Laboratory 1: Introduction to Hardware

Learning Objectives

- Learn to work with equipment
- Assemble circuits on breaddboard
- Build logic circuits with integrated circuits (ICs)

1. Introduction

This lab introduces the basic equipment and tools that you will need to build, power and characterize logic circuits. Furthermore, you will build two simple logic circuits.

1.1 Equipment

Power Supply

All the integrated circuits (ICs) used in the experiments are from the 74LS family of TTL circuits, and thus, require a supply voltage of +5V. Your power supply may provide several adjustable voltages, however, almost certainly will have a separate, non-adjustable +5V output. You should *only* connect the protoboard to this output, never to an adjustable one which can burn your circuit if the voltage is accidentally increased.

Most power supplies have a switch to cut off the voltage from the output without turning off the device. *To avoid creating short-circuits you must always cut off the supply voltage from the breadboard when introducing or removing wires.* The supply voltage should be connected to the breadboard in this way: the ground (GND) should be connected to the black jack of the breadboard, and the +5V should be connected to the red jack of the breadboard.

Logic Probe

To analyze and debug your circuit you will use the LPlOA logic probe. The probe can display the logic level at any point in the circuit by touching the point with the metal tip. For logic values 1 (high), the red LED is on, for logic values 0 (low), the green LED is on. The switches on the logic probe should be set to

- TTL
- MEM

The power is supplied to the logic probe from the breadboard.

1.2 Breadboard

By using a solderless breadboard, you may implement electronic circuits easily. A breadboard is a tool used for connecting the parts of your circuit. You can easily slide wires and components into the provided holes which have the right size for hookup wires and the ends of most components.

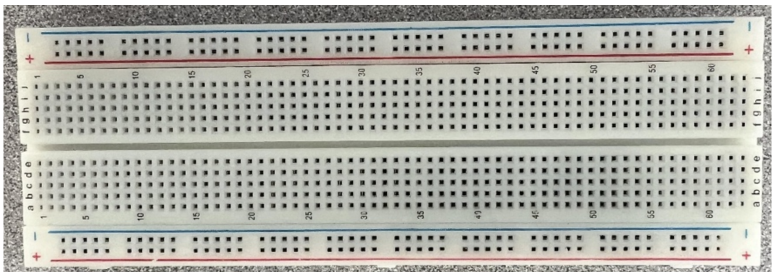

Figure 1: Front of a breadboard

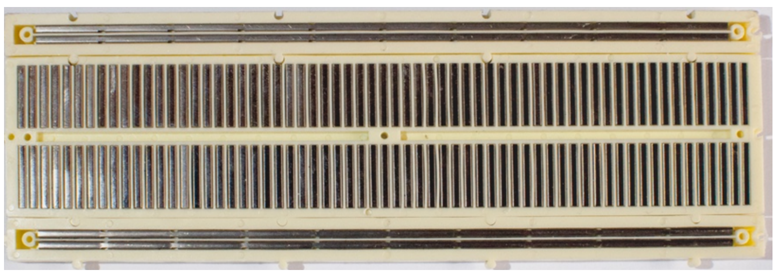

Figure 2: Back of a breadboard shown with the back insulation removed

Figure 1 and **Figure 2** show the front and back side of a breadboard, respecively. In **Figure 2**, the backside of the board has been removed to expose the metal strips connecting the holes. Don't remove the backside on your own board. It will make the board useless. From **Figure 2,** you can see two long lines on top and bottom of the boards. These can be used as power lines (power supply and ground (GND)). The short strips are separated by the divider in the center. The center divider can be used to mount integrated circuit chips (e.g., logic gates), on the breadboard. IC chips in a Dual In-line Package (DIP) have two rows of pins. The center divider on the breadboard isolates the top and bottom rows from one another. As such, you can utilize it for inserting DIP packages (each row of pins places on one side of the center divider).

1.3 The Input-Control/ Output-Display Unit (ICOD)

This unit is your interface with the circuits you will design. It is recommended you implement it carefully and give some thought on how to arrange it in the *upper left* block of the breadboard, which should be used only for this purpose.

The following components are needed to build the ICOD unit:

- miniature single-pole single-throw switch : 4
- LED: 4
- resistors, $R=620\ \Omega$, : 8
- 74LS04, hex inverter: 1

The unit contains four single-pole single-throw miniature switches for providing logic '0'or logic '1' inputs, and four LEDs for displaying the logic values of up to four signals.

Switches

Each of the four switches should be wired as shown in **Figure 3**. The pull-up resistor is $R = 6200\ \Omega$. When a switch is open, the circuit provides logic '1' to the gate input where it is connected. When the switch is closed, it provides logic '0'. You should arrange the four switches in a column with all of them having the same polarity. Thus, with a glimpse you can read the logic value of your (maximum) 4-bit input signal.

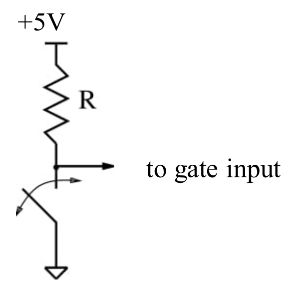

Figure 3: How to connect a single-pole single-throw switch.

