NORTH SOUTH UNIVERSITY

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

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CSE 331/ EEE 332 / EEE 453

Microprocessor Interfacing & Embedded System

Project Report

'Implementation of an Encryption Table Using Microcontroller'

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Group: **8**

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Table of Contents

1. Introduction

1.1 Main Objective

- This project's primary goal was to examine the power consumption of various microcontroller boards (which are offered for sale in the market) for a unique situation.
- Applying a 4 bit logic input in the microcontrollers is the special case.
- Following the application of an encryption algorithm in accordance with a provided truth table (Table 2.1.1), the microcontroller outputs a 4 bit value that can be displayed with LEDs.
- The goal of this experiment is to measure how much current the circuit draws for every possible logic that can be applied to the input and the entire system. For a 4 bit input, there are 16 possible inputs (ranging from 0000 to 1111); for each of these combinations, the circuit's current is measured. This is carried out for at least three different microcontroller boards with various specifications.
- A graphical analysis was done using the data that was gathered for all the boards.
  completed in order to compare the three boards.
- All of the microcontrollers' input conditions, such as a steady supply of power to the circuit, must be maintained in order to obtain valid results.

2. Method of Derivation

2.1 Truth Table

Input				Output			
I3	I2	I1	I0	O3	O2	O1	O0
0	0	0	0	0	1	0	0
0	0	0	1	0	1	0	1
0	0	1	0	1	0	1	1
0	0	1	1	0	1	0	0
0	1	0	0	0	0	1	0
0	1	0	1	1	0	1	0
0	1	1	0	1	0	0	1
0	1	1	1	1	1	1	0
1	0	0	0	1	1	0	1
1	0	0	1	0	0	1	1
1	0	1	0	1	0	1	0
1	0	1	1	1	0	0	0
1	1	0	0	1	1	0	0
1	1	0	1	1	1	1	1
1	1	1	0	0	0	0	0
1	1	1	1	0	1	0	0

Table 2.1.1: Truth Table

2.2 Boolean Expression using K-map

We have to derive the **Boolean expression** for the outputs according to the Truth Table (**Table 2.1.1**). So for each output we will get one Boolean expression. The Boolean expression were derive using **K-map**.

K-map :

O3 KMAP:

O3	I1,I0			
I3,I2	00	01	11	10
00	0	0	0	1
01	0	1	1	1
11	1	1	0	0
10	1	0	1	1

SOP: O3(I3, I2, I1, I0) = I3I2'I1 + I3'I1I0' + I3'I2I0 + I3I2'I0' + I3I2I1'

O2 KMAP:

O2	I1,I0			
I3,I2	00	01	11	10
00	1	1	1	0
01	0	0	1	0
11	1	1	1	0
10	1	0	0	0

SOP: O2(I3, I2, I1, I0) = I3'I2'I1' + I3'I1I0 + I3I1'I0' + I3I2I0

O1 KMAP:

O1	I1,I0			
I3,I2	00	01	11	10
00	0	0	0	1
01	1	1	1	0
11	0	1	0	0
10	0	1	0	1

SOP: O1(I3, I2, I1, I0) = I2'I1I0' + I3'I2I1' + I3'I2I0 + I3I1'I0

O0 KMAP:

