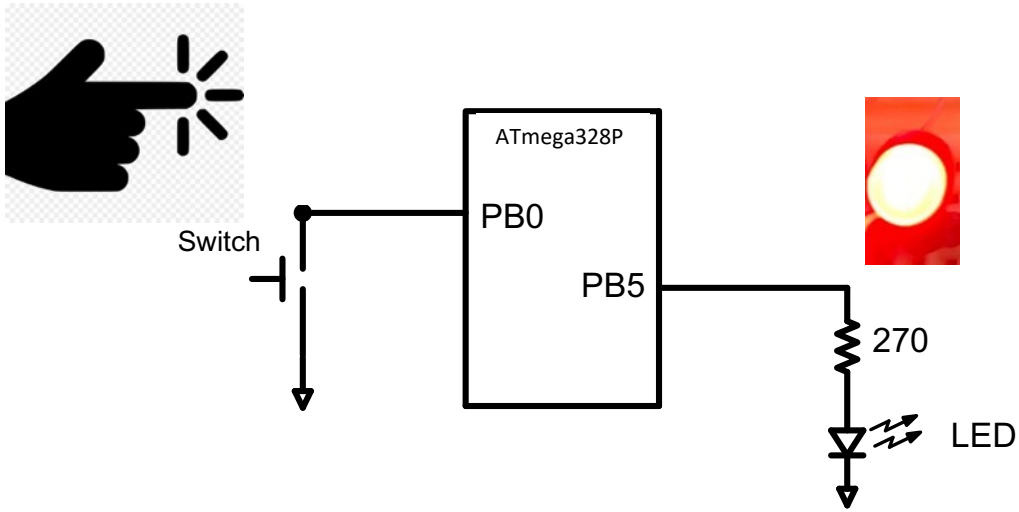
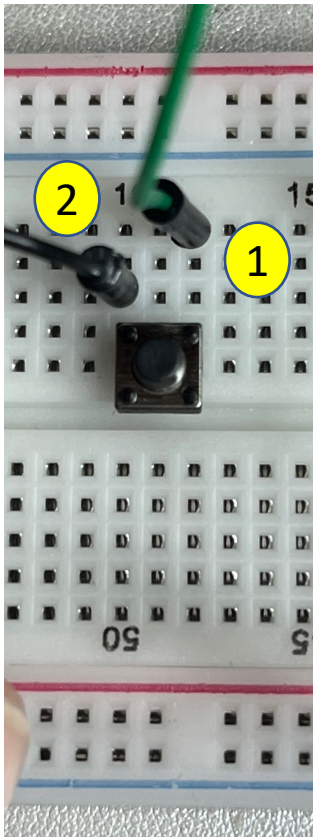
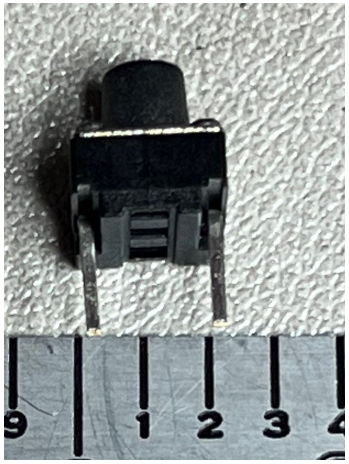
Lecture 8.4
button switches, LEDs, and GPIO Inputs



Prof. David McLaughlin
ECE Department
University of Massachusetts
Amherst, MA

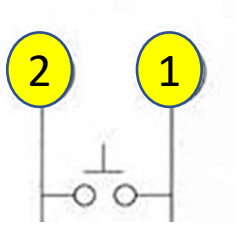
Momentary Push-Button Switch (2 pin)





pitch (pin spacing) is 0.2 inches or 5 mm.

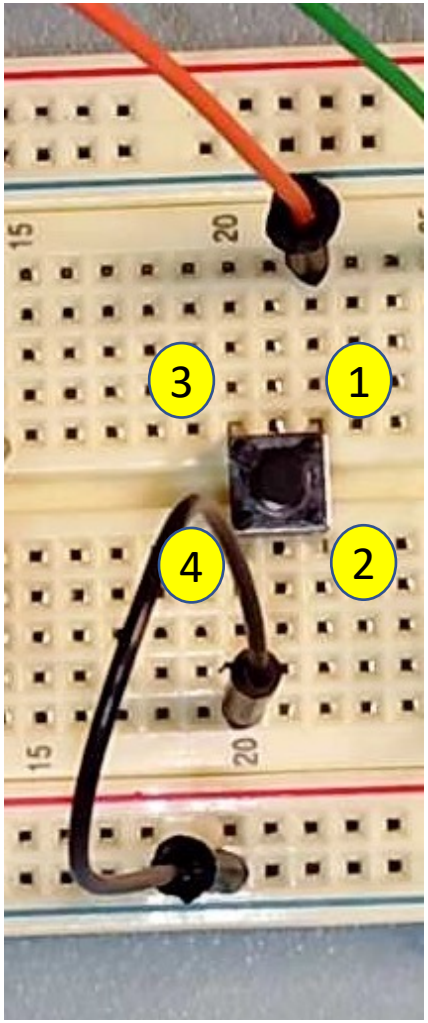
Too narrow to span the channel

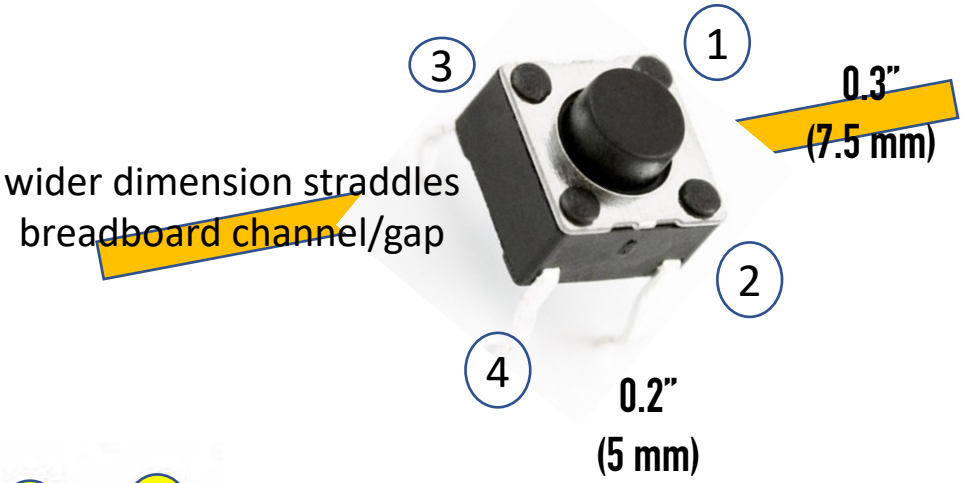


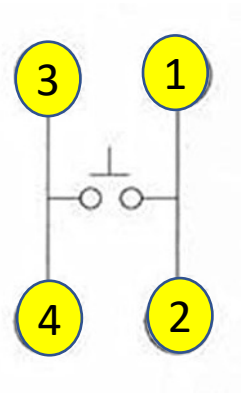
SPST (single-pole, single-throw) switch.

These 2-pin push-buttons are in the Eureak Leap ECE-231 kits Spring 2025
Marston 221 Parts Depot has 4-pin push-buttons.

Momentary Push-Button Switch (4 pin)



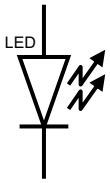


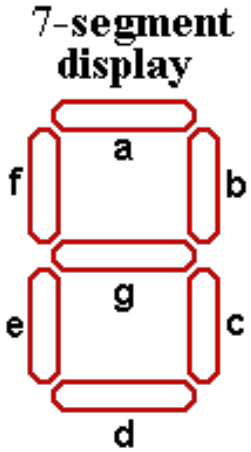


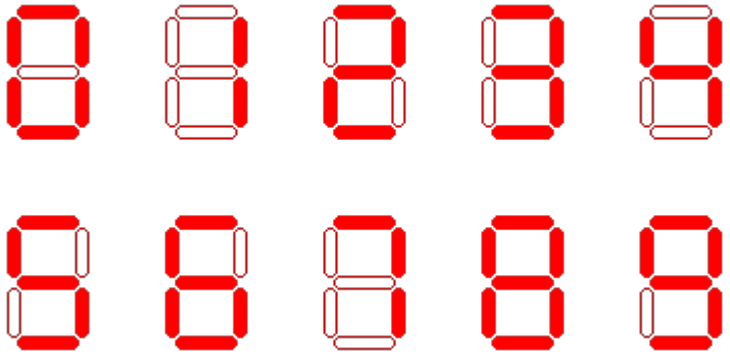
SPST (single-pole, single-throw) switch.

