

Principles and Applications of Microcontrollers

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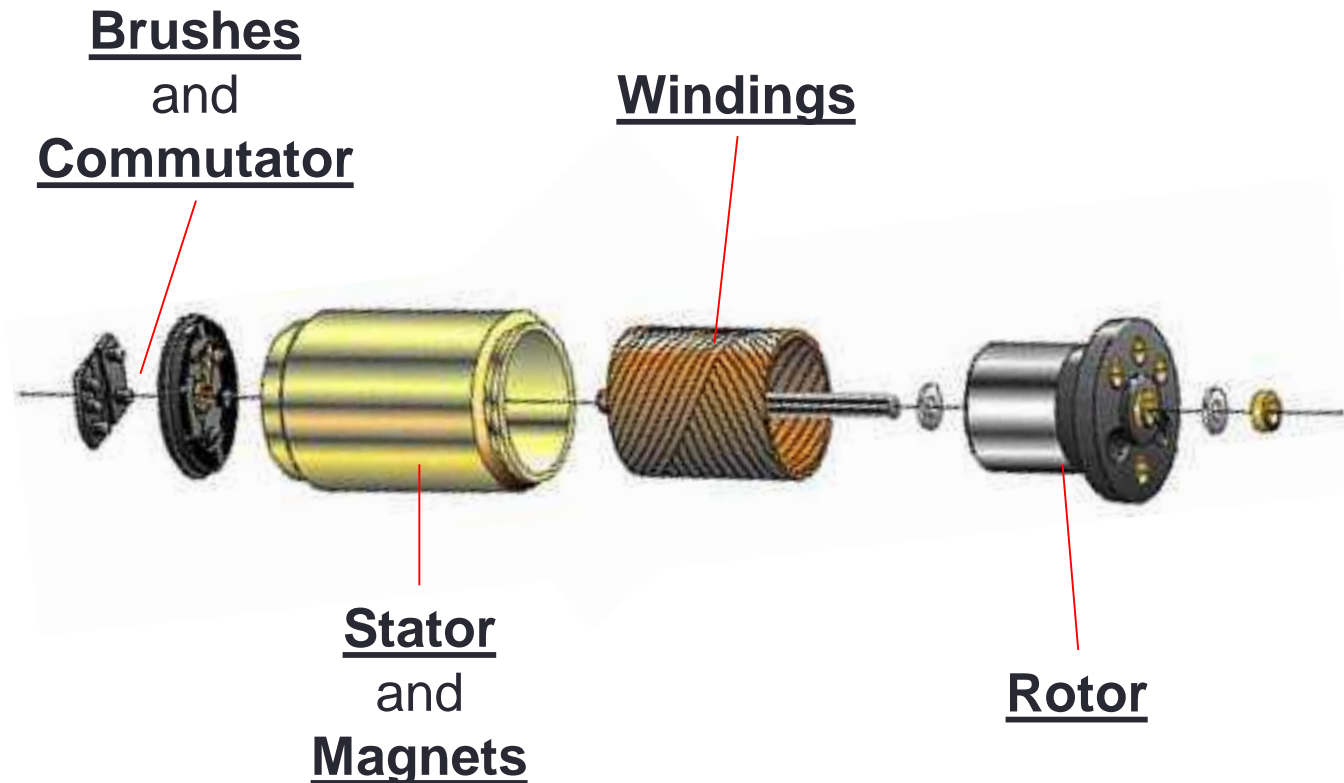
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Today:

- DC motor control
- Arduino PWM

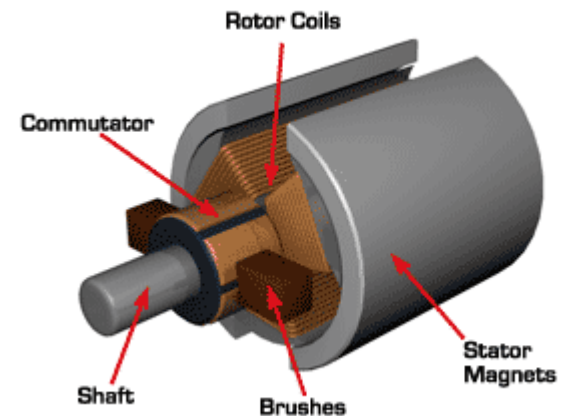
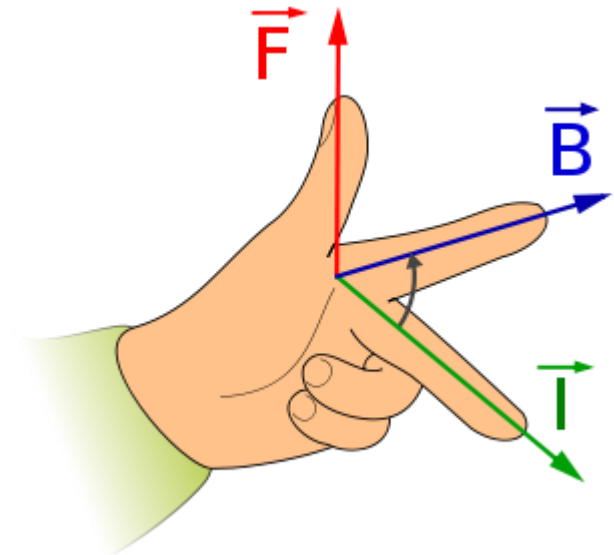
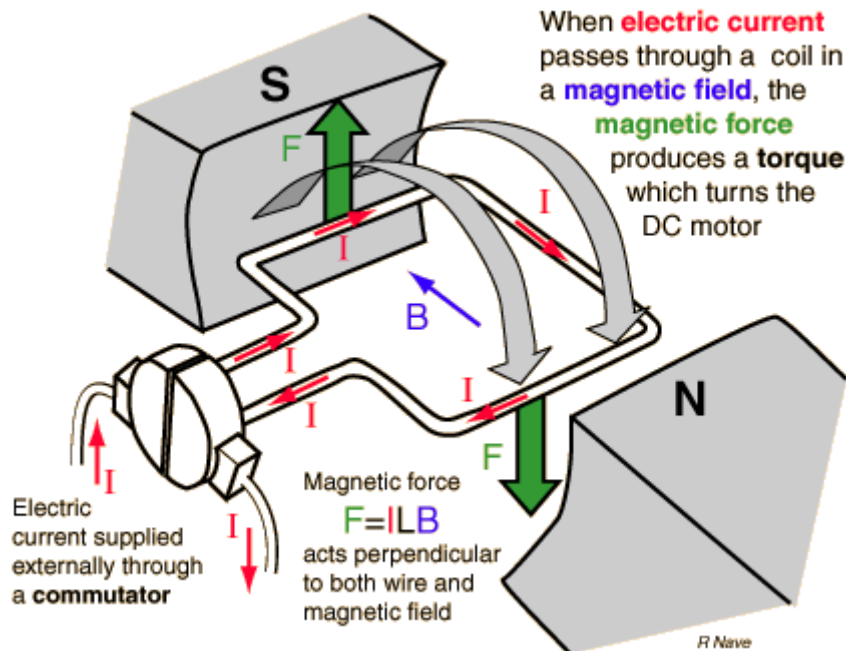