O0	I1,I0			
I3,I2	00	01	11	10
00	0	1	0	1
01	0	0	0	1
11	0	1	0	0
10	1	1	0	0

SOP: O0(I3, I2, I1, I0) = I2'I1'I0 + I3'I1I0' + I3I2'I1' + I3I1'I0

2.3 Logisim Simulation

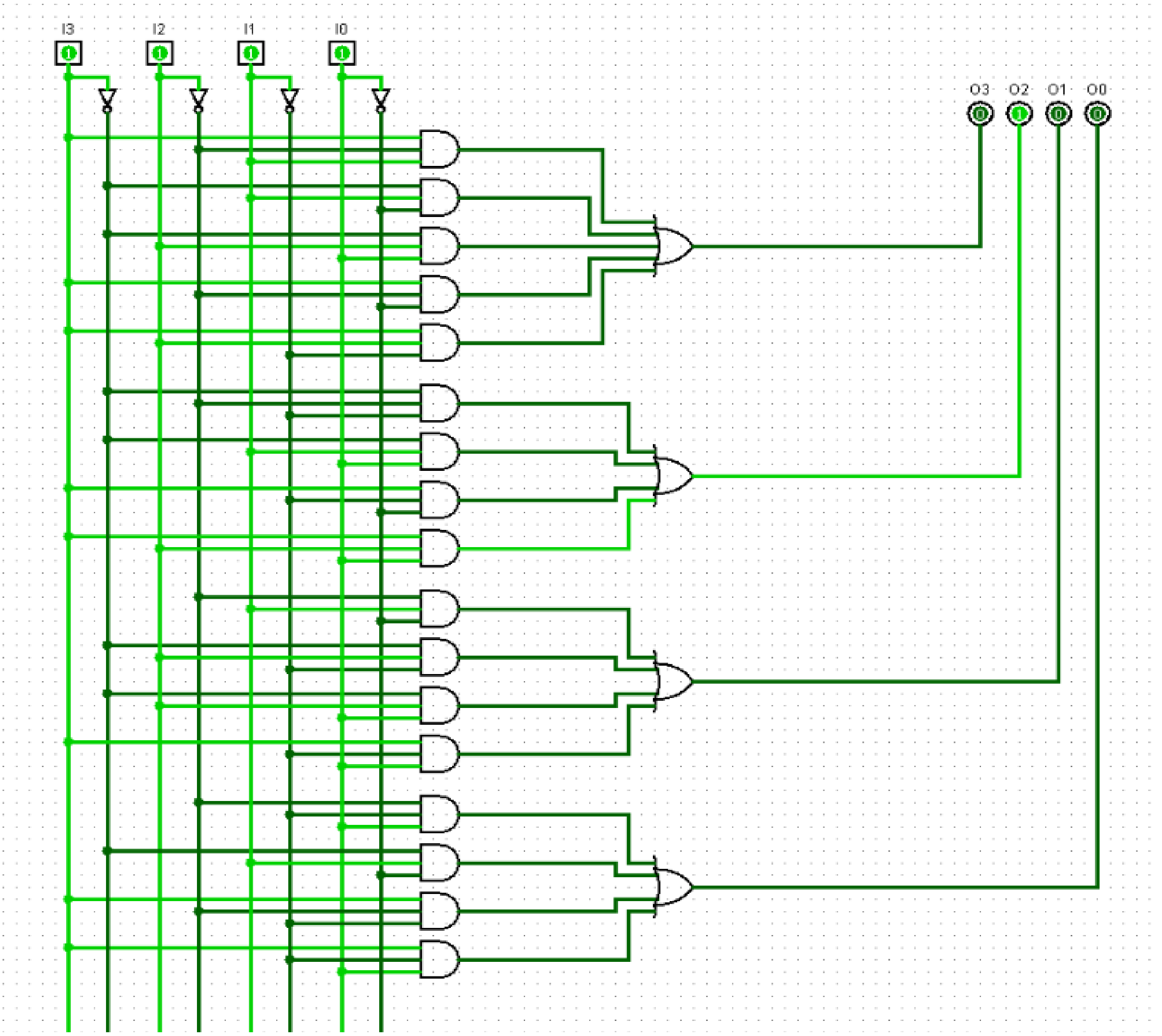


Figure 2.2.1: Logic Circuit for the derived Boolean Expressions.

3. Circuit Design & Simulation

3.1 Circuit Design Procedure

All commercial microcontroller boards have General Purpose Input Output (GPIO) pins that can be used to control digital inputs and outputs. GPIO pins are available in digital and analog varieties. There will be use for the digital GPIO pins. The pins can only be used for digital I/O in the Logic 0 (Low) and Logic 1 (High) states.

Circuit Connection Methodology:

-TheThe entire system is powered by a single 5V constant power supply, and the microcontroller requires 8 Digital GPIO pins: 4 for digital input and 4 for digital output.
-To provide the logic input sequence, we connected 4 input pins to 4 toggle switches (4 bit dip switches) with 4 pull down resistors (10 K each). We joined the four digital output pins to four LEDs.
-Each of the microcontroller boards used in the experiment follows this process.

We have done the experiment using:

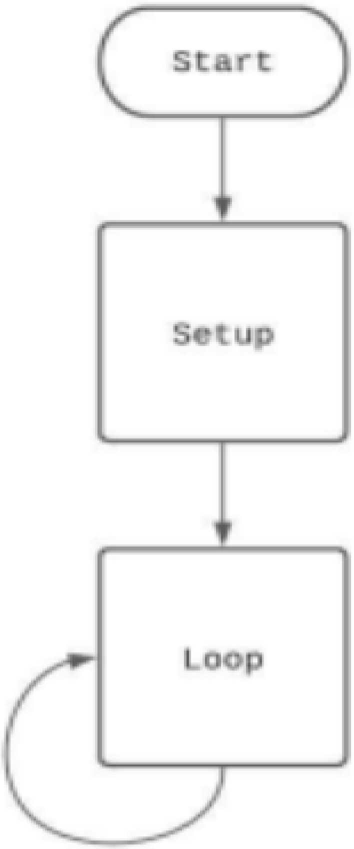
Arduino Uno R3 (16 MHz)

3.2 Simulation Procedure

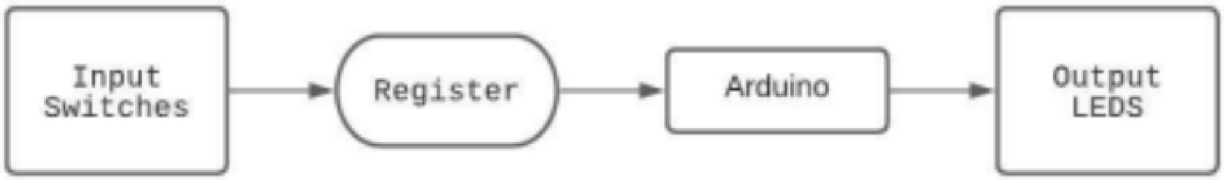
Proteus 8 Professional (Appendix A) is used for simulation. Since Proteus does not directly support Arduino simulation, we must first install a few specialized libraries, including those for the Arduino Uno.To use the derived Boolean expression, we must write our own code (all codes are provided in Appendix C). The Arduino IDE (Appendix A) will use this code to create a hex file that can be used to simulate the circuit in Proteus.

