CCE1013 – Computer Logic I

Practical 1

Dr Ing. Gianluca Valentino
gianluca.valentino@um.edu.mt

Introduction to Combinational Logic

Objectives

- To familiarize yourself with basic electronics components
- To design, build and test a basic combinational logic circuit

1. Before coming to the lab session

- Make sure you read this document thoroughly;
- Complete the Autodesk Tinkercad simulation in part 2;
- Prepare the truth table and schematic in part 4(a) and 4(b).

2. Developing a simple circuit on a breadboard

These practicals will focus on the implementation of combinational logic through digital circuits. However, a basic understanding of electric circuit theory and analog components, such as resistors, is necessary in order to successfully implement such circuits.

You will implement each combinational logic circuit on a breadboard, such as the one shown in Figure 1. A breadboard is a rectangular plastic board with a number of holes in it. These holes let you insert electronic components, such as logic gates, resistors and LEDs (see Figure 2), as well as connect a power supply.

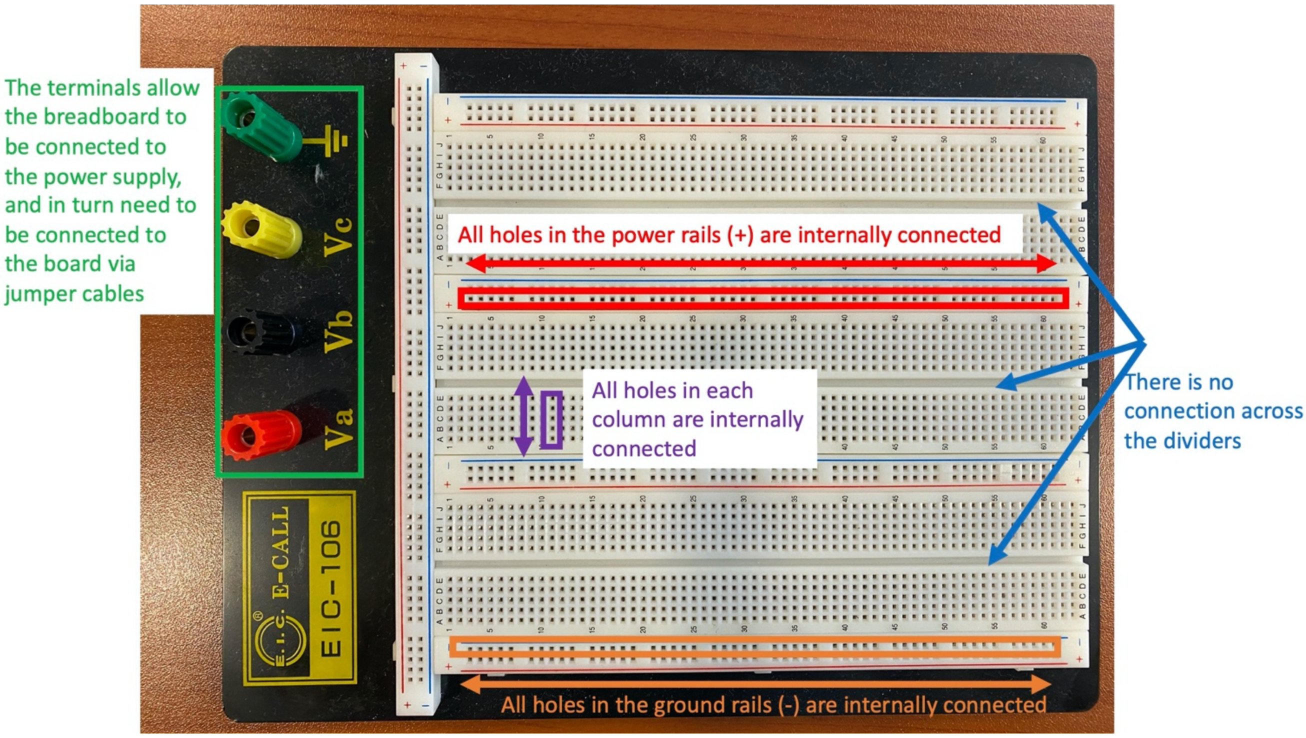

Figure 1 – Example of a breadboard.

