Lab 09: Measurement Equipment and Tools

Overview: This lab will introduce you to the available test and measurement equipment, plus some of the hardware commonly used in the lab (e.g. resistors - which are extensively used in electronic circuits to limit the current to a safe value for proper functioning of other elements, including the microprocessor itself).

This lab will also introduce you to a few simple hardware devices – including LEDs, switches, and buttons – and the associated constraints that need to be considered in order to use them effectively in design. Though an exact answer to a problem can be calculated, implementation of a design involves selection of commercially available devices that likely differ somewhat from the theoretical solution. Testing and evaluation are required to justify the choice of which devices to use for the best outcome.

Resources:
Power Supply       Breadboard
Multimeter         Resistors
Oscilloscope       LEDs
Function Generator  Switches

NOTE: DO NOT turn the power supply ON at any of the sections until the power supply current limit and circuit is confirmed by TA.
Equipment

Power Supply

Multimeter

Function Generator

Mixed Signal Oscilloscope
Lab Tasks

Part 0: Prepare the breadboard

a. Step 1: Prepare the breadboard. First make sure the breadboard includes feet, and both a red and a black peg terminal (for power and ground, respectively). Then bring power and ground from the terminals to the rails on the breadboard as shown and described below. *These wires should remain on your breadboard for the entire semester.*

1) Place a red wire from the red peg terminal of the breadboard to the closest red rail on the breadboard; with additional red wires, connect each of the red rails.

2) Place a black wire from the black peg terminal of the breadboard to the closest blue rail on the breadboard; with additional black wires, connect each of the blue rails.

Take a picture of your completed breadboard for your journal.

For all schematics, the red rail will be designated as vcc and the blue rail will be designated as gnd, and will be depicted as shown below:

\[
\begin{array}{c}
\text{VCC} \\
\hline
\text{GND}
\end{array}
\]

b. Step 2: Perform continuity checks on both switches provided (SparkFun COM-00102 and COM-00097)

Obtain a picture of (or sketch) the internal wiring (terminal arrangement) for each switch. Make sure to show the physical external connectors in relation to internal wiring. Label pole(s) and terminal(s).
c. Step 3: Observe the following when wiring components and powering the breadboard.

1) **Safety Standards:**
   - **To keep things from blowing up in your face (literally), be sure to limit current on the power supply to no more than 50-100 mA.**
   - Use the "Output On/Off" button on the power supply.
   - **Use just one set of wires to and from the breadboard – all power and ground are to be supplied from the rails.**

2) **Wiring Notes:**
   - Follow color coding standards when wiring the breadboard (red for power only, black for ground only, other colors for connecting components).
   - Wiring should be well laid-out (i.e. fairly direct routing, no crossing wires)
   - For wiring that will be left in place, all jumper wires should be close-fitting to the board.
Part 1: Getting familiar with resistors

a. For each different valued resistor in your kit (must have 5), determine the resistance value in ohms (Ω) using the color code. If you don't have 5 different resistor values, tell TA.

b. Verify resistance for each resistor using the multimeter. Push the Ω ohm button. Connect leads to **HI** and **LO Input** terminals (zero by shorting the leads together and pressing NULL button twice).

c. Record both the calculated and measured results in tabular form in your readme as follows.

<table>
<thead>
<tr>
<th>Resistor #</th>
<th>Color Bands (list in order)</th>
<th>Calculated R, Ω</th>
<th>Measured R, Ω</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

d. Select the two resistors that are closest in value to 300 and 80Ω; these will be referred to as R₁ and R₂ respectively. Calculate current for each at 3.3 V and 5.0V, and record the values in the table in part i.

e. Using the breadboard, wire a circuit with RL as instructed (power supply output OFF).

Perform continuity test to find out which electrical terminals on the breadboard are connected. Use the multimeter in continuity (Cont) mode to perform this task (note: use the **HI** and **LO** terminals). You should hear a tone each time a connection is made.

Have TA verify your power supply current limit and breadboard setup.

Attach a photo of completed breadboard.
Wait for TA to check the power supply current limit and circuit before continuing.

f. Set power supply voltage to 3.3 V and $I_{\text{max}}$ to 100 mA.

Connect circuit to multimeter, using the terminals labeled LO (-) and I (+). To measure current, change the multimeter function to DC I by pushing Shift and DC V. Measure current I with $R_1$ in the circuit.

g. Set power supply voltage to 5.0 V and measure the current again.

h. Repeat current measurements at 3.3 V and 5.0 V for $R_2$.

i. For your lab journal, record calculated and measured results in tabular form as follows. Include units for I (A, mA, or $\mu$A, as appropriate).