Direct Current (DC) Motor



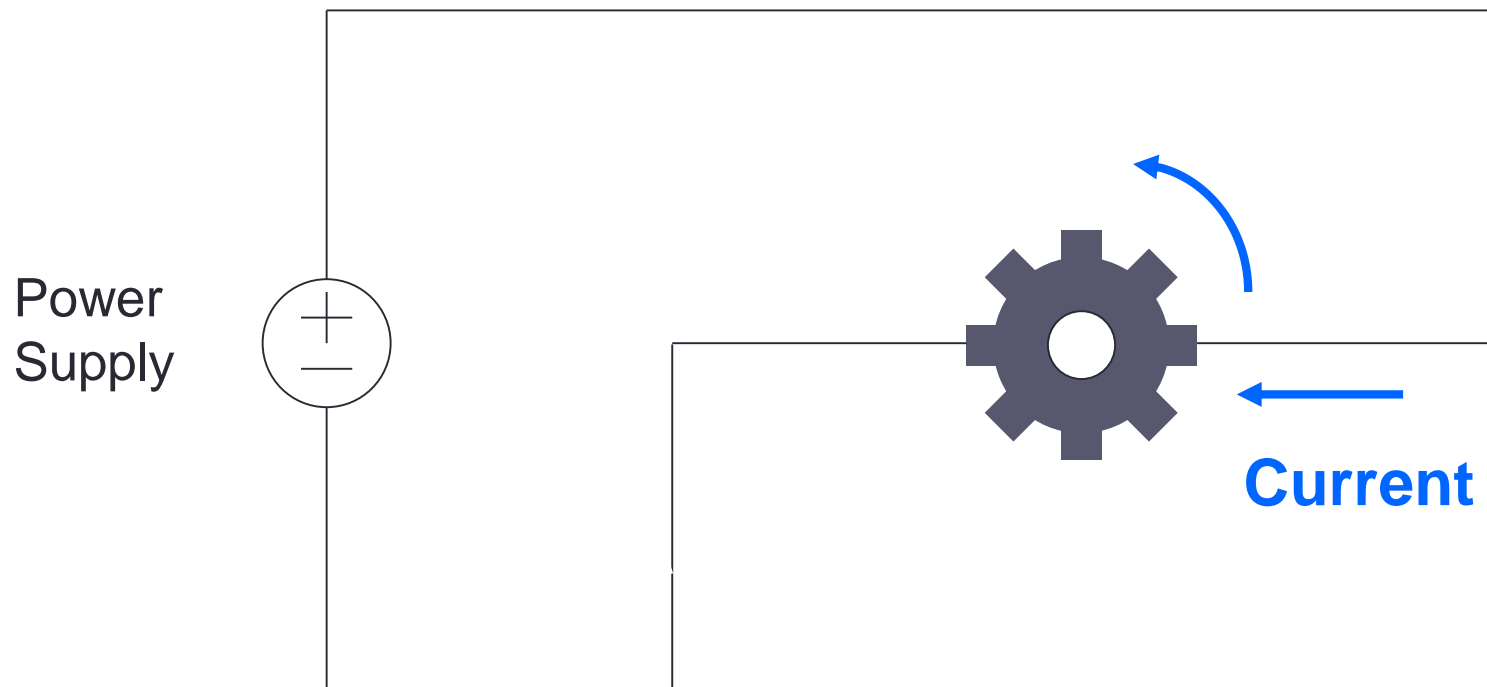
Working Principle of DC Motors

- Follows the Fleming's left-hand rule



Drive A DC Motor

- The motor rotates when a voltage is applied to it

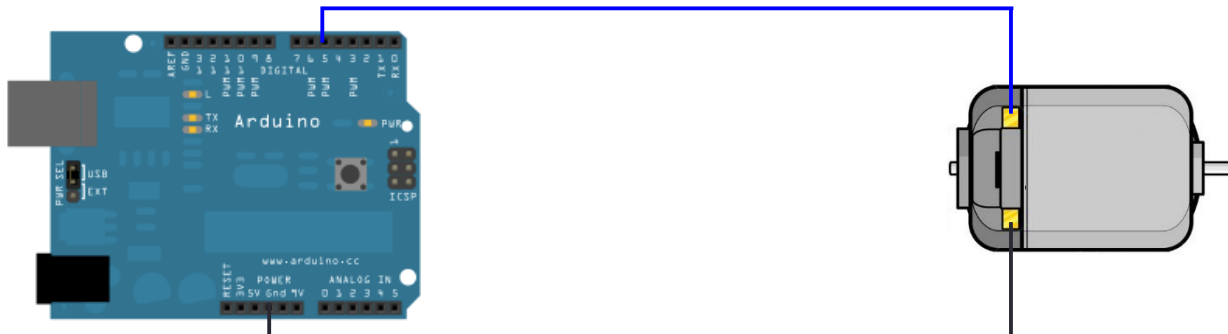


- What is the minimum current to drive the DC motor?

Does This Work?

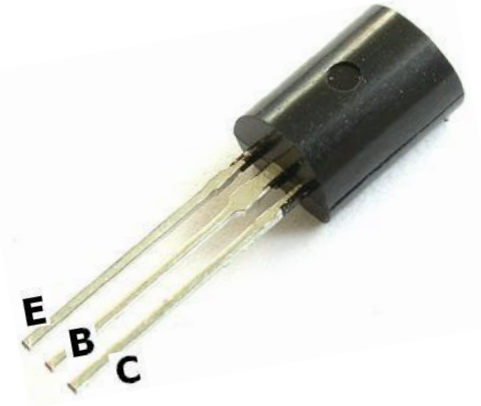
- Can one drive a DC motor by just wiring it to a MCU?

```
int motor = 5;  
void setup() {  
