



North South University
Department of Electrical & Computer Engineering
Summer 2023
CSE331
Microprocessor Interfacing & Embedded System
Project Report

***‘Implementation of an Encryption Table Using
Micro controller’***

Faculty: Dr. Dihan Md. Nuruddin Hasan (DMH)

Section: 1

Group: 8

Project members:

Name	ID	RDS Section
Ferdous Reza Niloy	2021281042	1
Rafiduzzaman Niloy	1921723642	1
Md. Afjal Hossain Dali	2013652042	1
Sanjana Islam	2013337642	1
Afsara Waziha	2021235642	1
Faizul Islam Bhuiyan	2012878042	1

Table of Contents

1. Main Objective	3
2. General Description	4
2.1 Arduino UNO R3	4
2.2 Arduino Mega 2560	5
2.3 Arduino IDE	5
2.4 Proteus 8 Pro	6
2.5 Logisim	6
3. Equipment Used	7
4. Method of Derivation	8
4.1 Truth Table	8
4.2 Karnaugh Map	9
4.3 Derived Boolean Output Expression from Karnaugh Map	11
5. Circuit Diagram with Values of Electrical Components	11
5.1 Logisim Circuit	11
5.2 Proteus Circuit	12
6. Circuit Operation Principles	13
7. Program Flow Chart	15
8. Arduino Program	16
8.1 Arduino Program for both Arduino UNO R3 and Mega using Arduino Libraries:	16
8.2 Hex Code	18
8.2.1 Hex Codes generated for use on Arduino UNO R3	18
8.2.2 Hex Code generated for use on Arduino Mega 2560	21
9 Result Analysis and Comparison Among The Boards Used	25
9.1 Hardware Comparison Among Boards Used	25
9.2 Power Consumption Comparison	26
9.3 Memory Size and Execution Time Comparison	27
10 Conclusion	28
11 Questions and Answers	29
11.1 Arduino UNO	29
11.2 Arduino Mega 2560	30
12.References	32
13 Resources	32

1. Main Objective

The objective of this project was to create a 4-bit encryption system that masks the output using Boolean Expression. The encryption algorithm was derived from a Truth Table of inputs and its subsequent output. The 4-bit input would be fed into a micro controller which would then encrypt the output according to the Truth Table using Boolean logic expression and display it via 4 LED's to signify 4-bits. A total of 16 possible encryption combinations are possible using this 4-bit circuit: from a value of 0 to 15 (ranging from 0000 to 1111); for each of these combinations, the circuit's current is measured.

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. This is carried out for two different micro controller boards with various specifications and compare their differences of program size, memory occupied, and time taken to execute the program.

The HEX file of the programmed Arduino IDE code was then imported to a circuit schematic designed in Proteus for simulation of the complete system. A virtual terminal was also used to monitor the execution. The encryption system was implemented using two different boards in Proteus:

Arduino UNO which uses the ATmega328p micro controller and Arduino Mega 2560 which uses the ATmega2560 micro controller. Both boards implemented the encryption program in each type of programming to compare the differences of performance and memory to ensure the results are consistent and reliable.

2.General Description

2.1 Arduino UNO R3

Arduino UNO R3 is a micro controller board based on the ATmega328P micro controller. It has a 16 MHz ceramic resonator (CSTCE16M0V53-R0), 6 analog inputs, 14 digital input/output pins (of which 6 can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button. It has a clock frequency of 16 MHz, 32 KB of flash memory, and 2 KB of SRAM. The Arduino UNO R3 supports serial communication via USB and interfaces such as UART, SPI, and I2C

It can run programs coded with standard C/C++ libraries and headers created for Arduino on the Arduino IDE. It's simplicity to use, small form factor makes it a popular prototyping board.

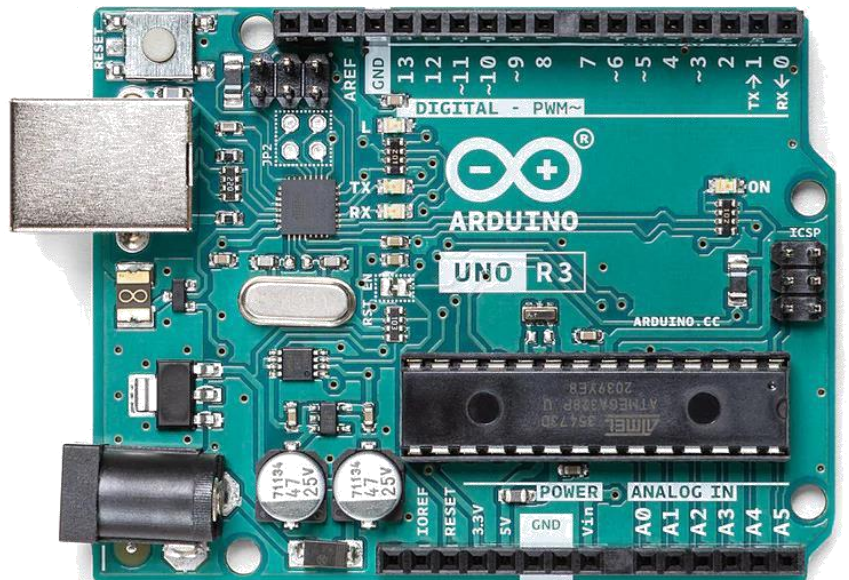


Figure : Arduino UNO Rev3

2.2 Arduino Mega 2560

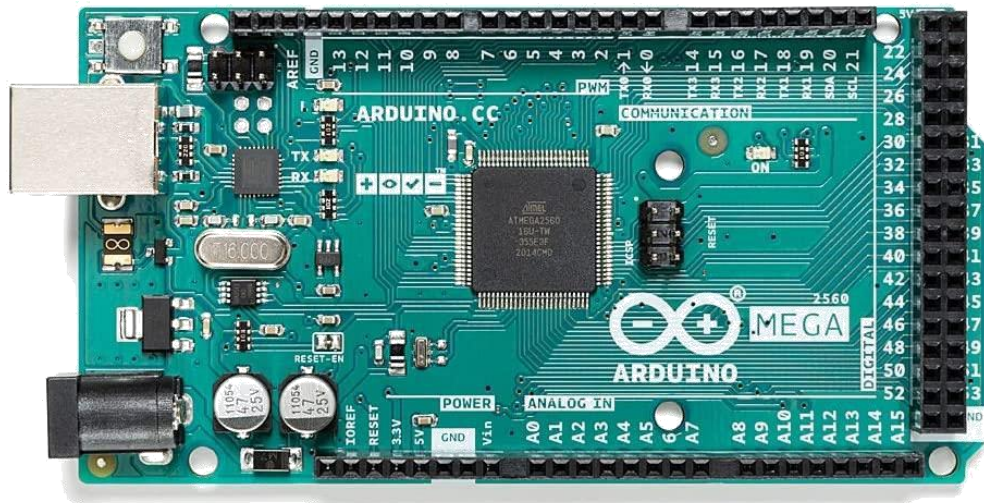


Figure : Arduino Mega 2560

The Arduino Mega 2560 is based on the Atmega2560 micro controller and is used for large projects that require high number of input and output ports. As such the Arduino Mega 2560 contains 54 digital IO pins and 16 analog pins. It also has 15 pins among the digital IO pins that supports PWM. Hence, it can support multiple components at a time to read and output values and data. The Arduino Mega 2560 supports serial communication via USB and interfaces such as UART, SPI, and I2C. To support this, it also contains 256 KB of memory to store large volumes of codes, and 8 KB of SRAM and 4 KB of EEPROM. This also owes to the boards large size. Like the Arduino UNO, the Arduino Mega 2560 has a clock frequency of 16 Mhz

2.3 Arduino IDE

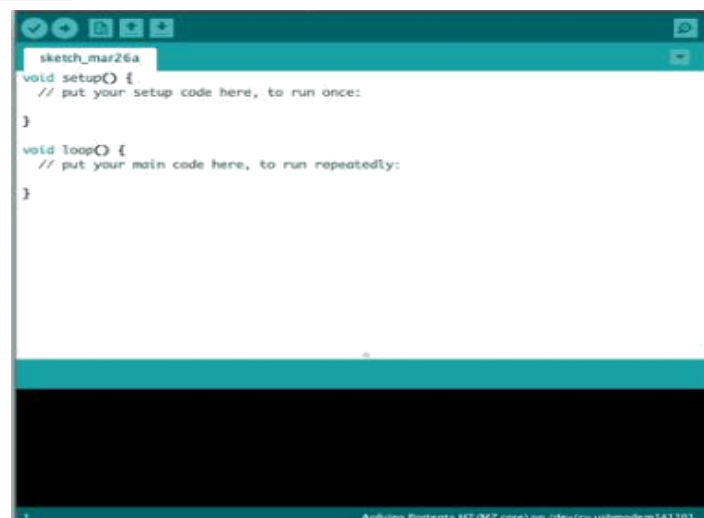


Figure : Arduino IDE

Arduino IDE is an integrated development environment that contains a text editor for writing code on C/C++ to program and develop projects on Arduino boards. The Arduino IDE is designed to be beginner-friendly and provides a simple way to write, compile, and upload code to Arduino boards. It contains a message area, a text console, a toolbar with buttons for common functions and a series of menus. Overall, the IDE provides a user-friendly interface for writing, compiling, and uploading codes to Arduino boards. It has set of libraries and functions that makes using the IDE and connecting code with the boards simple and easy.

