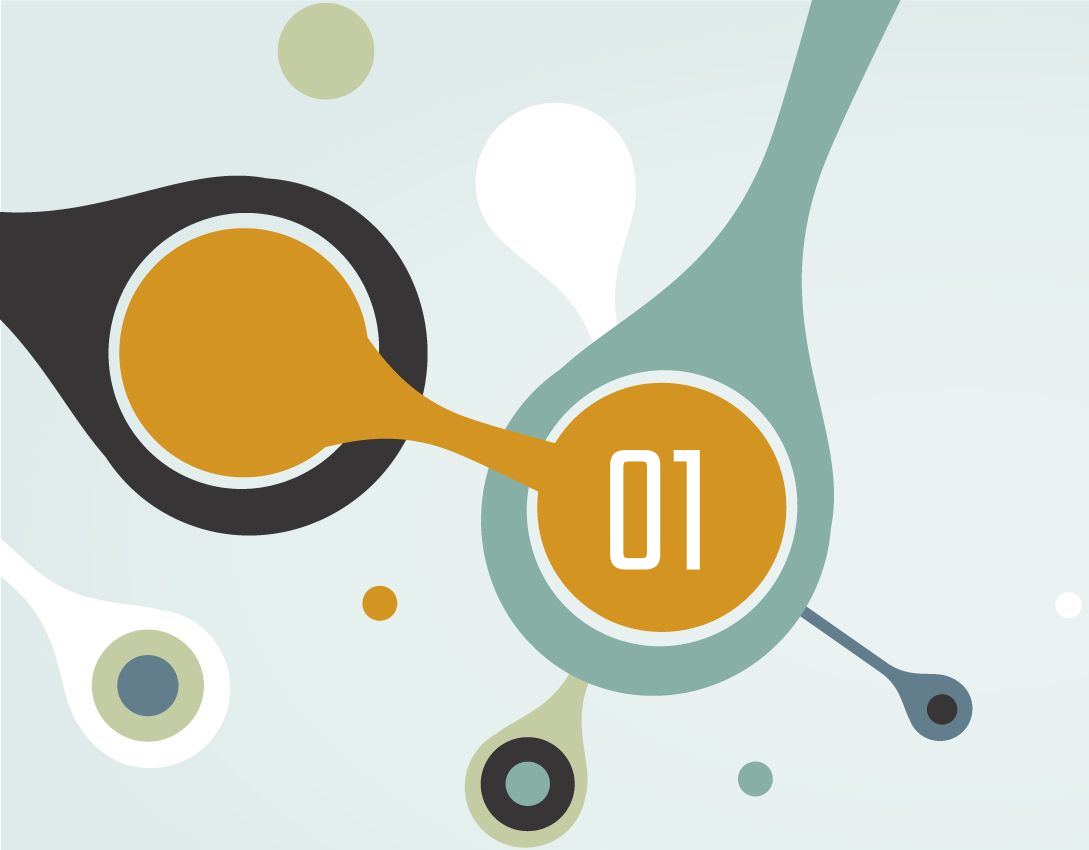
Embedded System Interfacing

Lecture 1
Digital Input Output part 1



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DIO

Digital Input Output

Digital Input Output

A Digital Input Output is a peripheral that deals with digital signals, either by generating a digital signal (***Output Mode***) or by receiving it (***Input Mode***).

1. **Digital Input:** A digital input detects if a voltage is above/below a specific threshold. If the voltage is higher than some value, the computer will detect the digital input as high/set/1. If the voltage is lower than some value, the computer will detect the digital input as low/clear/0.

2. **Digital Output:** A digital output allows you to control a voltage with a computer. If the computer instructs the output to be high, the output will produce a voltage (generally about 5 or 3.3 volts). If the computer instructs the output to be low, it is connected to ground and produces no voltage.

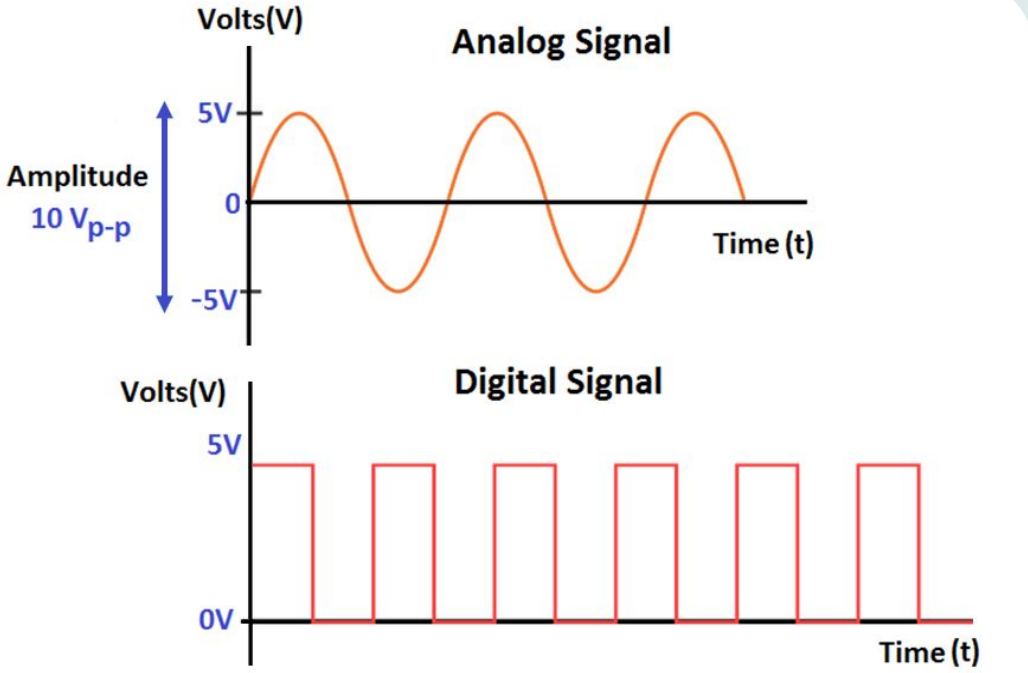
Analog Signal Vs Digital Signal

01
Analog Signal

An analog signal is time-varying and generally bound to a range (e.g. +12V to -12V), but there is an infinite number of values within that continuous range. An analog signal uses a given property of the medium to convey the signal's information, such as electricity moving through a wire.

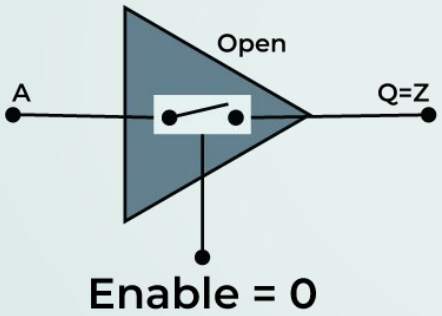
02
Digital Signal

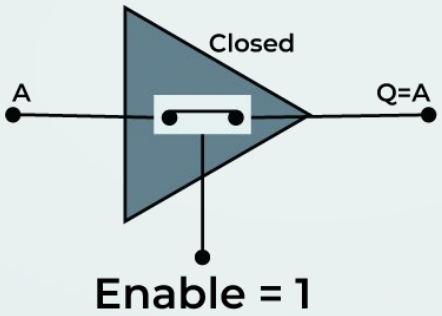
A digital signal is a signal that represents data as a sequence of discrete values. A digital signal can only take on one value from a finite set of possible values at a given time.



Tri State Buffer

The basic block unit for the DIO pin is the ***Tri-State Buffer***. Any DIO pin is consisting of a Tri-State buffer as a main component. The Tri-State buffer controls the output, the output depends on the Enable pin.