These 4-pin push-buttons are in the Marston 221 Parts Depot

LED Interfacing

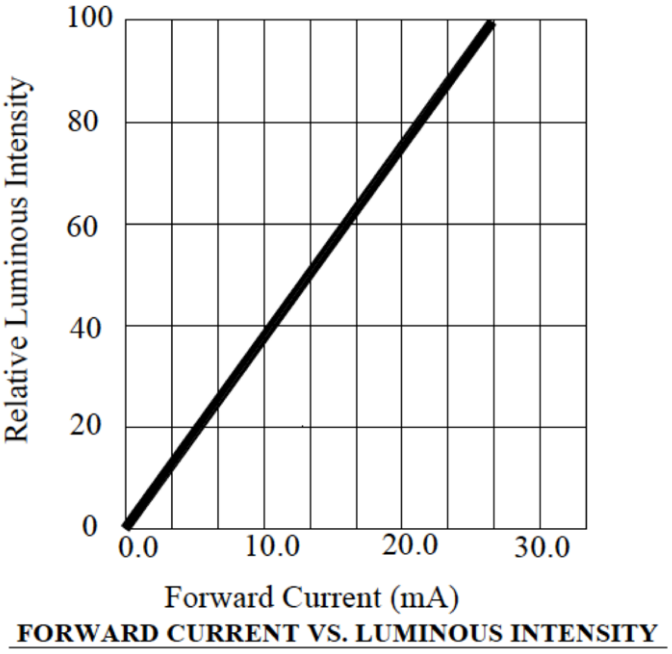




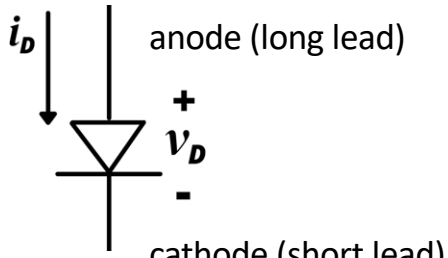


Get the polarity correct; use a current-limiting resistor

Light Emitting Diode (LED): brightness proportional to forward current
-- we consider here the LEDs in our kits --



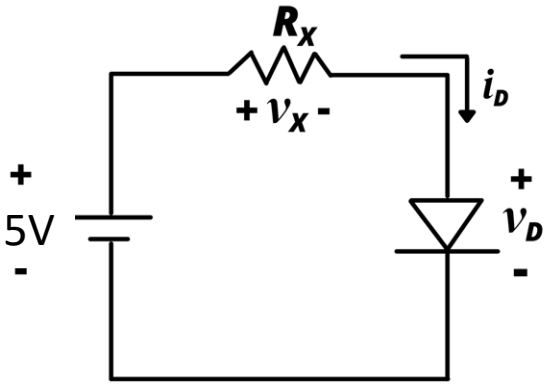
FORWARD CURRENT VS. LUMINOUS INTENSITY



forward voltage: v_D = 2V (depends on diode color)
forward current: i_d = 30 mA , max

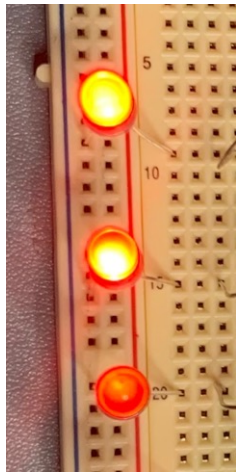
Want to know more about diodes? See
http://openbooks.library.umass.edu/funee/chapter/4-1/

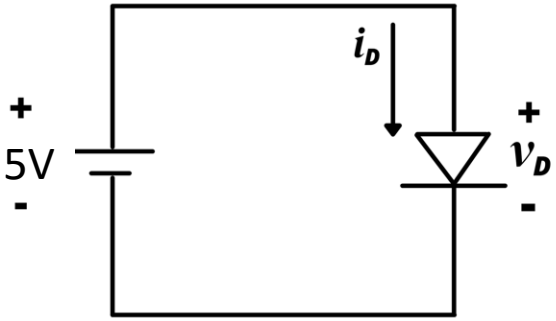
Use a current-limiting resistor to drive an LED



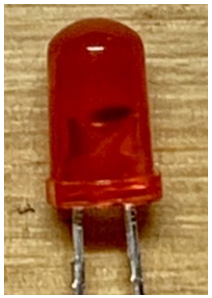
$-5 + v_x + v_D = 0$ (via Kirchoff's Voltage Law)
$-5 + i_D R_x + v_D = 0$ (via Ohm's Law)
$-5 + i_D R_x + 2 = 0$ (using $v_D = 2$ volts)
$i_D = 3/R_x$ (current is limited by resistance R_x)

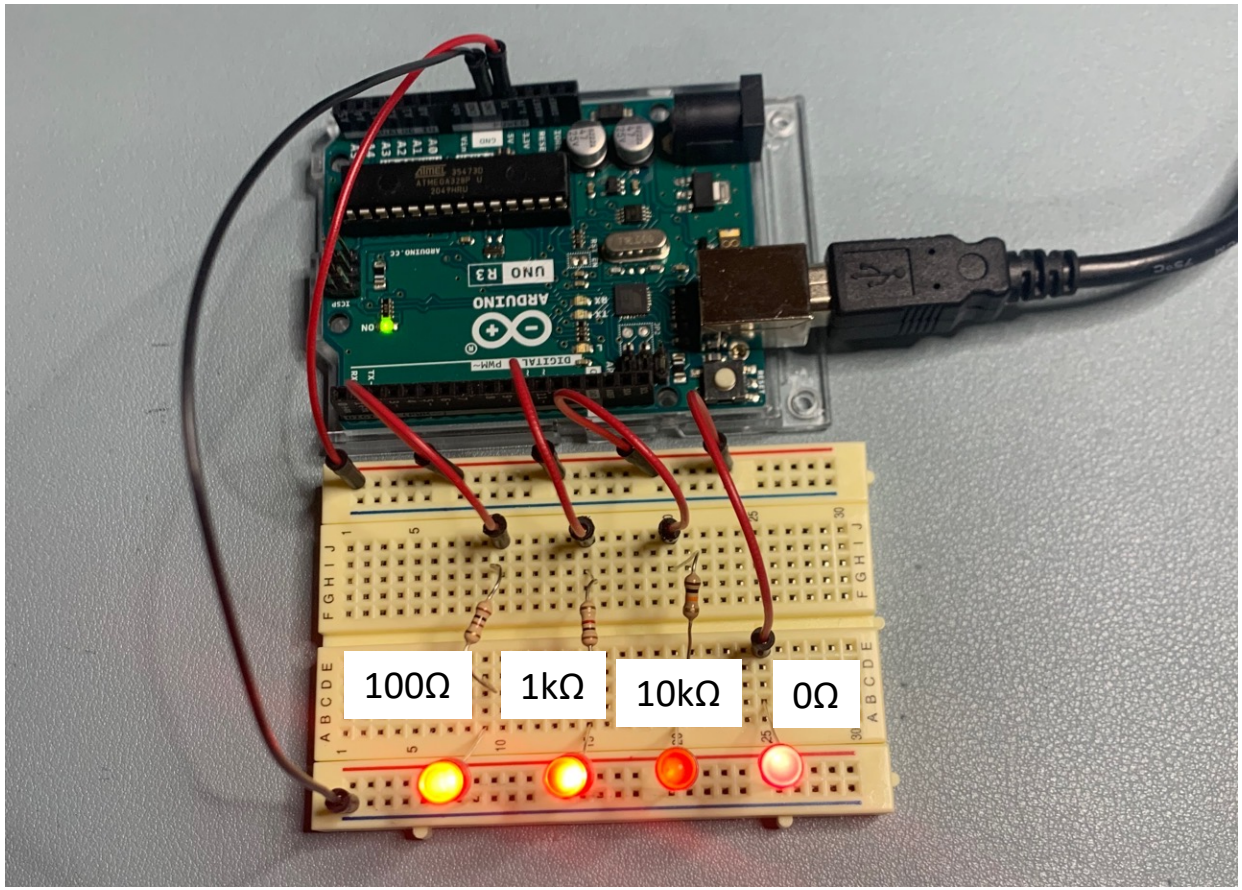
$R_x = 100\ \Omega \rightarrow i_d = 0.03$ A = 30 mA
$R_x = 1000\ \Omega = 1\text{k}\ \Omega \rightarrow i_d = 0.003$ A = 3 mA
$R_x = 10{,}000\ \Omega = 1\text{k}\ \Omega \rightarrow i_d = 0.0003$ A = 0.3 mA



