

# Basic I/O Interfacing on AlphaBot

Embedded Real-Time Systems (ERTS) Lab  
Indian Institute of Technology, Bombay



# Agenda for Discussion

- 1 AlphaBot Introduction
  - AlphaBot
- 2 Input-Output Ports in ATmega 328p
  - Overview of Ports
  - Ports in ATmega 328p
  - Accessing Ports
  - Examples
- 3 Write Your First Embedded C Program
  - LED Interfacing
  - Need for masking
  - Masking Operators



# AlphaBot



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## 1 Mobile robot development platform



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- 1 Mobile robot development platform
- 2 Plug-and-play modules like line tracking, obstacle avoidance, speed measuring, etc.



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- 3 L298P motor driver with diode protection circuit



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- 2 Plug-and-play modules like line tracking, obstacle avoidance, speed measuring, etc.
- 3 L298P motor driver with diode protection circuit
- 4 TLC1543 AD acquisition chip



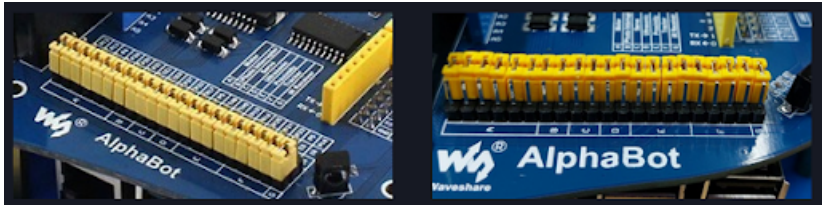


# AlphaBot Compatible Boards



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Compatible with Arduino/Raspberry Pi



**Figure:** (a) Robot with jumpers to select Arduino and (b) Robot with jumpers to select Raspberry Pi



# What are Ports?



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- ① Input Device:

Example: Switch, Sensors, etc...



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① Input Device:

Example: Switch, Sensors, etc...

② Output Device:

Example: Buzzer, LCD, Motors, LED, etc...



# Ports in ATmega 328p





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Port x;                      x = B and D

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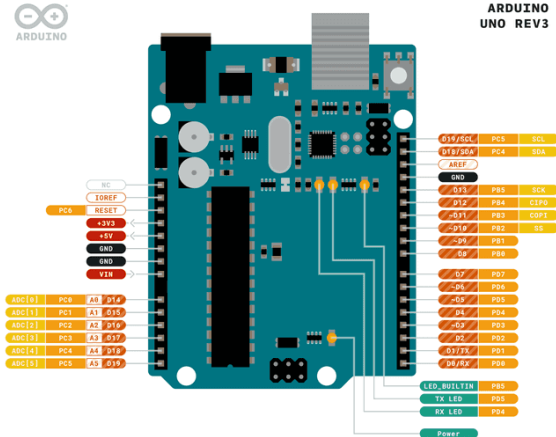
- All Port pins can be individually configured as Input/Output.



# Arduino - ATmega 328p pin mapping



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Ground	Internal Pin	Digital Pin	Microcontroller's Port
Power	SWD Pin	Analog Pin	
LED	Other Pin	Default	



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# Accessing Ports



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Each Port has three associated registers with it:

- ❶ DDR<sub>x</sub>            x = B, C and D
- ❷ PORT<sub>x</sub>           x = B, C and D
- ❸ PIN<sub>x</sub>            x = B, C and D



# Understanding DDRx Register



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- Data Direction Register



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DDRB =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	0	0	0	0



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DDRB = 0xF0



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- 3 Example:

Read data from Port B

PortB =

P7	P6	P5	P4	P3	P2	P1	P0
1	1	1	1	0	0	0	0

$x = \text{PINB}$

$x = 0xF0$



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Case 1: When Port x is defined as Output



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DDRB =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1



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Case 1: When Port x is defined as Output

① Purpose: Send data on Port x pins

② Example:

DDRB =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1

DDRB = 0xFF



# Understanding PORTx Register

Case 1: When Port x is defined as Output

① Purpose: Send data on Port x pins

② Example:

DDRB =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1

DDRB = 0xFF

PORTB = 0xFF



# Understanding PORTx Register



# Understanding PORTx Register

Case 2: When Port x is defined as Input



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- ① Purpose: Activate/deactivate Pull-up resistor





# Understanding PORTx Register

Case 2: When Port x is defined as Input

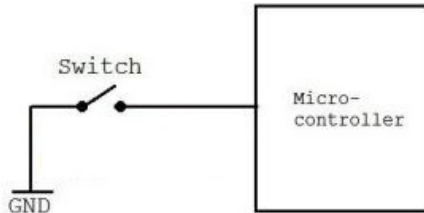
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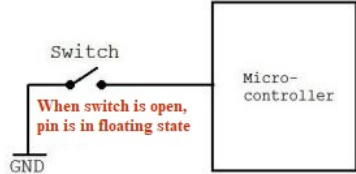
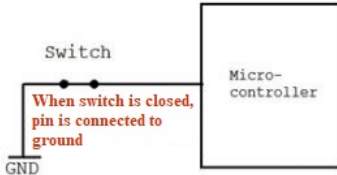
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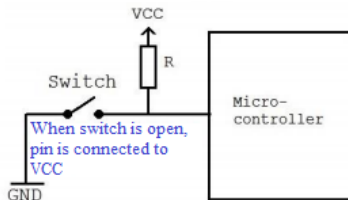
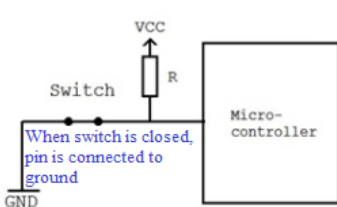
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Case 2: When Port x is defined as Input

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Case 2: When Port x is defined as Input

- ❶ Purpose: Activate/deactivate Pull-up resistor
  - a.  $\text{PORTx bit} = 1 \rightarrow$  Pull up is activated on Portx pin.



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Case 2: When Port x is defined as Input

- ❶ Purpose: Activate/deactivate Pull-up resistor
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DDRB =

D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	0



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DDRB =

D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	0

DDRB = 0x00



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DDRB = 0x00

PORTB = 0xFF





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Pull-Up is activated for all Pins of PortB.



# Examples

- Example 1: Make PortD as output port and send hex value 'D5'.



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- ① Step 1: Make Port D as Output port



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DDRD =



# Examples

- Example 1: Make PortD as output port and send hex value 'D5'.
- 1 Step 1: Make Port D as Output port

DDRD =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1



# Examples

- Example 1: Make PortD as output port and send hex value 'D5'.
- 1 Step 1: Make Port D as Output port

DDRD =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1

DDRD = 0xFF



# Examples

- Example 1: Make PortD as output port and send hex value 'D5'.

- ① Step 1: Make Port D as Output port

DDRD =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1

DDRD = 0xFF

- ② Step 2: Put data on the Port D





# Examples

- Example 1: Make PortD as output port and send hex value 'D5'.

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DDRD =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1

DDRD = 0xFF

- 2 Step 2: Put data on the Port D



# Examples

- Example 1: Make PortD as output port and send hex value 'D5'.

- 1 Step 1: Make Port D as Output port

DDRD =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1

DDRD = 0xFF

- 2 Step 2: Put data on the Port D

PORTD =



# Examples

- Example 1: Make PortD as output port and send hex value 'D5'.
- ➊ Step 1: Make Port D as Output port

DDRD =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1

DDRD = 0xFF

- ➋ Step 2: Put data on the Port D

PORTD =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	0	1	0	1	0	1



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- Example 1: Make PortD as output port and send hex value 'D5'.

- 1 Step 1: Make Port D as Output port

DDRD =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	1	1	1

DDRD = 0xFF

- 2 Step 2: Put data on the Port D

PORTD =

D7	D6	D5	D4	D3	D2	D1	D0
1	1	0	1	0	1	0	1

PORTD = 0xD5



## Examples (Cont..)

- Example 2: Make PortB input port with pull-up activated on all pins



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- ② Step 2: To activate Pull-up Resistor send data on Port B



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- Example 2: Make PortB input port with pull-up activated on all pins
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- ② Step 2: To activate Pull-up Resistor send data on Port B

PORTB =



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DDRB = 0x00

- 2 Step 2: To activate Pull-up Resistor send data on Port B

PORTB =

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## Examples (Cont..)