3.3 Program Logic Flow Chart

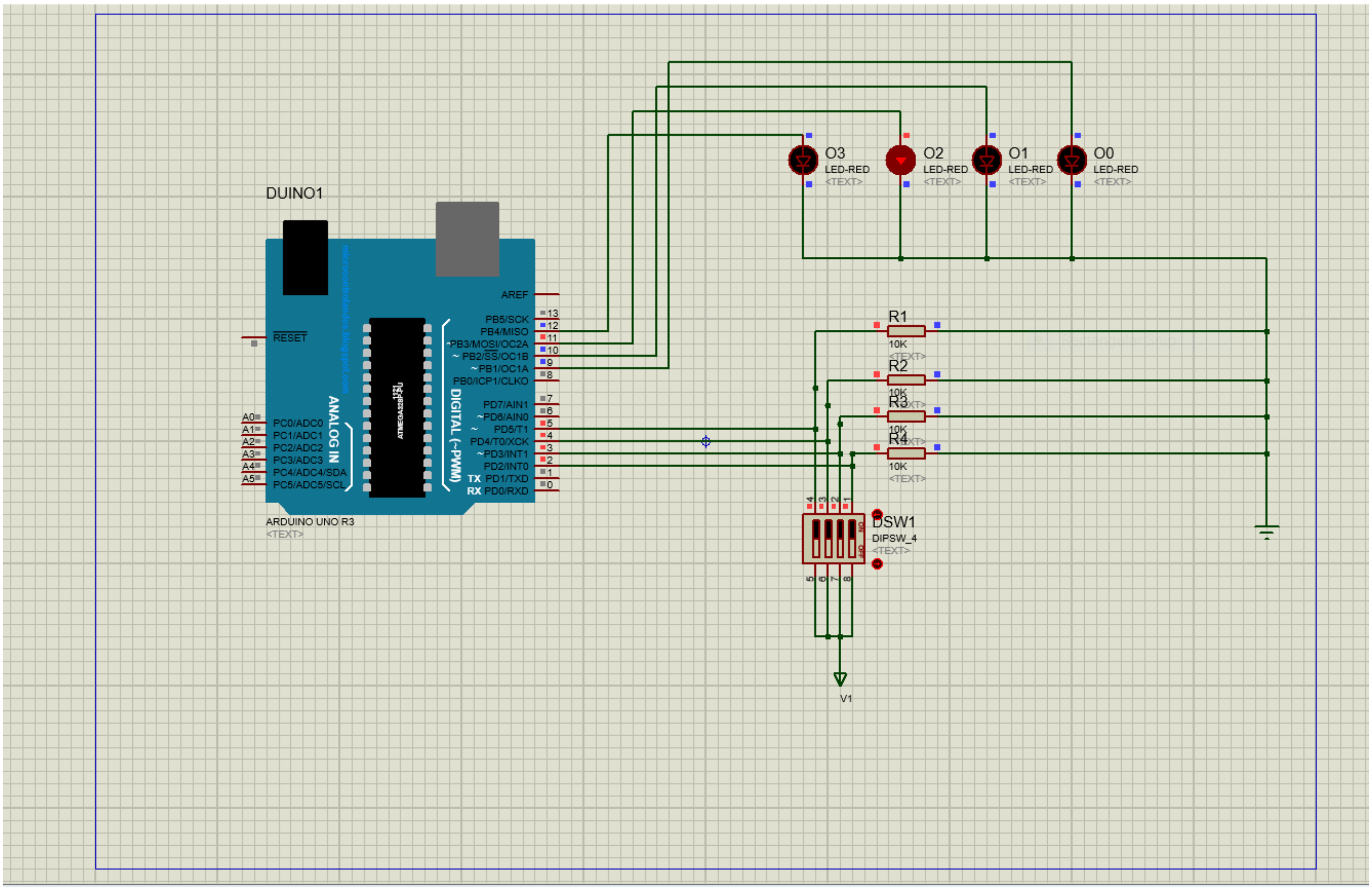
Arduino flowchart



Proteus flowchart



3.4 Arduino Uno R3 Simulation



4. Circuit Operation

4.1 Working Principle

- The whole system is powered by a **5V *(Vcc)*** power supply.
- Current from the ***Vcc*** is branched off in **two directions**:
    1. **Vin** pin of the microcontroller boards.
    2. Into the **Switch branch** (***Input Side of the Circuit***).

- In the switch branch there are 4 sub branches which represent the 4 logic inputs and each branch has a **10 KΩ pull down resistor**. The pull down resistors keep the **input at ground level** (Logic Low) when the switch is off.

- When the switch is **on**, current flows in all the 4 branches**. Internal resistance** of the input pins is much higher (in the range of **MΩ**) than 10 KΩ so a **small current flows into the input pins**. The rest of the current flows through the resistor to ground.

- The output LEDs are connect to 4 GPIO pins of microcontrollers. · Power delivered in the Vin pins is used to power the LEDs. (**A small amount of current also goes into the board through the input pins**) ·

- The microprocessor processes the input values received from the switch branch and delivers the appropriate logic to the output pins, hence light up the LEDs accordingly.

