ECE383: Microcomputers – Lab 3
Breadboarding Guidelines and Lab Component Usage

Goals: The goals of this lab are to introduce students to guidelines and sound practices for breadboarding digital systems and usage of relevant digital multimeter, oscilloscope, and power supply equipment.

1. Breadboarding and Circuit Construction Guidelines

Breadboarding is a fundamental technique for the construction, test, and debugging of electronic circuits including digital systems. Circuits that are properly constructed using sound breadboarding practices can be easily tested, debugged and modified. Following basic guidelines in circuit construction can facilitate the debugging and testing process. Properly formed circuits are regular and are laid out on a breadboarding surface with testing, debugging, and ease of modification in mind. Improperly laid out circuits can be difficult to debug and even more difficult to modify. We will adopt the following guidelines in the construction of all circuits.

1) All wiring and IC insertion should be done with no power applied to the breadboard. All connections should be checked before applying power to the breadboard.
2) Use a color code convention for wires in your design. Reserve red wires for power (+5V, +3.3V, etc.) and black for ground. If multiple power supplies are required, green may be used for the secondary power supply (i.e. red=+3.3V, green=+5V). Other colors (yellow, white, blue, etc.) can be used for signal wires.
3) Use only 22-24 gauge solid wire if possible. 22-24 gauge stranded wire that has been "tinned" with solder at the breadboard end may be used if necessary.
4) Wires should be cut to a desired length not longer than necessary. Stripping 1/4 to 3/8 inch of insulation from the wires and cutting the end of the wire on a 45 degree angle will allow for easy insertion into the breadboard. Push the wire as far as it will go into the breadboard to insure a good connection. Keep wires as low to the breadboard as feasible.
5) Wires should be laid out such that they never cross over an integrated circuit (IC) or component. This will facilitate removing ICs and other devices if it should be necessary to do so.
6) 1/4 watt resistors and most capacitors can usually be inserted directly into the breadboard after cutting tips to a 45 degree angle.
7) Breadboarding surfaces contain horizontal rows of connections that are typically used to distribute power to circuits being constructed. Use these rows to create power and ground busses for your circuit.
8) Orient all ICs in your design in the same direction on the breadboard. We will adopt the convention such that pin 1 of any DIP is located closest to the designer.

9) Before attempting to insert an IC into the breadboard make sure that all leads are straight. Straighten any bent pins with needle-nose pliers. For DIP (dual inline package) ICs, insert one side of the IC into the breadboard then gently insert the remaining sides. This will minimize the possibility of bending pins when inserting ICs into the breadboard.

10) Use only IC pullers to remove ICs from the breadboard. Using fingers or other objects increases the possibility of bending IC pins.

An example of a reasonably well-formed circuit on a breadboard is shown in Figure 1 below. Notable problems with this circuit include components connected over ICs and wires placed under components.

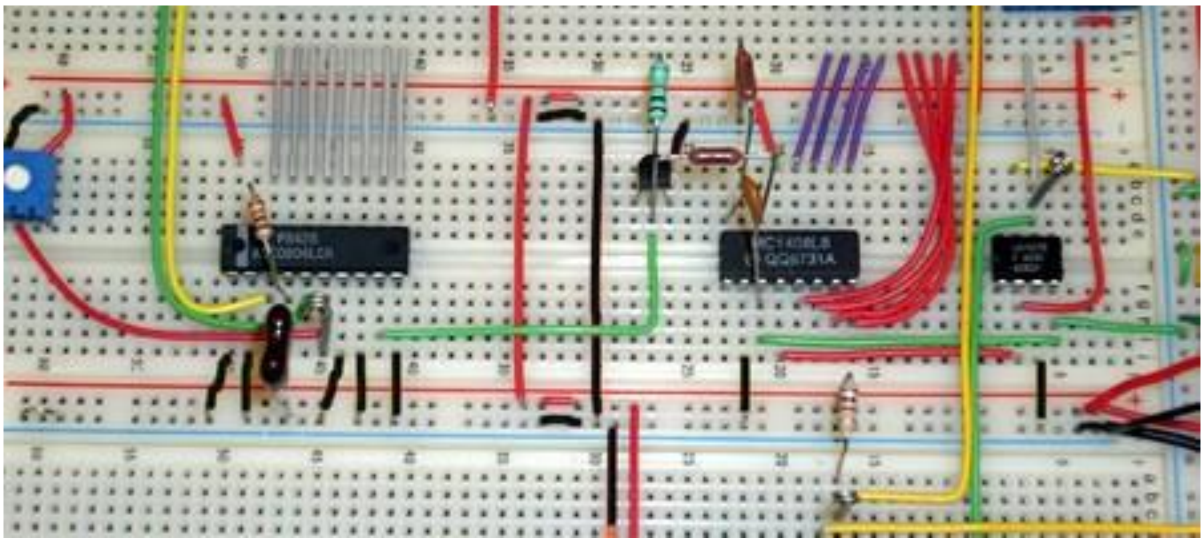


Figure 1. A breadboarded circuit.