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PORTB = 0xFF



# Examples





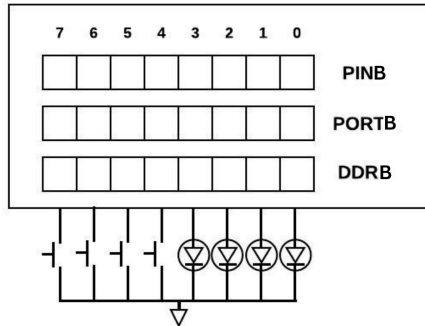
# Examples

- Example: Connect LEDs to lower nibble and Switches to upper nibble of PortB. Turn ON alternate LEDs (0 and 2) and activate pull up for all Switches. Read data using PIN register. What will be the content of PINB register, if only Switch at pin 5 is pressed?



# Examples

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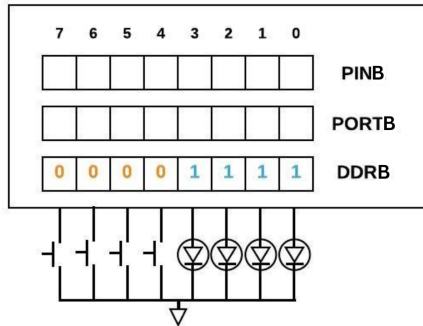
# Examples

- Step 1: Make upper nibble as Input and lower nibble as Output.



# Examples

- Step 1: Make upper nibble as Input and lower nibble as Output.



# Examples



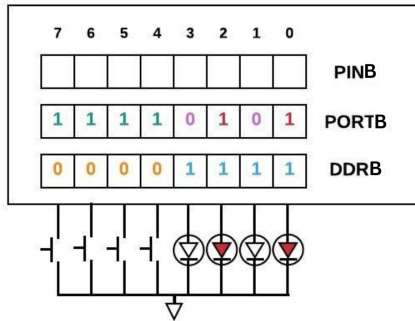
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- Step 2: Turn ON alternate LEDs (0 and 2) and activate pull up for Switches.



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# Examples



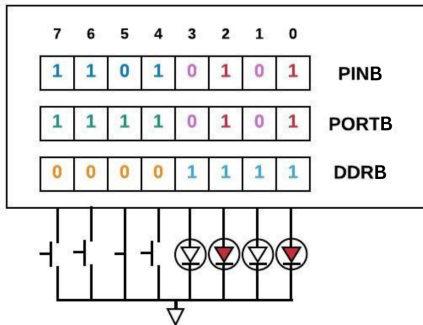
# Examples

- Step 3: Read data from PINB. On lower nibble we will get the same data and on upper nibble depending on Switch position, data will change.



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# LED Interfacing on AlphaBot



# LED Interfacing on AlphaBot

- 1 LED is connected to Port B pin 5 (Digital pin 13)



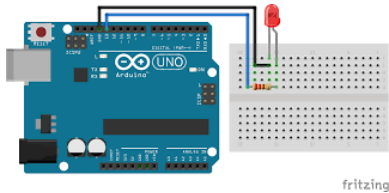
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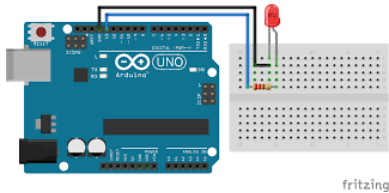
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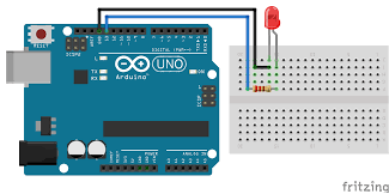
- 2 To turn ON LED:





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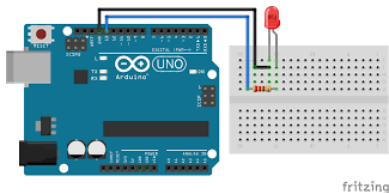