  pinMode(motor, OUTPUT);  
}  
void loop() {  
  digitalWrite(motor, HIGH);  
  delay(4000);  
  digitalWrite(motor, LOW);  
  delay(4000);  
}
```

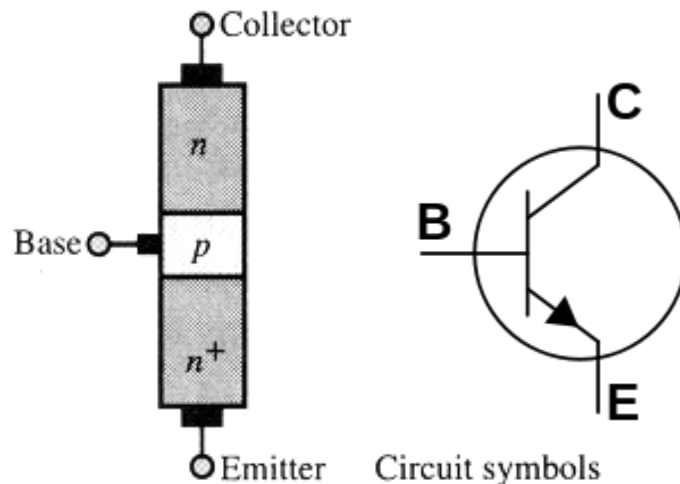


Bipolar Junction Transistor (BJT)

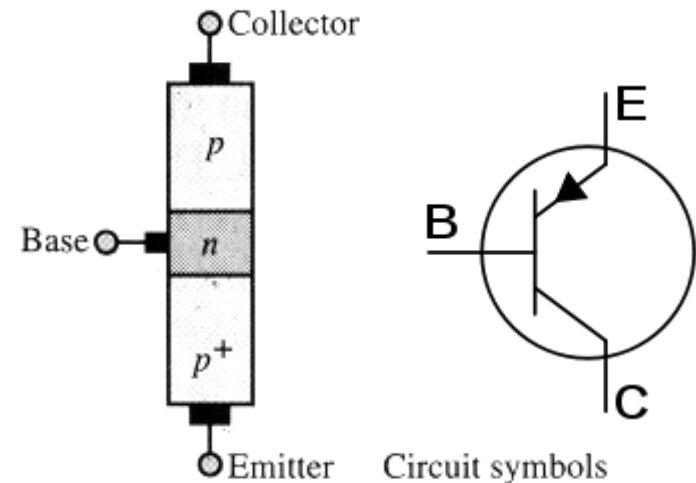
- Three-terminal semiconductor device
- Can perform switching: controlling a relative large current between or voltage across two terminals using a small control current or voltage



