PAT 451/551 INTERACTIVE MEDIA DESIGN I

MOSFETS: CONTROLLING HIGH-POWER DEVICES

GENERAL PRINCIPLE

POWER

to the device is supplied externally (NOT from the Arduino)

- For DC devices, from a wall-wart or other DC power supply

- For AC devices, from AC mains power outlet

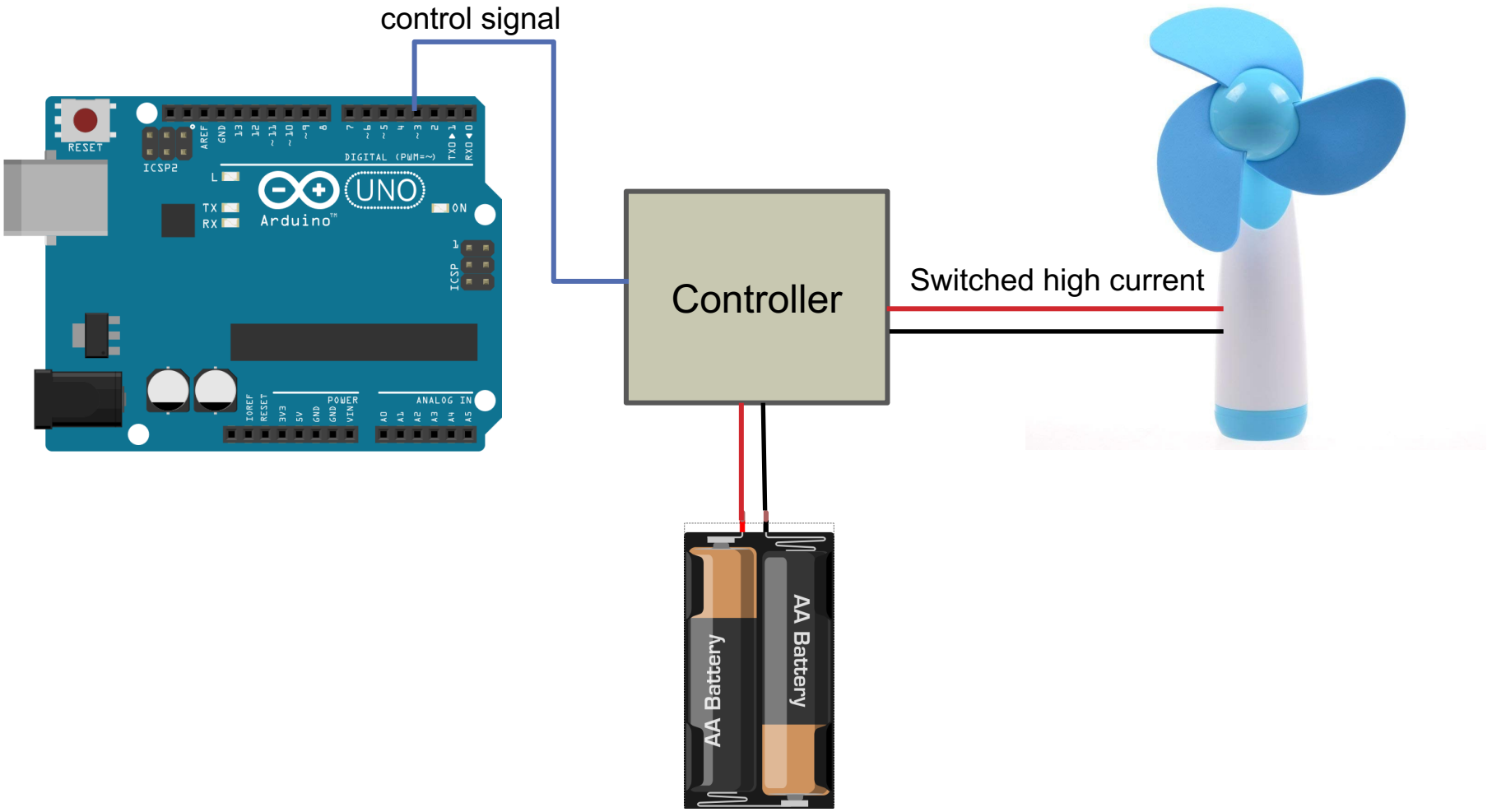
A chip or controller

allows the Arduino to switch on/off the current flow to that device using a low-voltage control signal

Why?