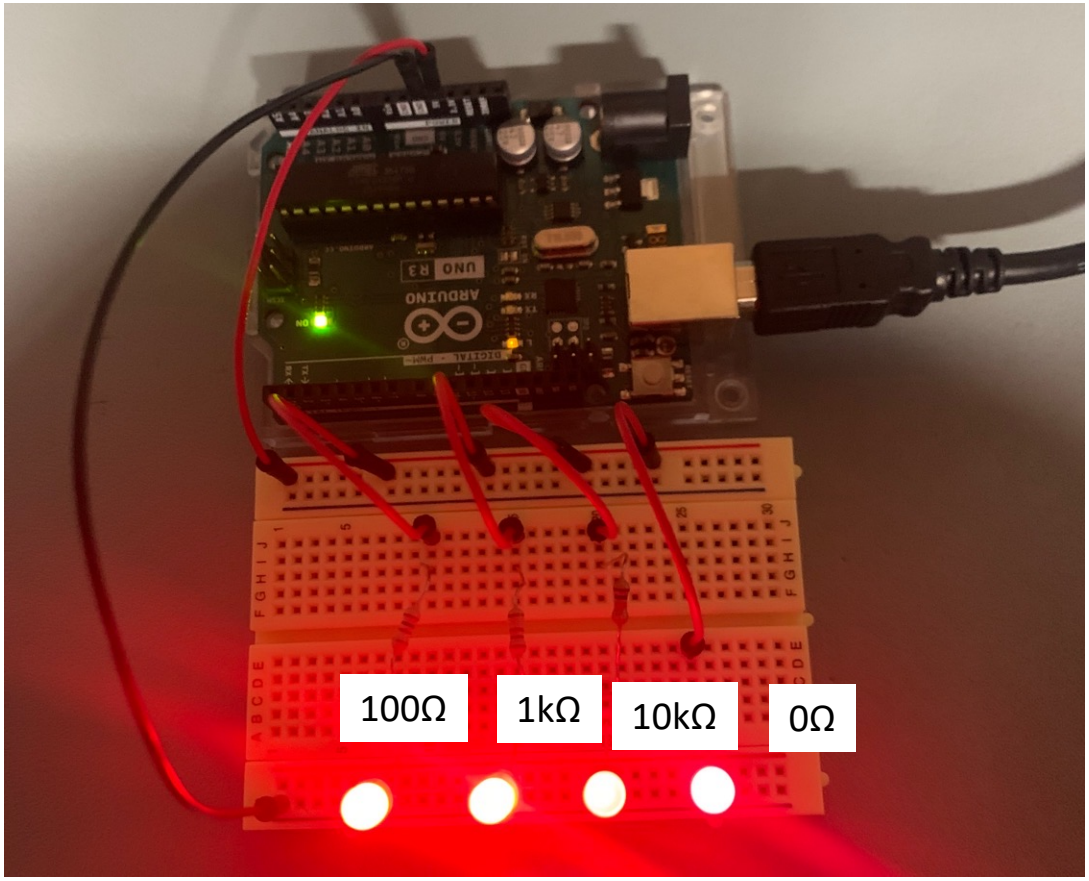


$R_x = 0\ \Omega \rightarrow i_d = \infty$ A
(limited by the max current from the power supply or by the resistance of the power supply & wires. In either case, the LED is damaged)



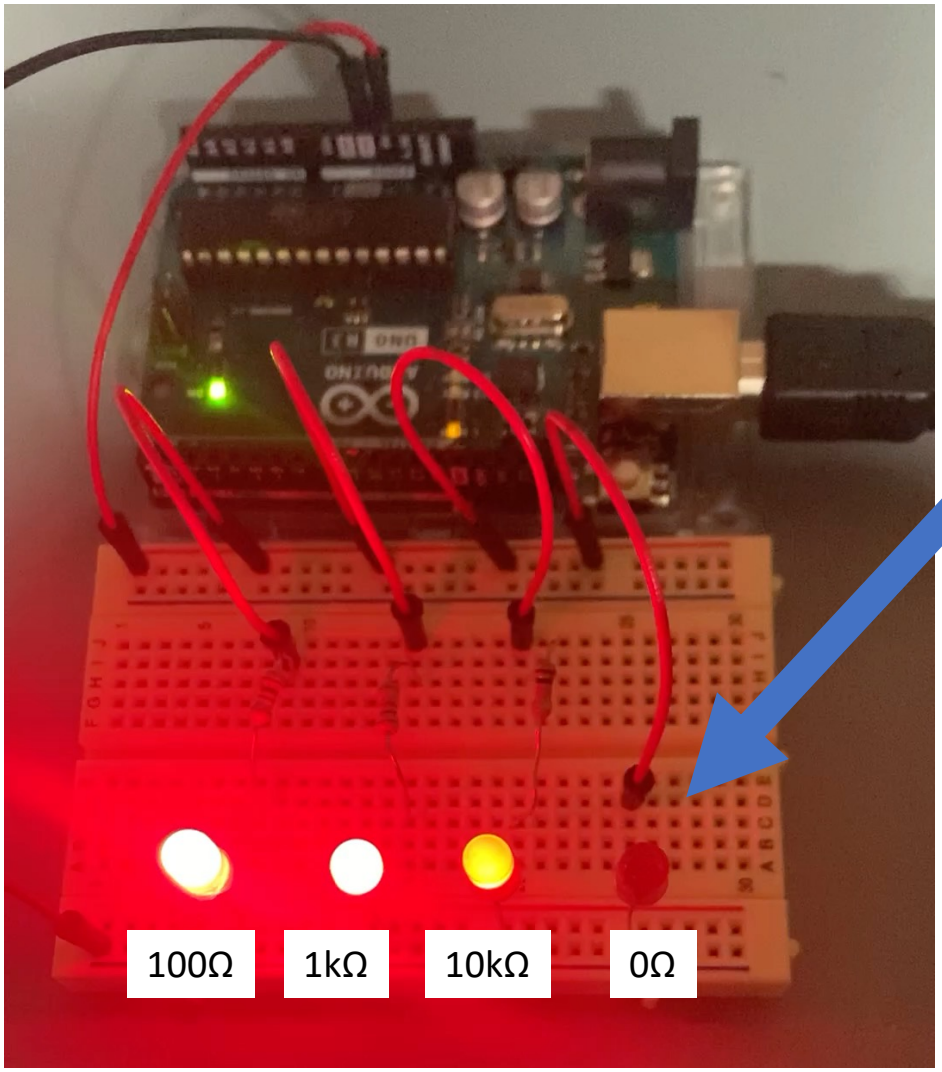


LED’s powered by the 5V output pin from Arduino Uno (200 mA max)



LED’s powered by the 5V output pin from Arduino Uno (200 mA max)

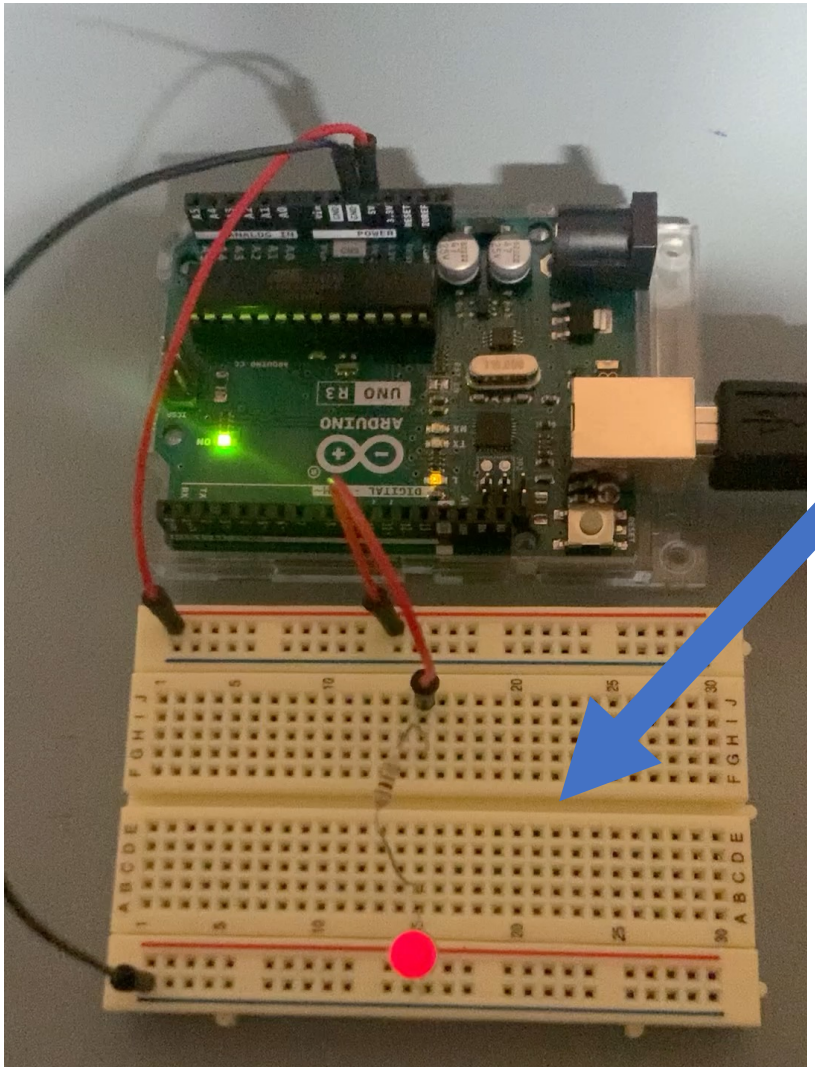
Room lights darkened; LEDS look much brighter.



Engineering Malpractice

This LED is damaged. It glows intermittently.

Suppose we return this damaged LED to our parts drawer and re-use it....



Re-using a damaged LED.

