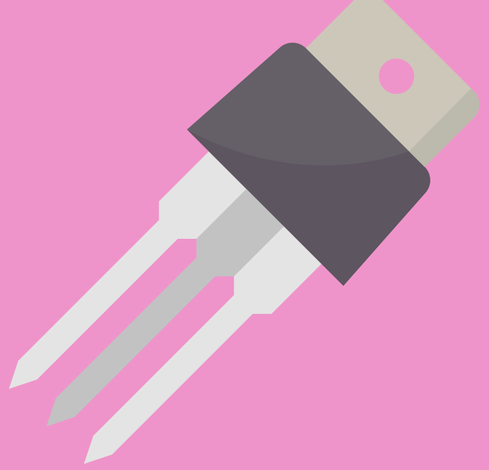
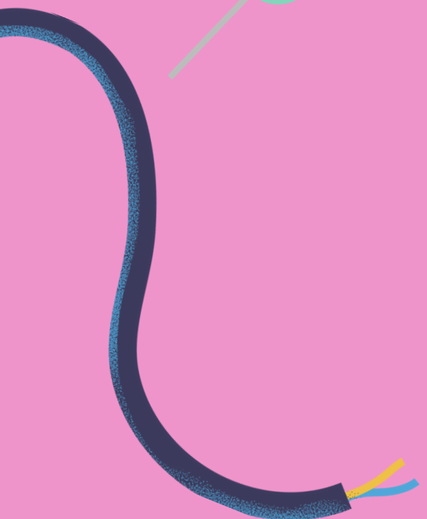


Digital Logic Gates

Anastasia Frattarole - NOR & XOR
Emely Garcia - XOR & Project Breakdown & Conclusion
Ilaisaane Fonua - NAND & NOT & Math models



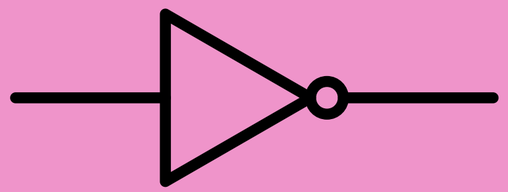
Background & Description of Project

Digital Logic Gates are the foundation to modern electricity, enabling devices to process and manipulate binary data.

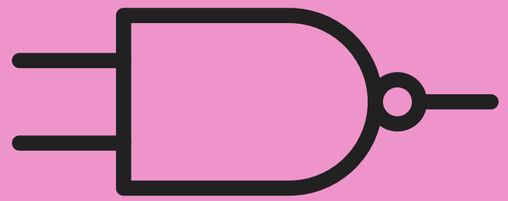
In this project we implement a set of basic digital logic gates: Inverter, NAND, NOR, and XOR.

Each gate is implemented using components like diodes, Bipolar Junction Transistors (BJTs), MOSFETS, resistors and LEDs.

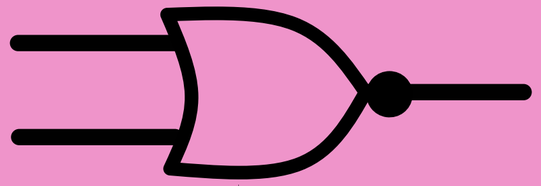
Project Breakdown Diagrams & Math Models



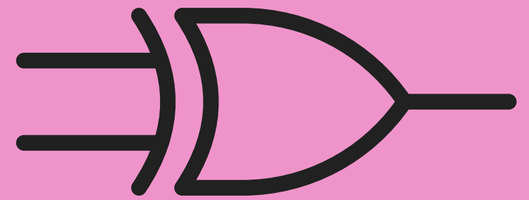
A



B



C



D

A

Inverter Logic Gate

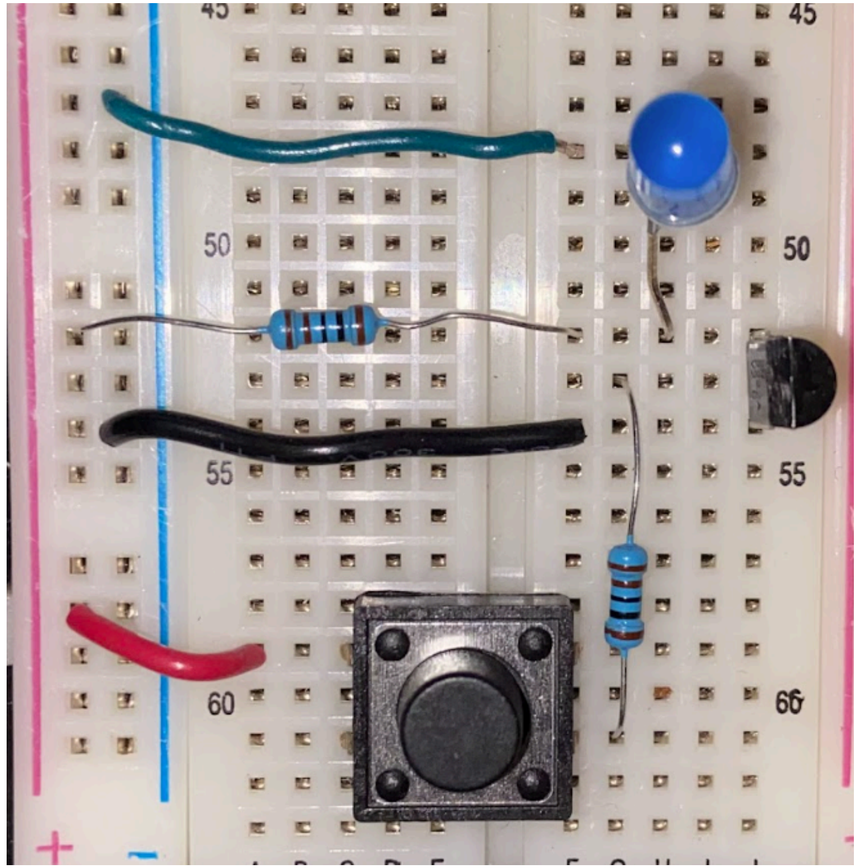
- Inverter logic gate is also known as a NOT gate.
- This gate implements the logical negation function. This means it takes in a single input and outputs the opposite logic.
- Boolean expression:

$$Y = \overline{X}$$

Input	Output
A	Y
0	1
1	0

An everyday example of an inverter logic gate would be car seatbelt warning:
Input: Seatbelt buckled (1) Output: Warning light / sound off (0)
Input: Seatbelt unbuckled (0) Output: Warning light / sound on (1)
Another use of inverter logic gates: when combined with capacitors and resistors, inverters can be used to create oscillators for clock generation in micro-controllers.

