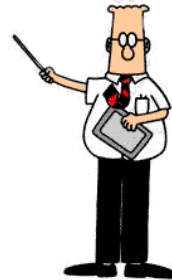


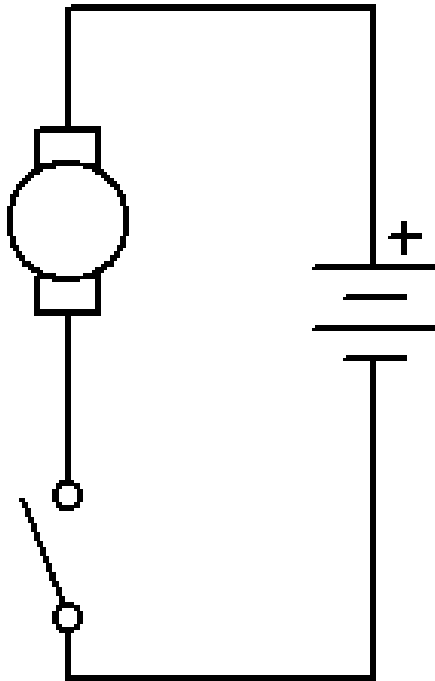
Controlling Motors



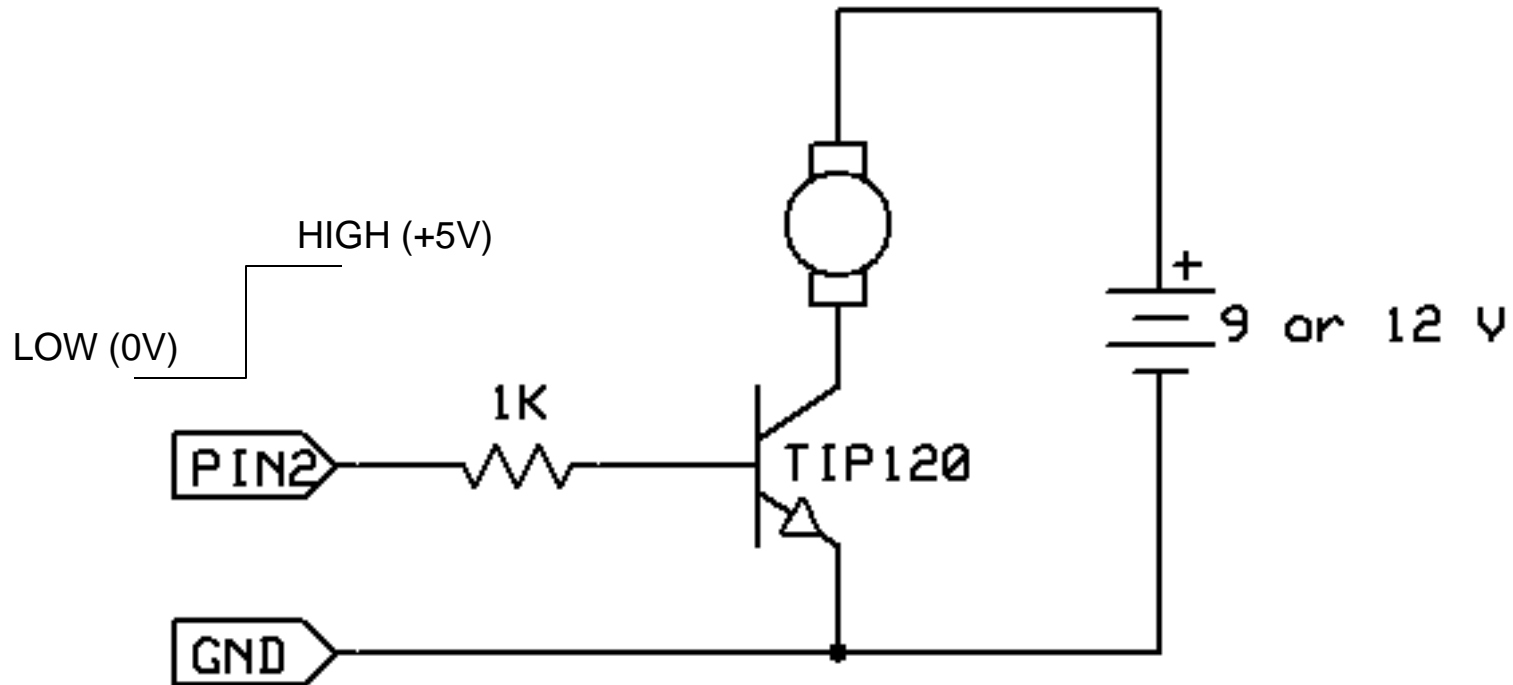
**OBEY
ME!**

On-Off Control

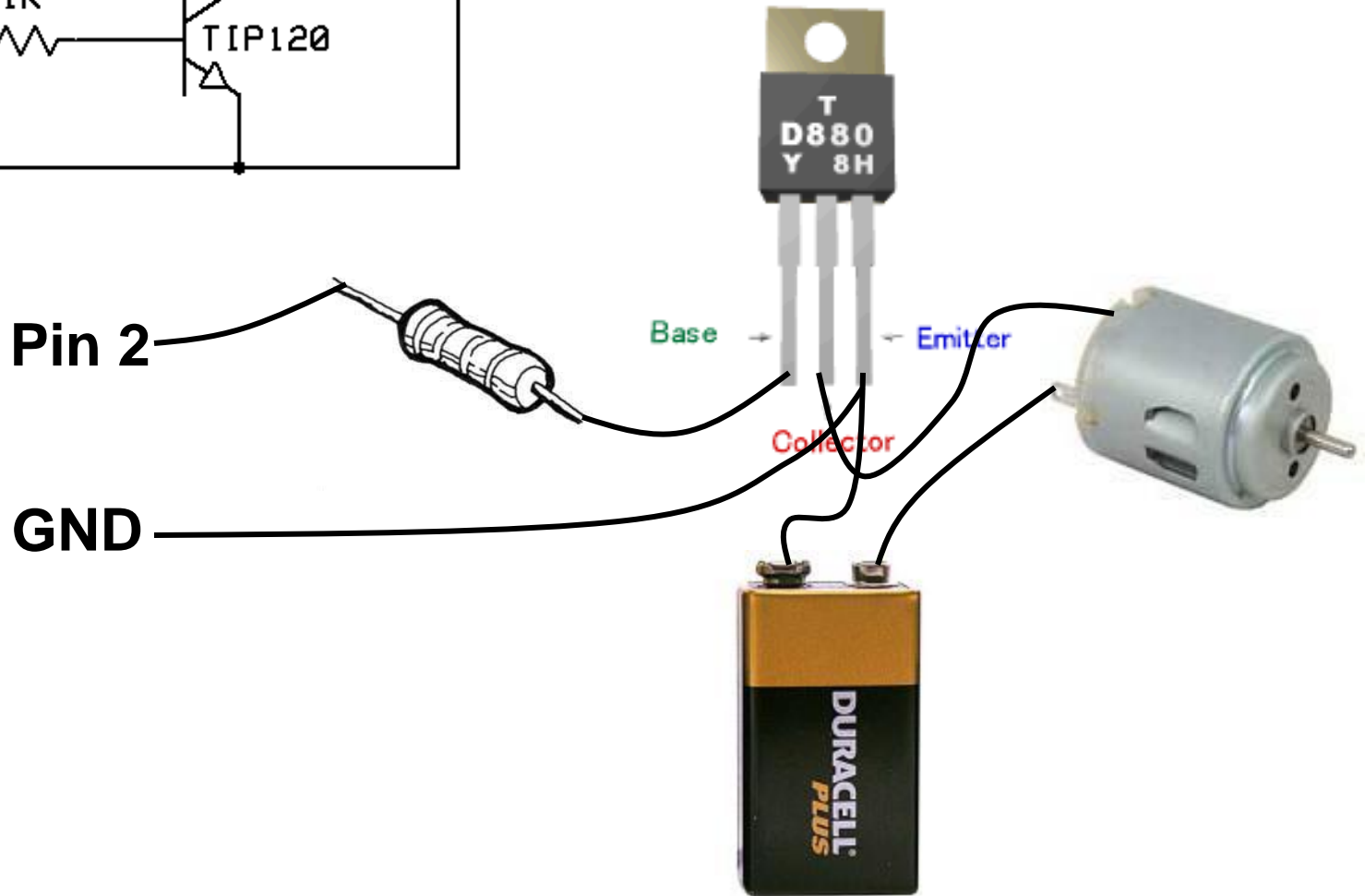
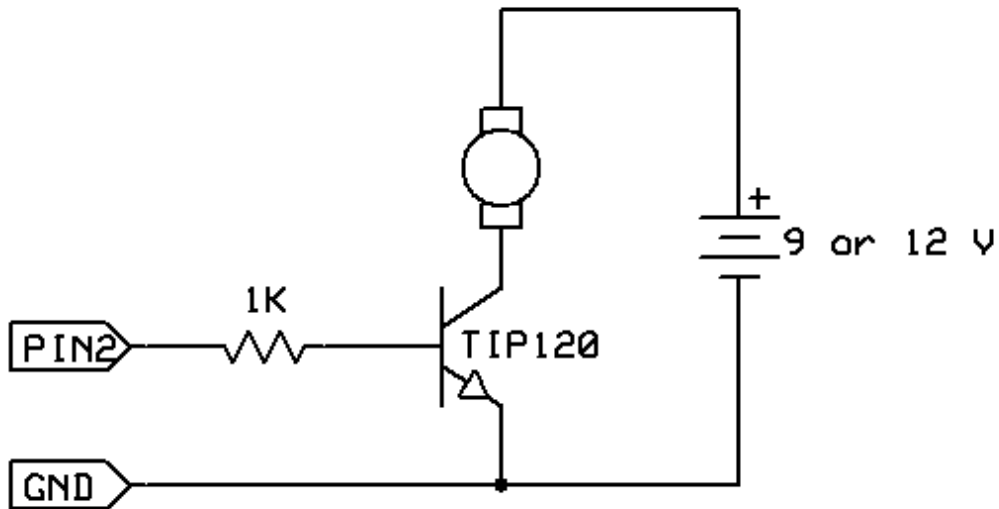
1. Switch control