Programs written on the Arduino IDE are called sketched and they are uploaded to the board via its upload feature with just one button click

2.4 Proteus 8 Pro

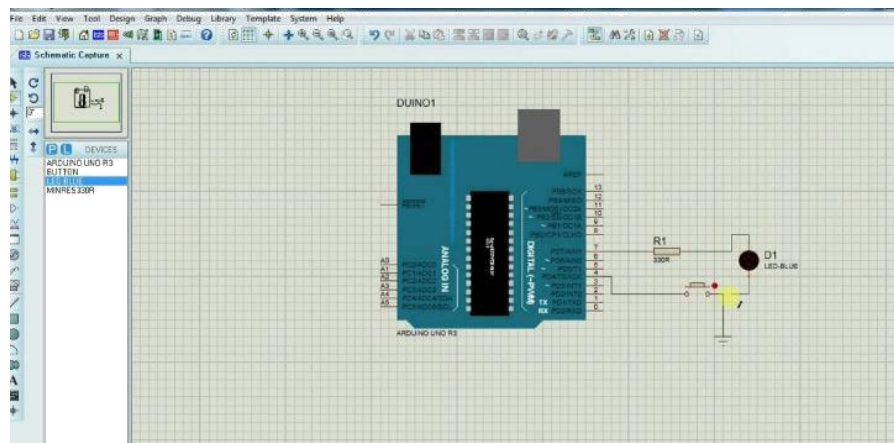


Figure : Proteus 8 Pro Interface

Proteus 8 Pro is a comprehensive and versatile tool for electronic circuit design, simulation, and PCB layout. Its intuitive interface, powerful simulation engine, and extensive component library make it a popular choice among electronics enthusiasts and professionals alike.

2.5 Logisim

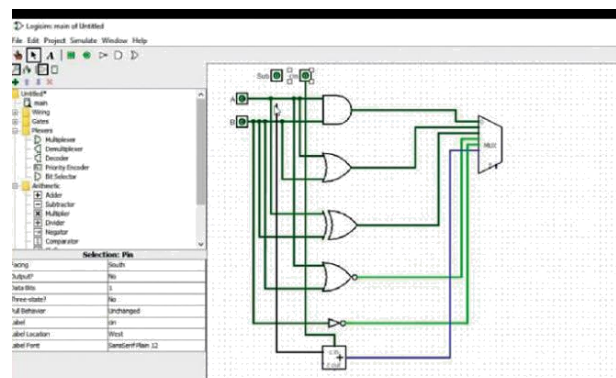


Figure : Logisim Interface

Logisim is an open-source program that assists in the design and simulation of logic circuits. The tool can be used to build both straightforward and intricate educational circuits and is intended for use in classrooms. The software contains a large collection of digital components that are widely used circuit design and simulation. It also has a user-friendly interface where components can be dragged and dropped and simulated in real time to see outputs and change inputs.

3.Equipment Used

•Single pole double throw switch:

It is an electrical switch that has one input terminal (pole) and can connect that terminal to one of two output terminals (throws).

•10 k Ω Resistor:

It is an electronic component that provides a resistance of 10,000 ohms to the flow of electric current.

•Red LED:

It is a semiconductor device that emits red light when an electric current is passed through it.

•Arduino UNO REV3:

It is a popular micro controller board that is widely used in electronics projects and prototyping. It is based on the ATmega328P micro controller and is part of the Arduino family of boards.

•Arduino Mega 2560:

It is a large and versatile micro controller board that has a larger flash memory and EEPROM than other Arduino boards. It is based on the ATmega2560 micro controller and provides similar functionality but in a larger form factor and capacity

4.Method of Derivation

4.1 Truth Table

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

4.2 Karnaugh Map



Figure : K map Derivation for O0

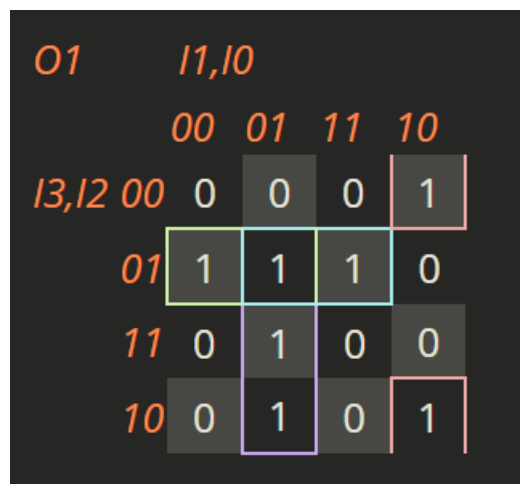


Figure : K map Derivation for O1

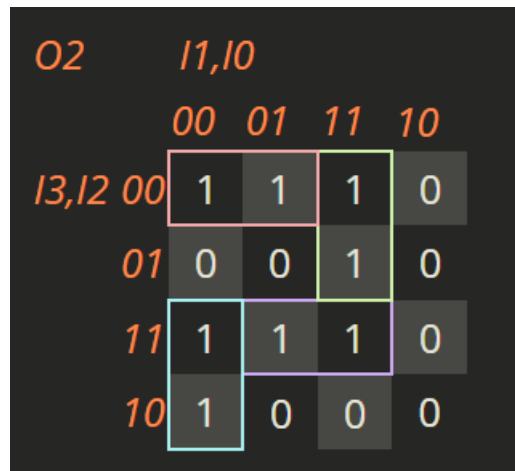


Figure : K map Derivation for O2



Figure : K map Derivation for O3

4.3 Derived Boolean Output Expression from Karnaugh Map

The Final Derived Expression for each output from the K maps is:

1. $O0(I3, I2, I1, I0) = I2' I1' I0 + I3' I1 I0' + I3 I2' I1' + I3 I1' I0$
2. $O1(I3, I2, I1, I0) = I2' I1 I0' + I3' I2 I1' + I3' I2 I0 + I3 I1' I0$
3. $O2(I3, I2, I1, I0) = I3' I2' I1' + I3' I1 I0 + I3 I1' I0' + I3 I2 I0$
4. $O3(I3, I2, I1, I0) = I3 I2' I1 + I3' I1 I0' + I3' I2 I0 + I3 I2' I0' + I3 I2 I1'$

