Laboratory Exercise 5.5
Combinational Circuit Design (Pre-session Lab)

Introduction

This pre-session activity is designed to practice implementing combinational logic circuits using standard TTL (Transistor-Transistor Logic) Integrated Circuits (ICs). Students will design and build a simple 2-to-1 Multiplexer (MUX) and verify its operation using LEDs, a voltmeter, and an oscilloscope.

Objectives

1. To understand the operation of a 2-to-1 Multiplexer.
2. To implement a combinational logic circuit using basic logic gates (AND, OR, NOT) on a breadboard.
3. To verify circuit functionality using LEDs.
4. To measure logic voltage levels using a digital multimeter.
5. To observe signal transitions and propagation delay using an oscilloscope.

Equipment Required

- DC Power Supply (+5V)
- Digital Multimeter
- Digital Oscilloscope
- Breadboard and Jumper Wires
- TTL ICs:
  - 74LS04 (Hex Inverter / NOT Gate)
  - 74LS08 (Quad 2-Input AND Gate)
  - 74LS32 (Quad 2-Input OR Gate)
- Resistors: 330Ω (for LEDs), $10k\Omega$ (for pull-up/pull-down)
- DIP switches
- LEDs (Red/Green)

Part I: Theory and Logic Design

A 2-to-1 Multiplexer (MUX) has two data inputs (I_0, I_1), one select input (S), and one output (Y). The operation is defined as follows:

- If $S = 0$, the output Y follows input I_0.
- If $S = 1$, the output Y follows input I_1.

Truth Table

Complete the truth table below to verify the logic.

Select (S)	**Input (I_1)**	**Input (I_0)**	**Output (Y)**
0	x	0	0
0	x	1	1
1	0	x	0
1	1	x	1

Table 1: Function Table of 2-to-1 MUX

The Boolean expression for the output Y is:

$$Y = \bar{S} \cdot I_0 + S \cdot I_1$$

Logic Circuit Diagram

Figure 1 shows the gate-level implementation of the 2-to-1 MUX.

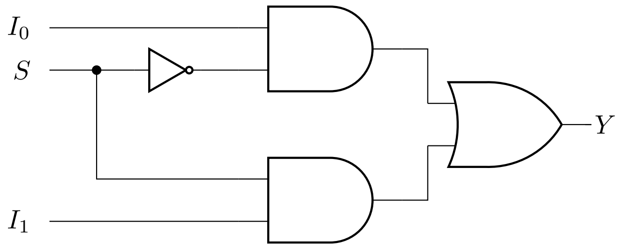


Figure 1: Logic Diagram of 2-to-1 MUX using Basic Gates.

Create a Quartus project for the 2-to-1 MUX circuit as follows:

1. Create a new Quartus project for your DE0-CV board.
2. **Implement the circuit using Schematic Design.** Draw the circuit using the Block Editor and appropriate logic gates (NOT, AND2, OR2).
3. Compile the schematic design and perform a functional simulation to verify its correctness.
4. Simulate the behavior by creating a vector waveform file (*.vwf). Specify the inputs (S, I_0, I_1) and output (Y).
5. Run the simulation. The resulting waveforms should demonstrate the MUX behavior:
   - When $S = 0$, Y should match I_0.
   - When $S = 1$, Y should match I_1.

Part II: Hardware Implementation

Schematic Diagram

Construct the switch input circuits as shown in Figure 2. Then, connect the Multiplexer circuit on the breadboard as shown in Figure 3.

- Use DIP switches for inputs S, I_0, I_1.
- Use $10k\Omega$ pull-down resistors to ensure logic '0' when OFF (Open).
- Use an LED with a 330Ω series resistor to display the output Y.