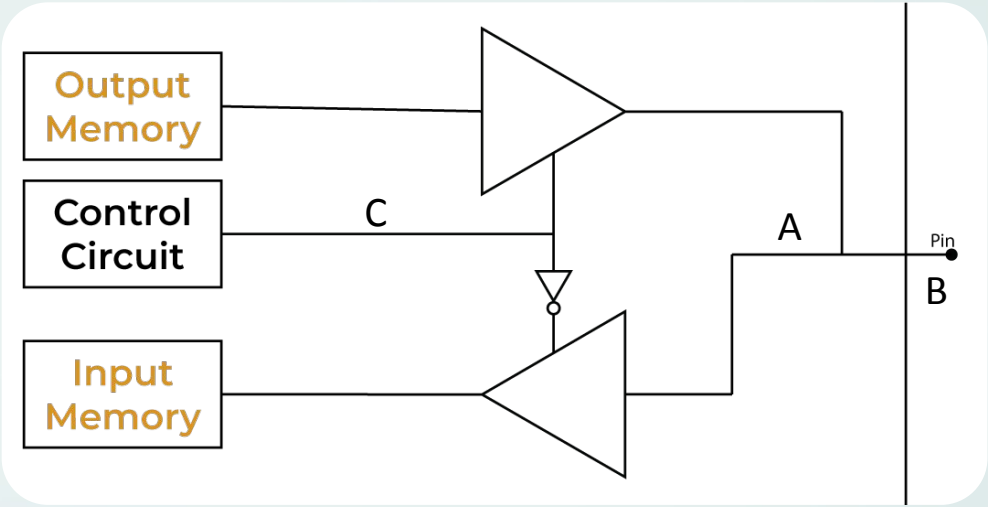


Enable	Output
1	Q=A
0	Q=Z

DIO Block Diagram

Writing 0 To C, Enables the Input Circuit and make the Buffer direction to (B --> A) which makes the PIN in ***Input Mode***

Writing 1 To C, Enables the Output Circuit and make the Buffer direction to (A --> B) which makes the PIN in ***Output Mode***



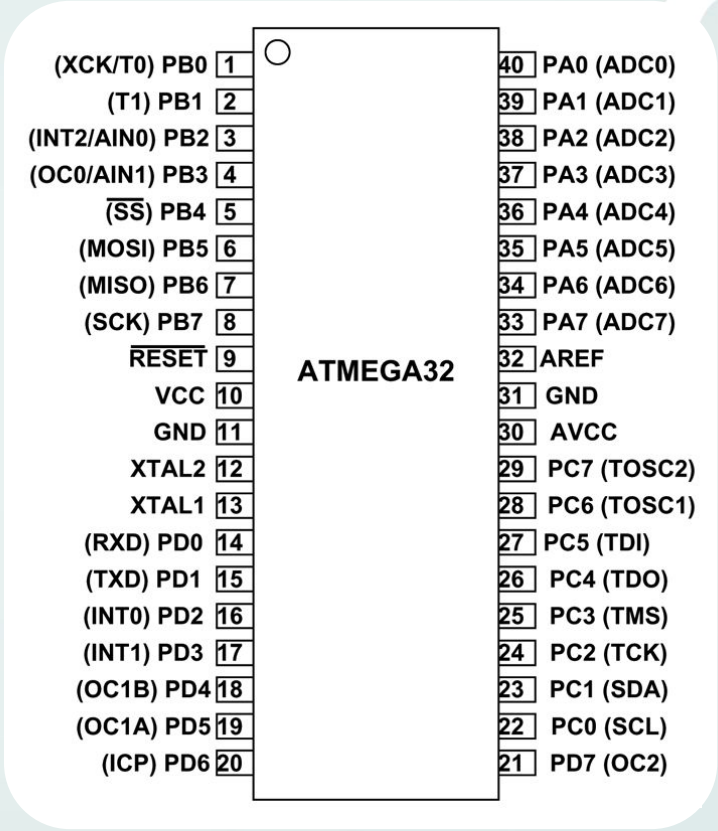
AVR Microcontroller

AVR Microcontroller

In our course, we will use Microcontroller AVR Atmega32. It has 32 DIO pins grouped as following:

1- PORTA has 8 DIO Pins from *A0* to *A7*
2- PORTB has 8 DIO Pins from *B0* to *B8*
3- PORTC has 8 DIO Pins from *C0* to *C8*
4- PORTD has 8 DIO Pins from *D0* to *D8*

Each pin can work either in input mode or output mode.



AVR DIO

Every port has 3 control registers
The size of each register is 8 bit, every bit *corresponding* to 1 Pin of the port

01

DDR

(Data Direction Register) in this register we can define the pin is output or input

If 1, this pin is output
If 0, this pin is input

02

PIN

we use this register in case the pin is defined input

If 1, Pin is connected to 5 volt

If 0, Pin is connected to 0 volt

03

PORT

This register is used in output mode to set the digital output value

If 1, this pin carry 5v
If 0, this pin carry 0v

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DIO Examples

01

Configuring Pin A0 and output 5V

```
DDRA=0b00000001 ;
PORTA=0b00000001 ;
```

Configuring All PORTD Output, lower half connected to 5V and upper half connected to ground

02

```
DDRA=255 ;
PORTA=0x0f ;
```

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Numbering System

03

Numbering System in C

Decimal	Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7

Numbering System

Converting between number bases using hexadecimal

In computer science, different number bases are used:

- **decimal** is base 10, which has ten units (0-9)
- **binary** is base 2, which has two units (0-1)
- **Hexadecimal**, also known as hex, is the third commonly used number system. It has 16 units - 0-9 and the letters A, B, C, D, E and F.

Decimal to Binary

01

Conversion steps:

1. Divide the number by 2.
2. Get the integer quotient for the next iteration.
3. Get the remainder for the binary digit.
4. Repeat the steps until the quotient is equal to 0.

Example #1

Convert 13 to binary:

So 13 = 1101

Division by 2	Quotient	Remainder	Bit #
13/2	6	1	0
6/2	3	0	1
3/2	1	1	2
1/2	0	1	3

What would these decimal numbers be in binary?

- 174 **- 50** **- 77**

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Binary to Decimal

For binary number with n digits: *dn-1 ... d3 d2 d1 d0*

The decimal number is equal to the sum of binary digits (dn) times their power of 2

(2n):vdecimal = *d*0×20 + *d*1×21 + *d*2×22 + ...

Example

Find the decimal value of 111001:

$111001 = 1 \cdot 25+1 \cdot 24+1 \cdot 23+0 \cdot 22+0 \cdot 21+1 \cdot 20 = 57$

binary number:	1	1	1	0	0	1
power of 2:	5_2	4_2	3_2	2_2	1_2	0_2

02

What would these binary numbers be in decimal?

- 10101110 **- 11110000** **- 11001010**

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Hexadecimal to Decimal

03

Whereas decimal place values are powers of 10, and binary place values are powers of 2, hex place values are powers of 16.

Each place value can be represented by the units 0 through to F.

To convert hex to decimal, simply take each place value that has a unit in it, and add them together.

65,536	4,096	256	16	1
			7	C

Example - hex number 7C

Result - (7 × 16) + (C × 1) = (7 × 16) + (12 × 1) = (112) + (12) = 124

What would these hex numbers be in decimal?

- 11 **- 2B** **- FA**

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Decimal to Hexadecimal

- If the decimal number is bigger than 16, divide it by 16. Take the hexadecimal equivalent of this result - this represents the first digit. Take the hexadecimal equivalent of the remainder - this represents the second digit.
- If the decimal number is smaller than 16, take the hexadecimal equivalent of the decimal number.

Example - convert 138 to hexadecimal
138 ÷ 16 = 8 remainder 10

8 = hex 8

10 = hex A

Result - 8A

04

What would these decimal numbers be in hex?

- 11 **- 22** **- 75**

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Binary to Hexadecimal

05

1. Start at the rightmost digit and break the binary number up into groups of four digits. These are known as **nibbles**. If there are less than four digits, use just that number of digits for that group.
2. Next, convert each group of four digits into decimal.
3. Convert each decimal value into its hex equivalent.
4. Put the hex digits together.

Example - 1101 to hex

1101 = decimal 13

13 = hex D

Result - D

What would these binary numbers be in hex?

- 110011 **- 11000011**

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Hexadecimal to Binary

1. Split the hex number into individual values.
2. Convert each hex value into its decimal equivalent.
3. Next, convert each decimal digit into binary, making sure to write four digits for each value.
4. Combine all four digits to make one binary number.

Example - hex 28 to binary

2 = decimal 2 8 = decimal 8

2 = binary 0010 8 = binary 1000

Result - 00101000

06

What would these hex numbers be in binary?

- AA **- 2B**

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DIO Applications

Digital Input Output

LED Interfacing

What is a LED?
Light Emitting Diode is an electrical element that emits light by supplying a voltage difference between its terminals.

LED Connection
The LED has two pins, positive and negative one. In your kit there are 8 LEDs all of them are common ground.

