Hands-on Lab 3: Motion

EECS 16B Fall 2022

Slides: links.eecs16b.org/lab3-slides

Administrivia

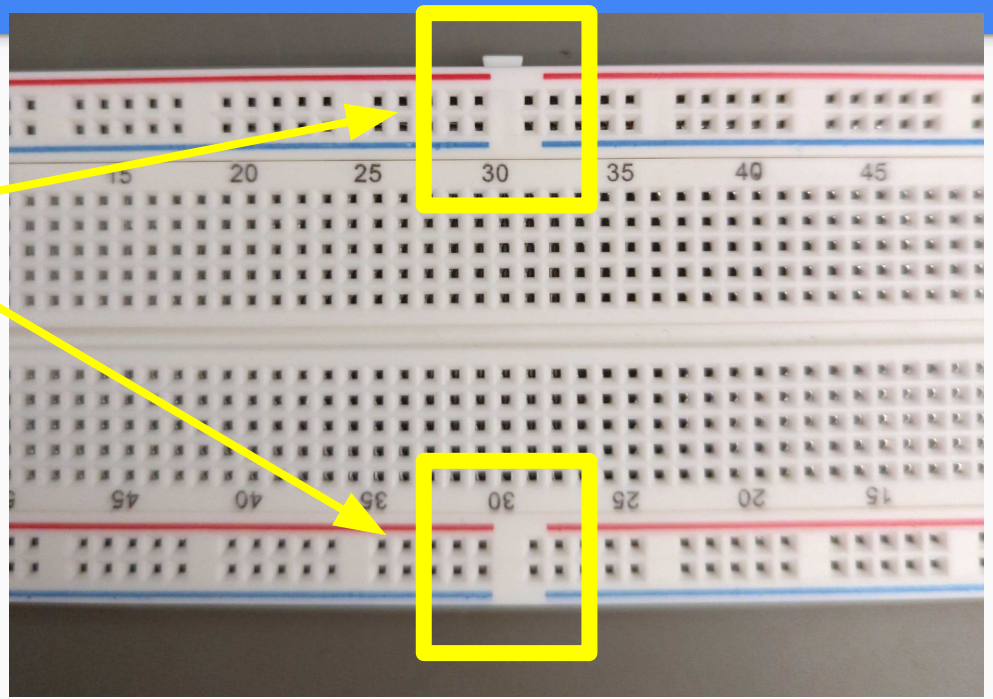
- Be a good team member, make sure you are contributing to the group

Lab 3 Overview

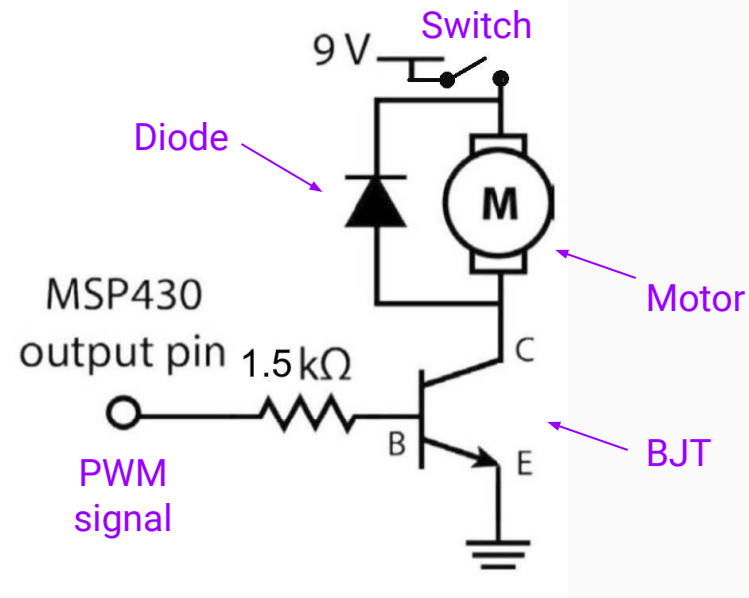
- Build and test motor controller circuits
  - Pulse Width Modulation (PWM) from Arduino
  - Bipolar Junction Transistor (BJT)
  - Switch
  - Diode
- Install and test encoders
  - Sensing the distance traveled and speed of the car

Caution!

