

Controlling the World from your Arduino

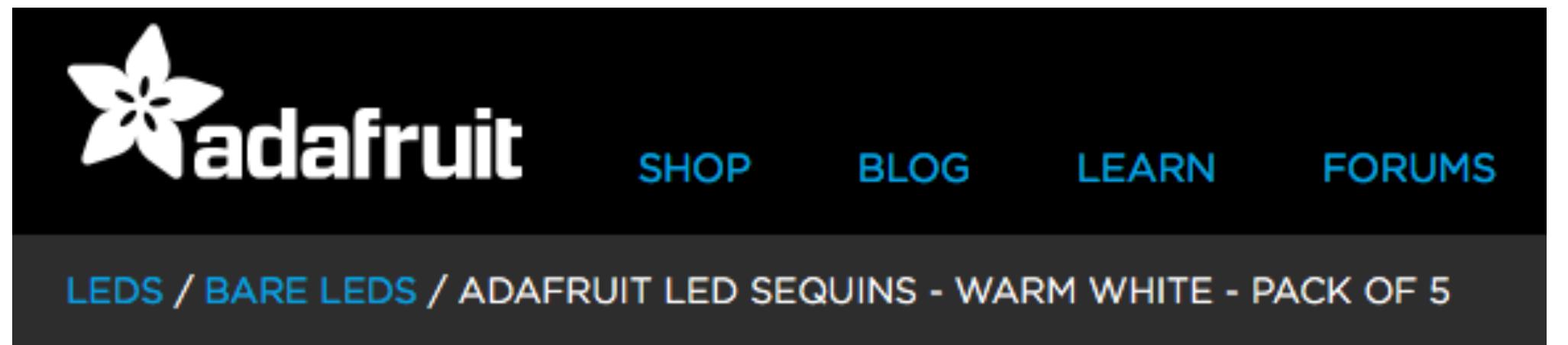
Rick Sellens

Direct Control with DIO

- 14 DIO pins can be set to either 0V (LOW) or 5V (HIGH) using **pinMode(XX,OUTPUT)** and **digitalWrite(XX,HIGH/LOW)**
- 6 of those can do PWM, automatically switching between 0V and 5V very quickly to simulate intermediate voltages **analogWrite(XX,val)**
- The catch: maximum 20 mA current per pin

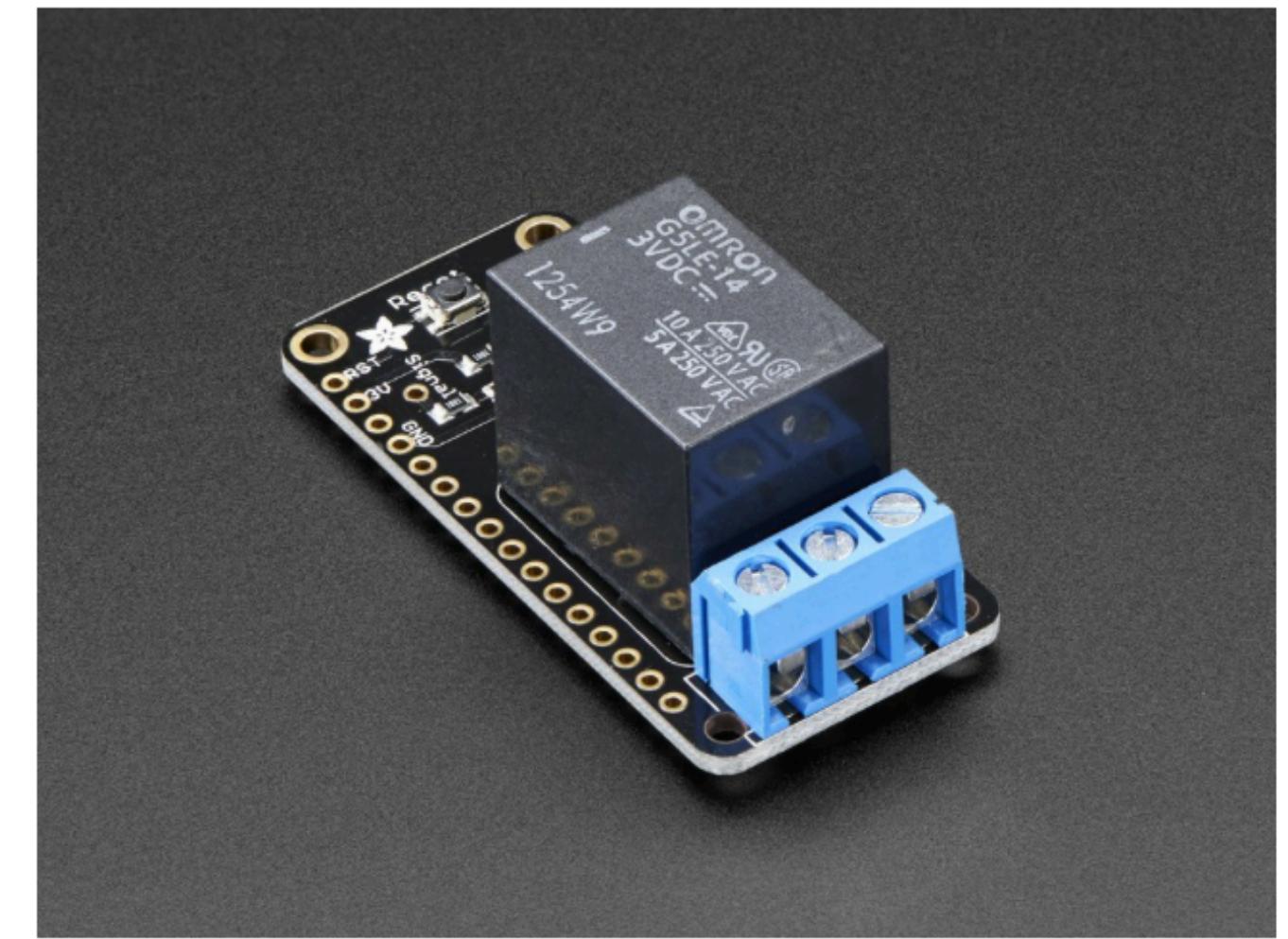
What can you do with 20 mA?

- 20 mA at 5 V is 100 mW (not much)
- enough to brightly light up an LED indicator
- enough to power many sensors
- enough to power a Wheatstone bridge with at least 250 ohm resistance
- **enough to switch a transistor on and off for higher current loads**



Relays

- Electromagnetically actuated mechanical switch
- $F=ma$ second order switching time, not for high speed or very frequent switching
- Isolate the power side from the control side for safety



Adafruit Power
Relay FeatherWing

PRODUCT ID: 3191

\$9.95
IN STOCK

1 ADD TO CART

QTY DISCOUNT
1-9 \$9.95
10-99 \$8.96
100+ \$7.96

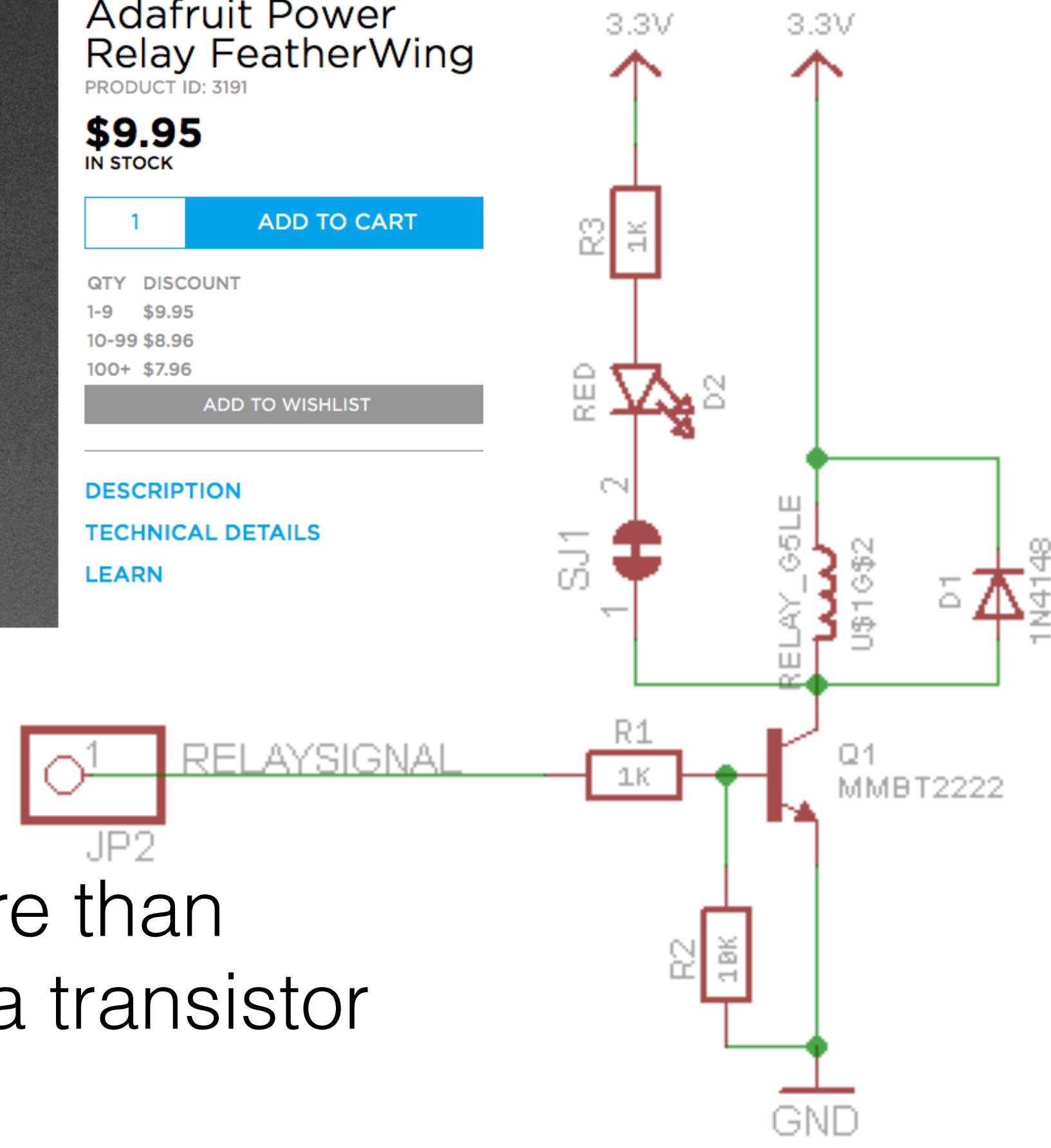
ADD TO WISHLIST

DESCRIPTION

TECHNICAL DETAILS

LEARN

- Coil draws more than 20 mA so use a transistor to switch it
 - DIO drives the transistor
 - transistor drives the relay coil
 - power to the load runs through the relay contacts

