Faculty of Engineering and Applied Science
Memorial University of Newfoundland
ENGI 3861 - Digital Logic
Fall 2008

Laboratory 1:
Lab Instruments and Simple Logic Circuits

Pre-lab

All students must review the complete lab prior to the lab period. Each group must complete all sections marked "PRE-LAB". The pre-lab will be checked by a TA at the start of the lab. If a group's pre-lab work is not complete, the group will not be allowed to complete the experiment.

Lab Report

Each group is expected to complete a lab report. At the end of the lab, hand in the lab report, which should include the pre-lab, along with the lab observations and comments requested. Where indicated, demonstrate the correct operation of your circuit to a TA and have them sign your lab report.

1. Introduction

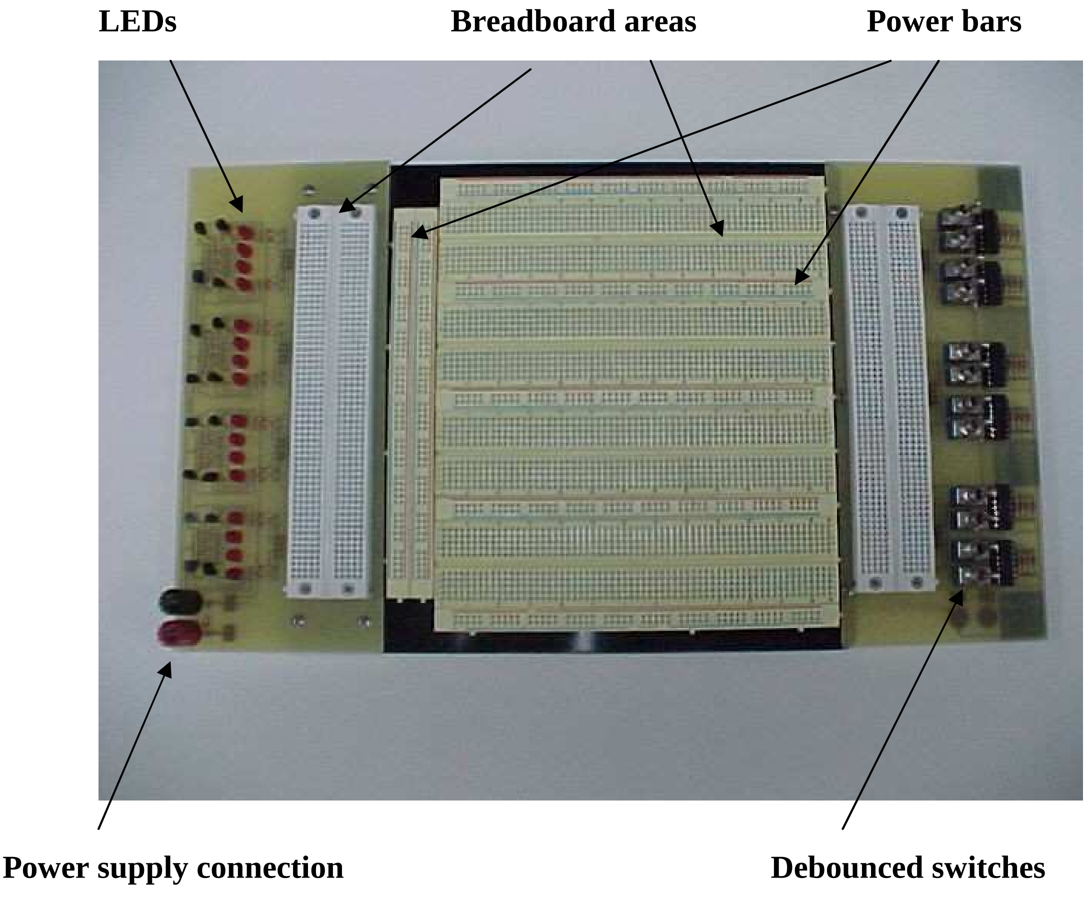
The purpose of this lab is to become familiar with the different types of test instruments used in the building, debugging, testing and repair of discrete digital electronic circuits and to construct some simple combinational logic circuits. Although modern digital circuits are typically integrated in chips containing many thousands, even millions of gates, the labs undertaken in this course will often involve wiring up individual gates in order to verify a circuit's design.