5. Circuit Diagram with Values of Electrical Components

5.1 Logisim Circuit

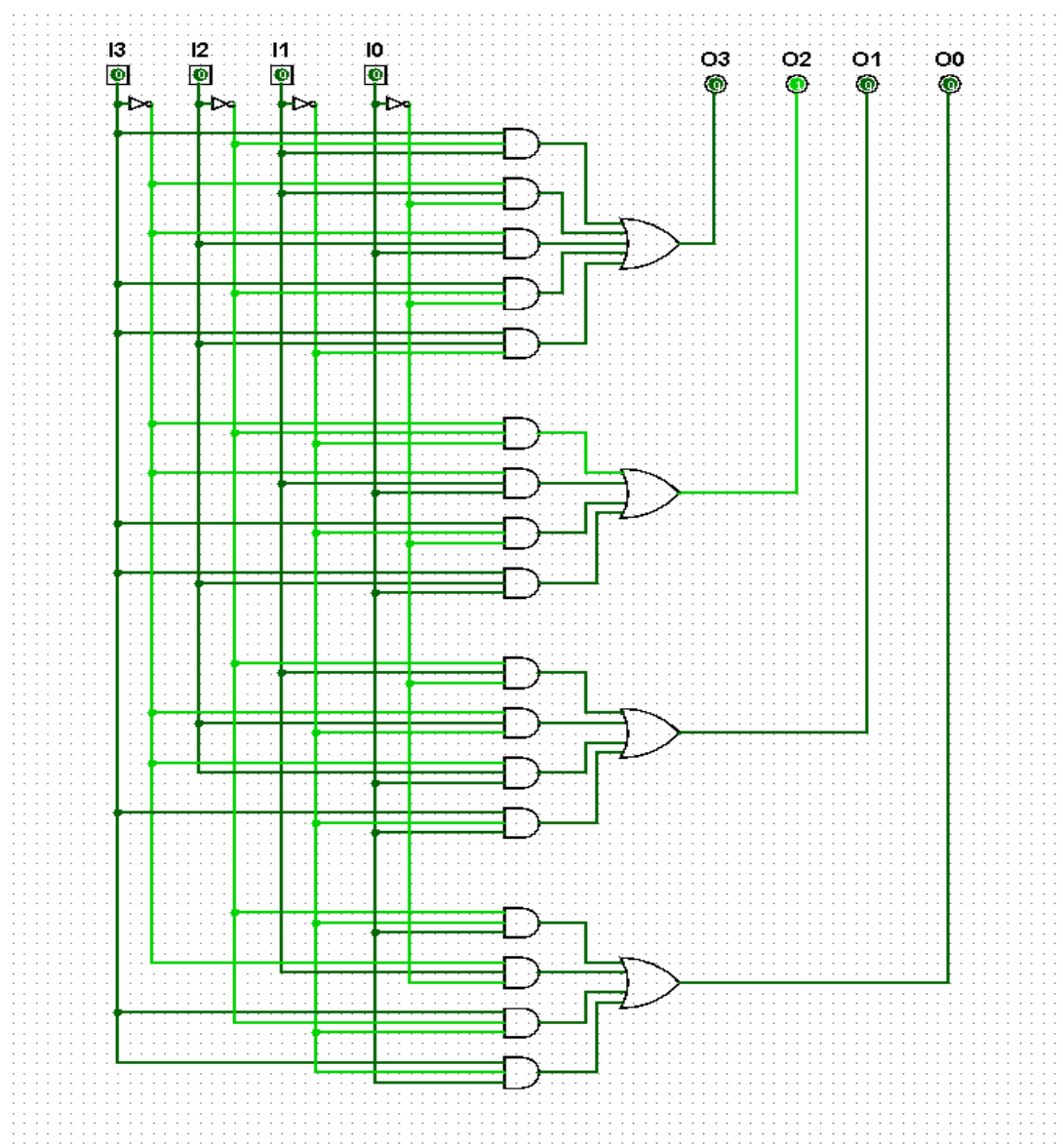


Figure : Logisim Simulation

5.2 Proteus Circuit

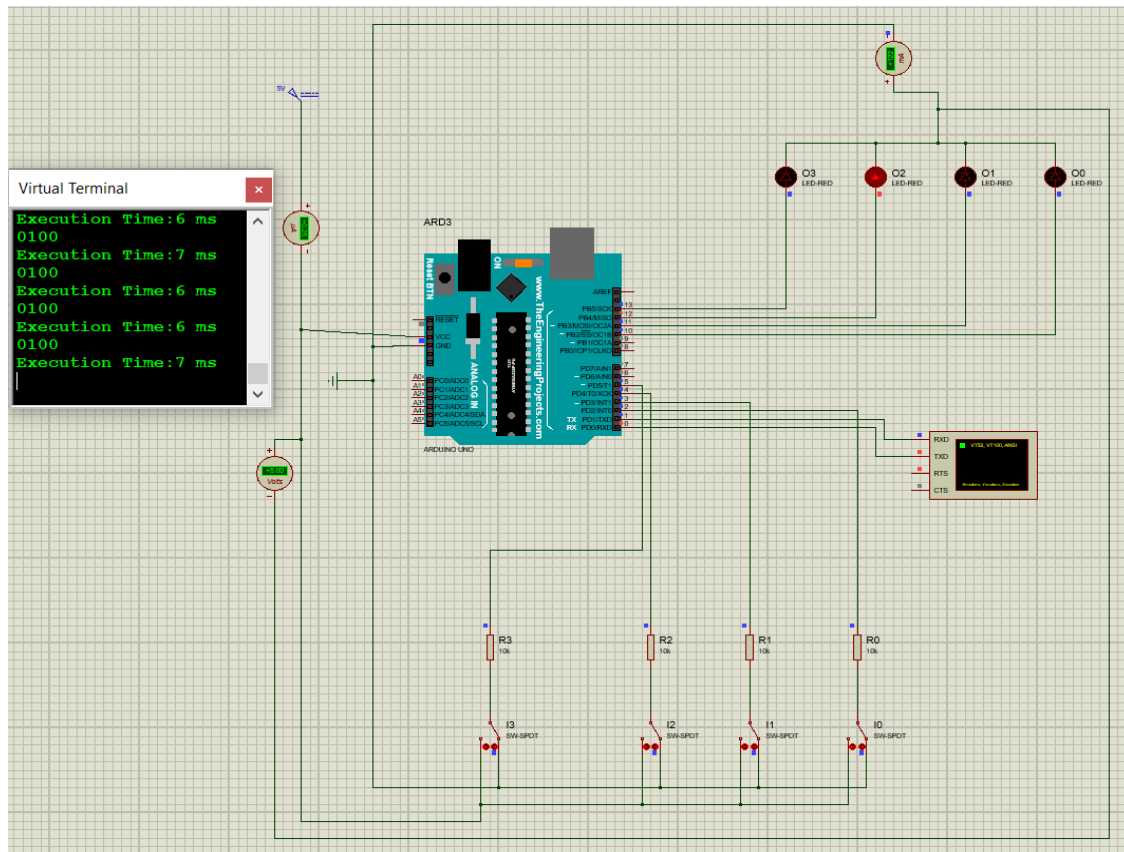


Figure : Proteus Simulation Demo for Arduino Uno

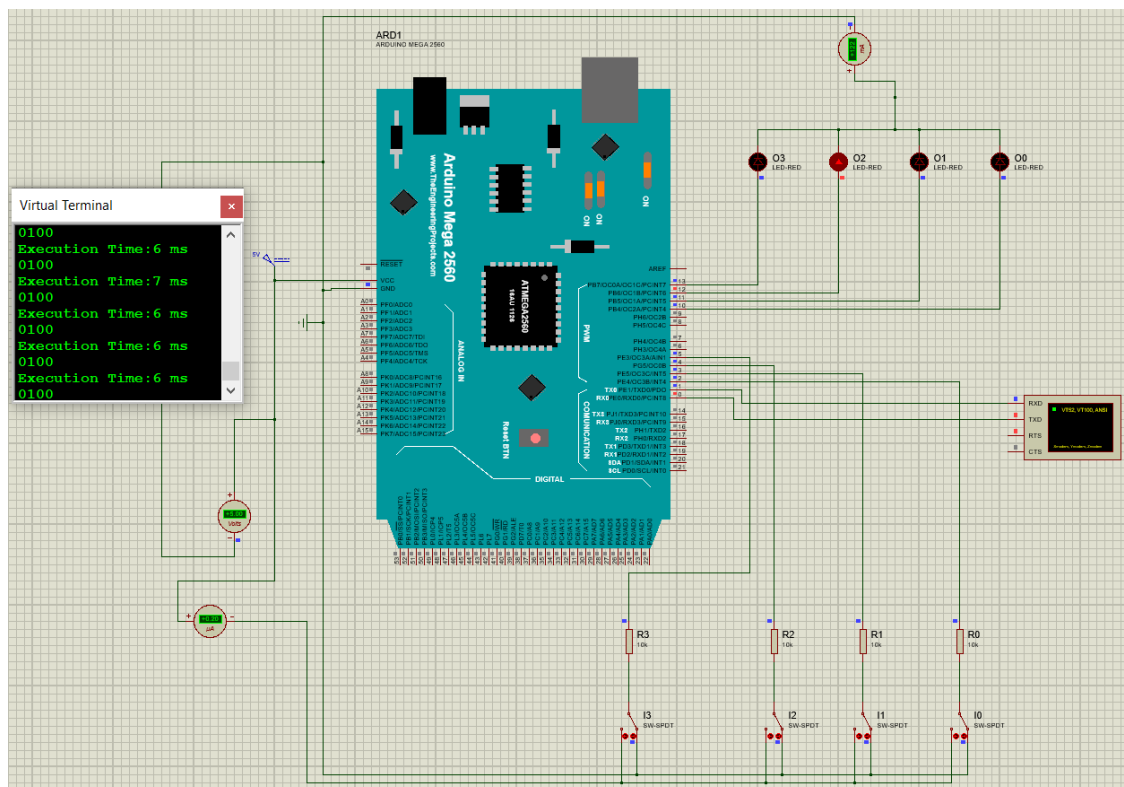


Figure : Proteus Simulation Demo for Arduino Mega 2560

6.Circuit Operation Principles

For our circuit operation the output equation from the Kmap is as follows:

$$\begin{aligned}O_0(I_3, I_2, I_1, I_0) &= I_2' I_1' I_0 + I_3' I_1 I_0' + I_3 I_2' I_1' + I_3 I_1' I_0 \\O_1(I_3, I_2, I_1, I_0) &= I_2' I_1 I_0' + I_3' I_2 I_1' + I_3' I_2 I_0 + I_3 I_1' I_0 \\O_2(I_3, I_2, I_1, I_0) &= I_3' I_2' I_1' + I_3' I_1 I_0 + I_3 I_1' I_0' + I_3 I_2 I_0 \\O_3(I_3, I_2, I_1, I_0) &= I_3 I_2' I_1 + I_3' I_1 I_0' + I_3' I_2 I_0 + I_3 I_2' I_0' + I_3 I_2 I_1'\end{aligned}$$

As a demo to test whether these expression is correct for our input bits, we designed a logic circuit on Logisim and simulated using four input and output bits and using the help AND, OR, and NOT gates to achieve the output equations.

Then, with the help of Proteus 8 Professional software, we built our main Hardware Circuit. We have used the following components:

Arduino Uno: We have used an Arduino Uno Model as our first board to test.

We will connect the Vcc pin of Arduino to a power supply of 5V. And we will connect the ground pin of the Arduino to a Ground component.

Arduino Mega: Used as the second board to test and compare. Connection of Vcc is same as with Arduino Uno.

Resistors: We have used a total of 4 resistors of 10k Ohms. These are connected with the SPDT switches.

Single Pole Double Throw Switches: We used four of these Switches with our Arduino Digital pins. They are arranged as follows:

Arduino UNO Digital Pin No. 2 ----- SPDT Switch I0
Arduino UNO Digital Pin No. 3 ----- SPDT Switch I1
Arduino UNO Digital Pin No. 4 ----- SPDT Switch I2
Arduino UNO Digital Pin No. 5 ----- SPDT Switch I3

The Resistors are connected in series with the pins and SPDT switches while the other pole of the switches is connected to the GND. Hence, one side of the switch acts as open while the other acts as closed and provides current flow and power to the pins.

LED's: We have connected Four LED's to the Digital Pins of Arduino to receive Output through those Pins. They are arranged in such way:

Arduino UNO Digital Pin No. 10 ----- LED O0

Arduino UNO Digital Pin No. 11 ----- LED O1

Arduino UNO Digital Pin No. 12 ----- LED O2

Arduino UNO Digital Pin No. 13 ----- LED O3

Finally, a Virtual Terminal is used to monitor the execution time to compare performance between Register Level Programming and C-programming. This execution time is analyzed in the Results Analysis section. The Hex file exported from Arduino IDE for both types of programming is imported on the board and simulated.

7. Program Flow Chart

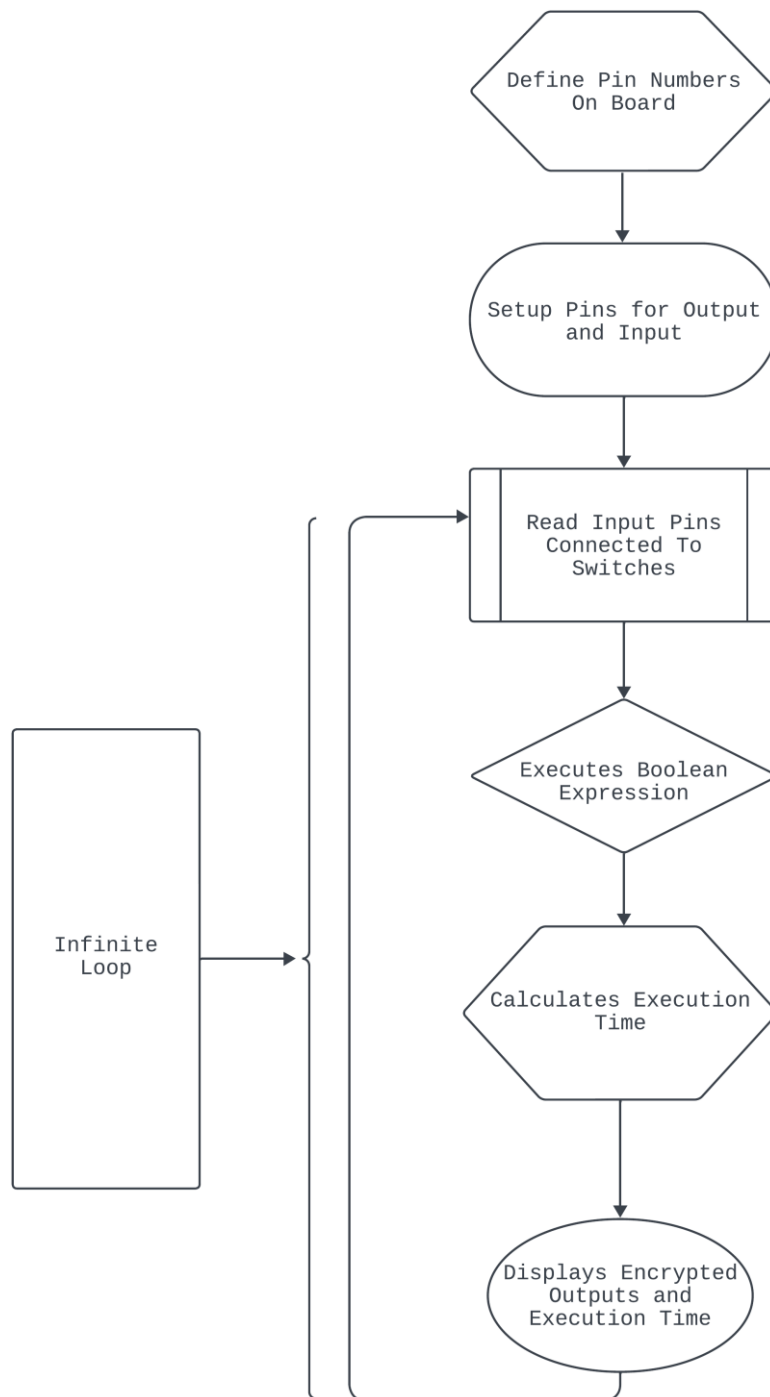


Figure : Program Loop Flowchart

8. Arduino Program

8.1 Arduino Program for both Arduino UNO R3 and Mega using Arduino Libraries

Arduino Code:

```
/// output LED variable declaration

int O0LED = 10; /// variable for O0 LED connected to pin 10
int O1LED = 11; /// variable for O1 LED connected to pin 11
int O2LED = 12; // variable for O2 LED connected to pin 12
int O3LED = 13; //variable for O3 LED connected to pin 13

/// switch input variable declaration

int I0Switch = 2; /// variable for switch O0 connected to pin 2
int I1Switch = 3; /// variable for switch O1 connected to pin 3
int I2Switch = 4; /// variable for switch O2 connected to pin 4
int I3Switch = 5; /// variable for switch O3 connected to pin 5

unsigned long startTime;
unsigned long endTime;

void setup()

{

    // sets Switches as input

    pinMode(I0Switch,INPUT);
    pinMode(I1Switch,INPUT);
    pinMode(I2Switch,INPUT);
    pinMode(I3Switch,INPUT);

    // sets LEDs as output

    pinMode(O0LED,OUTPUT);
    pinMode(O1LED,OUTPUT);
    pinMode(O2LED,OUTPUT);
    pinMode(O3LED,OUTPUT);

    Serial.begin(9600);
}
```



```

void loop()

{
    startTime = millis();

    boolean IOState = digitalRead(IOSwitch);
    boolean I1State = digitalRead(I1Switch);
    boolean I2State = digitalRead(I2Switch);
    boolean I3State = digitalRead(I3Switch);

    boolean O0State;
    boolean O1State;
    boolean O2State;
    boolean O3State;

    // Kmap Equation Logic

    O0State= (!I2State & !I1State & IOState)|(!I3State & I1State & !IOState)|(I3State & !I2State
        & !I1State)|(I3State & !I1State & IOState);

    O1State= (!I2State & I1State & !IOState)|(!I3State & I2State & !I1State)|(!I3State & I2State
        & IOState)|(I3State & !I1State & IOState);

    O2State= (!I3State & !I2State & !I1State)|(!I3State & I1State & IOState)|(I3State & !I1State
        & !IOState)|(I3State & I2State & IOState);

    O3State= (I3State & !I2State & I1State )|(!I3State & I1State & !IOState)|(!I3State & I2State
        & IOState)|(I3State & !I2State& !IOState)|(I3State & I2State & !I1State);

    digitalWrite(O0LED,O0State);
    digitalWrite(O1LED,O1State);
    digitalWrite(O2LED,O2State);
    digitalWrite(O3LED,O3State);

    Serial.print(O3State);
    Serial.print(O2State);
    Serial.print(O1State);
    Serial.println(O0State);
    endTime = millis();
    Serial.print("Execution Time:");
    Serial.print(endTime-startTime);
    Serial.println(" ms");

}