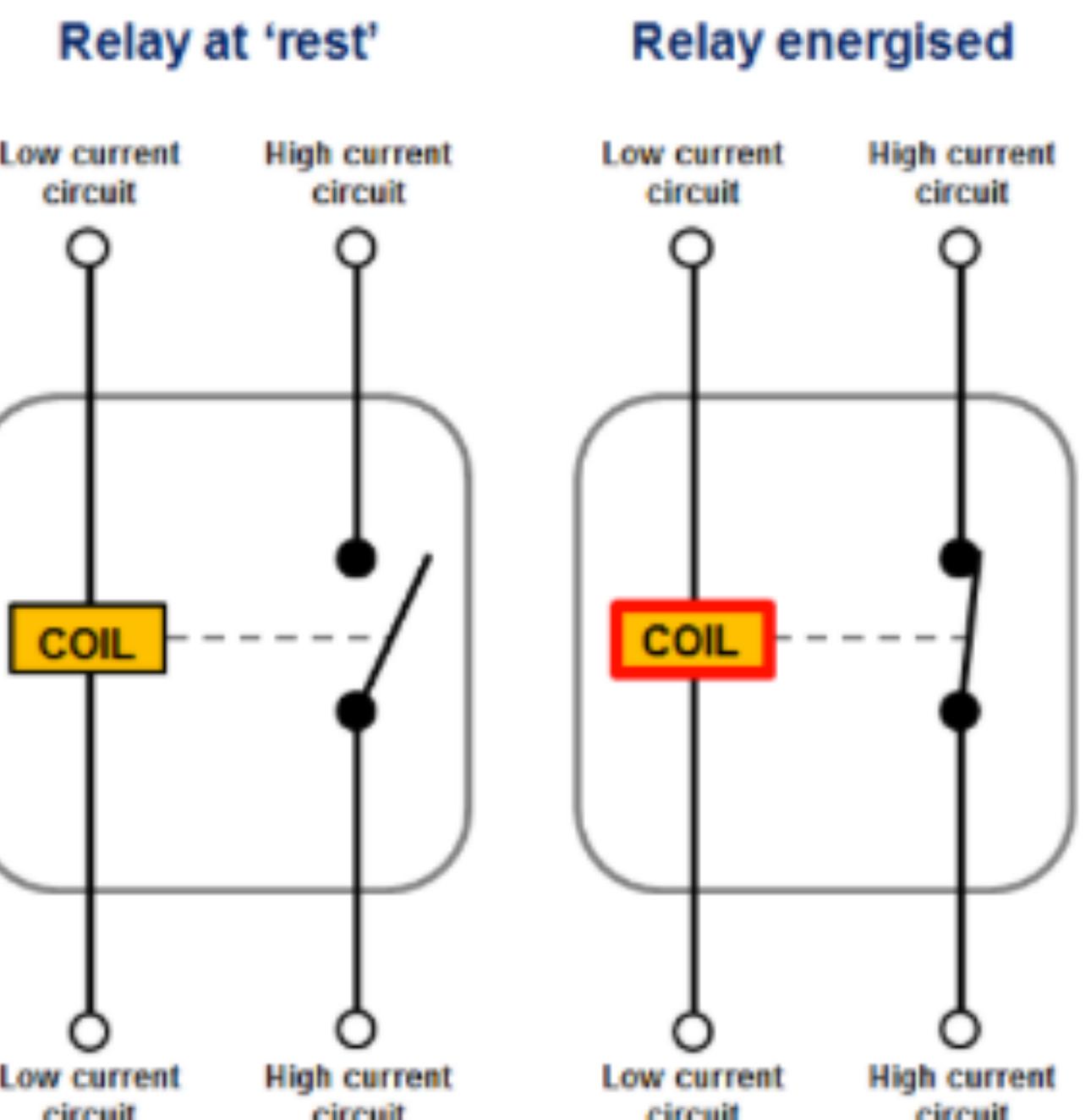
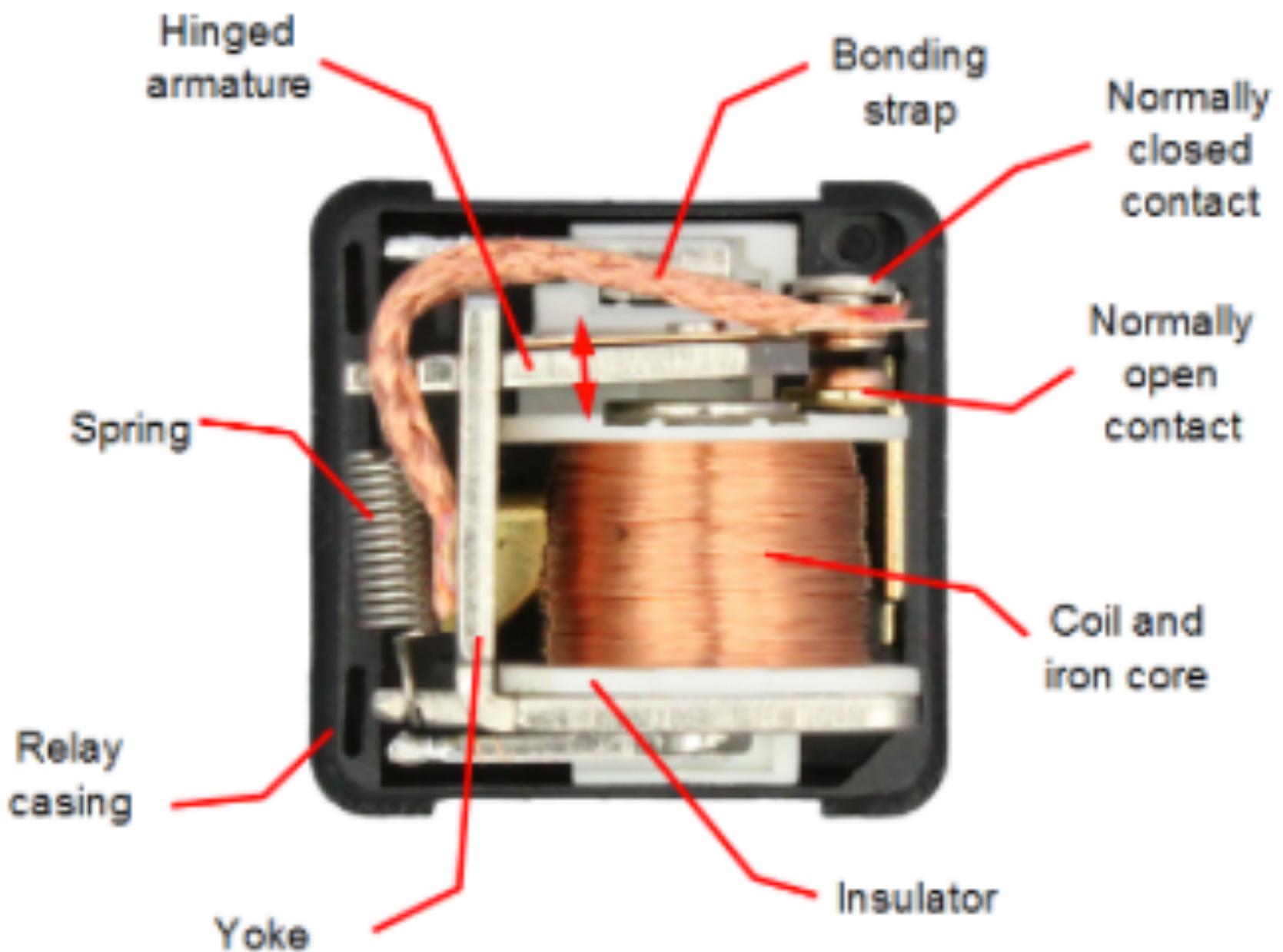


Small Relays in lots of Automotive Applications

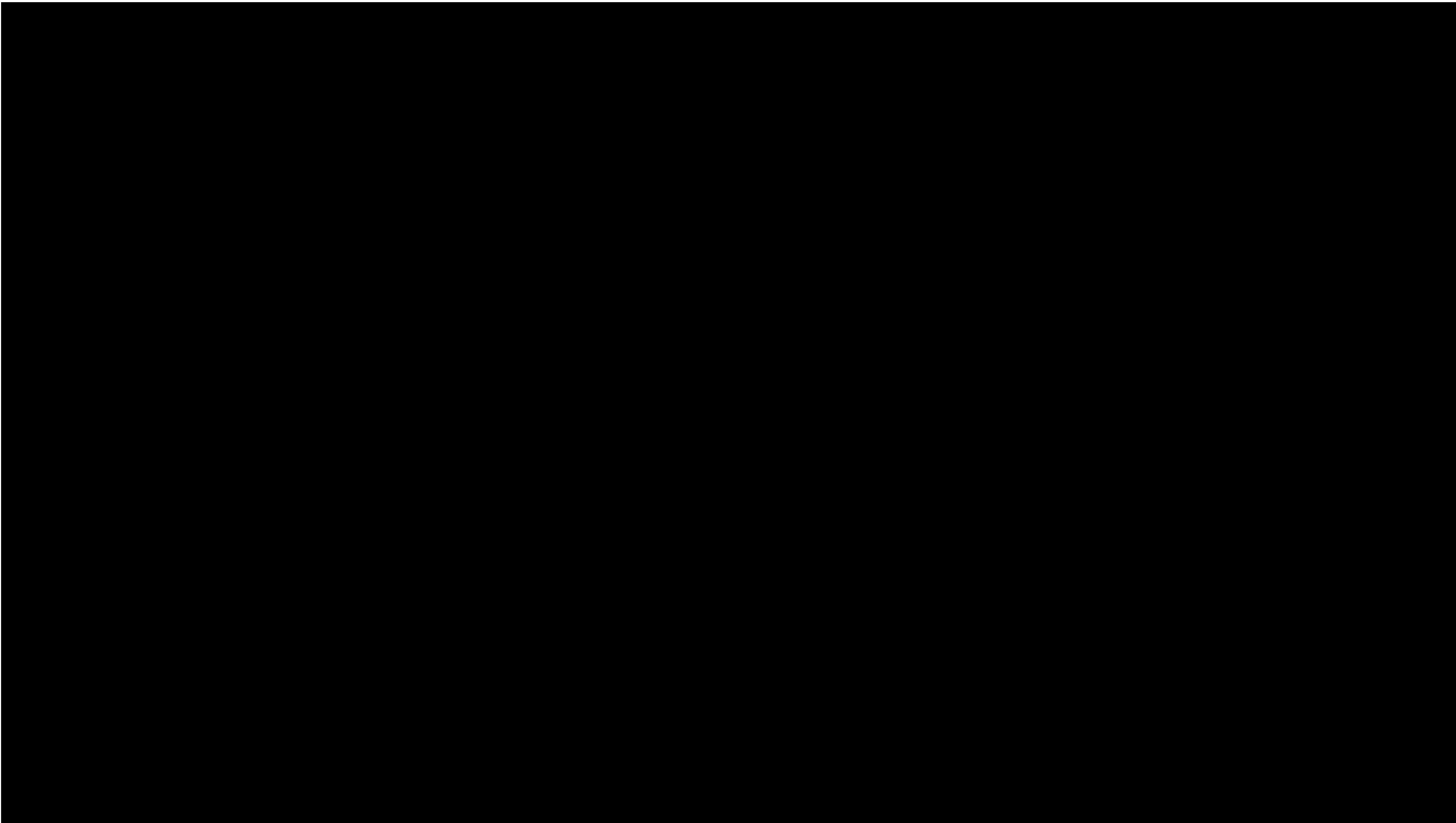
- Anywhere you want to use a relatively small (100 mA) current to switch a larger current (e.g. headlights)
- Resistance close to zero in high current path
- Cheap and standardized
- <http://www.12voltplanet.co.uk/relay-guide.html>