Figure 2 – A resistor (left), and a number of LEDs (right). The metallic wires coming out of each component are plugged into the holes in the breadboard to form a circuit.

Any electric circuit is formed when a conductive path (e.g. through components connected by wires) is created to allow electric charge to continuously move. This is known as **current**, with symbol **I** and units of **amps**, and it is analogous to the flow of liquid through a hollow pipe.

The force motivating the charge carriers to "flow" in a circuit is called a **voltage**, with symbol **V** and units of **volts**. Voltage is a specific measure of potential energy that is always relative between two points. Hence, it is also known as the *potential difference*.

Current tends to move through the conductors (e.g. wires, components) making up a circuit with some degree of friction, or opposition to motion. This is known as **resistance**, and has symbol **R** with units of Ohms (Ω).

Ohm's law relates these three quantities as follows:

$$V = IR$$

You will now design a simple circuit involving a DC power supply (5V), a 1 kΩ resistor and an LED. These can be connected together to form the circuit shown in Figure 3. Current always flows from the positive terminal of the power supply to the negative terminal.

The direction in which the LED is connected is important. The anode (the longer wire) has to be connected first, followed by the cathode. This is because LED stands for "Light Emitting Diode", and a diode is a component which allows current to flow only in one direction. On the other hand, the resistor can be connected in any direction.

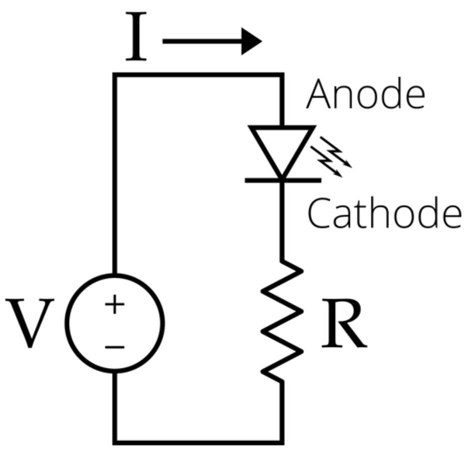

Figure 3 – A simple electric circuit with a DC power supply, an LED and a resistor.

Before implementing this circuit in real life, we will first perform a simulation using an online tool called Autodesk Tinkercad. Visit www.tinkercad.com and create a free account. When signing in, you should see a page similar to the one shown in Figure 4. Click on Circuits -> Create new circuit