NPN



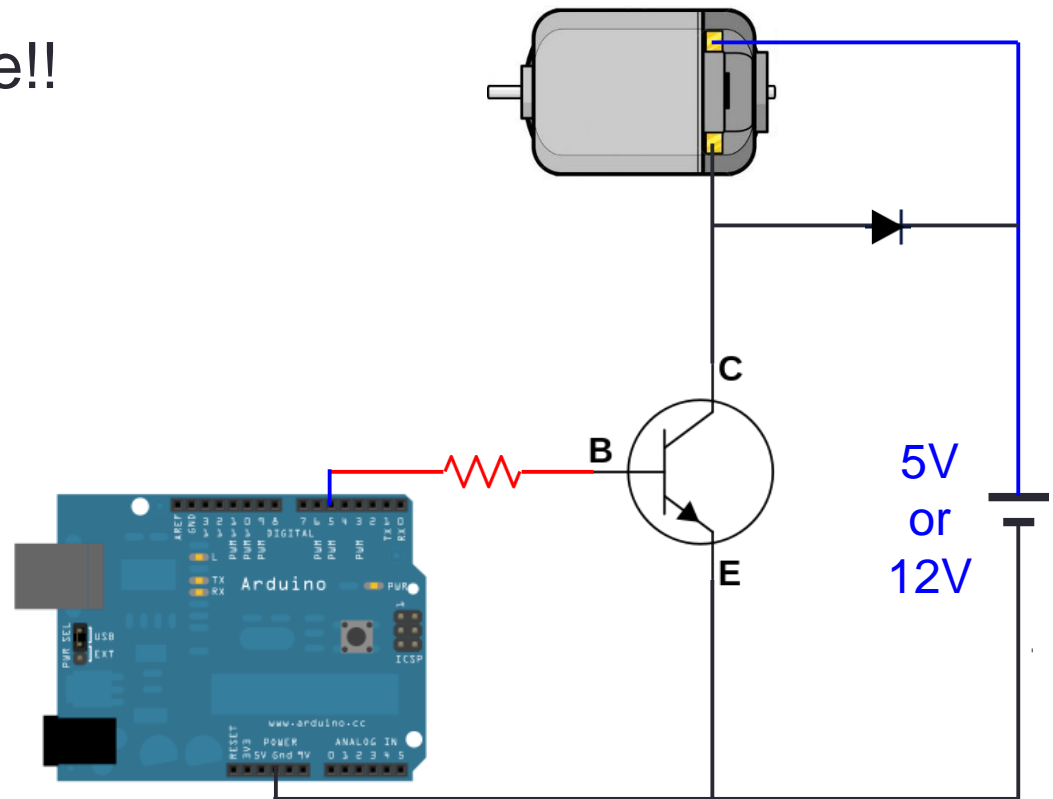
PNP



Drive A DC Motor Using An NPN BJT

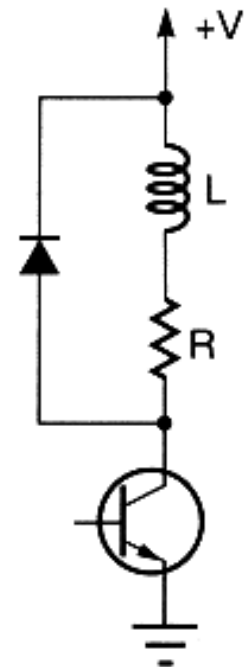
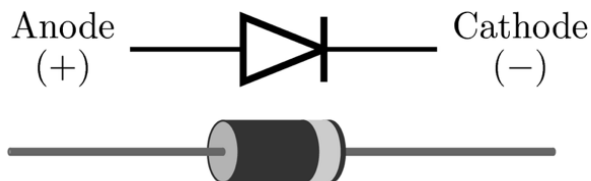
- How about this?
- Need a kickback diode!!

```
int motor = 5;  
void setup() {  
  pinMode(motor, OUTPUT);  
}  
void loop() {  
  digitalWrite(motor, HIGH);  
  delay(4000);  
  digitalWrite(motor, LOW);  
  delay(4000);  
}
```



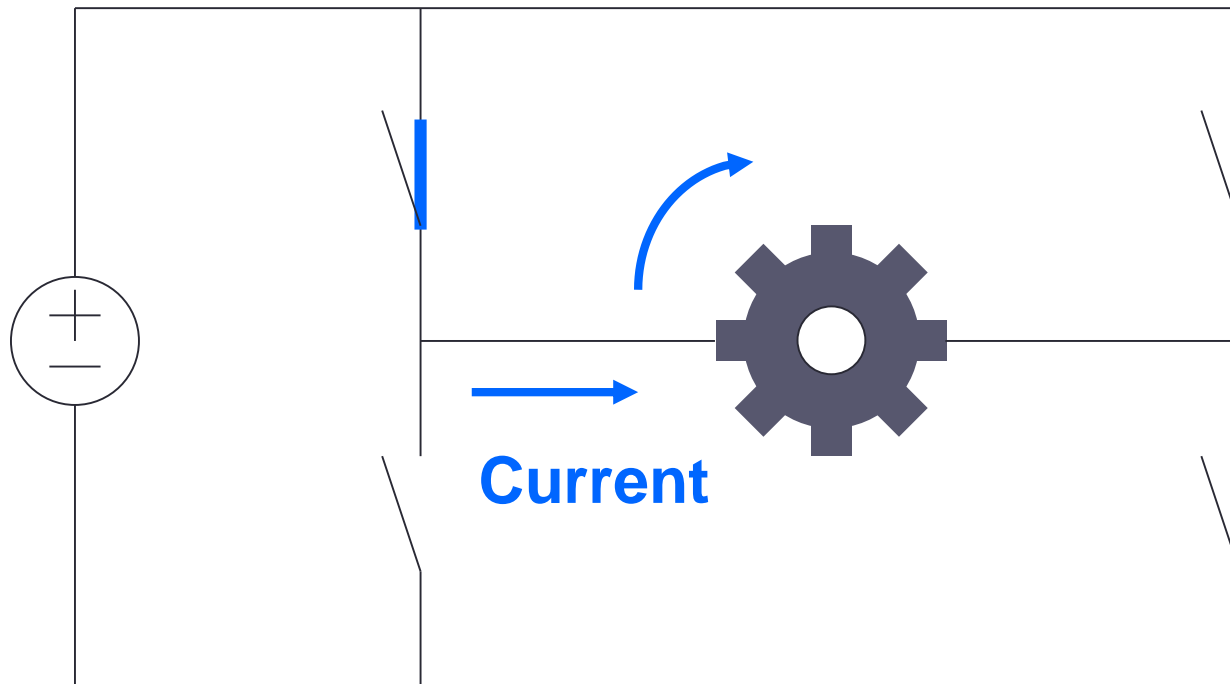
Kickback Diode

- The voltage across an inductor is: $V = L \cdot \frac{di}{dt}$
- A large voltage will build-up across the inductor at the moment of switch-off
- This voltage can be large enough to damage the transistor
- To avoid this, a freewheeling (kickback) diode can be added in parallel with the inductive load:



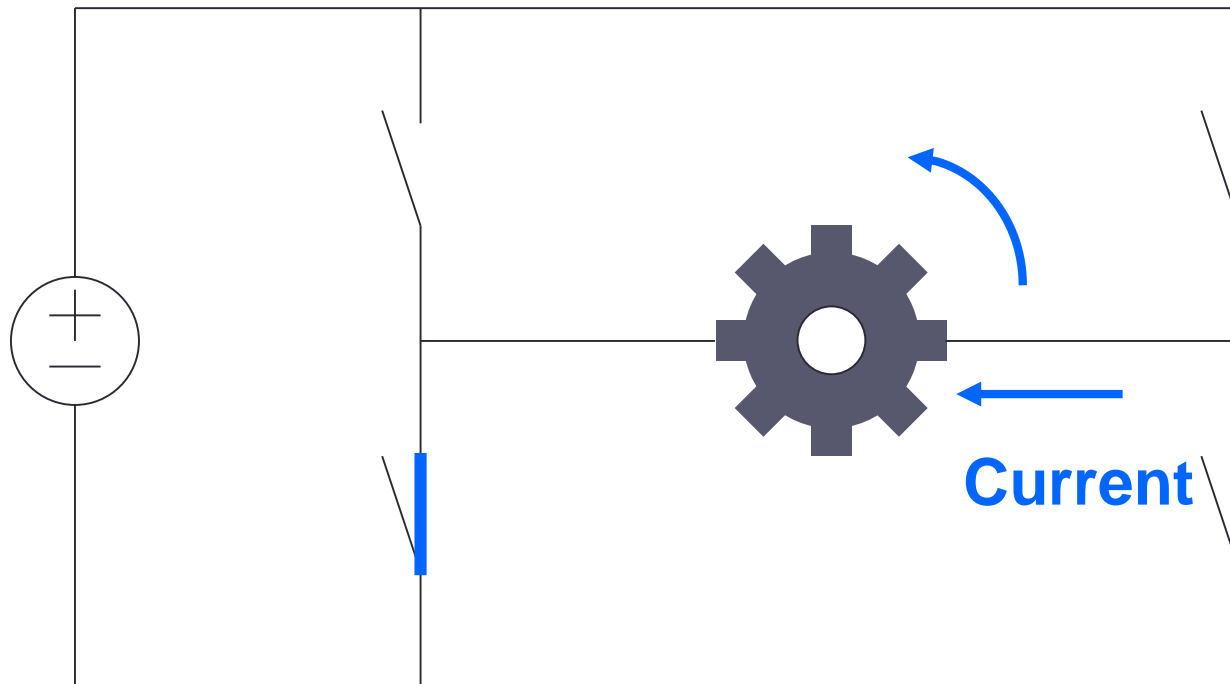
H-bridge Motor Drivers

- Built with four switches that enable a voltage to be applied across a load in either direction
- One switch is closed in each leg of the "H"