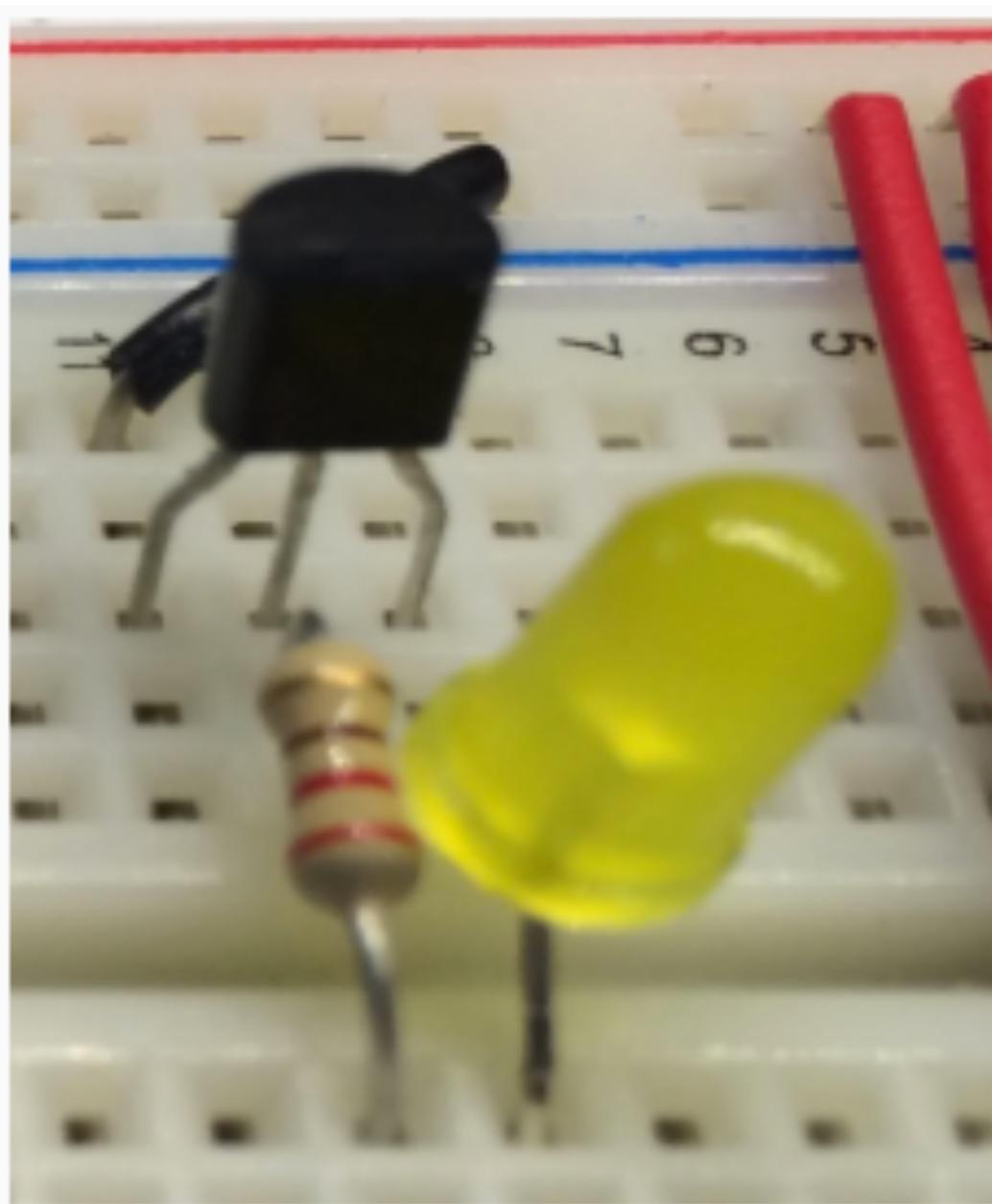
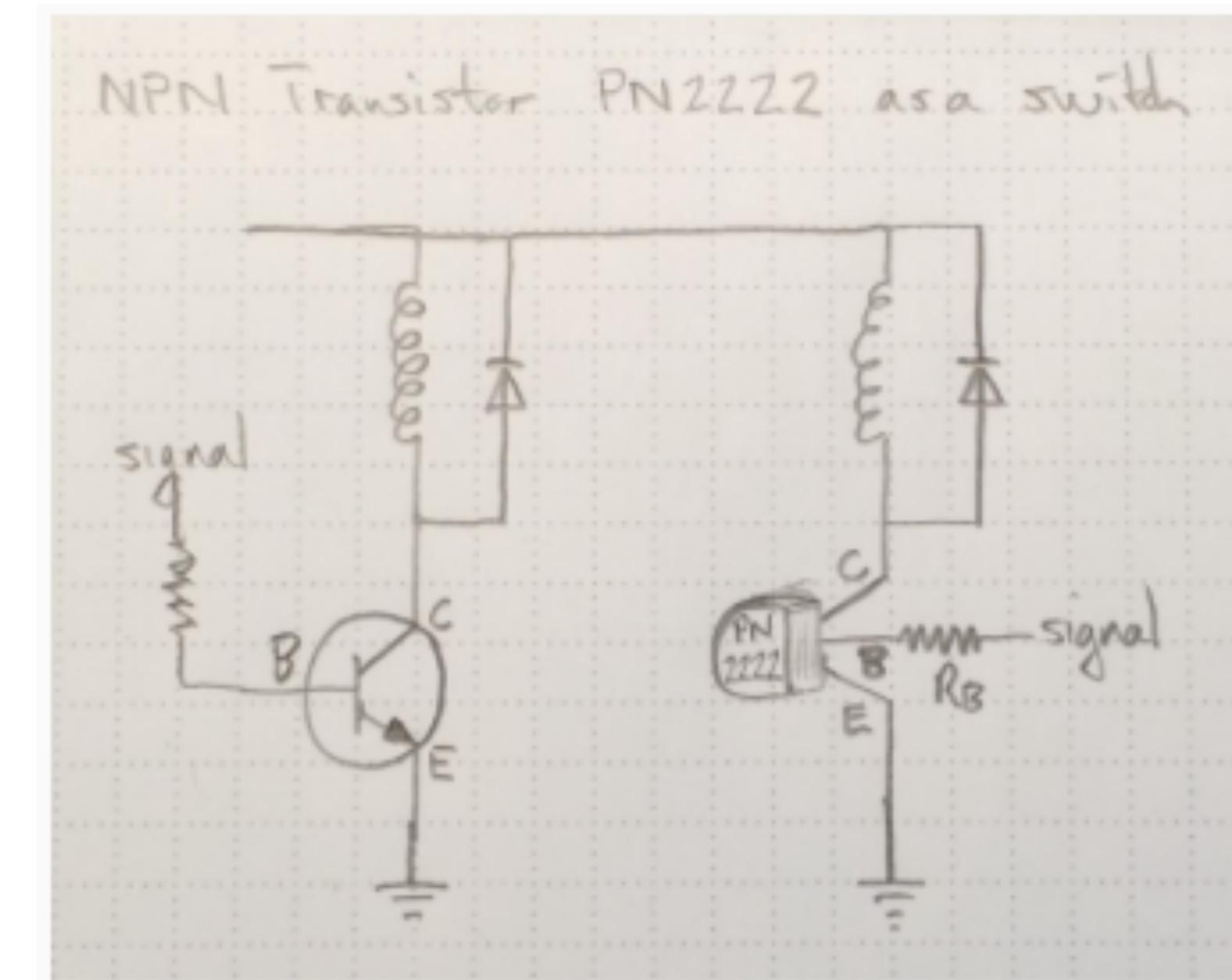
12V Universal Heated Rear Window Timer Relay - 10 Min Delay



Three of many transistor options for
controlling anything DC

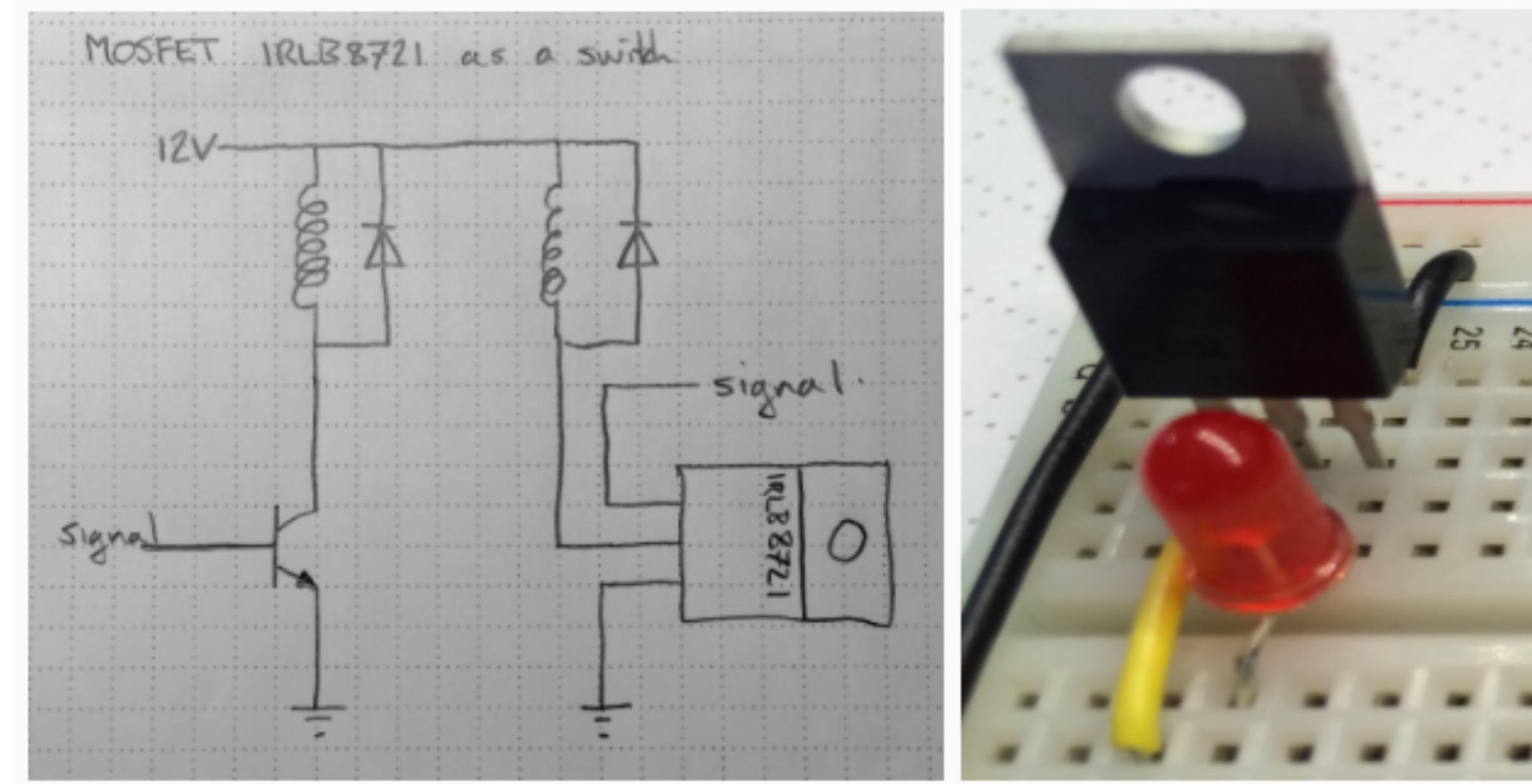


Solid State DC Switching



- Different transistors for different applications and power levels with low current signal
- An NPN transistor like this PN2222 (\$0.25) can be used to switch a DC load up to about 500 mA continuous or 1 A peak.
- small motors, relays, etc.

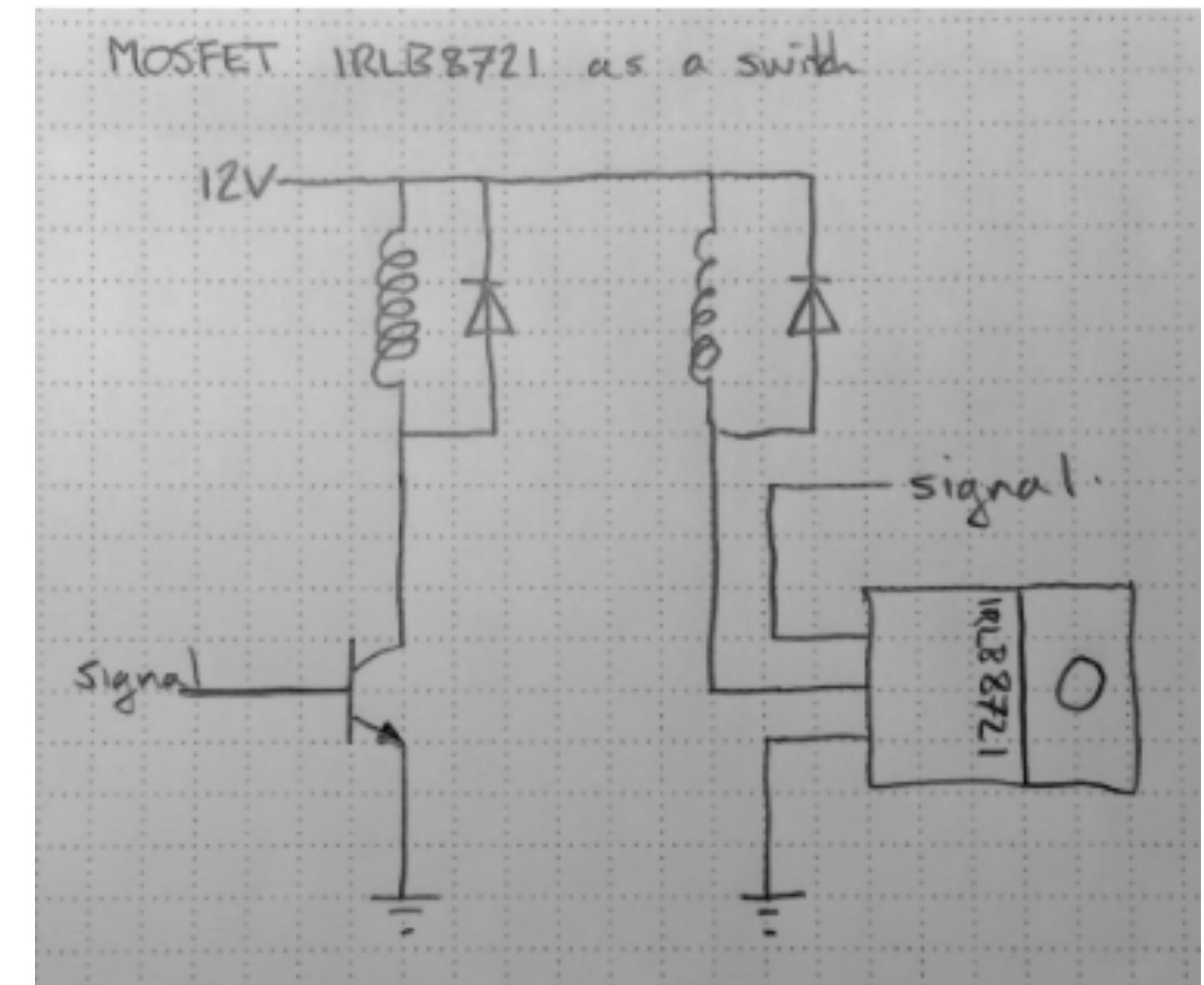
MOSFET for Higher DC Current



- An N Channel MOSFET (about \$2 each in small quantities) as a DC switch controlled from DIO
- I used an IRLB8721 which is good for up to 62 amps of low voltage current at room temperature.
- This MOSFET switching approach is overkill for low currents, and you could use a lighter duty switching transistor to save cost and bulk.

