Name: ______________________ SID: ____________________ Grade: ______________

# Lab 2

*Breadboard Prototyping – Adder*

In this lab, you will be designing logic circuit using breadboards with TTL ICs. This lab worksheet will be submitted for grading. Your design will be inspected by the instructor in the lab. Write down your name and SID on this worksheet now.

## Prior Knowledge

You have exercised most of the logic gates in the previous lab. In general, digital circuit is built on those gates by connecting them together (the output of a gate is connected to an input of another). There are two types of digital circuits: combinational logic and sequential logic. The difference between the two is that the latter involves clocks (events that trigger changes of system states). We will study more about clocks later in the semester. In this lab, we will be building a combinational logic to perform an addition.

You have seen that there are two states for each of the inputs and outputs in a digital logic, either on or off, logic high or logic low, and 1 or 0. Obviously, if we want to add two "digital numbers" together, each of them could only be either 1 or 0. This leads to 4 input combinations, i.e., 0 and 0, 0 and 1, 1 and 0, or 1 and 1. The output will be the result of adding two digital numbers. Again, the output could only be 1 or 0. Typically, we use a table to list all possible input combinations with their associated outputs. This table is called "truth table." To make things clear, we use 0 and 1 notations in a truth table. Each row in a truth table indicates one case of the operation. For example, the first row in Table 1 represents the case when the number 1 is 0, and the number 2 is 0, the output sum will be 0 and the carry will be 0 as well. A standard truth table has one output only. We however list both sum and carry in the truth table for convenience. When you read the truth table, you should cover carry column if you want to check the sum output. That way you have only one output. Keep in mind that the truth table is a combination of two: one for sum and the other for carry. Fill in the other three cases in the truth table for the above addition (called adder) tabularized as follows:

**Table 1 Truth Table of the Adder**

| Number 1 | Number 2 | Sum | Carry |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 1 | | |
| 1 | 0 | | |
| 1 | 1 | | |

| check |
|---|
| |

## Build the Digital Circuit

Once the truth table is derived, we will be able to build the circuit. There are some techniques to simplify the building process but we have not learned yet. So, let's do something else. First of all, think about what do we have? Logic gates. Right! However, what gates we should use for the circuit? One of the ways you could do is compare the truth table for the adder to the tables exercised in lab 1, and find something similar and go from there. The tables you have filled in lab 1 are actually truth tables. So what did you find?

| What gate has a very similar truth table to that of the sum in the adder? What gate has a very similar truth table to that of the carry in the adder? | check |
|---|---|
| Your finding: | |

Once you figure out what's the answer in the above question, you may go ahead and build your circuit accordingly. In this lab, however, we try to implement it in a more general way. Consider that there are two cases that make the sum to be 1. Do you see which two cases? Right, the second and the third cases. In the second case, given the inputs 0 and 1, if we INVERT the number 1, and AND it to the number 2, the sum will be 1. Similarly, in the second case, given the inputs 1 and 0, if we INVERT the number 2, and AND it to the number 1, the sum will be 1. We may combine the two outputs by an OR gate as follows:

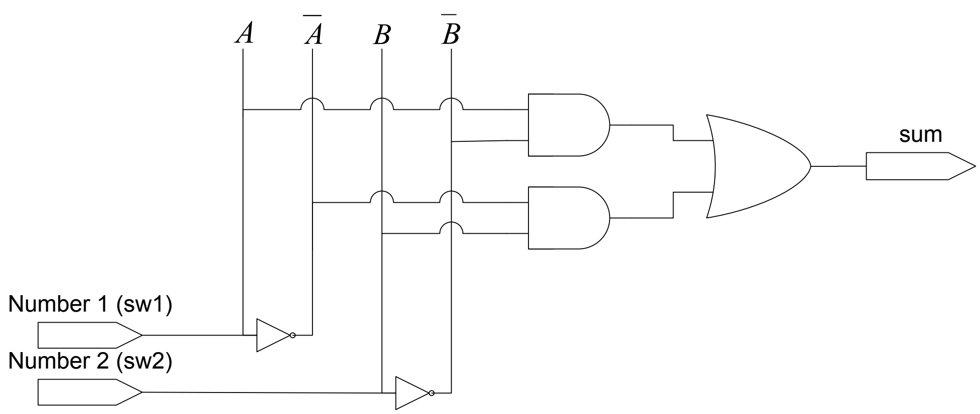


**Figure 1 The Sum Circuit in the Adder**

| In Figure 1, there is only one output, the sum, of the adder. We still need to have an output for the carry. Add the carry signal along with its circuit to the figure. | check |
|---|---|