The instruments experienced in this lab include digital breadboard, power supply, function generator, digital multimeter, logic probe, and oscilloscope. As well, although not used during this experiment, logic analyzers are frequently used in the design and test of digital circuits.

2. Equipment

In this course, you will build circuits on a board that has been fabricated in-house. See Figure 1. It has sufficient breadboard area to assemble circuits with 20 integrated circuits (ICs) and other components. Along the edges of the breadboards, long 'power bar' strips are provided; these are used to connect power (i.e., ground (GND) and + 5 V) lines. You will find it convenient to connect the GND and + 5 V input posts to power bars on the board; for example, any contact along the same bar to which GND is connected will be at ground level, and can be used as ground input. After carefully planning the layout of ICs on the board, each IC should be inserted into the chosen location, across the middle bridge in a breadboard, making sure that the pins are not bent. The digital board also has twelve debounced toggle switches that are used to provide input and clock signals to circuits, and sixteen LEDs that are used to display the outputs of the circuits.

The power supply requirement for simple digital circuits that will be built in this lab is fixed +5 V. A simple power supply unit is sufficient for the purpose. However, you might find a more sophisticated power supply on your desk. If you are connecting your board to a variable power supply output, measure the voltage and ensure that it does not exceed +5V, as the ICs may not withstand more than +5 V. It is also a good idea to always turn off the power supply while you are wiring (or modifying) a circuit.



3. 74xx Series ICs and Data Sheets

[Complete this section as PRE-LAB. Also, you may find it helpful to print off the data sheets of several devices required for this lab, namely, 7400, 7404, 7408, and 7432.]

In this course, you will be constructing circuits using the 74xx series of integrated circuits. It is straightfoward to find data sheets describing the properties (both functional and electrical) of the ICs by googling the appropriate chip number or going to the manufacturer's web page. For convenience, the data sheets for many of the devices used in this course can be found on the course website. Using data sheets, the Internet, or any other resource answer the following questions:

(a) A typical device used in the course is labelled SN74LS04. The last 2 digits ("04") identify the chip as containing inverters or NOT gates. What does SN represent? What is the meaning of LS? What is the difference between the 54xx and 74xx series of ICs?

(b) For SN74LS00 and SN74LS04, what are minimum acceptable values for V_{IH} and V_{OH} under recommended operating conditions? Maximum acceptable values for V_{OL} and V_{IL}? Compute the noise margins.

(c) For SN74LS00 and SN74LS04, determine the specifications for propagation delay for high-to-low and low-to-high transitions.

(d) Get an estimate of the cost of purchasing 1000 74LS00 "through hole" (that is, not surface mount) DIP (dual inline packaging) components. Specify the supplier and the location of their website.

(e) Sketch the pin configuration for 7400 and 7404 DIP chips.

4. Some Simple Measurements

In this section of the lab, you will use the digital board and 7400 and 7404 chips to get familiar with typical equipment used in the lab, including the power supply, logic probe, digital multimeter, function generator, and oscilloscope.

4.1 Basic Gate Operation

(a) Ensure the power to the digital board is off. Place the 7404 chip on the digital board and connect the power supply and ground to the appropriate pins on the chip. (Be sure not to apply more than +5V to the chip!) Connect one of the inverter inputs to a toggle switch. Turn on the power to the board and, using the logic probe, flip the switch and verify the correct input and operation of the inverter. ***Using the digital multimeter, measure and record the voltages of input and output for each different input level. Comment on whether the results are as expected.***

(b) Ensure the power to the digital board is off. Place the 7400 chip on the board and connect power and ground to the appropriate pins and toggle switches to the inputs of one of the chip's NAND gates. Turn on the power to the board and, using the logic probe, verify the correct operation of the NAND gate. ***Using the digital multimeter, measure and record the input voltages and output voltage for each possible input combination. Comment on whether the results are as expected.***

4.2 Using the Oscilloscope

The oscilloscope is perhaps the most useful piece of test apparatus in the lab. It can measure logic levels, pulse widths, rise and fall times, time between pulses, compare two signals, and measure the time delay or phase difference between two signals. The oscilloscope in the lab is capable of displaying two traces and there are separate knobs to adjust the magnitude level (vertical scale). A separate knob is available to adjust the time axis scale (the horizontal scale) or the time base. With older analog scopes, in order to get a steady trace on the screen, the input signal must be periodic in order for the scope to successfully "trigger" on a signal. However, the oscilloscope used in this lab is a digital storage scope that is capable of triggering on a single event and storing the resulting signal levels following the trigger.