```

8.2.Hex Code

8.2.1 Hex Codes generated for use on Arduino UNO R3

Arduino Library and C programming Hex Code:

```
:100000000C9462000C948A000C948A000C948A0070
:100010000C948A000C948A000C948A000C948A0038
:100020000C948A000C948A000C948A000C948A0028
:100030000C948A000C948A000C948A000C948A0018
:100040000C94C3020C948A000C9433030C940D039B
:100050000C948A000C948A000C948A000C948A00F8
:100060000C948A000C948A00000000024002700F1
:100070002A0000000000250028002B0000000000DE
:10008000230026002900040404040404040202DA
:100090000202020203030303030301020408102007
:1000A0004080010204081020010204081020000012
:1000B0000008000201000003040700000000000027
:1000C00000000E50411241FBECFEFD8E0DEBFCDBF96
:1000D00011E0A0E0B1E0E8E7FAE002C005900D927F
:1000E000AA32B107D9F721E0AAE2B1E001C01D921E
:1000F000A83DB207E1F710E0C2E6D0E004C02197C6
:10010000FE010E943405C136D107C9F70E9465037C
:100110000C943A050C940000833081F028F481306F
:1001200099F08230A9F008958730A9F08830C9F09D
:100130008430B1F4809180008F7D03C08091800075
:100140008F7780938000089584B58F7784BD08955C
:1001500084B58F7DFBCF8091B0008F778093B00006
:1001600008958091B0008F7DF9CFCF93DF93282F32
:1001700030E0F901E255FF4F8491F901E656FF4F57
:10018000D491F901EA57FF4FC491CC23A1F081111A
:100190000E948C00EC2FF0E0EE0FFF1FE458FF4FA1
:1001A000A591B491EC91ED2381E090E009F480E019
:1001B000DF91CF91089580E090E0FACF1F93CF9325
:1001C000DF93282F30E0F901E255FF4F8491F901C8
:1001D000E656FF4FD491F901EA57FF4FC491CC2363
:1001E000A9F0162F81110E948C00EC2FF0E0EE0F89
:1001F000FF1FEE58FF4FA591B4918FB7F894EC9183
:10020000111108C0D095DE23DC938FBFDF91CF9111
:100210001F910895DE2BF8CFCF93DF9390E0FC0180
:10022000E656FF4F24918A579F4FFC018491882303
:10023000D1F090E0880F991FFC01E859FF4FA5917C
:10024000B491FC01EE58FF4FC591D49161110EC0DD
:100250009FB7F8948C91E22FE0958E238C932881A0
:10026000E223E8839FBFDF91CF9108958FB7F89481
:10027000EC91E22BEC938FBFF6CFAF92BF92CF926F
:10028000DF92EF92FF920F931F93CF93DF936C0156
:100290007B018B01040F151FEB015E01AE18BF0837
:1002A000C017D10759F06991D601ED91FC910190E9
```

:1002B000F081E02DC6010995892B79F7C501DF9101
:1002C000CF911F910F91FF90EF90DF90CF90BF9053
:1002D000AF900895FC01538D448D252F30E0842F7D
:1002E00090E0821B930B541710F0CF96089501975E
:1002F0000895FC01918D828D981761F0A28DAE0F4B
:10030000BF2FB11D5D968C91928D9F5F9F73928FD1
:1003100090E008958FEF9FEF0895FC01918D828DFD
:10032000981731F0828DE80FF11D858D90E00895CA
:100330008FEF9FEF0895FC01918D228D892F90E022
:10034000805C9F4F821B91098F73992708958BE3DF
:1003500091E00E949B0121E0892B09F420E0822F8B
:10036000089580E090E0892B29F00E94A701811177
:100370000C9400000895FC01A48DA80FB92FB11DA5
:10038000A35ABF4F2C91848D90E001968F739927CB
:10039000848FA689B7892C93A089B1898C918370A9
:1003A00080648C93938D848D981306C00288F389A2
:1003B000E02D80818F7D80830895EF92FF920F93CF
:1003C0001F93CF93DF93EC0181E0888F9B8D8C8D01
:1003D00098131AC0E889F989808185FF15C09FB7F5
:1003E000F894EE89FF896083E889F98980818370B8
:1003F000806480839FBF81E090E0DF91CF911F9167
:100400000F91FF90EF900895F62E0B8D10E00F5F87
:100410001F4F0F731127E02E8C8D8E110CC00FB65D
:1004200007FCFACFE889F989808185FFF5CFCE01F5
:100430000E94BB01F1CFEB8DEC0FFD2FF11DE35AB4
:10044000FF4FF0829FB7F8940B8FEA89FB89808178
:100450008062CFCFCF93DF93EC01888D8823B9F0F2
:10046000AA89BB89E889F9898C9185FD03C08081BF
:1004700086FD0DC00FB607FCF7CF8C9185FFF2CF3C
:10048000808185FFEDCFCE010E94BB01E9CFDF91D6
:10049000CF910895FC0101900020E9F73197AF0159
:1004A000481B590BBC018BE391E00C943D018F92EA
:1004B0009F92AF92BF920F931F93CF93DF93CDB7CD
:1004C000DEB7A1970FB6F894DEBF0FBECDBF19A25D
:1004D000423008F44AE08E010F5D1F4F842E912CAC
:1004E000B12CA12CA50194010E941205E62FB9019F
:1004F000CA01EA30F4F4E05DD801EE938D01232BBC
:10050000242B252B79F790E080E0109719F0CD018E
:100510000E944A02A1960FB6F894DEBF0FBECDBF6F
:10052000DF91CF911F910F91BF90AF909F908F90CF
:100530000895E95CE1CFCF92DF92EF92FF92CF93E3
:10054000DF936B017C016DE28BE391E00E94DD01A2
:10055000EC0166277727CB016C197D098E099F096D
:100560004AE00E9457028C0F9D1FDF91CF91FF90B0
:10057000EF90DF90CF900895BC01990F880B990BF5
:100580004AE00C9457021F920F920FB60F9211245B
:100590002F933F938F939F93AF93BF938091370196
:1005A00090913801A0913901B0913A013091360112
:1005B00023E0230F2D3758F50196A11DB11D20937F
:1005C00036018093370190933801A0933901B0939D
:1005D0003A018091320190913301A0913401B091A0
:1005E00035010196A11DB11D809332019093330115
:1005F000A0933401B0933501BF91AF919F918F913A
:100600003F912F910F900FBE0F901F90189526E8E5
:10061000230F0296A11DB11DD2CF1F920F920FB6CC

