Principles and Applications of Microcontrollers

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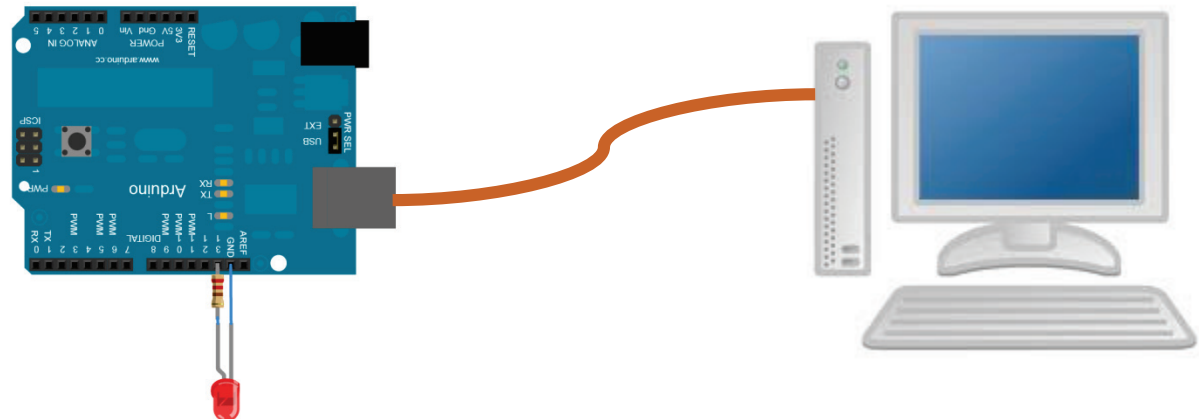
Today:

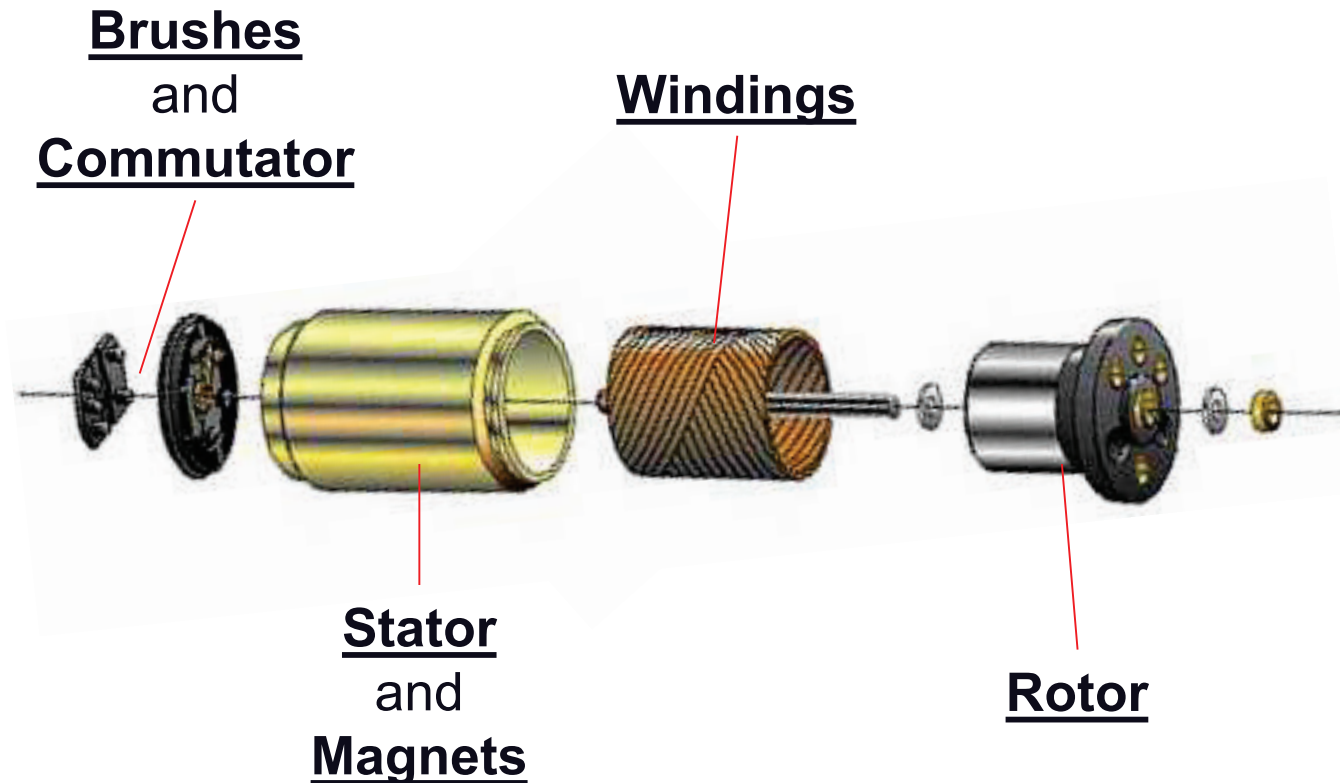- Arduino serial
- Arduino analog I/O
- DC motor control

