The University of Texas at Dallas
Electrical Engineering Department
EE 2110 Laboratory: Digital Logic and Computer System Fundamentals
Experiment #1 – Familiarization with Lab Equipment and Basic Logic Functions

1. **Introduction:** This course is intended as a companion laboratory to EE 2310, Digital Logic, Assembly Language Programming, and Computer Fundamentals. As such, we will be becoming familiar with simple digital circuits in the first few laboratories, since these relatively simple circuits make up all of the functional units in even the most sophisticated digital computer systems and microprocessor chips.

2. **Goal of this exercise:** The purpose of Experiment #1 is (1) to familiarize students with the laboratory equipment on which all of the digital hardware exercises will be performed, and (2) to understand the operation of fundamental logic gates – the AND, OR, NOT, NAND, NOR, and XOR circuits.

3. **Theory of experiment:** The Boolean functions listed above have been discussed in class. The basic definitions are:
   - **A AND B is true (or "1" or "high") if and only if ("iff") both A and B are true (or 1 or high). The AND mathematical symbol is "·". Thus, A·B = 1 iff A = B = 1.**
   - **A OR B is 1 if A or B or both A and B are 1. The OR function is represented mathematically as "+". A + B = 0 iff A = B = 0.**
   - **A NOT is 1 only if A is 0; A NOT is 0 only if A is 1. The output of NOT is always the opposite logic state of the input. The symbol for NOT is a line above the Boolean variable.**
   - **NAND: The output is 0 (or "low") if and only if ("iff") both inputs A and B are 1 ("high"). That is, the expression $\overline{A \cdot B} = 0$ iff A = B = 1. Otherwise the output of NAND is 1.**
   - **NOR: The output of NOR is 0 if inputs A or B or both is 1; it is 1 only if A and B are both 0.**
   - **XOR: The output of XOR is 1 only if inputs A=1 and B=0, or A=0 and B=1; it is 0 if A and B are both 0 or both 1. That is, <u>A XOR B is 1 only when A and B are opposite values</u>.**
   - **Most of these definitions hold for more than two inputs. For XOR, the output of XOR is 1 when the number of 1's on the input is ODD. When the number of 1's input is EVEN, the output of XOR is 0.**

   For the digital logic circuits to be used today, inputs are nominally +5 volts for logic 1, and 0 volts (technically less than about 0.7 volts) for logic 0. Likewise, circuit outputs are nominally 0 volts for 0 or false, and +5 volts for 1 or true. In today's experiment, we will verify that the electrical AND, OR, NOT, NAND, NOR, and XOR functions performed by the circuits in question do in fact correspond to the logic relations given above.

4. **Experimental Equipment List:** The following experimental components are required for this experimental procedure:
   - **IDL-800 Digital Lab. Circuits Evaluator ("breadboard" unit with test equipment and power supply built in)**
   - **IDL-800 User Manual, if necessary (in lab cabinet)**
   - **SN 74LS04 hex inverter (NOT) gate (digital logic kit)**
   - **SN 74LS00 and SN74LS08 quad 2-input NAND and AND gates (digital logic kit)**
   - **SN 74LS02 and SN 74LS32 quad 2-input NOR and OR gates (digital logic kit)**
   - **SN 74LS86 XOR gate (digital logic kit)**
   - **Breadboard wire connection kit**
   - **Pin assignment diagrams for 74LS04, 74LS00, 74LS08, 74LS02, 74LS32 and 74LS86**

5. Pre-Work: Prior to the laboratory period, study class notes and prepare a truth table for each of the six logic functions. Bring these truth tables to the laboratory. Also prepare truth tables for the four functions defined in part 12 of Section 6 below and bring them to the lab.

