CSC 258 - Digital Systems - Lab 0

Building Circuits using 7400-Series Chips

1. Introduction to the Digital Lab

The purpose of this lab is to illustrate the process of building logic circuits by using chips that contain individual logic gates. Although circuits are no longer built in this way in the industry, it is useful to see how the chips are connected together to understand the basic electrical connections.

Below is a description of the different pieces of equipment you will use: the protoboard, logic probe, wire strippers and digital switch/light board. **BEFORE the lab,** do the preparation specified in Section 2.0. During your lab, read through these sections and do the actions.

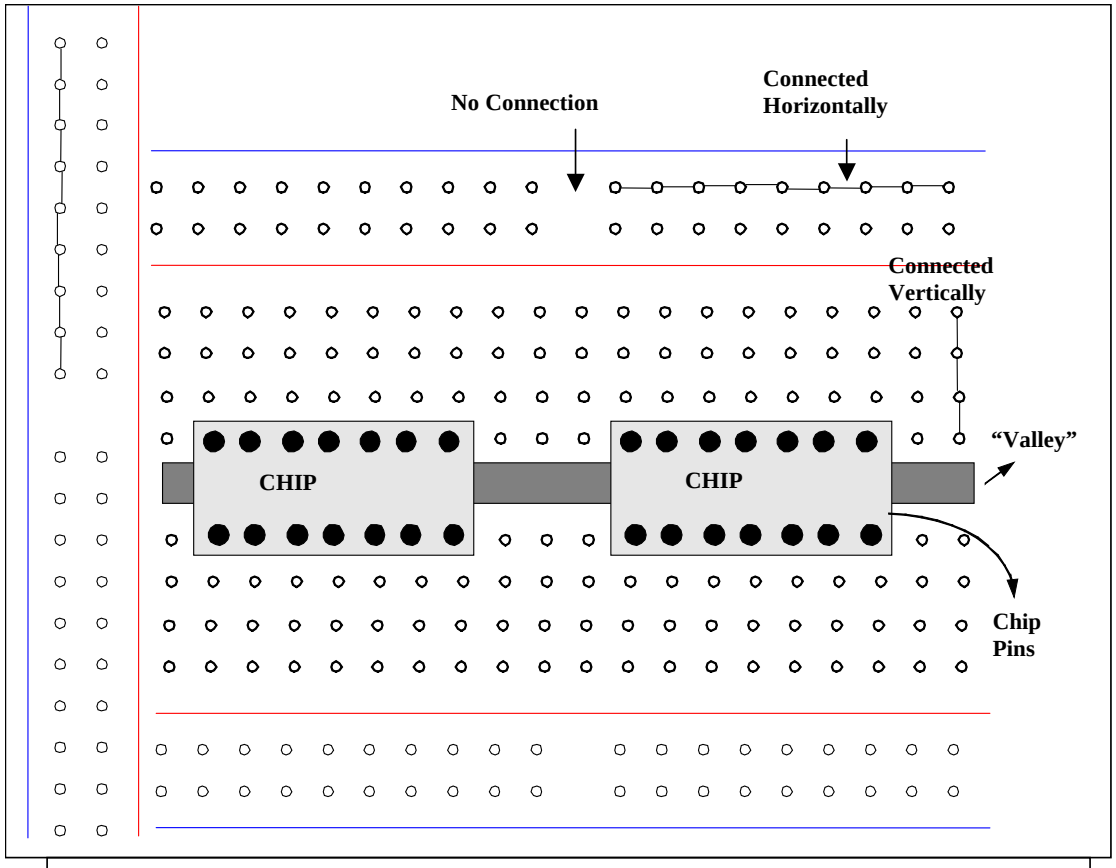


Figure 1 - Picture of the Protoboard

1.1 Protoboard

The protoboard is for holding and connecting chips. As illustrated in Figure 1, chips are inserted across the middle "valley" in the protoboard. The set of holes in a vertical line above the valley are connected electrically, as are the vertically aligned holes below the valley. So, each pin of the chip in the board is connected to the holes above (or below) the pin. To make a connection to a specific pin, you need only make connections between the holes by plugging the bare end of a wire into the holes above or below the pins.

In the figure the horizontal lines at the top and bottom of the board delineate holes that are connected horizontally; note that the space in the middle indicates a disconnection. The horizontally-connected holes at the top and the vertially connected holes at the side are usually connected to the power and ground provided by the external connector. The power and ground of the chips are then connected to these strips of holes. The first thing you should do in the lab is connect power and ground to these horizontal and vertical strips.

1.2 Digital Switch Board

The digital switch board provides switches that have digital output (5V = logic **1**, 0V = logic **0**) and lights that can be driven by logic signals (logic 1 turns a light on, logic 0 turns it off). Test the board by connecting the switches to the lights. These switches are "debounced", which means that for every on-off transition of the switch, there is only one electrical change of its output. (Without specific circuitry to make that happen, the electrical signal will "bounce" up and down many times for each physical transition of the switch; we will be covering this in a lecture later in the term).

