Laboratory Exercise #1
Digital Logic Gates

ECEN 248: Introduction to Digital Design

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ENGINEERING
TEXAS A&M UNIVERSITY

1 Introduction

Digital circuits makeup the cornerstone of modern computational hardware. By representing binary digits (i.e. $\{0,1\}$) with voltage levels, digital circuits are able to process binary numbers electronically. *Logic gates* are the fundamental components within digital circuits so understanding their behavior is important. Therefore, the purpose of this experiment is to introduce you to gate behavior and logic interpretation as well as the basics of circuit wiring and troubleshooting. To do so, we will explore the function of several of the basic *logic gates* discussed in lecture.

2 Background

Background information necessary for the completion of this lab assignment will be presented in the next few subsection.

2.1 The 7400 Series of Logic Gates

Logic gates are constructed from transistors, which are analog switches. These transistors can be forced to operate in two modes, namely "ON" or "OFF." In doing so, we can abstractly think of electronic signals within a digital circuit as being either HIGH or LOW (i.e. '1' or '0'). A digital gate takes as input one or more digital signals and outputs a digital signal as a result of a boolean operation. Figure 1 depicts the standard logic gate symbols and their associated boolean operation.

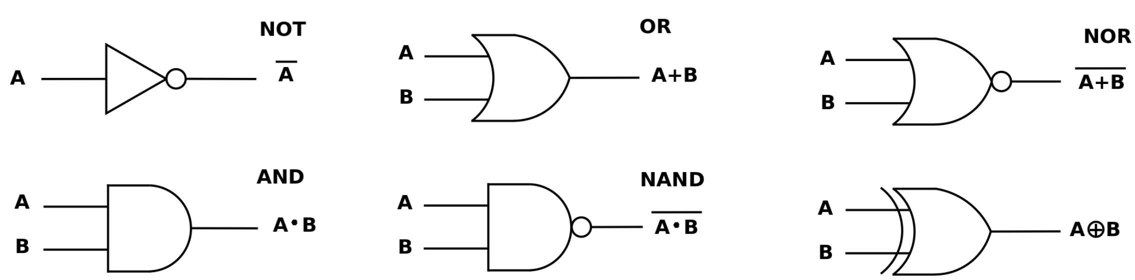

Figure 1: Logic Gates

The basic gates you will study in lecture are available in a series of Integrated Circuits (ICs) commonly referred to as the "7400" series. Within this series, there are various IC package types available; however, for bread-boarding digital circuits in the laboratory, we will use the Dual-Inline Package (DIP) type as shown

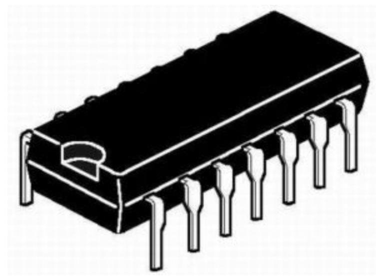

Figure 2: Dual-Inline Package

in Figure 2. As shown, the DIP features a black plastic package with pins on both sides, slightly resembling a flat caterpillar.

Figure 3 shows the DIP pinout diagrams for the NOT gates (left) and the AND gates (right). These pinout diagrams were taken from their respective datasheets and illustrate the function of each pin within a give IC package. Notice that the DIP on the left (7404) contains six NOT gates arranged in a counterclockwise fashion starting at the top-left of the IC. The DIP on the right (7408) contains four AND gates arranged in a similar fashion. Also note that the notch on the DIP designates the top of the IC package.

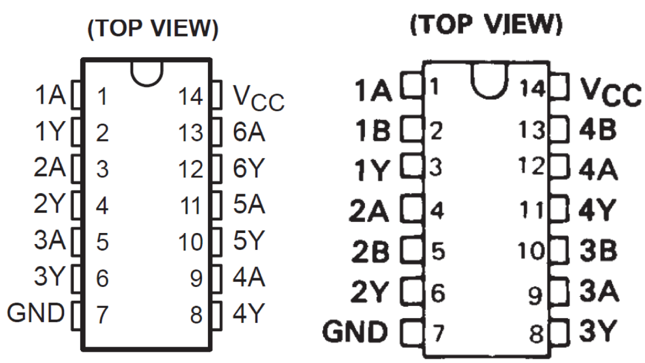

Figure 3: 7404 (NOT) & 7508 (AND) Pinout Diagrams

2.2 Bread-boarding Techniques

The first four labs require extensive bread-boarding of digital circuits. The bread-board used in ECEN248 is depicted in Figure 4. Take a moment to examine it. Here are a few techniques which will help you wire up your circuits:

1. Horizontal lines of points on the bread-board are electrically connected together. However, lines are not connected across the partition divisions (i.e. lines in different partition are independent).