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LED Coding

01

Configure Port Output

```
DDRA=0b00000001 ;  /*Configure Pin A0 in Output mode*/
```

02

LED ON

```
PORTA=0b00000001 ;  /*Set A0 to digital 1 i.e 5V*/
```

03

LED OFF

```
PORTA=0b00000000 ;  /*Set A0 to digital 0 i.e 0V*/
```

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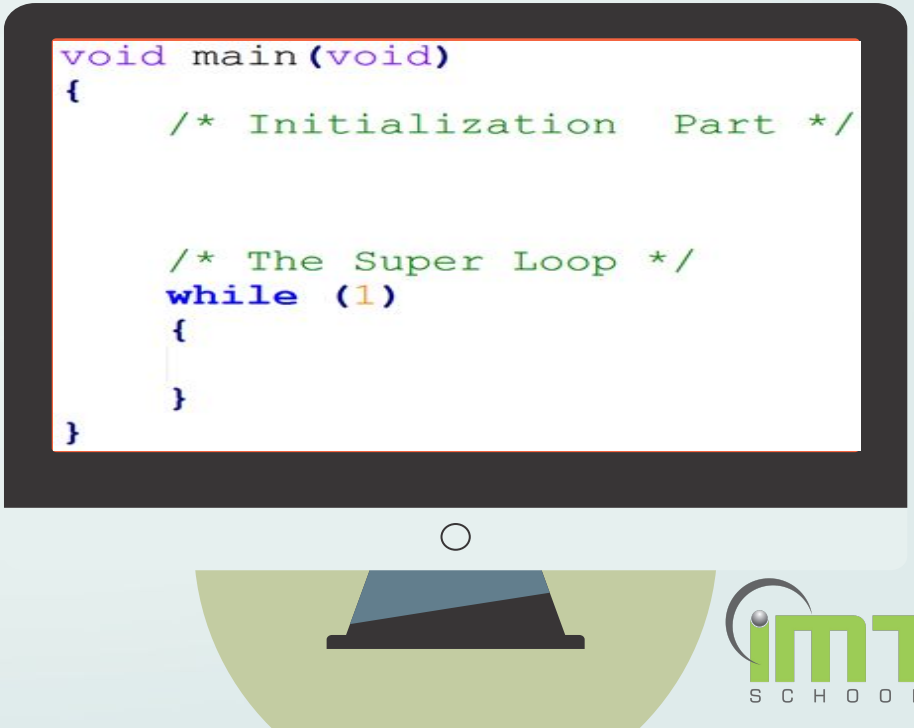
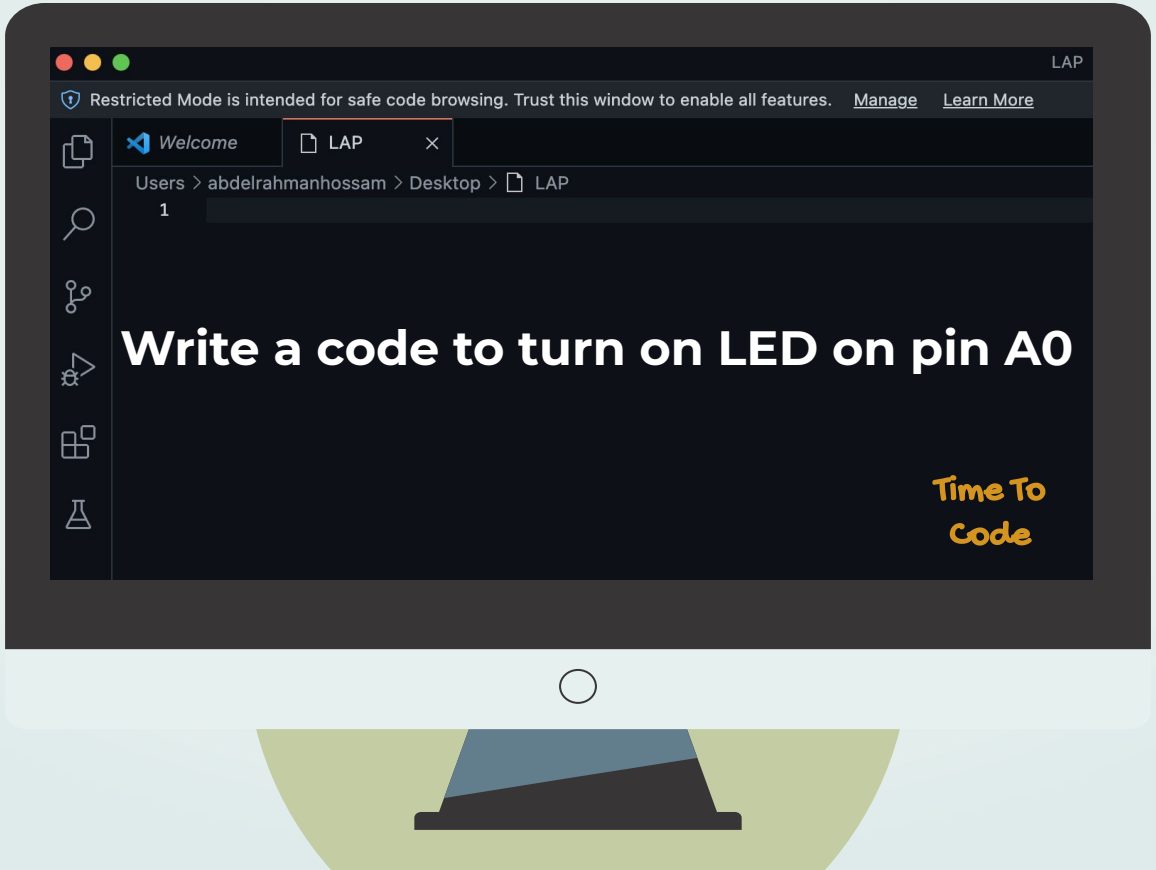
The Super Loop

Any C project in Embedded Systems application shall have an infinite loop called the ***super loop***. This loop is a ***must*** even if you we will leave it empty !

This loop prevents the program counter ***(PC)*** from continues incrementing over the flash memory and execute a garbage code. i.e. the while(1) represents the end of the code.



LAb 1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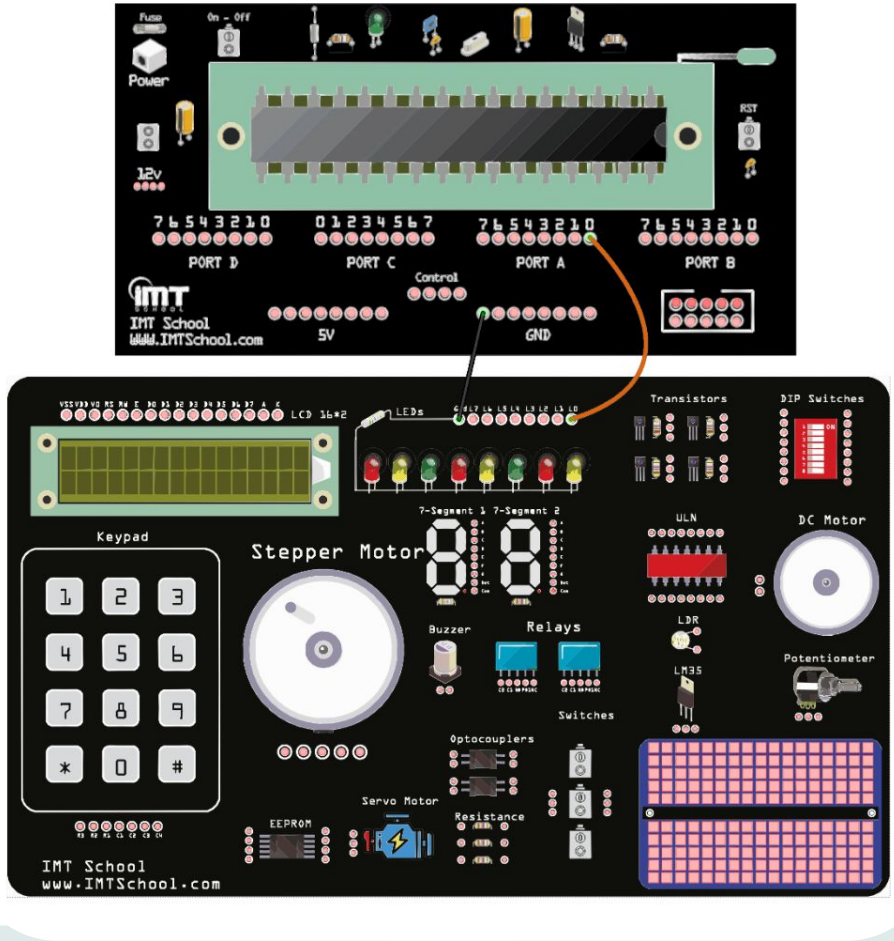
Write a code to turn on LED on pin A0
Time To Code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RST
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Delay Function