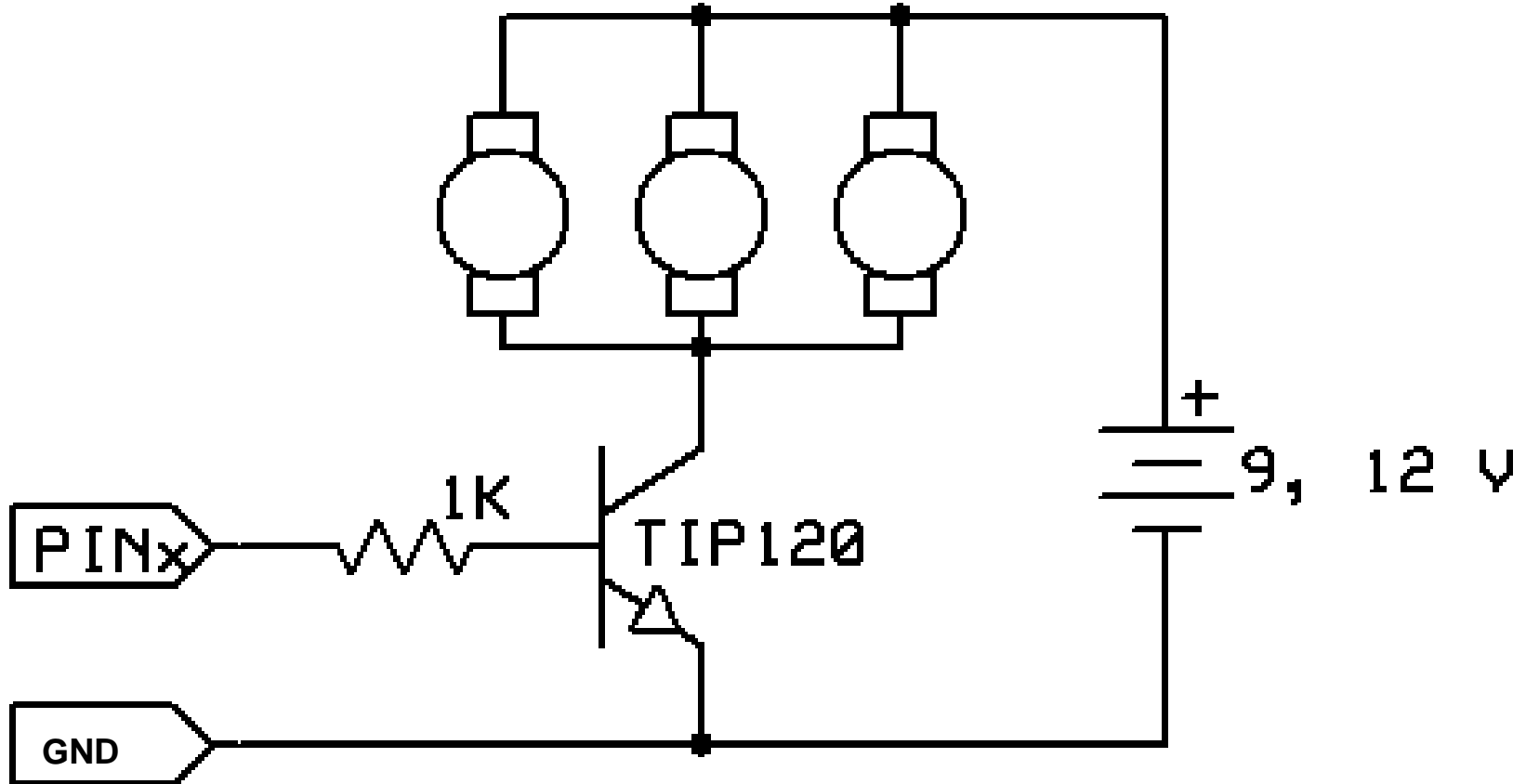
2. Transistor control



Type	I _{max} (mA)	V _{ce} (V)
2N3904	100	0.2
TIP120	1500	1.5

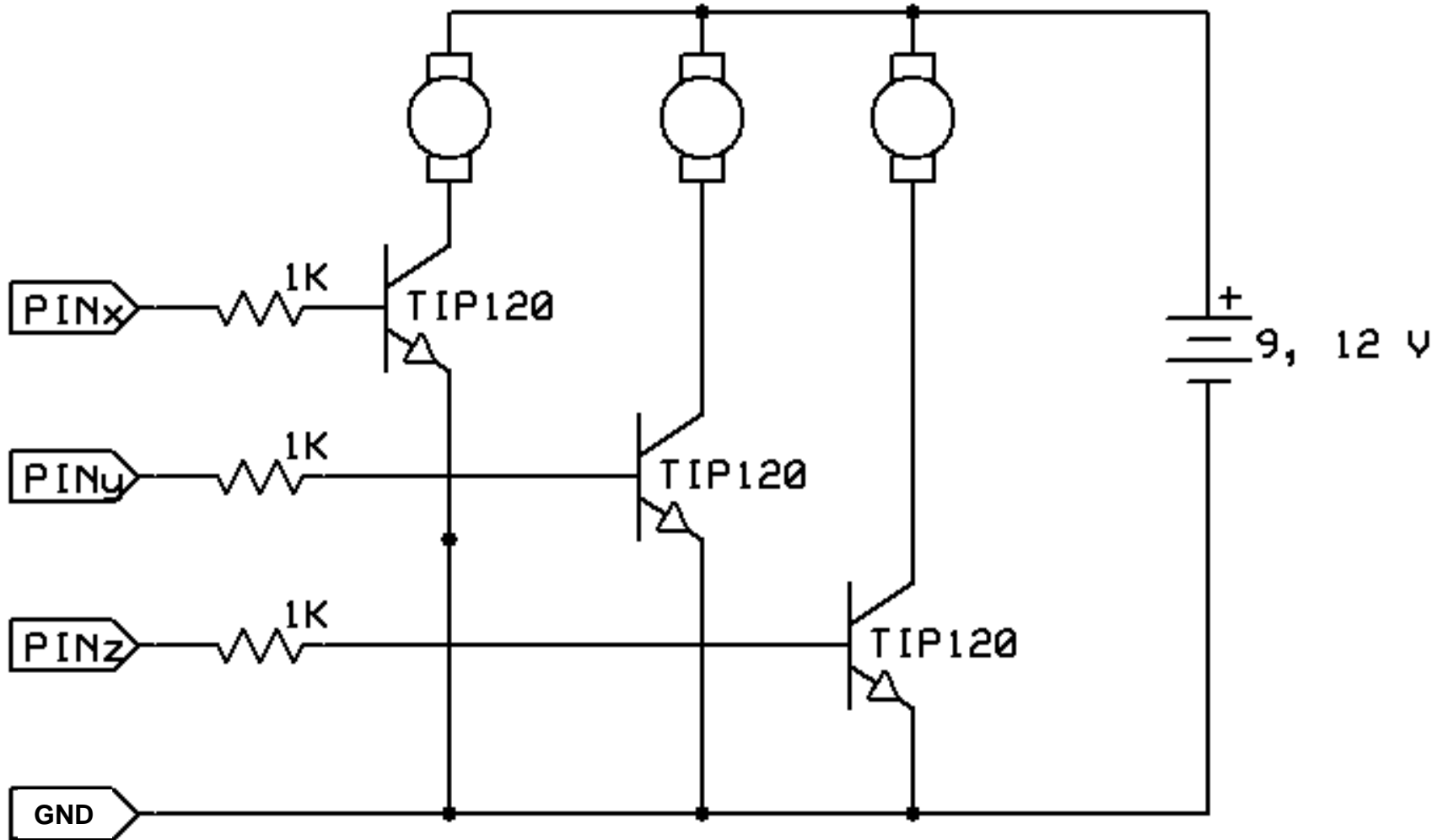


Several motors

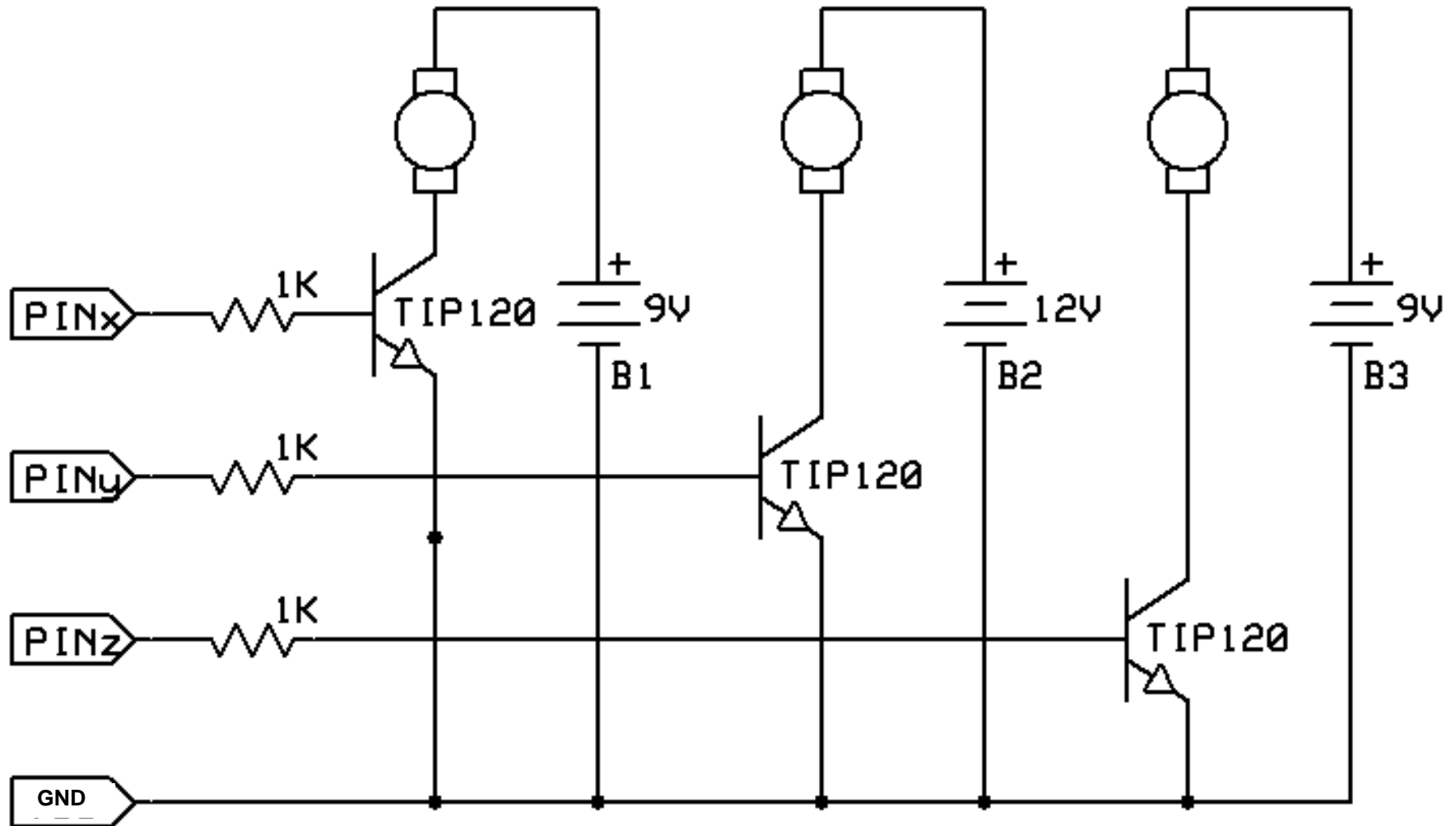


Watch out for TIP120 overheating

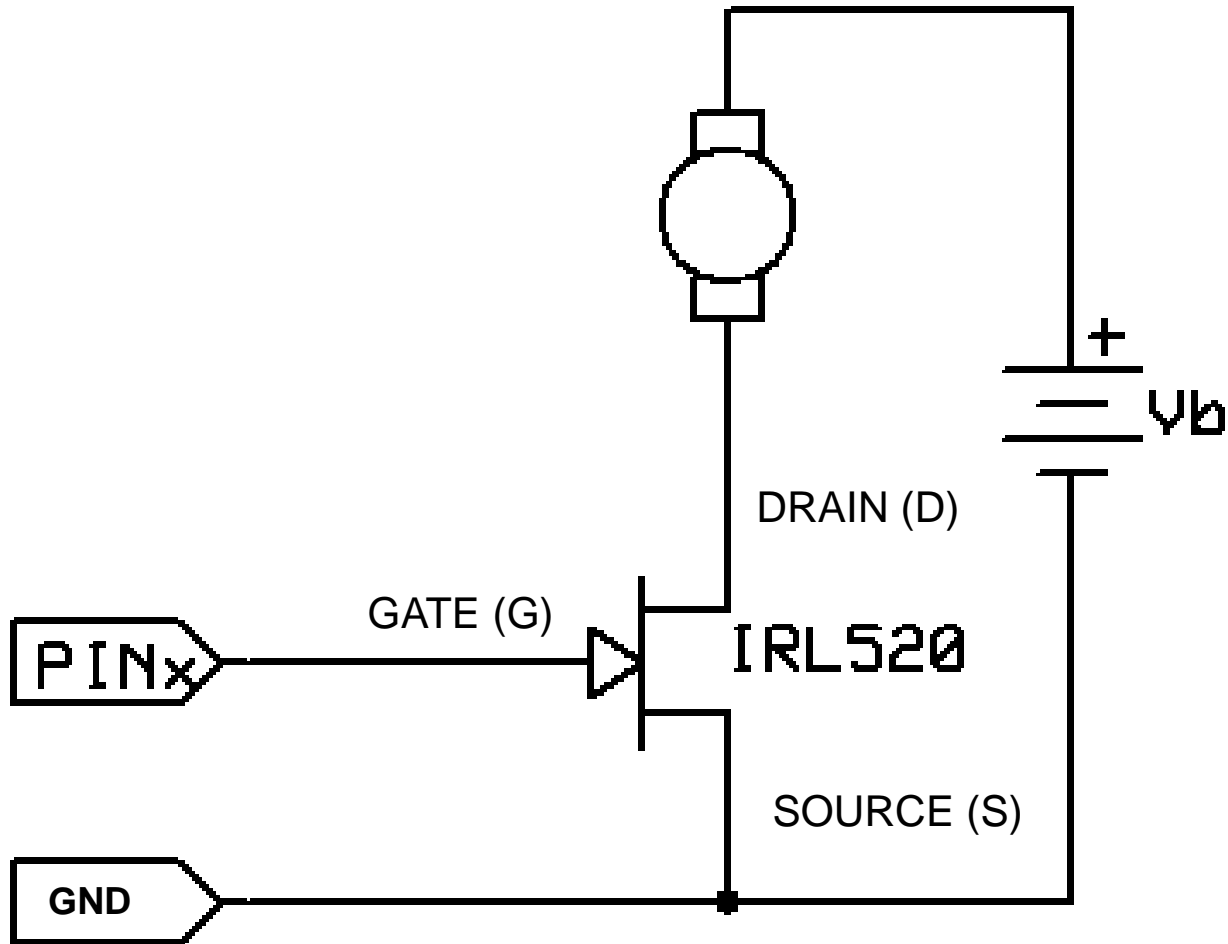
Several motors, each controlled

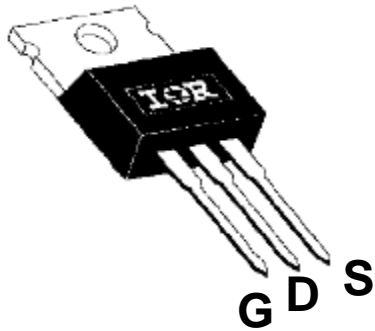


Several batteries



MOSFET Control





MOSFET

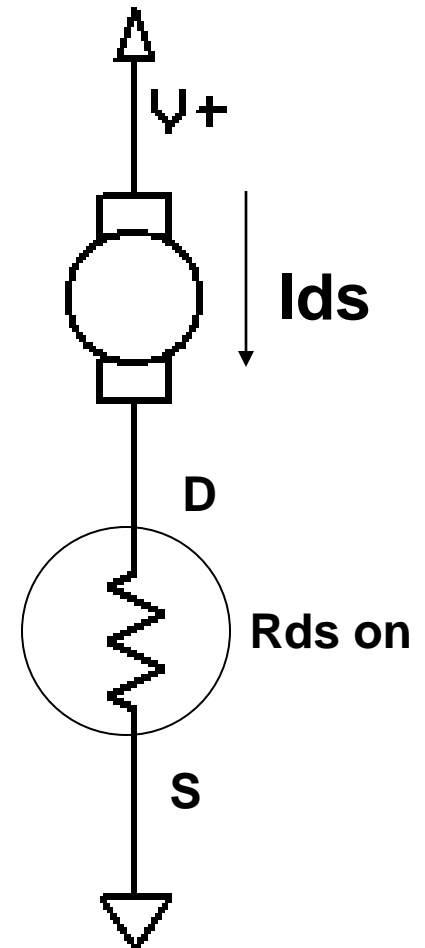
IRL520

Max current = 10 A

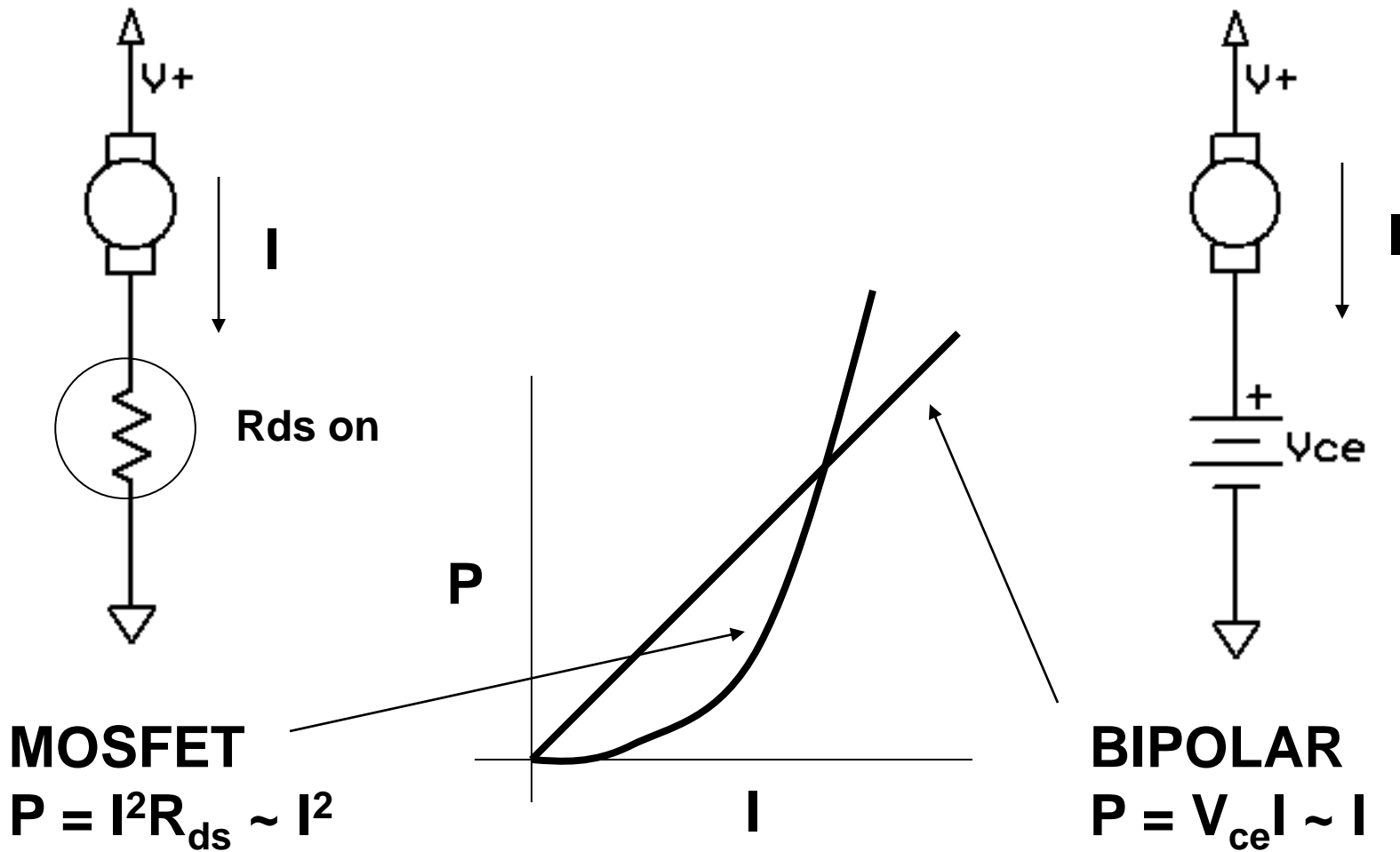
Rds on = 0.18 ohm

If motor draws 2.0 A
 $V_{ds} = I \cdot R = 2.0 \cdot .18 = .36V$
 $P = IV = 2 \cdot .36 = .72W$

For TIP120, $V_{ce} = 1.5V$
 $P = 2 \cdot 1.5 = 3W !$

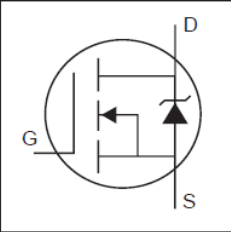


For high currents, bipolar wins

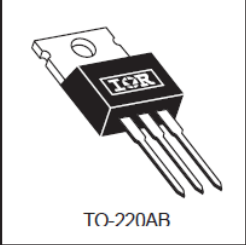


MOSFET Parts

IRL520N
HEXFET® Power MOSFET



$V_{DS} = 100V$
 $R_{DS(on)} = 0.18\Omega$
 $I_D = 10A$




TO-220AB

r
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s
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r
e

