

GPIO

(General Purpose Inputs Outputs)

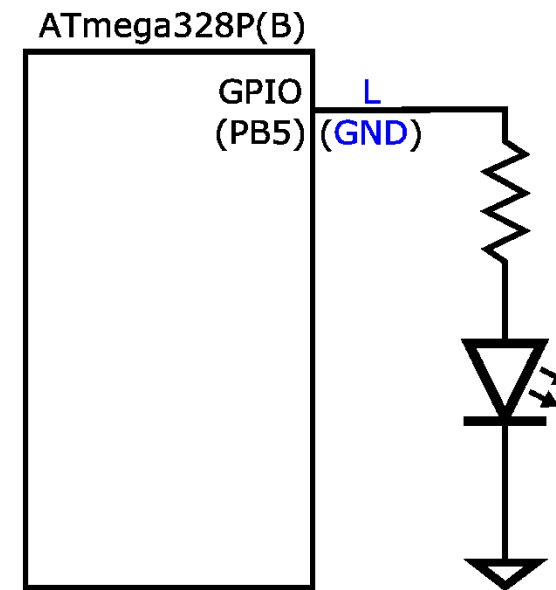
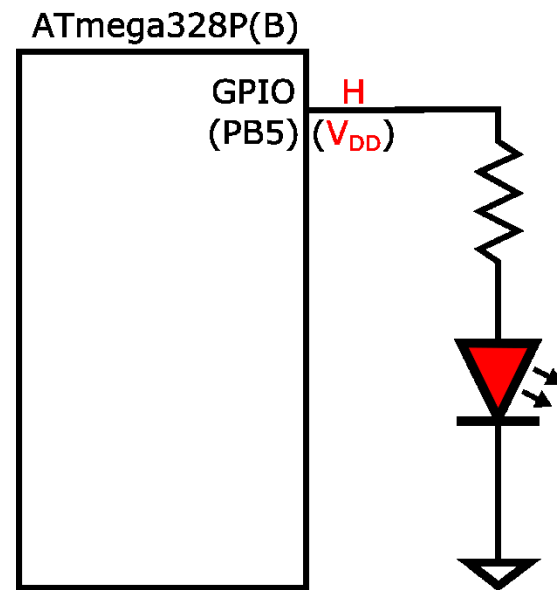
GPIO (General Purpose Input Output)

- General Purpose Input Output

- Is used for input or output **binary** data from/to a device whose communication protocol is not standard.
- Each port pin can be individually selectable for input or output mode.
- All port pins have individually selectable pull-up resistors with a supply-voltage invariant resistance.

GPIO (General Purpose Input Output)

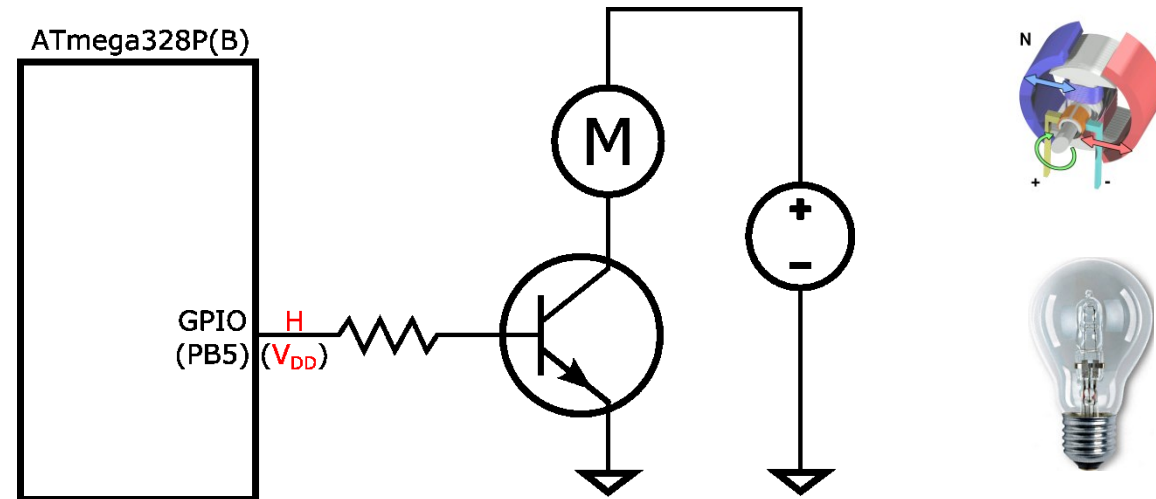
- General Purpose **Output** is used
 - to control a device whose function is controlled by binary value, i.e. '0' or '1'.
 - Examples: small dc power devices – Turn on/off **LEDs**