:100620000F9211242F933F934F935F936F937F9378
:100630008F939F93AF93BF93EF93FF938BE391E0DF
:100640000E94BB01FF91EF91BF91AF919F918F915C
:100650007F916F915F914F913F912F910F900FBEBE
:100660000F901F9018951F920F920FB60F921124A2
:100670002F938F939F93EF93FF93E0914B01F09112
:100680004C018081E0915101F091520182FD1BC02B
:100690009081809154018F5F8F7320915501821753
:1006A00041F0E0915401F0E0E55CFE4F958F8093BE
:1006B0005401FF91EF919F918F912F910F900FBE59
:1006C0000F901F9018958081F4CF789484B5826044
:1006D00084BD84B5816084BD85B5826085BD85B5E6
:1006E000816085BD80916E00816080936E00109264
:1006F00081008091810082608093810080918100DF
:10070000816080938100809180008160809380006F
:100710008091B10084608093B1008091B0008160CD
:100720008093B00080917A00846080937A008091F9
:100730007A00826080937A0080917A008160809351
:100740007A0080917A00806880937A001092C100CC
:1007500060E082E00E940C0160E083E00E940C01F6
:1007600060E084E00E940C0160E085E00E940C01E2
:1007700061E08AE00E940C0161E08BE00E940C01C4
:1007800061E08CE00E940C0161E08DE00E940C01B0
:10079000E0914B01F0914C0182E08083E0914701B0
:1007A000F09148011082E0914901F0914A018FECB
:1007B000808310925301E0914F01F091500186E047
:1007C0008083E0914D01F0914E01808180618083B2
:1007D000E0914D01F0914E01808188608083E0912D
:1007E0004D01F0914E01808180688083E0914D0140
:1007F000F0914E0180818F7D808300E010E02FB763
:10080000F8948091370190913801A0913901B0910D
:100810003A012FBF80932E0190932F01A0933001B6
:10082000B093310182E00E94B5004C01FF24F394A3
:10083000892B09F4F12C83E00E94B5005C01C1E032
:10084000892B09F4C0E084E00E94B5006C01EE241D
:10085000E394892B09F4E12C85E00E94B500AC01FA
:1008600071E0892B09F470E0D1E0C114D10409F0E2
:10087000D0E031E0A114B10409F030E0AC28BD288B
:1008800081E04115510509F080E0AC2FA823E1E09B
:10089000892809F0E0E09A2F9E23F72FFD23B72F38
:1008A000B323CF2CCB2261E0A114B10409F060E0A6
:1008B000D62EDF20D92A632F6F23D62ADC288E215B
:1008C0006F2D6823DC23DE23DC298323D82BD62B52
:1008D000E722A42AB52A21E0AB2809F020E0AF21C5
:1008E0002A2BBE23B22BFE20FB2A962BCF23C92B0B
:1008F000EF23CE2B3E21C32B6D2D8AE00E94DE001C
:100900006D2F8BE00E94DE006F2D8CE00E94DE00D8
:100910006C2F8DE00E94DE008C2F90E00E94BC02C4
:100920008F2D90E00E94BC028D2F90E00E94BC02AF
:100930006D2D70E090E080E04AE00E94570282E175
:1009400091E00E944A022FB7F8948091370190916C
:100950003801A0913901B0913A012FBF80932A014B
:1009600090932B01A0932C01B0932D0185E191E090
:100970000E944A0260912A0170912B0180912C0102
:1009800090912D01C0902E01D0902F01E090300168

:10099000F09031016C197D098E099F094AE00E948F
:1009A000570285E291E00E944A0282E191E00E94B2
:1009B0004A020115110509F422CF0E94A7018823DC
:1009C00009F41DCF0E9400001ACFEBE3F1E013827F
:1009D000128288EE93E0A0E0B0E084839583A68342
:1009E000B78384E091E09183808385EC90E09587E4
:1009F000848784EC90E09787868780EC90E0918BE9
:100A0000808B81EC90E0938B828B82EC90E0958BD5
:100A1000848B86EC90E0978B868B118E128E138ED2
:100A2000148E0895A1E21A2EAA1BBB1BFD010DC056
:100A3000AA1FBB1FEE1FFF1FA217B307E407F5078E
:100A400020F0A21BB30BE40BF50B661F771F881F6A
:100A5000991F1A9469F760957095809590959B0100
:100A6000AC01BD01CF010895EE0FFF1F0590F49179
:080A7000E02D0994F894FFCF7A
:100A780000000000DD013D016A012A029B017901A5
:100A88008D010D0A00457865637574696F6E205491
:0A0A9800696D653A00206D730000DF
:00000001FF

8.2.2 Hex Code generated for use on Arduino Mega 2560

Arduino Library and C programming Hex Code:

:100000000C9435010C9466010C9466010C94660105
:100010000C9466010C9466010C9466010C946601C4
:100020000C9466010C9466010C9466010C946601B4
:100030000C9466010C9466010C9466010C946601A4
:100040000C9466010C9466010C9466010C94660194
:100050000C9466010C9466010C9466010C940404E3
:100060000C9466010C9478040C944E040C94660174
:100070000C9466010C9466010C9466010C94660164
:100080000C9466010C9466010C9466010C94660154
:100090000C9466010C9466010C9466010C94660144
:1000A0000C9466010C9466010C9466010C94660134
:1000B0000C9466010C9466010C9466010C94660124
:1000C0000C9466010C9466010C9466010C94660114
:1000D0000C9466010C9466010C9466010C94660104
:1000E0000C9466010C94A7020C94C6010C94AF0109
:1000F0000C94C1010C94AB010C94B5020C94ED026C
:100100000C94B3010C9450060C94A1010C94C701FB
:100110000C9493020C94B9010C943A030C9484024D
:100120000C94CB010C9494010C9490010C949B01C1
:100130000C94A5010C9498010C94BD010C948601BB
:100140000C9457020C948C0100002100240027001D
:100150002A002D00300033000101000004010701D6
:100160000A0100002200250028002B002E0031008B
:10017000340002010000050108010B01000020000D
:100180002300260029002C002F003200000100006F
:10019000030106010901050505050705080808080A
:1001A000020202020A0A080804040404010101010F
:1001B000010101010303030303030303040707070A
:1001C0000C0C0C0C0C0C0C0C0C0C0202020206060606AF
:1001D000060606060B0B0B0B0B0B0B0B0B0B010210207C
:1001E000200808102040102040800201020108046D

:1001F0000201010204081020408080402010080401
:100200000201800402018040201008040201080459
:10021000020101020408102040800102040810209D
:10022000408000000A0B02090C0D0E0807030401B0
:1002300000000000000000000000000000000000BE
:100240000000000000000000000000000000000012118B
:10025000100000000000000000000000000000000008E
:10026000000000000000000000000500611241FBECFEF68
:10027000D1E2DEBFCDBF00E00CBF12E0A0E0B2E0F3
:10028000E2E5FDE000E00BBF02C007900D92AA324C
:10029000B107D9F722E0AAE2B2E001C01D92A83D61
:1002A000B207E1F711E0C5E3D1E000E006C0219715
:1002B0000109802FFE010E949F06C433D10780E010
:1002C0000807A9F70E94AE040C94A7060C9400003E
:1002D0008150823108F05AC0E82FF0E08827EC58AE
:1002E000FE4F8F4F0C949F069401980186018C015C
:1002F0009001C6019B01A101A501AB01AF01B301B2
:10030000B901BD01C601C101C701CB0180918000C7
:100310008F77809380000895809180008F7DF9CF42
:1003200080918000877FF5CF84B58F7784BD089555
:1003300084B58F7DFBCF8091B0008F778093B00024
:1003400008958091B0008F7DF9CF809190008F77D4
:10035000809390000895809190008F7DF9CF8091D7
:100360009000877FF5CF8091A0008F778093A000C9
:1003700008958091A0008F7DF9CF8091A000877FA4
:10038000F5CF809120018F7780932001089580918F
:1003900020018F7DF9CF80912001877FF5CFCF930A
:1003A000DF93282F30E0F901EE5DFD4F8491F901D4
:1003B000E452FE4FD491F901EA56FE4FC491CC238A
:1003C000A1F081110E946801EC2FF0E0EE0FFF1FF9
:1003D000E458FE4FA591B491EC91ED2381E090E0BB
:1003E00009F480E0DF91CF91089580E090E0FACFAA
:1003F0001F93CF93DF93282F30E0F901EE5DFD4F7F
:100400008491F901E452FE4FD491F901EA56FE4F6E
:10041000C491CC23A9F0162F81110E946801EC2F02
:10042000F0E0EE0FFF1FEE59FE4FA591B4918FB78C
:10043000F894EC91111108C0D095DE23DC938FBFA6
:10044000DF91CF911F910895DE2BF8CFCF93DF93EB
:1004500090E0FC01E452FE4F24918A569E4FFC012D
:1004600084918823D1F090E0880F991FFC01E85B0C
:10047000FE4FA591B491FC01EE59FE4FC591D49168
:1004800061110EC09FB7F8948C91E22FE0958E23F6
:100490008C932881E223E8839FBFDF91CF91089559
:1004A0008FB7F894EC91E22BEC938FBFF6CFAF921D
:1004B000BF92CF92DF92EF92FF920F931F93CF9351
:1004C000DF936C017B018B01040F151FEB015E01B3
:1004D000AE18BF08C017D10759F06991D601ED9148
:1004E000FC910190F081E02DC6011995892B79F7D7
:1004F000C501DF91CF911F910F91FF90EF90DF9099
:10050000CF90BF90AF900895FC01538D448D252F5F
:1005100030E0842F90E0821B930B541710F0CF969D
:10052000089501970895FC01918D828D981761F0CF
:10053000A28DAE0FBF2FB11D5D968C91928D9F5FE6
:100540009F73928F90E008958FEF9FEF0895FC01C5
:10055000918D828D981731F0828DE80FF11D858D78