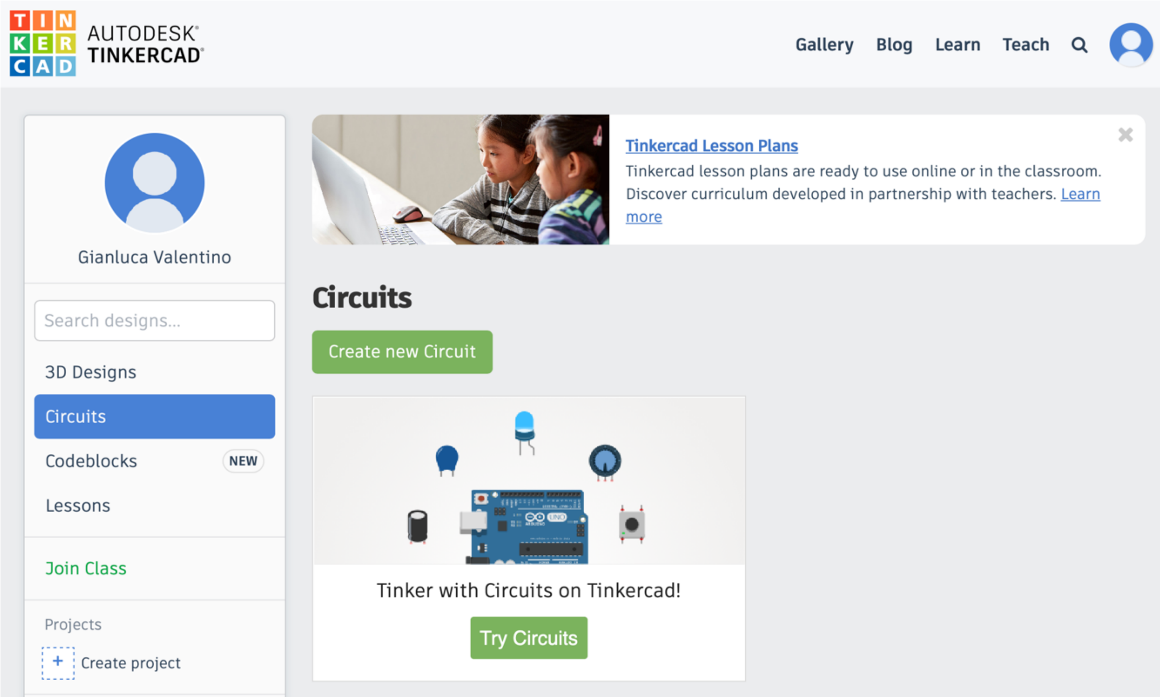

Figure 4 – Tinkercad website.

Using the tool, set up the circuit as shown in Figure 4. Make sure to set the DC power supply voltage to 5 V, and set the resistance of the resistor to 1 kΩ.

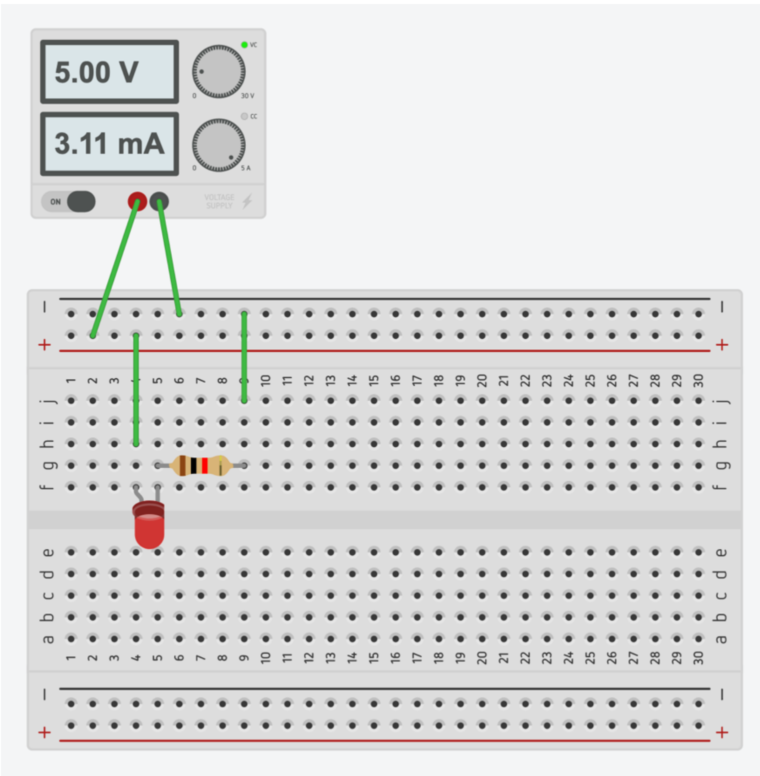

Figure 4 – Simple electric circuit set up in the Autodesk Tinkercad simulation tool.

If you start the simulation, you should see that the current in the circuit, as measured by the DC power supply, settles at 3.11 mA. Although the potential differences for each of the LED and the resistor are different, their sum of all the potential differences should be equal to 5V. On the other hand, the current flowing through the circuit is the same throughout.

A typical red LED has a forward operating voltage of 1.9 V. Therefore, the remaining 3.1 V is 'consumed' by the resistor. As we know that the resistance of the resistor is 1 kΩ, using V = IR, we can calculate that the current flowing through the circuit is:

$$I = \frac{V}{R} = \frac{3.1}{1 \times 10^3} = 0.0031\,A$$

or 3.1 mA.