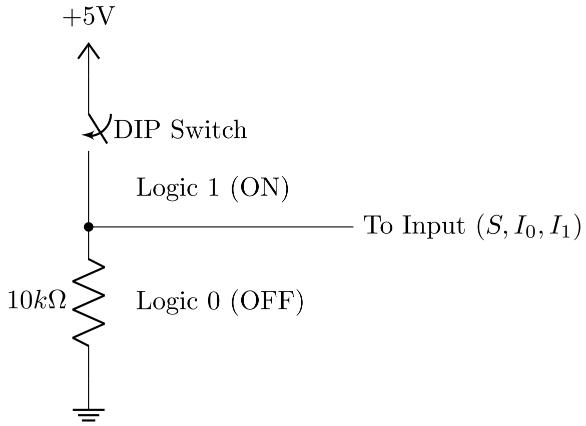
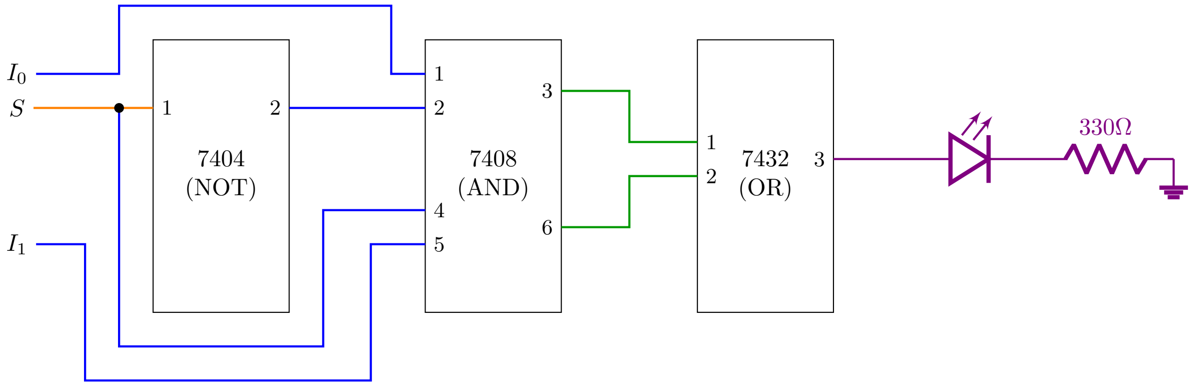


Figure 2: Input Switch Circuit (Active High).



Remember to connect Pin 14 to V_{CC} and Pin 7 to GND for all ICs.

Figure 3: Wiring Logic Diagram showing IC connections.

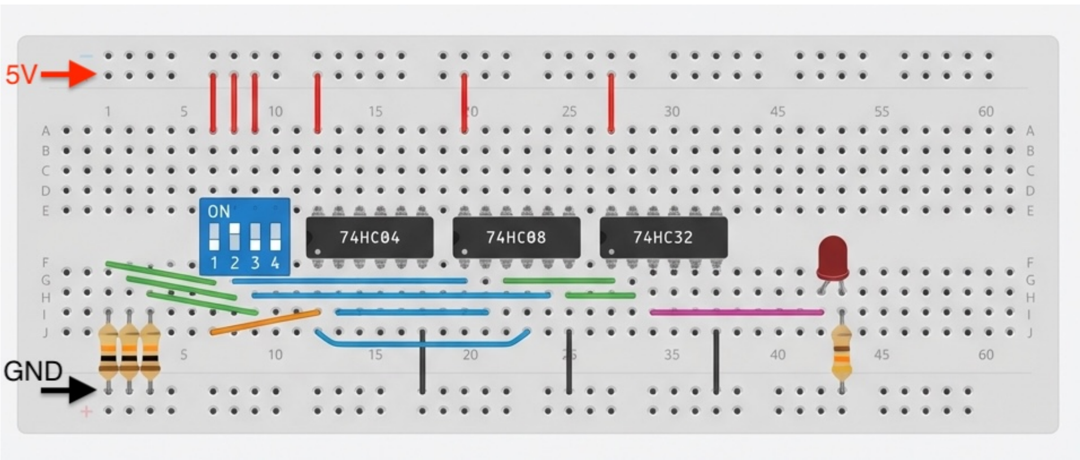


Figure 4: Breadboard implementation of the 2-to-1 MUX.

Step-by-step Implementation: Refer to Figure 4 for a visual guide of the breadboard layout.

1. Place the 7404, 7408, and 7432 ICs on the breadboard.
2. Connect Pin 14 (V_{CC}) to +5V and Pin 7 (GND) to Ground for all ICs.

3. Construct the circuit according to Figure 1 using jumper wires.
4. Connect the inputs S, I_0, I_1 to the switches/buttons.
5. Connect the output Y to the LED circuit.

Part III: Measurement and Verification

Functional Test

Verify the circuit operation by manually checking all combinations of S, I_0, I_1.

1. Set DIP switches keys to set S, I_0, I_1.
2. Observe the LED status.
3. Does it match the Truth Table in Table 1?

Voltage Measurement

Use a Digital Multimeter (Voltmeter mode) to measure the output voltage levels.

1. Connect the black probe to Ground (GND).
2. Connect the red probe to the Output (Y).
3. Measure the voltage when Y is Logic 0. Record the value: ____________ V.
4. Measure the voltage when Y is Logic 1. Record the value: ____________ V.
5. Do these values correspond to valid TTL logic levels?

Oscilloscope Observation

To visualize the switching behavior and signal integrity:

1. Set I_0 to Logic 0 and I_1 to Logic 1.
2. Connect Channel 1 of the oscilloscope to Select (S).
3. Connect Channel 2 of the oscilloscope to Output (Y).
4. Toggle S (switch ON/OFF) and observe the transition on the oscilloscope.
5. Capture the waveform showing the relationship between S and Y.
6. Set I_0 to Logic 1, I_1 to Logic 0, and repeat the observation.

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