LEDs

A light emitting diode (LED) is turned on whenever the voltage drop across it exceeds a threshold voltage (typically 1.6V). The brightness of the LED depends on the current through it, and values larger than 5mA should yield satisfactory results. The ability of a gate to supply (or sink) limits the current upward. The resistor $R = 6200\ \Omega$ makes sure that the current cannot exceed the maximum value allowed for a TTL gate. The negative polarity of the LED is the pin close to the flattened bevel.

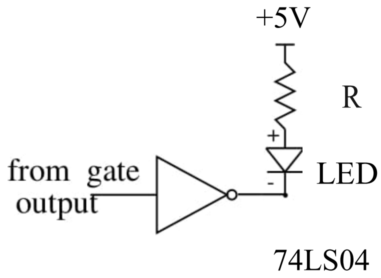

Figure 4: How to connect an LED.

Arrange the four LEDs in a column to have a (maximum) 4-bit output signal display.

To have the bright LED correspond to logic '1', the displayed signal must be inverted first. Be sure that you understand why. The IC 74LS04 contains six inverters. Mount this IC in the same breadboard block, and *do not use* the remaining two gates in your experiments.

To have a reliable ICOD unit the connections within the unit should have short wires and the leads of the eight resistors cut short enough to lie on the breadboard. Connect long wires to the four inputs and the four outputs, and label each of them with their name, e.g., IN0 or OUT2.

Once the ICOD unit is implemented, connect the four input lines to the four output lines and verify that the LEDs show what is set by the switches. Whenever in an experiment an LED is not in use, connect its gate input to the GND. The unused input lines should be connected to different empty horizontal bars. Never leave any wire hanging in the air.

1.4 Some Guidelines

i. When connecting with wires, try to use the following color convention:
  - use black wires for connections to GND
  - use red wires for connections to +5V
  - use green wires for all other connections

ii. Sometimes, you might need to strip the ends of the wires long enough to be able to place them into the holes of the breadboard. Make sure you don't have unisolated part of the wire visible.

iii. Before turning on the power supply for an implemented circuit, check if all Cs have their +5V and GND connected correctly.

iv. The ICs used in the experiments are mostly 14 or 16 pin packages. Generally, the bottom left pin is the GND and the top right pin is the +5V.

v. To remove an IC from the breadboard, use the meatllic tip of the logic proble. Genrly push the top below the IC and by slowly rocking it pry the IC loose.

2. Experiments

2.1 Implementing a simple logic function

As an example of logic circuit, we will implement the following simple logic function:

$$F(A, B, C) = A.B + A'.C + B.C$$

To implement this function, we would need "inverters", "AND" and "OR" logic gates. We can use the following to ICs:

IC Number	IC Name
74LS04	hex inverter
74LS08	quad 2-input AND
74LS32	quad 2-input OR

1. Complete the "truth table" for this fucntion.

A	B	C	A'	$A.B$	$A'.C$	$B.C$	$A.B + A'.C + B.C$
0	0	0					
0	0	1					
0	1	0					
0	1	1					
1	0	0					
1	0	1					
1	1	0					
1	1	1					

2. Check that the ICOD on your breadboard is working properly, by toggling each of the input pins from logic '0' (GND) to logic '1' (5V), and from logic '1' (5V) to logic '0' (GND).

3. Relaize the function $F(A, B, C)$ on the breadboard, using the listed ICs.

4. Connect the $A, B,$ and C inputs to three switches, and the output F to a display unit (LED). Generate all possible inputs listed in the truth table, and verify that the output follows the logic function listed in the truth table. If it doesn't, practice to find the issue and debug the cirucit.

5. How many logic gates did you use to realize this function $F(A, B, C)$? Take a note of this number.

2.2 Simplification

Now we consider the following funcion:

$$G(A, B, C) = A.B + A'C$$

1. Complete the "truth table" for this fucntion.

A	B	C	A'	$A.B$	$A'.C$	$A.B + A'.C$
0	0	0				
0	0	1				
0	1	0				
0	1	1				
1	0	0				
1	0	1				
1	1	0				
1	1	1				

2. Relaize the function $G(A, B, C)$ on the breadboard, using the listed ICs.

3. Connect the $A, B,$ and C inputs to three switches, and the output G to a display unit (LED). Generate all possible inputs listed in the truth table, and verify that the output follows the logic function listed in the truth table. If it doesn't, practice to find the issue and debug the cirucit.

4. How many logic gates did you use to realize this function $G(A, B, C)$? Take a note of this number.

5. Compare the truth tables of functions $F(A, B, C)$ and $G(A, B, C)$. What is your conclusion?

6. Compare the number of logic gates used to realize functions $F(A, B, C)$ and $G(A, B, C)$. What is your conclusion?

3. Lab 1 Report

Your report for Lab 1 should include the following:

- Completed truth table for functions $F(A, B, C)$and $G(A, B, C)$ and discussions on how these functions are related.
- Use Boolean axioms and theorems to find the relationship between $F(A, B, C)$and $G(A, B, C)$.
- Image of the circuits that you implemented to realize functions $F(A, B, C)$and $G(A, B, C)$.
- List the logic gates you used to realize each function.
- Compare the number of logic gates used for realizing each function and discuss your persepective.