2. Usage of Digital Multimeter, Oscilloscope, and Power Supply

Near the host computer, there is a digital multimeter, function generator, oscilloscope, and power supply located from left to right, respectively. This section gives a brief instruction on the use of those components.

The digital multimeter (DMM) is an electronic measuring instrument that measures voltage, current, resistance, and other associated values within an electrical circuit. Figure 2 shows the front panel of the DMM with brief descriptions.

Item	Description
1	USB Port
2	Display
3	Measurement Configuration and Instrument Operation Keys
4	HI and LO Sense Terminals
5	HI and LO Input Terminals
6	AC/DC Current Input Terminals (10 A terminal not available on 34460A)
7	On/Standby Switch
8	Softkeys
9	Cursor Navigation Keypad
10	Range Selection Keys
11	Front/Rear Switch (34461A/65A/70A only)

Figure 2. Front-panel of Keysight 34465A DMM with descriptions.

More details on this product can be found at http://literature.cdn.keysight.com/litweb/pdf/34460-90901.pdf. Below are brief instructions for measuring DC voltage and current, resistance, and capacitance.

To measure DC voltage, press **[DCV]** button in Measurement configuration, which is Item 3 in Figure 2. The display will show a voltage value in units as VDC. For the probes, configure the test leads as shown below.

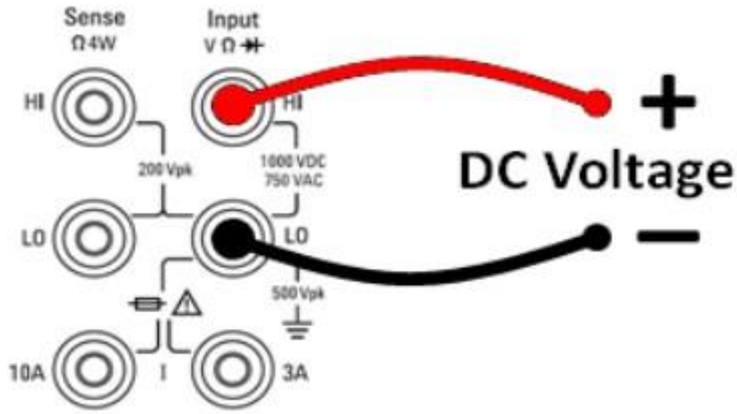
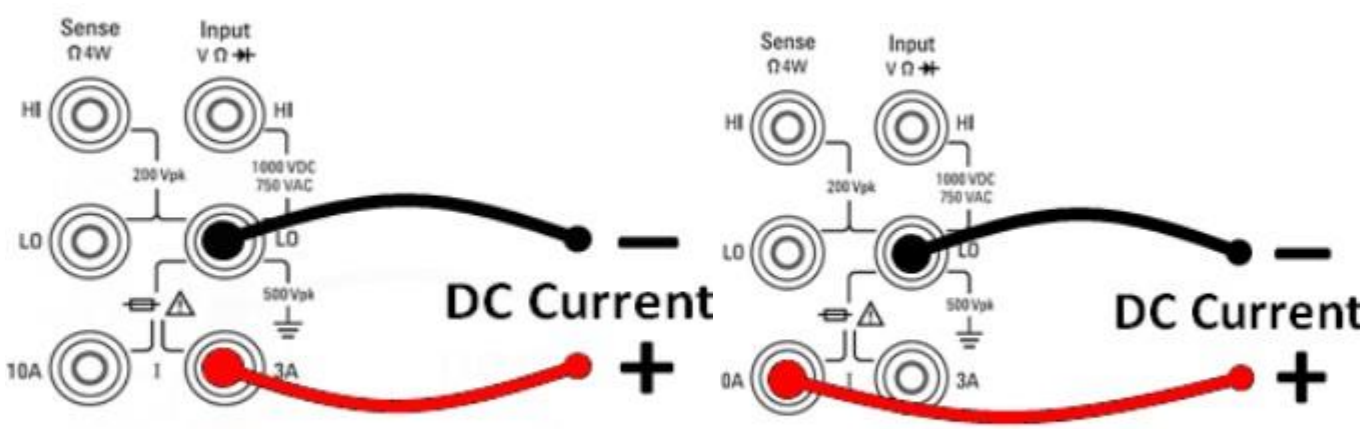


Figure 3. Probe setup for voltage measurement

To measure the resistance, press **[Ω2W]** on the front panel. Then, the display will show the unit is in Ω. Use the same probe configuration as in DC voltage measurement.