GPIO (General Purpose Input Output)

- General Purpose **Output** Example

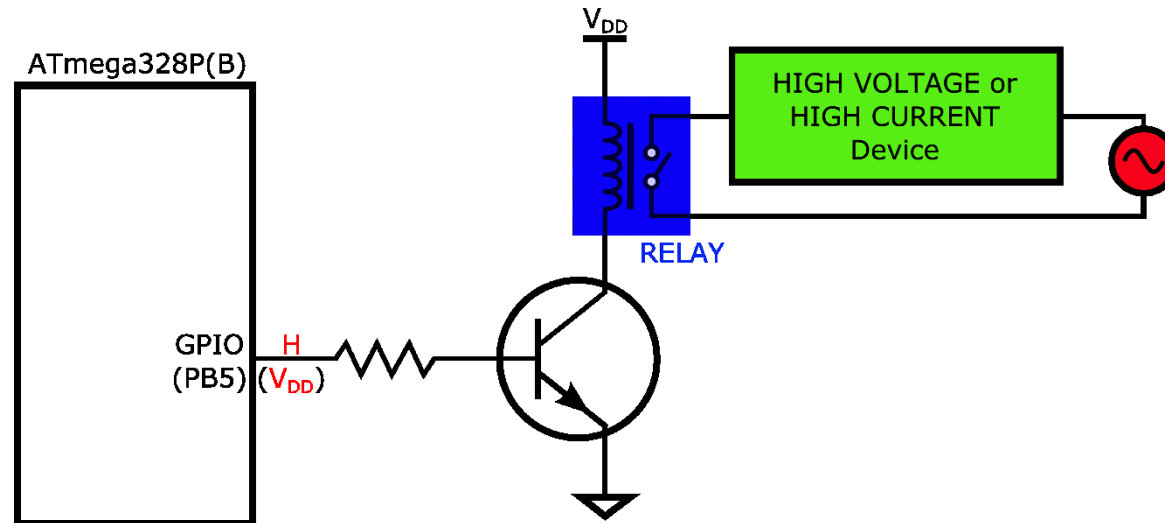
- to control a device whose function is controlled by binary value, i.e. '0' or '1'.
- Example: medium or high dc power devices - Turn on/off **motors or lamps**



GPIO (General Purpose Input Output)

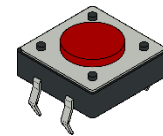
- General Purpose **Output** Example

- to control a device whose function is controlled by binary value, i.e. '0' or '1'.
- Example: low to high DC or AC power devices – Turn on/off **relays (heater, aircon)**

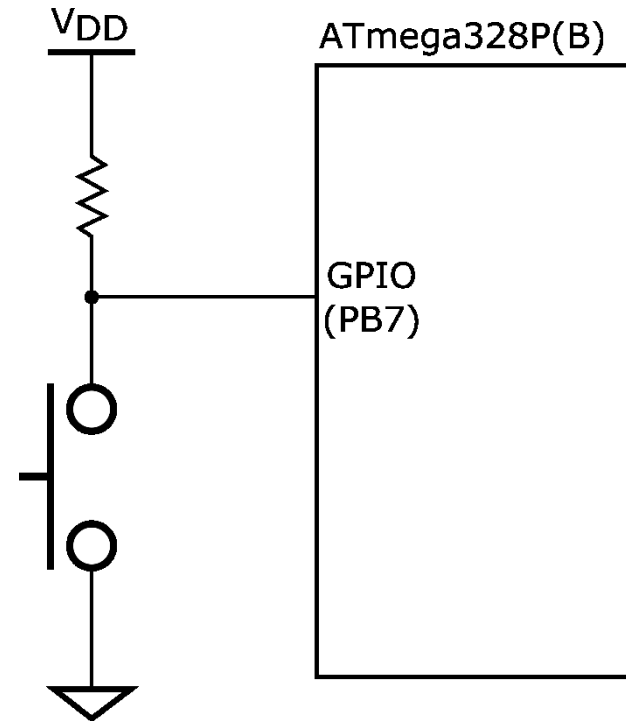


GPIO (General Purpose Input Output)

- General Purpose **Input** is used
 - to accept signal from a device whose output is binary value, i.e. '0' or '1'.
 - Examples: switches