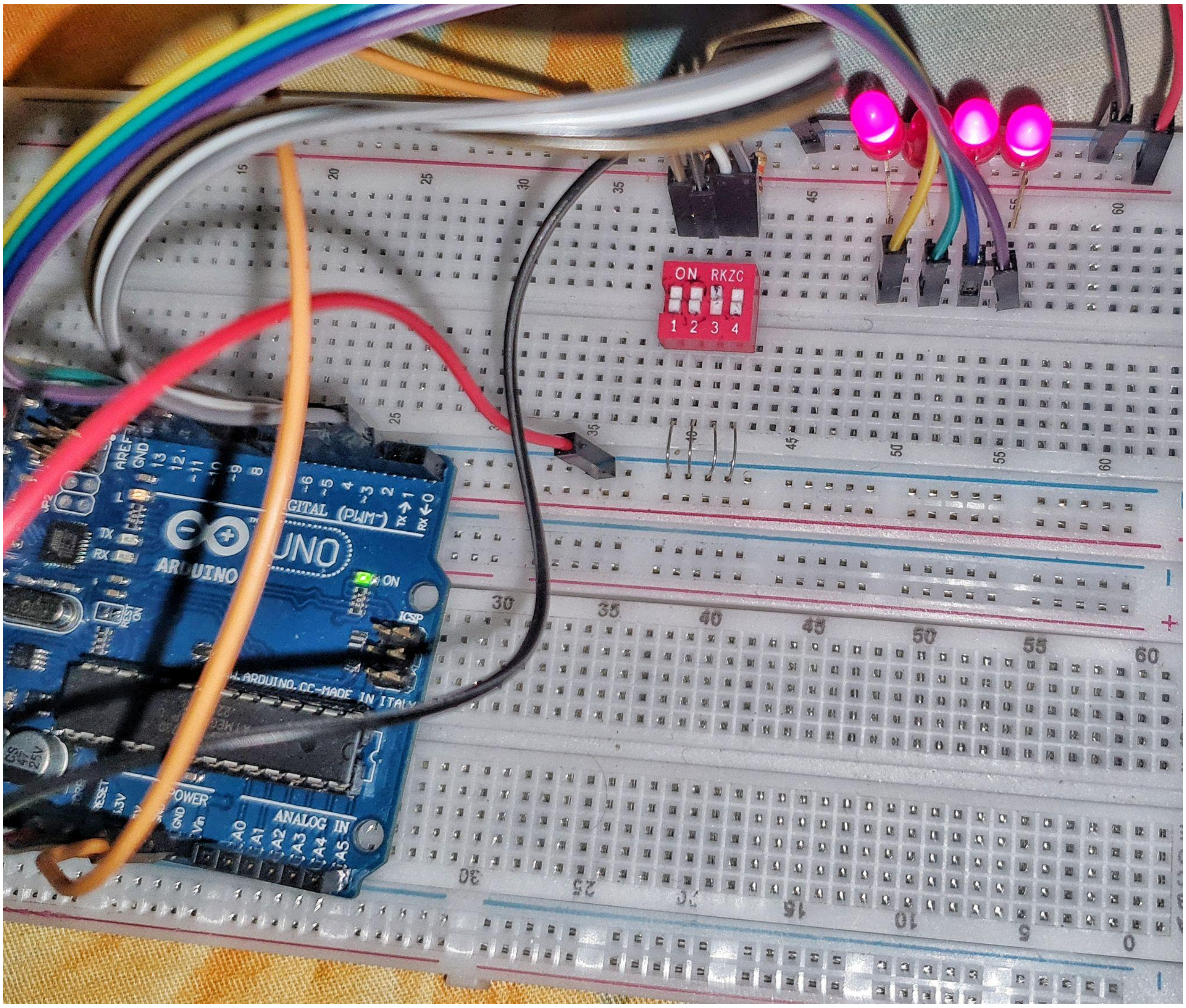
5. Hardware Implementation

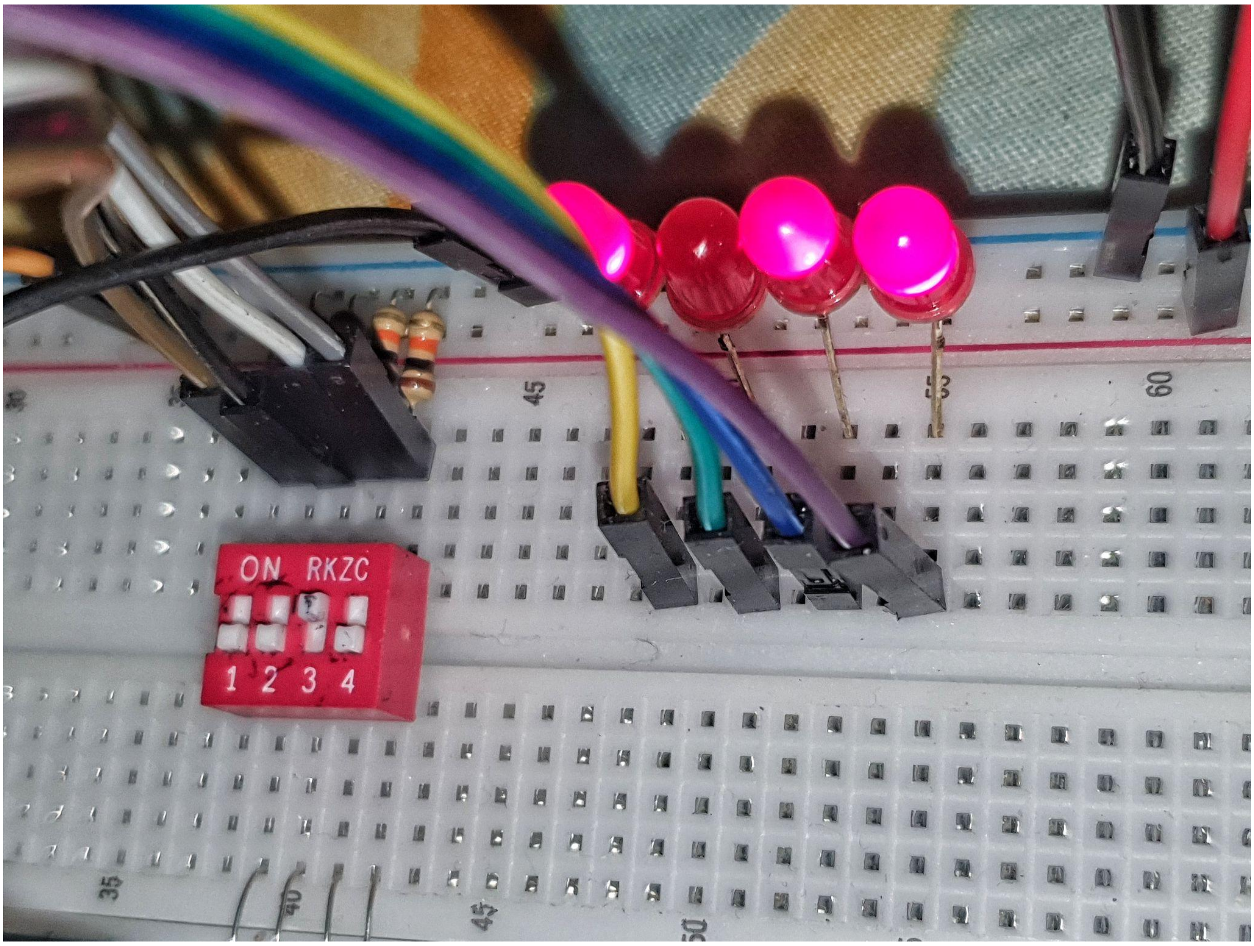
5.1 Equipment & Components Used

Serial No.	Name	Quantity
1	Variable DC Breadboard Power Supply	1
2	Breadboard	2
3	8-bit DIP Switch	1
4	Resistor (10 KΩ)	4
5	LED (Red)	4
6	Arduino Uno R3	1
7	Arduino Nano	1
8	NodeMCU V3 (ESP8266)	1
9	ANENG AN8009 Multimeter	1
10	Jumper Wires	As required
11	9V Battery	1

Table 5.1.1: Equipment & Components used.

5.2 Arduino Uno R3 Implementation





Circuit 5.2.1: Implementation of Arduino Uno and Current for ***0010*** *as input*

6. Data Collection & Graphical Analysis

6.1 Data Collection Procedure*

1. Since we are utilizing a fixed 5V constant power source, the power can be determined by measuring the current and applying the equation P = V I.
2. Current is measured in various circumstances for rigorous analysis and positions (described below) (explained below).
3. The experimental environment remaining constant across all of the boards was given the most importance.

6.2 IDLE State Power Consumption:

Idle Condition Power Consumption						
