Kettering University

CE-210 Digital Systems I

Lab Exercise 1

Truth Tables and Voltage Tables

Analysis of Simple Digital Circuits

Spring 2019

Lab report is due by the end of your today's lab session.

Section

Name | | **Number**

Lab Partner's Name and No ______________________

Purpose of this lab experiment

Objectives

- *Become familiar with the tools to be used in the first two weeks.*
- *Learn the physical meanings of logic 0 and logic 1.*
- *Better understand what truth tables and voltage tables are.*
- *Be able to empirically determine truth tables and voltage tables of unknown digital circuits.*

What to Hand In

Turn in this handout after you

- Complete the cover sheet
- Do all the experiments
- Answer all the questions.
- Also show your functional 74LS20-based circuit in Assignment 5 to the lab instructor.

Introduction

The function of a digital circuit may be described in a tabular format called a *truth table*. This *lookup* table lists *all possible input combinations* along with the corresponding output values, so that we can directly read the output value for a given input combination. Once a truth table is obtained, a digital circuit may be implemented to function in accordance with the table. This transformation is called the *design* of a digital circuit covered in Chapters 3 and 4 of your textbook.

In this week's lab we will look into the opposite scenario: we have a digital circuit available and wish to determine its truth table. This is called the *empirical analysis* of a digital circuit as a black box[1]. The procedure is straightforward. We assume that n, the number of input variables, is given:

1- Fill in the input column of an n-variable truth table. This column is an ascending list of all possible input combinations (2^n n-bit patterns). Figure 1*a* shows the input column of a 3-variable truth table as an example. Row numbers are also listed in this table. A row number is the decimal equivalent for the corresponding input combination.

Row	Input	Output
0	000	
1	001	
2	010	
3	011	
4	100	
5	101	
6	110	
7	111	

(a)

Row	Input	Output
0	L L L	
1	L L H	
2	L H L	
3	L H H	
4	H L L	
5	H L H	
6	H H L	
7	H H H	

(b)

Figure 1. Do not fill out! Three-variable blank tables: (a) truth table, (b) voltage table

2- Apply one bit-pattern at a time to the input of circuit, monitor the output, and enter the output value in the output column of that row. You need to perform this experiment 2^n times to fill out the whole table, where n is the number of input variables.

Question: What are the *physical* meanings of logic 1 and logic 0? In other words, what should we do with an input line (wire), A, so that the corresponding physical circuit recognizes A as a logic 1 or a logic 0?

[1] We only have access to the terminals (input/output) of a black box.
In Chapter 3, you will learn how to analyze a digital circuit *algebraically*.

Answer: In today's integrated circuit (IC) technologies, logic 1 and logic 0 are mostly mapped to two different *voltage* ranges, namely V_{high} or H for short, and V_{low} or L for short. For example, in TTL (Transistor-Transistor Logic) technology, which will be used in the first two weeks, the voltage ranges are *approximately* as follows:

2 volts < H < 5 volts

0 volt < L < 0.8 volts

These voltage ranges are graphically shown in Figure 2. The voltage range between 0.8 and 2 volts is undefined in order to provide logic gates with some noise immunity. Interested students may wish to consult a VLSI textbook for more details.

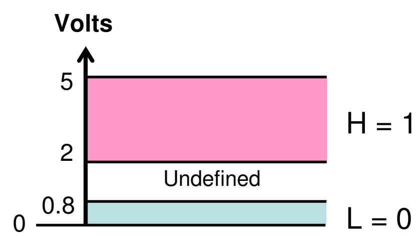

Figure 2. Approximate voltage ranges for TTL

There are obviously two possible mappings between {0, 1} and {H, L}. In Digital Systems I, logic 0 is assigned to L and logic 1 is assigned to H. By introducing H and L as the electrical counterparts of logic values, an electrical counterpart called *voltage table* is created for truth tables. A voltage table is obtained by simply replacing 1s with Hs and 0s with Ls in the truth table. Figure 1*b* illustrates the input column of a 3-variable voltage table, as an example.

In this week's lab, the instructor will explain the logic box that you will be using during the first two weeks. You will also learn how to determine ICs' pin numbers, how to place ICs on your breadboard and properly wire up circuits, how to supply power to circuits, how to generate input signals and apply them to circuits, and how to monitor signals. Power supply connections are normally not shown in circuit diagrams. But a digital circuit is comprised of electronic devices, hence has to be supplied with an appropriate voltage (5 volts for TTL) to operate.

Assignments

1. Place a 74LS00 chip across a breadboard's channel, while pin 1 is positioned in the lower right corner. The chips that you will use today each have 14 pins, where pin 14 is the V_{CC} pin and pin 7 is the ground (GND) pin. So, pin 14 goes to the *positive* terminal, and pin 7 goes to the *negative* terminal of the power supply. There are four identical and basic circuits or *gates* on the 74LS00, each with two inputs and one output. The two inputs that you are going to use are pins 1 and 2, and the corresponding output is pin 3. Connect the outputs of two slide switches on your logic box to the inputs of this circuit, and monitor the output of the circuit by connecting it to an LED pair on your logic box as illustrated in Figure 3. Apply all possible input combinations, and fill out the output column of the truth table shown in Figure 4*a*.