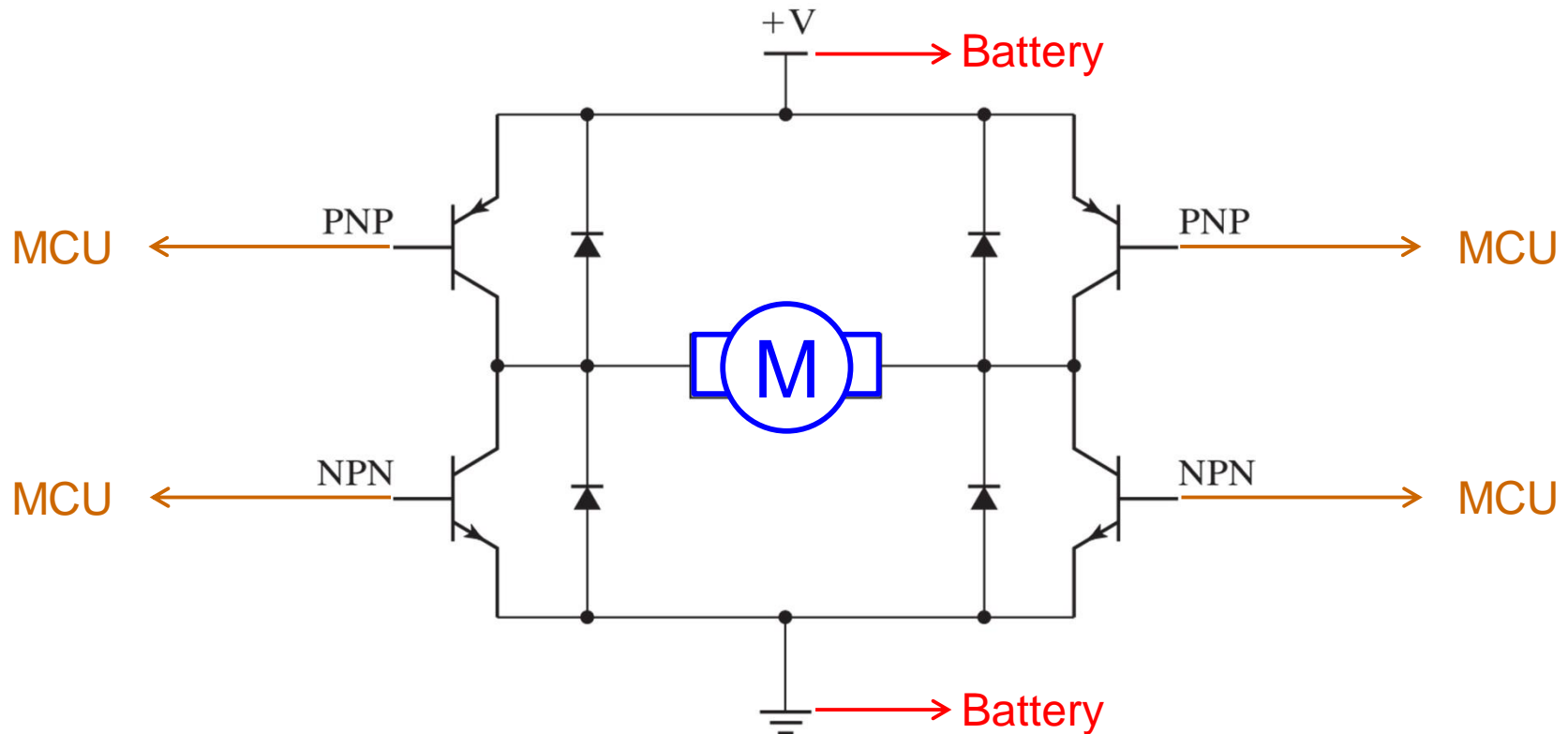
H-bridge Motor Driver (Cont'd)

- Built with four switches that enable a voltage to be applied across a load in either direction
- One switch is closed in each leg of the "H"

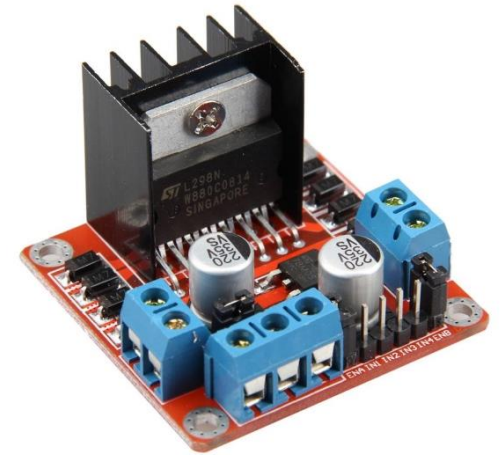
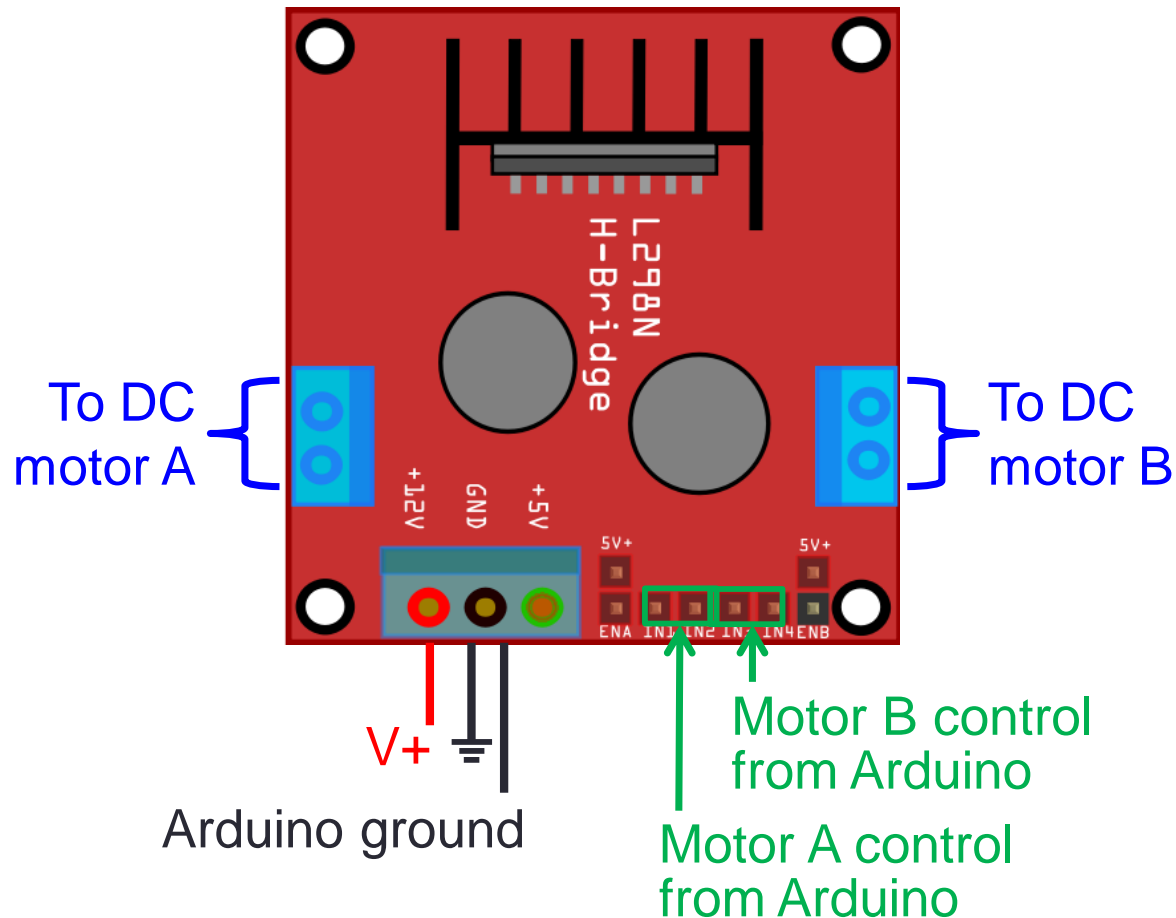