Board Name	**MCU**	**Frequency**	**Current (mA)**	**Avg Current (mA)**	**Ref. Voltage (V)**	**Power (mW)**
Arduino Uno R3	ATmega328P	16 MHz	29.3	29.4	5.0	147
			29.4			
			29.5			

Table 6.2.1: IDLE State Power Consumption

6.3 Input Side Power Consumption

Arduino UNO R3 Input Side Power Consumption					
Input Logic	**Output Logic**	**Current (mA)**	**Avg. Current (mA)**	**Voltage (V)**	**Power (mW)**
0000	0100	0	0	5.0	0
		0			
		0			
0001	0101	0.47	0.47	5.0	2.35
		0.48			
		0.46			
0010	1011	0.44	0.44	5.0	2.2
		0.45			
		0.43			
0011	0100	0.92	0.91	5.0	4.55
		0.91			
		0.90			
0100	0010	0.46	0.46	5.0	2.3
		0.45			
		0.47			
0101	1010	0.90	0.90	5.0	4.5
		0.89			
		0.91			
0110	1001	0.92	0.91	5.0	4.55
		0.91			
		0.90			
0111	1110	1.42	1.42	5.0	7.1
		1.43			
		1.41			
1000	1101	0.46	0.46	5.0	2.3
		0.45			

		0.47			
1001	0011	0.91	0.91	5.0	4.55
		0.92			
		0.90			
1010	1010	0.92	0.92	5.0	4.6
		0.91			
		0.93			
1011	1000	1.32	1.33	5.0	6.65
		1.33			
		1.34			
1100	1100	0.90	0.91	5.0	4.55
		0.92			
		0.91			
1101	1111	1.38	1.37	5.0	6.85
		1.36			
		1.37			
1110	0000	1.37	1.37	5.0	6.85
		1.38			
		1.36			
1111	0100	1.78	1.77	5.0	8.85
		1.77			
		1.76			