Inductive Loads need Diodes

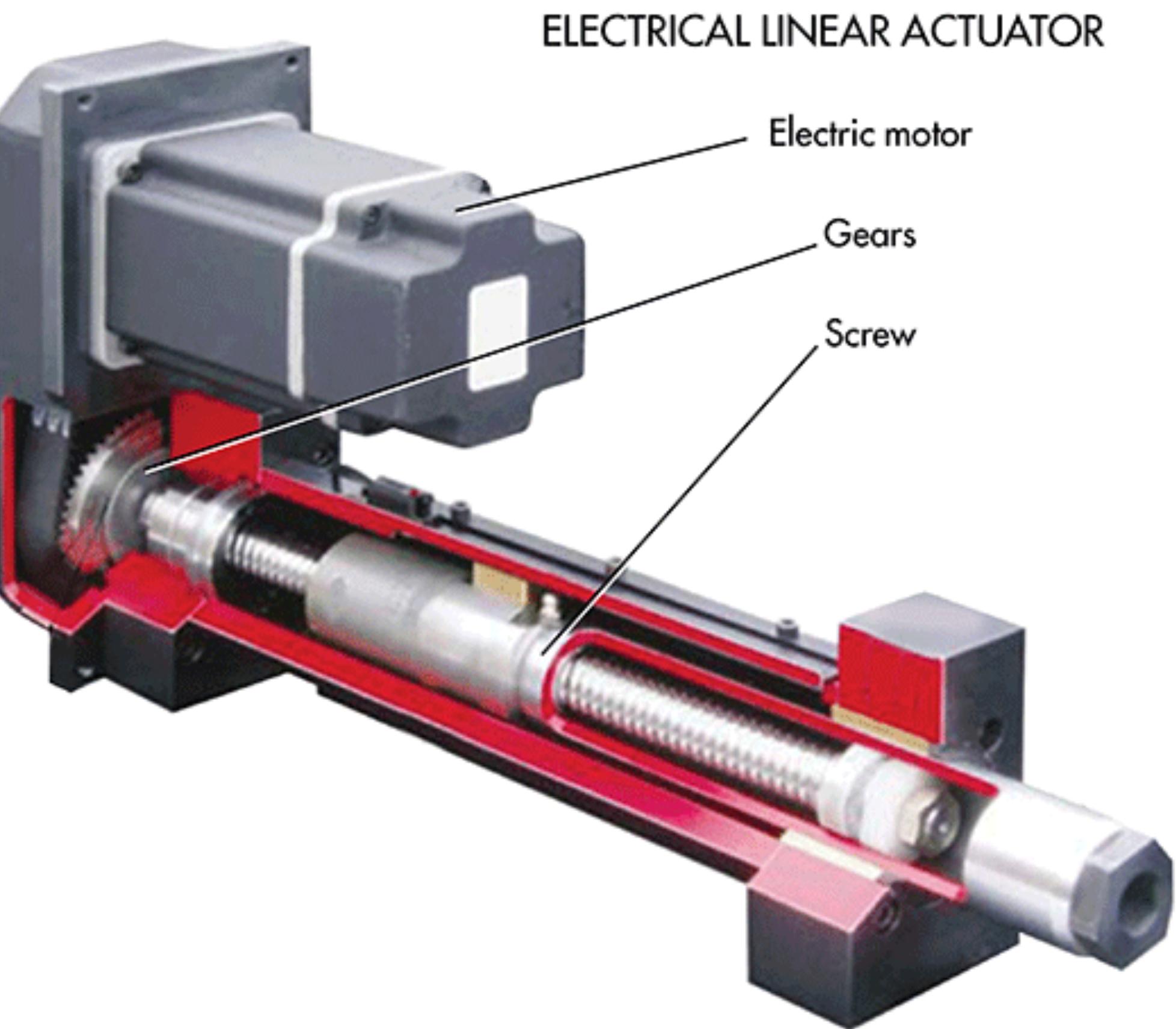
- Current in an inductor (motor, solenoid, relay coil) tends to keep flowing
- Switching off can produce voltage spikes and fry transistors and other components
- A diode allows current flow in only one direction
- This diode allows the current to keep going around the inductor until it dissipates





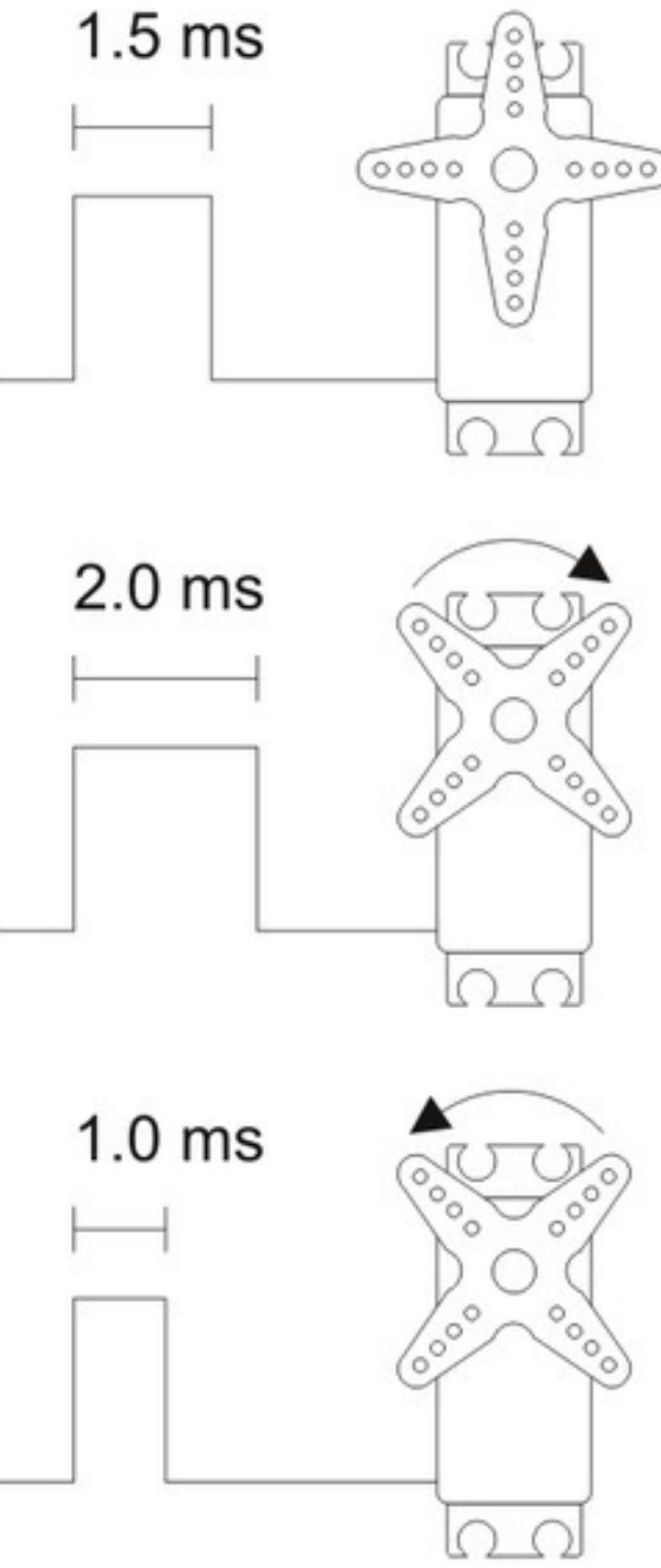
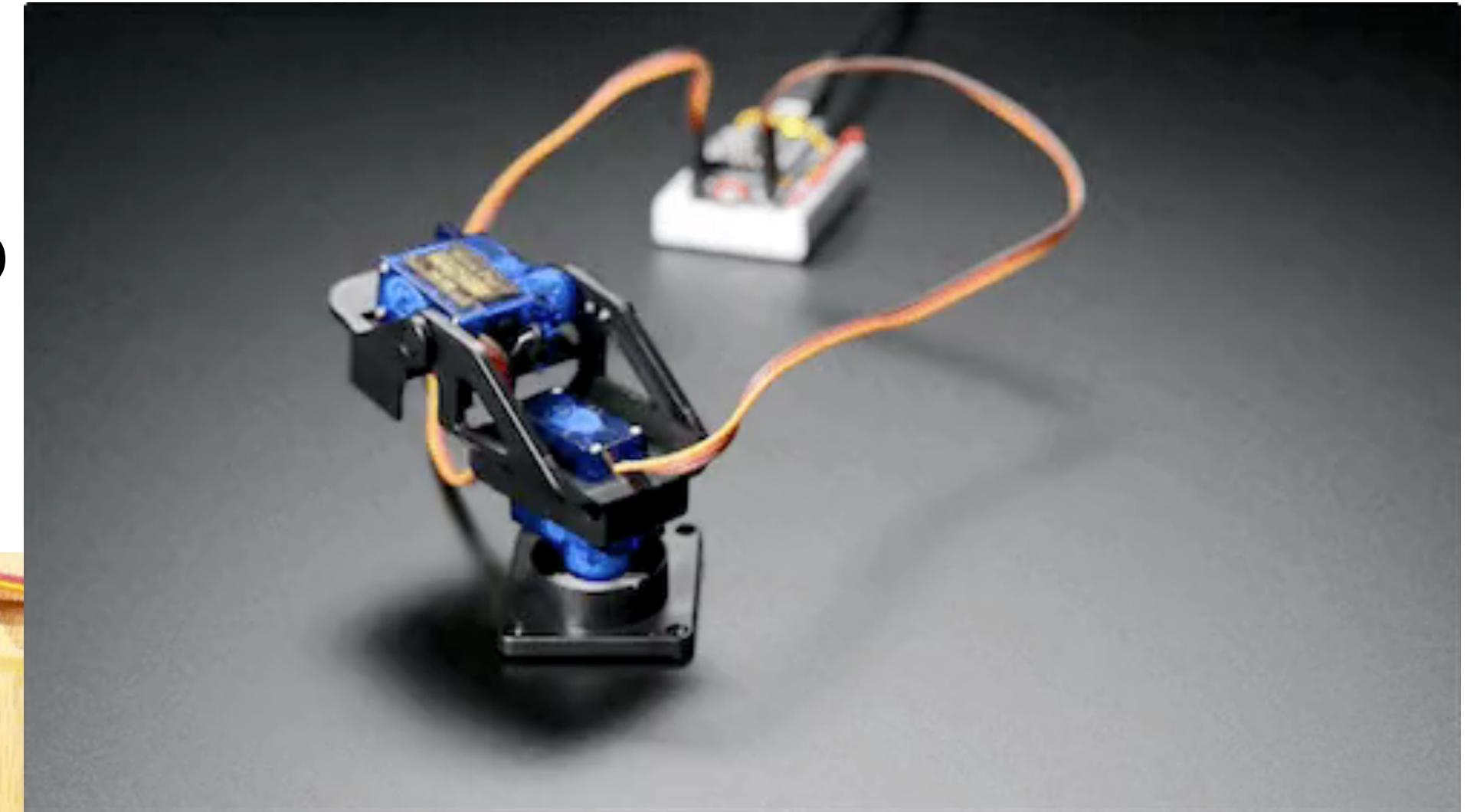
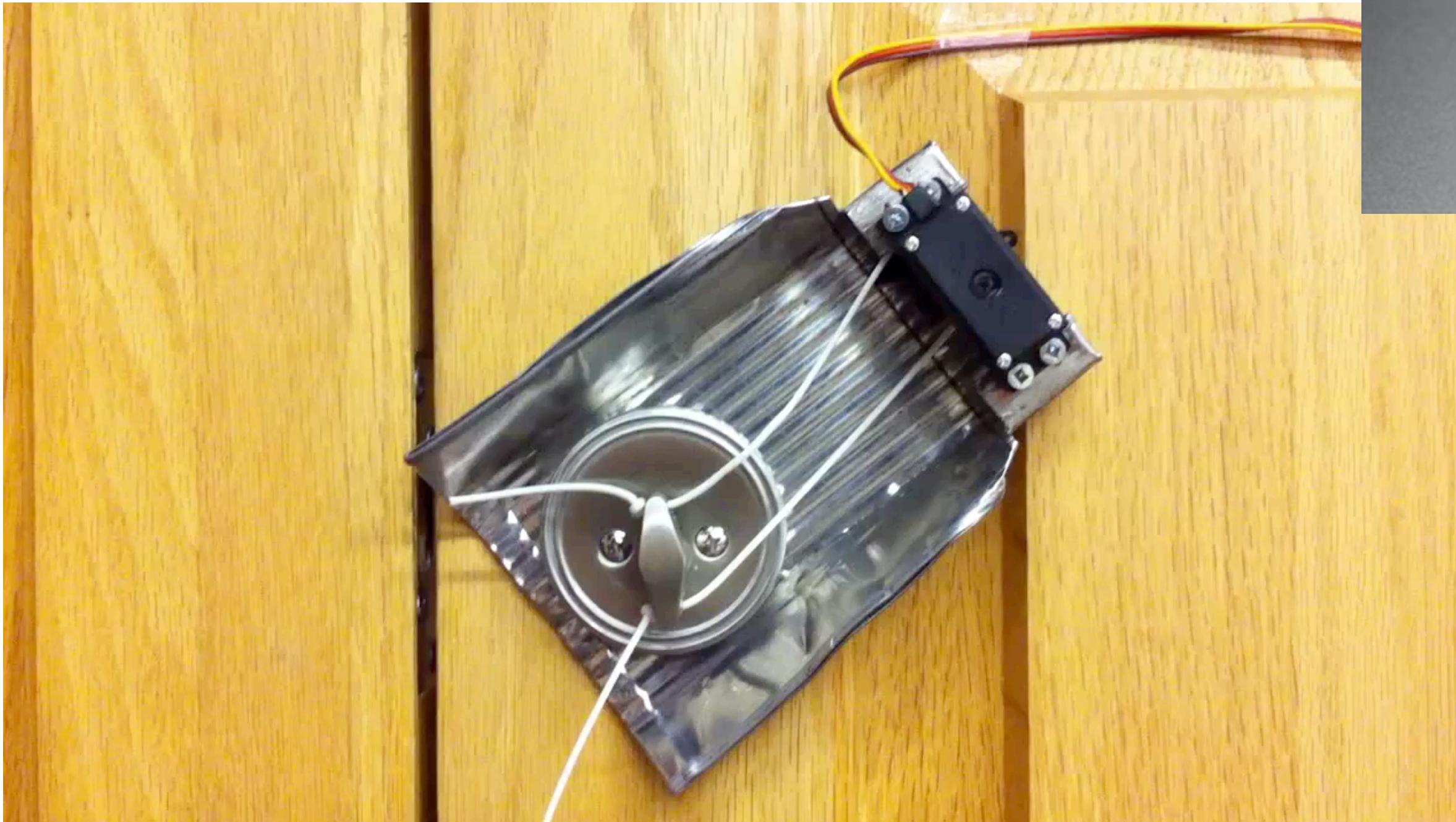
Linear Actuators

