Lab 0: Breadboarding and Components

Introduction

ECE 206 is a follow-up course to ECE 205. During the Fall and Spring semesters, ECE 205's Lab allows students to gain both breadboarding skills and exposure to various components. But during Summer, this content is replaced with simulation. To that end, the following document aims to explain breadboards, methods for breadboarding, and provide an overview of some basic components used in ECE 206.

Breadboarding:

Breadboards provide an easy way to prototype and develop circuits with operating frequencies below 5 MHz. This Lab will use a breadboard to accomplish various tasks, from displaying digits to closed-loop motor control. Breadboards are a compact and straightforward method to connect discrete components and integrated circuits (ICs) without having to solder or use excessive clips. The boards are composed of split rows of metal clips encased in plastic with holes on the front for both components leads and wires to connect through, see Fig. 1. The metal clips are bent to an hourglass shape to provide a point of contact for the wires. These hourglasses can be very firm for new boards and hard to insert components into until well used. The center slot allows the ICs and the Arduino Nano Every board to use either side of the breadboard, minimizing the vertical space taken up by these components.

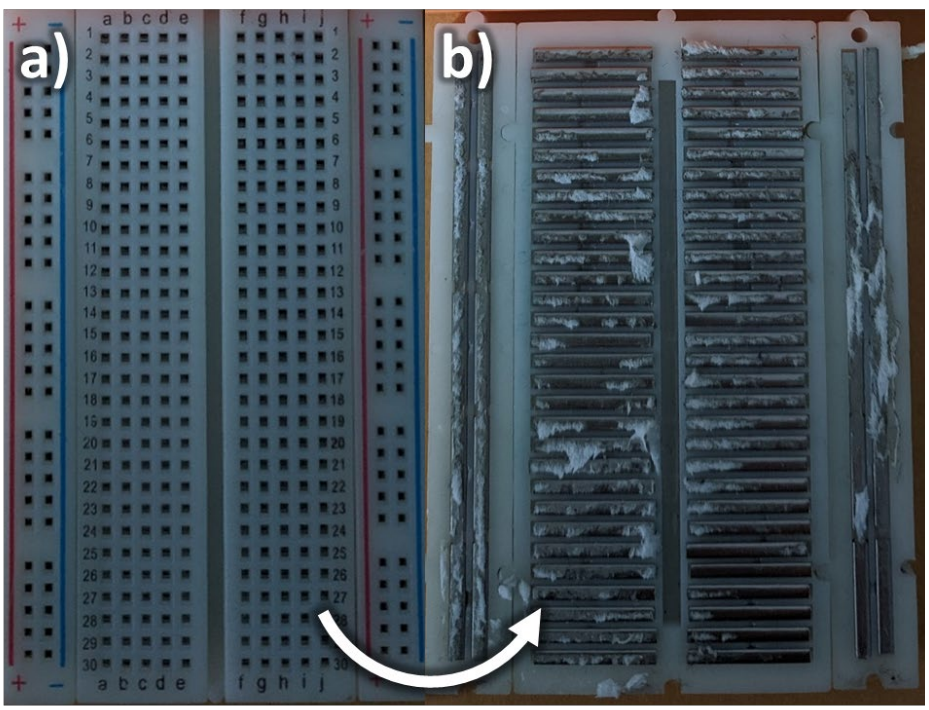

Figure 1. The a) front side of a half-size breadboard, featuring enumerated rows and columns with numbers and letters respectively. The side bus bars are labeled with a plus and minus and a middle slot sperates the ‘a’-‘e’ and ‘f’-‘j’ columns. b) The back of the same breadboard with the backing removed exposing the two columns of metal clips forming the basis of each row and the (removable) bus bars on either side of them.