Table 6.3.1: Arduino Uno R3 Input Side Power

6.4 Total System Power Consumption

Arduino UNO R3 Total Power Consumption with LED					
Input Logic	**Output Logic**	**Current (mA)**	**Avg. Current (mA)**	**Voltage (V)**	**Power (mW)**
0000	0100	79.9	79.8	5.0	399.0
		79.8			
		79.7			
0001	0101	117.7	117.6	5.0	588.0
		117.6			
		117.5			
0010	1011	145.9	145.8	5.0	729.0
		145.8			
		145.7			
0011	0100	80.4	80.3	5.0	401.5
		80.3			
		80.2			
0100	0010	79.9	79.8	5.0	399.0
		79.8			
		79.7			
0101	1010	116.8	116.7	5.0	583.5
		116.7			
		116.6			
0110	1001	117.3	117.2	5.0	586.0
		117.2			
		117.1			
0111	1110	145.5	145.4	5.0	729.0
		145.4			
		145.3			
		135.6			

1000	1101	135.5	135.5	5.0	677.5
		135.4			
1001	0011	117.5	117.4	5.0	587.0
		117.4			
		117.3			
1010	1010	116.8	116.7	5.0	583.5
		116.7			
		116.6			
1011	1000	79.8	79.7	5.0	398.5
		79.7			
		79.6			
1100	1100	116.8	116.7	5.0	583.5
		116.7			
		116.6			
1101	1111	168.4	168.3	5.0	841.5
		168.3			
		168.2			
1110	0000	29.1	29.0	5.0	145.0
		29.0			
		28.9			
1111	0100	80.6	80.5	5.0	402.5
		80.5			
		80.4			

Table 6.4.1: Arduino Uno R3 Total Power Consumption with LED

6.5 Total System Power Consumption without LEDs

Arduino UNO R3 Total Power Consumption without LED					
Input Logic	**Output Logic**	**Current (mA)**	**Avg. Current (mA)**	**Voltage (V)**	**Power (mW)**
0000	0100	42.6	42.5	5.0	212.5
		42.5			
		42.4			
0001	0101	43.1	43.0	5.0	215.0
		43.0			
		42.9			
0010	1011	43.2	43.1	5.0	215.5
		43.1			
		43.0			
0011	0100	43.5	43.4	5.0	217.0
		43.4			
		43.3			
0100	0010	43.0	42.9	5.0	214.5
		42.9			
		42.8			
0101	1010	43.6	43.5	5.0	217.5
		43.5			
		43.4			
0110	1001	43.7	43.6	5.0	218.0
		43.6			
		43.5			
0111	1110	44.2	44.1	5.0	220.5
		44.1			
		44.0			
		43.2			
		43.1			

1000	1101	43.0	43.1	5.0	215.5
1001	0011	43.6	43.5	5.0	217.5
		43.5			
		43.4			
1010	1010	43.6	43.5	5.0	217.5
		43.5			
		43.4			
1011	1000	44.0	43.9	5.0	219.5
		43.9			
		43.8			
1100	1100	43.7	43.6	5.0	218.0
		43.6			
		43.5			
1101	1111	44.2	44.1	5.0	220.5
		44.1			
		44.0			
1110	0000	44.0	43.9	5.0	219.5
		43.9			
		43.8			
1111	0100	44.6	44.5	5.0	222.5
		44.5			
		44.4			

Table 6.5.1: Arduino Uno R3 Total Power Consumption without LEDs

7. Question & Answers

7.1 Arduino Uno R3

1. What is the clock frequency of the microcontroller used?

Answer: 16 MHz.

2. What is the data bus width of the microcontroller used?

Answer: 8 bit.

3. What is the size of your hex file generated? Attach the hex codes in your report.

Answer: 3.38 KB. Hex file is attached in Appendix D.

4. Can the project be implemented by using interrupt?

Answer: Yes, because all Arduino Uno R3 pins can be utilized as interrupts.

5. Is the main routine required to be an infinite loop? Provide explanation in favor of your answer.

Answer: Yes, the primary procedure must have an infinite loop. This is because we must constantly check the input status and give a constant output logic. If it were not an infinite loop, the program would execute and terminate, and changing the input logic would not result in any output.

6. Is there any difference between level triggered and edge triggered operation for the given project?

Answer: As we are utilizing a toggle switch, there is no distinction between level and edge triggering.

7. Is the project referring encryption or decryption from input to output?

Answer: This resembles a cryptographic circuit. We are applying an encryption algorithms to the data we possess. This approach can be employed to decrypt and locate the original data.

8. References

1. Project materials provided by Dr. Dihan Md. Nuruddin Hassan.
2. https://www.techtarget.com/whatis/definition/routine
3. https://comparecamp.com/arduino-ide-review-pricing-pros-cons-features/
4. https://en.wikipedia.org/wiki/Proteus_Design_Suite
5. https://study.com/academy/lesson/introduction-to-logisim-setup overview.html

Appendix A: Software Specifications

Arduino IDE

Arduino IDE is an open-source tool that makes it possible for users to write as well as upload code to a work environment in real-time. Since the written code will be moved to the cloud, it's frequently used by those who need an additional level of redundancy. Arduino IDE offers full compatibility to any Arduino based software board. The software can easily be deployed in any Linux, Mac, or Windows operating systems. Most of its parts are written within JavaScript for seamless compilation and editing. While the tool's main aim is based on code writing, it offers several noteworthy functionalities. For instance, Arduino IDE lets users share important project information to company stakeholders. Users are given the freedom to make internal layouts and schematic modifications when needed. Comprehensive guides are available for those who need help in the installation process. Tutorials are present for users who have little experience dealing with the tool's framework. Arduino IDE is highly rated by users for its ease of use. It can conduct complex processes while keeping computer resources to a minimum. The tool makes it easy for users to access their libraries. At the same time, it offers updated support for the latest Arduino boards, which can help users with their sketches using the latest IDE version.