- DC motor drives screw through gears to produce linear motion
- potentiometer for position feedback
- This video from Progressive Automations shows an Arduino controlling some relays to drive a linear actuator
<https://youtu.be/lDJiohQcy4c>



Servo Motors

- 1 DIO pin per motor, pulsed to signal desired angle
- Control detail all happens in the servo
- <https://www.pololu.com/blog/17/servo-control-interface-in-detail>



	HS-422 Servo Motor Product Code : RB-Hit-27 27 Review(s) Regular Price: CAD \$12.81 Special Price: CAD \$12.15 In stock		HS-645MG Servo Motor Product Code : RB-Hit-29 10 Review(s) Regular Price: CAD \$40.37 Special Price: CAD \$37.34 In stock		HS-485HB Servo Motor Product Code : RB-Hit-87 9 Review(s) CAD \$19.99 In stock		9g Continuous Rotation Micro Servo Product Code : RB-Fit-02 8 Review(s) CAD \$6.40 In stock
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Small Reduction
Stepper Motor -
12VDC 32-Step 1/16
Gearing
PRODUCT ID: 918

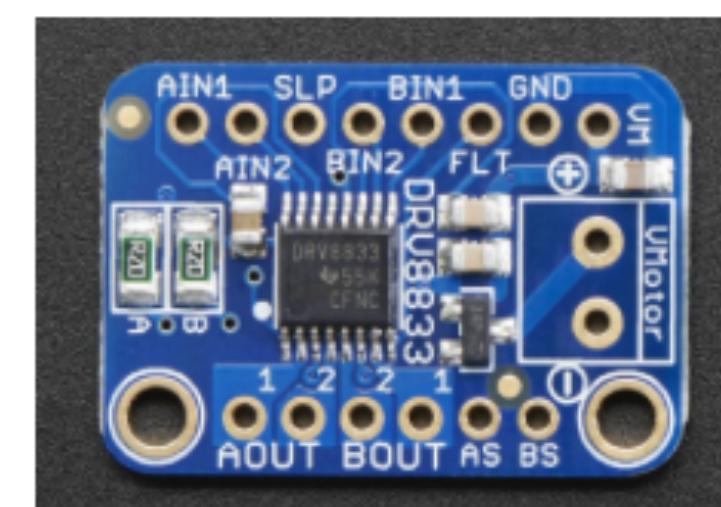
\$4.95

Stepper Motors

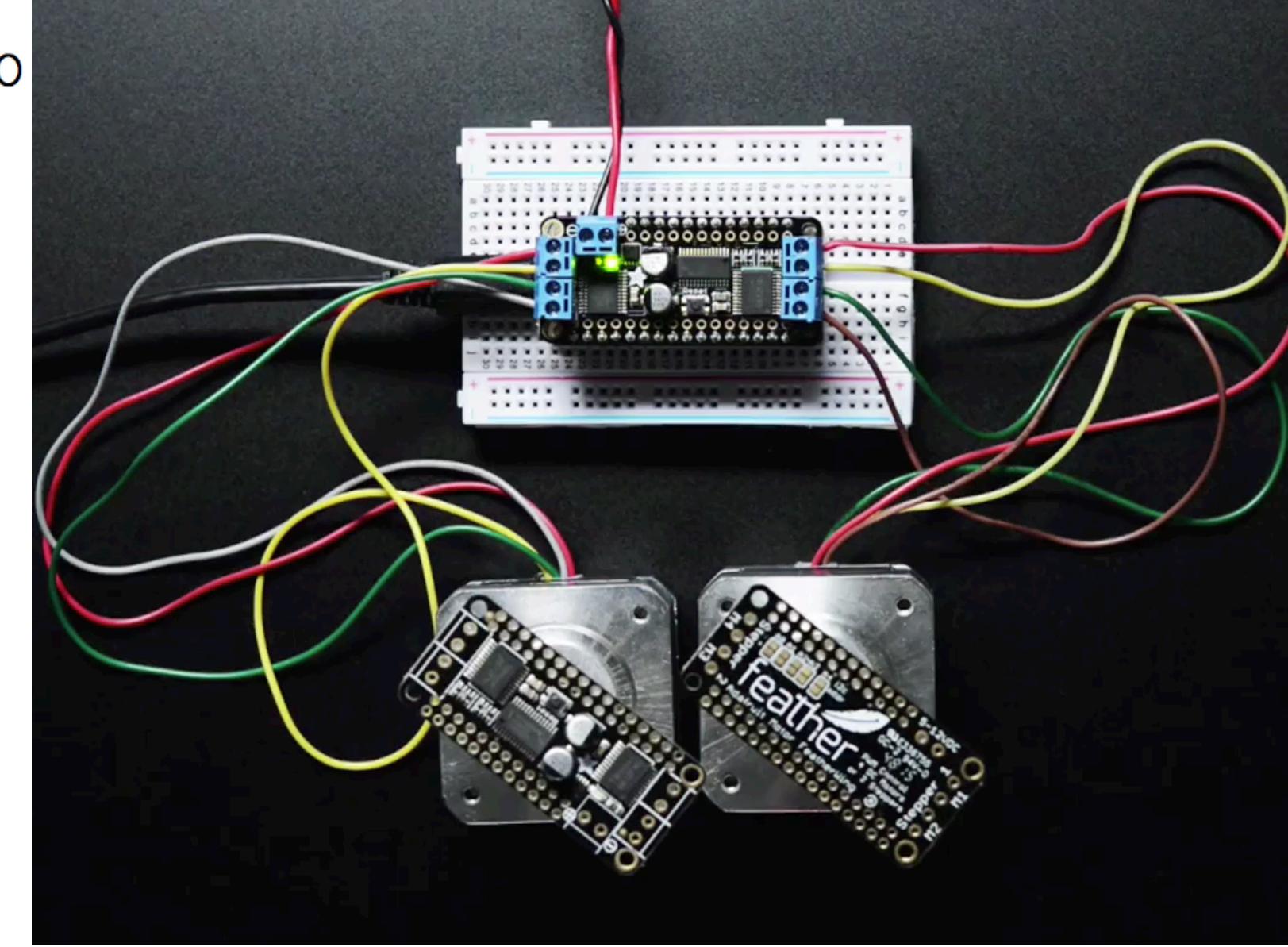
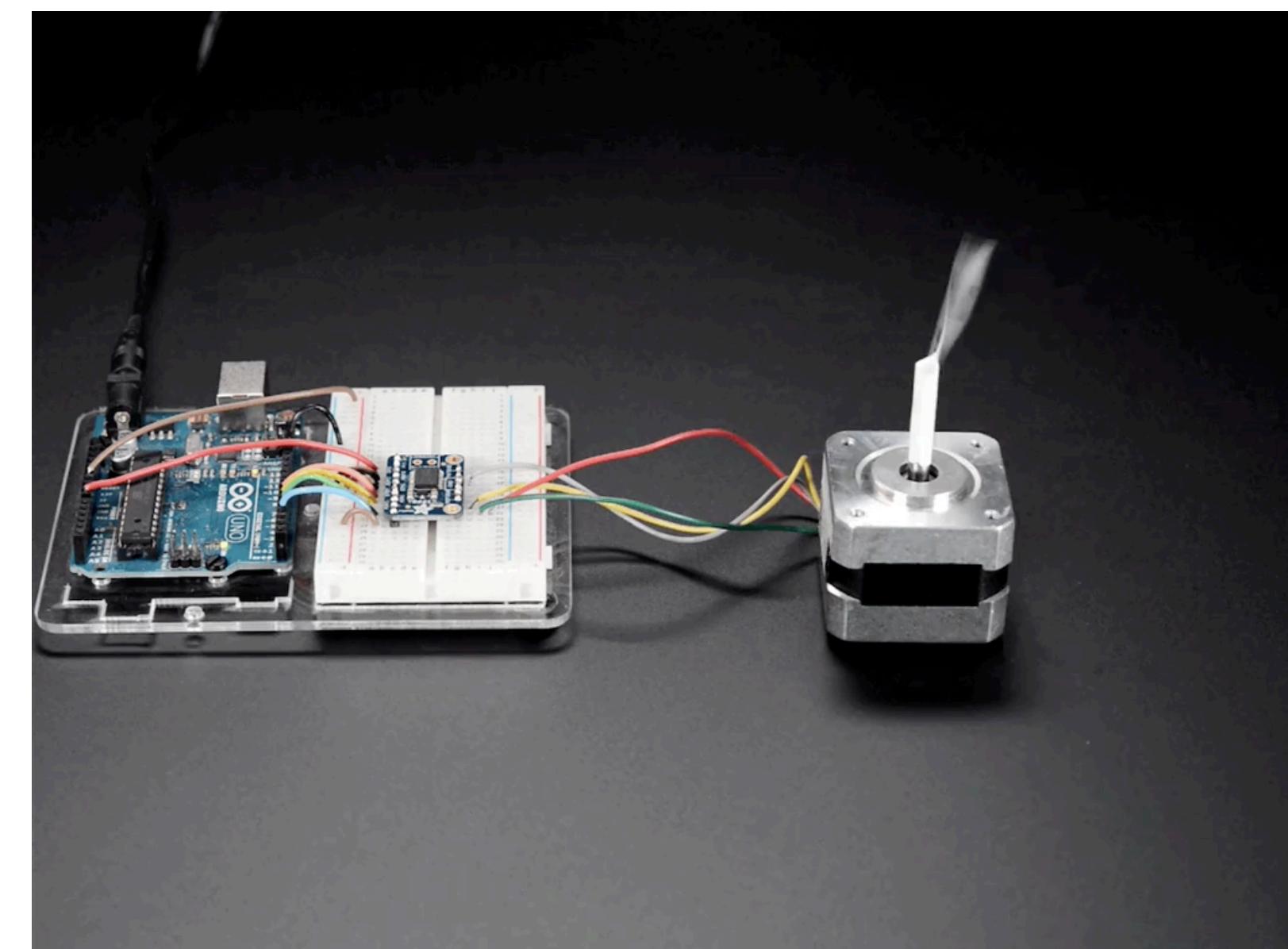