I
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l
C
e

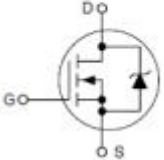
Rds on = 0.180 ohm
\$0.50

NTB125N02R




ON Semiconductor®
<http://onsemi.com>


125 AMPERES, 24 VOLTS
 $R_{DS(on)} = 3.7\text{ m}\Omega$ (Typ)



MARKING DIAGRAMS



TO-220AB
CASE 221A
STYLE 5

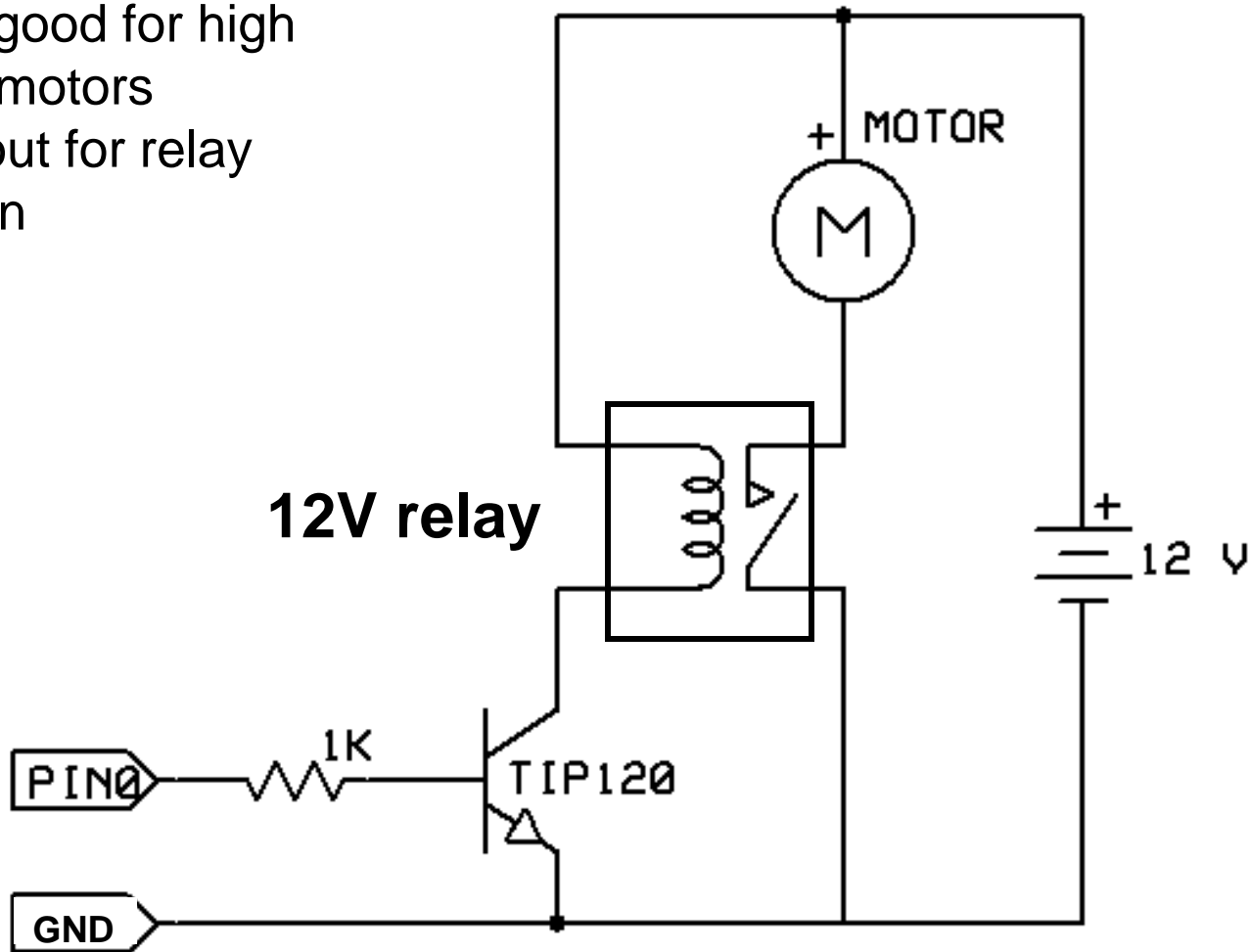


125N2RG
AYWW

Rds on = 0.0037 ohm
\$1.50