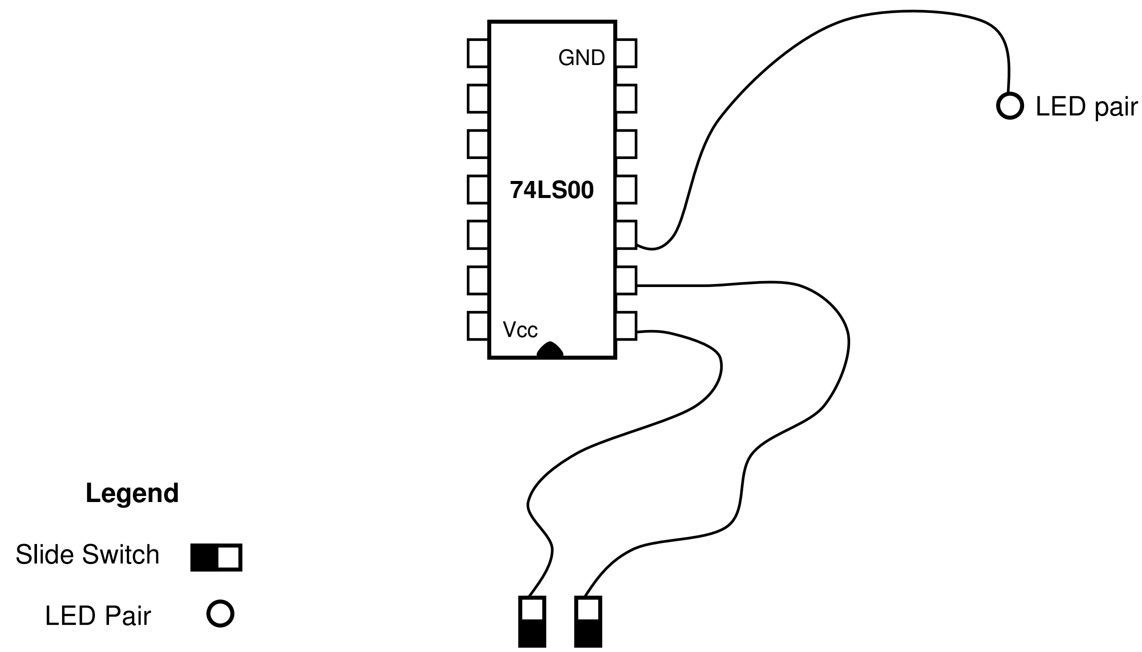

Figure 3. Test bench for Assignment 1

a b	y
0 0	
0 1	
1 0	
1 1	

74LS00

(a)

a b	y
0 0	
0 1	
1 0	
1 1	

74LS32

(b)

a b	y
0 0	
0 1	
1 0	
1 1	

74LS08

(c)

a b	y
0 0	
0 1	
1 0	
1 1	

74LS86

(d)

a b	y
0 0	
0 1	
1 0	
1 1	

74LS02

(e)

Figure 4. Truth tables for five digital circuits (to be filled out)

2. Repeat the above experiment with the following four-gate chips, and fill out the truth tables of Figure 4*b* to Figure 4*e*, respectively.

74LS32, 74LS08, 74LS86, 74LS02.

Note: The pins on the 74LS02 are different. Here, pins 2 and 3 are the input pins, and pin 1 is the output pin. The other chips have the same pin-out as the 74LS00 does.

3. You obtained the truth table of the 74LS02 in Figure 4*e*. Using symbols L and H, fill out the voltage table shown in Figure 5*a* for this circuit.

4. **Use 74LS02:** A test bench has already been set up for this assignment.

Make proper measurements to fill out the table shown in Figure 5*b*. You will obtain *actual* output voltages of a 74LS02 chip in volts using a voltmeter. Take a close look to see how the voltmeter has been hooked up to the circuit. You could also reach the voltage table in Figure 5*a* from the table obtained in Figure 5*b*.

a b	y
L L	
L H	
H L	
H H	

(a)

a b	y (volts)
L L	
L H	
H L	
H H	

(b)

Figure 5. Voltage tables for 74LS02 to be filled out with (a) Ls and Hs, (b) actual voltages in volts

5. **Use 74LS20:** Use one of the four-input circuits on a 74LS20 chip and carry out proper experiments to fill out the truth table shown in Figure 6. In this assignment, input pin numbers are 1, 2, 4 and 5, and pin 6 is the output. **Show your functional circuit** to the lab instructor.

Row	a b c d	z	Row	a b c d	z

Figure 6. Truth table for 74LS20 (to be filled out)