Arduino digital I/O pins can only sink/source 40mA. Most devices like motors, lights, solenoids require much more power than that.

GENERAL PRINCIPLE



CONTROLLER TYPES

Transistor

- Simplest for digital/binary on/off control
- DC devices only, current/load limited
- Fast switching, can be held on/off indefinitely
- Potentially noisy for continuous control
- No direction control for motors

H-Bridge

- Designed for motor control
- Usually used on a separate controller board
- Most can power 2 motors, direction and speed control
- DC or Stepper motors

Relay

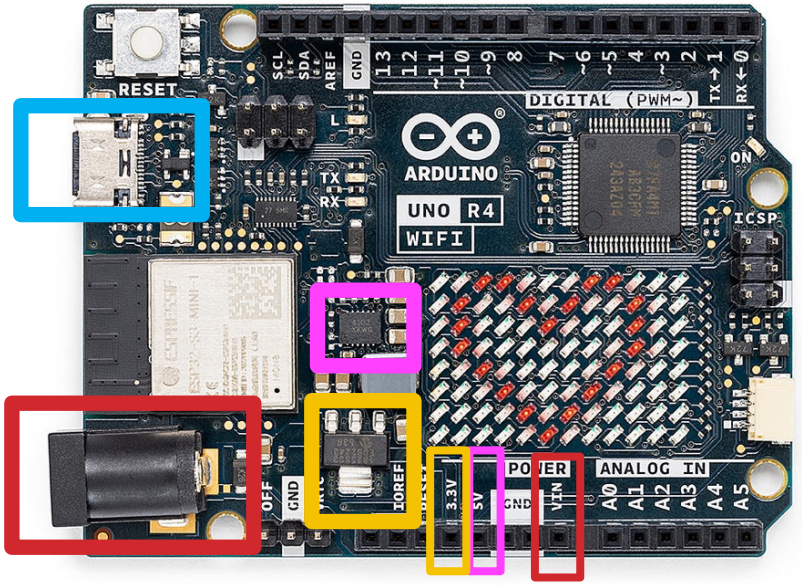
- For intermittent switching; can't be held indefinitely
- Can handle higher loads/current than transistors
- AC or DC versions
- Electromechanical or Transistor-based control