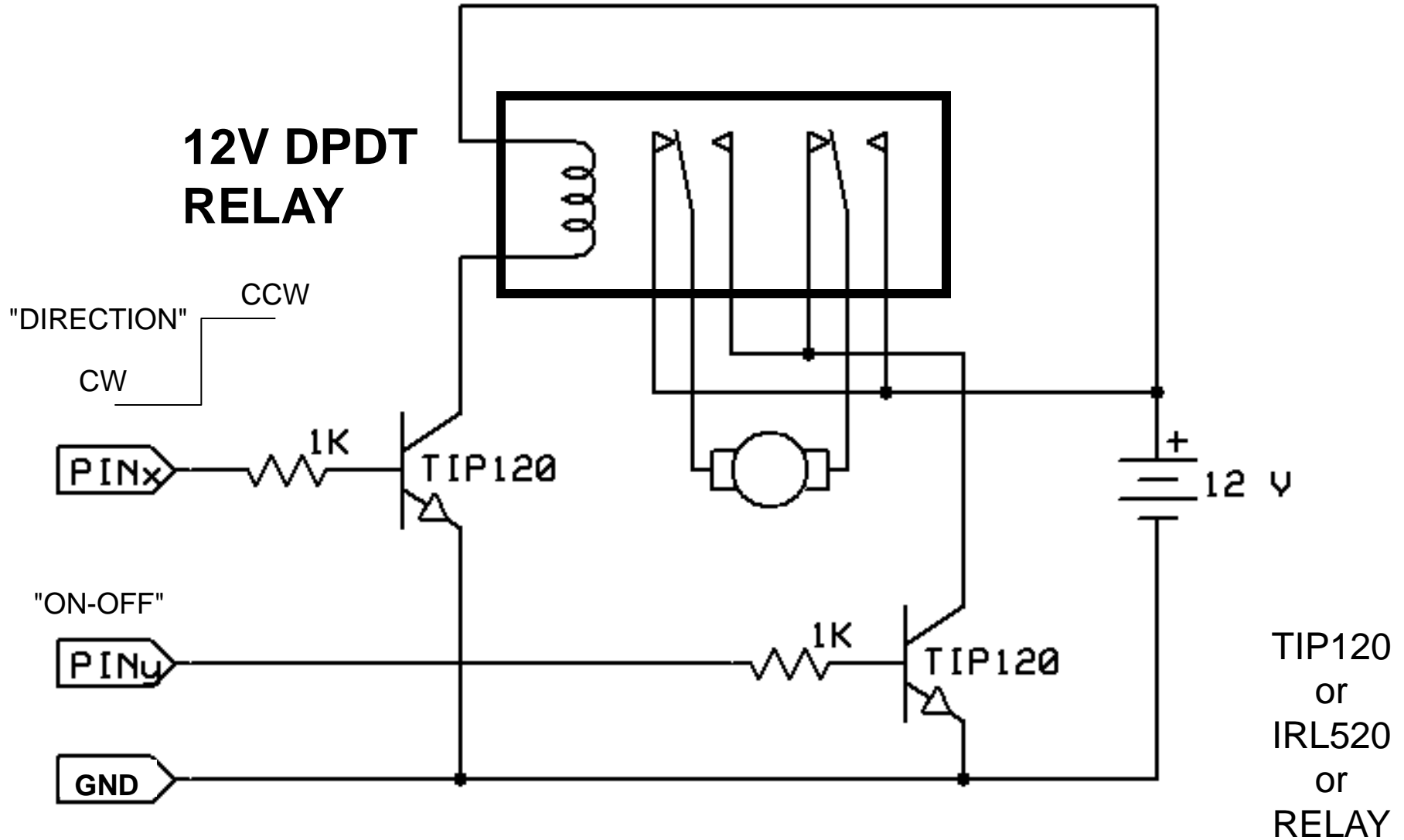
3. Relay control

- Relays good for high current motors
- Watch out for relay coil drain



TIP120 or 2N3904

Bi-directional motor control

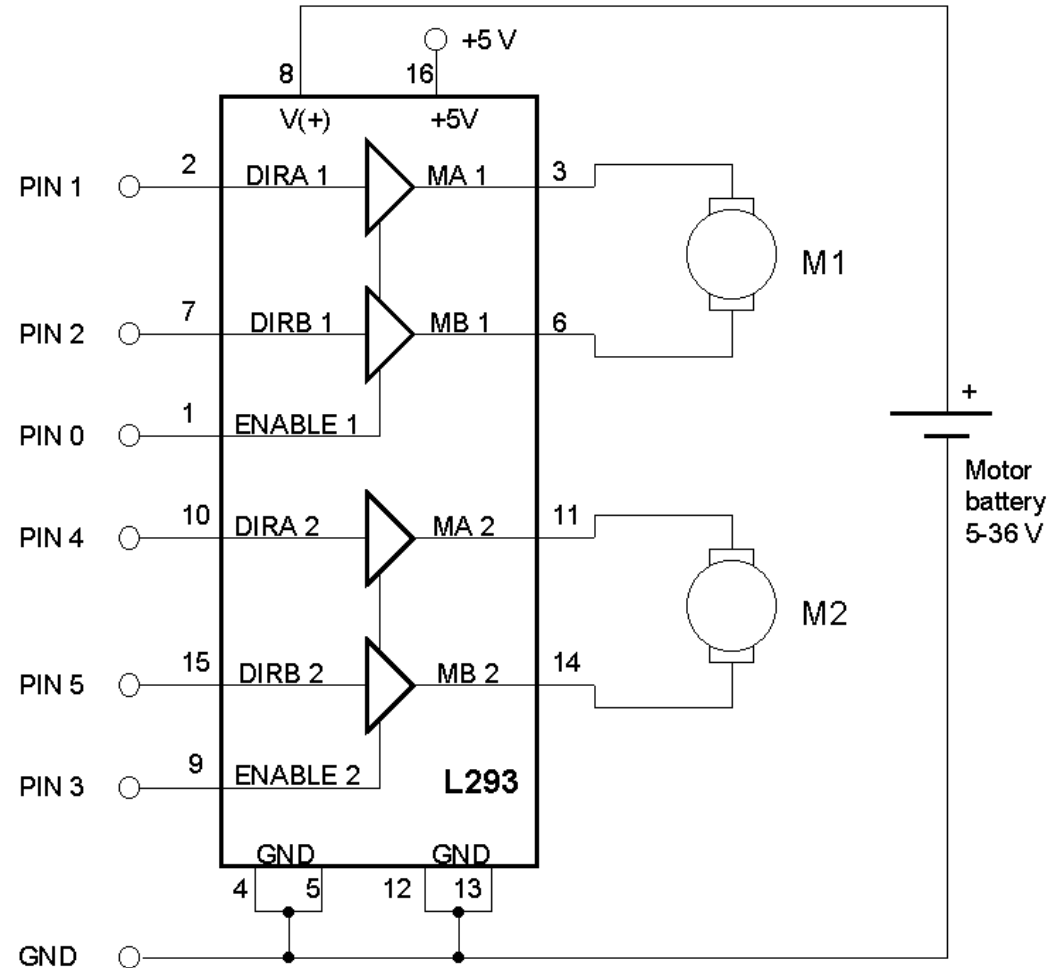


Bi-directional motor control with L293D

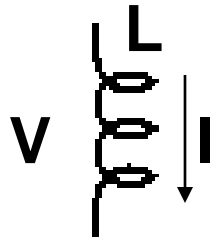


\$2.00

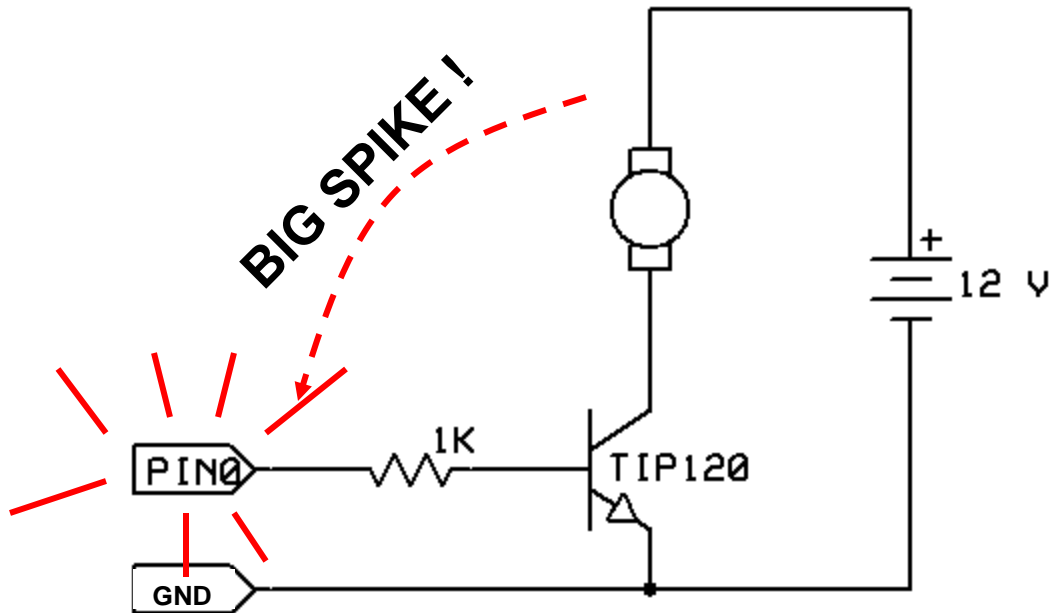
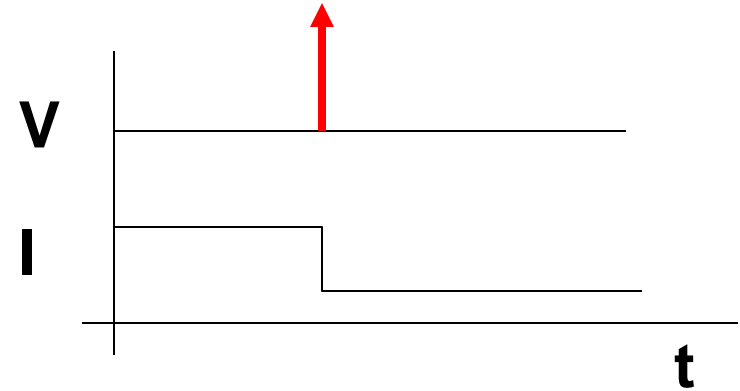
~600 mA limit