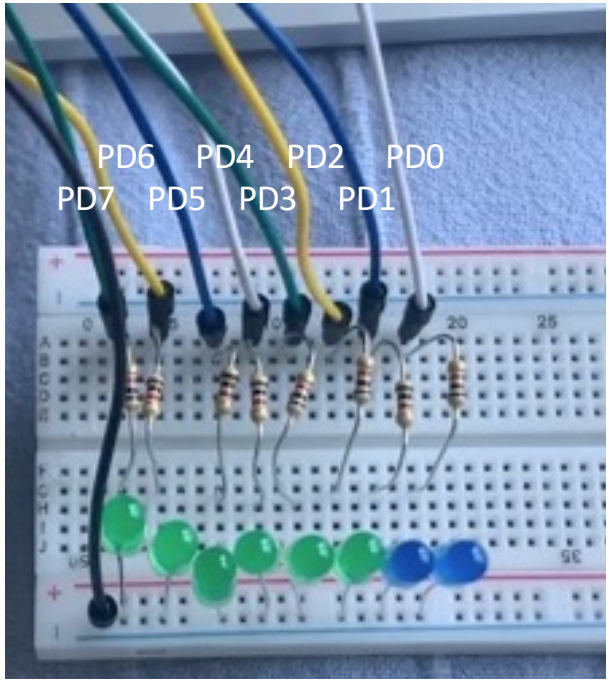
It should be on.
But it blinks intermittently.
Imagine using this damaged LED to diagnose an embedded system

8 bit binary counter

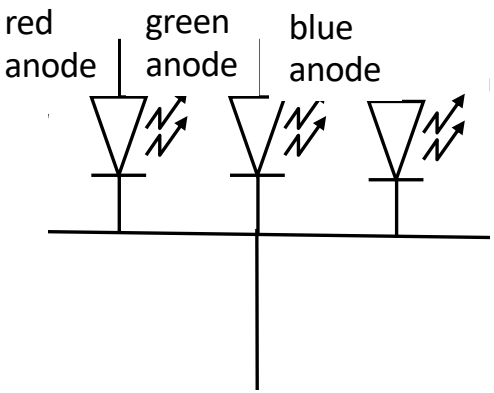
Note: your textbook typically has this line at the top of the code. This tells the compiler the frequency of the clock driving the ATmega328P. (The ATmega328P doesn't know time; it just counts CPU cycles.) We have the line -DF_CPU 16000000 in makefile that defines this.

```
 */

#define F_CPU 16000000UL
#include <util/delay.h>
#include <avr/io.h>

int main(void)
{
    unsigned char i=0;
    DDRD = 0xFF;
    while (1) {
        i++;
        PORTD=i;
        _delay_ms(100);

    }
}
```

8 LEDs connected to the pins of port D



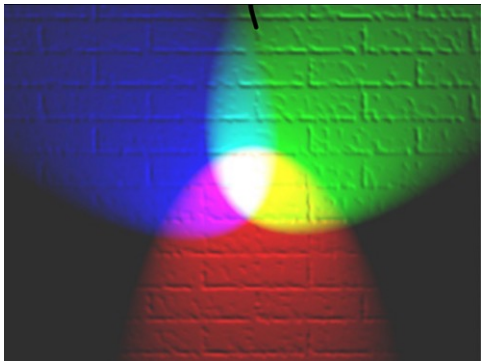
Common Cathode RGB LED



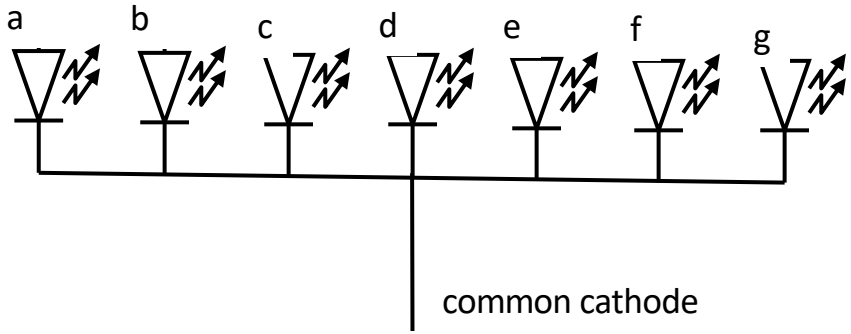
red, green, blue anodes (+)

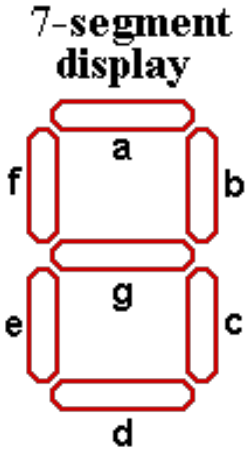
common cathode (-)

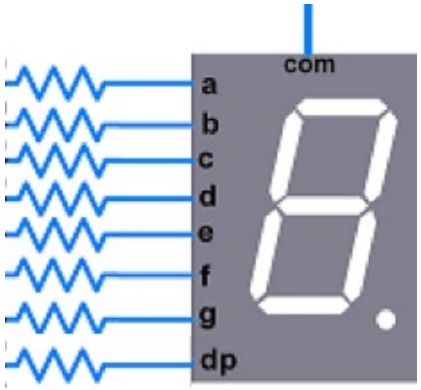
red + green = yellow
red + blue = magenta
green + blue = cyan
red + green + blue = white



Common Cathode 7 Segment LED



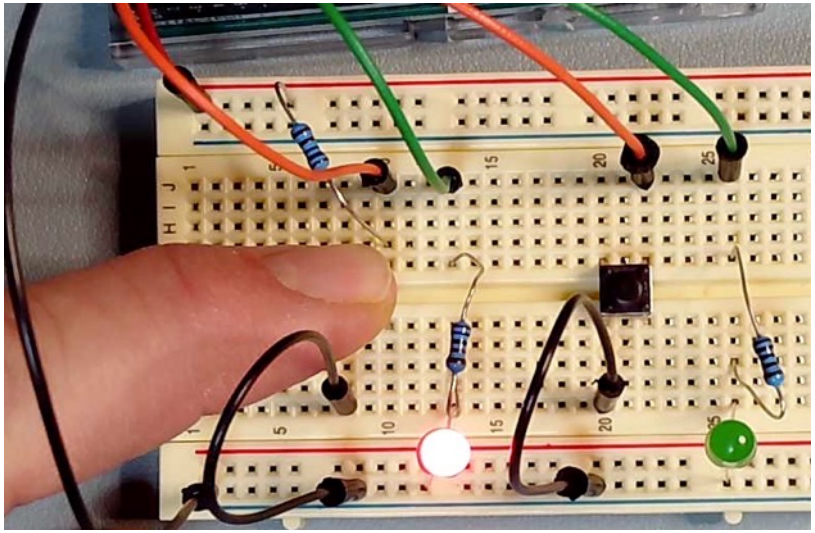




some also have a decimal point as an 8th segment

Turn on LEDs when buttons are pressed

left button→red LED
right button →green LED



The code for this app is included at the end of this deck of slides.

