to current mode from voltage mode without disconnecting the multimeter!

1.2 DC Power Supply

You actually have two DC power supplies, one in the stack of equipment, and the other in the box your breadboard is glued to. The breadboard isn't connected to any power as is, you have to connect wires to it from a power supply.

In future labs you'll use the power supply the breadboard is glued to, but for now anytime you need a DC voltage, use the HP supply.

The HP supply has one variable power "rail" a built in voltmeter and ammeter which show the voltage and current on this rail. It has three banana jacks (red, black and green). We will only be using the red and black ones. The green jack is grounded to earth through the third prong on the power cord. Without connecting to that jack we are using the supply in "floating" mode, i.e. not earth referenced.

- Turn on the HP power supply, the display shows the output voltage.
- Q. What range of voltages can you obtain? (Note the switch which lets you change ranges.)

The CC switch is very useful to keep from blowing things up. CC stands for "constant current", but it's often more useful to think of it as a "maximum current" setting.

- Hold down the CC button and use the CURRENT knob to set a max current of 100 mA. Don't touch this knob again until directed to do so.

1.3 The Breadboard

This will be where we build up all our circuits so you should make sure you clearly understand which holes are connected together. Figure 1 shows how the metal tabs are arranged beneath the surface.

- Clip a short piece of wire into each grabber for one of your meters.
- Set the multimeter to continuity test mode and check several locations around the board to make sure you understand what is connected and what isn't.

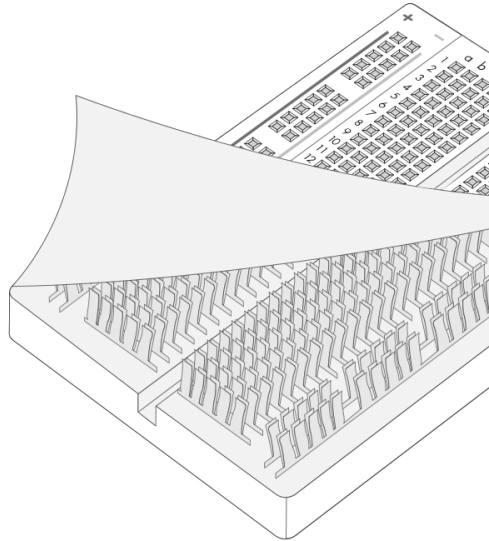


Figure 1: The internals of a solderless breadboard.

Source: <http://kit.microview.io/breadboard>

- Q. Draw a representative section of the breadboard. Draw lines through the holes to show which holes are connected together.

1.4 Testing with a simple circuit

- Place a $220\ \Omega$ resistor on the breadboard and apply 5 volts across it using the HP power supply.
- Q. Predict what current you should measure using Ohm's law.
- Q. Connect your multimeter in series (in mA mode) to get a more precise reading than the power supply gives. What current do you measure?

1.5 Function generators and Oscilloscopes

You have two function generators which can output square, triangle/sawtooth, and sine waves with various amplitudes and frequencies. (The black 2MHz one tends to be more reliable.)

- Turn on the black 2 MHz function generator and your oscilloscope.
 - Set the generator to the 1k frequency range and rotate the Amplitude knob to the middle of it's rotational range
 - Connect a coaxial cable from the output of the black 2 MHz function generator to the channel 1 input on your scope.
 - Use the “AUTO SET” button on the scope to quickly get going.
 - Be sure the attenuation is set to 1X under the channel 1 menu.
 - Set the signal to a square wave and adjust the DUTY knob.
- Q. What happens to the percent of time the square wave is in the high state as you adjust the DUTY knob? What about when you pull the knob out?
- This knob should generally be kept in the CAL position (rotated all the way counter-clockwise). Be sure to set it back to that position before moving on.

The “VCF IN” connection is used to set the frequency via an external voltage. We will discuss this more in upcoming labs. The TTL/CMOS knob controls the TTL/CMOS¹ output. This will always output a square wave at whatever frequency the main output is set to. This signal can be used as an external trigger source for your oscilloscope.