Note that the number 1 is connected to sw1, and the number 2 is connected sw2 on the digital trainer. The output sum and carry will be connected to an LED. So we may verify if the result is correct. You have seen AND and OR gates in lab 1. The INVERTER (NOT) gate is represented as a triangle. The following 7404 TTL packs 6 NOT gates.

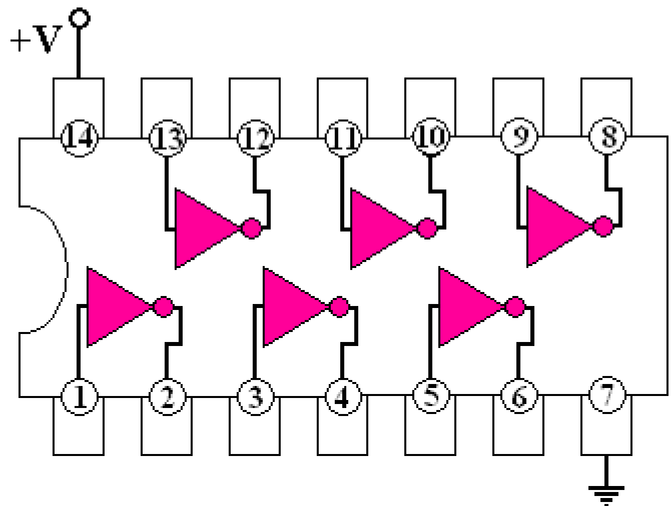


Figure 2 Chip Configuration for 7404 TTL

In this lab, you will build your adder circuit using AND, OR, and NOT gates as shown in Figure 1. You need three TTL ICs for this circuit. You may need to reference to lab 1 for other chip diagrams. Make sure all ICs are powered, and take advantage of color coded wire for better tracing your circuit. Try to wire your components in a neat way.

| Show your digital circuit. | Check |
|---|---|

## Full Adder Extension

The adder you have built was called half adder. Why half? You should have known the answer in the class. Don’t tear down the circuit yet. Keeping reading and see if you may reuse that circuit later. Next, we will build a full adder. A fuller adder has three inputs (carry input, number 1, and number 2), and two outputs (carry out and sum).

Table 2 Truth Table of the Full Adder

| Number 1 | Number 2 | Carry in | Sum | Carry out |
|---|---|---|---|---|
| 0 | 0 | 0 | | |
| 0 | 0 | 1 | | |
| 0 | 1 | 0 | | |
| 0 | 1 | 1 | | |
| 1 | 0 | 0 | | |
| 1 | 0 | 1 | | |
| 1 | 1 | 0 | | |
| 1 | 1 | 1 | | |

| check |
|---|

Okay, now think about how you may reuse the half adder and modifying it to compute as the above full adder. For the full adder, you are free to use any TTL logic ICs.

| Draw you full adder like the one shown in Figure 1. Treat your half adder as a black box (2 inputs and 2 outputs). Reuse you half adder as much as possible. | check |
|---|---|

After you schematic design got checked, go ahead to build the circuit on the breadboard.

| Show your digital circuit. | Check |
| --- | --- |
| | |

## Challenge (Extra Credits)

Construct a two-digit binary adder such as s = a + b, each of which is a 2-digit binary number. In this circuit, you have 5 inputs ($a_0$, $a_1$, $b_0$, $b_1$, and carry input) and 3 outputs ($s_0$, $s_1$, and carry output).

When done, put back parts into the right cabinets, and place all hardware back to its original locations. Have your TA or instructor check all items in this lab worksheet, and register your grade before you leave.