The first example of using a breadboard is simple series and parallel connections of resistors. See in Fig. 2, R_1 and R_2 are in parallel, forming a 500 Ω resistor, and R_3 is in series with the parallel combination. In Fig. 3, there is a demonstration of two cases of wiring resistors with the addition of wires. The first in Fig. 3a features a wire to connect two discrete rows. Connecting two rows may be helpful when more than five connections need to be made to the same point, as now there are a maximum of 8 connections that may be made to the one circuit node. Fig. 3b demonstrates a common mistake of shorting a resistor using a wire. By connecting both ends of the resistor with a wire, R_1 is shorted out (there is a path of no resistance) and would not be considered in whatever circuit it is built into in the same configuration.

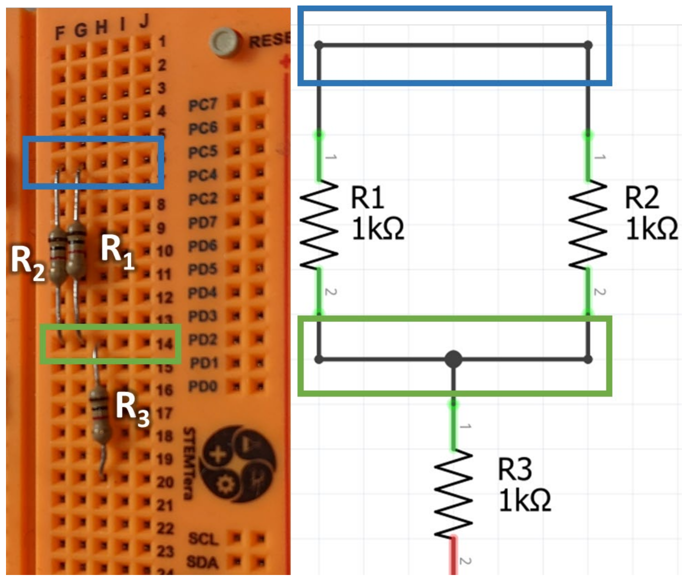

Figure 2. A parallel combination of R_1 and R_2 in series with R_3

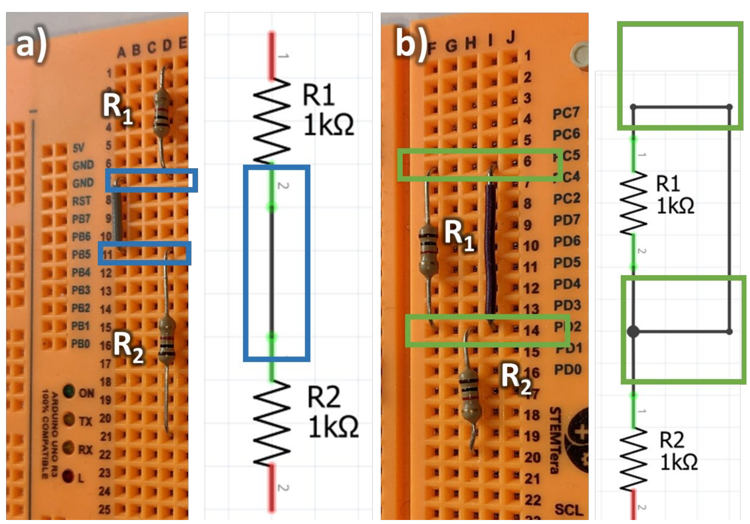

Figure 3. A a) series combination of resistors using a wire to connect two rows and b) a wire shorting out a resistor by connecting the two rows connected to either end of the resistor.