To measure the DC current, press **[Shift]** and then, **[DCV],** so that **[DCI]** can be selected. The display should show the current value with units in amps (A). For the probes, if the measuring current does not exceed 3A, configure the test leads as in (a). If it exceeds 3A, configure as in (b). If you are unsure how much current you will be measuring, start in configuration (b).



(a) (b)

Figure 4. Probe setup for a) below 3A and b) above 3A current measurement

The oscilloscope is a type of electronic test instrument that allows observation of constantly varying signal voltages. Figure 5 shows the front panel of the Keysight oscilloscope in the lab.

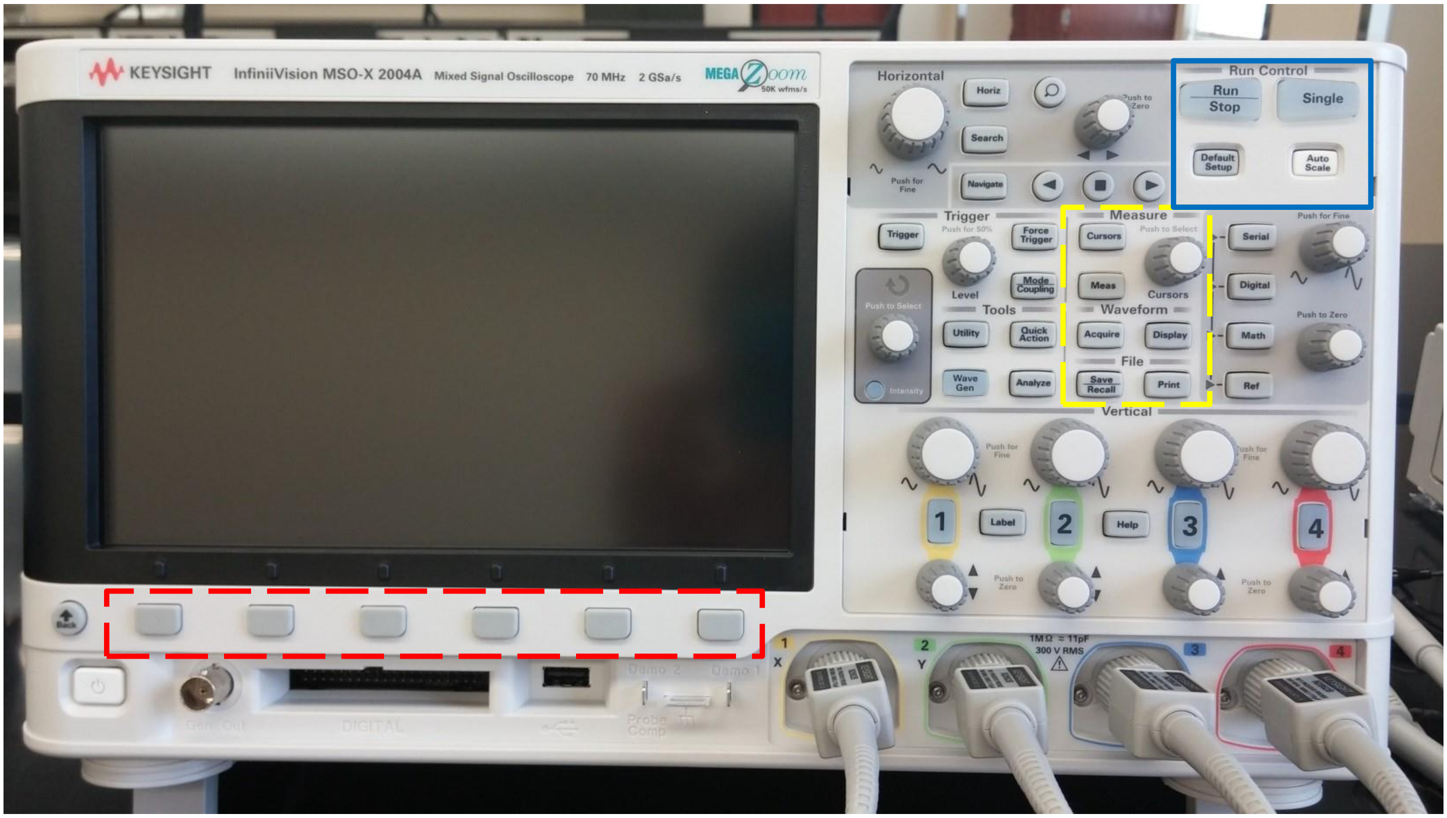


Figure 5. Front-panel of Keysight InfiniiVision MSO-X 2004 oscilloscope with descriptions

More details can be found at
http://www.keysight.com/upload/cmc_upload/All/2000_series_prog_guide.pdf?&cc=US&lc=eng.