Stepper motor -
NEMA-17 size - 200
steps/rev, 12V
350mA
PRODUCT ID: 324
\$14.00

- Allow you to move in angular steps under digital control signals
- raw signals on DIO, or use I2C with more advanced controllers
- multiple steps can approximate continuous rotation
- [https://www.arduino.cc/en/Reference/
Stepper](https://www.arduino.cc/en/Reference/Stepper)

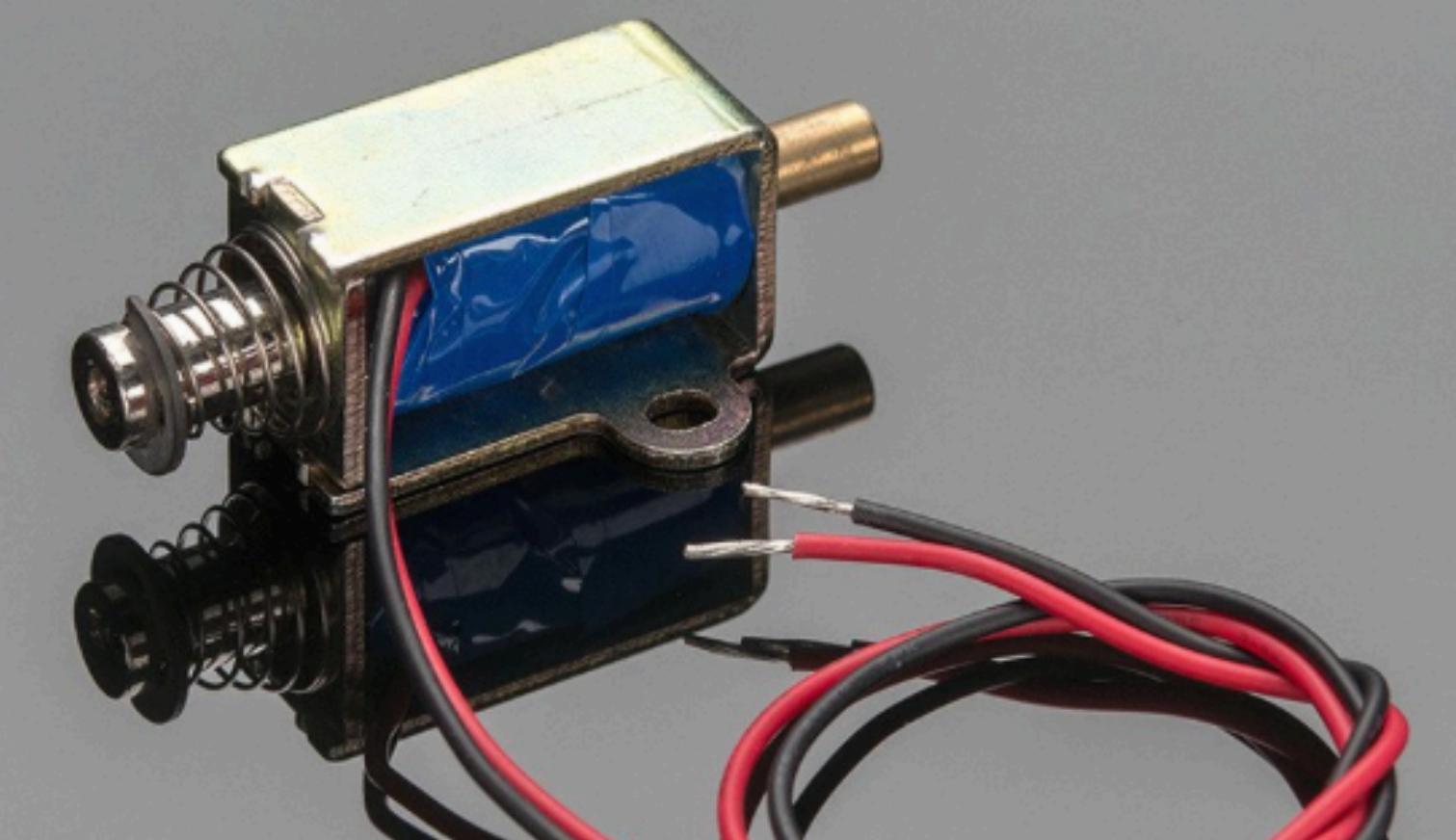


Adafruit
DRV8833
DC/Stepper
Motor Driver
Breakout Board



Solenoids

- Actuator element of a relay
- Either on or off push or pull
- Open or close locks, valves
- Inductive load needs diode protection

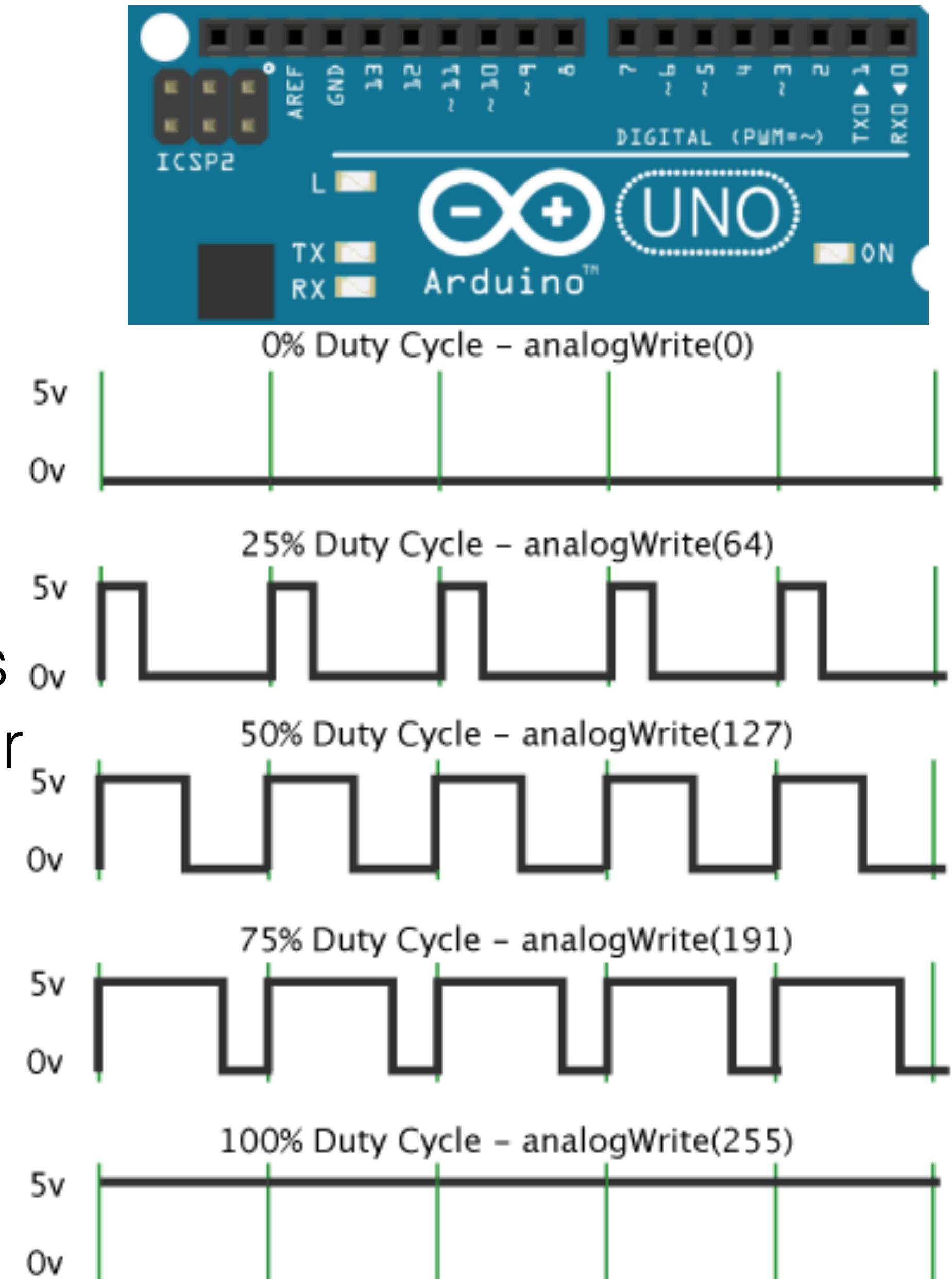


Switching ON/OFF May Not Be Enough

- Probably OK for Home Heating Thermostats, but...
 - Lights should be dimmable
 - Motors should run at controllable, variable different speeds
 - and be able to reverse direction

Pulse Width Modulation PWM

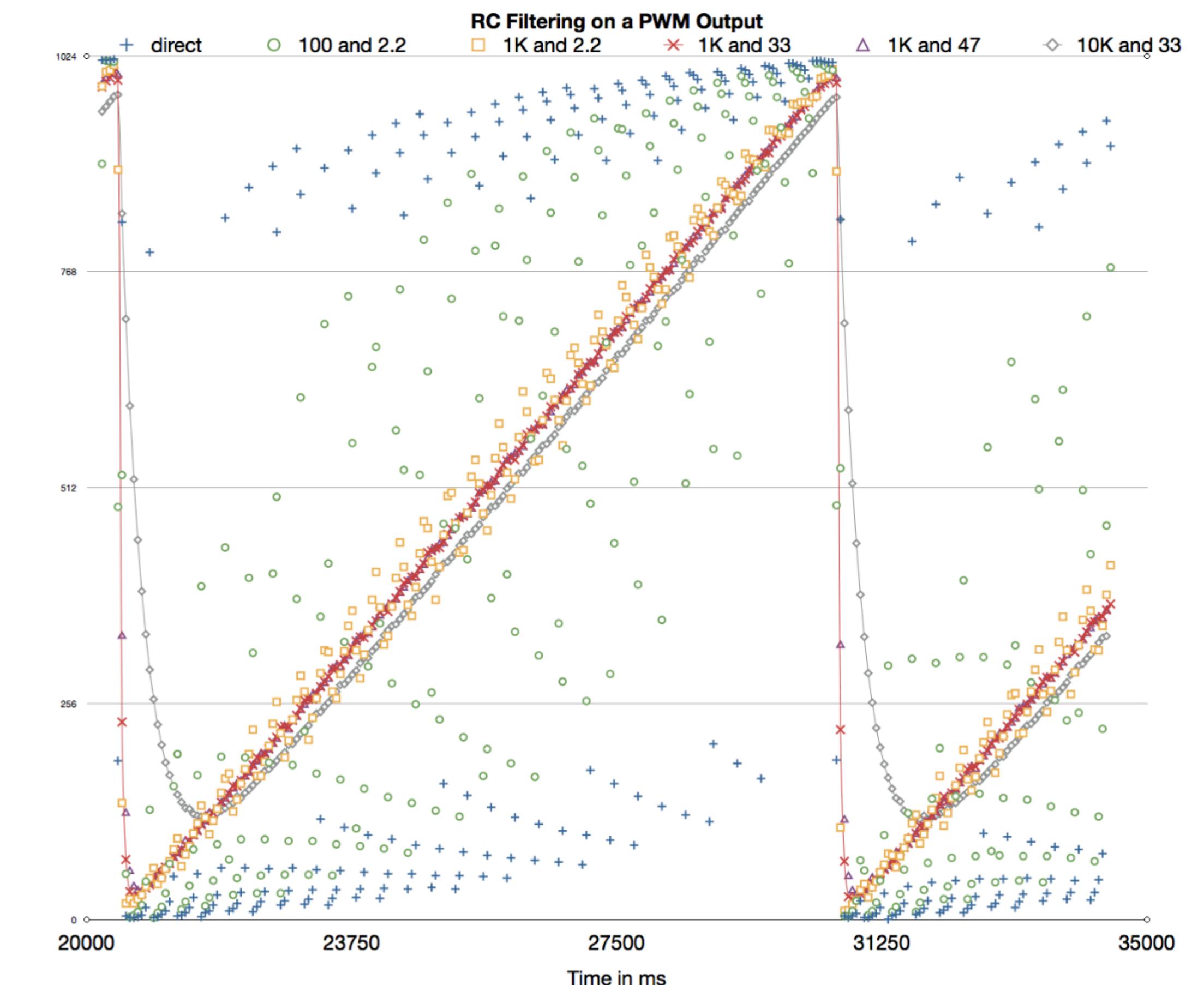
- available on pins 3,5,6,9,10,11
- pinMode(3,OUTPUT)
analogWrite(3,191)
will be at 5V at fraction $191/255$
 $= 74.9\%$ of the time
- LEDs will look dimmer
- <https://www.arduino.cc/en/Tutorial/PWM>