- Some breadboards may have a break in the power and ground rails
- Make sure to connect them with wires (4 total)!



Motor Controller Circuits

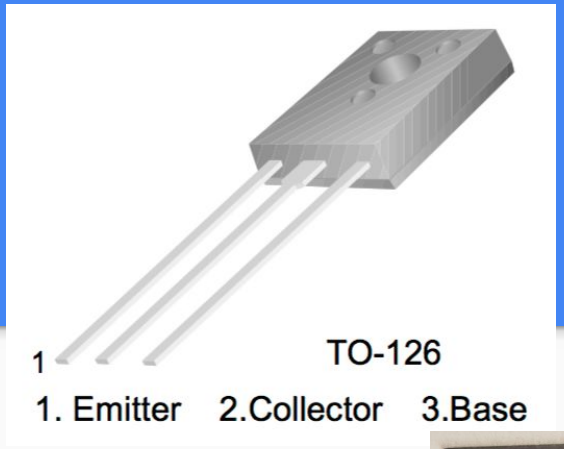


- We'll be building this circuit twice
  - Many new components!
- In the motor unit tests, we'll run over a range of **PWM values** to see the motors speed up and slow down

Pulse Width Modulation (PWM)

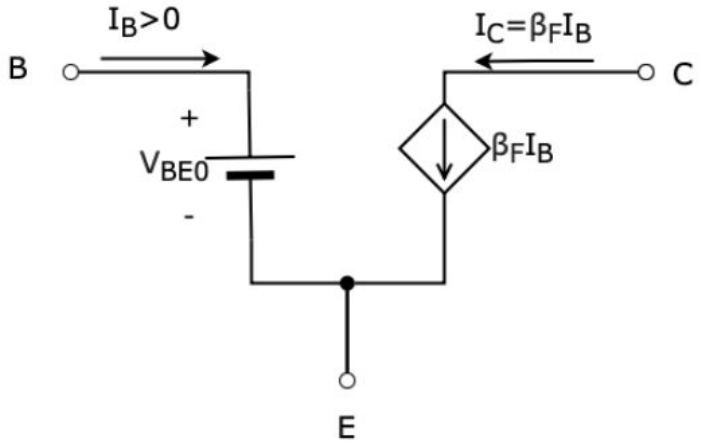
- Square wave with variable “on” time
  - “Duty cycle” is the percentage of time the signal spends “on” or at its “high” in one period
  - If period T = 1s, then 50% duty cycle means it spends .5s “on” and .5s “off”
- Method of supplying variable amounts of power to a component
  - We will be using this to control our motors
- Motors and multimeters unable to “react fast enough” to the rapid turning on and off, so see averaged-out analog voltage depending on duty cycle
  - Variable frequency, anywhere from a few hundreds to thousands of Hz
  - If “on” voltage is 3.3V, then 50% duty cycle means you see 1.65V