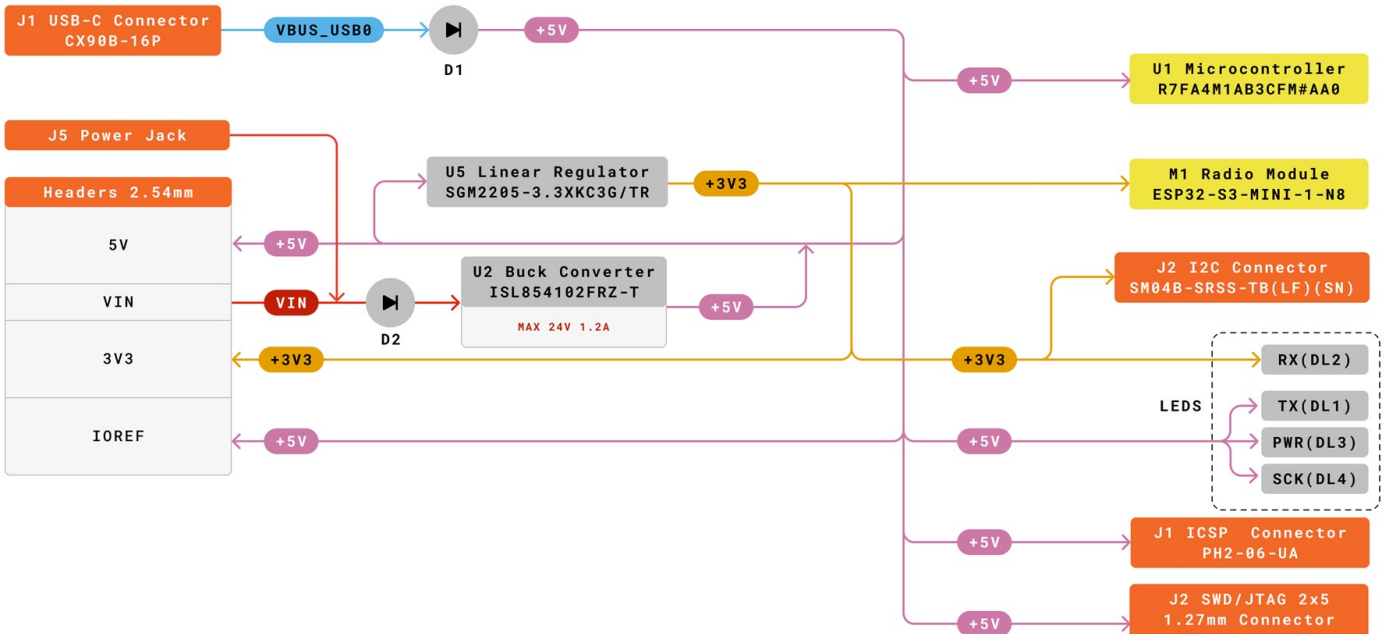
ARDUINO POWER ARCHITECTURE

V_in pin carries whatever voltage is supplied on the **barrel jack connector (red)**

5V Pin carries a 5V, either from the **Buck Converter** or **USB**

3.3V Pin carries 3.3V from a **voltage regulator**





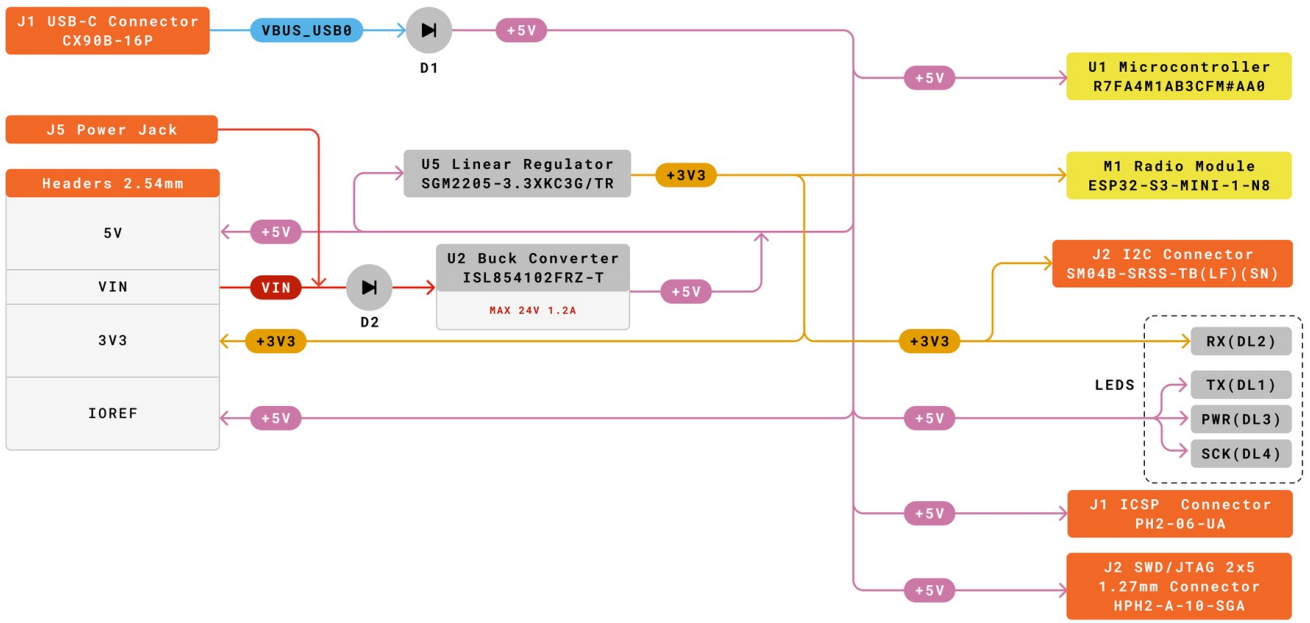
ARDUINO POWER ARCHITECTURE

Barrel jack connector:

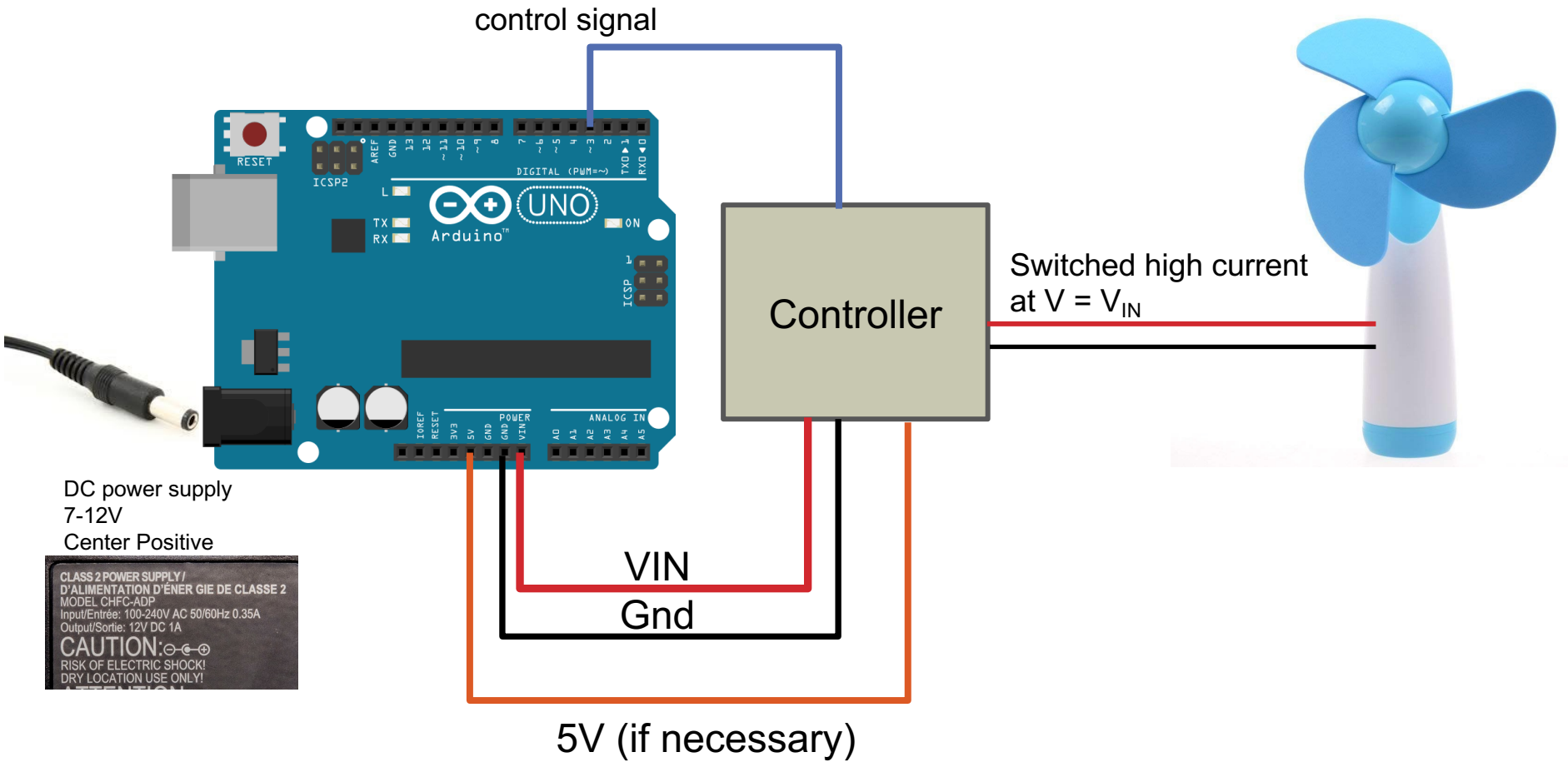
Must be 5-24V DC
center positive

If V_in > 6.6V, that voltage will be used to power the Arduino

If V_in < 6.6V, the 5V USB power will be used to power the Arduino



USING ARDUINO VIN



TRANSISTORS

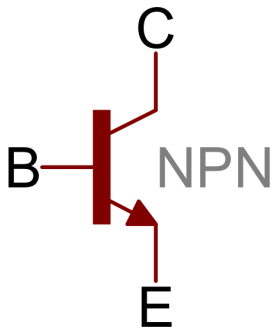
For a full tutorial, see: https://learn.sparkfun.com/tutorials/transistors/all

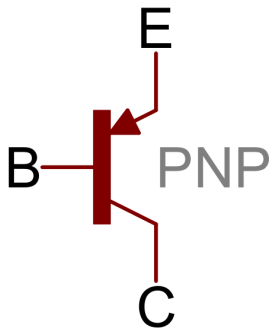
Two basic varieties: NPN and PNP