Quiz

- Connect the Arduino to a computer
- Blink the LED at
  - 2Hz when the key 'a'
  - ½Hz when the key 'b'
  - ⅛Hz when the key 'c'

  of the computer keyboard is pressed
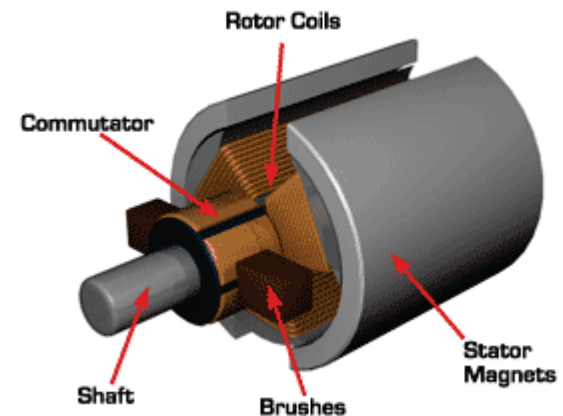- Turn of the LED if the key 'd' of the computer keyboard is pressed

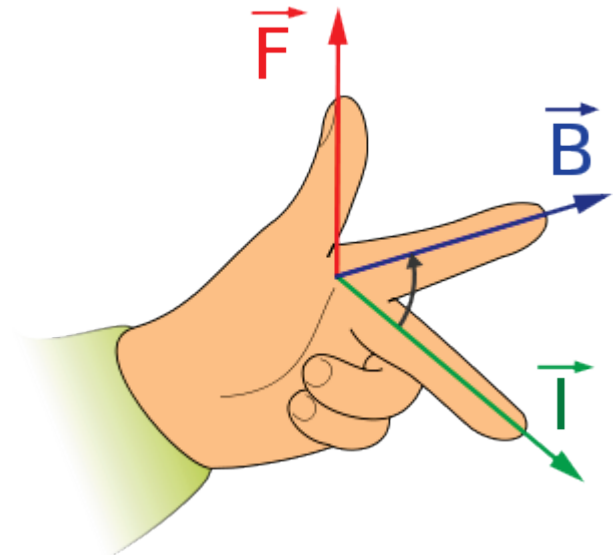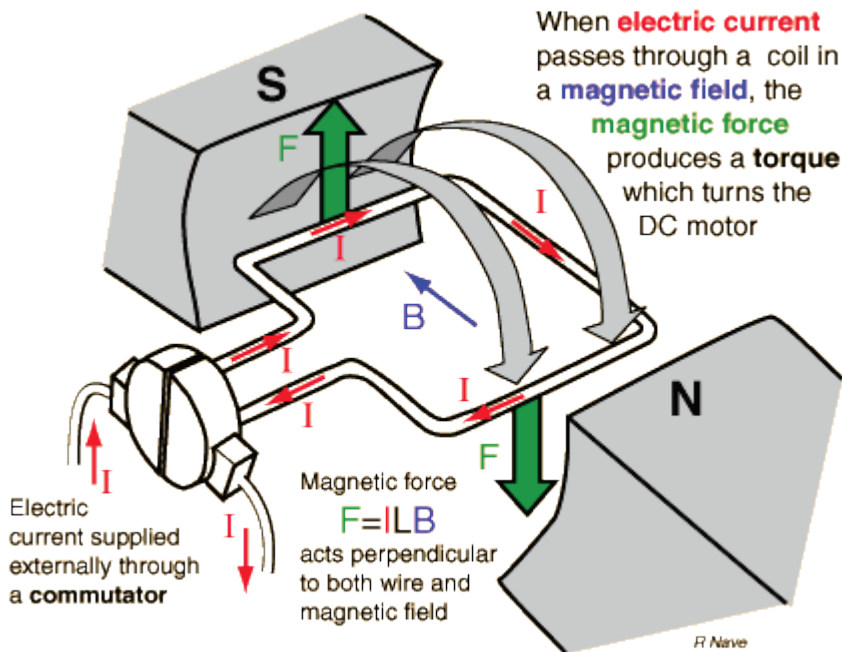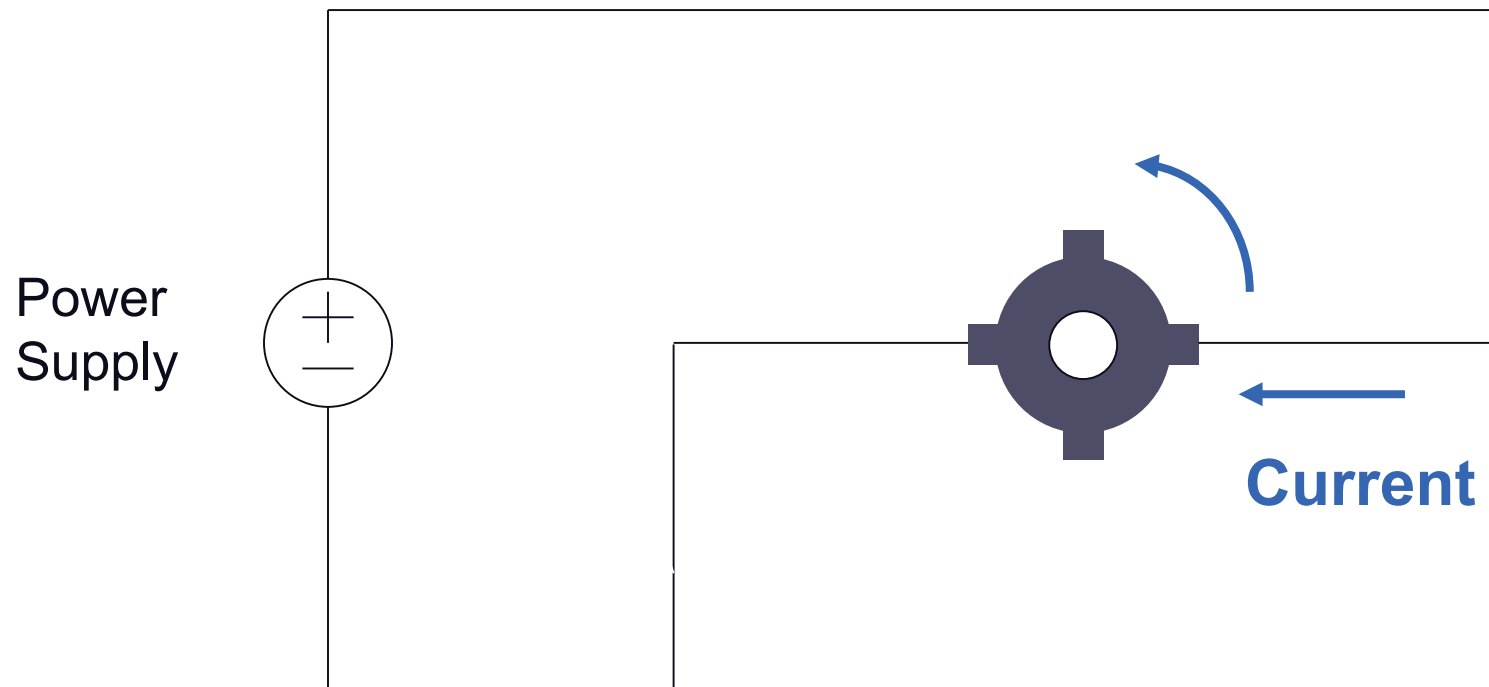# Direct Current (DC) Motor