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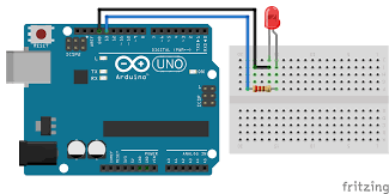


- 2 To turn ON LED: send logic HIGH on pin 5 of Port B



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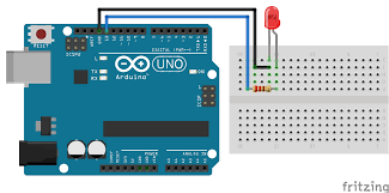


- 2 To turn ON LED: send logic HIGH on pin 5 of Port B
- 3 To turn OFF LED:



# LED Interfacing on AlphaBot

- 1 LED is connected to Port B pin 5 (Digital pin 13)

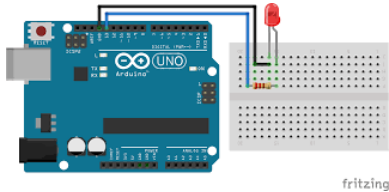


- 2 To turn ON LED: send logic HIGH on pin 5 of Port B
- 3 To turn OFF LED:



# LED Interfacing on AlphaBot

- 1 LED is connected to Port B pin 5 (Digital pin 13)



- 2 To turn ON LED: send logic HIGH on pin 5 of Port B
- 3 To turn OFF LED: send logic LOW on pin 5 of Port B



# LED Program



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DDRB = 0x20; // 0010 0000
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- 3 To turn OFF the LED set PB.5 output LOW





# LED Program

- 1 Configure PB.5 pin as Output.

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DDRB = 0x20; // 0010 0000
```

- 2 To turn ON the LED set PB.5 output HIGH

```
PORTB = 0x20; // 0010 0000
```

- 3 To turn OFF the LED set PB.5 output LOW

```
PORTB =
```



# LED Program

- 1 Configure PB.5 pin as Output.

```
DDRB = 0x20; // 0010 0000
```

- 2 To turn ON the LED set PB.5 output HIGH

```
PORTB = 0x20; // 0010 0000
```

- 3 To turn OFF the LED set PB.5 output LOW

```
PORTB = 0x00; // 0000 0000
```



# LED Program

- 1 Configure PB.5 pin as Output.