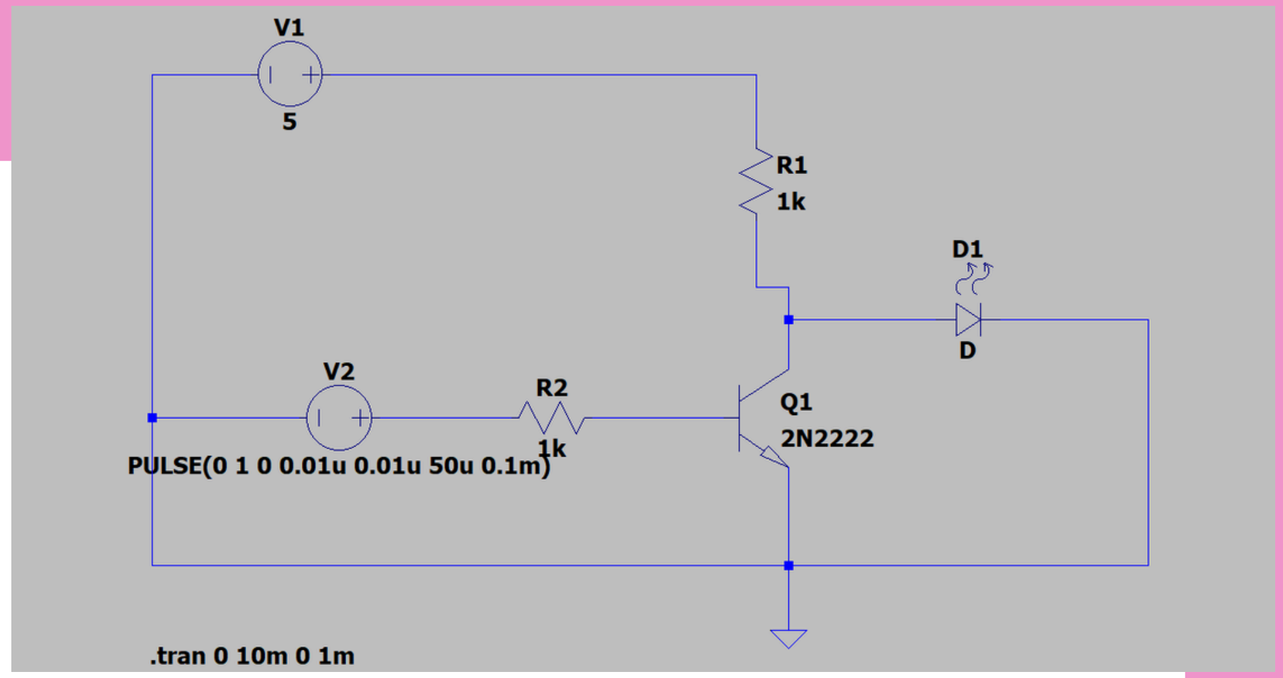
Inverter Circuit Implementation

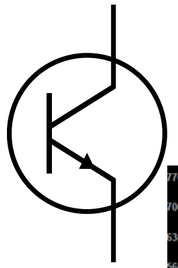


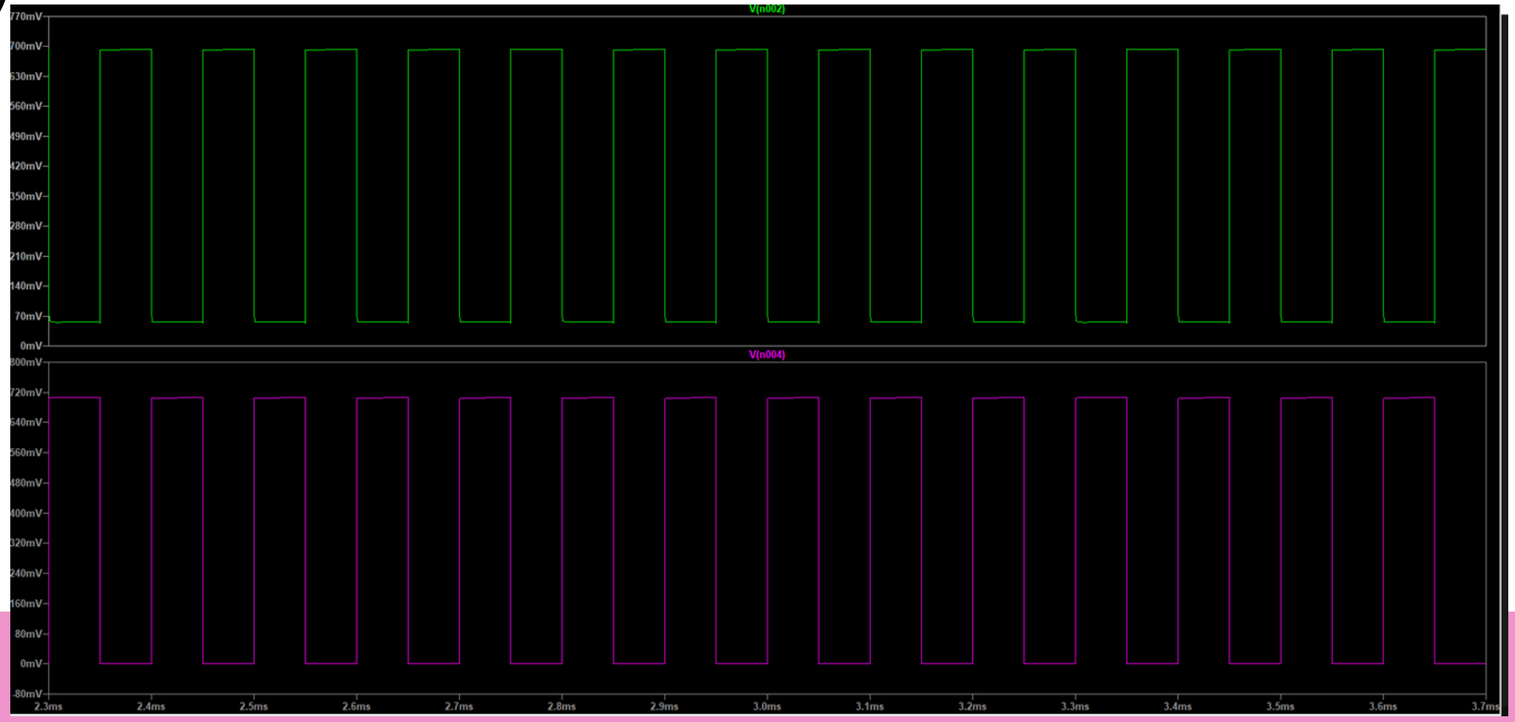
Components

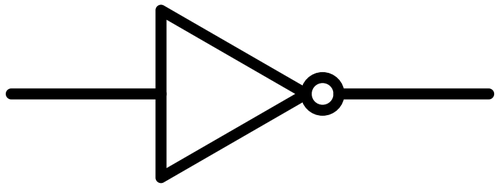
- Bipolar Junction Transistor (BJT 2N2222)
- Two 1kΩ resistors
  - used for biasing and load management
- One button
  - used for single input
- Blue LED
  - used for output indication
- 5V voltage source