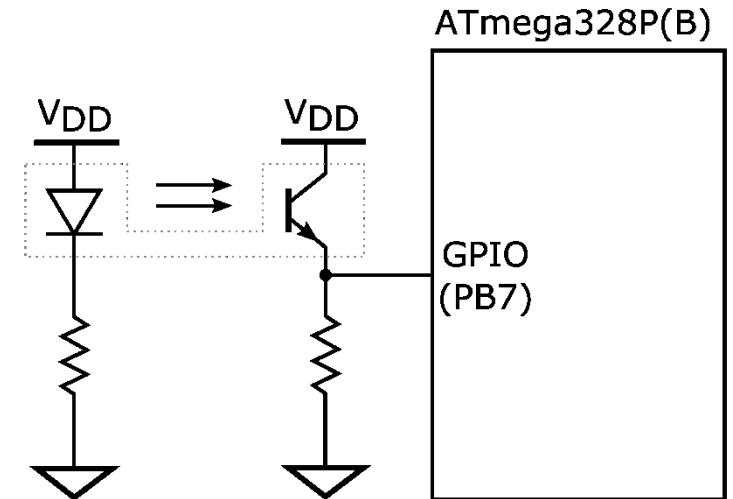
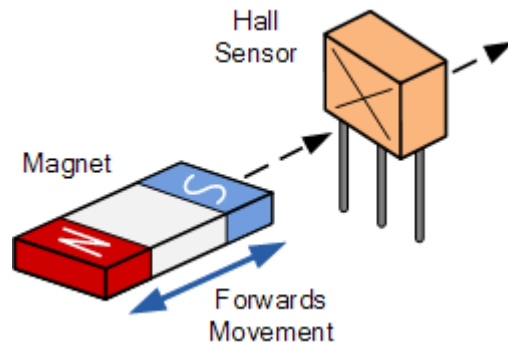


Switch



GPIO (General Purpose Input Output)

- General Purpose **Input** is used
 - to accept signal from a device whose output is binary value, i.e. '0' or '1'.
 - Examples: Hall-effect sensor, ultra-sonic sensor



GPIO (General Purpose Input Output)

- GPIO Registers

- **DDRx** register

- Data direction of GPIO pins

- **PORTx** register

- Output data value

- **PINx** register

- Input data value

GPIO (General Purpose Input Output)

DDR_x

x: Port name

DDRB, DDRC, DDRD

DDRB

Bit No.	7	6	5	4	3	2	1	0
Name	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0
Reset Value	0	0	0	0	0	0	0	0

➤ Determines data direction of GPIO pins

- 1 → Output
- 0 → Input

Example: Port B

- Bit 5 and 3: output
- Remaining bits: input

```
DDRB = 0b00101000;
```

Bit No.	7	6	5	4	3	2	1	0
Name	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0
Value	0	0	1	0	1	0	0	0

GPIO (General Purpose Input Output)

PORTx

x: Port name

PORTB, PORTC, PORTD

PORTB

Bit No.	7	6	5	4	3	2	1	0
Name	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0
Reset Value	0	0	0	0	0	0	0	0

➤ Holds output data value of GPIO pins

- 1 → High (V_{dd})
- 0 → Low (GND)

Example: Port B

- Bit 5: High, Bit 3: Low
- Remaining bits: input

```
PORTB = 0b00100000;
```

Bit No.	7	6	5	4	3	2	1	0
Name	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0
Value	0	0	1	0	0	0	0	0

GPIO (General Purpose Input Output)