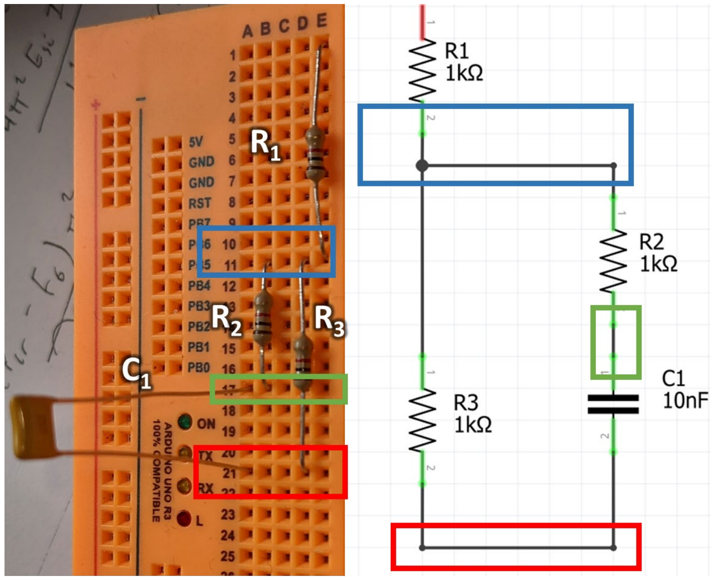

Figure 4. A circuit featuring both paralalel and series combinations of discrete passive components.

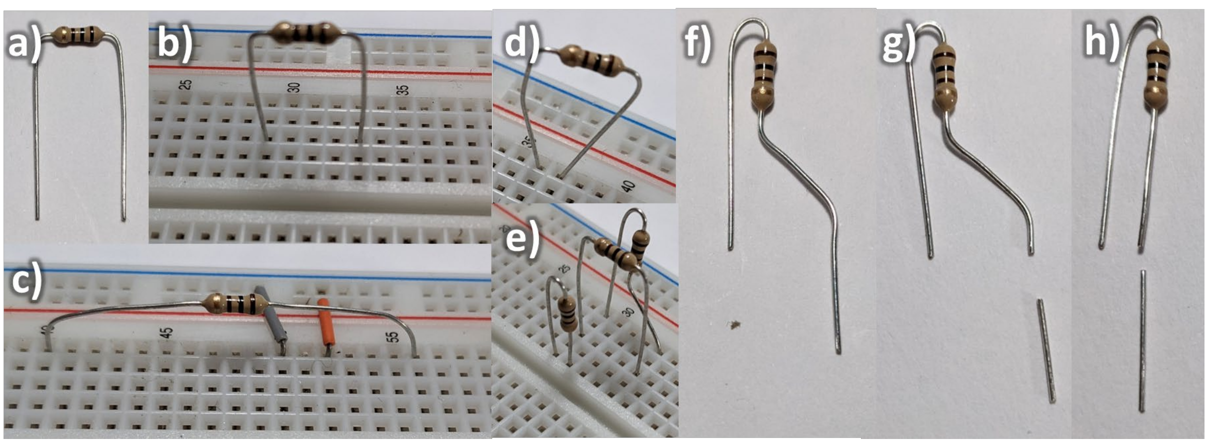

Figure 5. A variety of methods for bending the leads of resistors. In a) and b) simple right angle bends are demonstrated. c) and d) shows the longest and shortest span of a resistor without additional wire or effort in making bends. e) demonstrated both the more complex method shown in f)-h) and the simple resistor bendingmethod. f) and g) show the steps to making arbitrary width connections, but moving most of the resistor to be fairly compact and vertical. h) demonstrates a configuration for connecting two rows, but in a much smaller footprint than that shown in d).

The final example shown in Fig 4. above combines series and parallel circuits. The blue node connects R_1, R_2, and R_3. Then R_2 is in series with a ceramic capacitor, C_1. Finally, the series combination of C_1 and R_2 is in parallel with R_3. While Figures 1 through 4 show parallel and series connections of resistors and capacitors, how the leads (wires) of a component are bent matter and can make wiring a circuit easier or harder. Figure 5 demonstrates simple methods for bending wires (Fig. 5a-d) and a more complex technique that relies on a cutting tool (Fig. 5 f-h), like those provided at each bench in ECEB 4074. The methods demonstrated in Fig. 5 are helpful and straightforward to use with the provided resistors. It is worth noting excessive reshaping of resistors will make the leads hard to work with and eventually break.

Components:

There are two main groups of components: passive and active. Passive components generally are not powered and do not add energy to the circuit, including resistors, capacitors, and inductors. Active components typically feature some power supply and are often semiconductors. Examples of active components include transistors, ICs such as the NE555 timer, and voltage supplies. For ECE 206, both will be used in most labs.