Inverter Schematic & Simulation

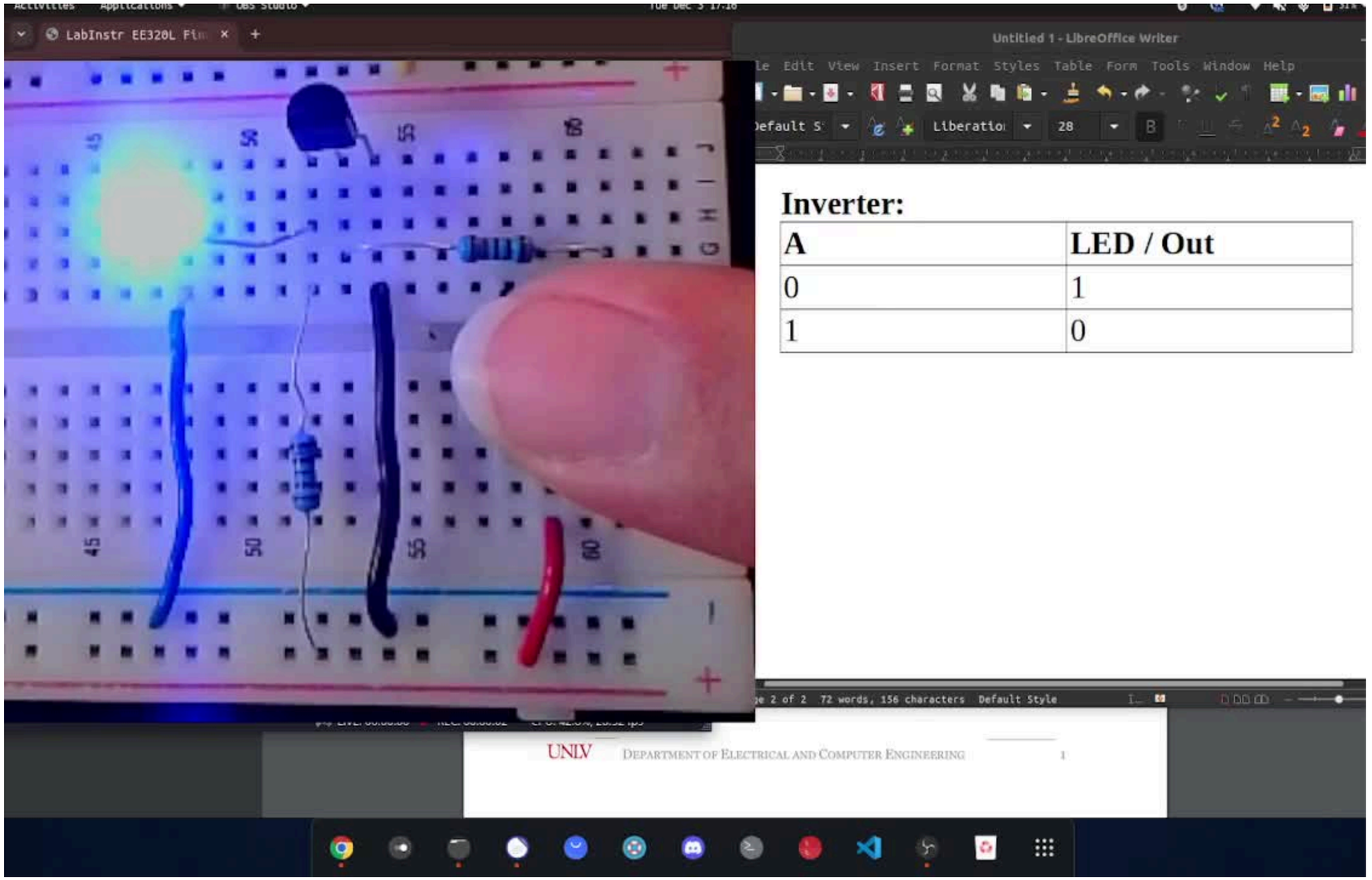








Demo - Inverter



B

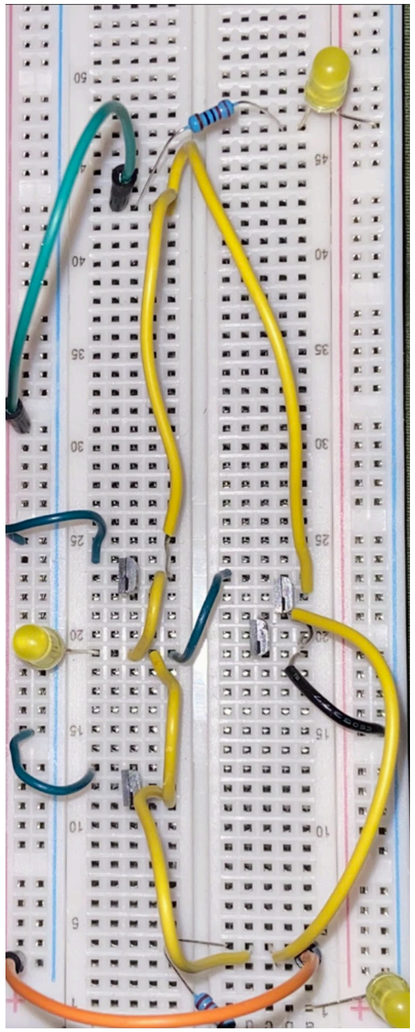
NAND Logic Gate

- NAND logic gate is a combination of the AND gate and NOT gate.
- The NAND gate implements the negated AND operation.
  - This means that it will take in two inputs perform the AND operation. Then invert the results.
- Boolean expression: $X = (A.B)'$

Input A	Input B	X = (A.B)'
0	0	1
0	1	1
1	0	1
1	1	0

An example of a NAND gate would be a home security system.
Input 1: Door is closed (1 = closed, 0 = open)
Input 2: Window is open (1 = closed, 0 = open)
Output: Alarm is triggered (1 = alarm sounds, 0 = no alarm)
This system will prevent false alarms from accruing.

NAND Circuit Implementation

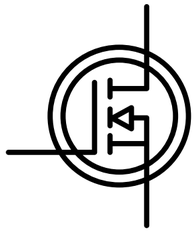


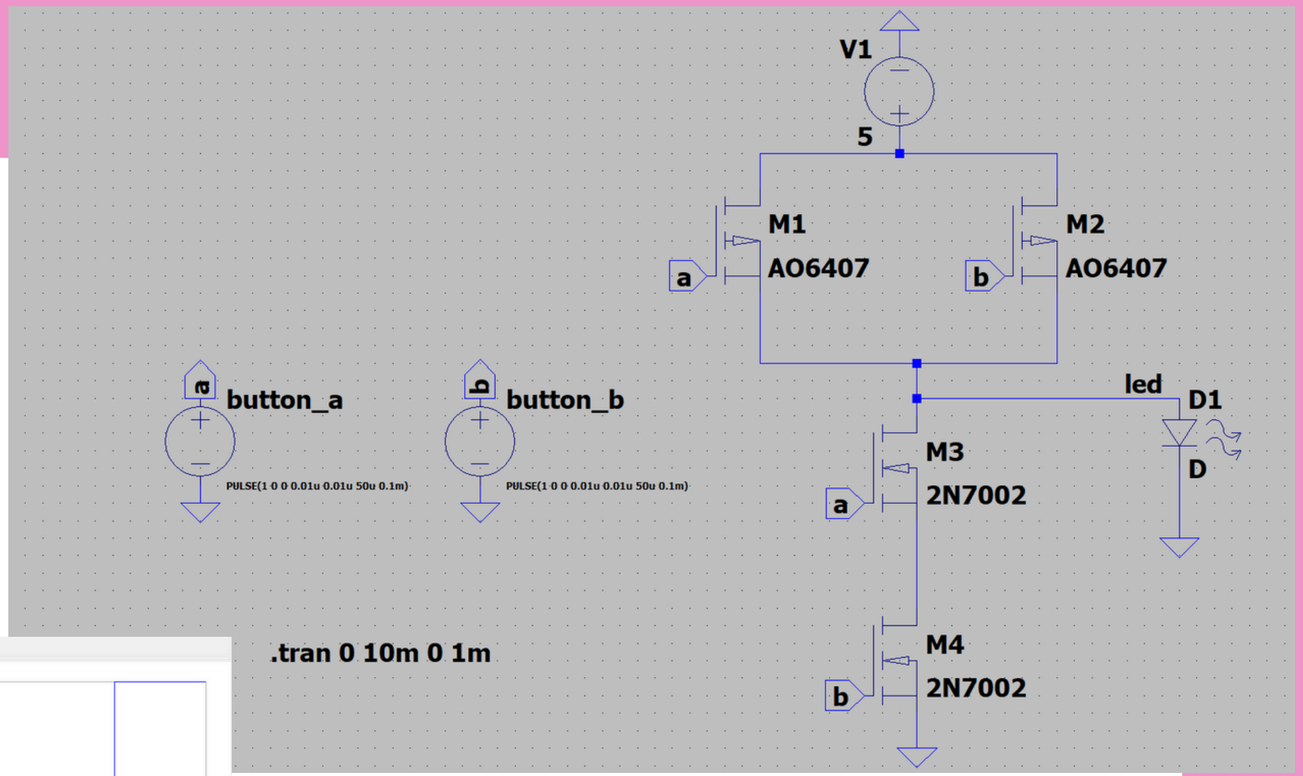
Components

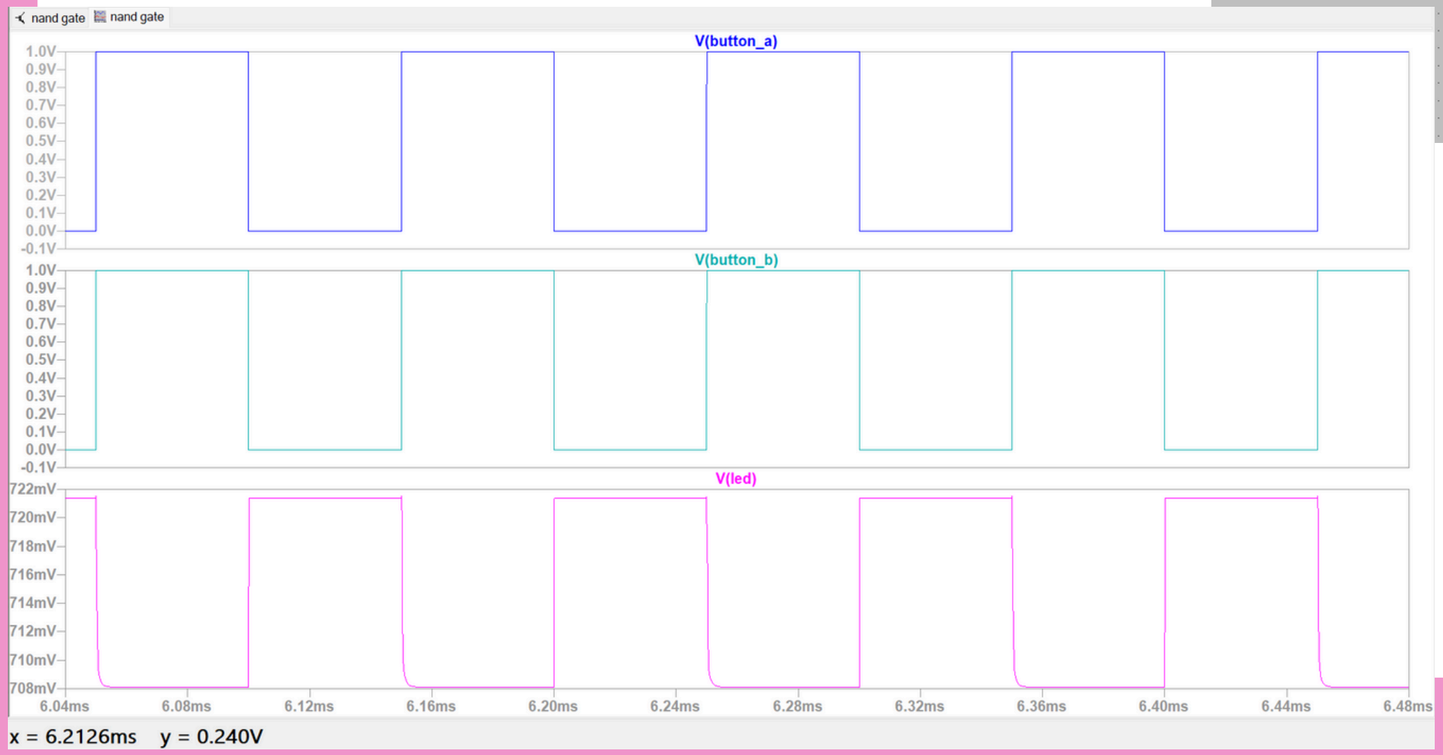
- Two PMOS transistors
- Two NMOS transistors
- Three yellow LED lights
  - two LEDs are used to display the input
  - one LED is used to display the output
- Two resistors
  - used for current limiting on the LEDs
- 5V voltage source