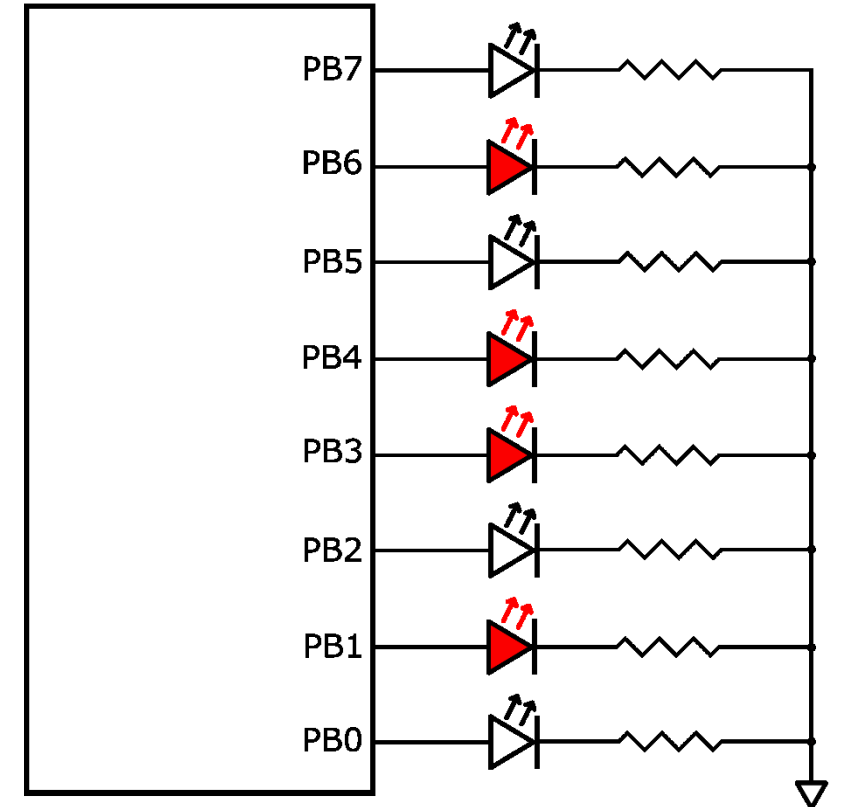
Example: Port B

- Turn on LEDs at PB6, PB4, PB3 and PB1
- Turn off LEDs at the remaining bits

```
PORTB = 0b01011010;
```

Bit No.	7	6	5	4	3	2	1	0
Name	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0
Value	0	1	0	1	1	0	1	0

ATmega328P



GPIO (General Purpose Input Output)

PINx Registers

x: Port name

PINB, PINC, PIND

Bit No.	7	6	5	4	3	2	1	0
Name	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0
Reset Value	0	0	0	0	0	0	0	0

- Used to read **input data** value of GPIO pins
 - High (V_{dd}) → 1
 - Low (GND) → 0

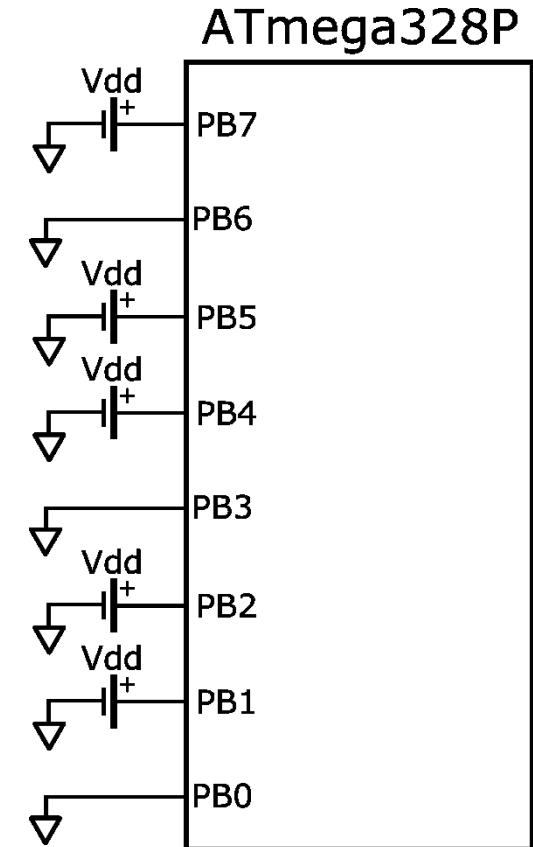
GPIO (General Purpose Input Output)

Example: PINB register value

- Assume that all bits of Port B are input mode.
- PINB register value for the right-hand side circuit is

PINB == 0b10110110

Bit No.	7	6	5	4	3	2	1	0
Name	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0
Value	1	0	1	1	0	1	1	0



GPIO (General Purpose Input Output)

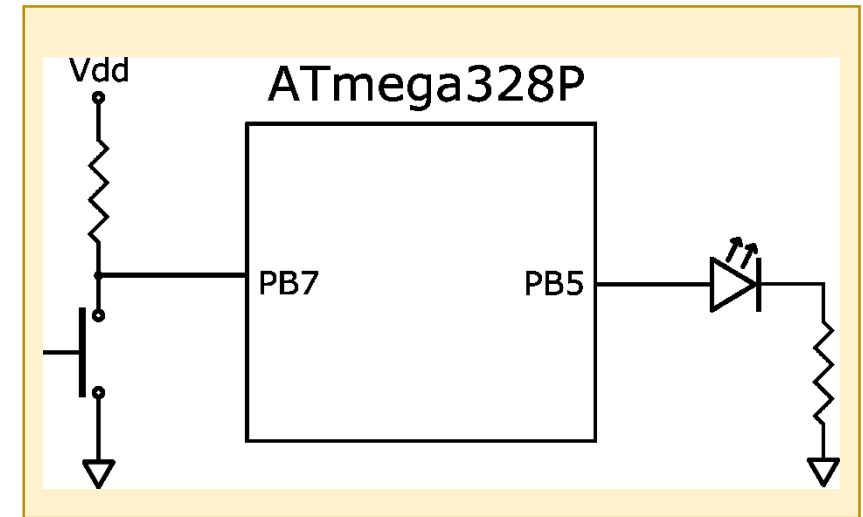
Example: **DDRB**, **PORTB** and **PINB** registers