Website: https://www.arduino.cc/en/software

Proteus 8 Professional

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing printed circuit boards.

Website: https://www.labcenter.com/downloads/

LogiSim

When learning computer architecture and logic circuits, you will need a real world, graphical example of what you are studying. Text and diagrams only go so far. A helpful tool for designing and simulating logic circuits is Logisim.

Because the tool lets you create large circuits from smaller circuits, you can design entire CPUs using Logisim. Further, the tool will run on any computer!

The interface itself is very intuitive and the use of color-coding of wires and elements allows for easy analysis and testing of circuits. You can also save the completed file as an image, or as a .circ file (core to Logisim).

Website: http://www.cburch.com/logisim/download.html

Appendix B: Hardware Specifications

Arduino Uno R3

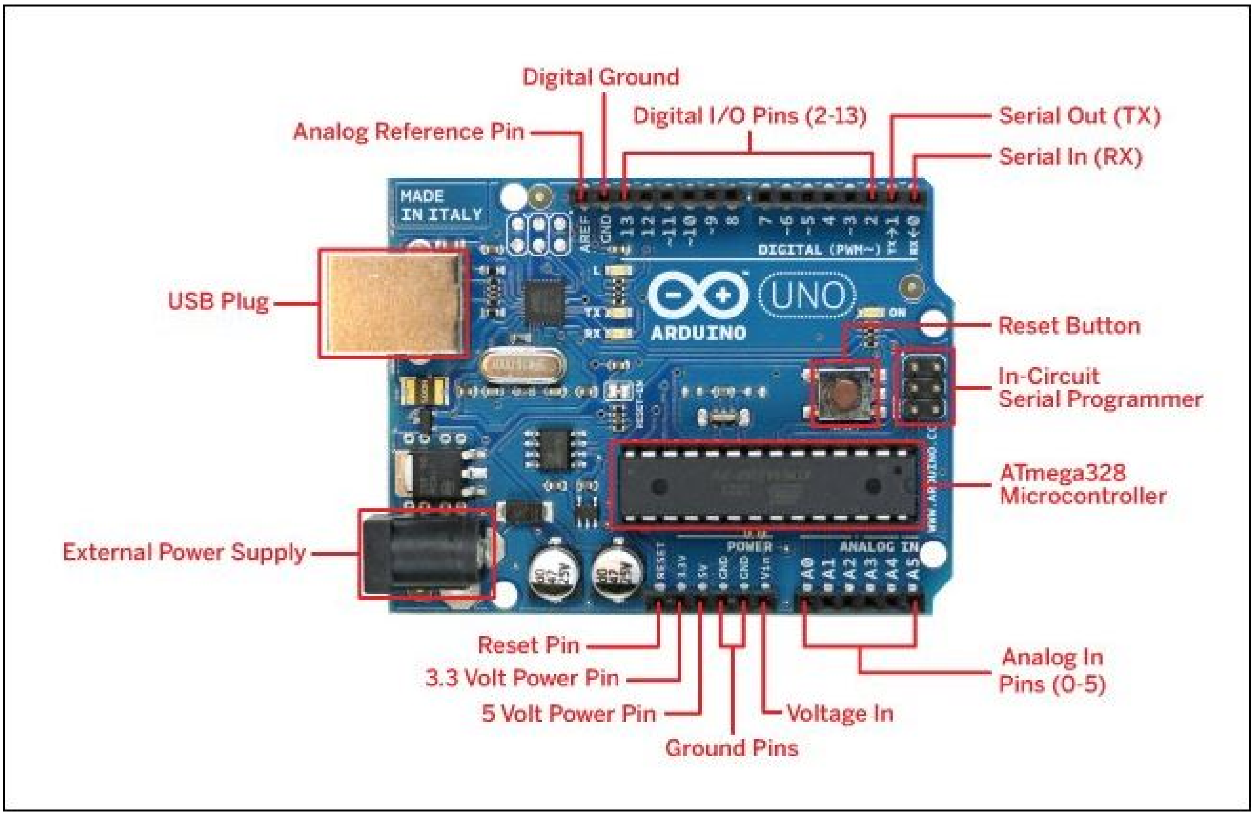
The Arduino UNO R3 is frequently used microcontroller board in the family of an Arduino. This is the latest third version of an Arduino board and released in the year 2011. The main advantage of this board is if we make a mistake we can change the microcontroller on the board. The main features of this board mainly include, it is available in DIP (dual-inline-package), detachable and ATmega328 microcontroller. The programming of this board can easily be loaded by using an Arduino computer program. This board has huge support from the Arduino community, which will make a very simple way to start working in embedded electronics, and many more applications. Please refer the link to know about Arduino – Basics, and Design.

Arduino Uno R3 Specifications

The Arduino Uno R3 board includes the following specifications.