Busy Loop Delay

Software Technique the use a loop with effect just to halt the processor for certain time. We will use a library called ***"avr/delay.h"*** that provides two basic functions:

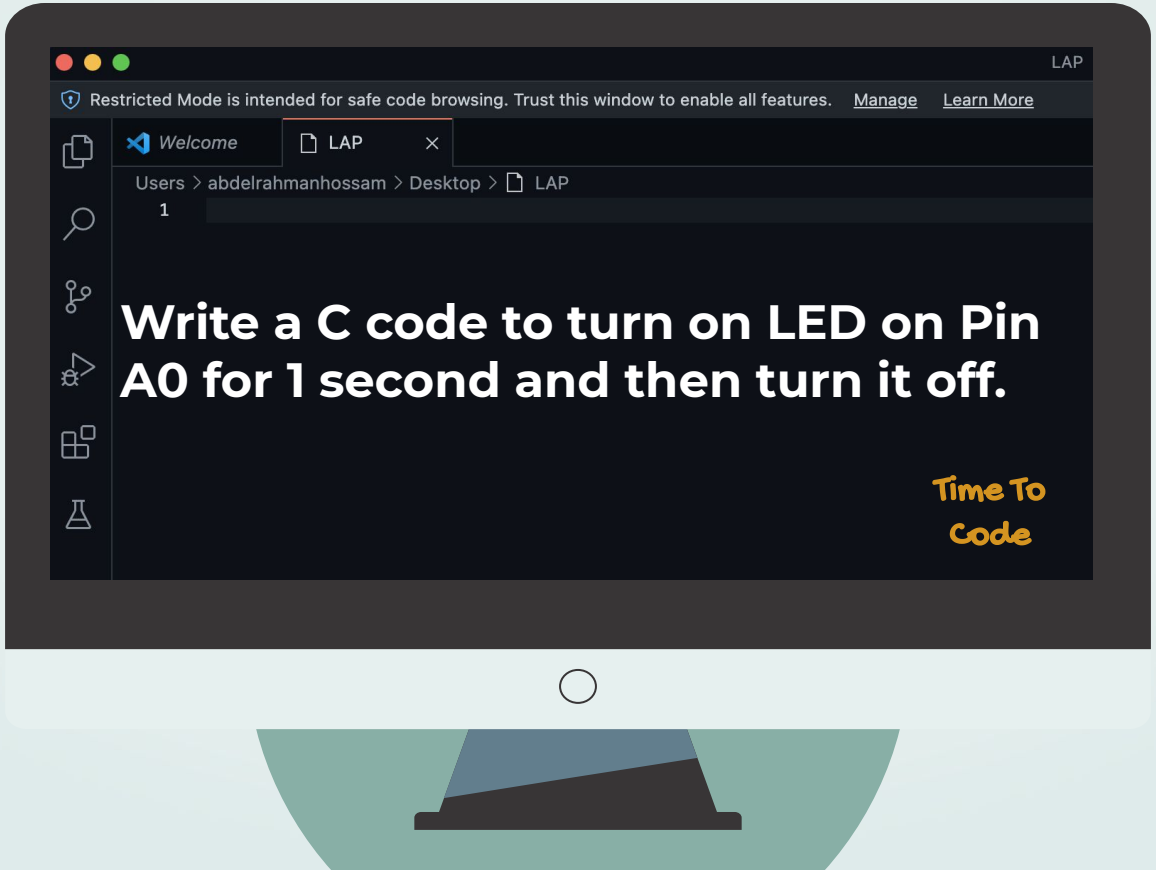
1- ***_delay_ms*** (*_value_in_ms*) /* Apply a delay in milliseconds */
2- ***_delay_us*** (*_value_in_us*) /* Apply a delay in microseconds */

Note

Before using the delay library, we have to define our system frequency by writing this command:

```
#define F_CPU   12000000  /* Define a CPU frequency of 12 Mega Hertz */
```

LAb 2



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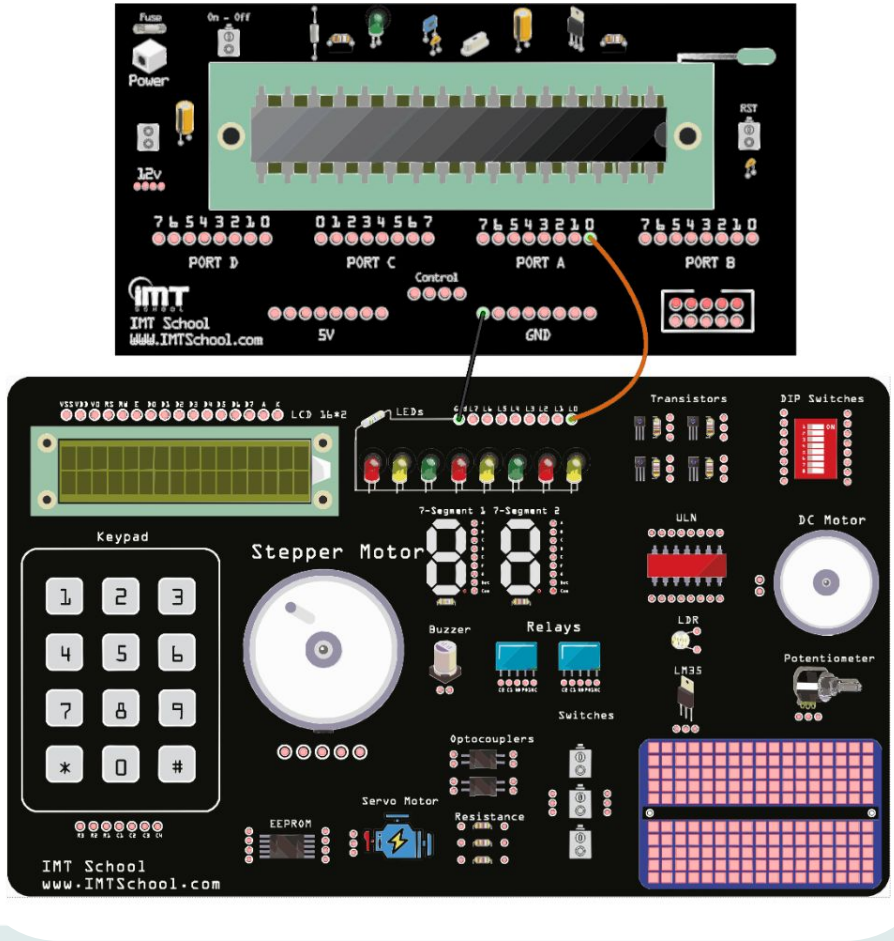
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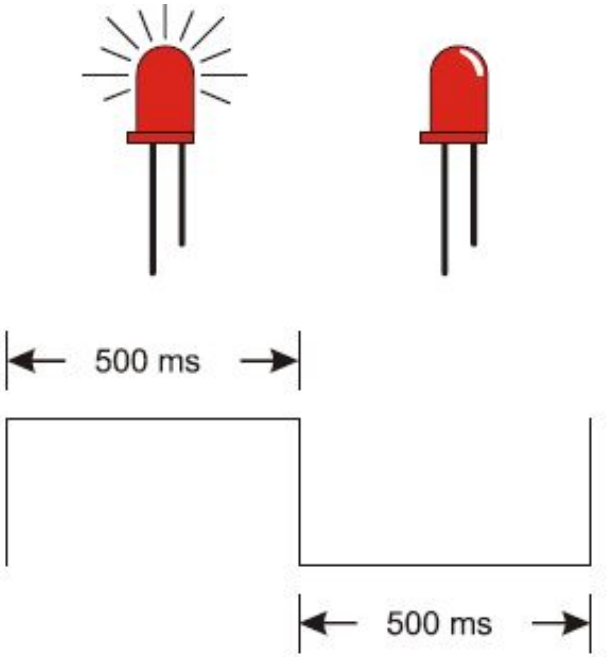
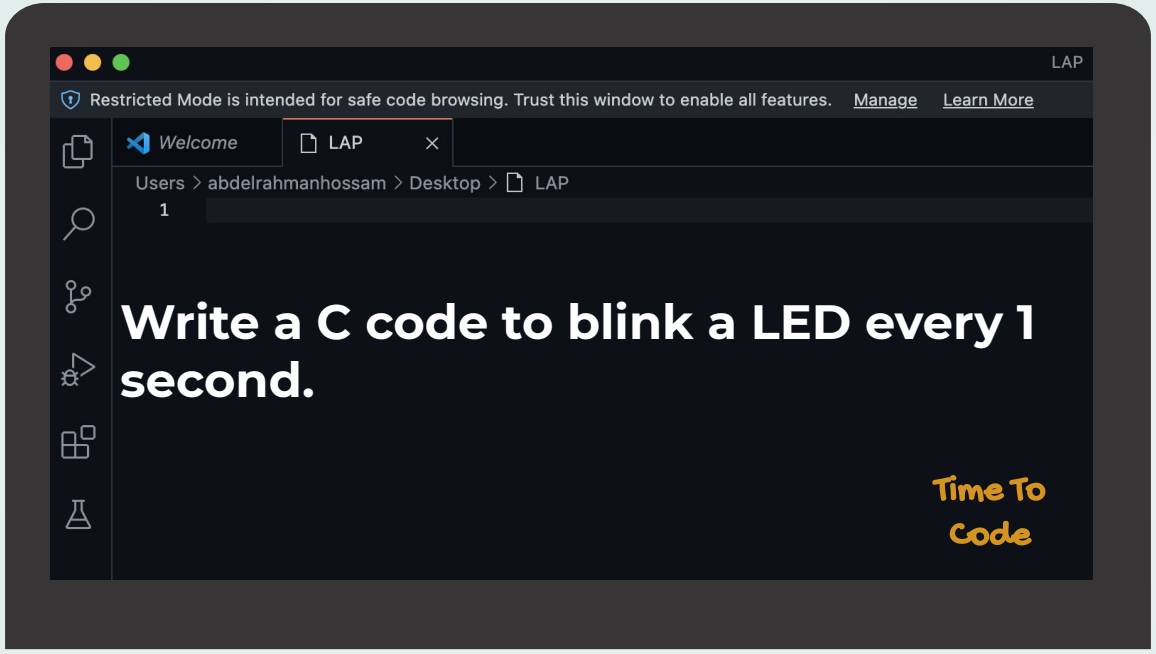
LED Blinking