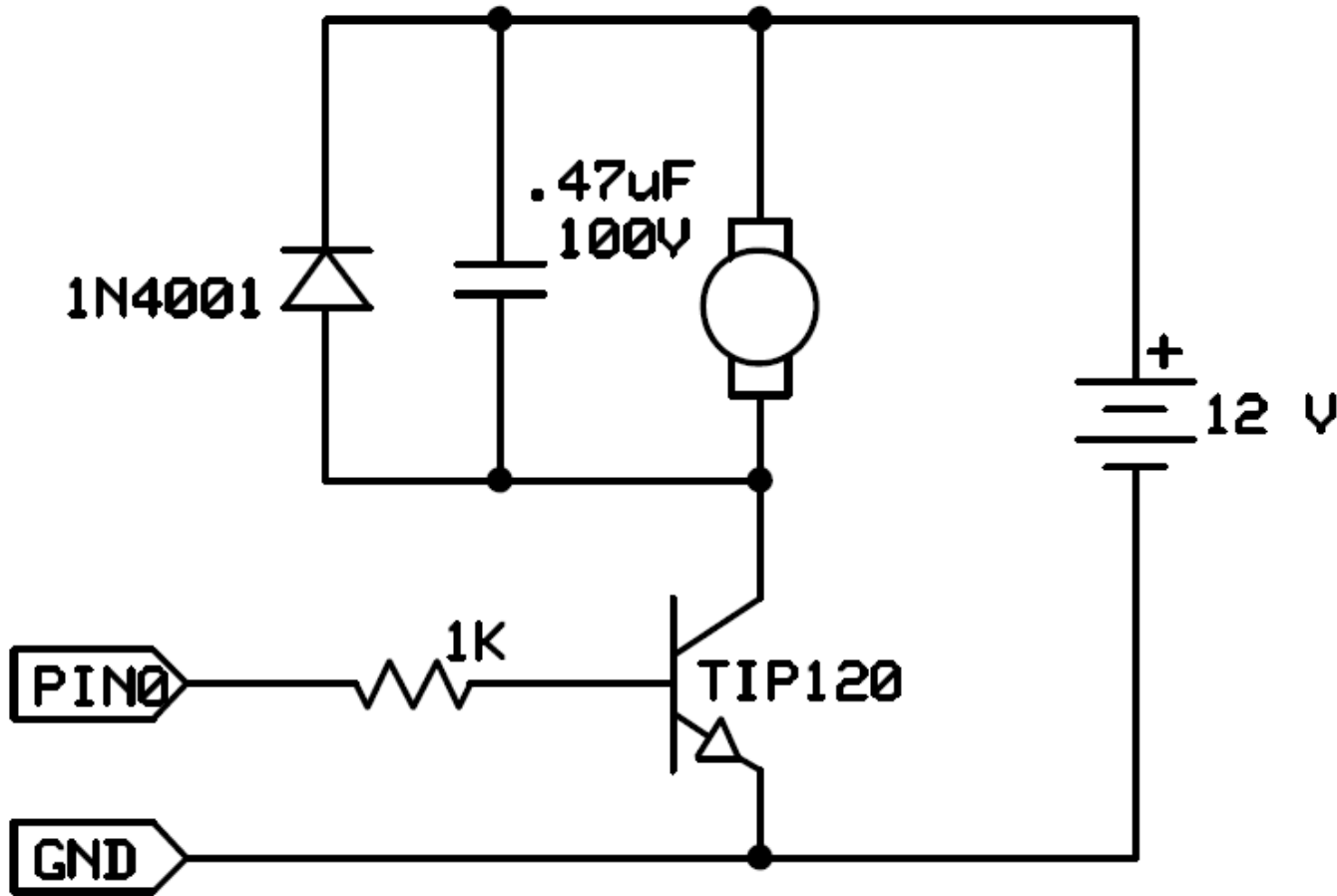
Inductive loads cause switching spikes



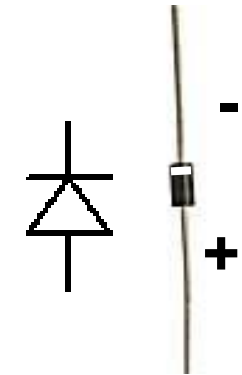
$$V = L \frac{dI}{dt}$$



Noise Spike Suppression

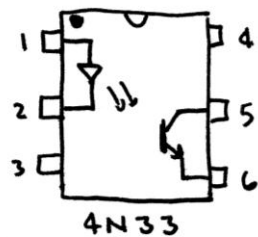
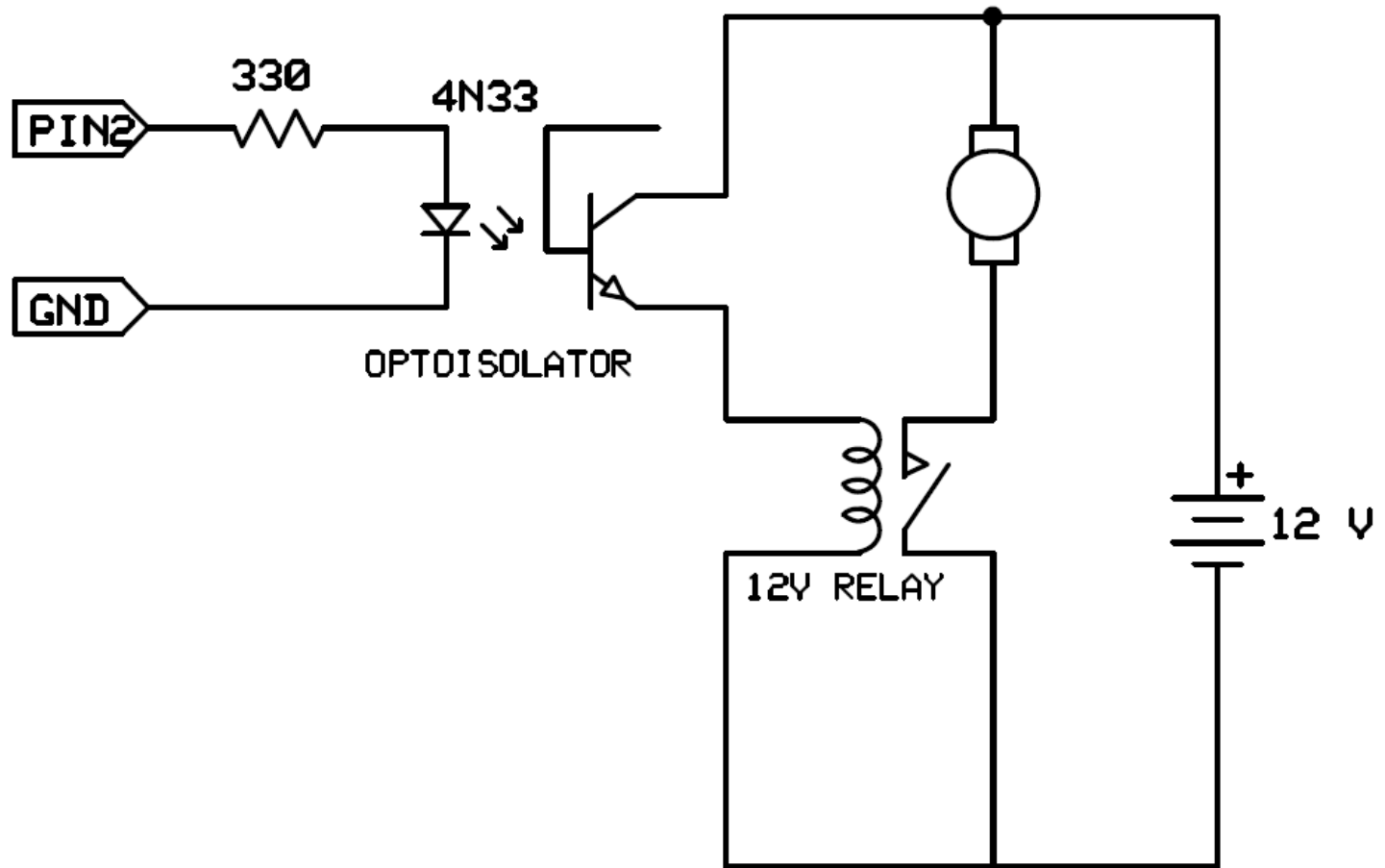