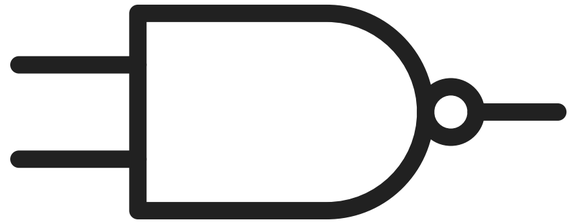
NAND

Schematic & Simulation

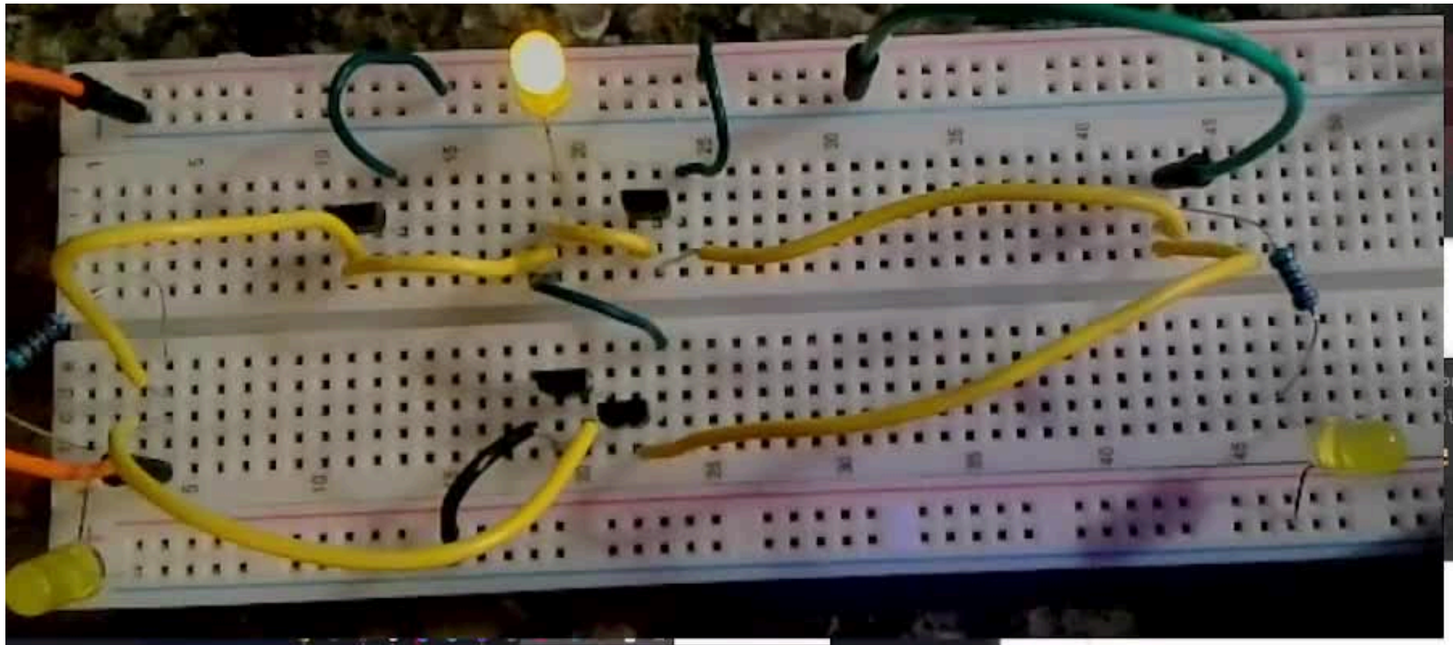


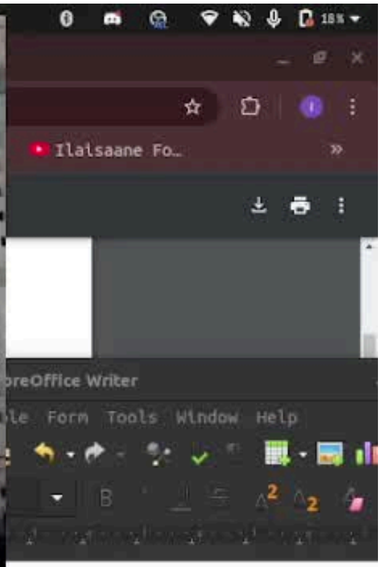


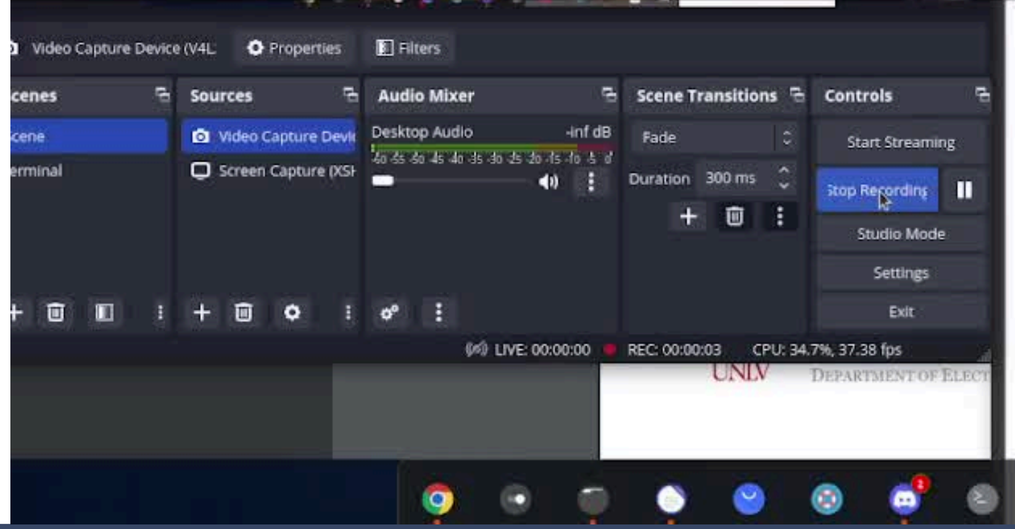




Demo - NAND







NAND Gate truth table:

A	B	LED / Out
0	0	1
0	1	1
1	0	1
1	1	0

c

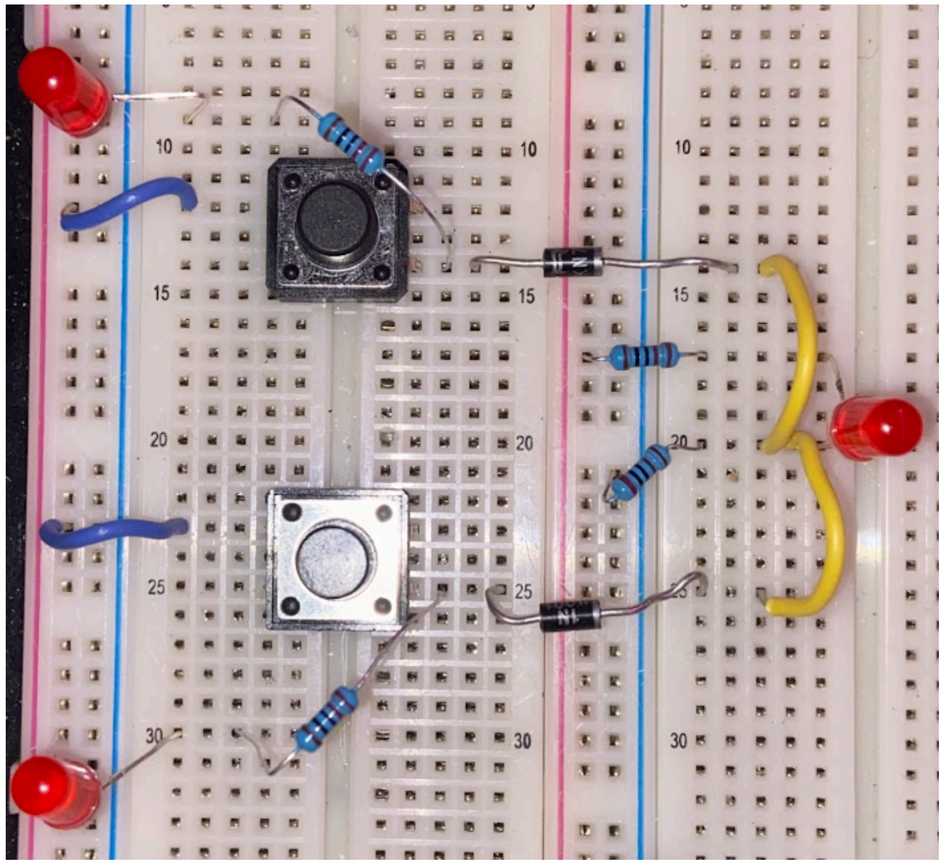
NOR Logic Gate

- NOR gate is a combination of the NOT gate and the OR gate.
- The NOR gate implements the logical negation of the OR function.
  - This means it will take in two inputs perform the OR operation and then inverts the result.
- Boolean expression: $Q=\overline{A+B}$

A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

An everyday example of the NOR gate would be a motion activated sprinkler:
Input 1: Motion (motion detected = 1, no motion = 0)
Input 2: Rain (rain detected = 1, no rain = 0)
Output: Sprinkler (on = 1, off = 0)
NOR gates are used for implementing timers, counters, and alarms due to their versatility and negation.