- Turn on LED at PB5 while a switch at PB7 is pressed (on).

```
#include <avr/io.h>

int main(void)
{
    DDRB = 0b00100000;           // set PB5 as OUTPUT mode

    while (1)
    {
        if ((PINB & 0b10000000) == 0) // if switch at PB7 is pressed
            PORTB = 0b00100000;       // turn ON LED at PB5
        else                            // else
            PORTB = 0b00000000;       // turn OFF LED at PB5
    }
}
```



GPIO (General Purpose Input Output)

Example: **DDRB**, **PORTB** and **PINB** registers

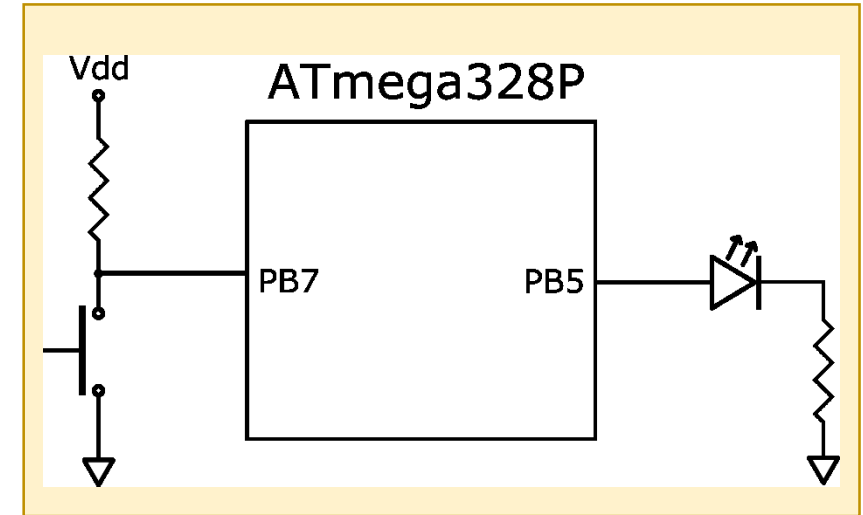
- Turn on LED at PB5 while a switch at PB7 is pressed (on).

```
#define SWITCH 7           // switch is connected at PB7
#define LED 5             // LED is connected at PB5

#include <avr/io.h>

int main(void)
{
    DDRB |= 1 << LED;      // set PB5 as OUTPUT mode

    while (1)
    {
        if ((PINB & (1 << SWITCH)) == 0) // if switch at PB7 is pressed
            PORTB |= 1 << LED;           // turn ON LED at PB5
        else
            PORTB &= ~(1 << LED);       // turn OFF LED at PB5
    }
}
```



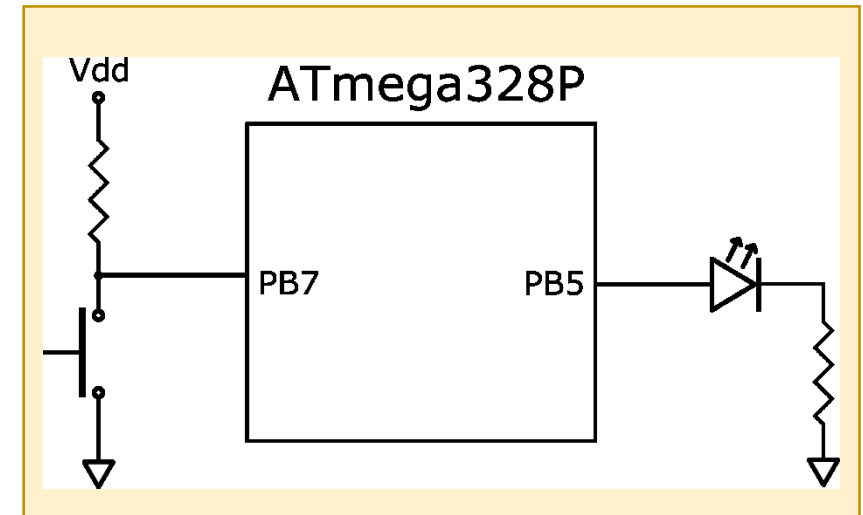
GPIO (General Purpose Input Output)

Example: **DDRB**, **PORTB** and **PINB** registers

- Toggle LED at PB5 whenever a switch at PB7 is pressed.

```
// toggle by XOR with '1'
#include <avr/io.h>
int main(void)
{
    DDRB |= (1 << 5);           // set PB5 as OUTPUT mode

    while (1)
    {
        if (!(PINB & (1 << 7))) // if switch at PB7 is pressed
        {
            PORTB ^= 1 << 5;    // toggle LED at PB5
            while (!(PINB & (1 << 7))); // wait until switch is released
        }
    }
}
```



