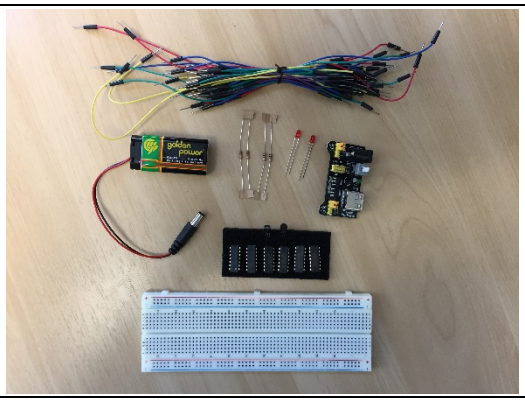
Lab 2

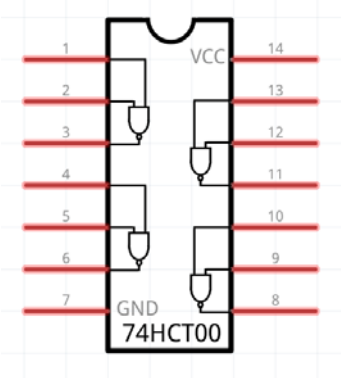
Objective: Understand Logic Gates and binary arithmetic.

Each Kit Should Contain

2 * LED 2 * 1K Ohms resister (Brown Black Red Gold) 2 * 10K Ohms resister (Brown Black Orange Gold) 1 * breadboard 1 * power board 1 * 9v battery (and connector) 2 * CTBC 547 JS Transistor (NPN) 2 * 74LS86 (quad 2-input XOR gate) 2 * 74LS08 (quad 2-input AND gate) 1 * 74LS00 (quad 2-input NAND gate) 1 * 74LS32 (quad 2-input OR gate) Bundle of Wire	

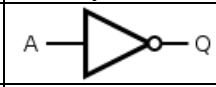
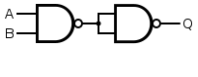
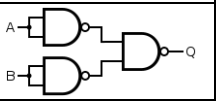
74LS00 quad 2-input NAND gate

This chip contains 4 NAND gates connected as shown in this schematic. Notice how the chip has a notch at one end – that is how you know which pin is which. The voltage pin (VCC) is at the opposite corner from the ground pin (GND).



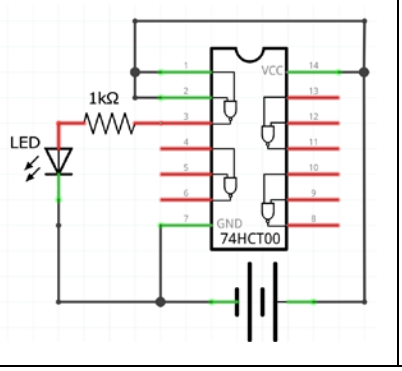
Gates To Gates

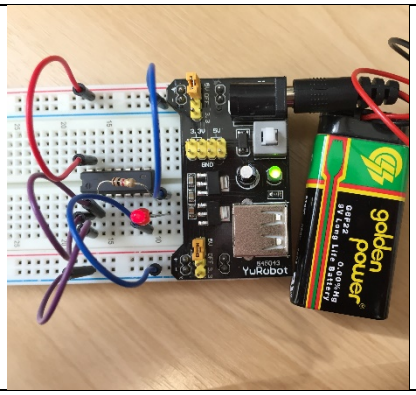
NOT, AND, and OR gates can all be built from NAND gates. This chart gives the translations.

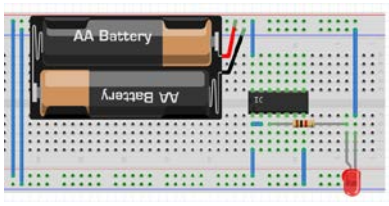
Gate	Symbol	Design
NOT		
AND		
OR		

Exercise 1: NOT from NAND

In this exercise we'll build a NOT gate from a NAND gate. Recall that a NOT gate is made from a NAND gate by connecting the two inputs together. The LED shows the output of the NOT gate. To work the gate, connect the input pins to either VCC or GND. In the schematic they are connected to VCC, in the photo they are connected to GND.