NOR Circuit Implementation

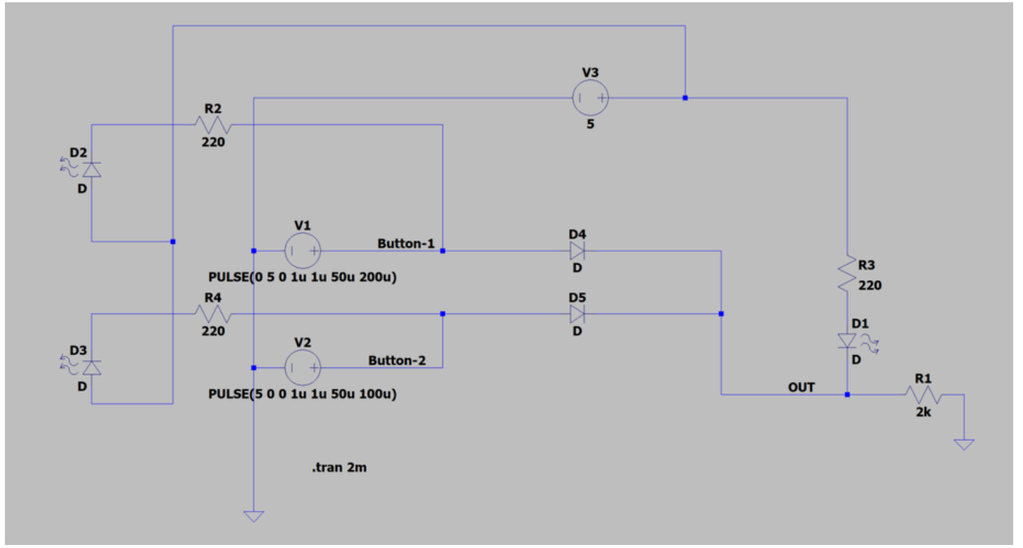


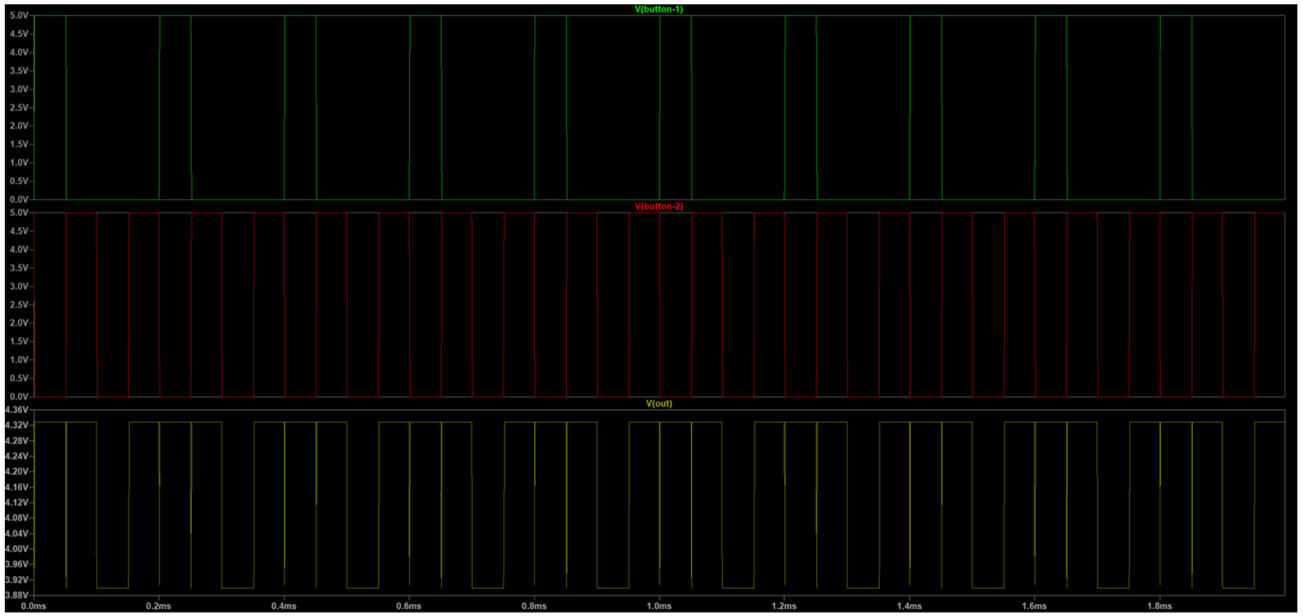
Components

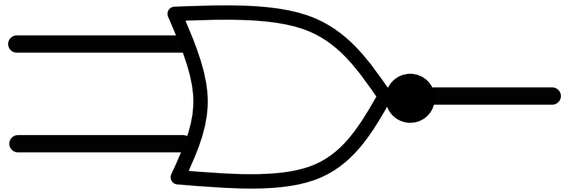
- Two regular diodes
- Four resistors
  - Three 220Ω resistors used for current limiting
  - One 2kΩ used as pull-up resistor
- Three red LEDs
  - Two LEDs used to indicate input
  - One LED used to indicate the output
- Two buttons
  - Used as the inputs of the circuit
- 5V voltage source