Passive Components

Passive components are generally simple, have two leads, and often feature fixed values. In addition, the component value is usually encoded into a color or alphanumeric code. This encoding is done as the size of the components makes writing the value outright illegible.

Throughhole resistors are encoded using color bands. While Resistors may have four or five color bands, in ECE 206, we'll be using 4-band resistors. The code can be read by starting on one side (generally, it's clear which end to do so) and reading off the colors related to the resistance value, as seen in Fig 6a. The value of a 4-band resistor is read by interpreting the first two bands as a single number. The third band is read as a power of ten. The final stripe is read as the tolerance. In our case, all tolerance bands should be gold or ±5%[1]. This tolerance indicates that the actual value of the resistor will be within ±5% of the nominal (stated) resistance value. For example, a 1 kΩ ±5% resistor would imply a resistance between 900 Ω and 1.1 kΩ. The actual resistance value can be important for circuits that rely on precise resistance values. For circuits constructed in ECE 206, ±5% is sufficient.

Capacitors, particularly ceramic capacitors, feature a similar coding system but use a combination of printed letters and numbers instead of colors. The code features three digits and an appended letter. The first two digits are read as a single number followed by a scale factor again as a power of ten. Finally, a letter is appended to indicate relative tolerance, similar to that of resistors. The resulting value is given in picoFarads, or 10^{-12} F.

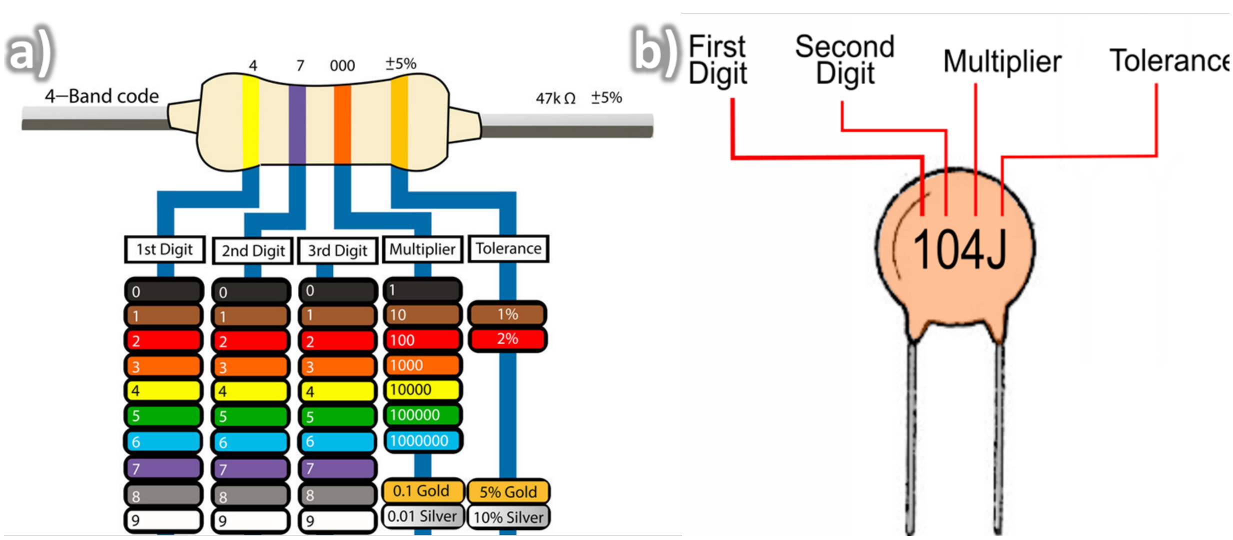

Figure 6. a) the color bands of resistors, shown is a 4-band coded resistor. The color shown above is that of a 47 kΩ resistor, that is $47 \cdot 10^3 \pm 5\%$.b) Features a ceramic capacitor, ceramic capacitors are encoded in a similar fashion to resistors, the shown capacitor is 100,000 pF, or 100 nF, or $10 \cdot 10^4$ pF $\pm 5\% = 10 \cdot 10^4 \cdot 10^{-12}$ F $\pm 5\%$.