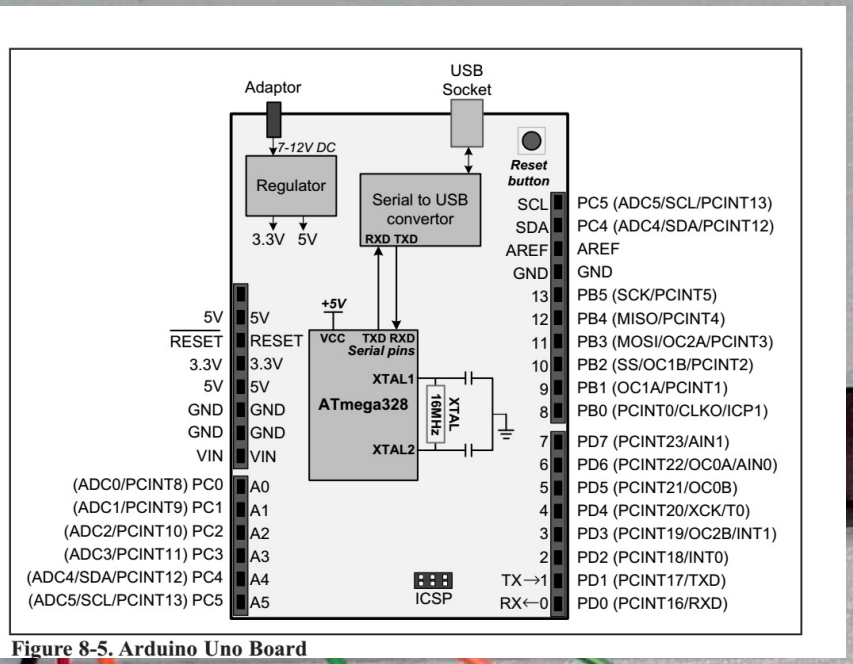
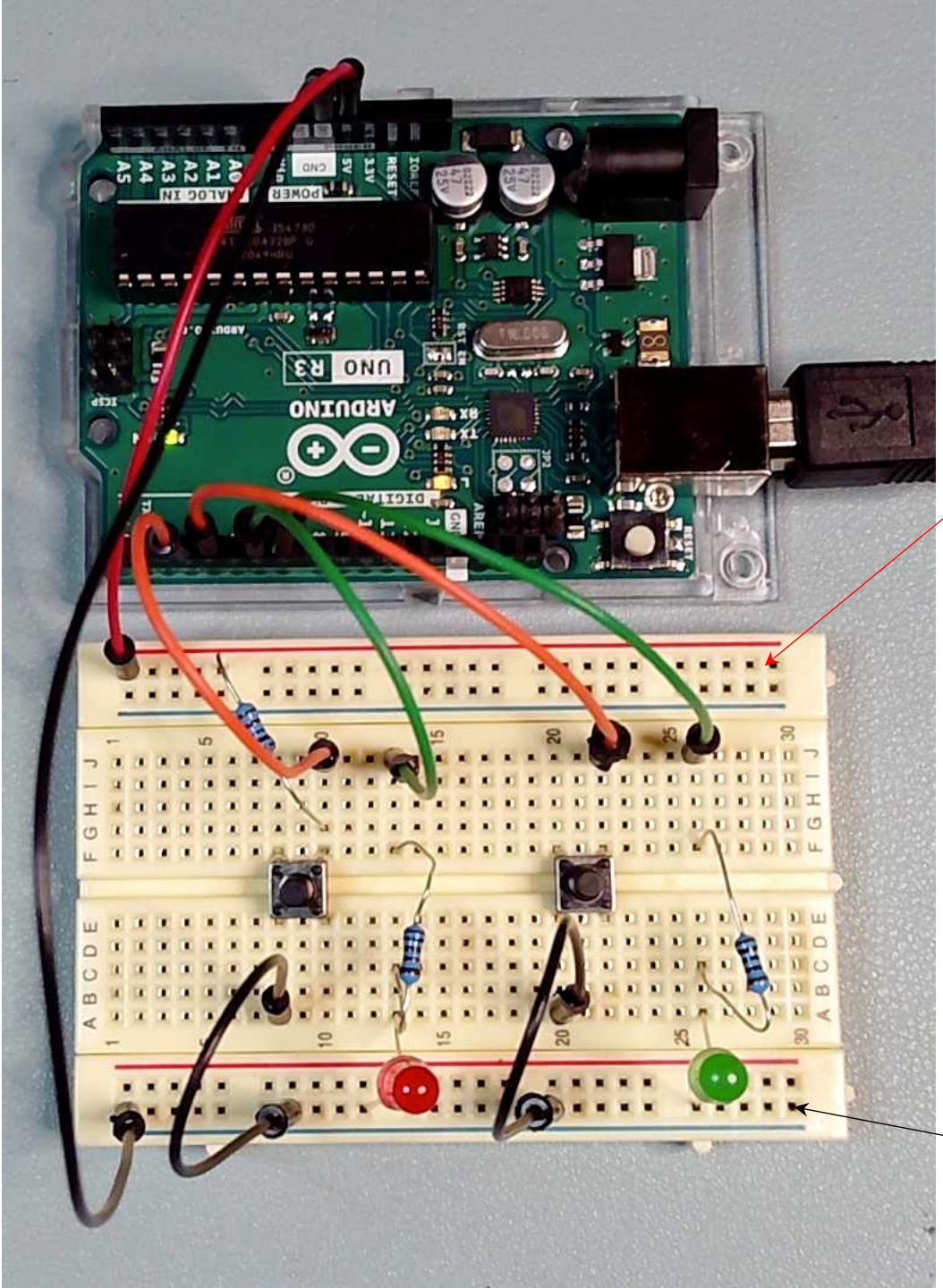
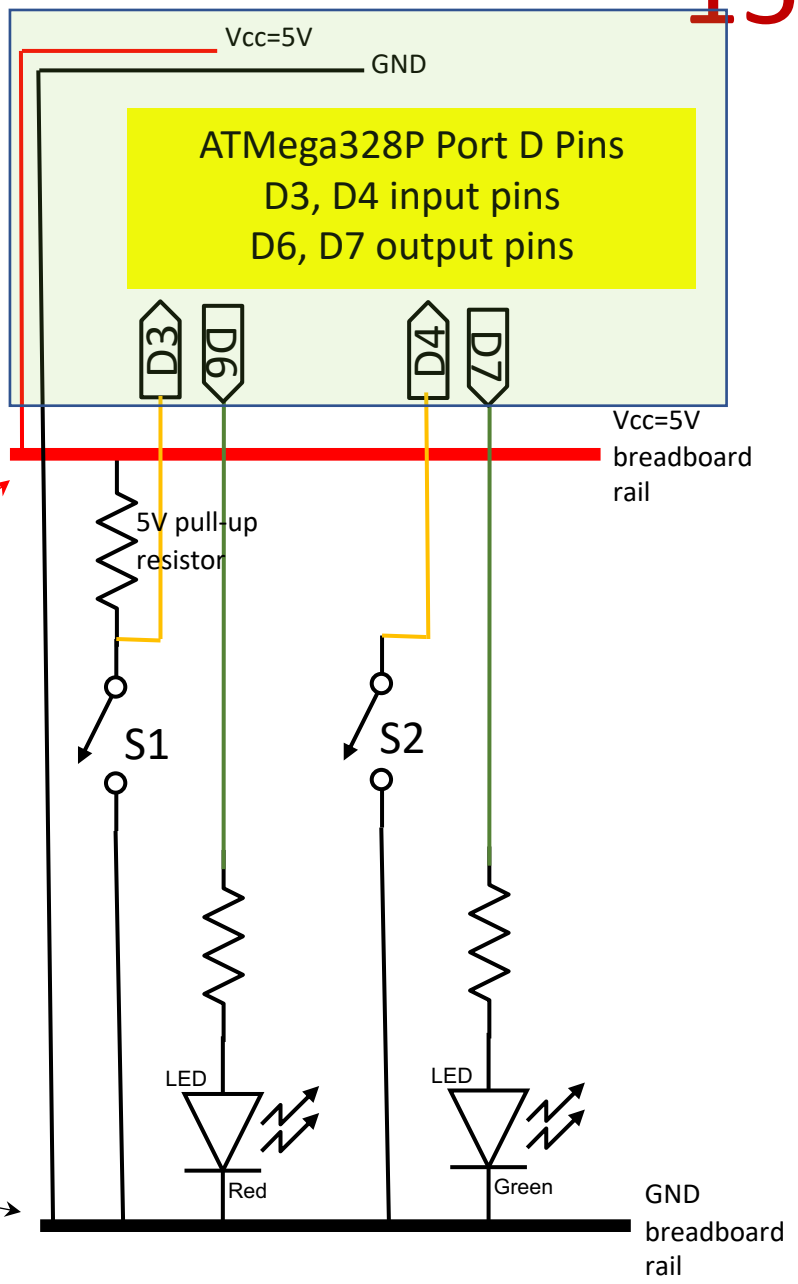


Figure 8-5. Arduino Uno Board


UNO R3
ARDUINO


Vcc=5V
GND
ATMega328P Port D Pins
D3, D4 input pins
D6, D7 output pins
D3
D6
D4
D7
Vcc=5V
breadboard
rail
5V pull-up
resistor
S1
S2
LED
Red
LED
Green
GND
breadboard
rail

Setting the pin direction:

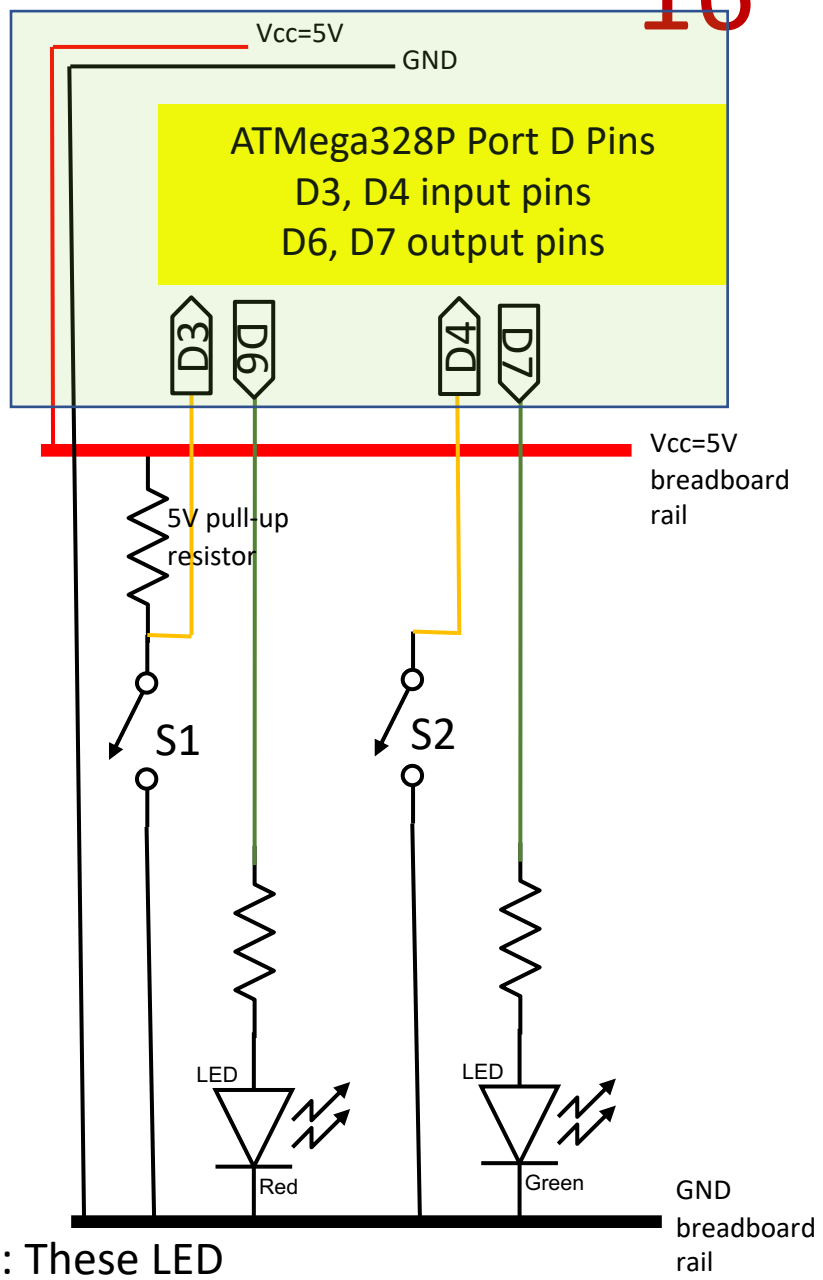
```
DDRD = 0x11000000;
     OR
DDRD = 1<<DDD6|1<<DDD7; //All others input
     OR
DDRD = 1<<6|1<<7;
```