LED Blinking Algorithm

```
/* Loop forever */
while (1)
{
   /* Turn LED on */
   PORTA = 0x01;

   /* Apply 0.5 Second Delay */
   _delay_ms(500);

  /* Turn LED off */
   PORTA = 0x00;

   /* Apply 0.5 Second Delay */
   _delay_ms(500);
}
```



LAb 3



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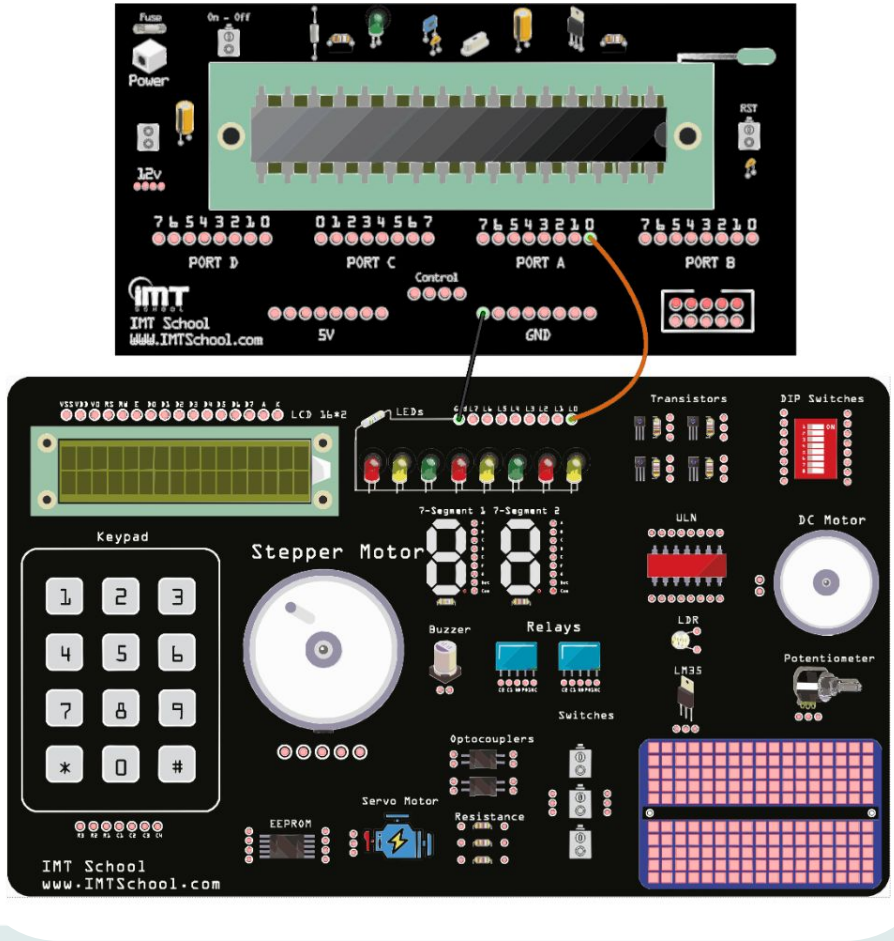
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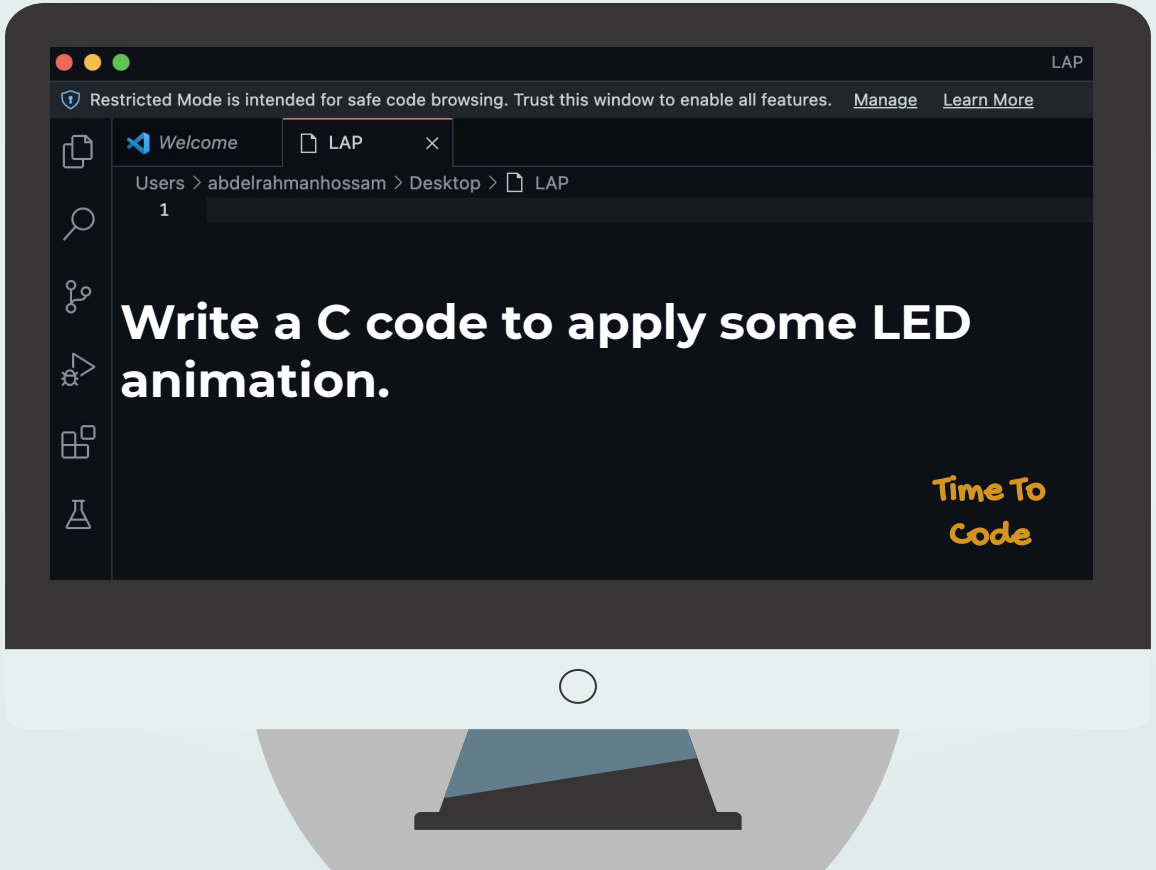