B = Base

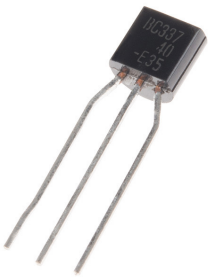
C = Collector

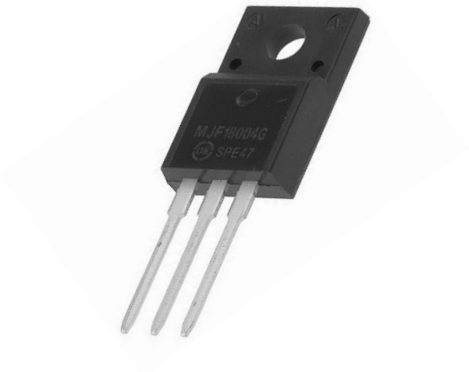
E = Emitter





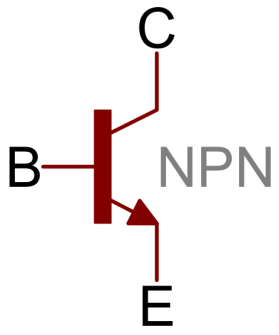
Most crudely, the base voltage controls current flow from the collector to the emitter.





TRANSISTORS

We'll most commonly use an NPN transistor



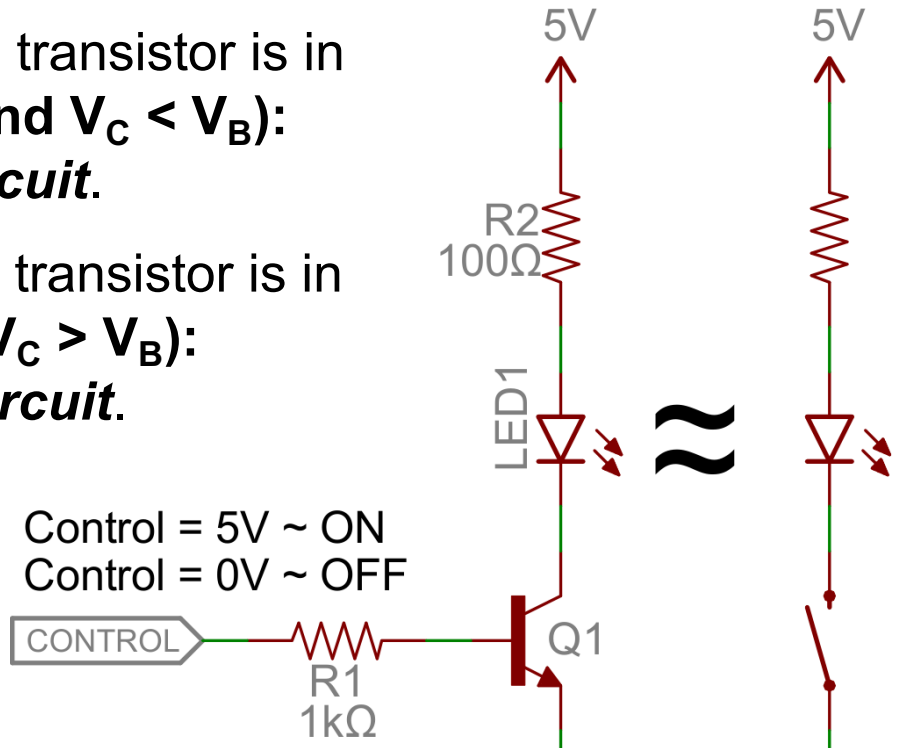
It has 4 modes, based on the relationship of the 3 voltages at C, B, and E