After pressing the power button, located in the bottom left, to power on, the display will show the 2-D graph while Run/Stop button in Run Control will glow green.

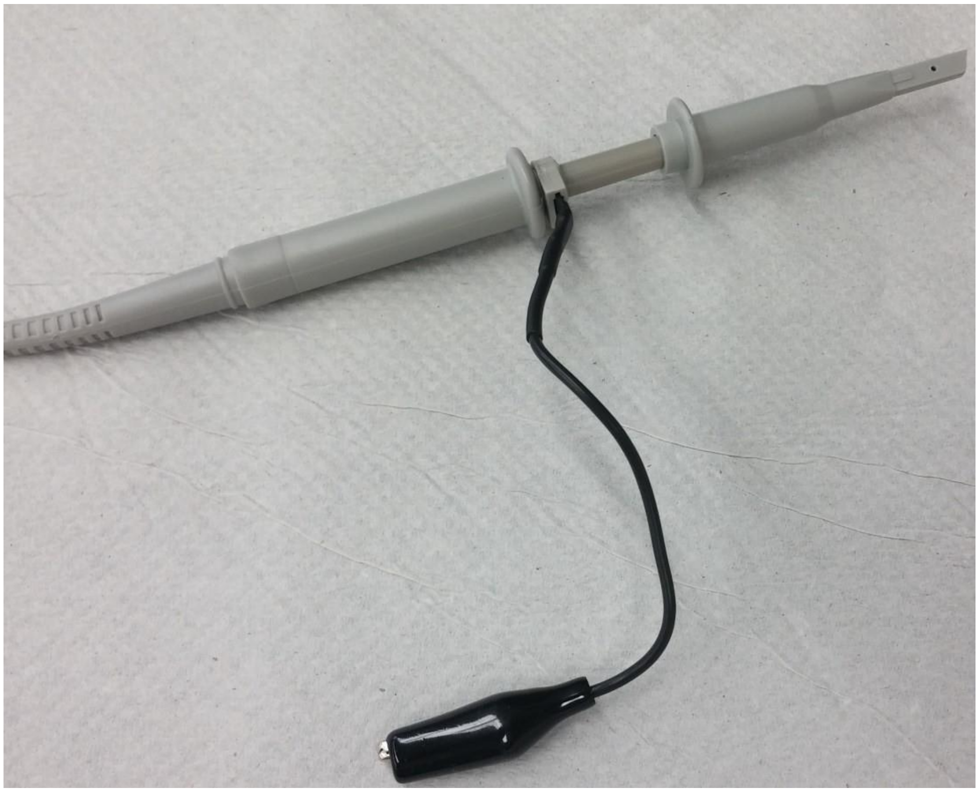


Figure 6. Oscilloscope probe

As above figure shows, there are two probes to be aware of. The top gray probe is used to measure the signal while the bottom black cable is for ground. **Black cable should be connected with the ground or negative terminal of either the circuit or power supply**. There are two ways of using the gray probe as shown. You can either pull the probe towards to the wire to use as the hook type or take out the lid to use as the pointer type.

a) b)

Figure 7. a) Hook type and b) pointer type oscilloscope probe

To show and add the desired measurement, press **[Meas]** button in the Measure section (yellow dotted section). Then, on the bottom of the screen, five menus will pop up: Source, Type, Add measurement, Settings, and Clear Meas. Press the second button in the lower bottom keypad (red dotted rectangle in Figure 3). Then, the following menus will pop up.

Figure 8. Measurement Window

To scroll down the menus, press the second button in the keypad. To add the measurement data, press the third button in the keypad. Then, on the bottom right of the screen, the measurement data will appear.

To Autoscale the display, press **[Auto Scale]** button in the Run control (blue rectangle in Figure 3).

The last lab component is called the power supply. Figure 9 shows the front-panel controls and indicators.