:1005600090E008958FEF9FEF0895FC01918D228D0B
:10057000892F90E0805C9F4F821B91098F73992790
:100580008958BE392E00E94B50221E0892B09F4E3
:1005900020E0822F0895FC01A48DA80FB92FB11D72
:1005A000A35ABF4F2C91848D90E001968F739927A9
:1005B000848FA689B7892C93A089B1898C91837087
:1005C00080648C93938D848D981306C00288F38980
:1005D000E02D80818F7D80830895EF92FF920F93AD
:1005E0001F93CF93DF93EC0181E0888F9B8D8C8DDF
:1005F00098131AC0E889F989808185FF15C09FB7D3
:10060000F894EE89FF896083E889F9898081837095
:10061000806480839FBF81E090E0DF91CF911F9144
:100620000F91FF90EF900895F62E0B8D10E00F5F65
:100630001F4F0F731127E02E8C8D8E110CC00FB63B
:1006400007FCFACFE889F989808185FFF5CFCE01D3
:100650000E94CB02F1CFEB8DEC0FFD2FF11DE35A81
:10066000FF4FF0829FB7F8940B8FEA89FB89808156
:100670008062CFCFCF93DF93EC01888D8823B9F0D0
:10068000AA89BB89E889F9898C9185FD03C080819D
:1006900086FD0DC00FB607FCF7CF8C9185FFF2CF1A
:1006A000808185FFEDCFCE010E94CB02E9CFDF91A3
:1006B000CF91089580E090E0892B29F00E94C1023B
:1006C00081110E94000080E090E0892B49F080E0D9
:1006D00090E0892B29F00E94000081110E94000007
:1006E00080E090E0892B49F080E090E0892B29F0B0
:1006F0000E94000081110E94000080E090E0892BA0
:1007000049F080E090E0892B29F00E9400008111DF
:100710000C9400000895FC0101900020E9F7319746
:10072000AF01481B590BBC018BE392E00C945702BC
:100730008F929F92AF92BF920F931F93CF93DF93AD
:10074000CDB7DEB7A1970FB6F894DEBF0FBECDBF11
:1007500019A2423008F44AE08E010F5D1F4F842E2B
:10076000912CB12CA12CA50194010E947D06E62FAD
:10077000B901CA01EA30F4F4E05DD801EE938D01CD
:10078000232B242B252B79F790E080E0109719F08C
:10079000CD010E948B03A1960FB6F894DEBF0FBE69
:1007A000CDBFDF91CF911F910F91BF90AF909F90E0
:1007B0008F900895E95CE1CFCF92DF92EF92FF92A4
:1007C000CF93DF936B017C016DE28BE392E00E949B
:1007D000ED02EC0166277727CB016C197D098E09A4
:1007E0009F094AE00E9498038C0F9D1FDF91CF91D3
:1007F000FF90EF90DF90CF900895BC01990F880B88
:10080000990B4AE00C9498031F920F920FB60F9227
:1008100011242F933F938F939F93AF93BF93809116
:10082000370290913802A0913902B0913A0230918A
:10083000360223E0230F2D3758F50196A11DB11D77
:10084000209336028093370290933802A0933902A6
:10085000B0933A028091320290913302A091340217
:10086000B09135020196A11DB11D80933202909383
:100870003302A0933402B0933502BF91AF919F91A0
:100880008F913F912F910F900FBE0F901F90189551
:1008900026E8230F0296A11DB11DD2CF1F920F9201
:1008A0000FB60F9211240BB60F922F933F934F93D5
:1008B0005F936F937F938F939F93AF93BF93EF93C8
:1008C000FF938BE392E00E94CB02FF91EF91BF91E7

:1008D000AF919F918F917F916F915F914F913F91D8
:1008E0002F910F900BBE0F900FBE0F901F90189579
:1008F0001F920F920FB60F9211240BB60F922F93E7
:100900008F939F93EF93FF93E0914B02F0914C02F2
:100910008081E0915102F091520282FD1DC09081D0
:10092000809154028F5F8F7320915502821741F09E
:10093000E0915402F0E0E55CFD4F958F8093540206
:10094000FF91EF919F918F912F910F900BBE0F9080
:100950000FBE0F901F9018958081F2CF789484B5C8
:10096000826084BD84B5816084BD85B5826085BDAB
:1009700085B5816085BD80916E00816080936E0039
:10098000109281008091810082608093810080912B
:1009900081008160809381008091800081608093DC
:1009A00080008091B10084608093B1008091B0009C
:1009B00081608093B000809191008260809391006B
:1009C000809191008160809391008091900081607E
:1009D000809390008091A10082608093A10080911B
:1009E000A10081608093A1008091A000816080932C
:1009F000A0008091210182608093210180912101DA
:100A00008160809321018091200181608093200189
:100A100080917A00846080937A0080917A0082606D
:100A200080937A0080917A00816080937A0080912F
:100A30007A00806880937A001092C10060E082E0C2
:100A40000E94260260E083E00E94260260E084E0CB
:100A50000E94260260E085E00E94260261E08AE0B2
:100A60000E94260261E08BE00E94260261E08CE099
:100A70000E94260261E08DE00E942602E0914B0276
:100A8000F0914C0282E08083E0914702F0914802AD
:100A90001082E0914902F0914A028FEC808310921B
:100AA0005302E0914F02F091500286E08083E09182
:100AB0004D02F0914E02808180618083E0914D0271
:100AC000F0914E02808188608083E0914D02F09128
:100AD0004E02808180688083E0914D02F0914E0249
:100AE00080818F7D80832FB7F89480913702909119
:100AF0003802A0913902B0913A022FBF80932E02A2
:100B000090932F02A0933002B093310282E00E94B2
:100B1000CF015C0111E0892B09F410E083E00E9411
:100B2000CF016C0101E0892B09F400E084E00E9410
:100B3000CF017C0199249394892B09F4912C85E0B1
:100B40000E94CF01AC01F1E0892B09F4F0E0D1E083
:100B5000E114F10409F0D0E031E0C114D10409F04E
:100B600030E0CE28DF2881E04115510509F080E012
:100B7000A02FA82371E0AB2809F070E09A2F9723EB
:100B8000EF2FED23BF2FB323E12EEB2261E0C11441
:100B9000D10409F060E0F62EF122F92A632F6E23CA
:100BA000F62AFE288921C12FC823D023D723DE2986
:100BB0008323D82BDC2B9F22C42AD52A21E0CD28E1
:100BC00009F020E0A1232A2BB7232B2B1921122B6C
:100BD0009C2BC02FCE23C92B7E23C72B3921C32B9F
:100BE0006F2D8AE00E94F8016D2F8BE00E94F801C2
:100BF000612F8CE00E94F8016C2F8DE00E94F801BB
:100C00008C2F90E00E94FD03812F90E00E94FD0355
:100C10008D2F90E00E94FD036F2D70E090E080E04A
:100C20004AE00E94980382E192E00E948B032FB772
:100C3000F8948091370290913802A0913902B091D6


```

:100C40003A022FBF80932A0290932B02A0932C028A
:100C5000B0932D0285E192E00E948B0360912A02FD
:100C600070912B0280912C0290912D0200912E0206
:100C700010912F022091300230913102601B710BD4
:100C8000820B930B4AE00E94980385E292E00E9457
:100C90008B0382E192E00E948B030E945A0323CFD0
:100CA000EBE3F2E01382128288EE93E0A0E0B0E082
:100CB00084839583A683B78384E092E091838083C5
:100CC00085EC90E09587848784EC90E09787868711
:100CD00080EC90E0918B808B81EC90E0938B828B09
:100CE00082EC90E0958B848B86EC90E0978B868BE2
:100CF000118E128E138E148E0895A1E21A2EAA1B45
:100D0000BB1BFD010DC0AA1FBB1FEE1FFF1FA217BB
:100D1000B307E407F50720F0A21BB30BE40BF50BB8
:100D2000661F771F881F991F1A9469F76095709541
:100D3000809590959B01AC01BD01CF010895EE0F08
:100D4000FF1F881F8BBF0790F691E02D1994F89430
:020D5000FFCFD3
:100D520000000000ED02570284023A03B50293023A
:100D6200A7020D0A00457865637574696F6E205499
:0A0D7200696D653A00206D73000002
:00000001FF