Why does this work?
1<<6 = 0000 0001 << 6 = 0100 0000
1<<7 = 0000 0001 << 7 = 1000 0000
So, 1<<6|1<<7 = 1100 0000

Turn the LEDS on or off:

```
PORTD|= 1<<PORTD6; //D6 high;red LED on
PORTD &= ~(1<<PORTD6); //D6 low;red LED off
```

Why does this work?
~(1<<PORTD6) = ~(0000 0001 <<6)
= ~(0100 0000)
= 1011 1111
PORTD = PORTD & 1011 1111



Turn Green LED on & off similarly via PORTD7. NOTE: These LED instructions leave the other bits of PORTD alone!

Reading the input pins:
we will get to this in a few slides...

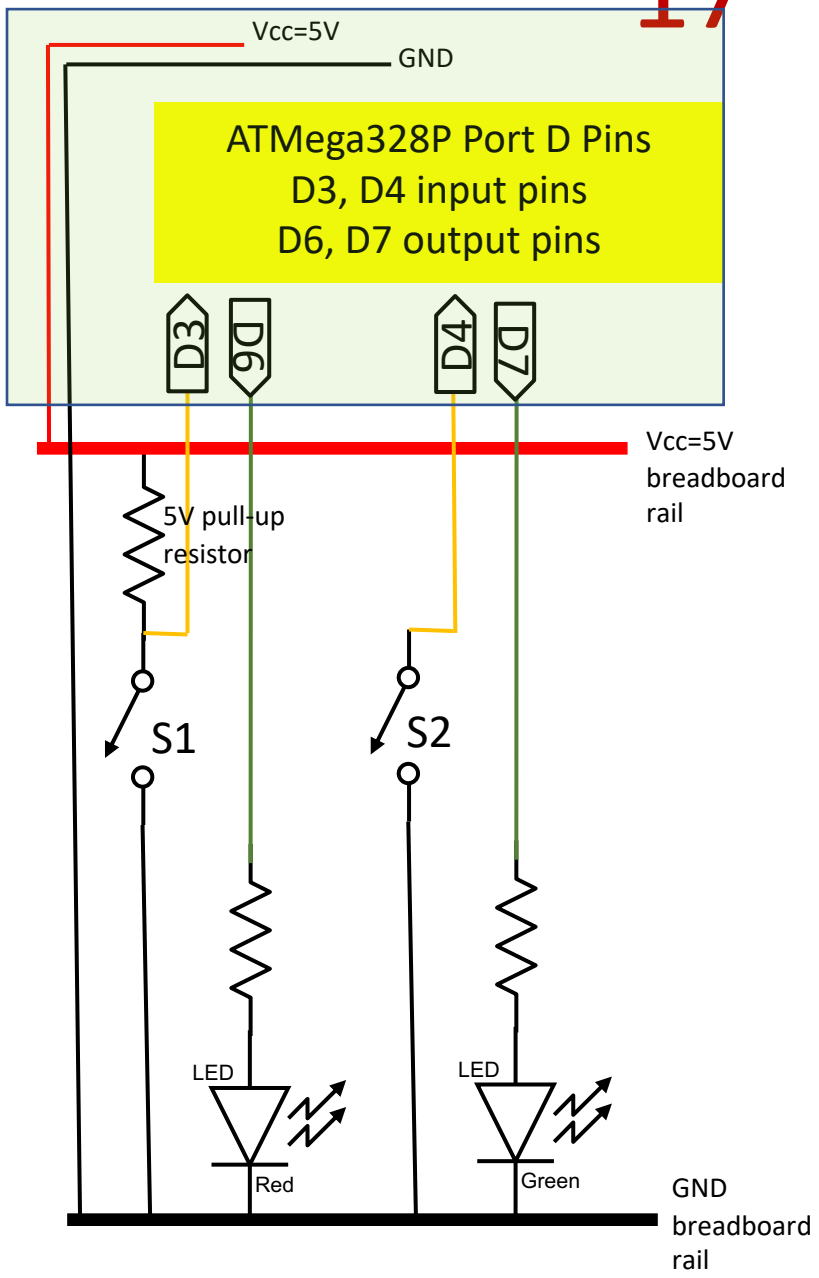
Switches, wires, voltages, and pin values
Let's see how the buttons make D3 & D4 high and low ...

S1	D3	S2	D4
Open	5V	Open	floating*
Closed	GND	Closed	GND

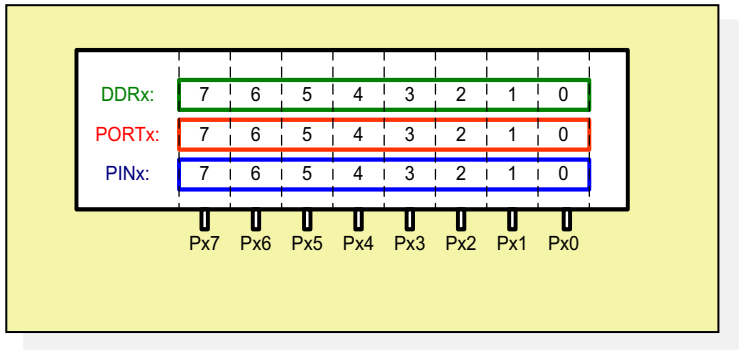
External pull-up resistor on S1 ensures that D3=5V when switch is open.

No exteral pull-up resistor on S2 means D6 is floating* when switch is open

* Depends on the input circuit for D4



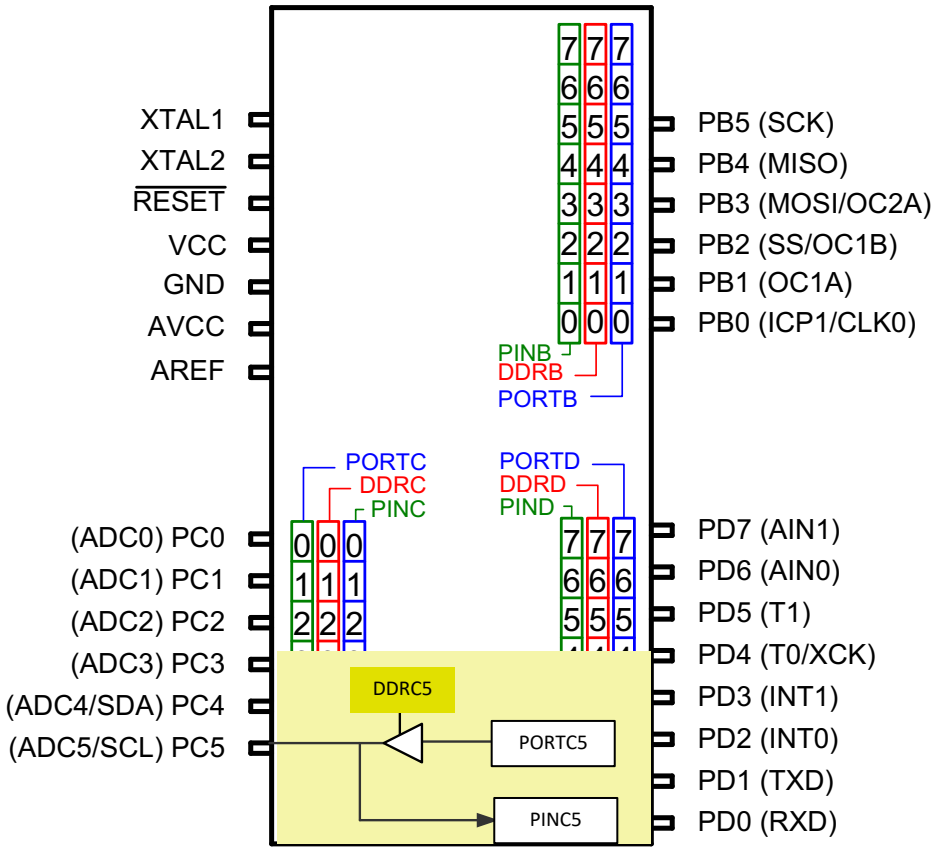
The structure of I/O pins & registers



we access the ports by writing to and reading from these registers.