You are now to set up this circuit on the breadboard. First, take a look at the DC power supply shown in Figure 5. This power supply has 3 possible outputs (channels). In these practicals, we will always use Channel 3, as it is configured to output a voltage of around 5V. Until your circuit is ready, leave the power supply OFF.

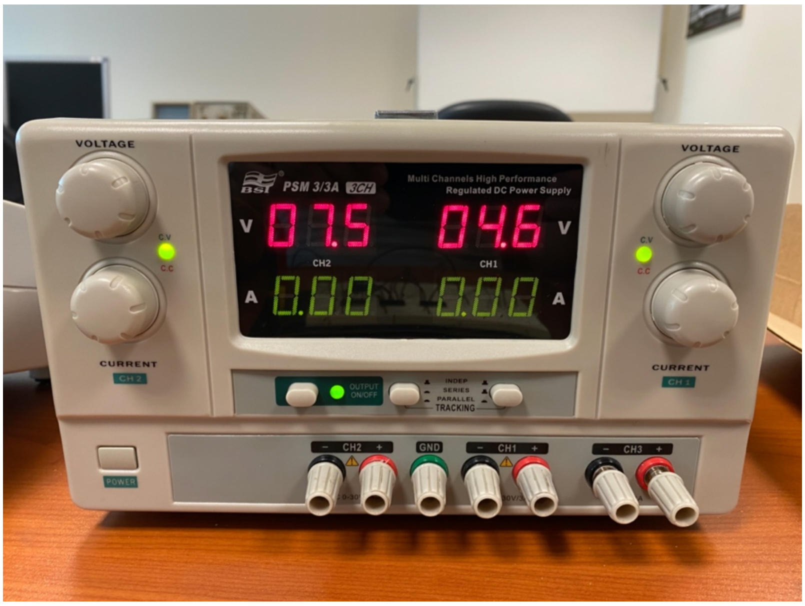

Figure 5 – DC Power Supply.

First, connect wires between two terminals on the breadboard to the power and ground rails respectively. Although the terminals are interchangeable, its best practice to connect e.g. V_a to the power rails (+) and the ground terminal ($\perp$) to the ground rail.

Then, using several wires, the resistor and the LED provided, set up the remainder of the circuit. Make sure to connect the longer wire of the LED first. Finally, using jumper cables, connect the DC power supply to the breadboard terminals, maintaining the colour coding (red = positive, black = negative).

You can now switch on the power supply ON. If your circuit is set up correctly, you should see the LED light up. Congratulations! Now switch OFF the power supply.

3. Debugging using a multimeter

In order to understand why a circuit does not work as intended (e.g. due to a wrong connection of components), it is useful to use a multimeter. A multimeter allows you to measure the current flowing in a circuit, or the voltage drop across a component (or a length of the circuit). In order to read current or voltage, the multimeter needs to be configured accordingly (see Figure 6).