6. Experimental Procedure:

Equipment Familiarization

1) **Become familiar with the IDL-800 chassis (refer to the manual at any time if additional clarification is needed). Note that the rear panel (forward-facing near-vertical panel at the back of unit) contains the master power on-off switch. In addition, the left side of the panel contains a function generator which can generate an electrical signal in three forms: sinusoidal, triangular, and square wave. Both the frequency and amplitude can be varied. On the right side of the panel, there is a digital voltmeter that can measure various voltages applied to circuits. Note that the voltmeter can be connected either to banana plugs or the small wire connectors that are used to connect circuit pins together.**
2) **Study the flat portion of the IDL-800 chassis. On the left side are two +5VDC (non-variable) power outputs, plus a variable DC supply with outputs of 0-15 and 0-(–15) V. On the right are wire connector-to-banana plug adapters and other inputs (which will not be used in this lab). At the bottom are some function switches that can apply +/– 5V, and two “pulse” switches which will apply a 1 (5V) or 0 (0V) as long as they are held down. There are also 8 “data” switches that can be switched to apply 1 or 0 (5V or 0V) to any input. At the rear of the flat board are data indicators, including two seven-segment displays which will display numbers, and 8 light-emitting diode (LED) indicators which can be connected to circuit pins to indicate whether a one (5V) or a 0 (0V) is present. <u>A 1 will light up the LED; a 0 turns it off</u>.**
3) **The center of the flat chassis area is the prototype board. At the top and bottom are “power busses.” When these are connected by the solid copper wires in the wire kit to one of the supplies (red to +, blue to ground or 0), all the other holes in the respective lines connect to that voltage element.**
4) **Note that the prototype board contains two several areas of pin holes. When a chip is plugged into any set of holes in such a way that it bridges the wide space in the middle of each group of holes, all holes in each row which contains a chip pin are also connected to that pin. Thus other components, logic inputs, or voltages can be connected to each pin of the circuit being evaluated. Note: There are two types of prototype boards available with the IDL-800. One set has vertical channels between sets of holes and one has horizontal channels. Either type is fine, but always make sure that the circuits are inserted into the board so that the body of the chip spans one of the channels.**
5) **Take some time to study the chassis, and ask questions of the instructor or TA if necessary.**

Experimental Procedure

6) **NOT Function:**
   - **Make sure the master power is off.**
   - **Find the hex inverter (74LS04) and carefully plug it into the breadboard so that the chip bridges the “valley” between two sets of holes. The exact location of the chip on the board is arbitrary.**
   - **Using the small solid copper wires from the kit supplied, connect +5V to pin 14 and 0V (ground) to pin 7. Remember that the “notch” is located on the end of the chip where pin 1 is. Looking down from the top, pin 1 is on the left, and pin 14 is on the right; pin numbering is counter-clockwise from 1 to 14 (refer to diagram on last page).**
   - **There are six inverters (NOT functions) on the chip. Any will do equally well, but this example uses the first, which has input on pin 1 and output on pin 2. Connect one of the data switch outputs at the bottom of the panel (bottom right) to the input (pin 1) of the**

inverter. Connect the output of the inverter (pin 2) to one of the LED diode inputs at the top of the horizontal portion of the IDL-800. Make sure that the data switch is in the 0 position.

- **Turn on the power. Verify that the LED is on; since the input is 0, the output should be 1 (0V), so the diode should be illuminated.**
- **Turn the data switch to 1. Verify that the LED is extinguished. The input is now 1, so the output is NOT-1, or 0. Toggle the switch several times to verify that the inverter or NOT gate output is always opposite of the input.**
- **Turn off the power and disconnect the circuit connections.**

7) AND Function:

- **Find the 74LS08 chip and plug it into the board as you did the 74LS04. Connect pins 7 and 14 to ground and +5V as before. Note that there are 4 equal AND circuits on the chip, but these instructions use the first one numerically (refer to the pin-out diagram as needed).**
- **Connect two data switches to the AND gate inputs, pins 1 and 2. Make sure both inputs are 0. Connect the AND gate output, pin 3, to an LED input.**
- **Turn on the power. Verify that the LED is off. Turn one data switch on (to 1). The LED should stay off. Turn that data switch back to 0, and turn the other to 1. The LED should still be off. Now turn both switches on (to 1). The LED should light. This verifies that the AND function is as defined – the output is 1 iff both inputs are 1. Try this switching several times to get the "feel" of the circuit.**
- **Turn off the power and disconnect the circuit connections.**

8) OR Function:

- **Find the 74LS32 chip and plug it into the board as you did the other circuits. Connect pins 7 and 14 to ground and +5V, respectively, as before. Note that there are 4 equal OR circuits on the chip, but these instructions use the first one numerically (refer to the pin-out diagram as needed).**
- **Connect two data switches to the OR gate inputs, pins 1 and 2. Make sure both inputs are 0. Connect the OR gate output, pin 3, to an LED input.**
- **Turn on the power. Verify that the LED is off. Turn one data switch on (to 1). The LED should light up. Turn that data switch back to 0, and turn the other to 1. The LED should light up once again. Now turn both switches on (to 1). The LED should light under this condition also. This verifies that the OR function is as defined – the output is 1 if either or both inputs are 1. Try this switching several times as above to get the "feel" of the circuit.**
- **Turn off the power and disconnect the circuit connections.**