· It is an ATmega328P based Microcontroller
· The Operating Voltage of the Arduino is 5V
· The recommended input voltage ranges from 7V to 12V · The i/p voltage (limit) is 6V to 20V
· Digital input and output pins-14
· Digital input & output pins (PWM)-6
· Analog i/p pins are 6
· DC Current for each I/O Pin is 20 mA
· DC Current used for 3.3V Pin is 50 mA
· Flash Memory -32 KB, and 0.5 KB memory is used by the boot loader · SRAM is 2 KB
· EEPROM is 1 KB
· The speed of the CLK is 16 MHz
· In Built LED
· Length and width of the Arduino are 68.6 mm X 53.4 mm · The weight of the Arduino board is 25 g

Pin Diagram:



Digital Ground
Analog Reference Pin
Digital I/O Pins (2-13)
Serial Out (TX)
Serial In (RX)
USB Plug
Reset Button
In-Circuit
Serial Programmer
ATmega328
Microcontroller
External Power Supply
Reset Pin
3.3 Volt Power Pin
5 Volt Power Pin
Ground Pins
Voltage In
Analog In
Pins (0-5)
MADE
IN ITALY
UNO
ARDUINO
DIGITAL (PWM~)
POWER
ANALOG IN

ANENG AN8009 Multimeter

Generic GB Digital Multimeter AN8009 LCD Display 9999 Counts AC/DC Tester-Black.

Features:

1. Operating Temperature: 0 - 40 鈩?br>Operating Humidity: 鈮?5%RH
2. Storage Condition: -20~60 鈩?br>Storage Humidity: 鈮?0%RH
3. DIY Supplies: Electrical
4. Operating Mode: Auto/Manual Ranging
5. Measuring Inductance Range: no
6. Measuring Temperature Range: -20~1000 C/-4F-1832F

Descriptions:

1. Measuring Capacitance Range: 9.99nF/99.99nF/999.9nF/9.99uF/99.99uF/999.9uF/9.9 99MF

2. Measuring Voltage Range: 999.9mV/9.999V/99.99V/999.9V

3. Measuring Current Range:60mA/600mA/10A

4. Measuring Resistance Range: 99.99/999.9/9.999k/99.99k/999.9K/999.9M

5. Frequency: 99.99Hz/999.9Hz/9.999KHz/99.99KHz/999.9KHz/9.999MHz

6. Square Wave Output: 50Hz/100Hz/200Hz/300Hz/400Hz/500Hz/600Hz/700Hz/800H z/

900Hz/1000Hz/200

7. DC/AC Voltage(mV): 9.999mV/99.99mV

8. DC/AC Voltage(V): 999.9mV/9.999V/99.99V/750ACV(999.9DCV)

9. DC/AC Current (mA&A): 999.9mA/9.999A

10. DC/AC Current (uA): 99.99 渭 A/999.9 渭 A

11. Display Type: Digital Display

12. Diode Test: Yes

13. Continuity: Yes

14. Duty Cycle: 1%-99%

15. Sample Rate: 3 times per second

16. Power: 2 * 1.5V AAA batteries.

Appendix C: Codes

Arduino Uno R3

```
// CSE331.1 (Fall 2022)
// Group-8
// Code for Arduino Uno R3:



int pin_I3 = 5;
int pin_I2 = 4;
int pin_I1 = 3;
int pin_I0 = 2;

int pin_O3 = 12;
int pin_O2 = 11;
int pin_O1 = 10;
int pin_O0 = 9;

void setup() {
  pinMode(pin_O3, OUTPUT);
  pinMode(pin_O2, OUTPUT);
  pinMode(pin_O1, OUTPUT);
  pinMode(pin_O0, OUTPUT);

  pinMode(pin_I3, INPUT);
  pinMode(pin_I2, INPUT);
  pinMode(pin_I1, INPUT);
  pinMode(pin_I0, INPUT);

}

void loop() {
  bool I3 = digitalRead(pin_I3) == HIGH;
  bool I2 = digitalRead(pin_I2) == HIGH;
  bool I1 = digitalRead(pin_I1) == HIGH;
  bool I0 = digitalRead(pin_I0) == HIGH;

  bool O3 = (I3 && !I2 && I1) || (!I3 && I1 && !I0) || (!I3 && I2 && I0) || (I3 && !I2 && !I0) || (I3 && I2 && !I1);
  bool O2 = (!I3 && !I2 && !I1) || (!I3 && I1 && I0) || (I3 && !I1 && !I0) || (I3 && I2 && I0);
  bool O1 = (!I2 && I1 && !I0) || (!I3 && I2 && !I1) || (!I3 && I2 && I0) || (I3 && !I1 && I0);
```

```
  bool O0 = (!I2 && !I1 && I0) || (!I3 && I1 && !I0) || (!I3 && I1 && !I0) || (I3 && !I2 && !I1) || (I3 && !I1 && I0);

  digitalWrite(pin_O3, O3 ? HIGH : LOW);
  digitalWrite(pin_O2, O2 ? HIGH : LOW);
  digitalWrite(pin_O1, O1 ? HIGH : LOW);
  digitalWrite(pin_O0, O0 ? HIGH : LOW);

}
```

Appendix D: Resources

Hex Codes:

:100000000C9461000C9473000C9473000C947300B6
:100010000C9473000C9473000C9473000C94730094
:100020000C9473000C9473000C9473000C94730084
:100030000C9473000C9473000C9473000C94730074
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Logisim File:
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Proteus Files:
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