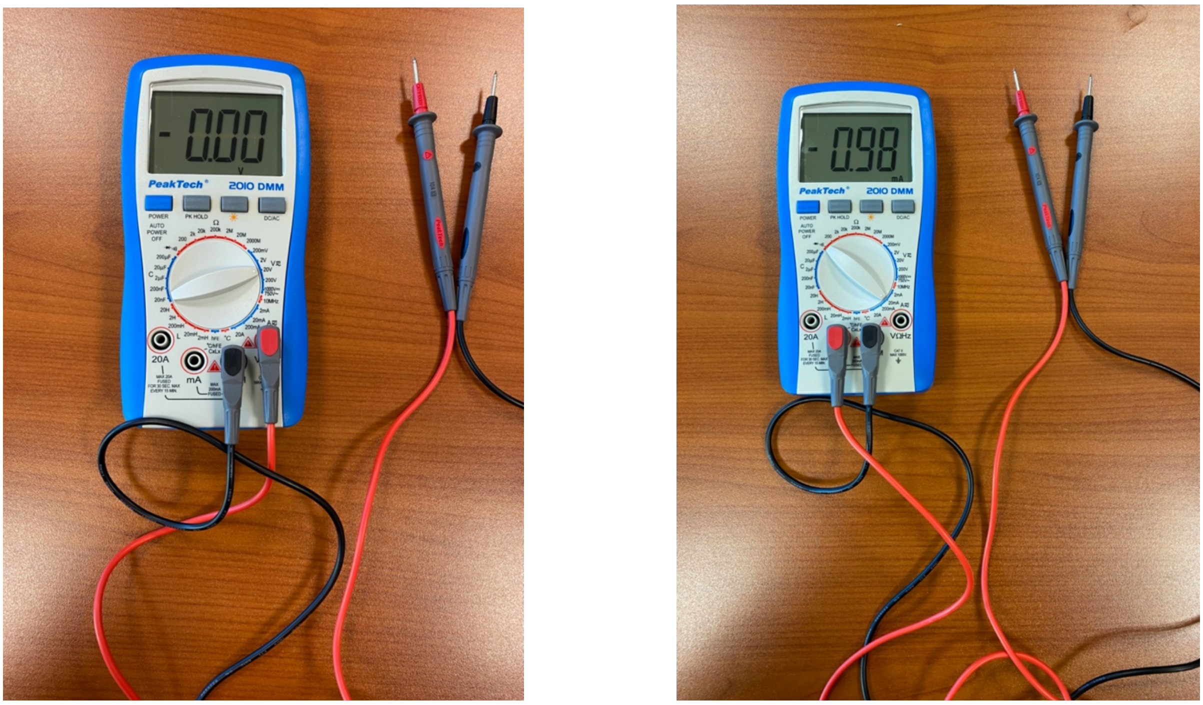

Figure 6 – Multimeter set up to read voltage (left) and current (right).

The voltage can then be read by connecting the multimeter *in parallel* to one (or more) of the circuit components (see Fig. 7), while the current can be read by connecting the multimeter *in series* with the circuit (see Fig. 8). Make sure that you switch OFF the power supply before disconnecting one of the components to connect the multimeter in series.

When using the multimeter to debug combinational logic circuits, typically we are only interested in the voltage, and with a 5V power supply, 5V will indicate logic ‘1’, while 0-0.3 V would indicate logic ‘0’.