Actual Analog Output

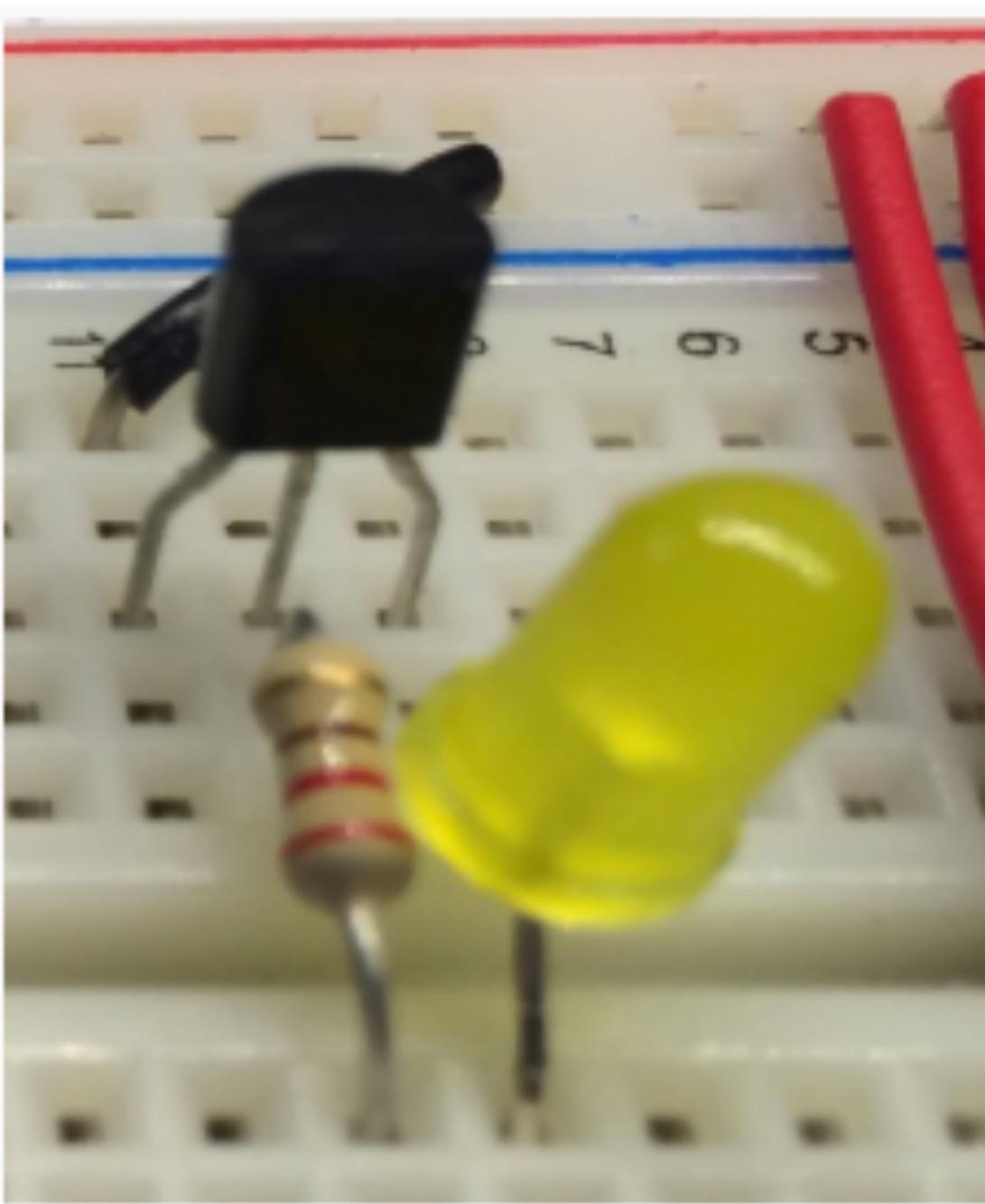
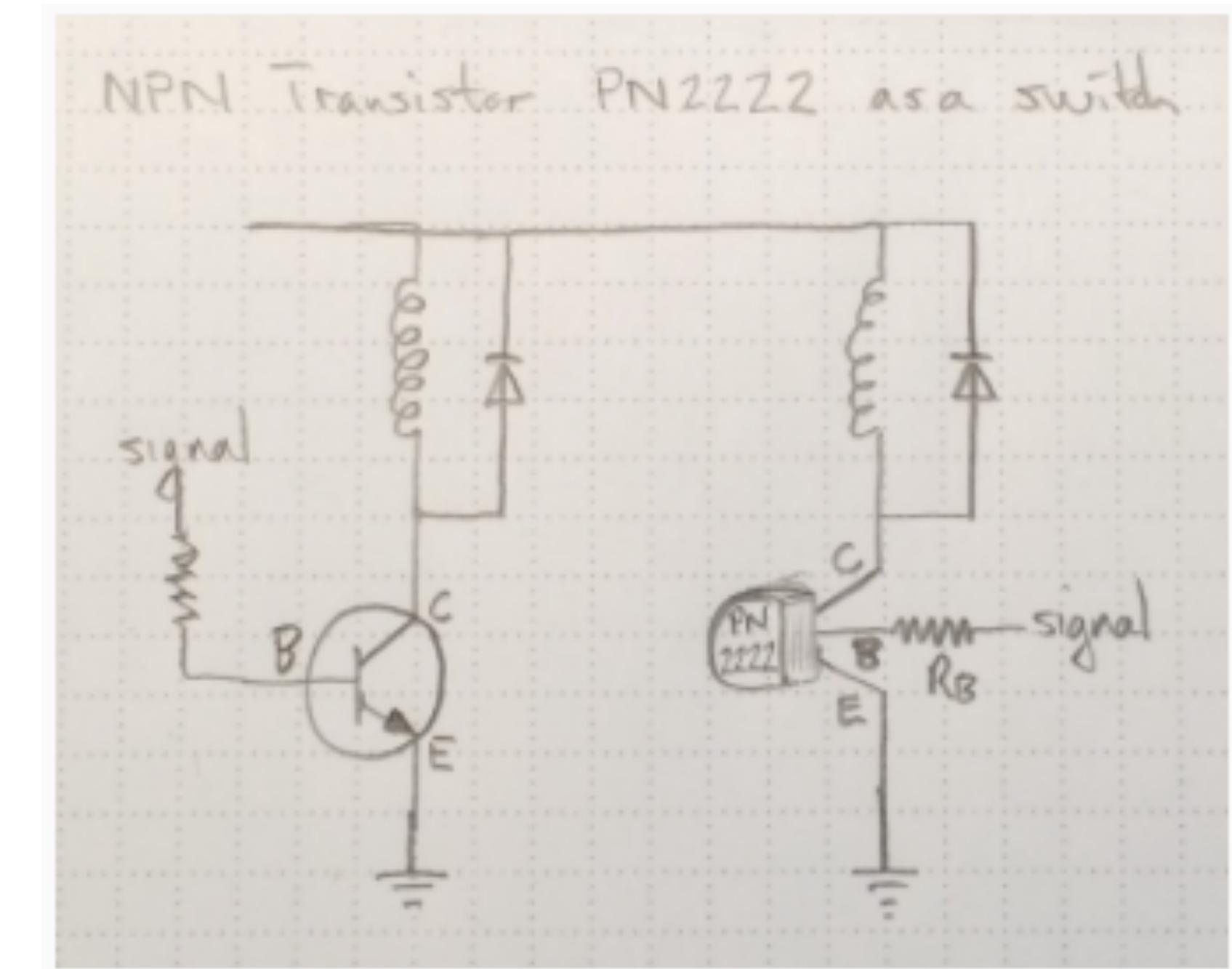
- Some processors provide digital to analog converters (DAC) to allow you to create arbitrary $Voltage(t)$ for sound, music, etc.
- With capacitors you can smooth the PWM to make it more like a constant DC voltage (this is the idea behind switching power supplies)
- for an RC circuit example:

<http://rwsarduino.blogspot.ca/2012/06/stable-analog-output.html>



Solid State DC Switching with PWM

- Transistors switch very quickly
- Input signal pulsed on and off with PWM
- Output will pulse on and off in response
- Can use PWM for dimming LED lighting
- Variable speed control in DC motors



Motor Drivers



Pololu item #: 2994 **187** in stock

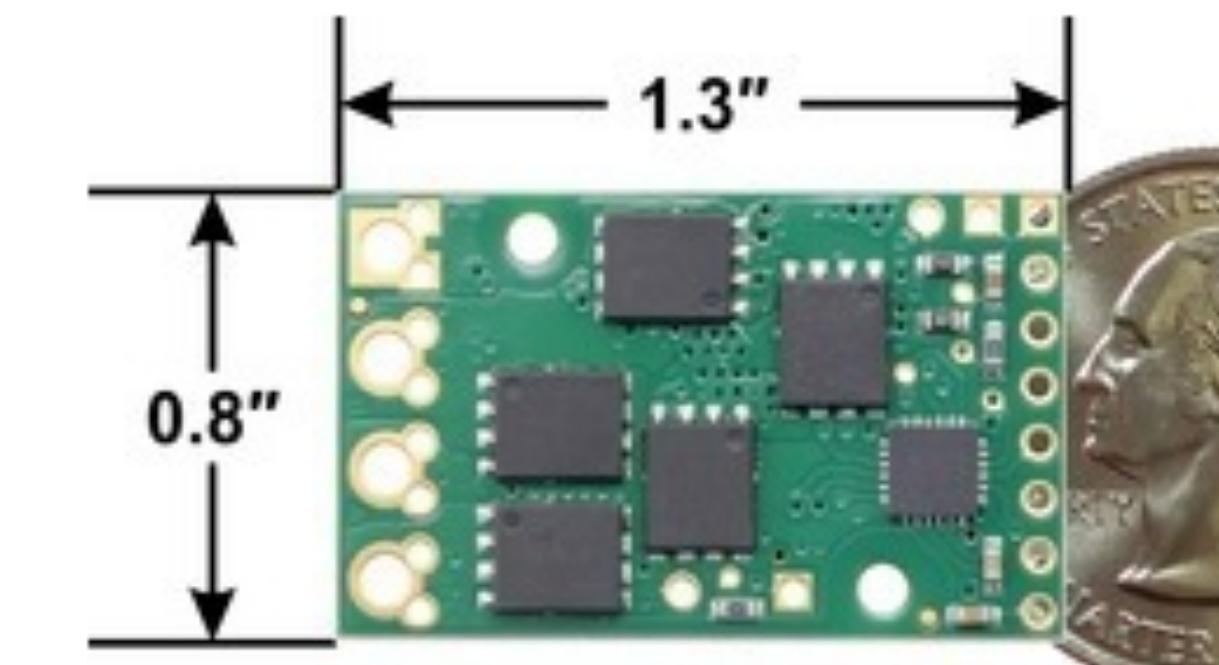
Price break	Unit price (US\$)
1	39.95
5	35.96
25	31.96
100	27.96

