# Lab 02 – NAND and OR via DeMorgan's Law and Circuit Propagation Delay

Students work in pairs.

Due: By the end of your lab session today.

Learning objectives:

1. Gain experience with the uses of NAND gates and more experience with the breadboard.
2. Consider worst case propagation delay as the digital logic circuit property that is analogous to worst case execution time for algorithms.

Bill of Materials: circuit-ready breadboard (console cable attached, 10 Ohm 2 Watt resistor installed, and necessary power and ground wires installed to energize rails on both long edges of the breadboard), 2x pushbuttons, 2x 10Kohm, 2x LED, 1x 7400, six wire colors.

Required equipment:

1. Lab kit as provided by your TAs.

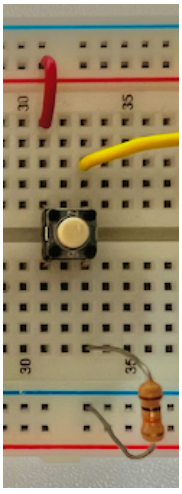
## Background

DeMorgan's Law states a generalization of the concept of negation, widely applicable across various areas of mathematics, including Boolean logic used to model digital logic circuits.

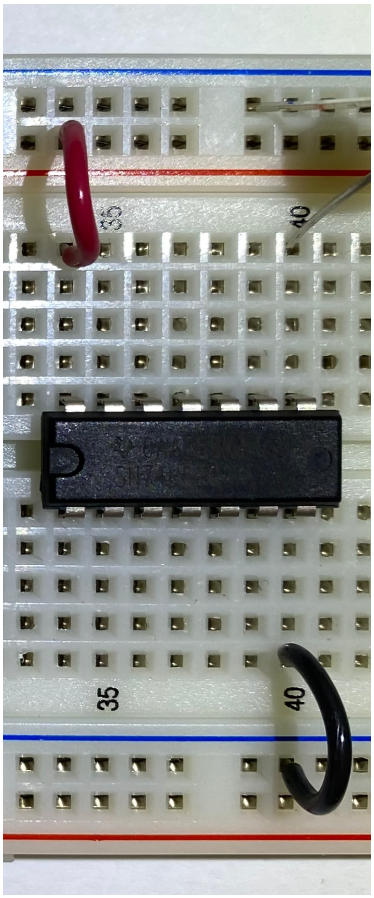
## Instructions

Using your lab kit, build the following circuit on the breadboard.

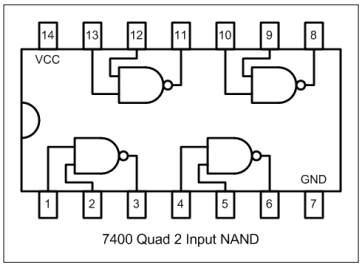
1. Two active-high pushbutton input circuits for inputs A and B. Separate the pushbuttons by 5 rows on your breadboard, say rows 10 and 15, so that it is easy to individually push each button. Here is a picture of the circuit needed for logic signal A. In identical circuit is needed for logic signal B. The logic signal Output of the circuit in the photo is the yellow wire; ignore the row 31 location and go with rows 10 and 15.




2. Find the Quad 2-Input NAND logic circuit in your lab kit, called the 7400 for short. Insert the 7400 chip to straddle the breadboard gutter with the notch facing to the left and the labeling on the chip right side up to you. Add red and black wires to power the 7400.




The positions of the 7400's pins on the breadboard will match their positions in this diagram showing the internal arrangement of the 4 NAND gates in this chip. Pin 14 Vcc connect to high voltage via the read wire; Pin 7, GND, connects to Ground via the black wire. Remember that the red buses on the long sides of the breadboard carry +5 volt reference and the blue buses carry 0 volts, or ground.




3. Connect the long lead of an LED from PIN 8 to the Ground bus. Connect another LED from PIN 6 to Ground.
4. Now using
    a. Green wire to transport pushbutton logic signal A to every place where it will be needed in Step 5,
    b. Yellow wire for transport of signal B,
    c. Orange wire for all logic signals contributing to the Boolean function A+B, and
    d. No insulation color for output of A NAND B.

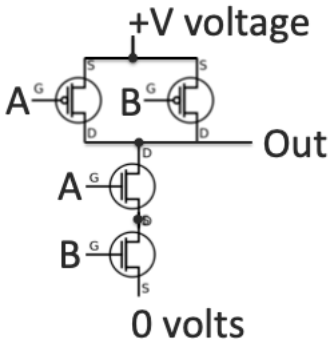
5. Connect signals A and B to the 7400 and connect gates of the 7400 to build
    a. the A NAND B logic function with its output connected to one of the LEDs.
    b. the A OR B logic function (use DeMorgan's Law to design this circuit) with its output connected to one of the LEDs.

When your circuit is complete test that it produces LED outputs that conform to the truth tables of the NAND and OR functions.

Propagation Delay. All circuits have propagation delay because electrons must move through some distance in the circuit, and the speed of light is an upper bound on the speed of movement. To determine worst case propagation delay in a circuit, find the data sheet propagation delay value for each type of gate and for the given circuit conditions. Then, for each logic signal input through a series of logic gates to each logic signal output, sum the gate delays. The worst case is the maximum of these summed gate delays. There may be several paths through the circuit that each have this worst case propagation delay.

Prepare to answer the following questions for your TA:

1. How did you use DeMorgan's Law in designing your OR circuit?
2. What would happen to the operation of your circuit if the labels of the A and B signals were swapped? Why?
3. If each NAND gate circuit is this,




   then how many transistors are used to build the 2-intput OR function from 2-input NAND gates?
4. From the 7400 Quad 2-input NAND integrated circuit data sheet, what is the worst case propagation delay in nanoseconds (unit abbreviation is ns) for A NAND B and for A OR B as constructed on your breadboard? Assume that the power supply voltage is 4.5 volts and ignore the non-zero propagation delay in the wires on your breadboard.

Now call your TA to earn points as described below.

## Grading

Scoring (up to 20 points possible):

1. [8] Demonstrate correct operation of your circuit for all 4 possible inputs to your TA.
2. [12, 3 each] Answer the four questions above for your TA.