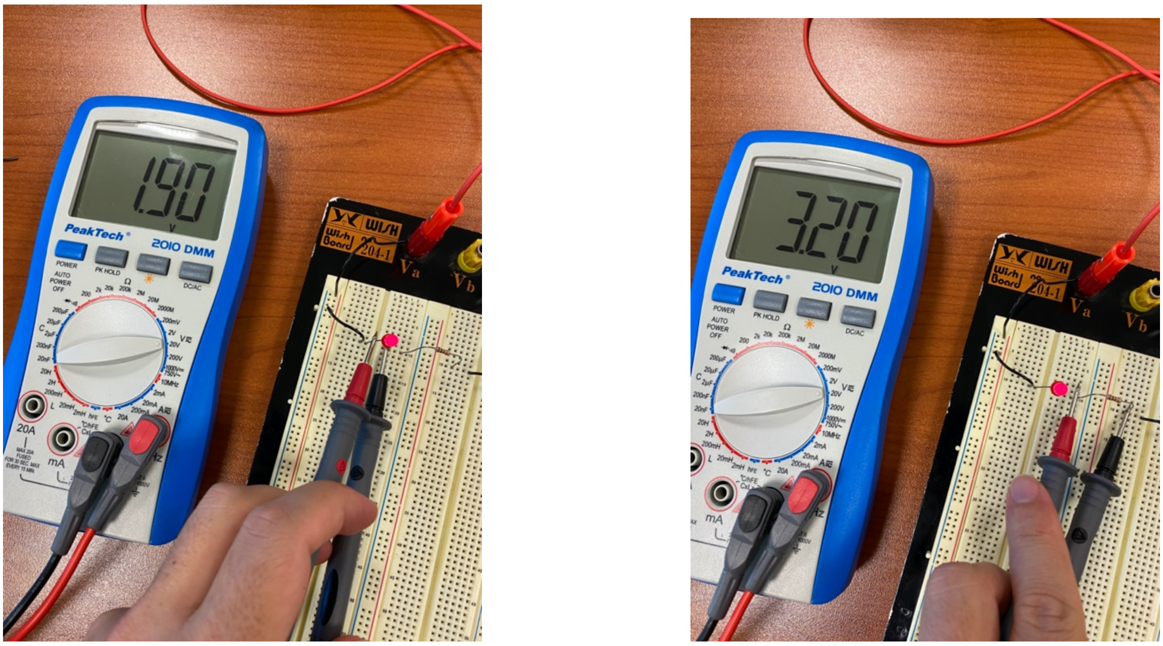

Figure 7 – Reading the voltage across the LED (left) and the resistor (right).

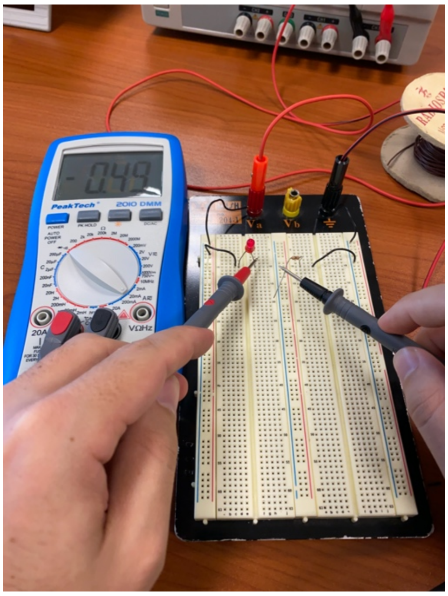

Figure 8 – Measuring the current through the circuit.

4. Developing a simple combinational logic circuit

If you are going to develop the circuit using physical hardware, only commence part 4(c) if you have successfully completed the hardware circuit in part 2.

We will now develop a simple combinational logic circuit which follows the following Boolean logic function:

$$F = A.B + A \oplus B$$

(a) Using the above Boolean logic function, write down the truth table.

(b) Produce a schematic using logic gates which represents the Boolean logic function.

(c) Implement the schematic through an electric circuit.

You will need the following components:

- A breadboard
- A 5V DC Power Supply
- An 8-way DIP switch (of which only 2 inputs will be used for A and B)
- Three 1 kΩ resistors (1 for the LED, 2 for each of the A and B DIP switch inputs)
- An LED to indicate the output F
- A 7408 Quadruple 2-input AND gate IC
- A 7432 Quadruple 2-input OR gate IC
- A 7486 Quadruple 2-input Exclusive OR gate IC

You will need to implement the inputs into your combinational logic circuit and the 8-way DIP switch as shown in Figure 9.