NOR

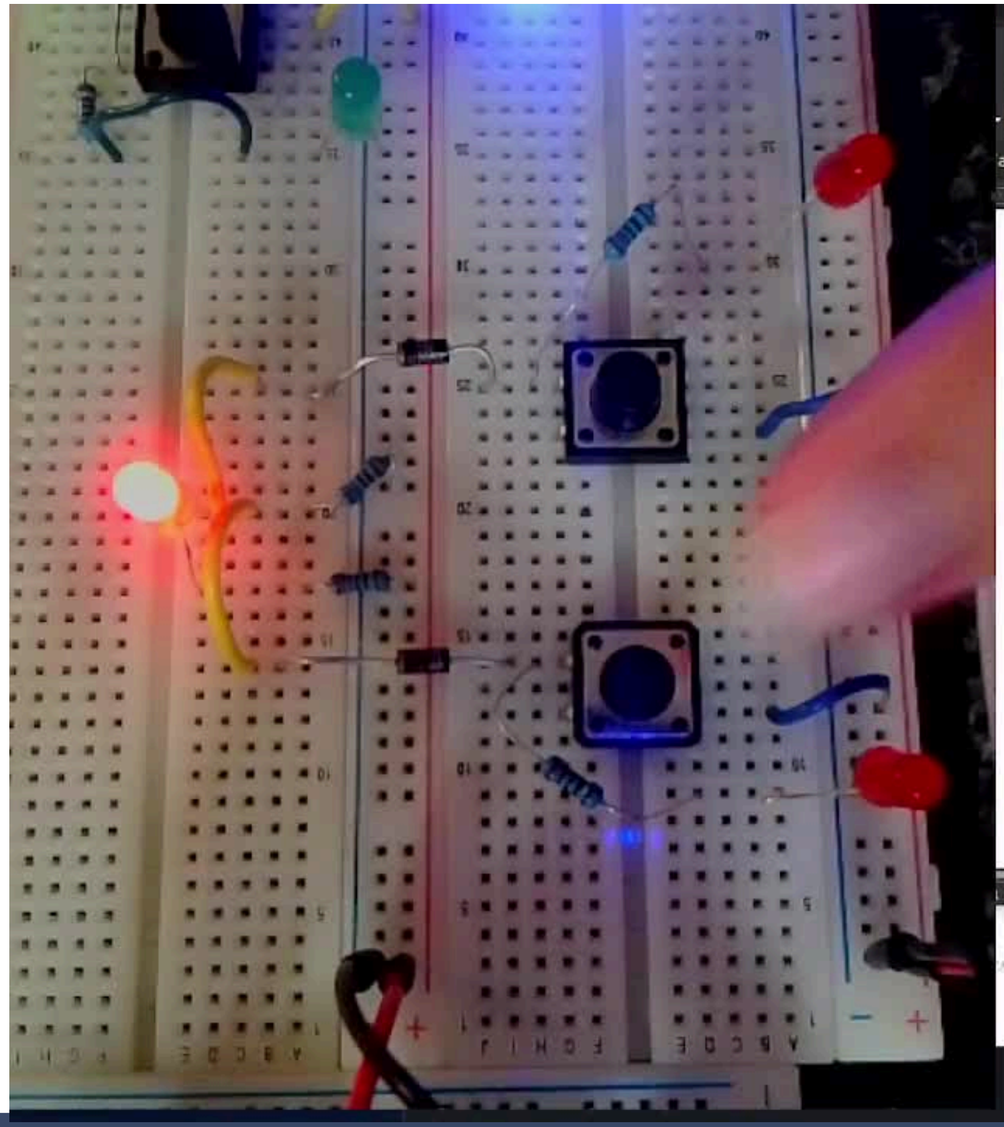
Schematic & Simulation

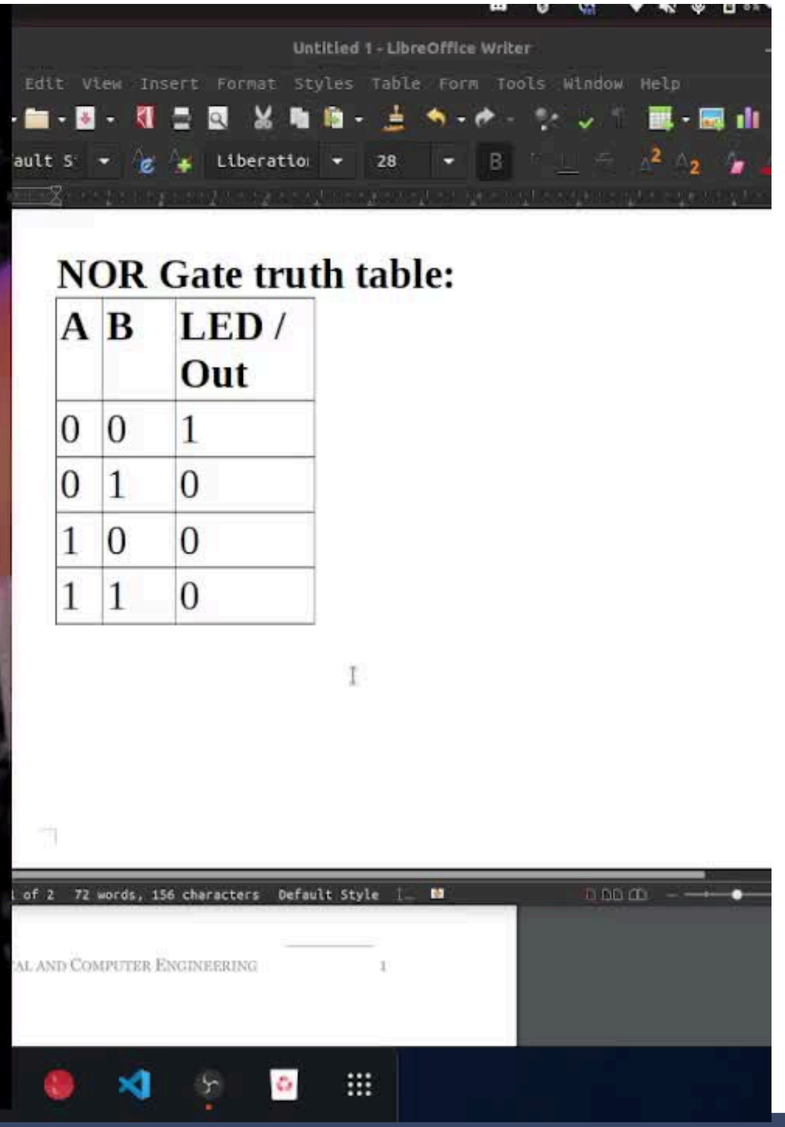






Demo - NOR




Untitled 1 - LibreOffice Writer
Edit View Insert Format Styles Table Form Tools Window Help
NOR Gate truth table:
A B LED / Out
0 0 1
0 1 0
1 0 0
1 1 0
of 2 72 words, 156 characters Default Style
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D

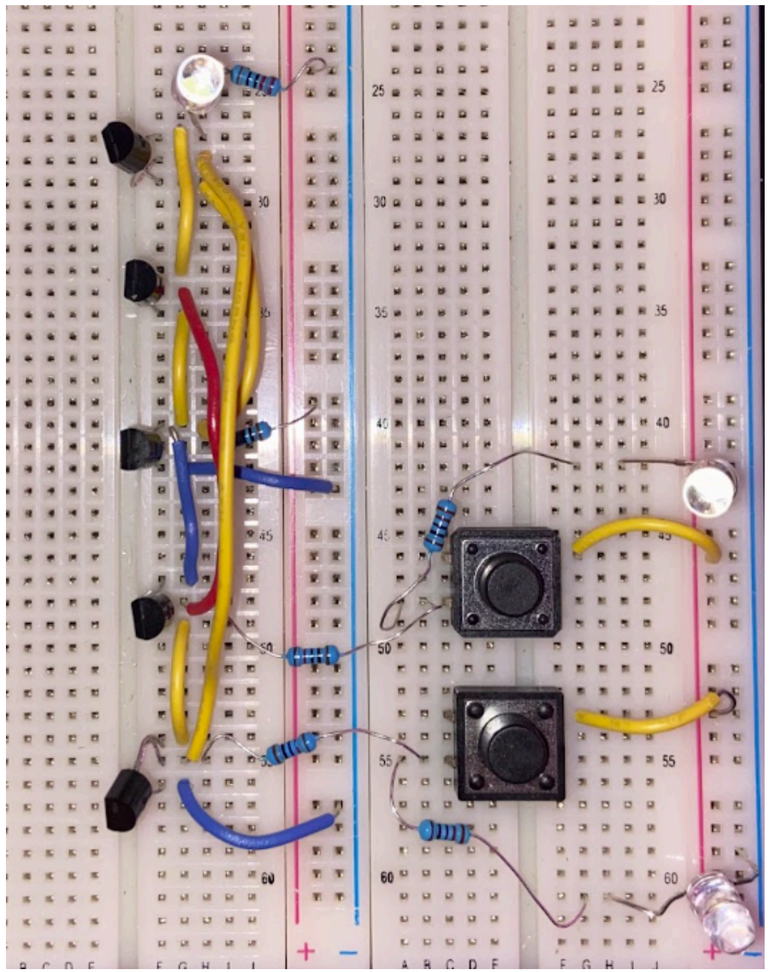
XOR Logic Gate

- Exclusive OR gate is also known as an XOR gate.
- This gate is high when the inputs are ODD. This means it takes multiple inputs and outputs a 1 if the number of inputs are odd.
- Boolean expression: $A \oplus B$

A	B	Output
0	0	0
1	0	1
0	1	1
1	1	0

An everyday example of XOR gates is used in password matching login systems:
If the input (password) is entered differs at any bit the XOR gate will output 1 meaning there is a mismatch. If all bits are entered correctly XOR gate will output 0, granting access to the user.