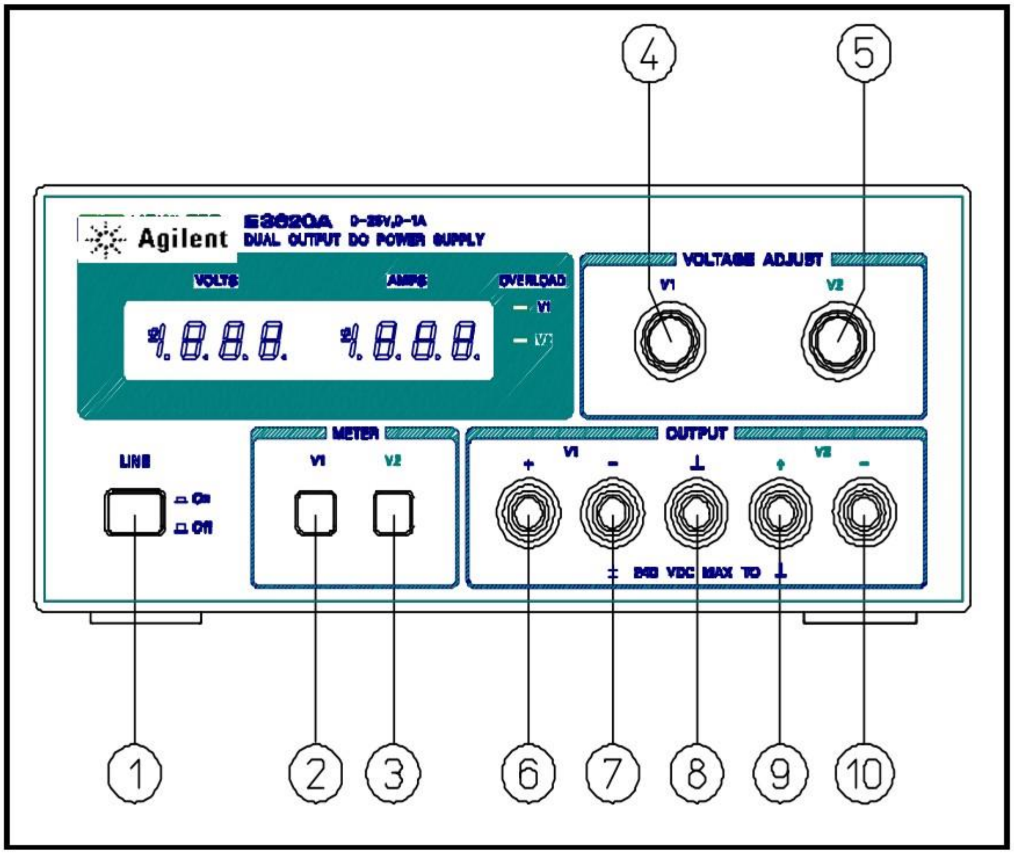


Figure 9. Front-panel of Keysight E3620A Power supply

The detailed instruction is given at http://literature.cdn.keysight.com/litweb/pdf/E3620-90001.pdf?id=1000000668-1:epsg:man.

By pressing the ② or ③ buttons, the user can change the power supply while by adjusting the knob ④ and ⑤, the voltage can be adjusted. ⑥ through ⑩ is a terminal for V1, ground, and V2, respectively. The user can access this terminal by using either banana plug or simple AWG wire. If the wire is used for connection, unscrew the terminal by turning it to the left and put stripped wire in the middle hole.

3. Exercise 1:

Goal: The goal of this exercise is to introduce the DMM and demonstrate how to measure electronic component properties. This exercise requires the following components: a 2.2 kΩ resistor (R1), a 910 Ω resistor (R2), and a 1 μF capacitor (C).

Measuring Component Values: Using wire cutters, clip the leads on the components so that they can be inserted into the breadboard in a manner similar to Figure 10 below. Orient the capacitor C such that the positive lead, which has longer leg, is to the right. Make sure power is turned off on the breadboard when inserting components. Using needle nose pliers to grasp the component leads will aid in the insertion of the components into the breadboard.

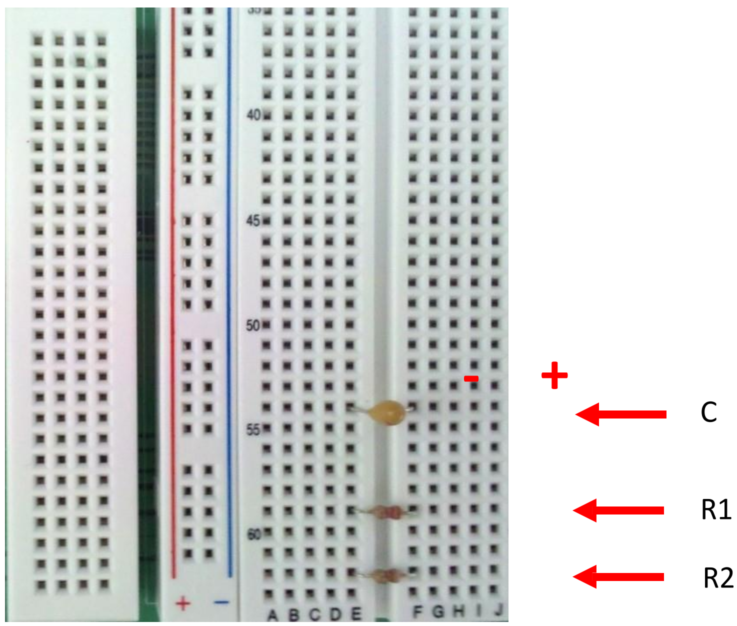


Figure 10. Component layout on the Breadboard.