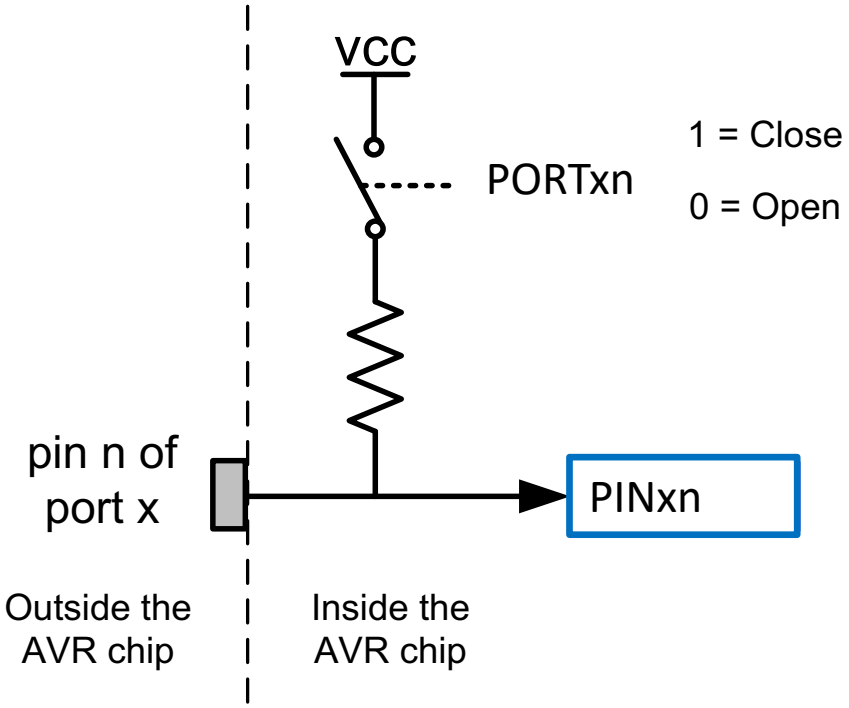
Example:

```
DDRB =  0xFF; //set as outputs
DDRB =  0x00; //set as inputs
PORTB = 0x00; //set pins low
input_value = PINC; //read pins
```

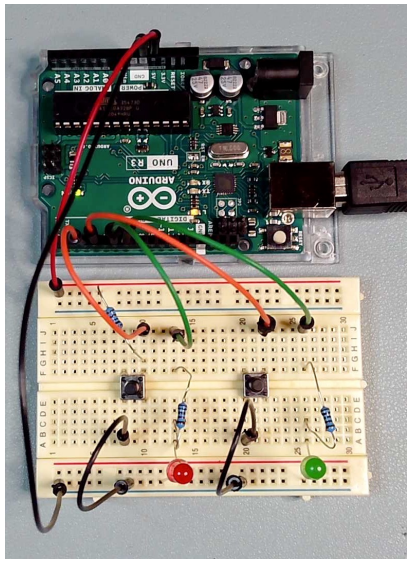


Input pins & pull-up resistors

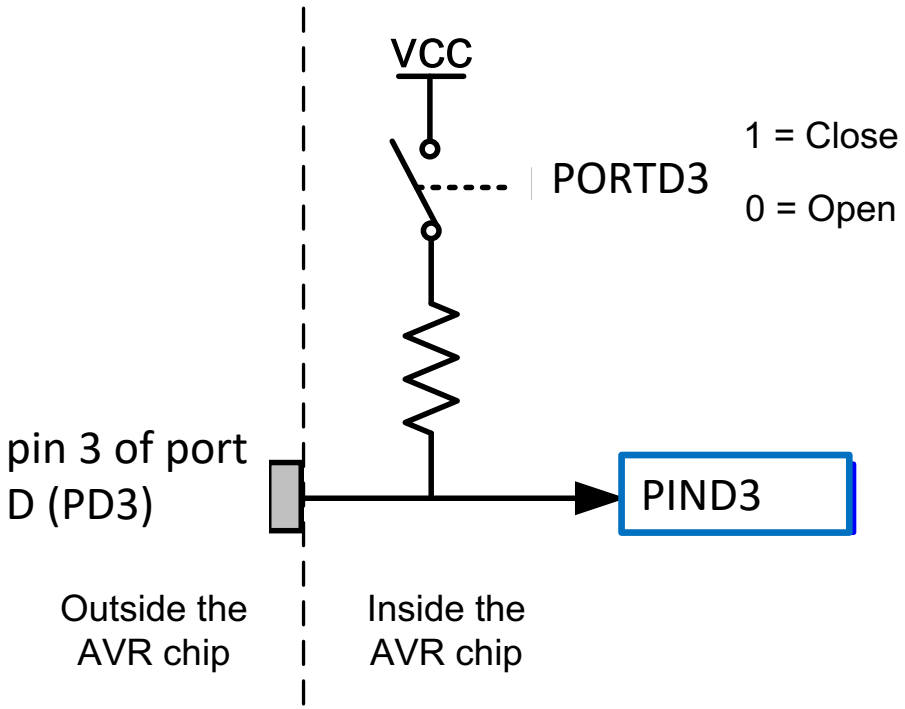
DDRXn =0 (pin set as input)		
PORTxn	Pxn (input voltage)	PINxn (input logic)
0, high Z	0V	0
0, high Z	5V	1
0, high Z	float	don't use
1, pullup	0V	0
1, pullup	5V	1
1, pullup	float	1



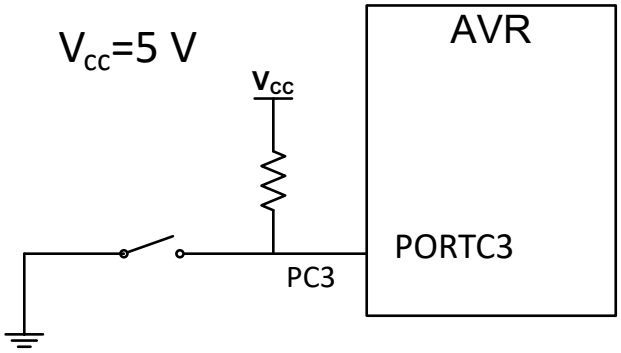
Example: Port D, pin 3



DDRD3 = 0 (pin set as input)		
PORTD3	PD3 (input voltage)	PIND3 (input logic)
0, high Z	0V	0
0, high Z	5V	1
0, high Z	float	don't use
1, pullup	0V	0
1, pullup	5V	1
1, pullup	float	1

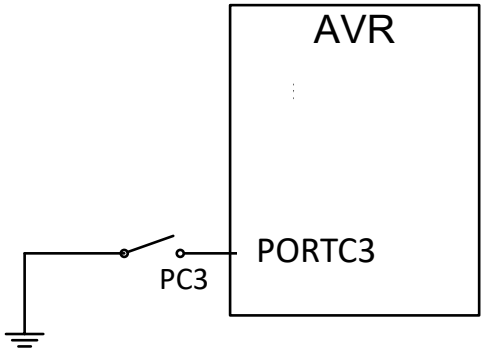


Momentary SPST switch input (1)



External Pull-up (DDRC3=0; PORTC3=0)

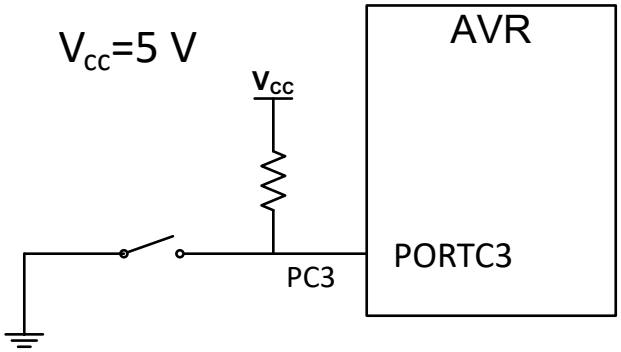
Switch Closed	PC3 = 0V	PINC3 = 0
Switch Open	PC3 = 5*V*	PINC3 = 1



No External Pull-up (DDRC3=0; PORTC3=0)

Switch Closed	PC3 = 0V	PINC3 = 0
Switch Open	PC3 = floating	PINC3= ?

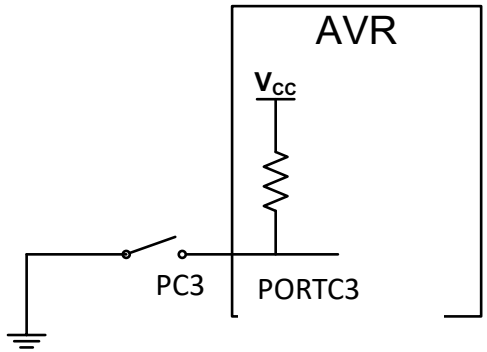
Momentary SPST switch input (2)



External Pull-up (DDRC3=0; PORTC3=0)

Switch Closed	PC3 = 0V	PINC3=0
Switch Open	PC3 = 5*V*	PINC3=1

These are not C assignment statements. Our C compiler does not allow for bit-level assignments. We use bit-level manipulation instead.



