ES 4 Lab 1: Getting started
Lab report due a week after your lab session (18-22 September 2023)

1 Introduction

The aim of this lab is for you to get comfortable using the lab equipment and building circuits on a breadboard. These will be essential skills for the remainder of the labs this semester.

After successfully completing this lab, you should be able to:

- Use a power supply to provide a constant voltage to a circuit
- Use a digital multimeter to measure voltages
- Use a breadboard to make circuit connections
- Wire up LEDs with current-limiting resistors
- Use buttons with pulldown or pullup resistors to control voltages
- Connect a 74-series chip to perform logic
- Translate a circuit schematic into a physical implementation on a breadboard

2 Lab tools

L1: Follow the video tutorial posted on the course website to get started with the digital multimeter (aka DMM or just "meter") and DC power supply (DCPS, or just "power supply").

L2: Get some sort of note-taking device handy, and take notes on what you're doing and what the results are as you work through the remainder of the lab.

If you do not already have a preferred digital note-taking system, we strongly suggest OneNote (onenote.com). It's free through Tufts, and you can run it simultaneously on your laptop, phone and the lab computers. This makes it very easy to capture photos, write text, copy code into your report, and even draw freehand diagrams or annotations.

Taking good lab notes is an important skill which you'll practice throughout the course, so we'll ask you to submit your notes from this lab and give you feedback.

3 Building circuits

Our primary tool for prototyping circuits is a "breadboard". This is a plastic board with hundreds of holes and embedded metal strips which can be used to make electrical connections. The figure below shows which holes (called "tie points") are electrically connected inside the breadboard:
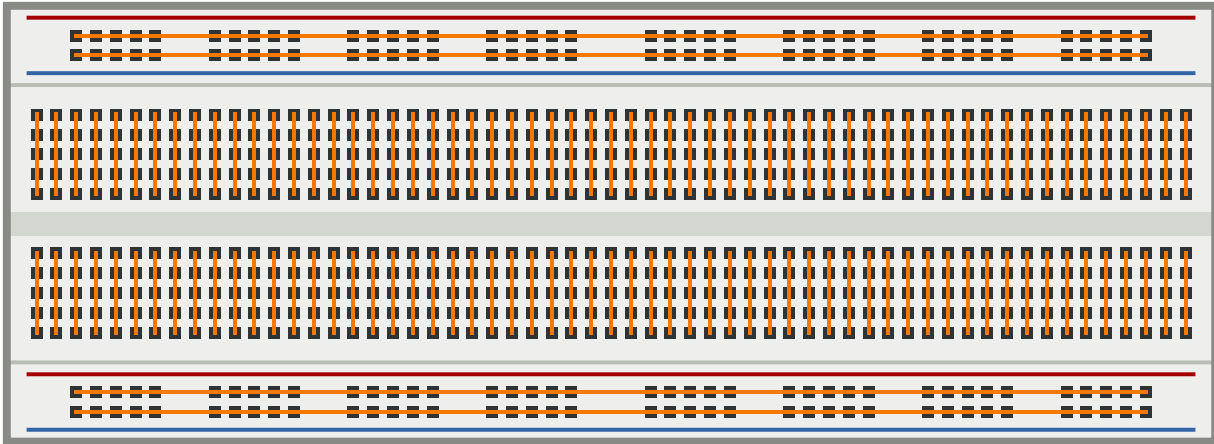
Each side of the breadboard also has two "rails" which run the full length of the breadboard.[1] By convention, we use the blue rails for the negative power supply (aka "ground") and the red rails for the positive power supply (aka "power", "5 V", or "V_{cc}").

See this TinkerCAD circuit for an example of how (and how not) to connect things on a breadboard.

A schematic is an idealized representation of a circuit. If you don't have much experience with circuit schematics, consult the references on the course website, or talk through it with your TA.

L3: Build this circuit on your breadboard. This TinkerCAD design shows one way to lay it out on a breadboard. When you press the switch, the LED should light up.
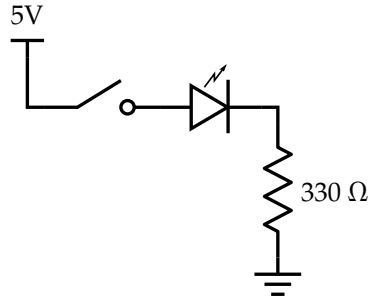

L4: What happens if you turn the LED around? (i.e., put the long lead on the ground side?)