Quantity:

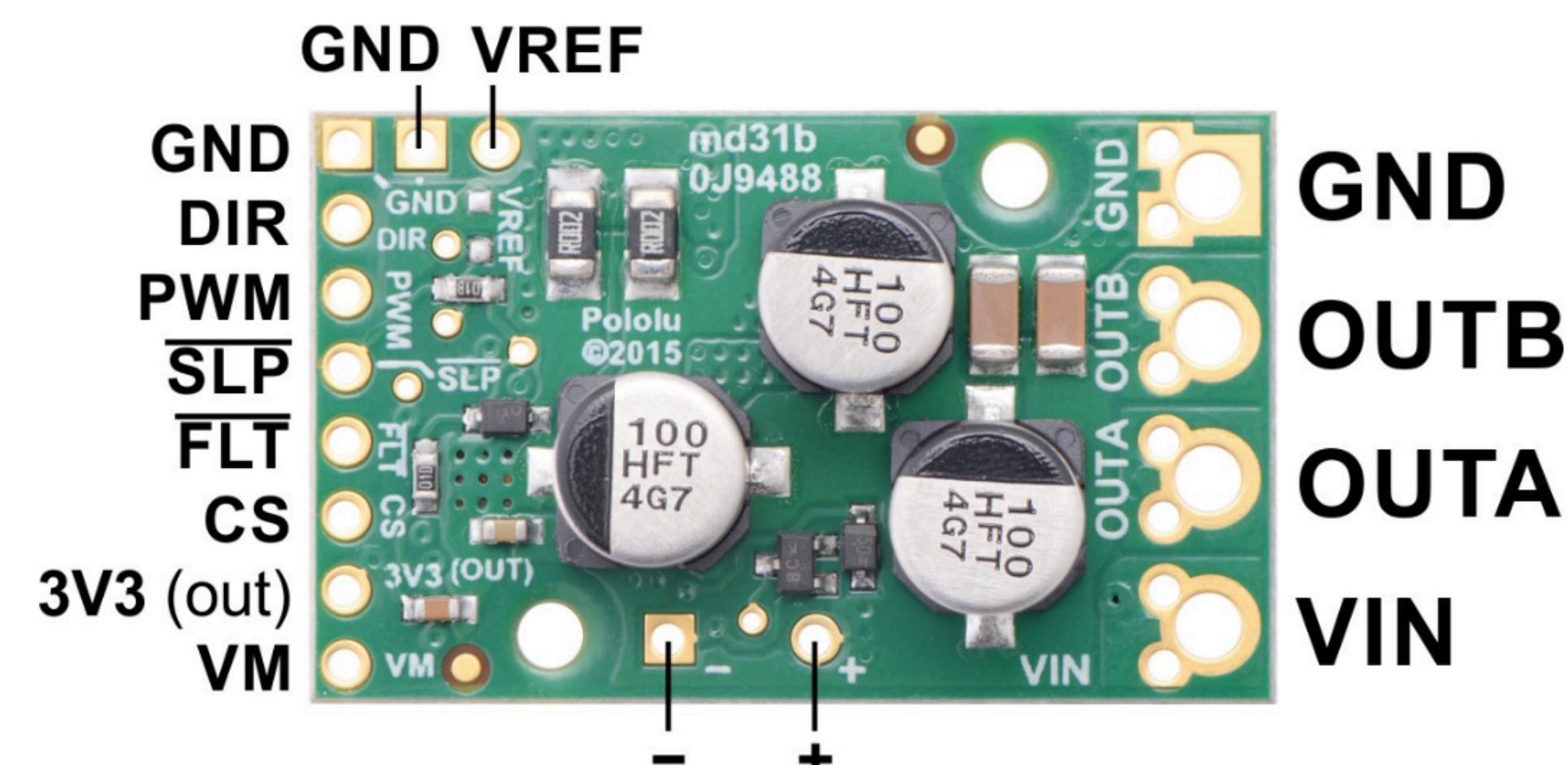
Add to cart

[backorders allowed](#)

Add to wish list

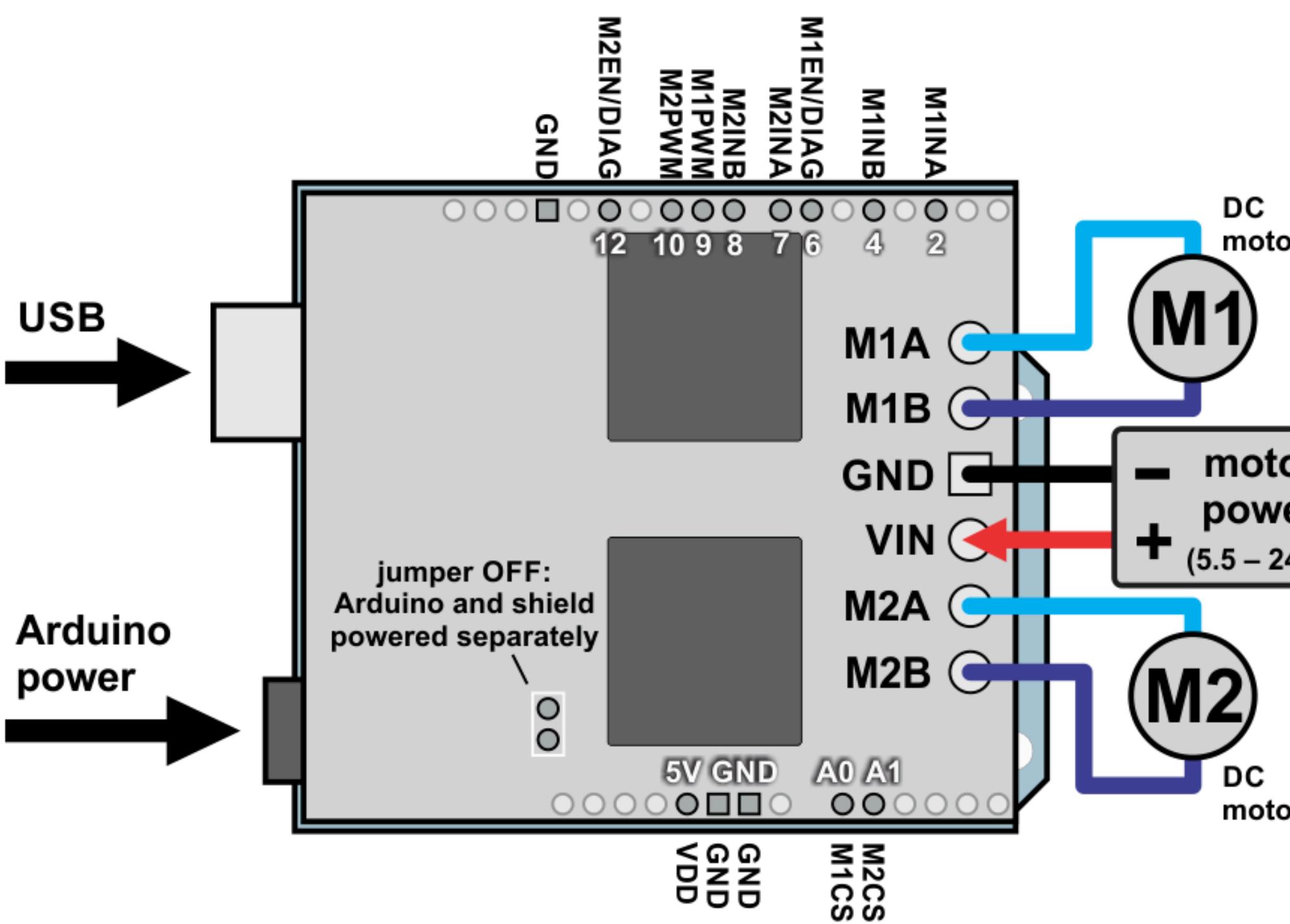


- Use a packaged driver circuit rather than designing your own — it will work better!
- Separate the motor power supply from the control system
- Control direction with DIR connected to a DIO pin and speed with PWM connected to another

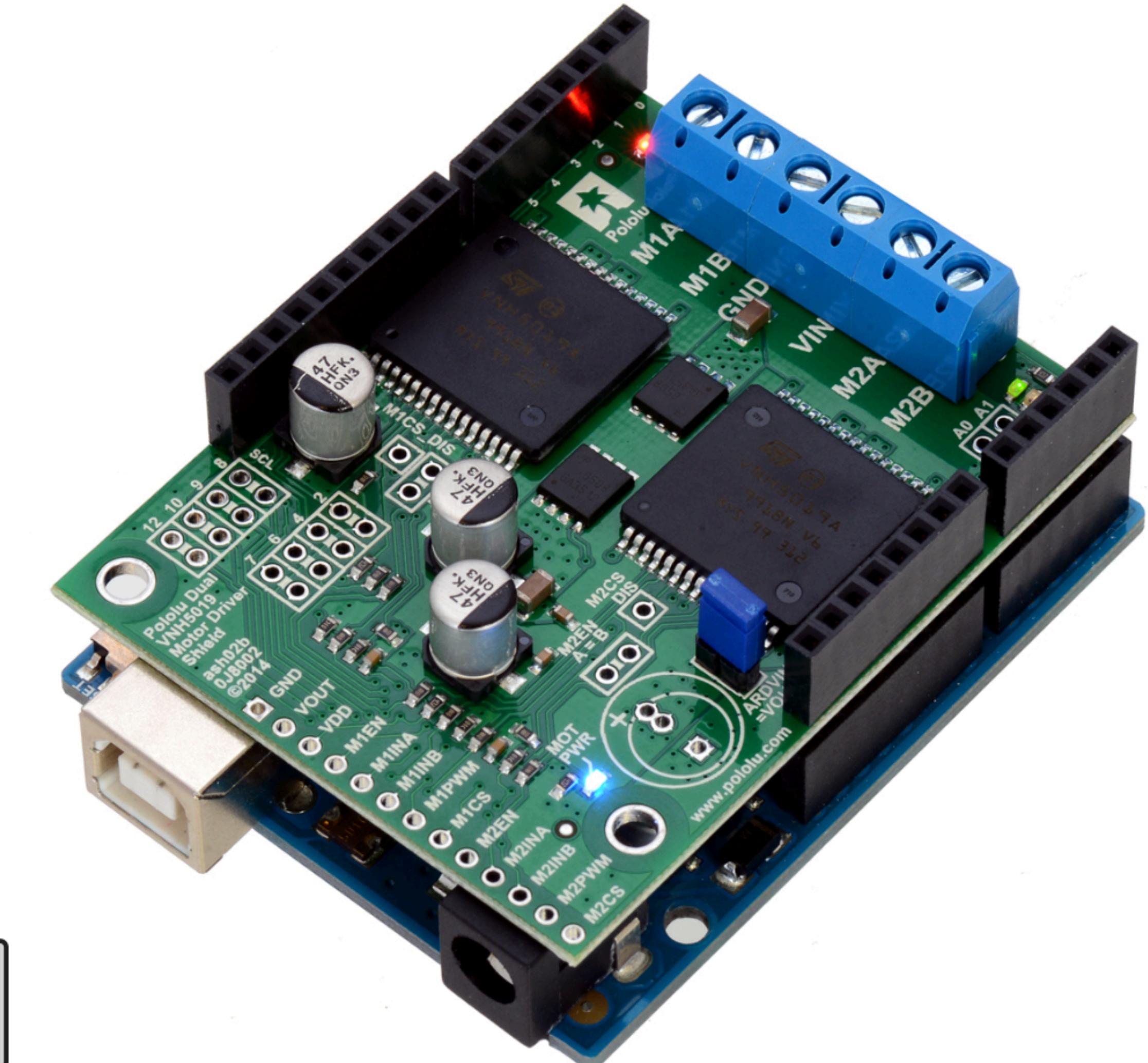


Shields can make connections simpler

- wiring is probably where your prototype will fail...



Programmable Controllers » Arduino » Arduino Shields »
Pololu Dual VNH5019 Motor Driver Shield for Arduino



Pololu dual VNH5019 motor driver shield, assembled and connected to an Arduino Uno R3.

Controlling Your World

- Decide what elements you want to control and how you want them to change in response to conditions, then initialize in the setup()
 - Measure the conditions
 - Change the control outputs
 - Repeat in the loop()
- Limits are mostly from what you can conceive of controlling