Read the webpage http://en.wikipedia.org/wiki/Electronic_color_code. Using information from that page, determine which of the supplied resistors is R1 and which is R2. Also using information from that page, determine the range of actual resistance values for R1 and R2 and record those values below.

> **Deliverable 1:** Using the color code information for resistors, what is the tolerance band (in %) of R1 and R2?

> **Deliverable 2:** Using the tolerance of R1 and R2, what is the expected range (in Ohms) that these resistors could be within?

Deliverable 3: Measure R1 using the digital multimeter and capture/upload a photo of the reported value on the instrument.

Deliverable 4: Measure R2 using the digital multimeter and capture/upload a photo of the reported value on the instrument.

Deliverable 5: Does the measured resistance of both R1 and R2 fall within the expected ranges that you previously calculated? If not, comment on why this may be the case.

Connect the positive probe to positive leg of C while the negative probe with other leg. Click **[Shift]** and then, **[Freq]** to measure capacitor. Make sure that the display shows “nF” unit at the end of the screen.

C = ___________(1μF nominal)

Deliverable 6: Measure C using the digital multimeter and capture/upload a photo of the reported value on the instrument.

Deliverable 7: What is the % error of the measured capacitor from it's nominal value? Why do you think the measured capacitor disagrees from the nominal value?

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4. Exercise 2:

Goal: The goal of this exercise is to build a voltage divider on the breadboard. The DMM is still used in this exercise. This exercise requires the following components: a 2.2 kΩ resistor (R1) and a 910 Ω resistor (R2).

Using R1 and R2, assemble a voltage divider circuit shown in Figure 11 on the breadboard.

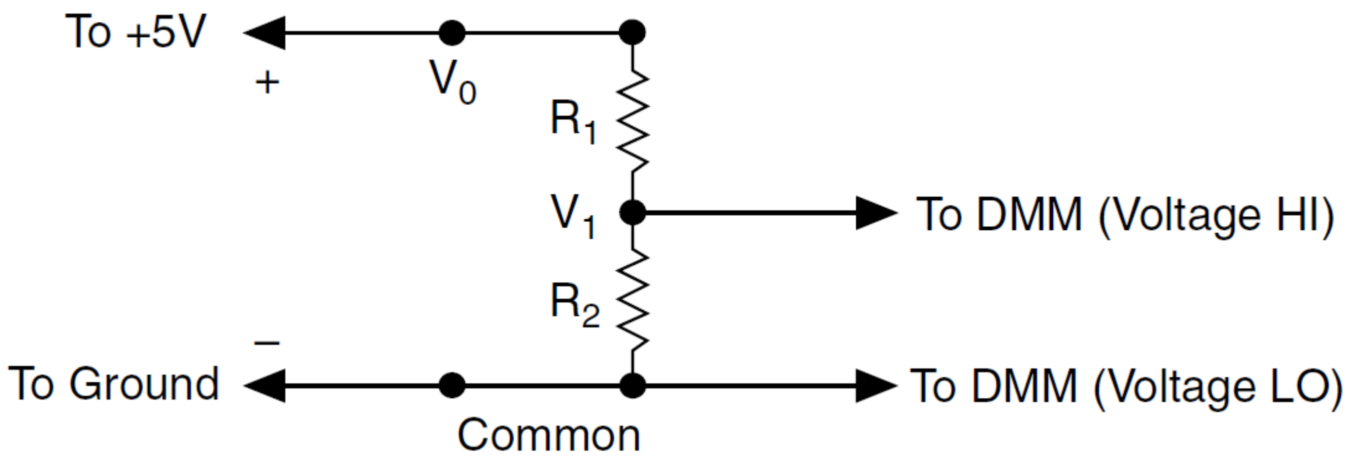

Figure 11. Voltage Divider Circuit Using R1 and R2.

Don't click the power button before TA checks the circuit.

According to circuit theory, the output voltage V1 is as follows:

$$\mathrm{V1} = \frac{\mathrm{R2}}{\mathrm{R1} + \mathrm{R2}} \times V0$$

Using the previously measured values for R1, R2, and V0, calculate V1.