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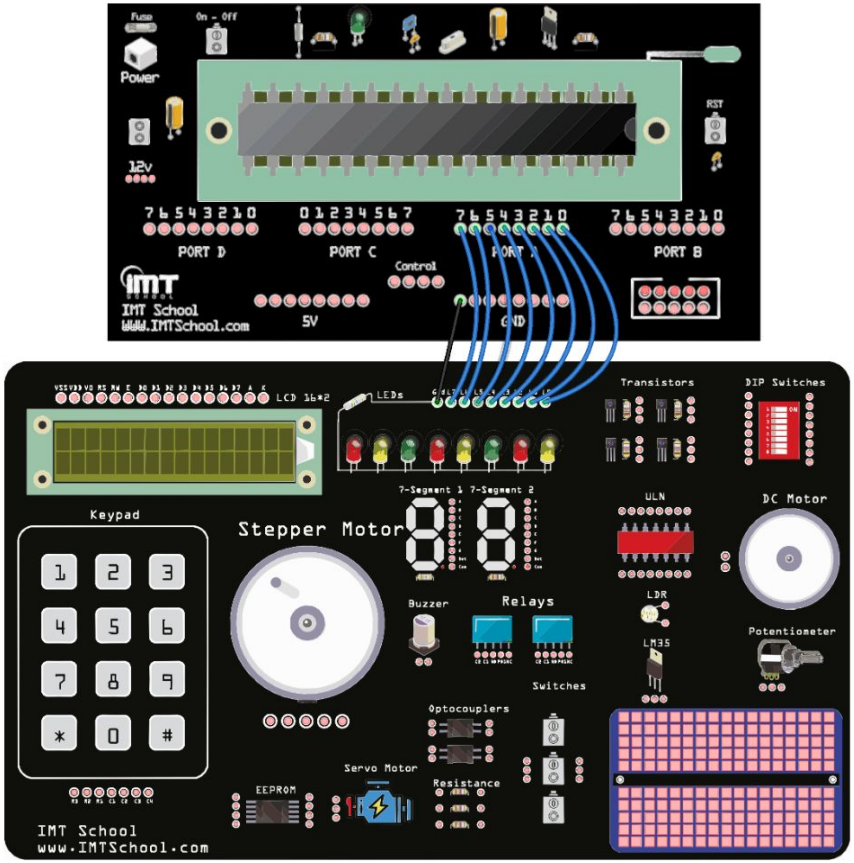
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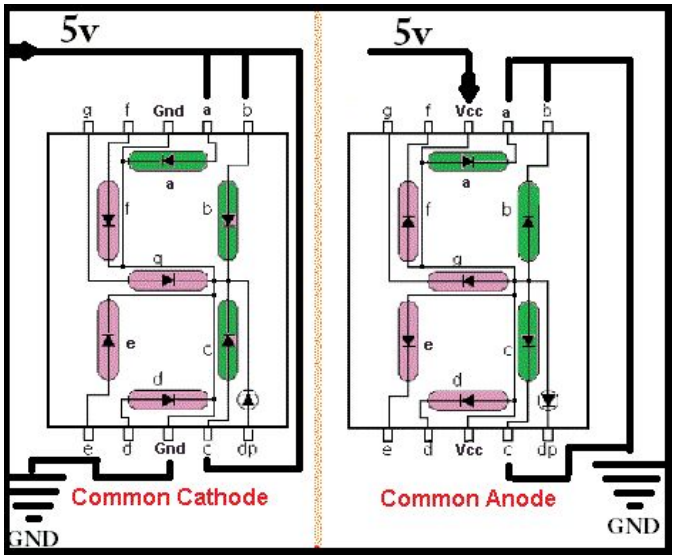
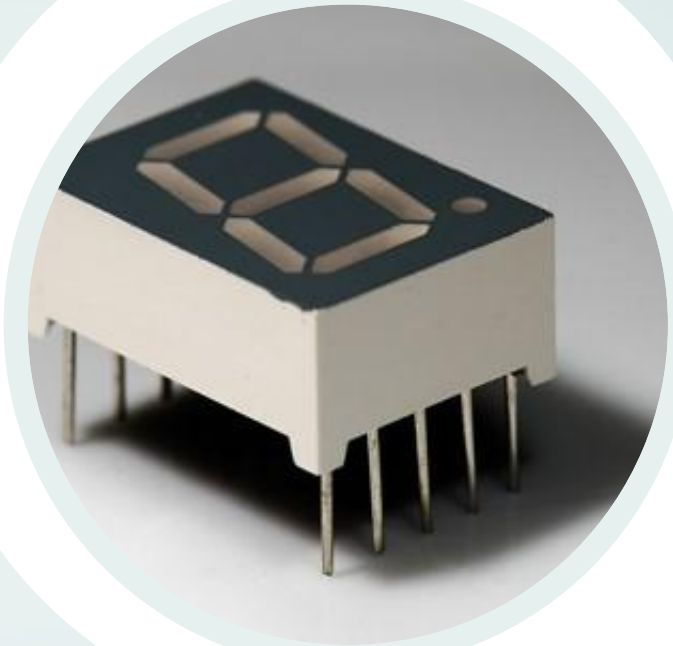
7-Segment Interfacing

What is a 7-Segments?

A seven-**segment** display is a form of electronic display device for displaying decimal numerals that is an alternative to the more complex dot matrix displays.





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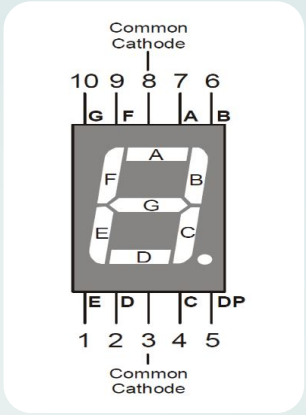
7-Segment Coding

7–segment is common cathode :

Assuming Connecting the 7-Segment lines (a to g) to PD0 to PD6 in the microcontroller kit



01 Configure Port Output

DDRD=255 ; /*Configure port D in Output mode*/

02

PORTD=0b00000110 ;

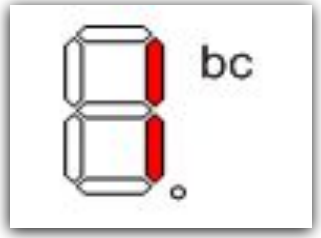
Set second and third pin in PORTD to carry 5v.

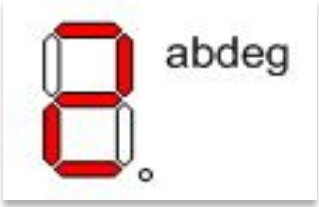
03

PORTD=0b01011011 ;

Set D0 , D1 , D3 , D4 & D6 in PORTD to carry 5v that connected by A,B,D,E,G

outputs on 7-segement





7-Segment Truth Table

Decimal	BCD	G	F	E	D	C	B	A
0	0000	0	1	1	1	1	1	1
1	0001	0	0	0	0	1	1	0
2	0010	1	0	1	1	0	1	1
3	0011	1	0	0	1	1	1	1
4	0100	1	1	0	0	1	1	0
5	0101	1	1	0	1	1	0	1
6	0110	1	1	1	1	1	0	1
7	0111	0	0	0	0	1	1	1
8	1000	1	1	1	1	1	1	1
9	1001	1	1	0	1	1	1	1