2. Vertical line are **NOT** electrically connected, except in the case of a power or ground line (see Figure 4).

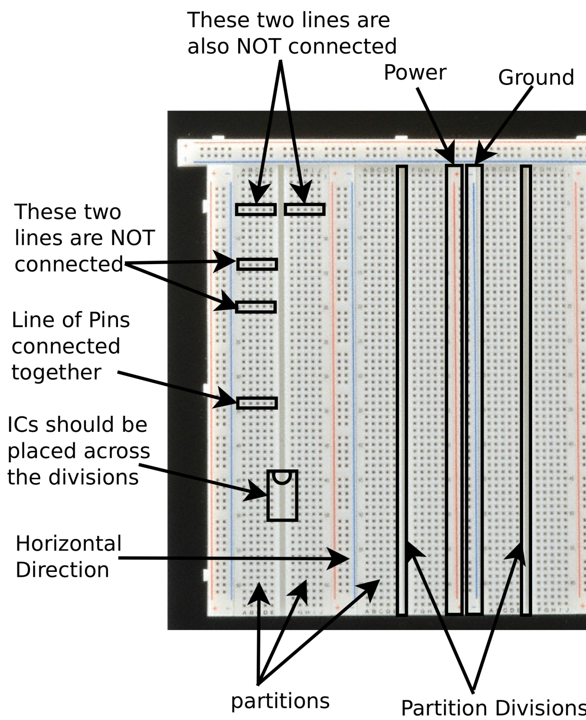

Figure 4: Twin Industries TW-E41-1060 Bread-Board

3. Power and Ground lines shown vertically in Figure 4 are electrically connected. In lab, you will connect the 5V supply to one of the pins in the Power line. This will connect the entire column to the 5V supply. Similarly, the Ground signal needs to be connected to one pin in the Ground line.

4. All the Integrated Circuits (ICs) in the design should be placed across one of the partition divisions as shown in Figure 4. Do not place an IC in only one partition because this will short pins together causing the IC to burn up.

5. Wires connecting different IC pins should traverse horizontally or vertically **only**. Do not connect wires diagonally across the breadboard as this will result in a messy design making it difficult to debug.

6. Use smaller wires when connecting nearby points on the breadboard. Please use wire strippers to shorten wires if smaller sized wires are not available. This will help keep your design clean and easy to debug.

7. You may decide to always place the IC in such a way that the notch is located on the top (or bottom) as shown in Figure 4. This may help you identify pin numbers. Similarly, it might be a good idea to use color codes while wiring up your design. For example, you could assign black wires to the least significant bit, white wires to the next significant bit, green wires to the next, and red wires for the most significant bit. The color code and order of assignment is entirely your choice and for your convenience in identifying wire connections while debugging.

8. Before placing the components on the breadboard, plan the placement of your ICs such that it minimizes wiring distance on the breadboard. ICs with high connectivity should be placed near each other. For example, if LED display inputs are connected to OR gate outputs, then try to place the OR gate IC as close as possible to the LED display.

2.3 Components and Equipment

This section will provide you with a brief description of some of the components and equipment you will be using throughout the semester.

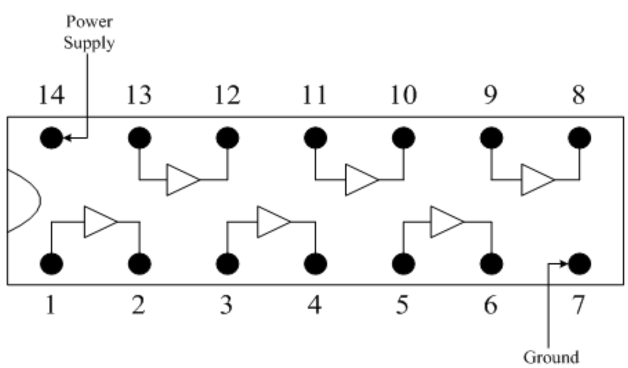

Figure 5: 74ALS04 pin-out

1. Figure 5 shows the pin-out of a 74ALS04 inverter chip. With the IC notch towards left, the pin numbers are counted in a clockwise direction as shown in the figure. The left most pin on the bottom row is pin 1 and the left most pin on the top row is pin 14. Never connect the output of an inverter to supply or ground as this will damage it.