Brushes
and
Commutator

Windings

Stator
and
Magnets

Rotor

Working Principle of DC Motors

- Follows the Fleming's left-hand rule

When **electric current** passes through a coil in a **magnetic field**, the **magnetic force** produces a **torque** which turns the DC motor

Electric current supplied externally through a **commutator**

Magnetic force $F=ILB$ acts perpendicular to both wire and magnetic field

R Nave

Drive A DC Motor

- The motor rotates when a voltage is applied to it
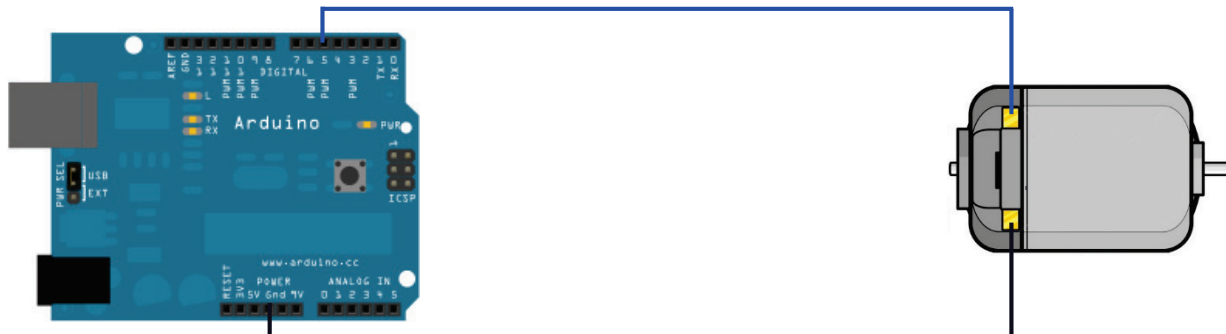
Power Supply

Current

- What is the minimum current to drive the DC motor?
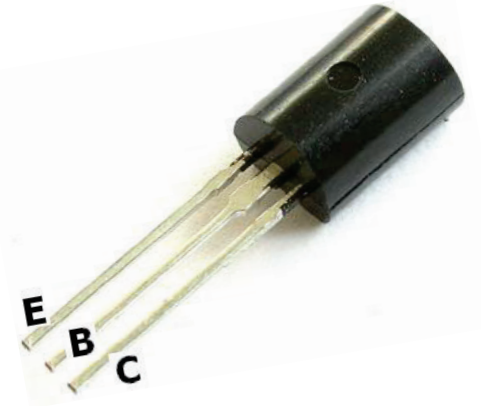
Drive A DC Motor Using A MCU?