L5: What happens if you swap the positions of the LED and the switch? (i.e., put the switch between the LED and ground?) What about the resistor? Draw schematics of what you tried and make notes about the outcome.

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[1]Sometimes these rails are split in the middle – it's always wise to check this with a meter first!

4   Pull-ups

In the previous experiments, the switch was used to make or break an electrical connection. But a logic gate needs a high voltage (5V) or a low voltage (0V) as the input, not "connected" or "disconnected". We can easily produce a low voltage when the switch is closed (pressed) by connecting the switch between the logic gate input and ground:

To logic
gate input
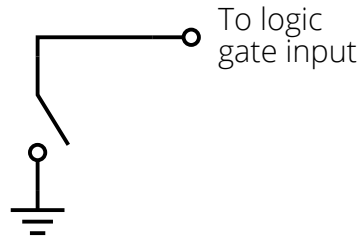
But when the switch is open (not pressed), then the gate is left "floating": neither high nor low, just disconnected. That may seem harmless, but it's not a valid input, and the circuit may behave unpredictably.

The solution is to connect a large-ish resistor between the switch and power (5V). As before, closing the switch connects the gate directly to ground, giving a low input. But now when the switch is open, the resistor provides a weak connection to power, which pulls the gate voltage up to a logic "high":

5V

To logic
gate input
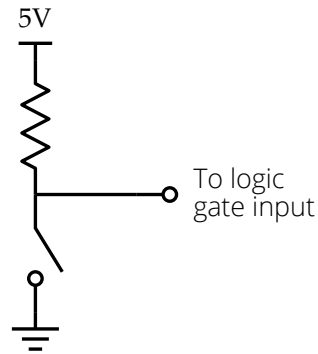
L6: Build the circuit above, and use the voltmeter at the point labeled "logic gate input" to confirm that the output switches between high (5V) and low (0V) when the switch is pressed.

5   Logic gates

The diagram below shows the logical internals of the 7400 quad NAND gate. There are power and ground (Vcc and GND) pins which supply power to the whole chip, plus four separate NAND gates. To use the first NAND gate, you'd connect the inputs to pins 1 and 2, and pin 3 would be the output.

The IC should be inserted straddling the middle of the breadboard, so that one side connects to the top columns, and the other to the bottom columns. Note the little semicircle on one end which helps you orient the chip.
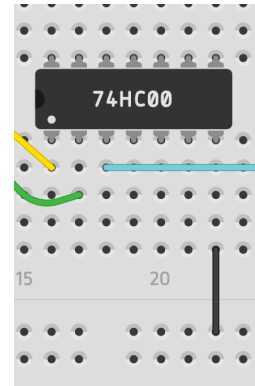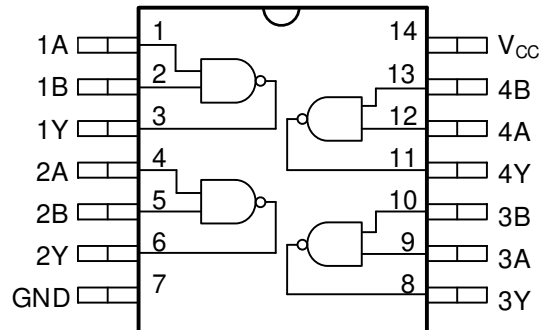
L7: Build the circuit below. You can use any of the four NAND gates in the package. Don't forget to wire up 5V (Vcc) and ground for the NAND chip! We've left those wires off the diagram, but the gate won't function without power!
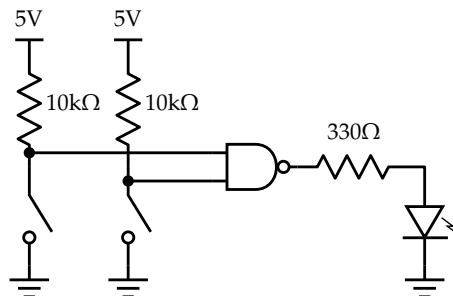
L8: Test your circuit to confirm that it works. Make sure you test all possible combinations of the inputs! Remember that pressing the button is a **low** input.

6   What to turn in

There is no formal lab report to turn in, just submit the notes you took along the way.