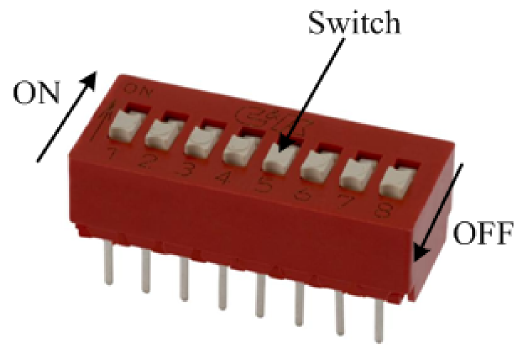

Figure 6: 16-pin DIP Switch

2. Figure 6 depicts a DIP switch, which is a set of electrical switches that are packaged in a standard Dual In-line Package (DIP). This type of switch is designed to be used on a printed circuit board or bread-board along with other electronic components and provides user input to a digital circuit. DIP switches usually come in packages with eight switches. The eight switch package offers up to 256 total combinations. In this lab class, we will use these DIP switches to read in a 0 (Off condition) or a 1 (On condition) from the user.

3. In Figure 7, pictures the multimeter use in lab. A multimeter is an instrument used to measure current, voltage, resistance etc. The knob in the center of the multimeter is used to select the mode of operation, while the measured values can be read on the LCD display. Please note that the modes of operation include various precision settings in addition to the type of measurement. The multimeter probes plug into the appropriate holes towards the bottom of the multimeter, depending on the type of measurement being made.

4. The oscilloscope, shown in Figure 8, is a device which can display waveforms of signals with respect to time. The Tektronix TDS2022 has 2 channels and supports a bandwidth of 200MHz. Two channels enable us to view two different waveforms simultaneously on the LCD screen, each measured with a different input probe. Alternatively, we can change the settings on the front panel to display only one of the two channels at a time. Each channel has a vertical position knob and a Volts per Division knob. One time per division knob controls both channels.

5. The power supply used in lab is depicted in Figure 9. In this lab, mostly we will be using +5V as most of our digital ICs operate at these supply voltages. If you need a second power supply, you can use the +20V supply adjusted at the required voltage level.