```
DDRB = 0x20; // 0010 0000
```

- 2 To turn ON the LED set PB.5 output HIGH

```
PORTB = 0x20; // 0010 0000
```

- 3 To turn OFF the LED set PB.5 output LOW

```
PORTB = 0x00; // 0000 0000
```



# Need for masking

- 1 Sometimes, we need to change the state of one or more pins of the port thereby keeping the rest of the pins unchanged.



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- 1 Sometimes, we need to change the state of one or more pins of the port thereby keeping the rest of the pins unchanged.
- 2 AVR is not bit addressable.
- 3 No 'address' to a specific bit.
- 4 Use of different masking operators.



# Masking Operators

In general, there are three operators used for masking:





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- ✓ OR operator → to SET a particular bit
- ✓ AND operator → to RESET a particular bit



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In general, there are three operators used for masking:

- ✓ OR operator → to SET a particular bit
- ✓ AND operator → to RESET a particular bit
- ✓ EXOR operator → to TOGGLE a particular bit

Two more operators can be used:

- NOT operator
- Shift operators



# NOT Operator

- ① Purpose: To perform negation on all bits.



# NOT Operator

- 1 Purpose: To perform negation on all bits.
- 2 Symbol:  $\sim$



# NOT Operator

- ❶ Purpose: To perform negation on all bits.
- ❷ Symbol:  $\sim$
- ❸ Example:

A =

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1





# NOT Operator

- ❶ Purpose: To perform negation on all bits.
- ❷ Symbol:  $\sim$
- ❸ Example:

A =

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1



# NOT Operator

- 1 Purpose: To perform negation on all bits.
- 2 Symbol:  $\sim$
- 3 Example:

$$A =$$

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1

$$\sim A =$$

B7	B6	B5	B4	B3	B2	B1	B0
0	1	1	1	1	1	0	0



# Shift Operator

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- 4 Example:

A =

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1

$A \ll 2 =$

B7	B6	B5	B4	B3	B2	B1	B0
0	0	0	0	1	1	0	0





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- 2 Types: Left Shift and Right Shift
- 3 Symbol: Left shift ( $\ll$ ) and right shift ( $\gg$ )
- 4 Example:

$$A =$$

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1

$$A \ll 2 =$$

B7	B6	B5	B4	B3	B2	B1	B0
0	0	0	0	1	1	0	0

$$A \gg 2 =$$

B7	B6	B5	B4	B3	B2	B1	B0
0	0	1	0	0	0	0	0



# OR Operator

- ① Purpose: To SET particular bit/s.



# OR Operator

- 1 Purpose: To SET particular bit/s.
- 2 Symbol: |



# OR Operator

- ❶ Purpose: To SET particular bit/s.
- ❷ Symbol: |
- ❸ Truth Table:

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



# Example

## ① Example: Setting a bit :



# Example

① Example: Setting a bit :

- ② Consider register has data 0x83 (unknown to us). We want to set 2nd bit of register and keep rest of the data intact.

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1



# Example

① Example: Setting a bit :

- a. Consider register has data 0x83 (unknown to us). We want to set 2nd bit of register and keep rest of the data intact.

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1	0	0	0	0	0	1	1



# Example

## 1 Example: Setting a bit :

- a. Consider register has data 0x83 (unknown to us). We want to set 2nd bit of register and keep rest of the data intact.

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1

- b. Expected output is:

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1





## Example

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1



## Example

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1

OR

B7	B6	B5	B4	B3	B2	B1	B0
0	0	0	0	0	1	0	0



## Example

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1

OR

B7	B6	B5	B4	B3	B2	B1	B0
0	0	0	0	0	1	0	0

Output same as Expected output:

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1



## Example

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1

OR

B7	B6	B5	B4	B3	B2	B1	B0
0	0	0	0	0	1	0	0

Output same as Expected output:

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1

① `register_name = register_name | 0x04;`



## Example

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1

OR

B7	B6	B5	B4	B3	B2	B1	B0
0	0	0	0	0	1	0	0

Output same as Expected output:

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1

① `register_name = register_name | 0x04;`

② `register_name |= 0x04;`



# Example of Masking with Shift Operator

```
1 register_name |= 0x04;
```



# Example of Masking with Shift Operator

- 1 register\_name |= 0x04;
- 2 0x04 can also be written as 1<<2



# Example of Masking with Shift Operator

- 1 `register_name |= 0x04;`
- 2 `0x04` can also be written as `1<<2`
- 3 In general, statement can be written as:

`Register_name |= (1 << pin_no)`





# Example of Masking with Shift Operator

- 1 `register_name |= 0x04;`
- 2 `0x04` can also be written as `1<<2`
- 3 In general, statement can be written as:

`Register_name |= (1 << pin_no)`

- 4 For setting multiple bits at once the statement can be written as:

`Register_name |= ((1 << pin_no1) | (1 << pin_no2))`



# AND Operator

- ① Purpose: To RESET particular bit/s.



# AND Operator

- 1 Purpose: To RESET particular bit/s.
- 2 Symbol: &



# AND Operator

- 1 Purpose: To RESET particular bit/s.
- 2 Symbol: &
- 3 Truth Table:

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



# Example

- ① Example: Resetting a bit :



# Example

① Example: Resetting a bit :

- ② Consider register has data 0x87 (unknown to us). We want to reset pin 2 and keep rest of the data intact.

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1



# Example

❶ Example: Resetting a bit :

- ❷ Consider register has data 0x87 (unknown to us). We want to reset pin 2 and keep rest of the data intact.

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1



# Example

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- a. Consider register has data 0x87 (unknown to us). We want to reset pin 2 and keep rest of the data intact.

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1

- b. Expected output is:

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1





# Example

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- a. Consider register has data 0x87 (unknown to us). We want to reset pin 2 and keep rest of the data intact.

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- a. Consider register has data 0x87 (unknown to us). We want to reset pin 2 and keep rest of the data intact.

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1	0	0	0	0	1	1	1

- b. Expected output is:

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1



## Example

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1



## Example

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1

AND

B7	B6	B5	B4	B3	B2	B1	B0
1	1	1	1	1	0	1	1



## Example

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1

AND

B7	B6	B5	B4	B3	B2	B1	B0
1	1	1	1	1	0	1	1

Output same as Expected output:

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1



## Example

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1

AND

B7	B6	B5	B4	B3	B2	B1	B0
1	1	1	1	1	0	1	1

Output same as Expected output:

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1

① `register_name = register_name & 0xFB;`



## Example

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	1	1	1

AND

B7	B6	B5	B4	B3	B2	B1	B0
1	1	1	1	1	0	1	1

Output same as Expected output:

B7	B6	B5	B4	B3	B2	B1	B0
1	0	0	0	0	0	1	1

- 1 register\_name = register\_name & 0xFB;
- 2 register\_name &= 0xFB;



# Example of Masking with Shift Operator

❶ register\_name &= 0xFB;





# Example of Masking with Shift Operator

- 1 register\_name &= 0xFB;
- 2 0xFB can also be written as  $\sim (1 \ll 2)$



# Example of Masking with Shift Operator

- 1 register\_name &= 0xFB;
- 2 0xFB can also be written as  $\sim (1 \ll 2)$
- 3 In general, statement can be written as:

Register\_name &=  $\sim (1 \ll pin\_no)$



## Example of Masking with Shift Operator

❶ `register_name &= 0xFB;`

❷ `0xFB` can also be written as `~(1 << 2)`

❸ In general, statement can be written as:

`Register_name &= ~(1 << pin_no)`

❹ For resetting multiple bits at once the statement can be written as:

`Register_name &= ~((1 << pin_no1) | (1 << pin_no2))`



# LED Example with Masking

- 1 Configure PB.5 pin as Output.