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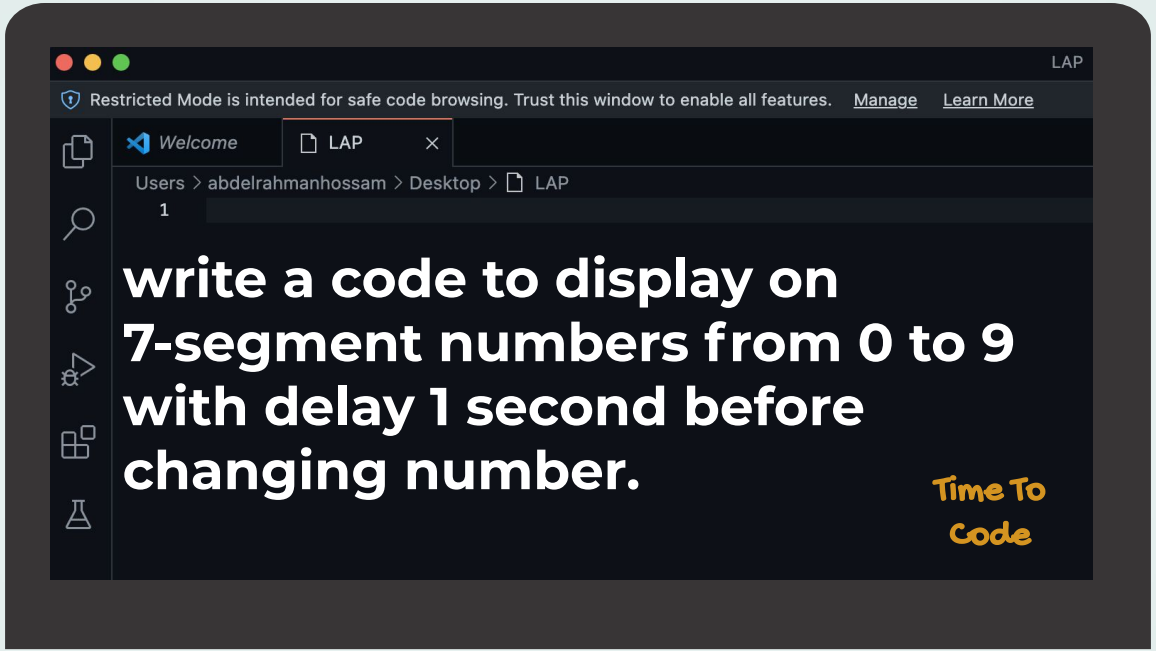
LAb 5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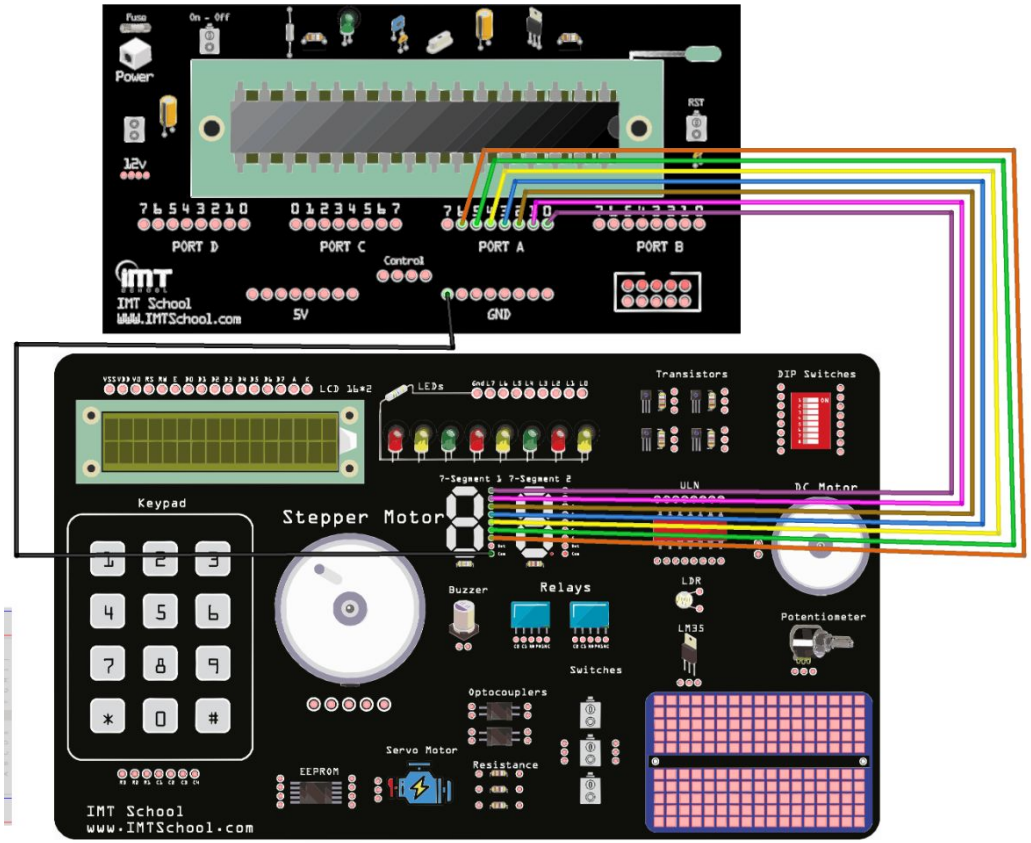
1
write a code to display on 7-segment numbers from 0 to 9 with delay 1 second before changing number.
Time To Code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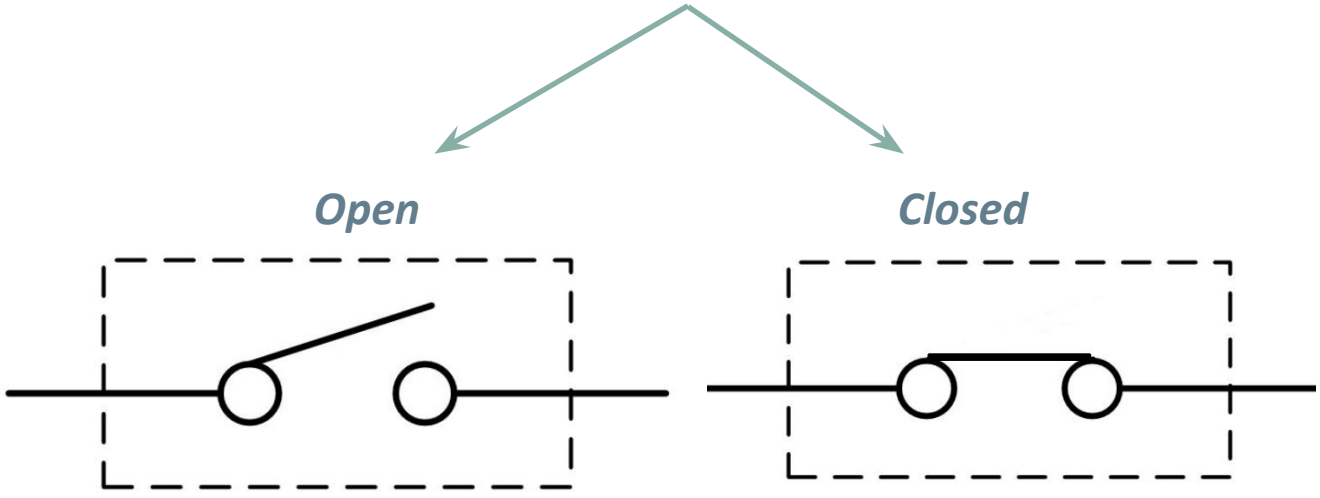
Mechanical Switches

Mechanical switch

is an electrical component that can connect or break an electrical circuit.

Switch States



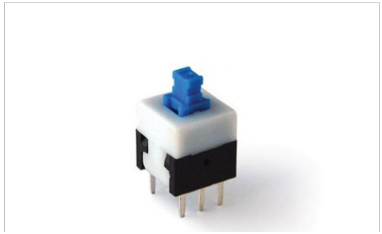
Open Circuit

Short Circuit

Mechanical Switches

Tactile switch

Push Button

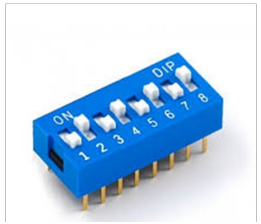


Paddle Switch

Rocker Switch

Toggle Switch

DIP Switch



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Mechanical Switches

Thumbwheel Switch

Limit Switch

Slide Switch

Rotary Switch

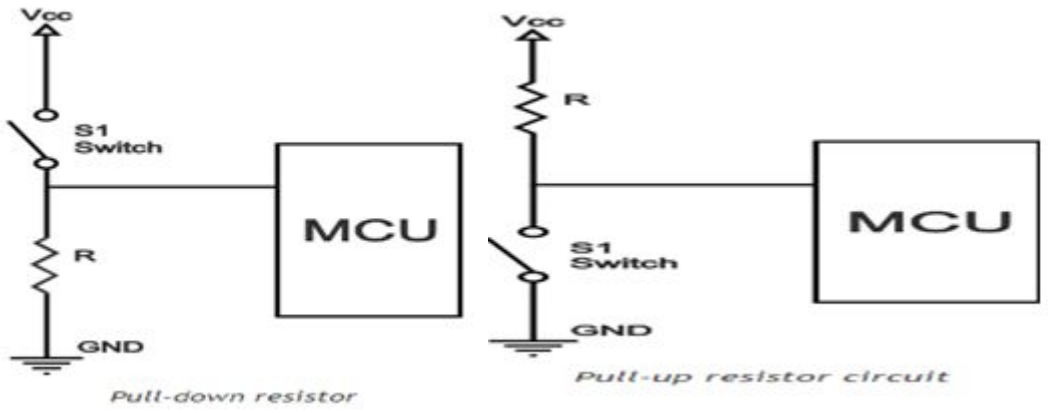
Reed Switch

Key Switch

Knife Switch

Mechanical Switch Interfacing

Switch shall be connected by pull up or pull down resistor to avoid short circuits.