Sometimes certain ranges on a function generator will go bad and cause you to think your circuit is bad when it is actually the equipment. We can use the scope to double check the shape and frequency of the wave.

- Hit the “measure” button on your scope and set it to display frequency and Pk-Pk amplitude for channel 1.
 - Set the black 2 Mhz function generator to output a sine wave and test each frequency range by looking at the output on your scope. If you see any distortions in the signal or if the frequencies don't agree, alert your instructor. (Note that the number on the generator updates each time the “Gate” light flashes.)
 - Repeat for the 5 MHz generator.
- Q. What is the minimum and maximum peak-to-peak voltage each generator is capable of outputting? (Note the -20dB setting can be used to output very small signals.)

¹TTL stands for transistor-transistor-logic and CMOS stands for Complementary metal-oxide-semiconductor.

Part II: Identifying electrical components

There are an assortment of electrical components on your desk.

- Q. Make a list of what each one is and a few properties (value, uncertainty, pin out, etc...) which you are able to ascertain via the markings and numbers.

Looking up data sheets is an important part of working with electronics, so don't hesitate to Google part numbers such as "LM337 datasheet". Another very useful resource is the table of components at the front of your textbook.

Part III: Voltage divider circuits

A voltage divider is the first of the standard "circuit building blocks" we will encounter.

3.1 DC divider

- Using the HP power supply set to 5 volts, build the circuit shown in figure 2.
- Q. Measure the voltage drop across each resistor.
- Q. Calculate the power dissipated in each resistor.
- Q. Change $R1$ to $510\ \Omega$ and repeat the same calculations and measurements.

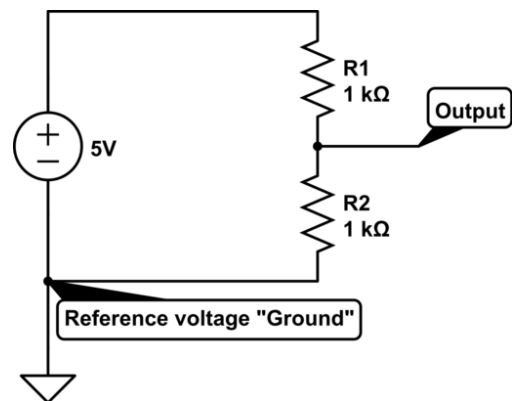


Figure 2: A voltage divider circuit

3.2 AC divider

You should always make sure your oscilloscope probe is properly compensated.

- Connect a scope probe (in X10 mode) from channel 1 to the test signal (lower right corner of the scope.) You should see a 5 Vpp 1 kHz square wave.
- Using a plastic screwdriver, adjust the compensation variable capacitor located in the housing of the BNC connector for the probe.
- Adjust until the square wave looks correct.
- Q. Look up "Oscilloscope probe compensation" and describe its purpose and how it works.
- Q. Describe the effect you observed on the square wave due to changing the compensation.

We can use a voltage divider to attenuate an alternating voltage just as we did for DC voltage.

- Build the circuit in figure 3.
- Connect the scope probes as shown.
- Adjust the scope so that both channels have the same volts/div
- Use the peak to peak voltage measurement of channel 1 to set the input amplitude to 5 volts.

Q. Measure both the period and output V_{pp} using the cursors and using the measure menu.

Q. How does the output V_{pp} (channel 2) compare to the input (channel 1)?

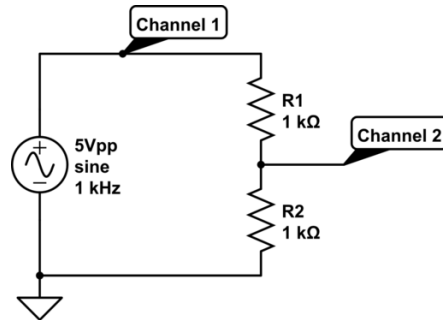


Figure 3: Voltage divider circuit with an alternating voltage source.

Part IV: Uncertainty

Calculate equivalent resistance using three methods and propagate the uncertainty.