Figure 7: Extech Instruments model MN36 auto-ranging Multi-meter

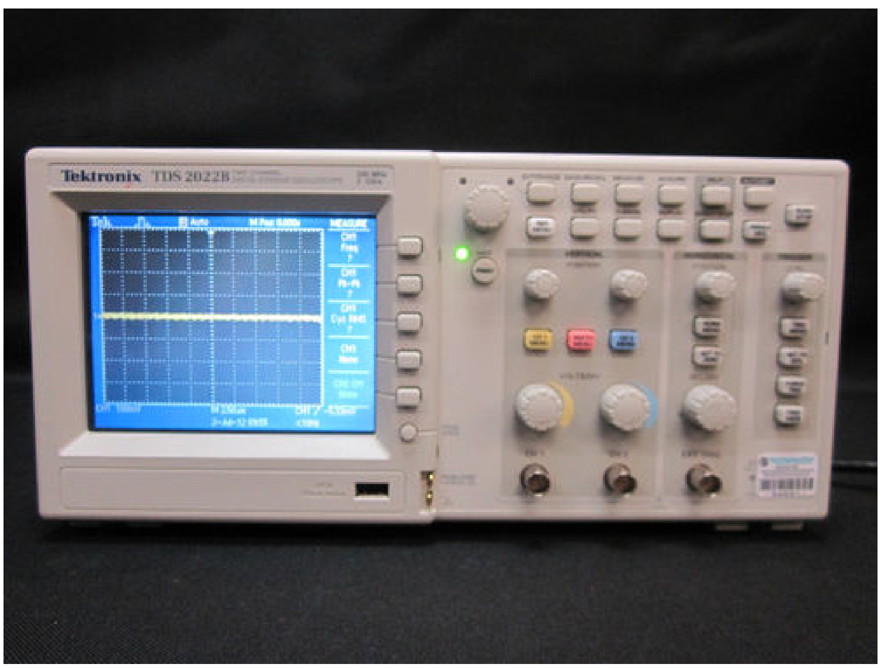

Figure 8: Tektronix TDS2022 Oscilloscope

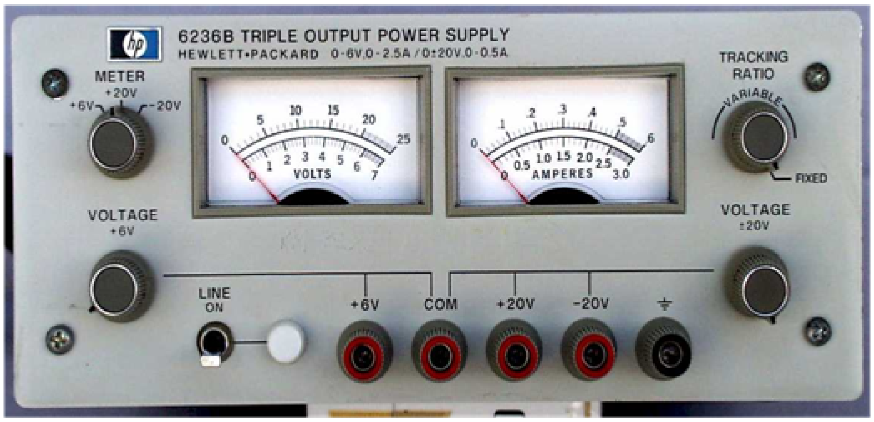

Figure 9: HP6236B Power Supply

6. In lab, we will be using a function generator to provide various types of signals as input to our circuits. In a digital lab, a function generator is a great clock signal source! Figure 10 depicts the function generator in lab.

Figure 10: HP33120A Function Generator

7. For the later labs, we will be programming more complicated digital circuits into the FPGA board shown in Figure 11. Field Programmable Gate Arrays (FPGAs) provide a tremendous amount of reprogrammable logic within a single IC package. The development board allows us to evaluate the

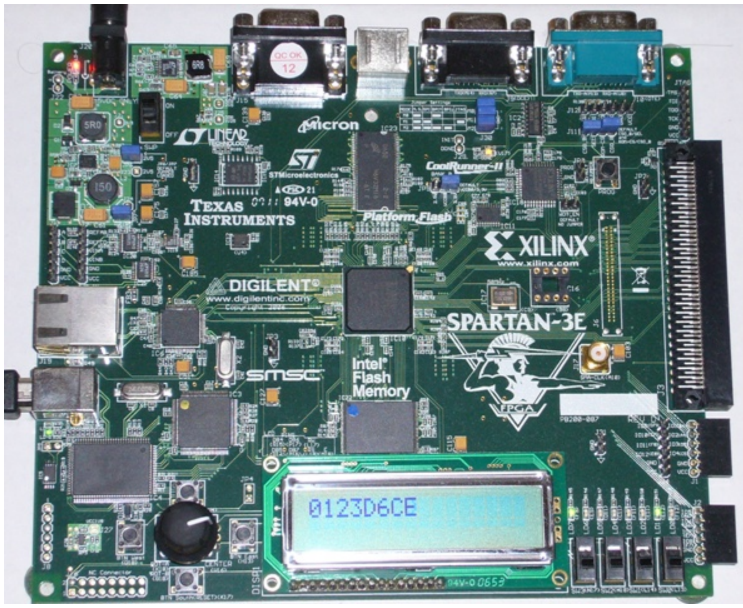

Figure 11: Spartan-3E Development Board

FPGA without the need for fancy soldering machines!

3 Pre-lab

The T.A. will demonstrate the use of the oscilloscopes, power supplies and multimeters in the beginning of this lab. No formal Pre-lab submission is required for this lab assignment

4 Lab Procedure

We will look at the behavior of logic gates in Figure 1. Each of these gates is embedded in an integrated circuit package. Consult the datasheets of each component for the pin-outs, electrical and timing characteristics of these circuits. All datasheets are available on www.alldatasheet.com.