In AVR Microcontroller, all DIO pins have internal pull up resistors that can be activated or not.

Input Digital Pin

Floating

/* Configure PIN as input */

```
DDR -> 0
```

In this state, the DIO pin has 3 states, 0 when connected to GND, 1 when connected to VCC, floating when not connected to anything which may be read as 0 or as 1 !

Note Never let an input pin as floating to avoid noise affection.

Internal Pull Up

```
DDR -> 0
```
/* Configure PIN as input */

```
PORT -> 1
```
/* Activate Internal Pull up */

In this state, the DIO pin has 2 states only, 0 when connected to GND, 1 when connected to VCC or when not connected to anything.

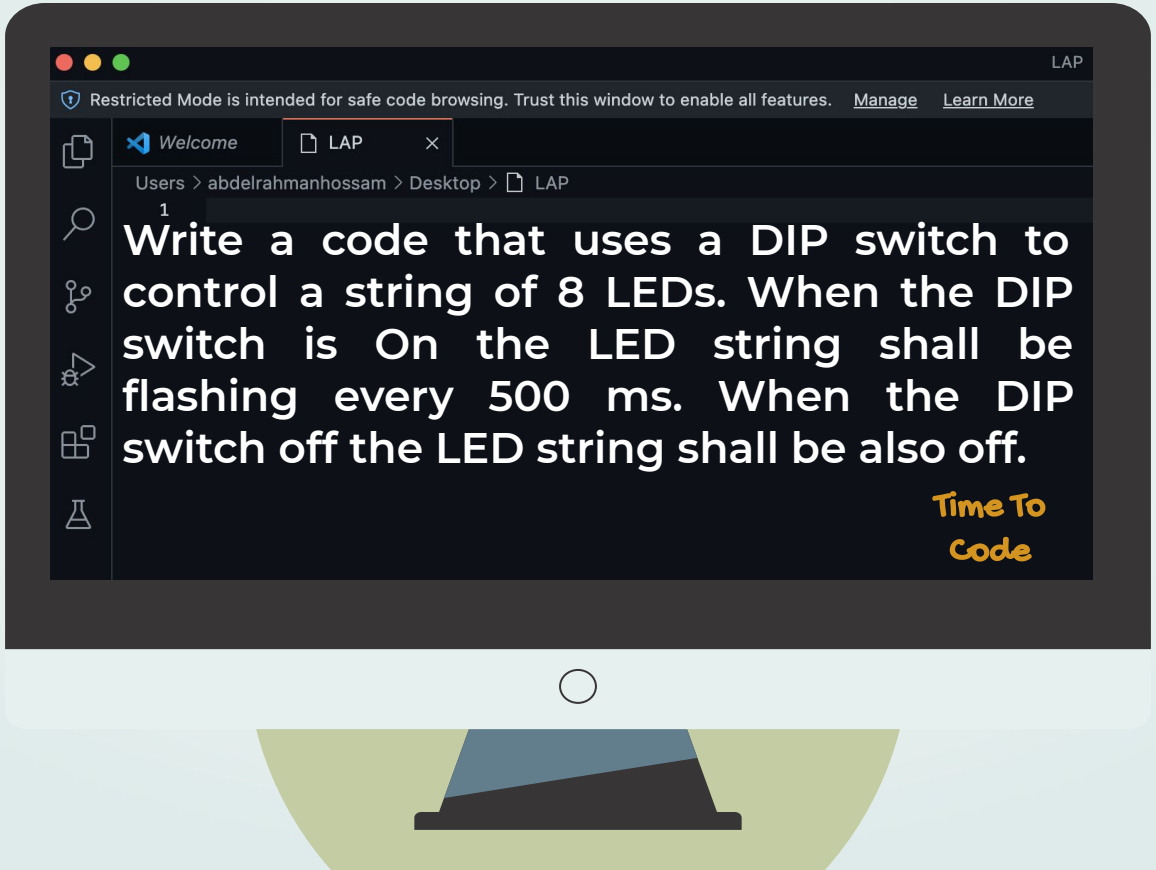
Reading Input Pins

The registers ***PINA, PINB, PINC*** and ***PIND*** are used to check the status of the input pins. If the corresponding bit for a certain pin is ***0***, then the pin is connected to ***GND***. If the corresponding bit for a certain pin is ***1***, then the pin is connected to ***VCC***.

```
/* Check if Pin A0 is conncted to GND  */
if ( (PINA & 0b00000001) == 0)

/* Check if Pin B3 is connected to VCC */
if ( (PINB & 0b00001000) != 0)
```

LAb 6



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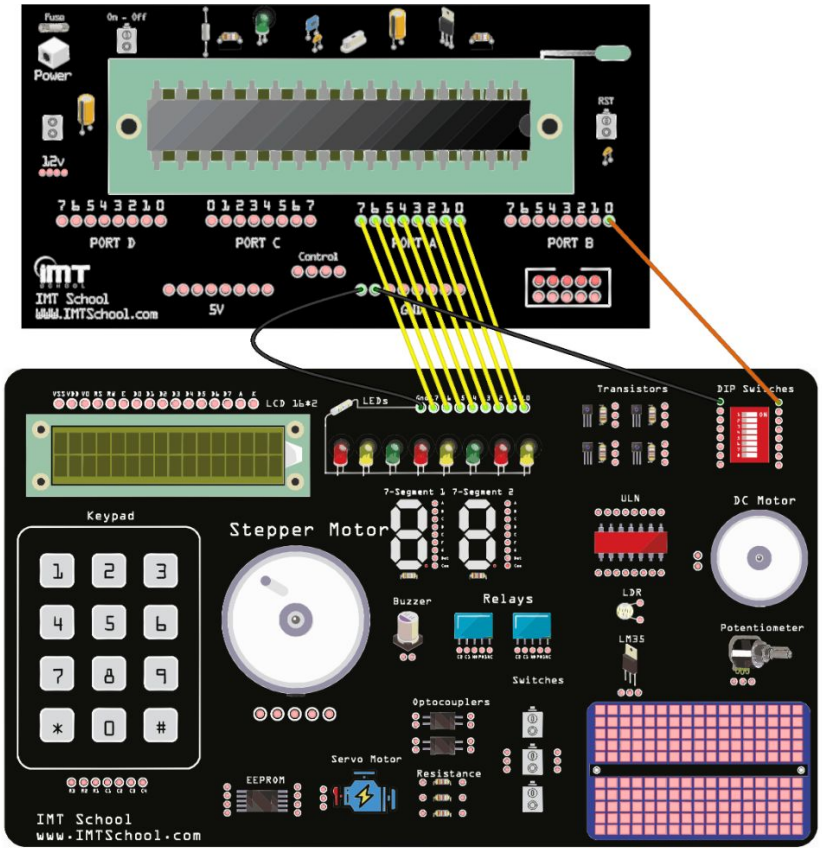
Fuse
On - Off
Power
12v
RST
76543210
01234567
76543210
76543210
PORT D
PORT C
PORT A
PORT B
Control
IMT School
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5V
GND
LCD 16x2
8 LEDs
Transistors
DIP Switches
7-Segment 1
7-Segment 2
ULN
DC Motor
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Stepper Motor
Buzzer
Relays
LDR
LM35
Potentiometer
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The End

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Assignments

Talk is cheap
show me the Code

- Linus Torvalds

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Assignment 1

Write a C code that simulate the traffic lightening system:

1- Turn On Green LED for 10 seconds
2- Turn On Yellow LED for 3 seconds
3- Turn On Red LED for 10 seconds
4- Apply these forever while counting the seconds down on a two 7-segment displays.

Assignment 2

Write a C code that apply 8 different animations on 8 LED string based on the value of 3 way DIP Switch as following:

DIP value	LED Action
1	Flashing every 500 ms
2	Shifting Left every 250 ms
3	Shifting Right every 250 ms
4	2-LEDs Converging every 300 ms
5	2-LEDs Diverging every 300 ms
6	Ping Pong effect every 250 ms
7	Incrementing (Snake effect) every 300 ms
8	2-LEDs Converging/Diverging every 300 ms

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