XOR Circuit Implementation

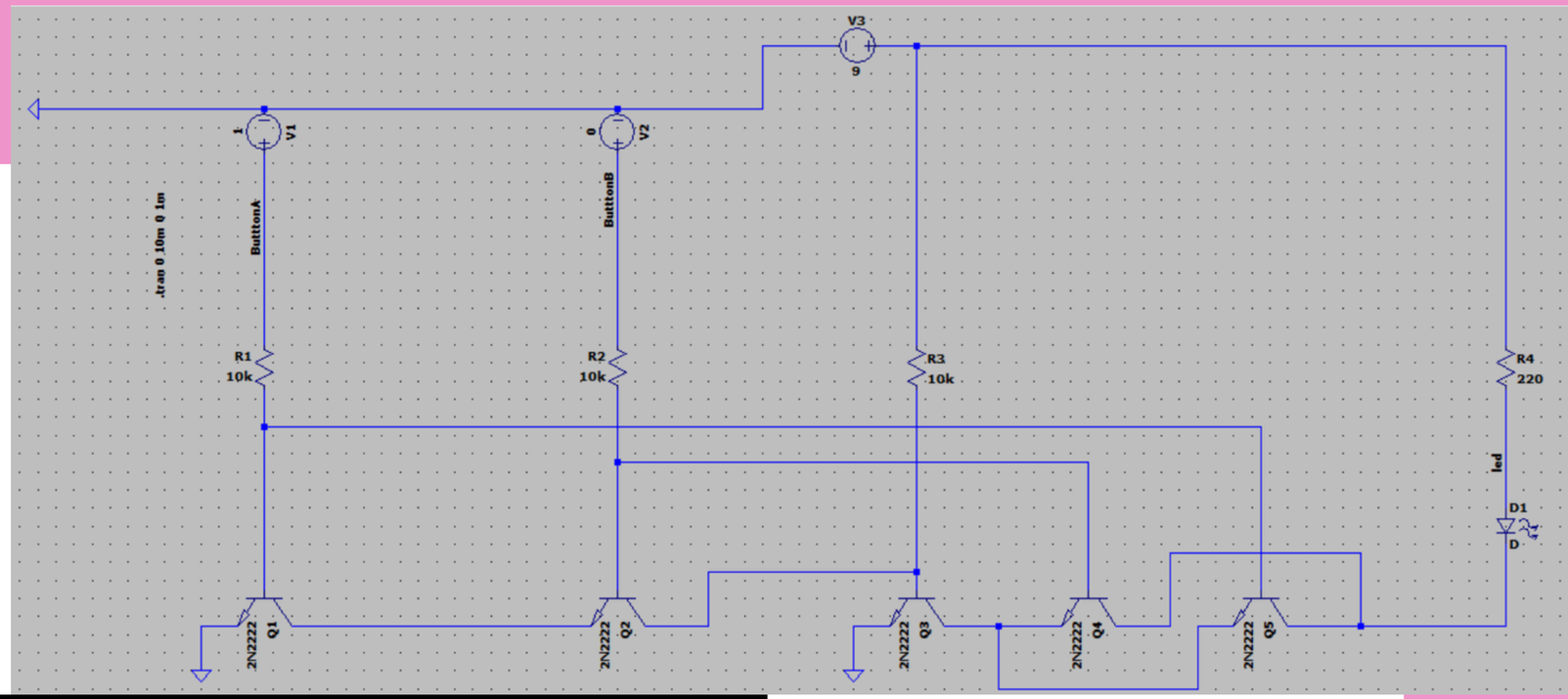


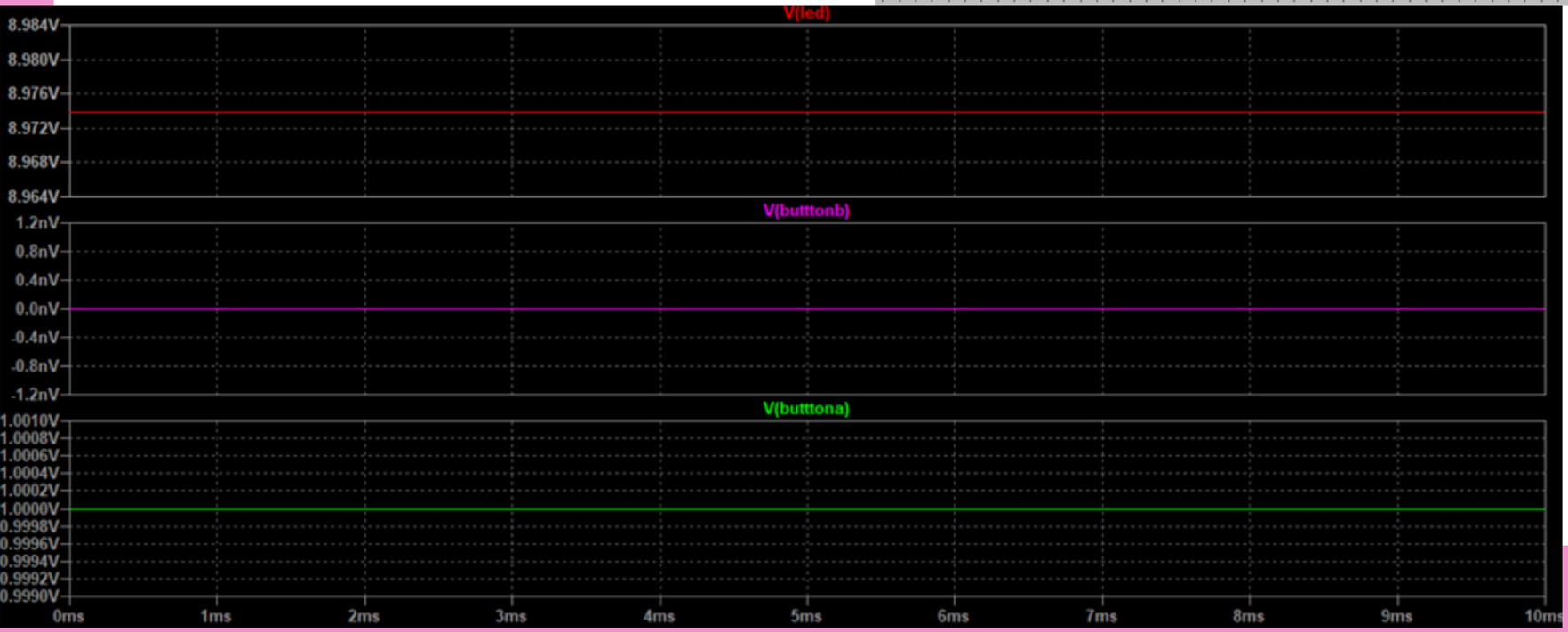
Components

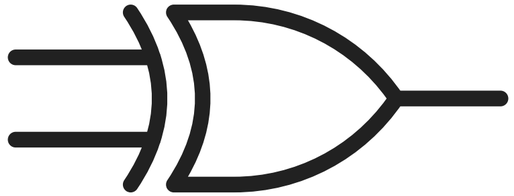
- Five Bipolar Junction Transistors (BJT 2N2222)
- Six resistors
  - Three 10kΩ resistors used for input biasing
  - Three 220Ω resistors used for current limiting
- Three white LED lights
  - Two are used for indicating input
  - One is used for indicating the output
- Two buttons
  - Used as inputs