Next, turn on the power supply and set it to 5V. Measure the voltage around R2. Record your results below

Deliverable 8: Capture/upload a photo of the voltage divider circuit that you have built (with the connections to the digital multimeter for the measurement of V1 shown). The measurement for V1 must be clearly visible in this photo.

Deliverable 9: Calculate and report the nominal value of V1, the value calculated using the experimental measurements of R1,R2, V0, and the measured value of V1.

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5. Exercise 3:

Goal: The goal of this exercise is to use the DMM to measure current. The DMM is still used in this exercise. This exercise requires the following components: a 2.2 kΩ resistor (R1) and a 910 Ω resistor (R2).

According to Ohms law, the current (***I***) flowing in the previous circuit is equal to *V1*/*R2*. Using the measured values of *V1* and *R2*, calculate the current.

Build the circuit as shown in Figure 12.

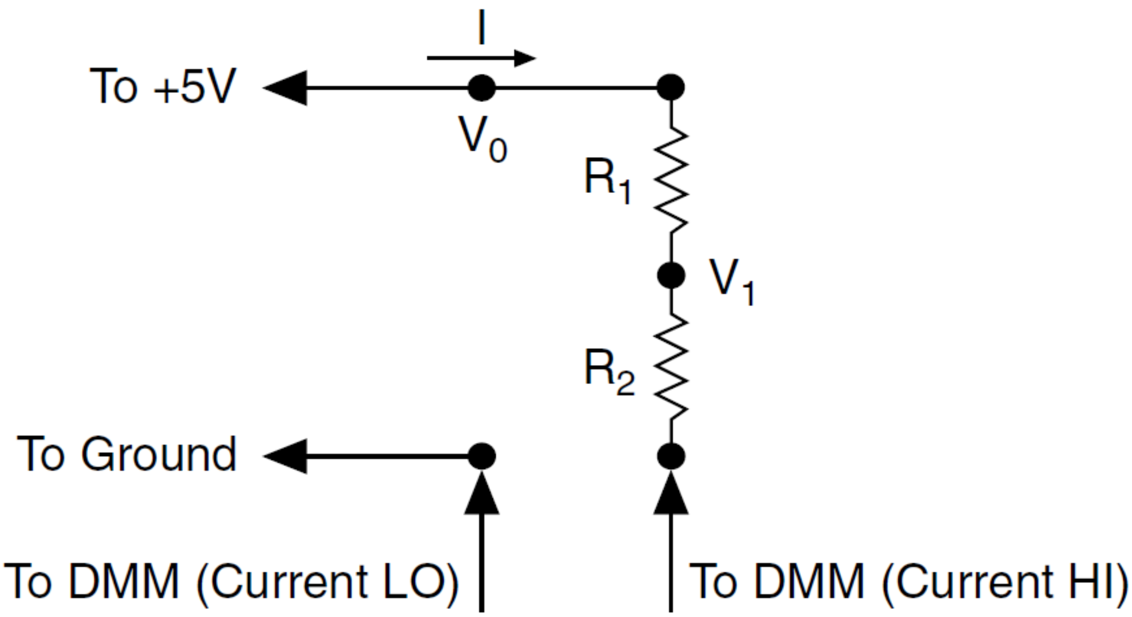


Figure 12. Measuring Current in the Voltage Divider.

Measure the current and record your results below. If you are unsure how to properly measure current using the DMM, **STOP WHAT YOU ARE DOING AND ASK THE TA.**

Deliverable 10: Capture/upload a photo of the voltage divider circuit that you have built (with the connections to the digital multimeter for the measurement of I1 shown). The measurement for I1 must be clearly visible in this photo.

Deliverable 11: Calculate and report the nominal value of I1, the value calculated using the experimental measurements of R1,R2, V0, and the measured value of I1.

6. Exercise 4:

Goal: The goal of this exercise is to build a digital clock circuit on the breadboard using resistors, capacitors, and a 555 timer chip. This exercise utilizes the oscilloscope. This exercise requires the following components: a 10 kΩ resistor (R_A) a 100 kΩ resistor (R_B), a 1 µF capacitor and a 555 timer chip.