- 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);
}
```
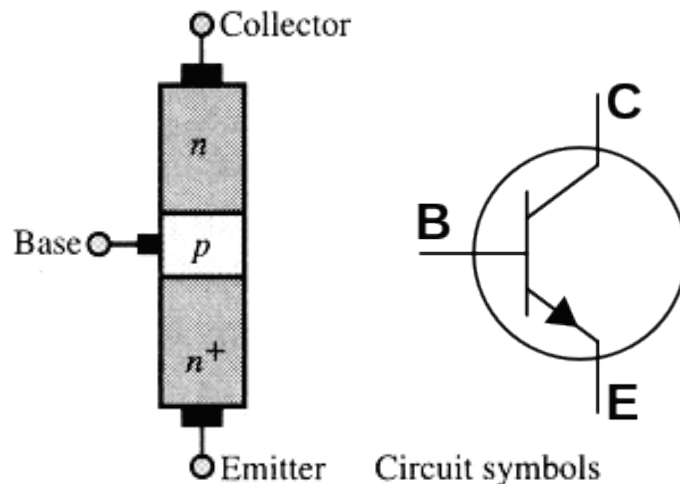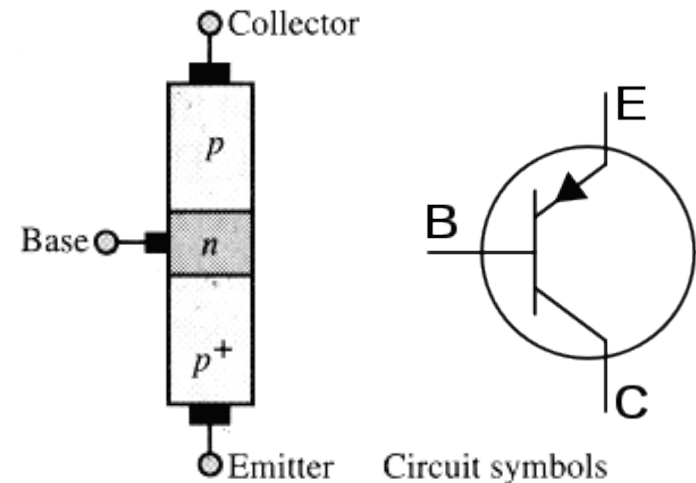
Bipolar Junction Transistor (BJT)

- 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
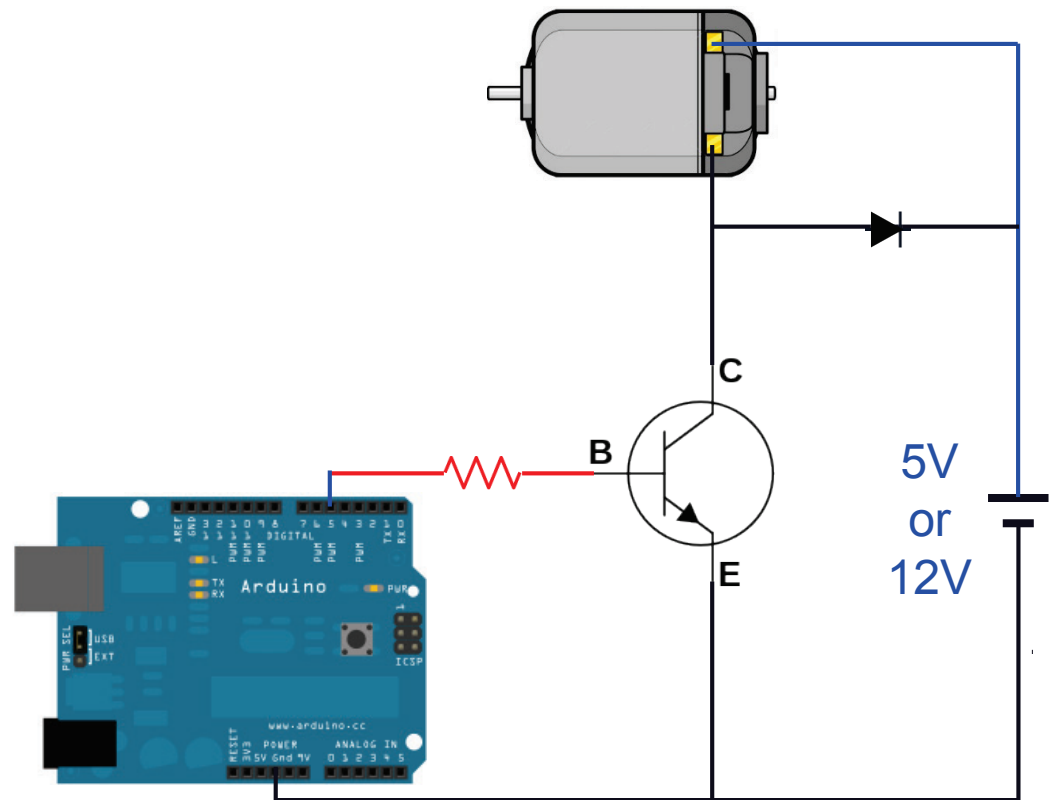
NPN

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: $V_{IND} = L \cdot \dfrac{di_{IND}}{dt}$

- 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:
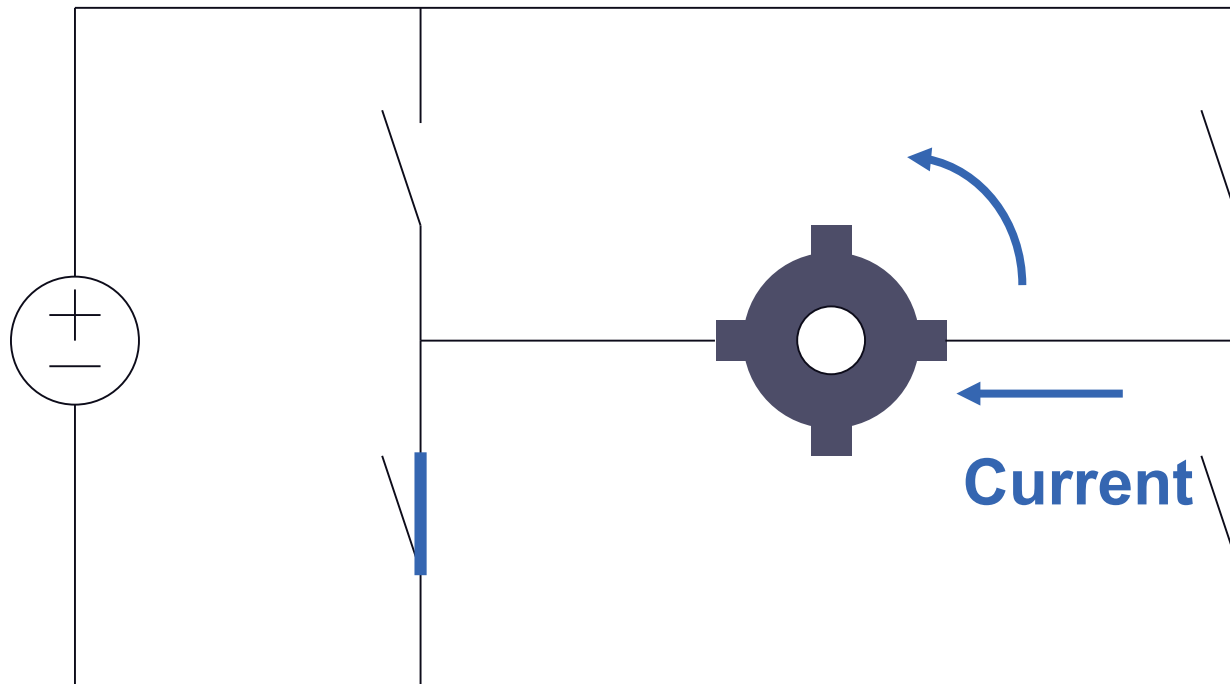
Anode (+)   Cathode (−)

+V

L

R
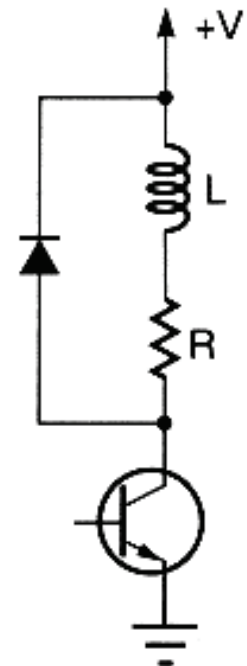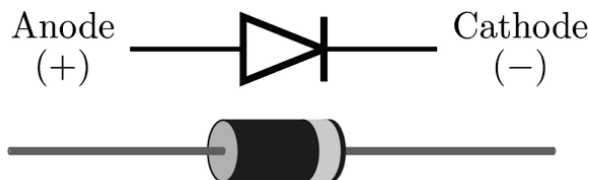
H-bridge Motor Drivers

• Built with four switches that enable a voltage to be applied across a load in either direction

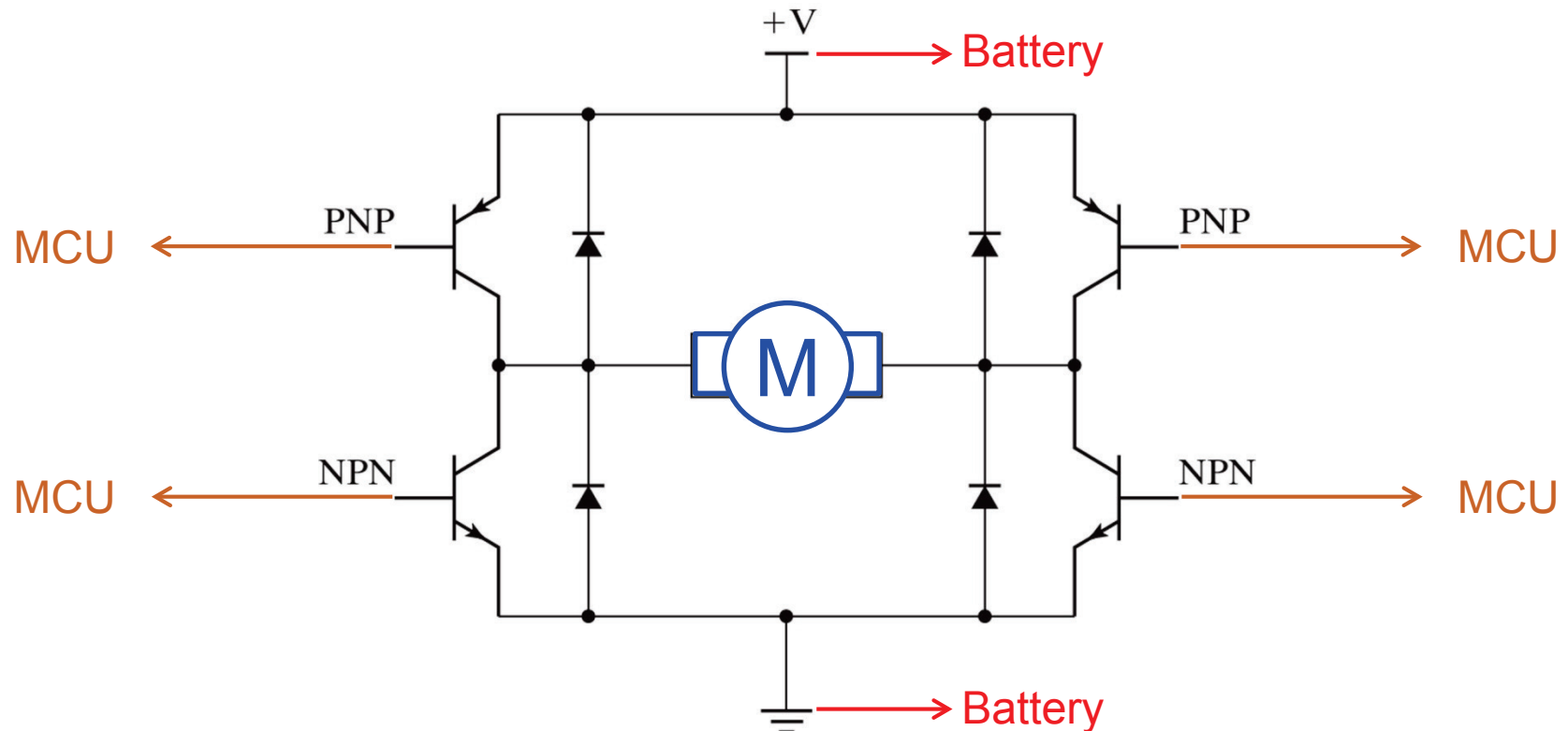• One switch is closed in each leg of the "H"

Current
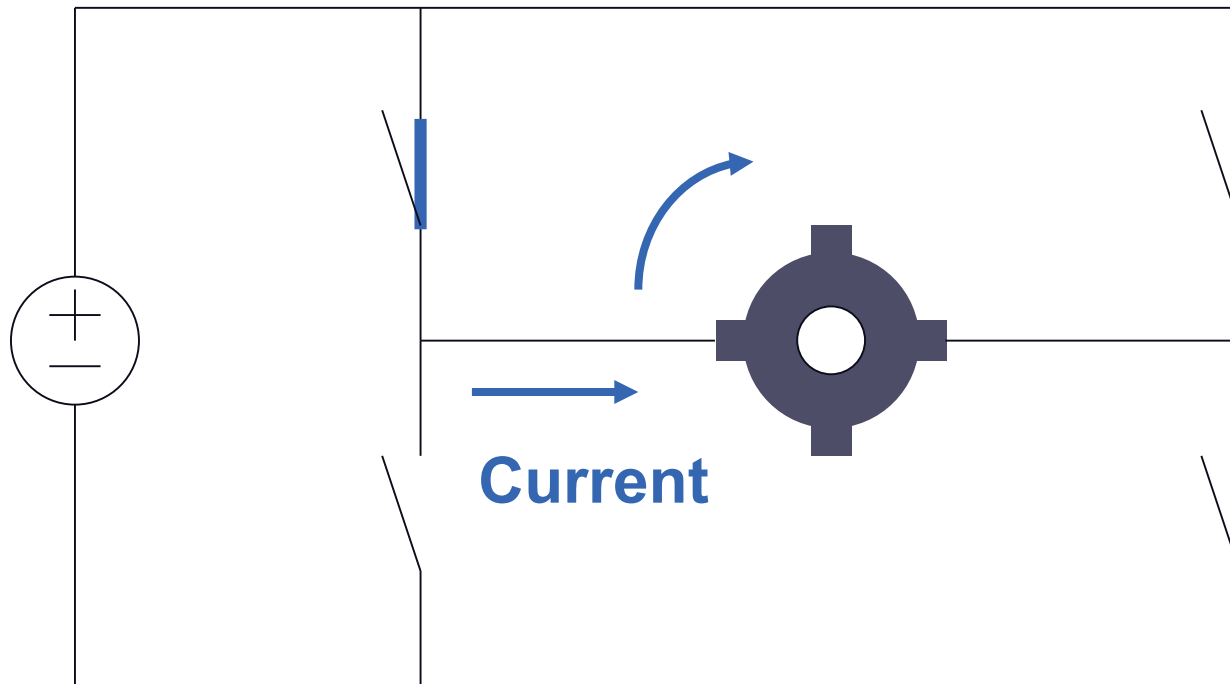