.47, 100V
mylar



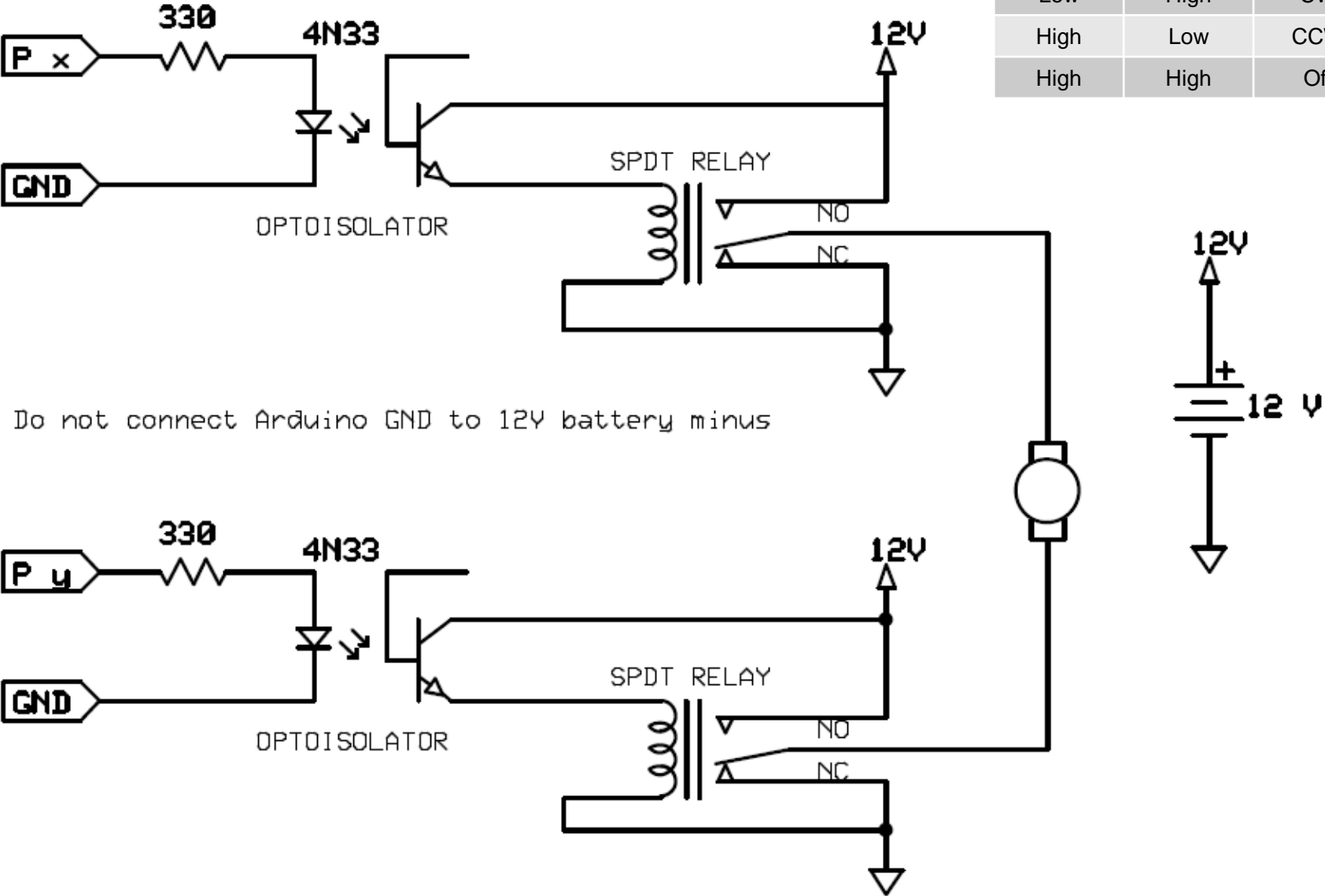
diode

Use Optoisolator to Control Spikes



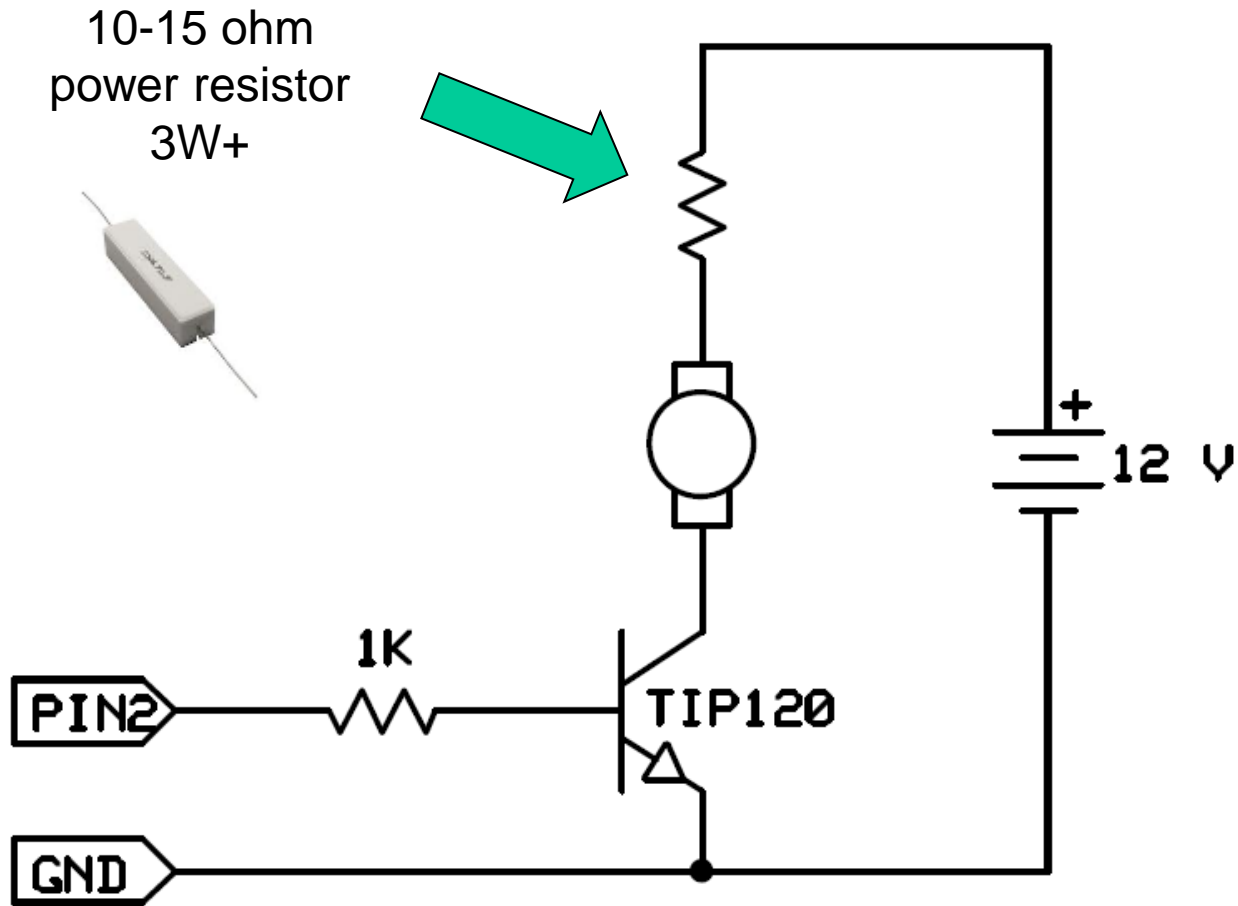
Isolated Bi-Directional Motor Control

CONTROL		
PIN x	PIN y	MOTOR
Low	Low	Off
Low	High	CW
High	Low	CCW
High	High	Off



Controlling Motor Speed

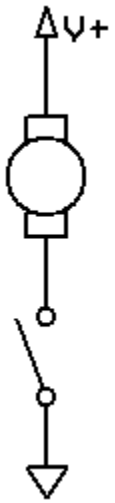
Slowing Motor With a Power Resistor



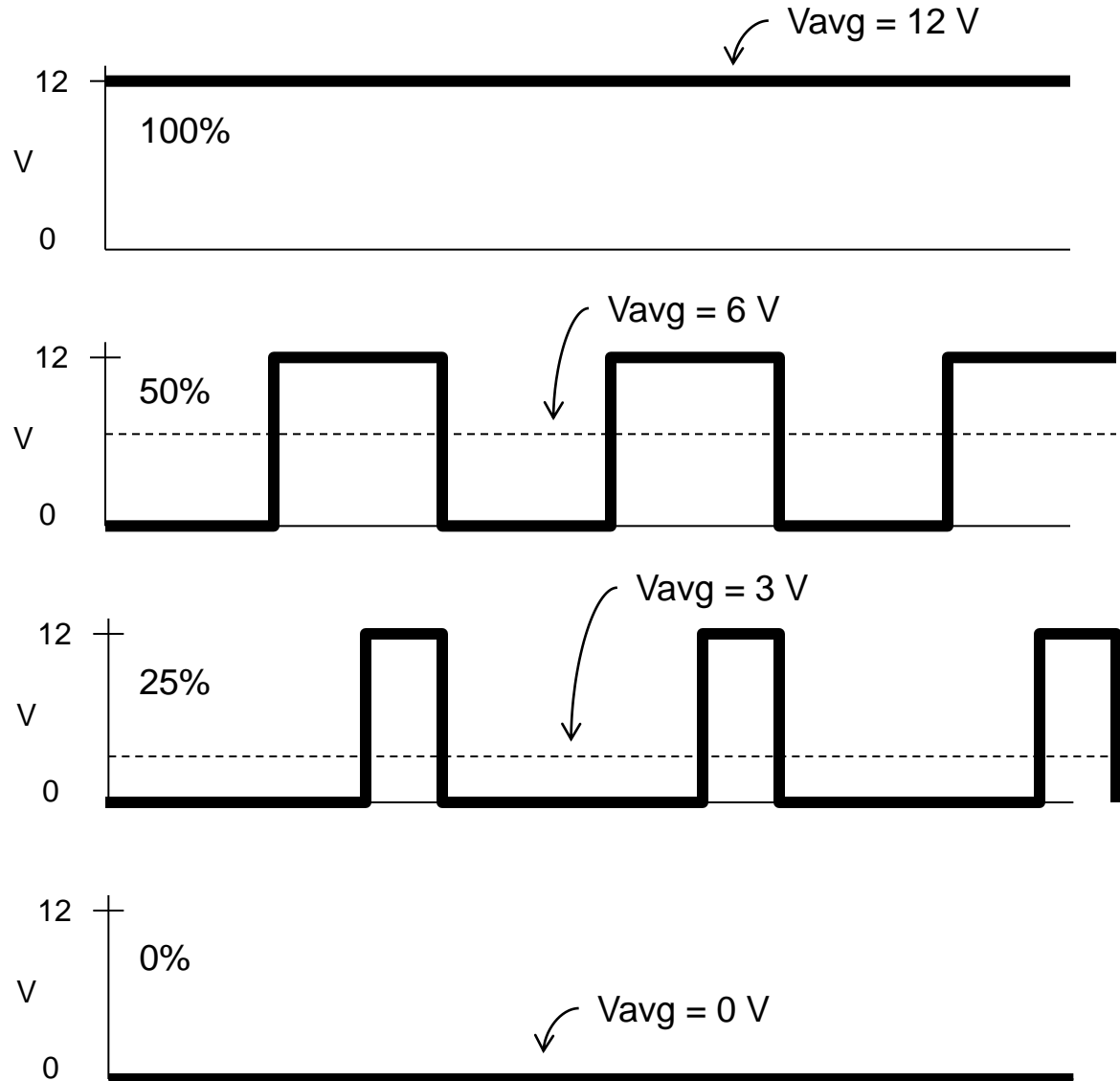
Need a load resistor?
Try a flashlight bulb,
or a second motor



Control Speed by Pulse Width Modulation (PWM)



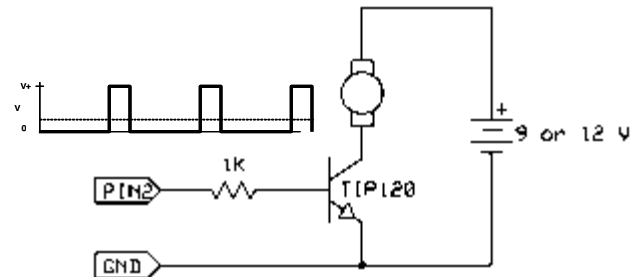
Open and close
switch rapidly



PWM for Variable Speed

```
...  
while (digitalRead(6) == HIGH) {  
    digitalWrite(11, HIGH);  
    delay(5);  
    digitalWrite(11, LOW);  
    delay(35);  
}  
...
```

```
...  
//run at 3 speeds  
analogWrite(11, 64); //slow  
delay(2000);  
analogWrite(11, 128); //medium  
delay(2000);  
analogWrite(11, 255); //fast  
delay(2000);  
...
```



Duty cycle = $5/40 = 12.5\%$

Watch out for voltage spikes!

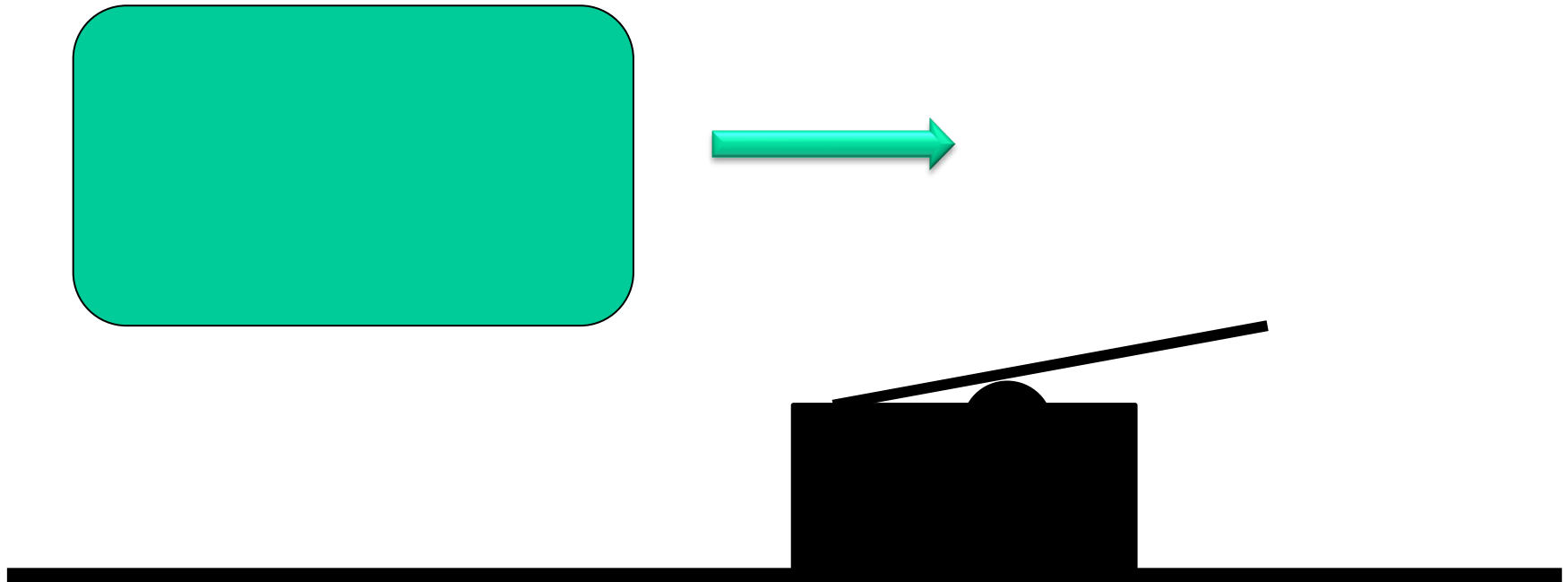
Arduino analogWrite PWM
valid on pins 3, 5, 6, 9, 10, 11

Remember