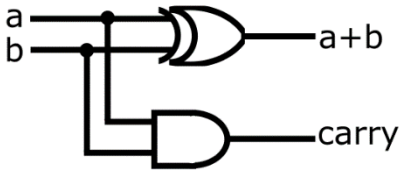




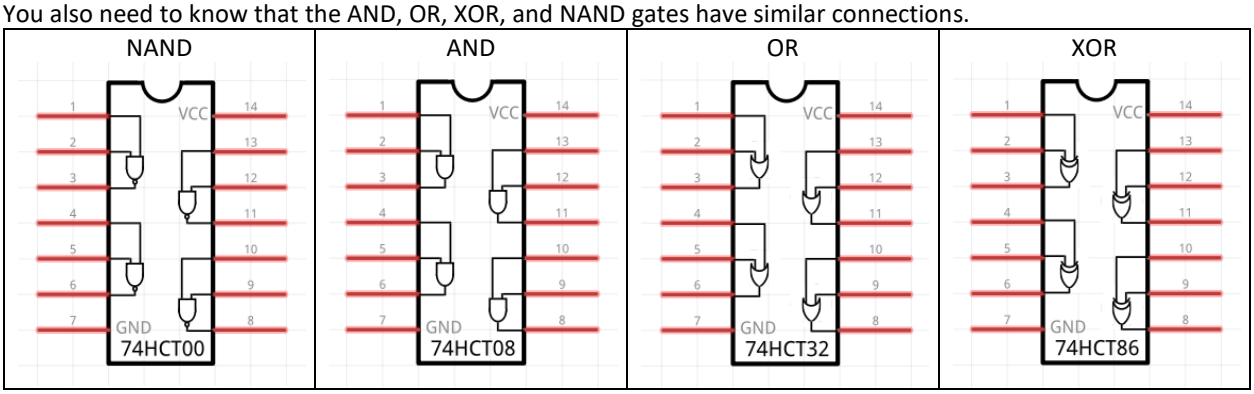
Exercise 2: AND gate from NAND gets
To build an AND gate you'll need two NAND gates. There are four in the 74LS00, you only need two of them.

Exercise 3: OR gate from NAND gates
To build an OR gate you'll need three NAND gates. There are four in the 74LS00, you only need three of them.

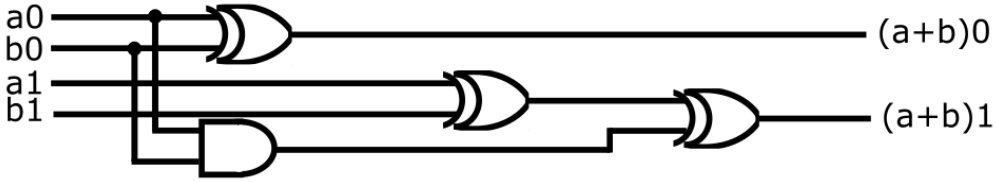
Exercise 4: Half Adder
Recall that in binary a+b = a XOR b and that the "carry" is a AND b. That is, to build a circuit that adds two 1-bit numbers together and produces a 2-bit answer we only need 2 gates. The circuit looks like this



You also need to know that the AND, OR, XOR, and NAND gates have similar connections.



Extra (Optional) Exercise: 2-bit Adder
The circuit for a half adder takes two bits as input and adds with carry. The circuit for adding 2-bit integers must use that carry. Build the 2-bit adder and make sure it works by testing all combinations of input. Don't worry about the final carry at the moment (it just makes the circuit mode complex). Notice how the half adder is included in this circuit. Hint: annotate this diagram with which pins on which chips are which connections, that way it is obvious which wires should go where when you wire it up.



Extra (Optional) Exercise: 2-bit Adder with Carry
Add the carry logic to the previous (optional) exercise to create a circuit that adds two 2-bit numbers together to make a 3-bit answer (2 bits plus carry).

Summary
We have seen how you can make AND, OR, and NOT gates from NAND gates. We then build a circuit to do binary addition. Previously we saw how 2's complement could be used for negative numbers and how subtraction can be expressed as addition.