4.1 Experiment 1

We will start by setting up the DC power supply and multi-meter for our use. Be sure both are turned off. Then check to see that the multi-meter is set to measure DC, and be sure the red lead is connected to the red multi-meter input that is marked for voltage. Finally, set the scale to the range you need to measure (usually between 0V to 5V for digital circuits). Now, set the DC power supply voltage output to zero (turn the coarse adjustment counterclockwise until it stops). Connect the red lead of the power supply to the red lead of the multi-meter. Likewise, connect the black lead of the power supply to the black lead of the multi-meter.

Note: Do not connect Power (RED) and Ground (Black) together. This will cause a short.

Turn on both the multimeter and the power supply. The multimeter should read very close to zero. Turn the coarse adjustment clockwise until the multimeter reads 5V. If the multimeter display does not change significantly when you turn the coarse adjustment, turn the power supply off and recheck your connections. You may have a short. When the multimeter reads 5V, the adjustments are complete and you should turn off the power supply. You are ready to test your first gate. We will start by wiring a 74ALS04 (inverter) gate. Please refer to the pin configuration given in the 74ALS04 datasheet. Insert the 74ALS04 chip onto the breadboard. Be sure you are not shorting pins together. Identify the power (VCC) and ground (GND) pins for the 74ALS04 from the pin-out of the 74ALS04 in the datasheet. Connect the VCC pin to the red lead of the power supply and connect the GND pin to the black lead of the power supply. This chip (7404) contains 6 different inverter gates. Each inverter gate has an input pin and a corresponding output pin. Choose one of the gates and connect the red lead of the multimeter to the gate output. The black lead of the multimeter should always be connected to the black lead of the power supply (at the GND pin). Then connect a wire from either the VCC pin to the input (for a logic High input) or from the GND to the input (for a logic Low input). Do not connect both at the same time, as this will cause a short. Turn on the power supply and observe the gate output. Assume A is the input to the inverter (either High or Low) and that Y is the output. Fill in Table 1 in your post-lab report according to the logic behavior that you observe.

Table 1: Truth Table for Inverter (NOT Gate)

A (High/Low)	Y (Volts)	Y (High/Low)
Low		
High		

Note: First fill in the second column of the table using the readings from the multimeter. Then determine the answers to the last column based upon these readings. If the output is high (H), the multimeter will read approximately 3.9V - 4.2V; when it is low (L), the multimeter will read about 91.9 mV. If you read a voltage between these values, you have likely wired your circuit incorrectly. Please demonstrate your progress so far to the TA.

4.2 Experiment 2

We are going to repeat the same experiment with the gates 74LS00 (NAND), 74LS02 (NOR), 74LS08 (AND), 74LS32 (OR), and 74LS86 (XOR). Note that each of the gates has two inputs and one output. Fill in Table 2, 1.3 below in your post-lab report to indicate the observed responses of these gates. So far we have reviewed the voltage behavior (H/L) of various gates. This is an abstract way to interpret this voltage behavior which is called *logic interpretation*.

Note: Demonstrate your progress so far to the TA.

Table 2: Truth Table for AND & OR Gates

A (H/L)	B (H/L)	AND2 (V)	AND2 (H/L)	OR2 (V)	OR2 (H/L)
L	L				
L	H				
H	L				
H	H				

Table 3: Truth Table for NAND, NOR, & XOR Gates

A (H/L)	B (H/L)	NAND2 (V)	NAND2 (H/L)	NOR2 (V)	NOR2 (H/L)	XOR2 (V)	XOR2 (H/L)
L	L						
L	H						
H	L						
H	H						

4.3 Post-Lab Deliverables

Please include the following items in your post-lab write-up in addition to the deliverables mentioned in the *Policies and Procedures* document.

1. Provide a copy of each truth table in your final lab report.

5 Important Student Feedback

The last part of lab requests your feedback. We are continually trying to improve the laboratory exercises to enhance your learning experience, and we are unable to do so without your feedback. Please include the following post-lab deliverables in your lab write-up.

Note: If you have any other comments regarding the lab that you wish to bring to your instructor's attention, please feel free to include them as well.

1. What did you like most about the lab assignment and why? What did you like least about it and why?

2. Were there any section of the lab manual that were unclear? If so, what was unclear? Do you have any suggestions for improving the clarity?

3. What suggestions do you have to improve the overall lab assignment?