[1] There exist a number of online tools to find resistor values instead of using a chart.

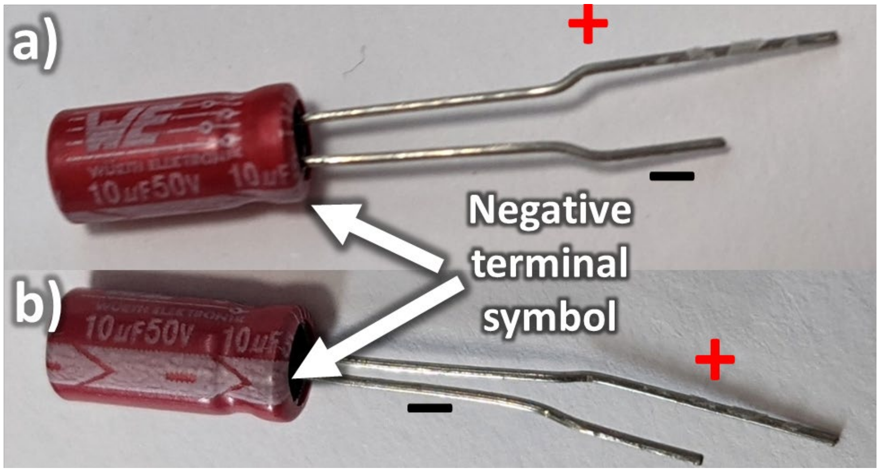

Figure 7. a) and b) show a 10 µF (10^{-6}), 50 V rated capacitor with ethe negative stripe denoted.

In addition to ceramic capacitors, we use electrolytic capacitors. Electrolytic capacitors use some conductive foil, an electrolyte for a dielectric, and a layer of oxide to separate one of the foil layers and the dielectric. While this electrolyte is a conductor, currents are not from individual electrons. Instead, the flow of the electrolytic ions creates the large polarizing field needed for the capacitor. Electrolytic capacitors are polarized; that is to say, one side should be at a positive potential when referenced to the other. This polarization is due to the electrolyte dielectric. An anode and cathode must be present for the capacitor ions to flow. A reverse voltage can destroy them by causing chemical reactions by adding enough energy to begin the chemical reaction. For example, if an Aluminum electrolytic capacitor were reverse-biased, the dielectric would disassociate, and an electrolytic reaction would occur. Specifically, the cathode (positive terminal) would begin to be oxidized, and any hydrogen would be liberated at the anode (negative terminal). This electrolytic reaction produces heat, hydrogen, and pressure due to the sealed nature of a capacitor and is a risk to be aware of. While the voltages used in ECE 206 may not be enough to drive the reaction rapidly, your circuit will not function properly and you may damage the capacitor. With this in mind, electrolytic capacitor polarity is vital for safety and is marked on the capacitor body.

The capacitor used in the Lab is marked with a white line with in-laid minus signs, as seen in Fig. 7. Also, the cathode (minus side) often has a shorter lead, although this is not always true. The value and rating for electrolytic capacitors are noted on the barrel of the capacitor. For example, in the capacitor shown in Fig. 7, it can be seen it is a 10 µF 50 V capacitor. The voltage rating is for the maximum forward voltage that can be applied before the dielectric breaks down.

Active Components

Active components add energy into a circuit by either providing or controlling some source. These components generally do not feature static values or simple linear relationships between voltage and current. In addition, active components often have more than two connection points. Therefore, a component's datasheet is the most helpful tool when using and understanding it. Datasheets provide a pinout, fundamental parameters, example circuits, equations relating to function, mechanical drawings, measured data, and maximum ratings. In ECE 206, the components' datasheet will be posted and available to the students.