H-bridge Motor Driver (Cont'd)

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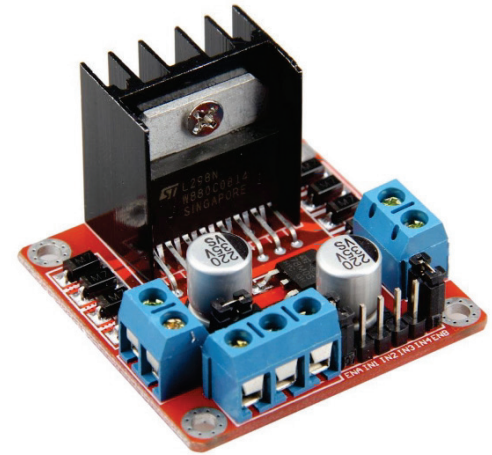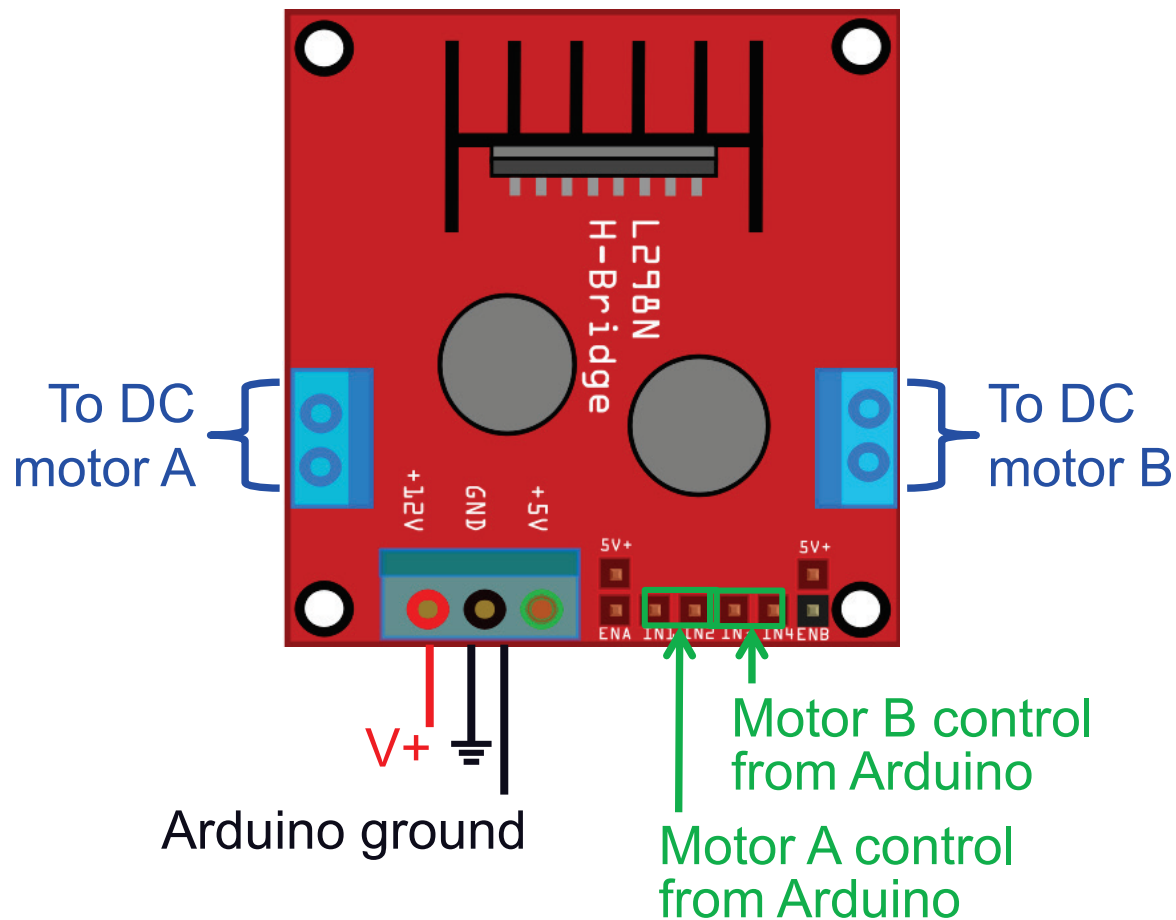- One switch is closed in each leg of the "H"

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

To DC motor A

To DC motor B

+12V   GND   +5V

V+

Arduino ground

5V+   5V+

ENA IN1 IN2 IN3 IN4 ENB

Motor B control from Arduino

Motor A control from Arduino