The board also provides a clock, which can have its frequency varied by inserting different capacitors into the holes next to it, and a seven-segment display.

1.3 Logic Probe

The logic probe is used for measuring the logic values of signals on the board. Be sure that it has power attached, to the correct terminals. To test the probe, touch it to the +5V on the protoboard and ground, to ensure that it correctly indicates the values high (1) and low (0) respectively.

The logic probe also can indicate when a signal is changed (oscillating). Touch the probe to the clock on the digital board to see how the probe indicates oscillation.

1.4 Wire Strippers and Chip Puller

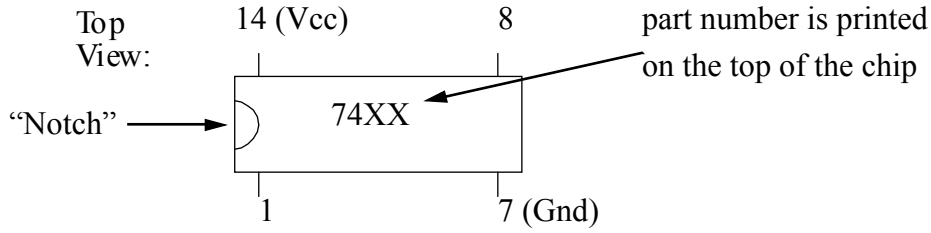
The wire strippers are attached to each workstation to make sure they don't get lost. If you haven't ever stripped a wire, try it!

The chip puller should always be used to remove chips from the protoboard. Doing it with your fingers will bend the pins and ultimately break them, so don't!

1.5 7400-series Chip Packages

The chips that you will use in this lab are Small Scale Integration (SSI - meaning not much logic on a single chip) 7400 series. Depending on exactly which chip you end up using in the lab you may have to set the logic probe to one of two settings: TTL or CMOS. This setting depends on the type of technolgy used for the transistors in the chips.

All of the chips you will use are "Dual In-line Packages" or DIPs. Most of the packages are 14 pins, and the pins are number from looking at the chip from the top: Below the "notch" is pin 1 to pin 7, and above the notch is pin 14 down to 8.



NOTE that Pin 14 must always be connected to VCC (+5V) and pin 7 to ground (0V).

2. Preparation for Lab 0 *(do this before the lab)*

Design each of the circuits specified below using **only** 74LS04 (NOT), 74LS08 (AND) and 74LS32 (OR) series gates, **as given on the attached sheets**. Choose the actual pin numbers of the chips that you will use when you build your circuit and show them on your circuit diagram - this will make the construction of your circuit easier.

In each case, show all of the steps required to go from the specification given below, to the final circuit, including: assigning variable names to inputs and outputs, deriving a truth table, the logic function, and then a schematic picture of the final circuit, with pin numbers and chip types.

Make sure to print out your work and bring it to the lab!

Important: You are allowed to use **only** the following packages (see sheet attached): 74LS04 (NOT gates), 74LS08 (AND gates) and 74LS32 (OR gates).

Part I

Design a circuit that has in three inputs (**a** , **b** and **c**) and one output (**f**), where **f** performs the following logic function (note that $\overline{x}$ is the notation for "x inverted" or "`not x`")

$$f = \overline{a}b + ac$$

Part II

Design a circuit that has two inputs (**x** and **y**) and one output (**f**). This circuit makes **f** true (`1`) when **x** and **y** are different, and makes **f** false (`0`) when they are the same.

Part III

Design a circuit with three inputs (**a**, **b**, and **c**) and three outputs (**f1**, **f2, and f3**).

- The first output (**f1**) should only be true (`1`) when **all three** of the inputs are low (i.e. have a value of `0`).
- The second output (**f2**) should only be true (`1`) when **exactly two** of the inputs are high (i.e. have a value of `1`).
- The third output (**f3**) should be true (`1`) whenever **an odd number** of the inputs are high.

Optional: Can you implement all three functions at the same time in a way that is cheaper (i.e. using fewer gates and/or wires) than doing each part separately?

3. In-Lab Exercise (do this during your lab session)

The purpose of this lab is to get familiar with the equipment *and* to build and test several combinational circuits, and get a sense of how to debug circuits that don't work.

3.1 Equipment Familiarization

Read through Section 1 of this handout, and test your equipment as indicated in that section. Make sure you know how all this stuff works; you will be using it heavily in this course, and we're likely to put questions about it on midterms and exams.

3.2 Building, Testing and Debugging Circuits

i. For each of the logic functions you designed in the preparation, build the circuit on the protoboard using chips which are available in the lab. Use switches on the switch board as input and the lights as output (your TAs will demonstrate how at the beginning of the lab). Remember to hook up the power!