1. **Saturation Mode**: $V_E < V_B$ **and** $V_C < V_B$
   - Transistor acts like a ***short circuit*** — current flows freely from C to E
2. **Cut-off Mode:** $V_E > V_B$ **and** $V_C > V_B$
   - Transistor acts like an ***open circuit***— no current flows
3. **Active Mode:** $V_C > V_B > V_E$
   - Transistor acts like an *amplifier* — current from C to E is *proportional to* current flowing into the base
4. **Reverse Active Mode:** $V_C < V_B < V_E$
   - Transistor acts like a *reverse amplifier* — current from E to C is *proportional to* current flowing into the base (rarely used)

TRANSISTOR AS SWITCH

When Control signal is at 5V, transistor is in **Saturation Mode ($V_E < V_B$ and $V_C < V_B$):** transistor acts as a ***short circuit***.

When Control signal is at 0V, transistor is in **Cut-off Mode ($V_E > V_B$ and $V_C > V_B$):** transistor acts as an ***open circuit***.



R1 is needed here to limit the current into the Base of the Transistor. It can only accept about 10-100mA of current

MOSFETS

Tutorial Here! https://youtu.be/CFt8hkh17_w

The Transistors we've looked at are technically

Bipolar Junction Transistors (BJT)

Most modern power applications use

Metal-Oxide Field-Effect Transistors (MOSFET)

The principles are the same, but we replace

Base (B) with Gate (G)

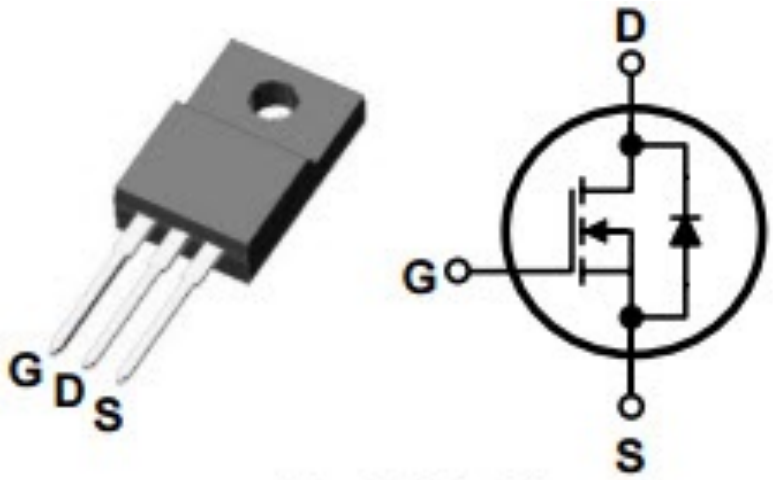
Collector (C) with Source (S)

Emitter (E) with Drain (D)