9) NAND Function:

- **Find the 74LS00 chip and plug it into the board as you did the chips last week. Connect pin 7 to ground (0) and pin 14 to +5V as before. Note that there are 4 equal NAND circuits on the chip, but these instructions will use the first one numerically (refer to the pin-out diagram as needed).**
- **Connect two data switches to the NAND gate inputs, pins 1 and 2. Make sure both inputs (switch positions) are 0. Connect the NAND gate output, pin 3, to an LED input.**
- **Turn on the power. Verify that the LED is on. Turn one data switch on (to 1). The LED should stay on. Turn that data switch back to 0, and turn the other to 1. The LED should still be on. Now turn both switches on (to 1). The LED should go out. This verifies that the NAND function is as defined – the output is 0 iff both inputs are 1. Try this switching several times to get the "feel" of the circuit.**
- **Turn off the power and disconnect the circuit connections.**

10) NOR Function:

- **Find the 74LS02 chip and plug it into the board as you did the other circuits. Connect pins 7 and 14 to ground and +5V, respectively, as before. Note that there are 4 equal NOR circuits on the chip, but these instructions use the first one numerically (refer to the pin-out diagram as needed).**
- **The pin connections on the 74LS02 are somewhat different from the 74LS00. Connect two data switches to the NOR gate inputs, pins 2 and 3. Make sure both inputs are 0. Connect the NOR gate output, pin 1, to an LED input.**

- **Turn on the power. Verify that the LED is on. Turn one data switch on (to 1). The LED should go out. Turn that data switch back to 0, and turn the other to 1. The LED should turn off once again. Now turn both switches on (to logic 1). The LED should be out under this condition also. This verifies that the NOR function is as defined – the output is 0 if either or both inputs are 1. Try the combinations several times to get the "feel" of the circuit.**
- **Turn off the power and disconnect the circuit connections.**

11) **XOR Function:**
- **Find the 74LS86 chip and plug it into the board. Connect pin 7 to ground (0) and pin 14 to +5V as usual. Note that as for most of these small-scale integrated circuits, there are 4 identical XOR gates on the chip; once again, these instructions will use the first one numerically (refer to the pin-out diagram as needed).**
- **Connect two data switches to the XOR gate inputs, pins 1 and 2. Make sure both inputs (switch positions) are 0. Connect the XOR gate output, pin 3, to an LED input.**
- **Turn on the power. Verify that the LED is off. Turn one data switch on (to 1). The LED should illuminate. Turn that data switch back to 0, and turn the other to 1. The LED should also turn on for this input. Now turn both switches on (to 1). The LED should go on when the first switch is turned on and go out when the second is turned on. This verifies that the XOR function is as defined – the output is 0 if both inputs are 0 or 1, and 1 if one input is 1 and the other 0. Try the combinations several times to get the "feel" of the circuit.**
- **Turn off the power and disconnect the circuit connections.**

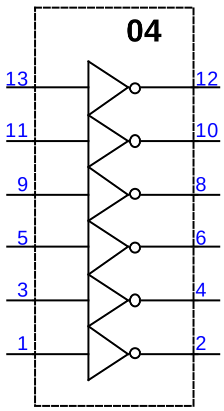
12) **Solving for several expressions:**
- **Consider the following expression: $Y = (A \cdot B) \cdot (C \cdot D)$. Use the quad AND gate chip to connect a circuit which will satisfy this expression (you should have the truth table done as part of the pre-work). Verify that Y is 1 iff A through D are all logic 1.**
- **The following logic expressions can be constructed very simply using the six logic gates that we have used in the lab. Remember in the expressions below that the "NOT" designation is a line above the expression. Construct all three circuits and make sure that their electrical performance matches the truth tables that you developed in the pre-work.**
  - $Y = \overline{A \cdot B} + C \cdot D$
  - **An alternate expression for the XOR function is: $(A \oplus B) = A \cdot \overline{B} + \overline{A} \cdot B$. Assume that the XOR chip is not available, and construct the XOR function from AND, OR, and NOT gates. Validate that the circuit performance matches the truth table for XOR.**
- **In the third EE 2310 class, you were given a specification and told to develop a truth table, a corresponding Boolean expression, and the resulting circuit design. Build that circuit design in this lab, and use the input switches to verify that the output of the circuit matches the truth table for all eight combinations of the input variables.**

7. **Equipment Disassembly:** The experimental procedure is complete. Please disassemble the circuit wiring, replace in the wiring kit box. Check with your laboratory TA and return the wire and parts kits to the cabinet or leave them on your workbench as directed. Make sure that your work area is clean.