```

9.Result Analysis and Comparison Among The Boards Used

9.1 Hardware Comparison Among Boards Used

Hardware Specifications	Arduino Uno R3	Arduino Mega 2560
Micro controller Used	ATmega328p	ATmega2560
Flash Memory	32 KB	256KB
EEPROM	1 KB	4KB
Clock Frequency	16 MHz	16 MHz
PWM pins	6	15
Analog Pins	6	16
Digital Pins	14	54
SRAM	2 KB	8 KB
Power	5V	5V

Table : Hardware Specification of Arduino UNO R3 and Arduino Mega 2560

9.2 Power Consumption Comparison:

InPut Bits	OutPut Bits	Current (mA)	Voltage (V)	Power (mW)
0000	0100	365	5	1825
1000	1101	365	5	1825
0100	0010	243	5	1215
1100	1100	243	5	1215
0010	1011	243	5	1215
1010	1011	122	5	610
0110	1001	243	5	1215
1110	0000	243	5	1215
0001	0101	243	5	1215
1001	0011	243	5	1215
0101	1010	243	5	1215
1101	1111	122	5	610
0011	0100	365	5	1825
1011	1000	243	5	1215
0111	1110	356	5	1825
1111	0100	122	5	610

Table:Current Voltage and Power use for **Arduino UNO R3**

InPut Bits	OutPut Bits	Current (mA)	Voltage (V)	Power (mW)
0000	0100	365	5	1825
1000	1101	365	5	1825
0100	0010	243	5	1215
1100	1100	243	5	1215
0010	1011	243	5	1215
1010	1011	122	5	610
0110	1001	243	5	1215
1110	0000	243	5	1215
0001	0101	243	5	1215
1001	0011	243	5	1215
0101	1010	243	5	1215
1101	1111	122	5	610
0011	0100	365	5	1825
1011	1000	243	5	1215
0111	1110	356	5	1825
1111	0100	122	5	610

Table: Current Voltage and Power use for **Arduino Mega 2560**

Both Arduino UNO R3 and Mega show the same current draw, voltage, and Power consumption since both use the same number of components and resistors connected to it and both have same 5V power input via DC Generator. Increasing supplied power increases the current drawn.

9.3 Memory Size and Execution Time Comparison

	Arduino UNO R3	Arduino Mega 2560
	C Programming	C Programming
Program Memory Size	2750 bytes	3474 bytes
Local Variable Size Left	1832 bytes	7976 bytes
Global Variable Size	216 bytes	216 bytes
Program Execution Time	6-7 milliseconds	6-7 milliseconds

Table: Program memory Size, Variable Size and Program Execution Time using
Arduino Uno R3 and Arduino Mega 2560

The program when used with Arduino UNO R3 uses 2750 bytes in C programming .

Out of a maximum of 32256 bytes. Hence uses only 8.52% of memory , respectively. From a maximum of 2048 bytes for variable size, C programme use 216 bytes for Global Variables, allocating 1832 bytes for local variables when coded with C language,

When used with Arduino Mega 2560, the C programme takes up 3474 bytes out of 253952 bytes which is only 1.3% of the maximum program memory size.

It also uses 222 bytes of variable memory for Global variable out of a maximum of 8192 bytes, leaving 7970 bytes for local variables,.

Moreover, when C programming is used. The code executes in 6-7 milliseconds. Here program execution time means the time between switch reading to LED lighting output

10 Conclusion;

This project's primary goal was to examine the power consumption of various microcontroller boards (Arduino Uno R3 and Arduino Mega 2560) for a unique situation. Applying a 4-bit logic input in the microcontrollers is a particular case.

This experiment shows that C-programming is much easier to code for due to its massive libraries and functions. Both boards show that the program size occupies less memory and has a faster execution time.

It can be concluded that the data and results of this project are reliable.

.

11. Questions and Answers

11.1 Arduino UNO

1. What is the clock frequency of the micro controller used?

Answer: 16 MHz is the clock frequency of the micro controller.

2. What is the data bus width of the micro controller used?

Answer: The data bus width of the micro controller used is 8 bit.

3. What is the size of your hex file generated?

Answer: For default programming- 8KB, for Register Level Programming- 6KB

4. Can the project be implemented by using interrupt?

Answer: Yes, since Arduino UNO pins support interrupt use. External Interrupt are supported on digital pin 2 and 3 while Pin Change interrupt are supported on any of the 20 pins, A0-A5 and D0-D13.

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

Answer: Yes, the main routine is required to be an infinite loop. Since we need to continuously provide input using switches and monitor the output accordingly as well as monitor the execution time continuously, for each input and output. Without an infinite loop, the program would run once and then terminate.

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

Answer: Since we are using SPDT switch, one terminal connects to ground and the other connects to input pins. There is no difference between level trigger and edge trigger in this project. The toggling switch provides either an ON-1 (ON/HIGH) signal or ON-2 (OFF/LOW) signal.

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

Answer: The project refers to an encryption circuit from input to output where an encryption algorithm is applied to a given piece of information. Here, input of 4 bits corresponds to a unique 4-bit output, encrypting the original input.

11.2 Arduino Mega 2560

1. What is the clock frequency of the micro controller used?

Answer: 16 MHz is the clock frequency of the micro controller.

2. What is the data bus width of the micro controller used?

Answer: The data bus width of the micro controller used is 8 bit.

3. What is the size of your hex file generated?

Answer: For default programming- 10KB, for Register Level Programming- 7KB

4. Can the project be implemented by using interrupt?

Answer: Yes, since Arduino Mega 2560 pins support interrupt use. It supports up to 6 external interrupt on digital pin 2,3,18,19,20,21. Like UNO, Pin Change Interrupt can be implemented on all pins.

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

Answer: Yes, the main routine is required to be an infinite loop. Since we need to continuously provide input using switches and monitor the output accordingly as well as monitor the execution time continuously, for each input and output. Without an infinite loop, the program would run once and then terminate.

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

Answer: Since we are using SPDT switch, one terminal connects to ground and the other connects to input pins. There is no difference between level trigger and edge trigger in this project. The toggling switch provides either an ON-1 (ON/HIGH) signal or ON-2 (OFF/LOW) signal.

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

Answer: The project refers to an encryption circuit from input to output where an encryption algorithm is applied to a given piece of information. Here, input of 4 bits corresponds to a unique 4-bit output, encrypting the original input.

12.References:

1. Materials provided by Dr. Dihan Md. Nuruddin Hassan (DMH).
2. Differentiate between arduino uno and arduino mega - Semiconductor for You (semiconductorforu.com)
3. Tinkercad + Arduino Lesson 4: Blink an LED (DDR and PORT registers) - YouTube
4. Arduino Uno Vs Nano Vs Mega, Pinout, and technical Specifications (electronicclinic.com)
6. Arduino Comparison Guide - SparkFun Learn

13.Resources:

1.Project Materials Drive link:

https://drive.google.com/drive/folders/1BPo7y-ts3qASD2YVE2BX_1l3AU37RCXs?usp=sharing

2.Project Demonstration Video Drive link:

https://drive.google.com/drive/folders/16KjSFGUJxN5Bwj6nfHyR60_ToXlYVUd?usp=sharing

3.Project members and their contributions:

Ferdous Reza Niloy	Wrote the code for both Arduino Uno R3 and mega2560 , hex code , designed Arduino mega2560 in proteus
Rafiduzzaman Niloy	Result Analysis and Comparison Among The Boards Used
Md. Afjal Hossain Dali	K map derivation and designed the logisim circuit
Sanjana Islam	Wrote the lab report and designed Arduino Uno R3 in proteus
Afsara Waziha	Wrote the lab report , circuit operation principles , designed the flowchart
Faizul Islam Bhuiyan	Conclusion and Question Answer