Motor Drivers – H-bridge (Cont'd)

- H-bridge – 4 transistors arranged in two 'push-pull' pairs
- Allows current to flow through the motor in either direction with a single-polarity power supply



L298 Dual H-bridge Board

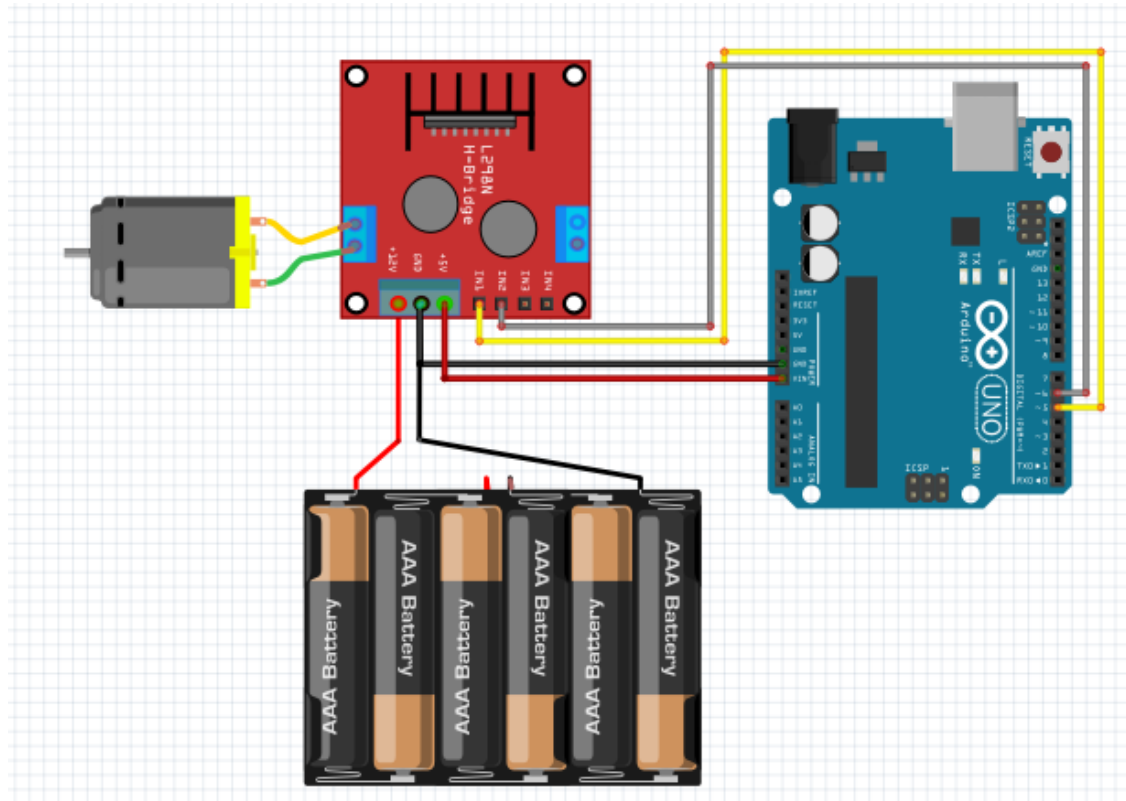


IN1	IN2	Motor A
1	0	CW
0	1	CCW

IN3	IN4	Motor B
1	0	CW
0	1	CCW

Example – DC Motor

- Rotate a DC motor clockwise and counter-clockwise back and forth
- Remember to wire Arduino ground to the H-bridge ground

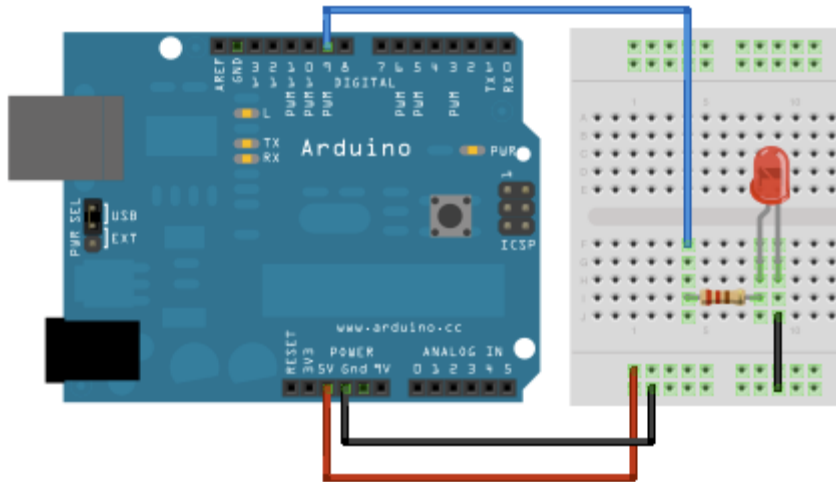


Sketch Code – DC Motor

```
void setup() {  
  pinMode(5, OUTPUT);  
  pinMode(6, OUTPUT);  
}  
  
void loop() {  
  digitalWrite(5, HIGH);  
  digitalWrite(6, LOW);  
  delay(4000);  
  digitalWrite(6, HIGH);  
  digitalWrite(5, LOW);  
  delay(4000);  
}
```