GPIO (General Purpose Input Output)

PIN_x Registers (used to toggle)

x: Port name

PIN_B, PIN_C, PIN_D

- Used to **toggle** data in the PORT_x register
 - Writing '1' to PIN_{xn} → **toggle** n bit in the PORT_x register
 - Writing '0' to PIN_{xn} → no change in the PORT_x register

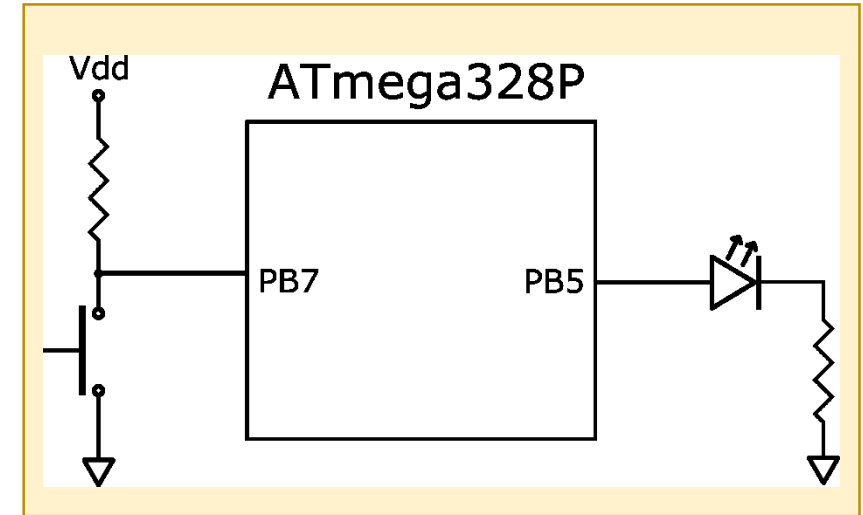
GPIO (General Purpose Input Output)

Example: **DDRB**, **PORTB** and **PINB** registers

- Toggle LED at PB5 whenever a switch at PB7 is pressed.

```
// toggle by writing '1' to PINB
#include <avr/io.h>
int main(void)
{
    DDRB |= (1 << 5);           // set PB5 as OUTPUT mode

    while (1)
    {
        if (!(PINB & (1 << 7))) // if switch at PB7 is pressed
        {
            PINB |= 1 << 5;     // toggle LED at PB5
            while (!(PINB & (1 << 7))); // wait until switch is released
        }
    }
}
```

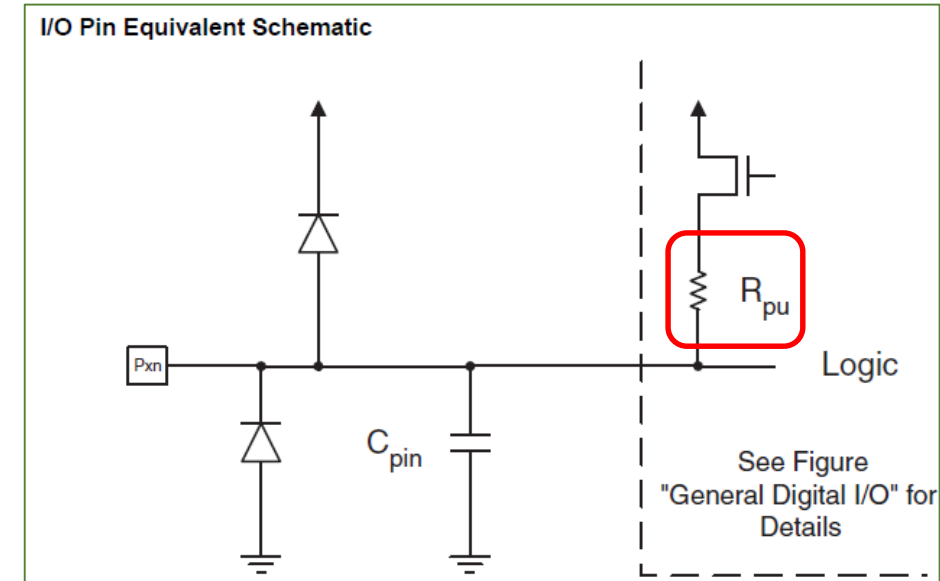


GPIO (General Purpose Input Output)

- Global pull-up control: **PUD** bit in **MCUCR** register
 - **0** → Pull-up **enable**
 - **1** → All pull-ups in the GPIO are **disabled**.

MCUCR

Bit No.	7	6	5	4	3	2	1	0
Name	-	BODS	BODSE	PUD	-	-	IVSEL	IVCE
Reset Value	0	0	0	0	0	0	0	0



- Individual pull-up control: each bit in **PORTx** register for input mode
 - **1** → Pull-up **enable**
 - **0** → Pull-up in the GPIO pin is **disabled**.