You can configure a 555 timer chip, together with resistors R_A, R_B, and capacitor C, to act as a digital clock source. Complete the following steps to build and perform measurements on a 555 digital clock circuit:

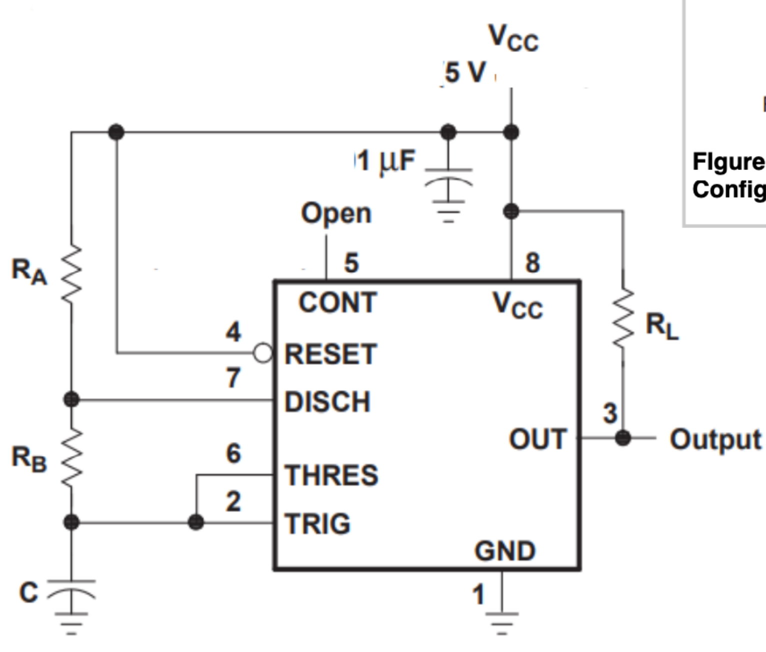
1. Using the procedure in Exercise 1, measure the component values and fill in the following:

   R_A ________________________Ω (10 kΩ nominal)

   R_B ________________________Ω (100 kΩ nominal)

   C ________________________µF (1 µF nominal)

2. Build the clock circuit on the breadboard as shown in Figure 13. Power (+5 V) goes to pins 8 and 4, and the ground goes to pin 1. The timing chain of R_A, R_B, and C straddles the power supply. It has a connection between the resistors going to pin 7 and a connection between R_B and C going to pins 2 and 6.



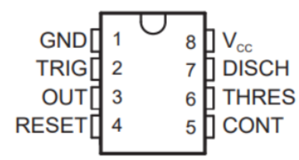


Figure 13-2. NA/NE/SA/SE555 Pin Configuration and Function

Figure 13. 555 Timer-Based Digital Clock Circuit.

3. Wire the 555 output pin 3 to a lead of the oscilloscope (and don't forget to connect the black cable of the oscilloscope probe to ground).

The 555 Timer oscillator circuit has a Period T of:

$$\mathrm{T} = 0.693 * (\mathrm{R_A} + 2R_B) * C\ seconds$$

The 555 Timer oscillator circuit frequency is related to the period by:

$$\mathrm{F} = \frac{1}{\mathrm{T}} Hz$$

The 555 Timer oscillator circuit has a Duty Cycle (On time/Period) of:

$$\mathrm{DC} = \frac{\mathrm{R_A} + R_B}{R_A + 2 * R_B}$$

4. Select Auto Scale button on the oscilloscope.
5. In Measure section, click **[Meas]** button and then clear all measurements at the bottom of the screen by clicking **[Clear Meas]**, which is fifth button in red dotted rectangle as shown in Figure 3.
6. Then, add the **Period**, **+Width**, **Duty cycle** and **Frequency** in measurement window. If you don't know how, read **Page 7** of this lab.
7. Complete the following (use Figure 14 as your reference):

Cycle time ________________________ (seconds)

On time ________________________ (seconds)

Duty factor ________________________ (%)

Frequency ________________________ (Hz)

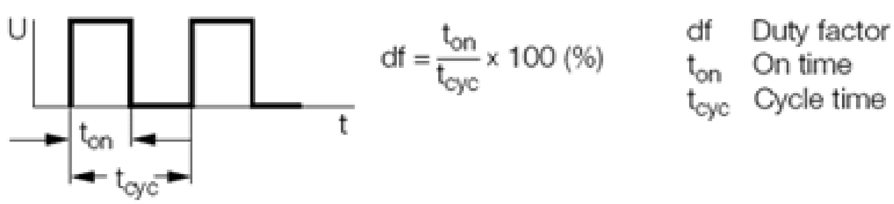


Figure 14. Duty cycle reference

Deliverable 12: Capture/upload a photo of your breadboarded circuit that clearly shows all components and where you have connected the oscilloscope probe for measurement

Deliverable 13: Capture/upload a photo of the oscilloscope capturing the 555 timer waveform and the measurements of Period, +Width, Duty cycle, and Frequency.

Deliverable 14: Capture/upload a photo of your hand calculations of the 555 timer oscillator Period (T), frequency, and duty cycle using the experimentally measured values of Ra, Rb, and C.

Deliverable 15: What is the % error of the measured duty cycle from its nominal/calculated value? If you observe a deviation greater than 5%, can you comment on possible sources of error?