There are two main active components used in the Lab. The first is the Arduino Nano Every. The Nano Every features pins that provide 5 V and ground and power the circuits constructed throughout the course. It also has analog and digital input and output (I/O) ports that can both control and observe the circuits made in class. Unfortunately, the pinout is not printed on the Nano Every itself. Still, it can be seen in the pinout provided in Fig 8. and the starter document in the Lab 1 page of the wiki. The second component is transistors, in particular MOSFETs. An example of a MOSFET and pinout is presented in Fig. 9a. Transistor pinouts will be distributed in the relevant lab handouts but, in general, feature three pins. In addition, we will use the NE555 timer, the NE555 is packaged in an eight-pin Plastic Dual Inline Package (PDIP) and the pins are numbered as shown in Fig 9b.

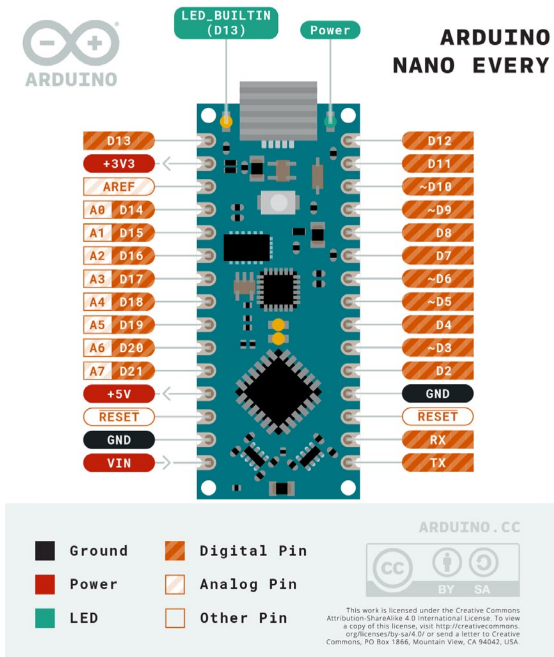

Figure 8. The pinout and pin description of the Arduino Nano Every. While other Arduino products have the pins labeled on the board, the Nano Every does not. Due to the lack of noted pins, it is recommended to keep a copy of the pinout easly accessible for the lab.

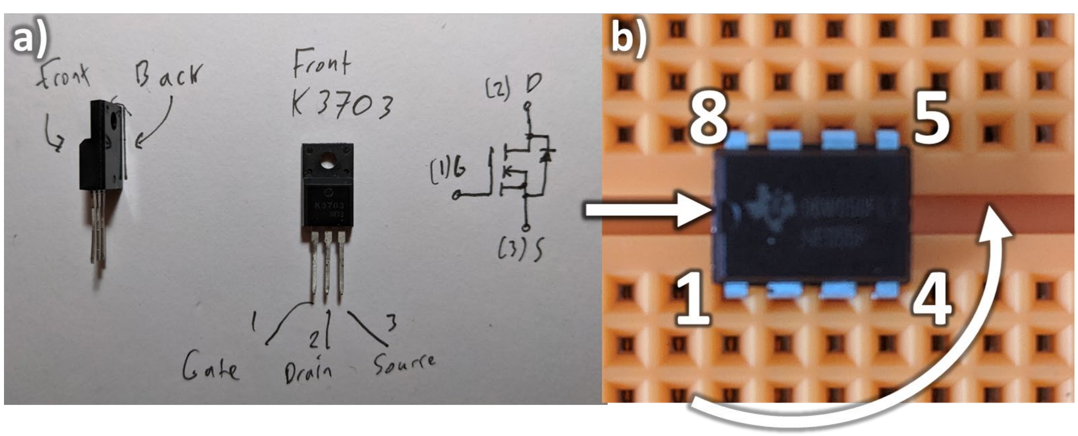

Figure 9. a) A K3703, a n-channel MOSFET (NMOS). The front and back, pinout, and the circuit diagram are given. b) The NE555 timer chip, the small divet on the left denotes the side pin 1 is on and the pins count up counter clockwise around the chip from 1 to 8 as noted.

Conclusion

This document covered both how to use a breadboard as well as an overview of some of the components that will be used in the Lab today. While skills and familiarity will come from lab time, this document is a suitable reference for ECE 206. Additional help can be sought from the Lab section's TA and provided previous semester recordings.