The oscilloscope probe is a delicate and expensive piece of apparatus. Therefore, it is important that the probes are handled with care. Most probes come with a switch to select the attenuation level between 1x ("times one") and 10x ("times ten"). If the 10x setting is used, then the trace will be 10 times as small as what you would expect for the scale you have selected.

(a) Connect the function generator through a wire to the digital board using the TTL output and adjust the output to generate a square pulse train at a frequency of 1 kHz. Using Channel 1 of the scope measure the amplitude and frequency of the signal. (The ground of the function generator should be connected to GND on the digital board. Also, the scope probe's ground clip should be connected to a GND contact on the digital board, and the probe connected to the output on the function generator.) ***Sketch the signal, indicating the appropriate time and magnitude values.***

(b) Change the frequency and observe the waveform – you will have to adjust the time base scale whenever the frequency of the input signal changes considerably. ***Sketch the trace when the frequency is (1) increased 10 MHz and (2) decreased to 20 Hertz.***

(c) Ensure that the power supply to the digital board is off and install a 7404 hex inverter (6 inverters in one package) on the digital board. Connect the power and ground pins and connect the function generator output to pin 1 of the 7404 – this is the input of one of the six inverters on the device; the output of this inverter is available on pin 2.

(d) Turn the power supply on and observe the waveforms on the input and output of the inverter (pins 1 & 2) using two channels of the oscilloscope.

(e) Turn the power supply off. Connect all six inverters inside the 7404 IC in series (but not in a loop). Connect the function generator output to the input of the first inverter.

(f) Turn the power supply on and observe the waveforms on the input to the first inverter and the output of the sixth inverter in the chain. Increase the frequency of the input signal to several megahertz. You will see two square pulse trains on the oscilloscopes, and there will be a small phase (time) shift between the two. ***Sketch your observations, being sure to indicate any appropriate scales. Determine the delay between the two waveforms during the upswing and downswing of the pulse. Calculate the average propagation delay per inverter for low-to-high and high-to-low transitions. Compare these values to the values determined from the data sheet.***

(g) Now turn off the power to the digital board and place a 7400 NAND IC on the board, connecting up the power and ground. Connect the function generator to one input of a NAND gate and connect a toggle switch to the other input. Connect Channel 1 of the scope to the input from the toggle switch and Channel 2 to the output of the NAND. With the toggle switch set to "high", use the scope to observe the output of the NAND gate. Using the "trigger menu" button, set the scope to trigger on the falling edge of Channel 1 and select the "single sequence" trace. Flip the switch so that the input goes from high to low and observe the resulting display on the scope. ***Sketch the display so that both signals are clearly visible. Repeat for two more traces. Explain what is being observed in the traces.***

5. Simple Combinational Circuit

(a) As **PRE-LAB**, determine how to use NAND gates to produce (1) an inverter, (2) a 2-input OR function, and (3) a 2-input AND function. In the lab, using a single 7400 IC (quad 2-input NAND), connect a circuit that produces each gate above. Verify your circuits by checking its truth table using the logic probe. ***Record the results of your testing in your lab report.***

(b) As **PRE-LAB**, determine how to use NAND gates to produce the Boolean function

$$Y = A \cdot B + C \cdot \mathrm{D}.$$

In the lab, using a single 7400 IC, connect a circuit that implements the Boolean function and verify your circuit by checking its truth table using the logic probe. ***Record the results of your testing in your lab report.***

(c) Consider a digital circuit to compute odd parity for a 3-bit vector. As **PRE-LAB**, determine an algebraic expression (sum of products) to compute the parity bit. Draw the circuit diagram to realize the function based on 2-input AND, 2-input OR, and NOT gates. (Note, in order to save time in the lab, it would be best to mark pin numbers on the diagram.) In the lab, implement a circuit that does the same logic function using only 2-input AND, OR, and NOT gates. (That is, using 7404, 7408, and 7432 ICs.) ***Record the results of your testing in your lab report. Demonstrate the correct operation of your circuit to a TA and have them sign your lab report.***

Be sure to submit your lab report at the end of the lab period, including pre-lab, observations, recordings, comments, and TA signatures.

Revised by H. Heys, Sep. 15, 2008