NPN BJT ~~ N-Channel MOSFET

PNP BJT ~~ P-Channel MOSFET

MOSFET AS SWITCH

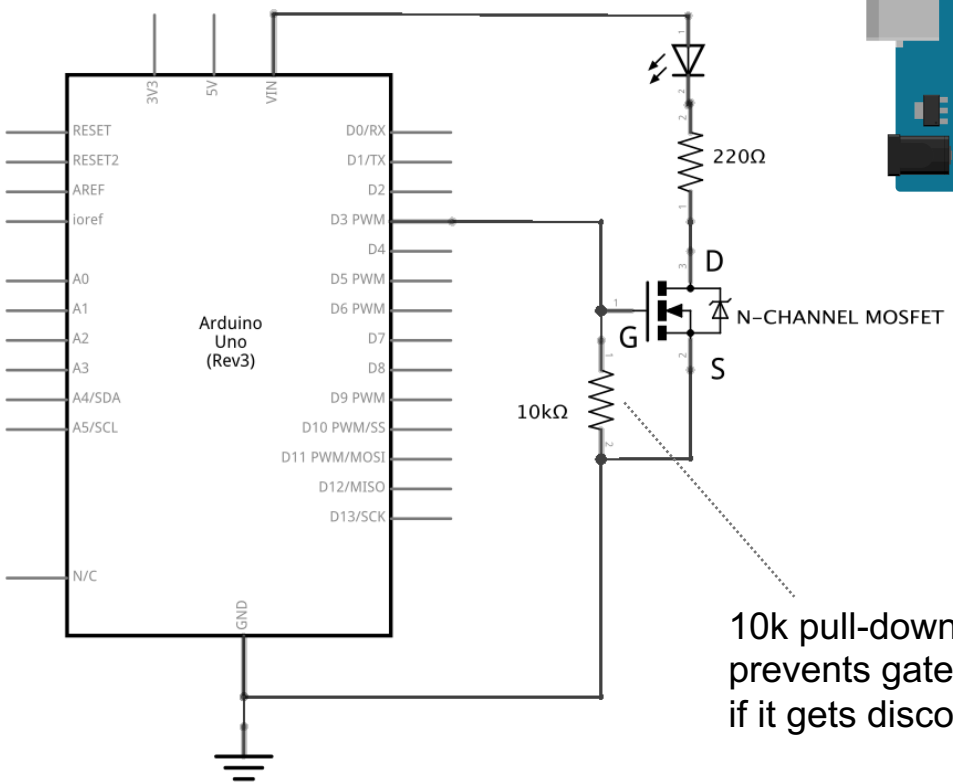


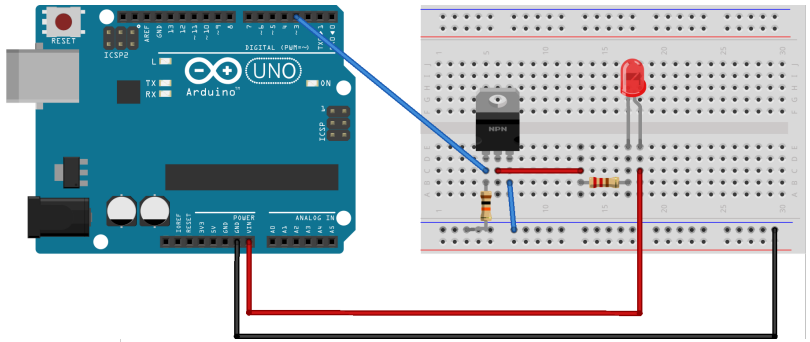
N channel MOSFET Pinout

If $V_{gate} > V_{source}$ current flows from D to S (short circuit)

If $V_{gate} \leq V_{source}$ no current flows from D to S (open circuit)