- Measure each of the four resistors shown in figure 4 with your multimeter and make note of the measurement uncertainties.
- Using your HP power supply set to 9 volts, build the circuit in figure 4.
- Measure the power supply voltage and the current through the circuit with your multimeter. Make note of the measurement uncertainties.

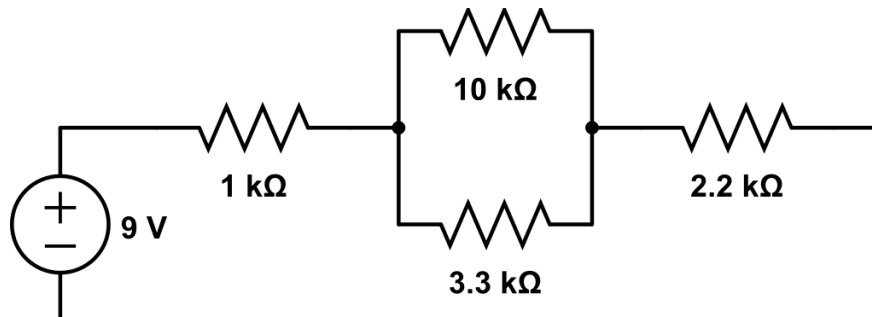


Figure 4

Show your work for the following questions, including all measured values along with their absolute uncertainties.

- Q. Write out the full equation for R_{equiv} assigning the variables R_1 through R_4 to the four resistors.
- Q. Using formula 1.1 from Lab Zero (for the total partial derivative), derive an equation for ΔR_{equiv} in terms of $R_1, R_2, R_3, R_4, \Delta R_1, \Delta R_2, \Delta R_3$ and ΔR_4 .
- Q. Using the same formula, derive an equation for ΔR_{equiv} from $R_{equiv} = V_{total}/I_{total}$ in terms of $V_{total}, I_{total}, \Delta V_{total}$ and ΔI_{total} .
- Q. Calculate the equivalent resistance and uncertainty based on the color band codes (factory specified value and uncertainty).
- Q. Calculate the equivalent resistance and uncertainty based on the resistance values and uncertainties obtained from measuring each resistor with your multimeter.
- Q. Calculate the equivalent resistance and uncertainty using Ohms law, $R = V/I$, and the voltage and current measurements you obtained with your multimeter.

You should have three resistance values with associated uncertainties (“error bars”), display them in a cleanly formatted table in your lab report.

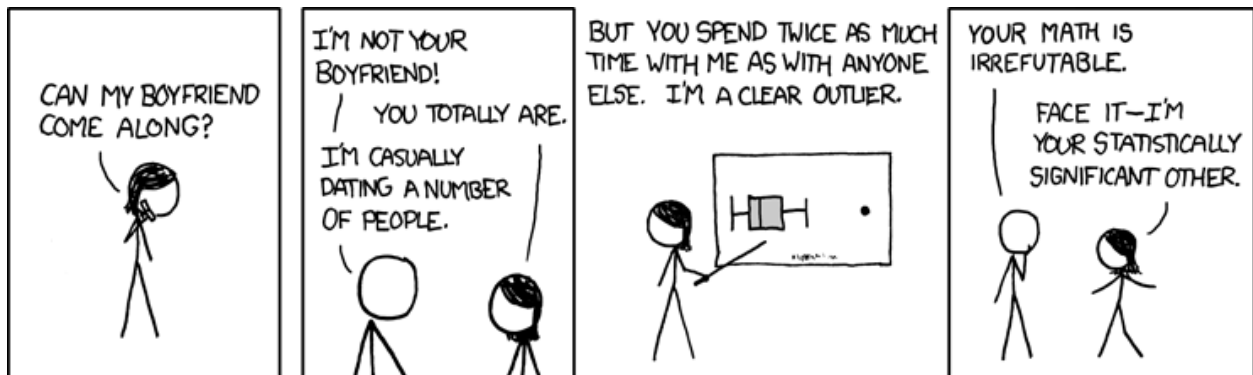


Figure 5: <https://xkcd.com/539/>