**When motor runs slower,
torque is less**

Controlling Motor Position

Detect Position with a Switch



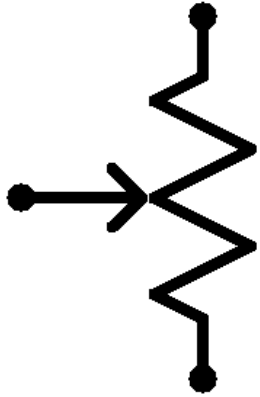
Code

Motor on

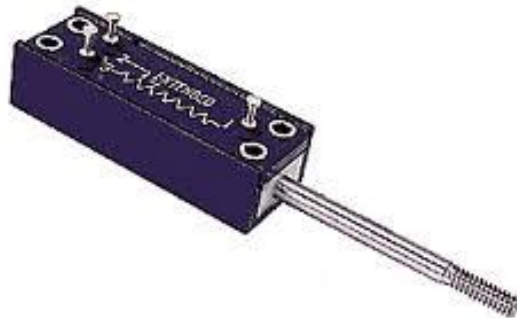
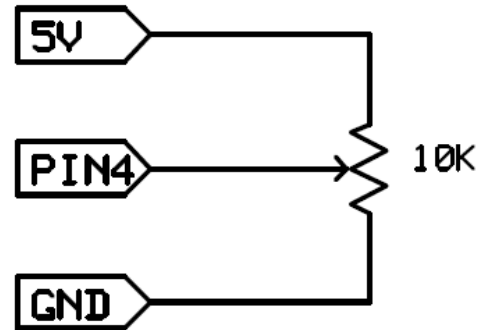
Wait for switch closed

Motor off

Detect Position with a Potentiometer



- Output voltage varies between 0 and 5V as angle changes
- Read with `analogRead()` function, www.arduino.cc/en/Reference/AnalogRead



Stepper Motor

- One pulse per step
- 48, 100, 200 steps/rev common
- Send to precise position by a set # of pulses
- If high torque disturbance can be bumped out of holding detent
- 4 Arduino pins
- ULN2003A interface driver or 4 transistors
- See stepper motor section at <https://sites.google.com/a/umn.edu/me2011/arduino>



Servo Motor

- Gearmotor with internal position feedback and internal controller
- Control position with continuous pulse stream; width of pulse determines position
- Typical range: 90 to 180 degrees
- Common in hobby robotics; primary application from RC airplanes
- Can modify for continuous rotation
- See servo motor section at <https://sites.google.com/a/umn.edu/me2011/arduino>