Internal Pull-up (DDRC3=0; PORTC3=1)

Switch Closed	PC3 = 0V	PINC3=0
Switch Open	PC3 = 5*V*	PINC3=1

```
DDRC &=  ~(1<<DDC3);   //makes DDRC3=0; other bits of DDRC not alterted
PORTC |= (1>>PORT3);   // makes PORTC3=1; other bits of PORTC not altered
```

Checking a bit in a Byte

Let's check if bit 5 of a particular byte is high...

Bit-by-bit AND with a mask 0010 0000 (1 in bit 5 position, 0 elsewhere)

Result is 0 if bit 5 is 0.
Result is non-zero if bit 5 is 1.

- We can use & operator to see if a bit in a byte is 1 or 0

```
xxxx xxxx
&  0010 0000
-----------
00x0 0000
```

OR

```
xxxx xxxx
&    (1 << 5)
-----------
00x0 0000
```

Let's apply this logic to testing the status (1 or 0) of PINC5

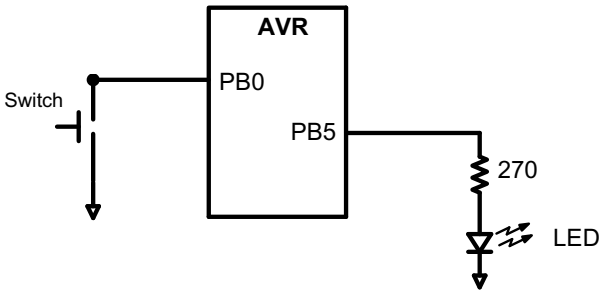
```
if( ((PINC & 0b00100000) != 0)  // Test if bit 5 of PINC is high
if( ((PINC & (1<<5)) != 0)  // Same test using shift operator for mask
if( ((PINC & (1<<PINC5)) != 0)  // Same test using PINC5 instead of 5
if( ((PINC & (1<<PINC5)) == 0)  // Test if PINC5 is low
```

why don't we do this: `if( ((PINC & (1<<PINC5)) == 1)`
Assume PINC5=1. Then PINC & (1<<PINC5) = XX1XXXXX & 00100000 = 00100000 = 32

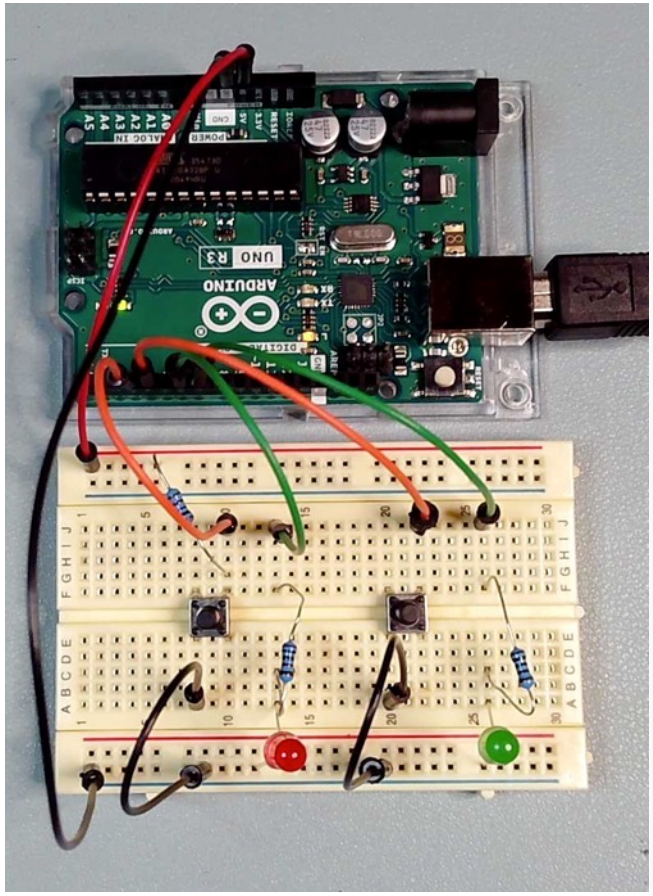
Example

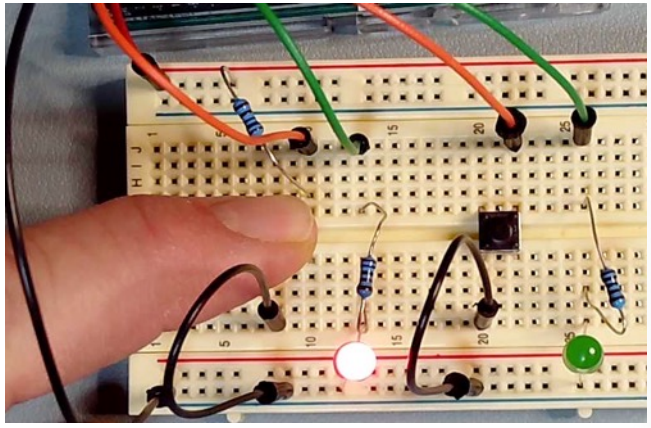
A switch without external pullup is connected to pin PB0. An LED is connected to pin PB5. Write a program segment to turn on the LED when the switch is pressed.

logic: PB5 = ~ PB0




```
DDRB = (1<<DDB5);  // PB5 output; other PORTB pins inputs
PORTB = (1<<PORTB0); // Activate internal pullup on PB0
while(1)
{
    if ( (PINB & (1<<PINB0) ) == 0)   // Is PB0=0 (button pressed?)
        PORTB |= (1<<PORTB5);         // Make PB5 high; LED on
    else
        PORTB &= ~(1<<PORTB5);    // Make PB5 low; LED off
}
```





switches2.c

switches2.c 3

Users > davemclaughlin > Documents > codingProjects > embedded > blinkswitch > C s

```c
/* switches2.c This code turns on LEDs when  momemtary pushbutton
switches are pressed. Input pins on PD3 and PD4. LEDS on PD6 on PD7
D. McLaughlin 2/21/22 */

#include <avr/io.h>
#include <util/delay.h>

int main(void){
    DDRD = 1<<DDD6|1<<DDD7;             // Set D6, D7 as output
    PORTD = 1<<PORTD3|1<<PORTD4;        // Set pullup on D3 & D4

    while(1){

        if  ((PIND & (1<<PIND3)) == 0){ // PIND3 is 0 when pressed
            PORTD |= (1<<PORTD6);       // P6 high when P3 is pressed
        } else {
            PORTD &= ~(1<<PORTD6);      // P6 low when P3 not pressed
        }

        if  ((PIND & (1<<PIND4)) == 0){ // PIND4=0 when pressed
            PORTD |= (1<<PORTD7);       // P7 high when P4 is pressed
        } else {
            PORTD &= ~(1<<PORTD7);      // P7 low when P4 not pressed
        }


    }
    return(0);
}

/***** End of File *****/
```

Internal pull-ups activated,so external pull-up resistors not needed

Summary: Set, Clear, Toggle, and test a single bit:

Consider PIN 4 of PORTB, corresponding to hardware pin PB4

PORTB:

7	6	5	4	3	2	1	0

Set PB4 (make 5V output voltage on PB4)

```
PORTB = 0xFF;                    // Sets all bits high. This is brute force!
PORTB = PORTB | 0b0010000;       // Sets bit 4 high; other pins unaltered. Difficult to read.
PORTB = PORTB | (1<<4);          // Set PORTB4 high; other pins unaltered
PORTB |= (1<<4);                 //  Set PORTB4 high; other pins unaltered
PORTB |= (1<<PORTB4);            //  Set PORTB4 high; other pins unaltered
```

Clear PB4 (make 0V output voltage on PB4)

```
PORTB = PORTB & 0b11101111;      // Clear PORTB4 using a mask
PORTB &= 0b11101111;             // Same as above
PORTB &= ~(1<<4);                // ~(1<<4) = ~(00010000) = 11101111
PORTB &= ~(1<<PORTB4)            // Easiest to understand
```

Toggle PB4 (5V to 0V; 0V to 5V)

```
PORTB = ~ PORTB;                 // Toggles all bits of PORTB. This is brute force!
PORTB = PORTB ^ 0b00010000;      // Toggles bit 4 of PORTB
PORTB ^= 0b00010000;             // Toggles bit 4 of PORTB using shorthand
PORTB ^= (1<<4);                 // Another way of writing previous statement
PORTB ^=(1<<PORTB4);             // Easiest to understand,
```

Test (determine if input on PB4 is 0V)

```
if ( (PINB & 0b00010000) == 0)   // Test if PINB4 is equal to zero
 if ( (PINB & (1<<4)) == 0)      // Same as above
if ((PINB & (1<<PINB4)) == 0)    // Same as above. Supposedly easier to understand
```