XOR

Schematic & Simulation

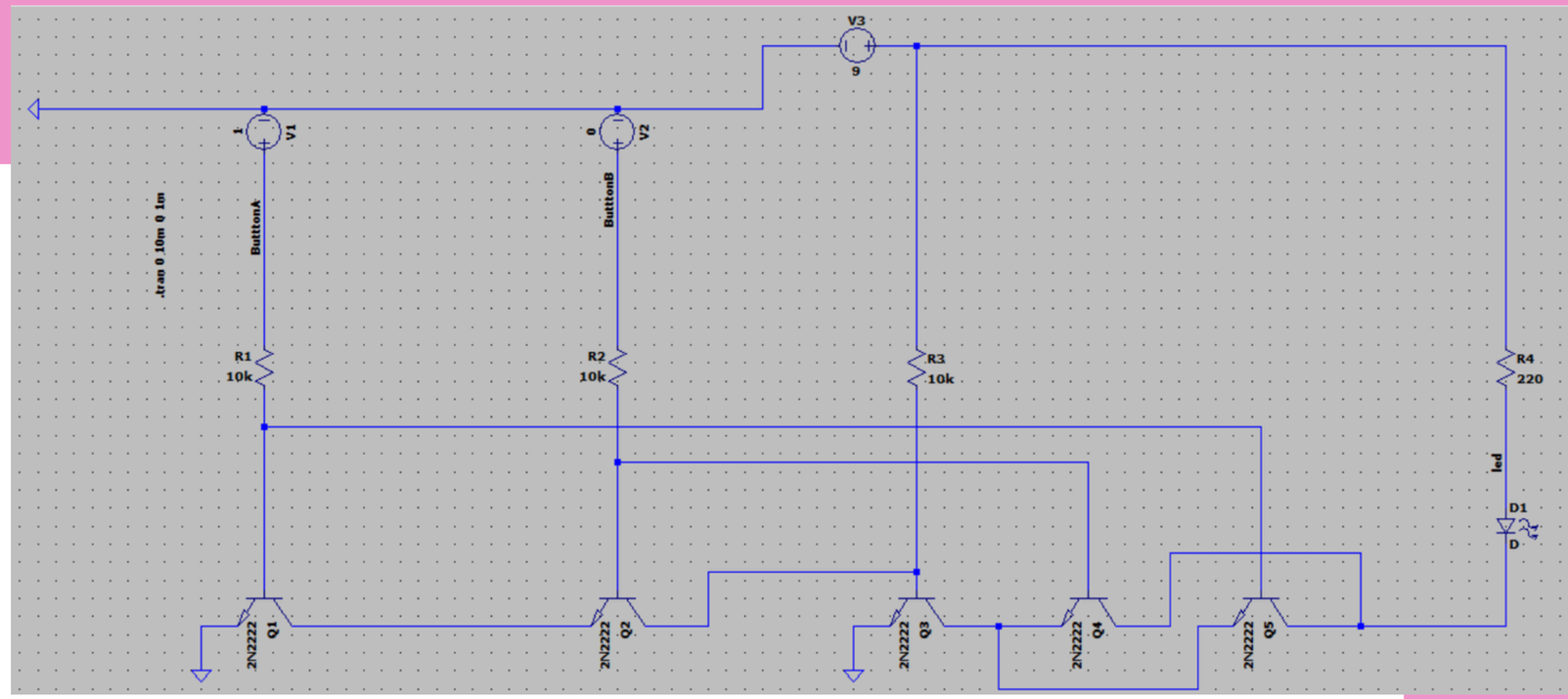


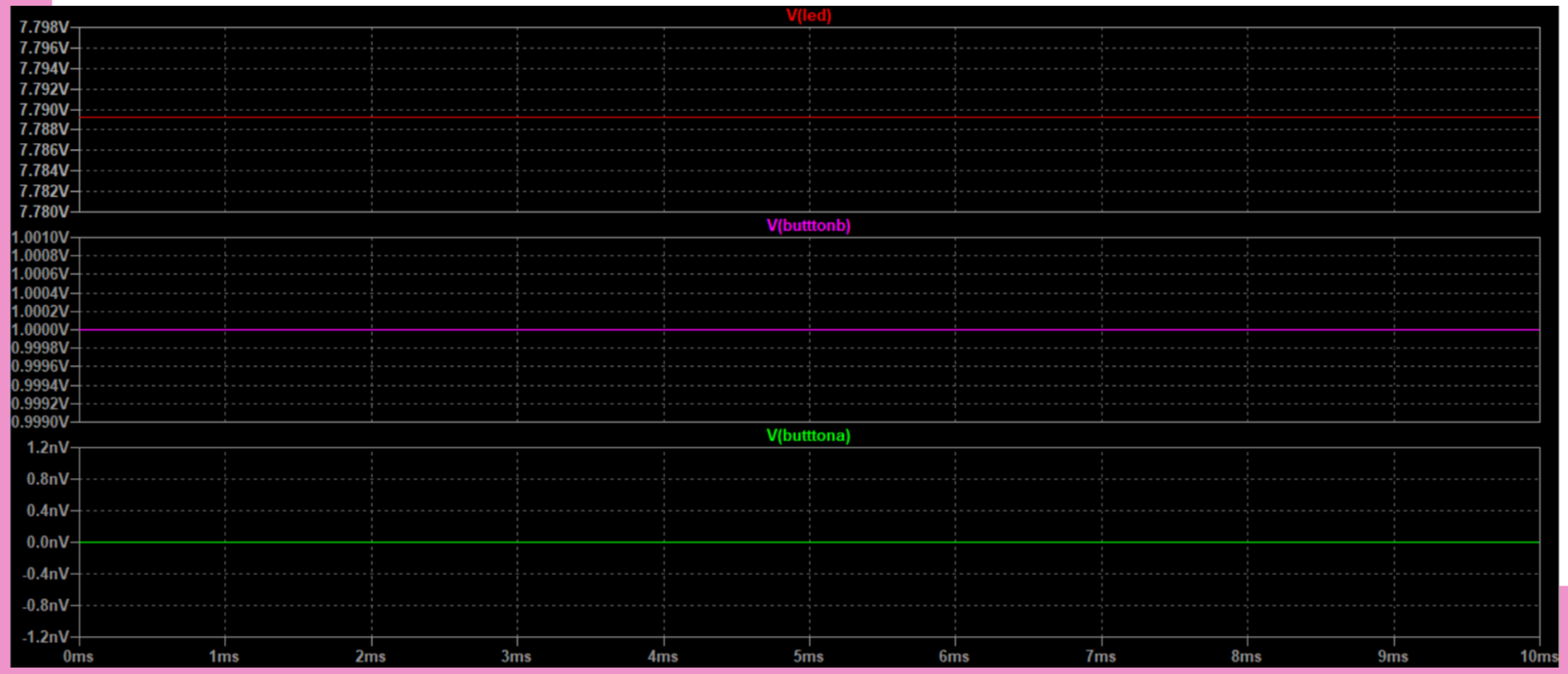


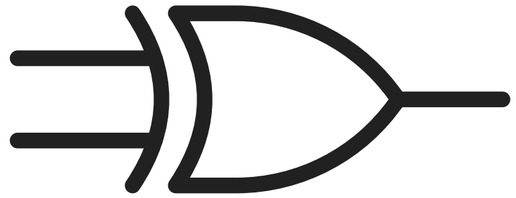


XOR (EX2)

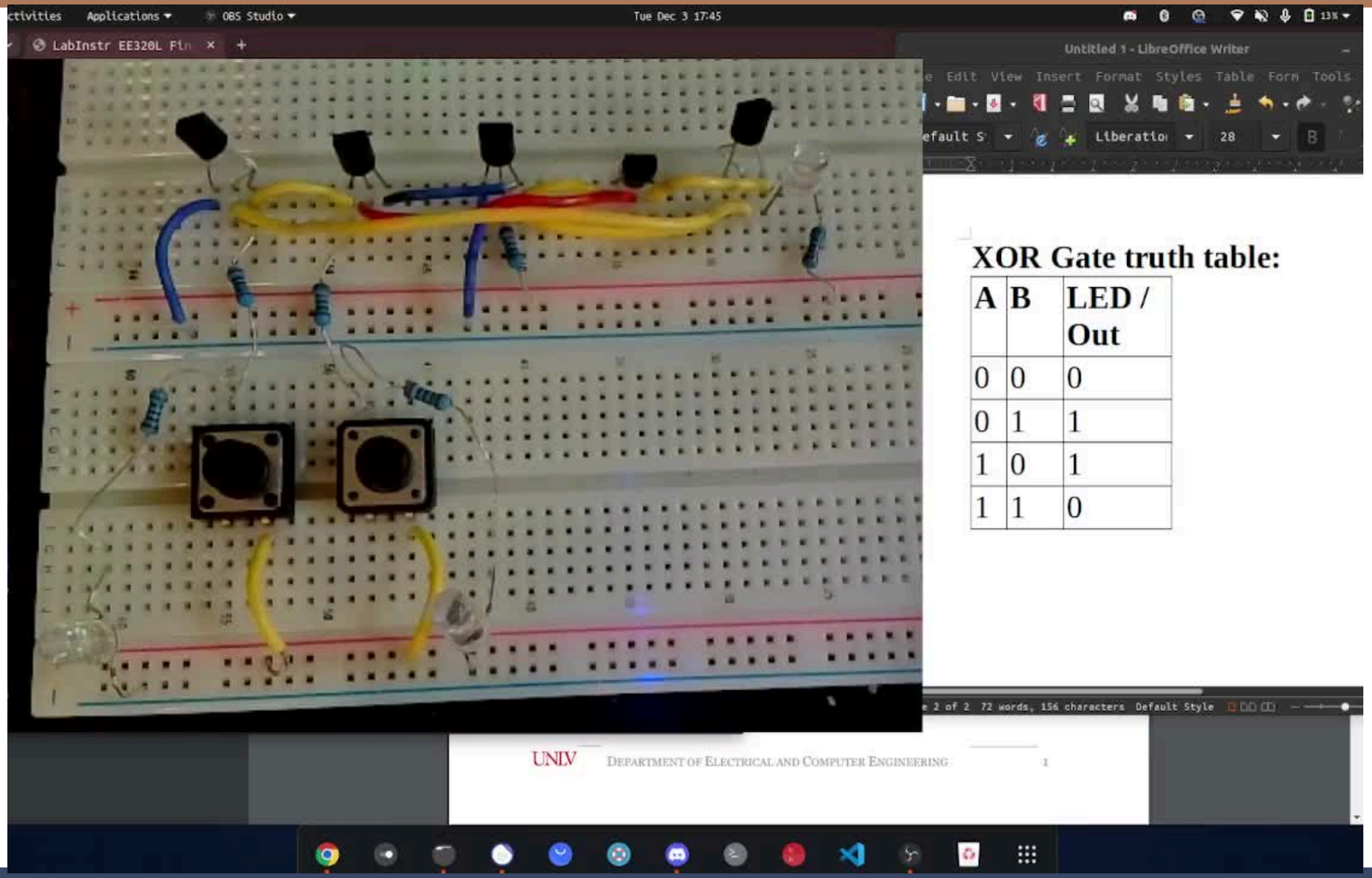
Schematic & Simulation







Demo - XOR


Activities
Applications
OBS Studio
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LabInstr EE320L Fin
Untitled 1 - LibreOffice Writer
File Edit View Insert Format Styles Table Form Tools
XOR Gate truth table:
A B LED / Out
0 0 0
0 1 1
1 0 1
1 1 0
Page 2 of 2 72 words, 156 characters Default Style
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Conclusion

- Learned how to test and build digital logic gates using diodes, BJTs, MOSFETs, and resistors
- Strengthen our knowledge of each component’s functionality & strengthen our testing skills with our Oscilloscope
- One issue: LTspice had some examples of XOR not working as intended but in the demo video all cases were successful
- In the Lab, we had problems with circuits, but after we made sure everything was plugged in all the way, changed bad buttons, and burnt-out LEDs, we got better results.

References

1	https://www.electronics-tutorials.ws/filter/filter_7.html
2	https://www.youtube.com/watch?v=1K-B-2Fv4w4&ab_channel=electronzapdotcom
3	https://circuitdigest.com/electronic-circuits/how-to-build-xor-logic-gate-using-transistors
4	https://youtu.be/nB6724G3b3E?si=B8MIRTAwe7QeY3US https://circuitdigest.com/electronic-circuits/how-to-build-xor-logic-gate-using-transistors
5	https://www.youtube.com/watch?v=9lqwSaIDm2g https://www.youtube.com/watch?v=f3zRz0d9XA8

Thank you!