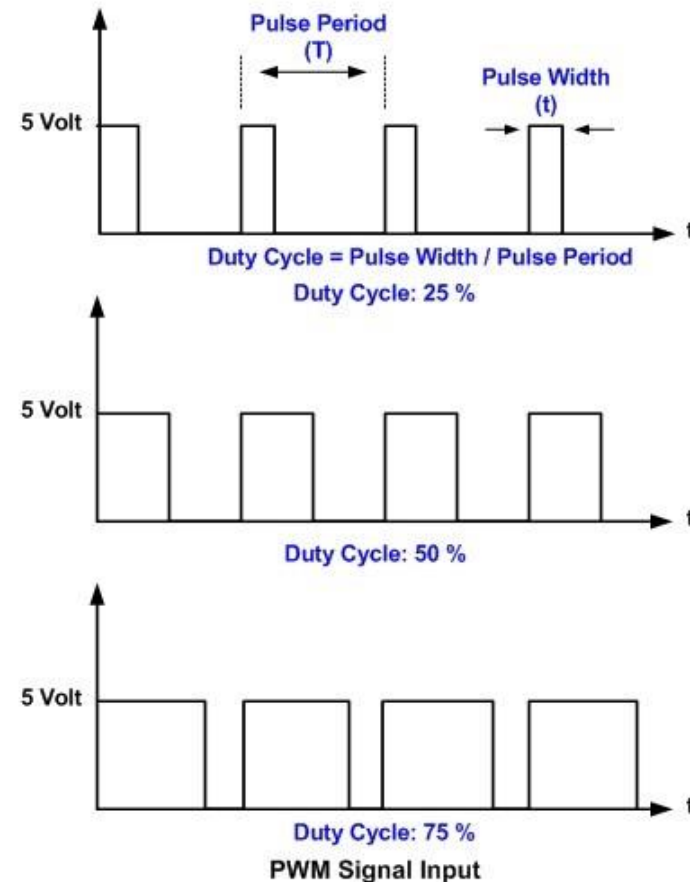
Example – Fading

- Fade an LED using pulse width modulation (PWM)
- PWM signals are square waves at about 490Hz



Small
Value
Large

`analogWrite(Pin, Value)`



Sketch Code – Fading

```
int ledPin = 9;  // LED connected to digital pin 9

void setup() {
}

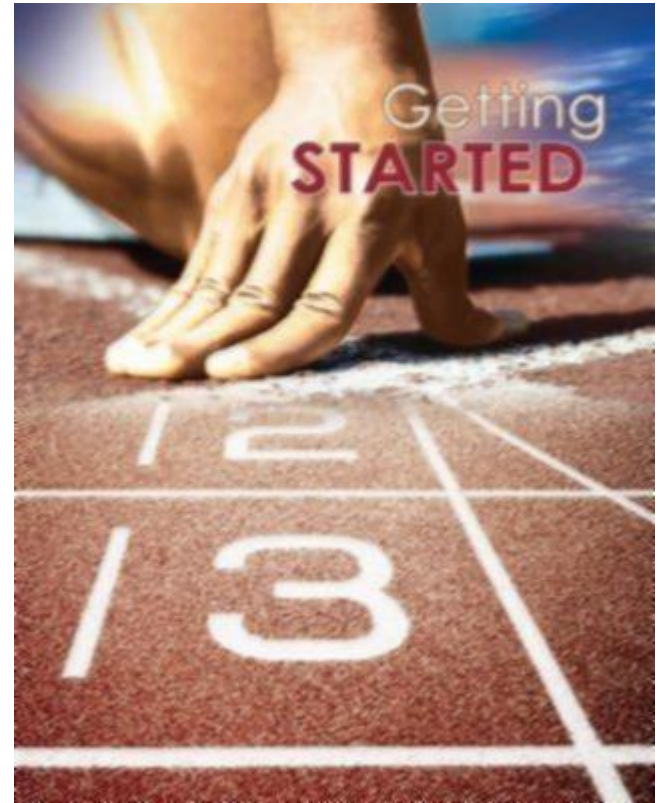
void loop() {
  // fade in from min to max in increments of 5 points:
  for (int fadeValue = 0 ; fadeValue <= 255; fadeValue += 5) {
    analogWrite(ledPin, fadeValue);
    delay(30); // wait for 30 milliseconds to see the dimming effect
  }
  // fade out from max to min in increments of 5 points:
  for (int fadeValue = 255 ; fadeValue >= 0; fadeValue -= 5) {
    analogWrite(ledPin, fadeValue);
    delay(30); // wait for 30 milliseconds to see the dimming effect
  }
}
```

What are the minimum and maximum `analogWrite` values?

What Have We Learned So Far?

- BJT transistors can be used as a switch
- DC motors are usually driven using H-bridges
- Kickback diodes are used to prevent damages caused by switch-off current introduced by an inductor
- There is an approach to output pseudo analog signals using digital outputs - PWM

Getting Started



Reference

- <http://www.arduino.cc/>
- ATmega328P data sheet