GPIO (General Purpose Input Output)

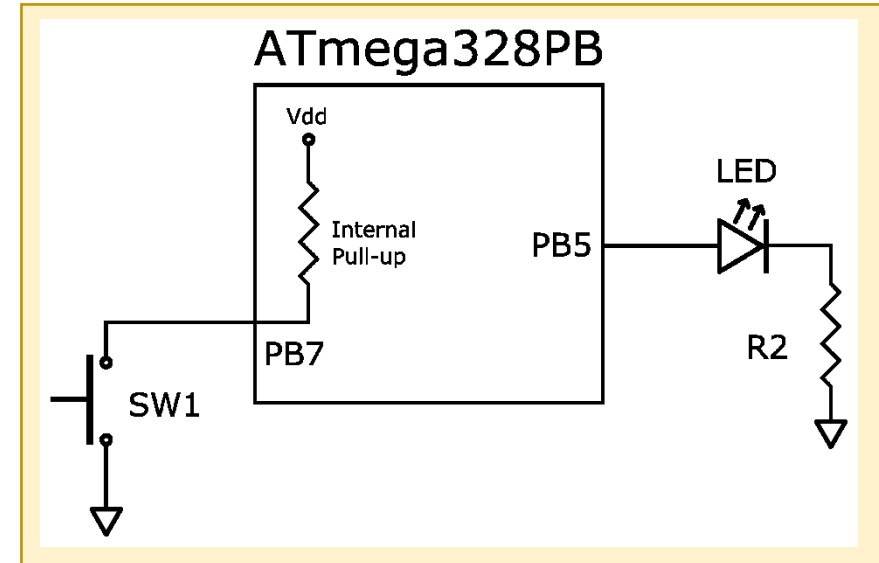
Example: DDRB, PORTB and PINB registers

- Turn on LED at PB5 while a switch at PB7 is pressed (on).
- External pull-up resistor was replaced by internal pull-up resistor.

```
#include <avr/io.h>

int main(void)
{
    DDRB = 0b00100000; // set PB5 as OUTPUT mode
    PORTB = 0b10000000; // enable Pull-Up at PB7

    while (1)
    {
        if ((PINB & 0b10000000) == 0) // if switch at PB7 is pressed
            PORTB = 0b10100000; // turn ON LED at PB5
        else // else
            PORTB = 0b10000000; // turn OFF LED at PB5
    }
}
```



atmega328p_gpio_input_output_internal_pull_up.png

GPIO (General Purpose Input Output)

- Symmetrical drive characteristics with both high sink and source capability.
 - $I_{OH\ max}$ = 20mA at VCC = 5V, 10mA at VCC = 3V
 - The sum of all IOH, for ports C0 - C5, D0- D4, ADC7, RESET should not exceed 150mA.
 - The sum of all IOH, for ports B0 - B5, D5 - D7, ADC6, XTAL1, XTAL2 should not exceed 150mA.
 - $I_{OL\ max}$ = 20mA at VCC = 5V, 10mA at VCC = 3V
 - The sum of all IOL, for ports C0 - C5, ADC7, ADC6 should not exceed 100mA.
 - The sum of all IOL, for ports B0 - B5, D5 - D7, XTAL1, XTAL2 should not exceed 100mA.
 - The sum of all IOL, for ports D0 - D4, RESET should not exceed 100mA.

GPIO (General Purpose Input Output)

ATmega328P GPIO Pin Driver Strength

Figure 35-22 ATmega328PB: I/O Pin Output Voltage vs. Sink Current ($V_{CC} = 3V$)

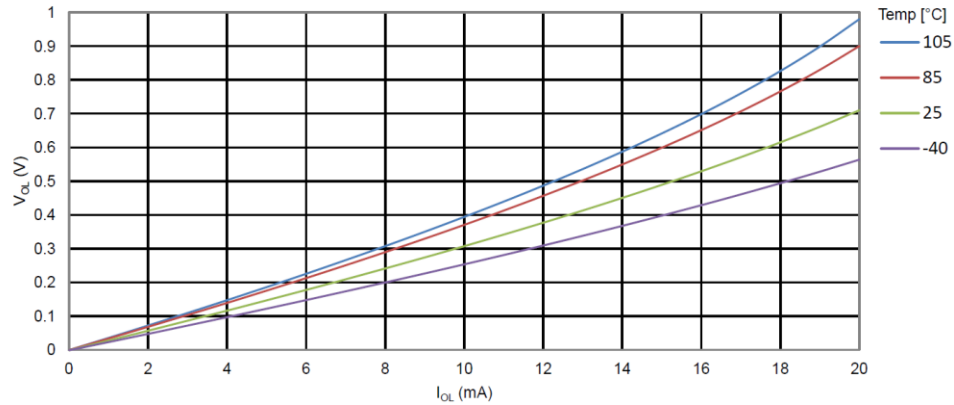


Figure 35-23 ATmega328PB: I/O Pin Output Voltage vs. Sink Current ($V_{CC} = 5V$)