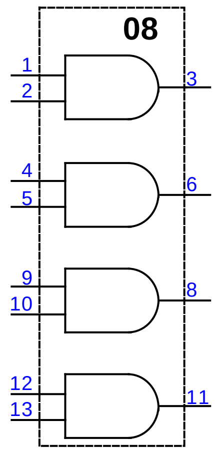
8. **Laboratory Report:** Your laboratory report should follow the form which is located on the website. In your write-up, discuss your results. Also do the following:

- **Discuss any problems with the procedure.**
- **Include your truth tables for the functions in part 12 of Section 6.**
- **Show the wiring for each of the circuits that you built in part 12 of Section 6. Make sure you remember to show the <u>pin numbers</u> of the gates that you connected (you do not have to show the entire circuit packages, just the gates you used).**
- **Using data from the circuit you designed in the EE 2310 class assignment, discuss your results. Did the circuit output match all eight cases in the truth table?**

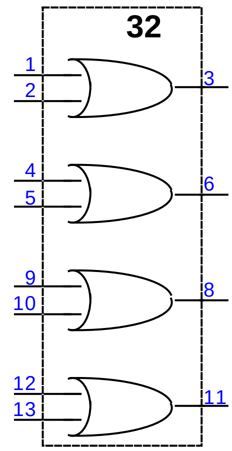
9. Circuit Diagrams: Here are the pin-outs for the circuit elements used in this laboratory:



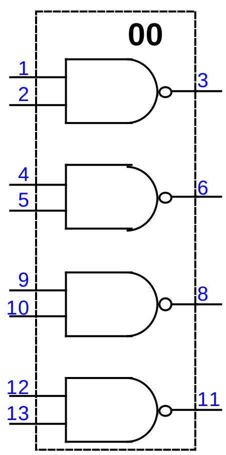
SN 74LS04 Hex inverter gate



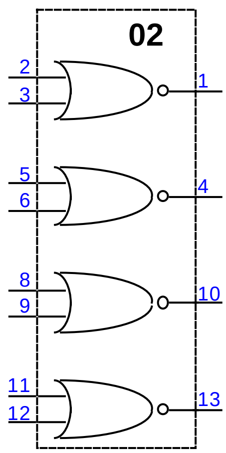
SN 74LS08 Quad 2-input AND gate



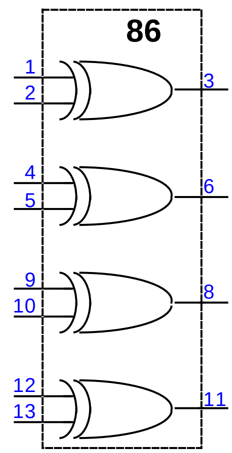
SN 74LS32 Quad 2-input OR gate



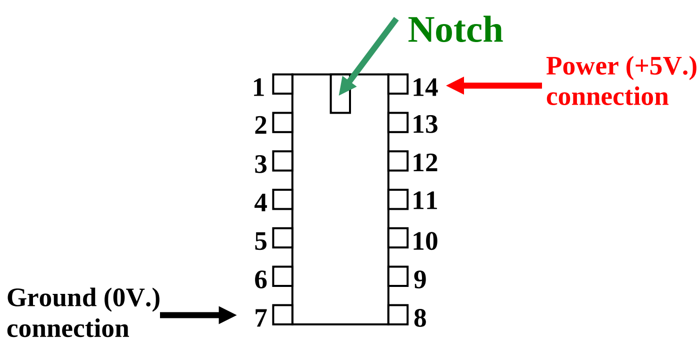
SN 74LS00 Quad 2-input NAND gate



SN 74LS02 Quad 2-input NOR gate



SN 74LS86 Quad 2-input XOR gate



74 LS XXX Chip Outline