```
DDRB |= (1 << 5);
```

- 2 To turn ON the LED set PB.5 output HIGH

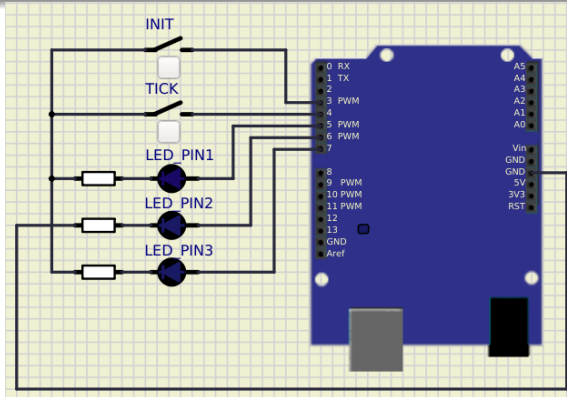
```
PORTB |= (1 << 5);
```

- 3 To turn OFF the LED set PB.5 output LOW

```
PORTB &= ~ (1 << 5);
```



## 3 Bit Counter



- ❶ Initial – Into non-counting mode
- ❷ INIT – Goes into counting mode
- ❸ TICK – At every Tick counter increments
- ❹ Once counter reaches 7 – Goes back to non-counting mode



# EXOR Operator

- ① Purpose: To TOGGLE particular bit.



# EXOR Operator

- 1 Purpose: To TOGGLE particular bit.
- 2 Symbol: ^



# EXOR Operator

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- 3 Truth Table:

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





# EXOR Operator

- 1 Purpose: To TOGGLE particular bit.
- 2 Symbol: ^
- 3 Truth Table:

A	B	Output
0	0	0
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1	0	1
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- ❷ Symbol: ^
- ❸ Truth Table:

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

- ❹ For one bit:  
 $\text{Register\_name} \wedge = (1 \ll \text{pin\_no})$



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- 1 Purpose: To TOGGLE particular bit.
- 2 Symbol: ^
- 3 Truth Table:

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

- 4 For one bit:  
 $\text{Register\_name} \wedge = (1 \ll \text{pin\_no})$
- 5 For toggling multiple bits:  
 $\text{Register\_name} \wedge = ( (1 \ll \text{pin\_no1}) | (1 \ll \text{pin\_no2}) )$



# Thank You!

Post your queries on: [support@e-yantra.org](mailto:support@e-yantra.org)