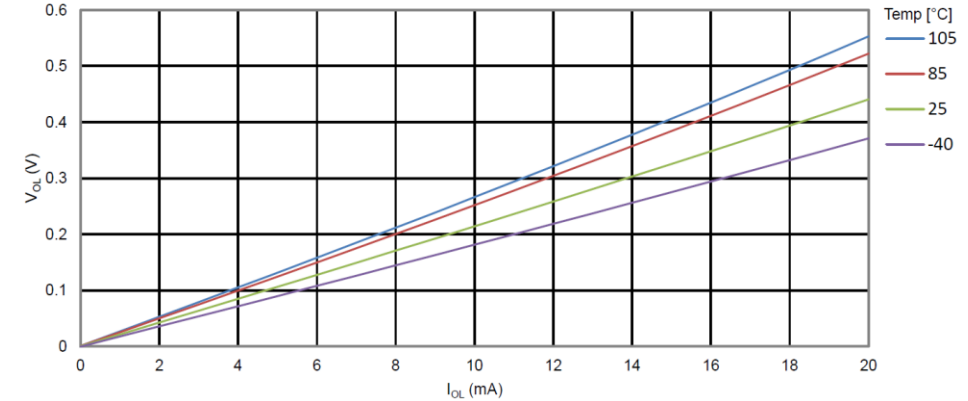


Figure 35-24 ATmega328PB: I/O Pin Output Voltage vs. Source Current ($V_{CC} = 3V$)

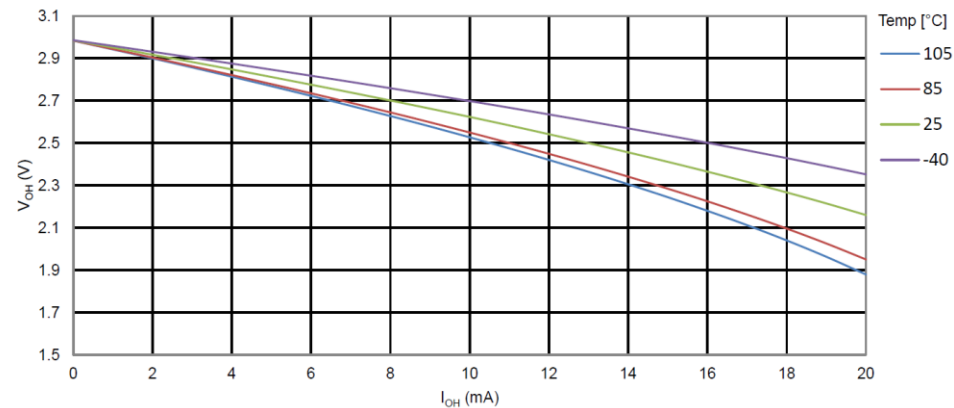
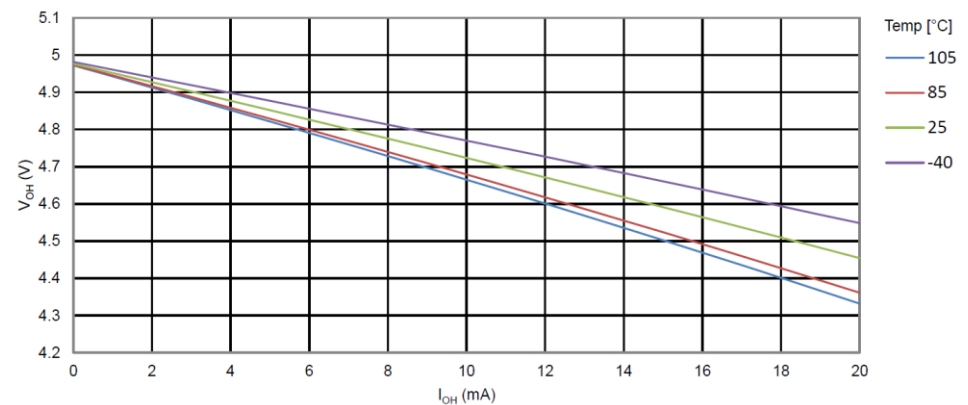


Figure 35-25 ATmega328PB: I/O Pin Output Voltage vs. Source Current ($V_{CC} = 5V$)



What's next?