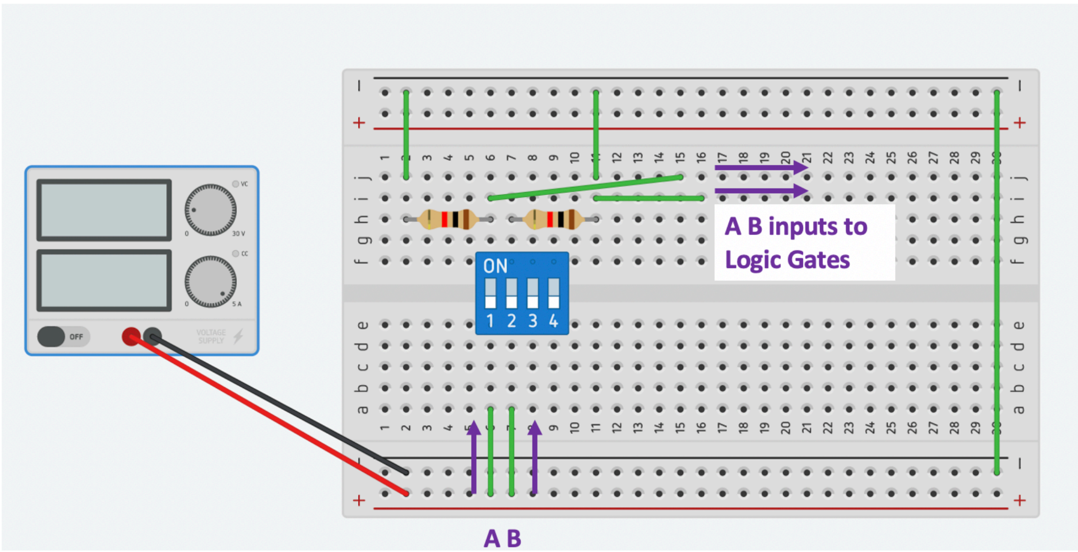

Figure 9 – Connecting the DIP switch to pull-up resistors.

The resistors in this configuration are known as **pull-down resistors**: they ensure that when the switch is OFF (i.e. the switch is open and the circuit is broken), the input voltage to the logic gate is pulled down to ground (i.e. logic low or '0'). On the other hand, when the switch is ON (i.e. the switch is closed and a circuit is formed), the input is at a logic high or '1' value.

Once the DIP switch is set up, we can now implement the combinational logic circuit itself. We will not use individual logic gates, but Integrated circuits (ICs).

Go to https://www.alldatasheet.com and input the identifier which you can see on the top of the 7408 AND gate IC. This will give you access to the datasheet for this component. The datasheet will tell you interesting information, such as the manufacturer, the recommended operating voltage and temperature, and the propagation delay time. In order to connect our IC, we will need to look at the pin arrangement (reproduced in Figure 10):

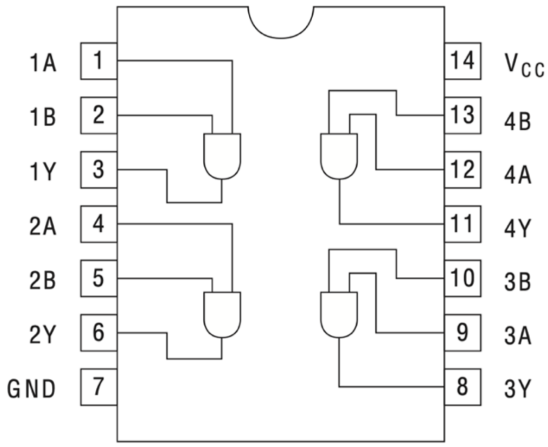

Figure 10 – Pin arrangement diagram for the 7408 AND gate.

From the above diagram, we can see that the IC has 14 pins, 12 of which are the inputs and outputs of the 4 AND gates packaged in the IC, and the remaining pins which correspond to the supply (V_{cc}) and ground (GND) of the chip. The notch at the top can also be found on the chip itself, for orientation purposes. You can therefore connect inputs A and B to pins 1 and 2, and the output will be available on pin 3. V_{cc} should be connected to the positive power rail, while GND should be connected to the negative ground rail.

Connect the other two ICs (XOR and OR) in order to form the complete circuit. Once again, search for the datasheets in each case to make sure that you connect the correct pins.

The next step is to connect the output of the OR gate to a resistor, which in turn is connected in series to the LED. Finally, the output of the LED can be connected to the ground terminal.

Switch ON the power supply, and verify that your circuit works as expected by trying all the combinations of the A and B input switches.

5. Deliverable

Complete part 4(c) using EITHER Tinkercad OR physical components (subject to availability).

Your report should include:

- The truth table developed in part 4(a);
- The schematic from part 4(b);
- A photo (or screenshot) of the circuit developed in part 4(c);
- Photos (or screenshots) showing the result of each of the possible input combinations.

The deadline for the deliverable is 11th December 2020.