<table>
<thead>
<tr>
<th>Resistor</th>
<th>Current I at V = 3.3 V</th>
<th>Current I at V = 5.0 v</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calculated</td>
<td>Measured</td>
</tr>
<tr>
<td>$R_1$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_2$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Have TA verify your table results.

A Word document with table templates for parts c and i is provided on the Lab02 webpage for use in your lab journal.
Part 2: Buttons and LEDs

a. Task 1: Perform the following actions for the circuit shown below:

1) Calculate the ideal current limiting resistance $R_L$ for the red LED (based on test current specified for LED 754-1274-ND on the digikey website).

2) If the resistors in your kit do not match the calculated ideal value, pick the two available resistors ($R_1, R_2$) closest in value (one higher and one lower values, if available). Calculate the resulting current for each of these two resistors. Compare highest calculated current to the LED’s maximum (continuous) DC current rating (from the LED datasheet).

3) If both $R_1$ and $R_2$ produce currents that are within the LED rating, wire each resistor into the circuit (one at a time) and note both the current being used (via the power supply) and relative LED brightness.

Include the following in your journal:

i. Table including the following information (include units):

<table>
<thead>
<tr>
<th>LED part number</th>
<th>Test current</th>
<th>Maximum rated current</th>
<th>$R_L$, $\Omega$</th>
<th>$R_1$</th>
<th>Calc. current</th>
<th>$R_2$</th>
<th>Calc. current</th>
</tr>
</thead>
</table>

ii. Current used and brightness observations with resistor(s) tried

iii. Which circuit uses more power? (where power in watts ($W$) = $I^2 \times R$)

b. Task 2: Show breadboard with illuminated LED and selected resistor, plus calculations supporting your resistor choice (breadboard wiring to be checked for conformance with safety and color coding standards, and for well laid-out wiring).
Part 3: Function Generator and Oscilloscope

a. Task 1: Connect the oscilloscope probe ground to ground on your breadboard. Also connect the oscilloscope signal probe to the anode (more positive voltage side) of your LED in circuit from Part 2 above. Observe the constant 3.3v level indicated on the oscilloscope. To measure the voltage on the oscilloscope you may push the "Quick Meas" button. This display will show the voltage along with other information. Try varying the Vcc voltage from 3.3v down to below 1.8v and observe what happens to the brightness of the LED. It dims. This is a simple way to control the brightness of the LED. However the drawback is that LED brightness is NOT a linear function of your Vcc voltage.

b. Task 2: Now turn off the power supply output and disconnect it from your circuit. Connect the ground (black) lead from the function generator to your circuit ground. Turn on the function generator and push the “Square” button. Then push the "Frequency/Period" button. Set the frequency with the dial to 200 Hz. Push the "amplitude" button and set it with the dial to 3.3v. Push the "Offset" button and set it to 1.65v. Finally, push the "Duty Cycle" button and set it to 50%. Connect the red lead from the function generator to Vcc on your circuit. The LED should be on. The oscilloscope should show a square wave with both on (positive) and off (zero) portions of the wave equal in duration (when duty cycle is 50%). If the oscilloscope is not “synched” change the “Trigger Level” knob (upper right corner of scope) to make the square wave appear stationary on the screen. You may also need to adjust the “Horizontal” time scale on the upper controls of the oscilloscope to show at least one cycle.

c. Task 3: With the "Duty Cycle" button still activated, use the dial to set the duty cycle to 40, 30, and 20% (by changing the 10’s digit). You should observe that the LED dims very precisely as you reduce the duty cycle. Try increasing the duty cycle slowly back to 50% and all the way to 80% and observe how the LED brightens. This is called "pulse-width modulation" and is the best method for adjusting the brightness of LEDs. This is how the brightness of all computer monitors and LCD TVs are adjusted. Make sure you observe how the duty cycle (amount of time the LED is on) changes with the oscilloscope.

d. Task 4: Change the function generator frequency from 200 Hz to 10 Hz and notice what happens to the LED. At what frequency are you able to see the LED blink? This may be different for different people.

e. Task 5: Demo LED "pulse-width modulation" to your local TA.

Include the following in your journal:

- Photo of completed breadboard with oscilloscope and function generator connections.
- Photo of oscilloscope output with a duty cycle of other than 50%.

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Lab 2 Deliverables

- Readme.pdf with all the required parts – label and name each section