N-CHANNEL MOSFET AS SWITCH

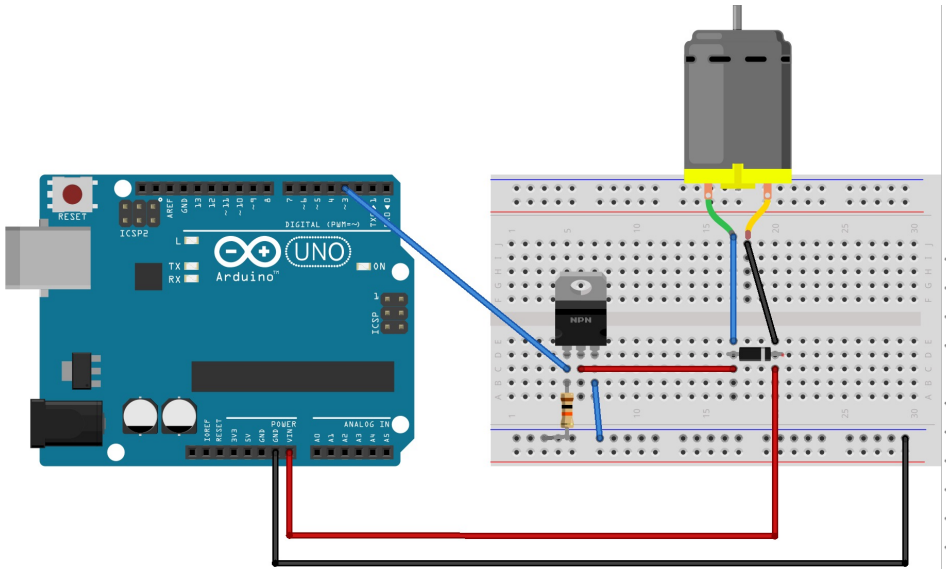


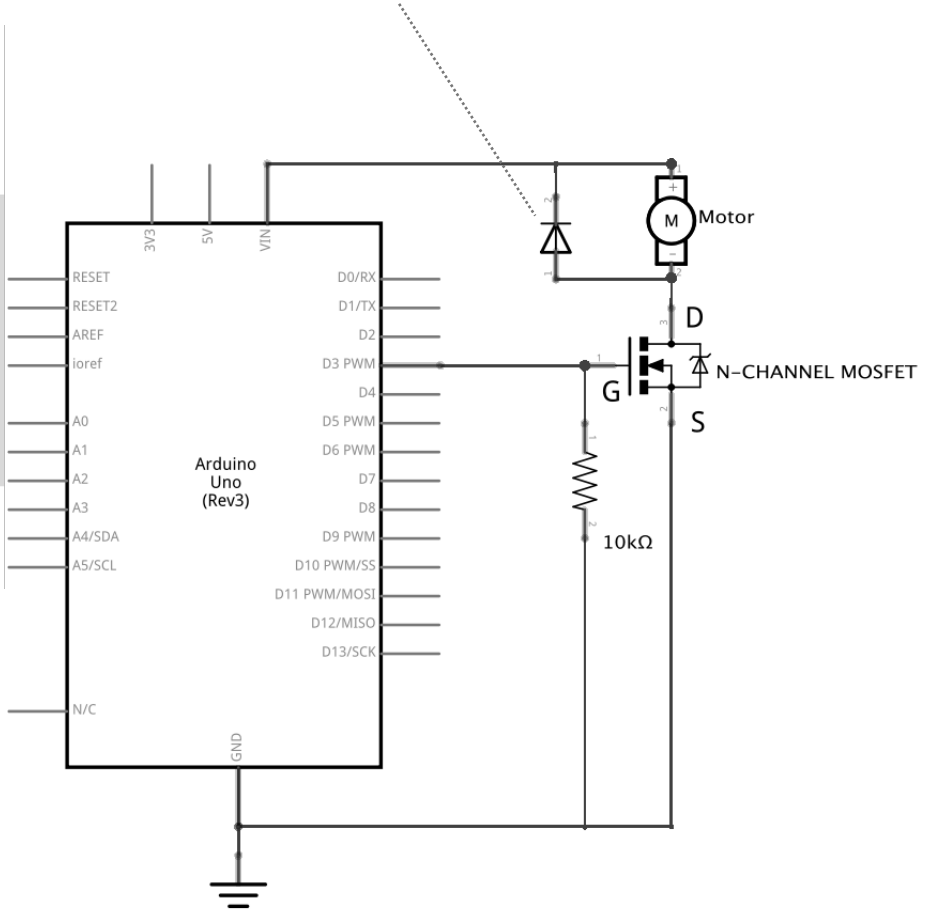


10k pull-down resistor
prevents gate voltage from floating
if it gets disconnected

N-CHANNEL MOSFET AS MOTOR DRIVER

“flyback” diode dissipates backward current flow from shutdown spikes
(happens with motors and solenoids)





OTHER RESOURCES

Sparkfun Transistor Tutorial:
https://learn.sparkfun.com/tutorials/transistors/all

Make: Electronics, Chap. 2:
https://search.lib.umich.edu/catalog/9918729002850638 1

Relays:
https://learn.adafruit.com/adafruit-power-relay-featherwing

https://howtomechatronics.com/tutorials/arduino/control-high-voltage-devices-arduino-relay-tutorial/