   Show your teaching assistant that each circuit works correctly once it does.

ii. Once the final circuit is working and you have shown it to your TA, get another group to introduce a bug into the circuit (or get the TA to do it). For example, switch two wires, or switch a gate. Then, switch places with another group – your job will be to debug the other group's circuit. You are required to determine what the cause of the non-function is. To do this you must show concrete proof of the cause.

NOTE: Do not switch power and ground on your chips when adding bugs; we don't want to fry the chips!

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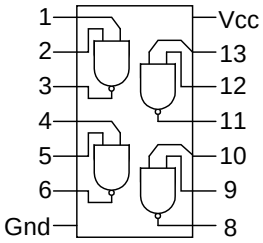
Pin-Out Information for 7400-series Chips and Digital Board

Here are the Pin-out numbers and schematics for all of the chips used in Lab 1:
(Note: Some of the chips are colour-coded this year, to make them easier to identify)

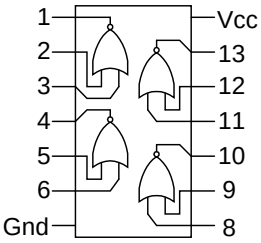
Pin-out of Selected TTL Chips

74LS00/03



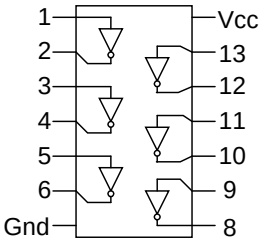
Quad 2-input NAND
Red

74LS02



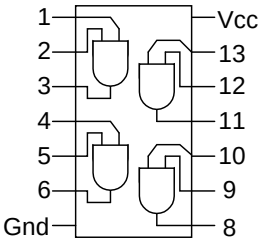
Quad 2-input NOR
Yellow

74LS04/05



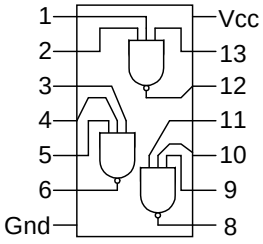
Hex INVERTER
Green

74LS08/09



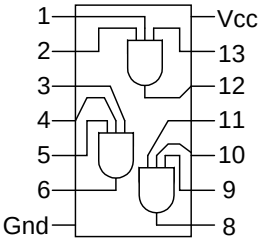
Quad 2-input AND
Blue

74LS10



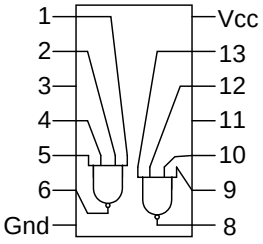
Triple 3-input NAND
Grey

74LS11



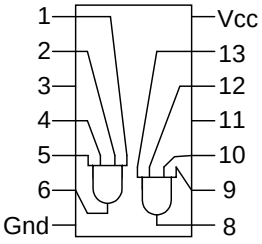
Triple 3-input AND

74LS20



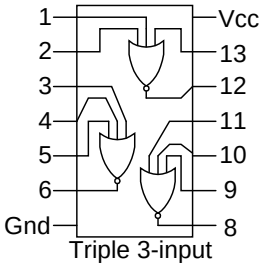
Dual 4-input NAND

74LS21



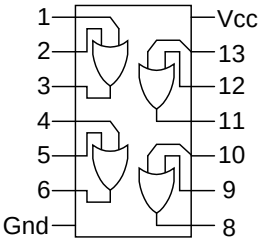
Dual 4-input AND

74LS27



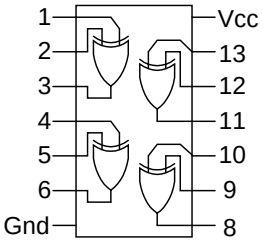
Triple 3-input NOR

74LS32



Quad 2-input OR
Orange

74LS86



Quad 2-input XOR

Here are the pin out connections for the header on the digital switch board:

Digital Board Header Pin Assignment						
Pin#	**Description**				**Description**	**Pin#**
1	Switch #1	o		o	Switch #2	2
3	Switch #3	o		o	Switch #4	4
5	Switch #5	o		o	Switch #6	6
7	Switch #7	o		o	Switch #8	8
9	Ground	o		o	NC	10
11	Ground	o		o	NC	12
13	Ground	o		o	NC	14
15	Ground	o		o	NC	16
17	LED #1	o		o	LED #2	18
19	LED #3	o		o	LED #4	20
21	LED #5	o		o	LED #6	22
23	LED #7	o		o	LED #8	24
25	Ground	o		o	NC	26
27	Ground	o		o	NC	28
29	Ground	o		o	NC	30
31	Ground	o		o	NC	32
33	Clock	o		o	NC	34
35	NC	o		o	NC	36
37	NC	o		o	Pulse Button	38
39	NC	o		o	NC	40