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
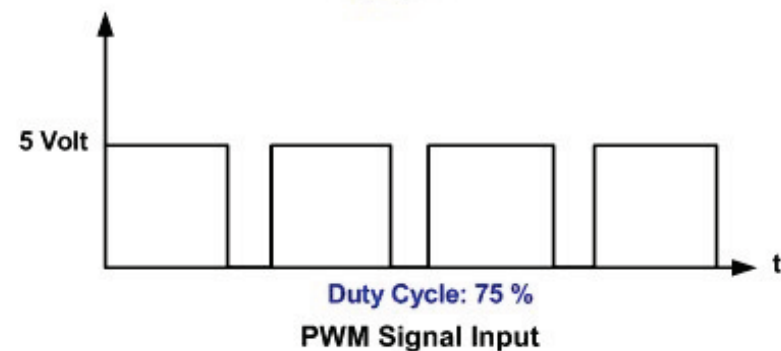
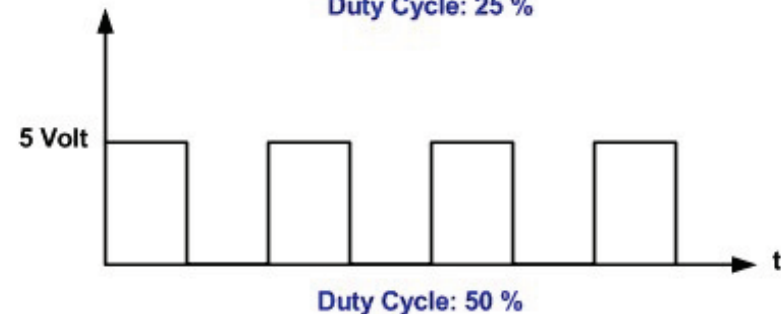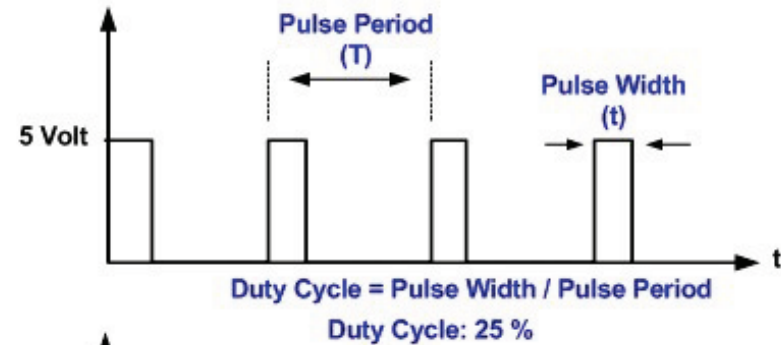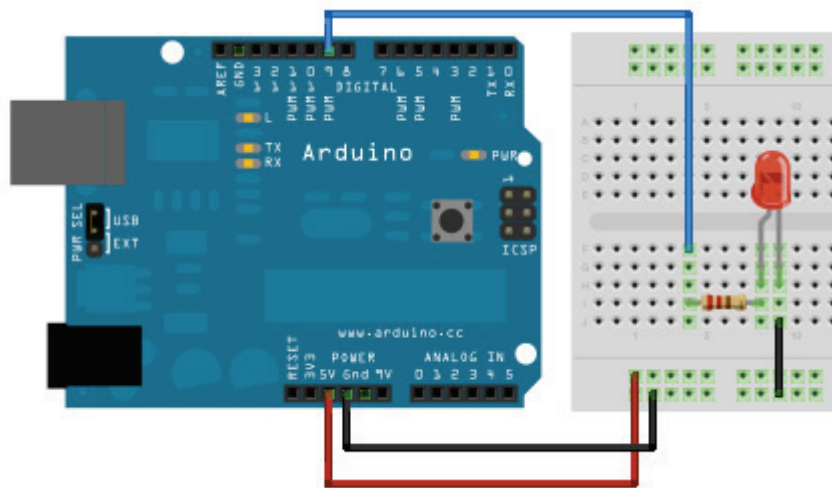- Remember to wire Arduino ground to the H-bridge ground
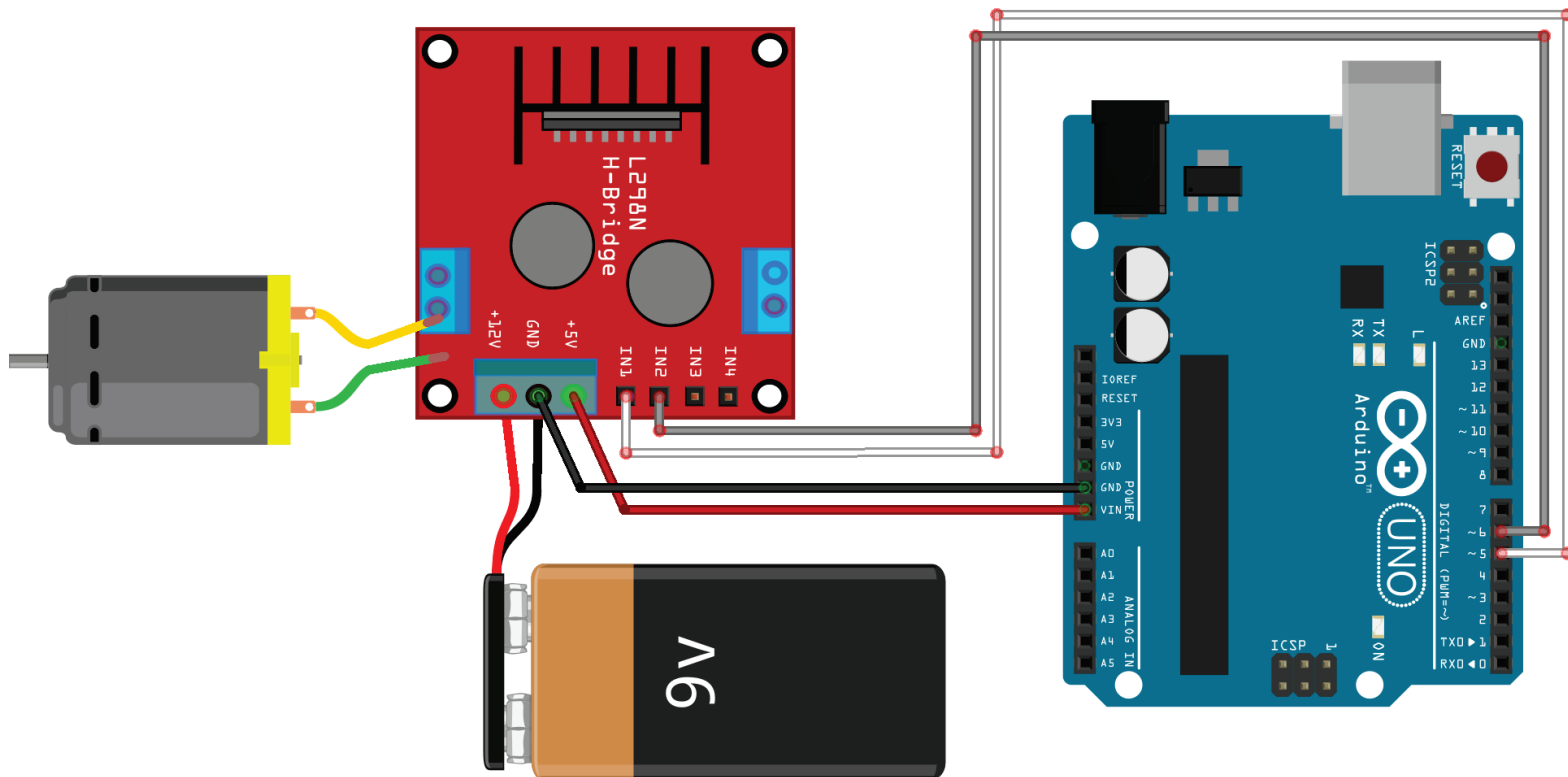
Sketch Code – DC Motor

```
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

- Fad an LED off and on with pulse width modulation (PWM)
- PWM signals are square waves about 490Hz

PWM signal

Pulse Period (T)

Pulse Width (t)

5 Volt

Duty Cycle = Pulse Width / Pulse Period

Duty Cycle: 25 %

5 Volt

Duty Cycle: 50 %

5 Volt

Duty Cycle: 75 %

PWM Signal Input
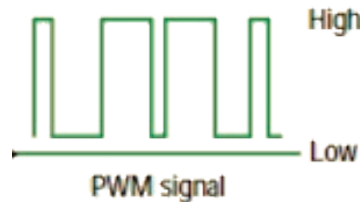
Sketch Code – Fading

```
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 drived 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