New Component: BJT

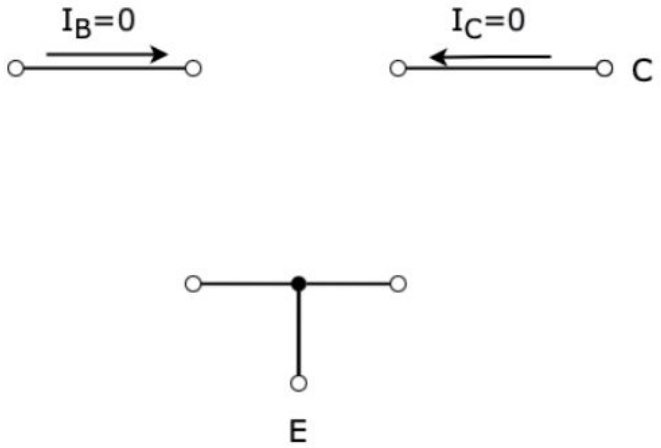


- Bipolar Junction Transistor
  - 3 pins: Base (B), Collector (C), Emitter (E)
  - Analogous to MOSFETs: Base -> Gate, Collector -> Drain, Emitter -> Source
- NPN BJT behaves similarly to NMOS
  - High Base voltage turns BJT “on” and conducts current from Collector to Emitter
  - High Gate voltage turns NMOS “on” and conducts current from Drain to Source
  - More accurate model description in lab note
- NOT the voltage regulator component
  - Body is fully black plastic, does not have a metal tab sticking up
  - Orientation of the picture is with the 3 dots on the plastic body facing you

NPN BJT Model



(a) Model of BJT in ON mode (when MSP430 output pin is HIGH)



(b) Model of BJT in OFF mode (when MSP430 output pin is LOW)

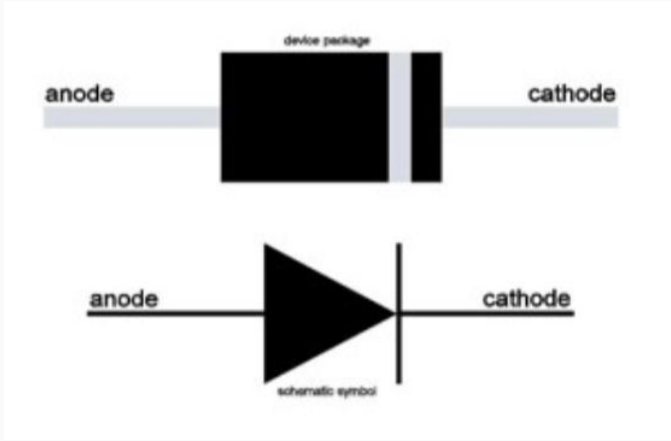
Figure 3: Model of NPN BJT in Different Modes

New Component: Switch

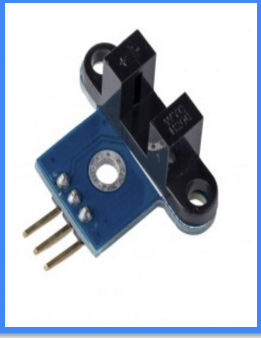
- Middle pin is ALWAYS shorted (connected) to something
  - If switch is in the left position, left and middle pins are shorted together
  - If switch is in right position, right and middle pins are shorted together
- Connect your motors to middle pin, 9V to side pin, GND to other side pin
  - Toggle your motors being connected to 9V and GND
- **DO NOT CONNECT 9V OR GND TO MIDDLE PIN**
  - You will short 9V to GND if you flip the switch
  - Fastest way to say goodbye to your circuit, battery, and breadboard
  - **DON'T DO IT!**

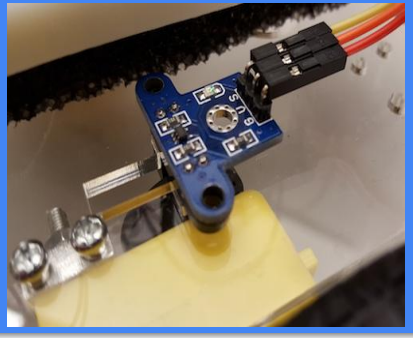
New Component: Diode

- Anode is +
- Cathode is -
- **Direction is important**
  - Diodes conduct current one way but not the other
  - Make sure you double check that you have connected it in correct direction
- **not light emitting!**



New Component: Encoders (Photointerrupters)





- Beam of light between 2 “legs”
- As wheel turns, rotates encoder wheel with it
  - Encoder wheel has many holes in it
  - As wheel rotates, spokes block and holes unblock the beam of light
- Can calculate velocity of car from rate of encoder value change
- 3 pins
  - **“G”** = ground, connect to breadboard 0V negative rail
  - **“V”** = voltage, connect to breadboard 3.3V positive rail from output of 3.3V regulator, NOT Arduino’s 3.3V pin
  - **“S”** = encoder signal; input to voltage divider whose output goes to Arduino pins (2 and 3)

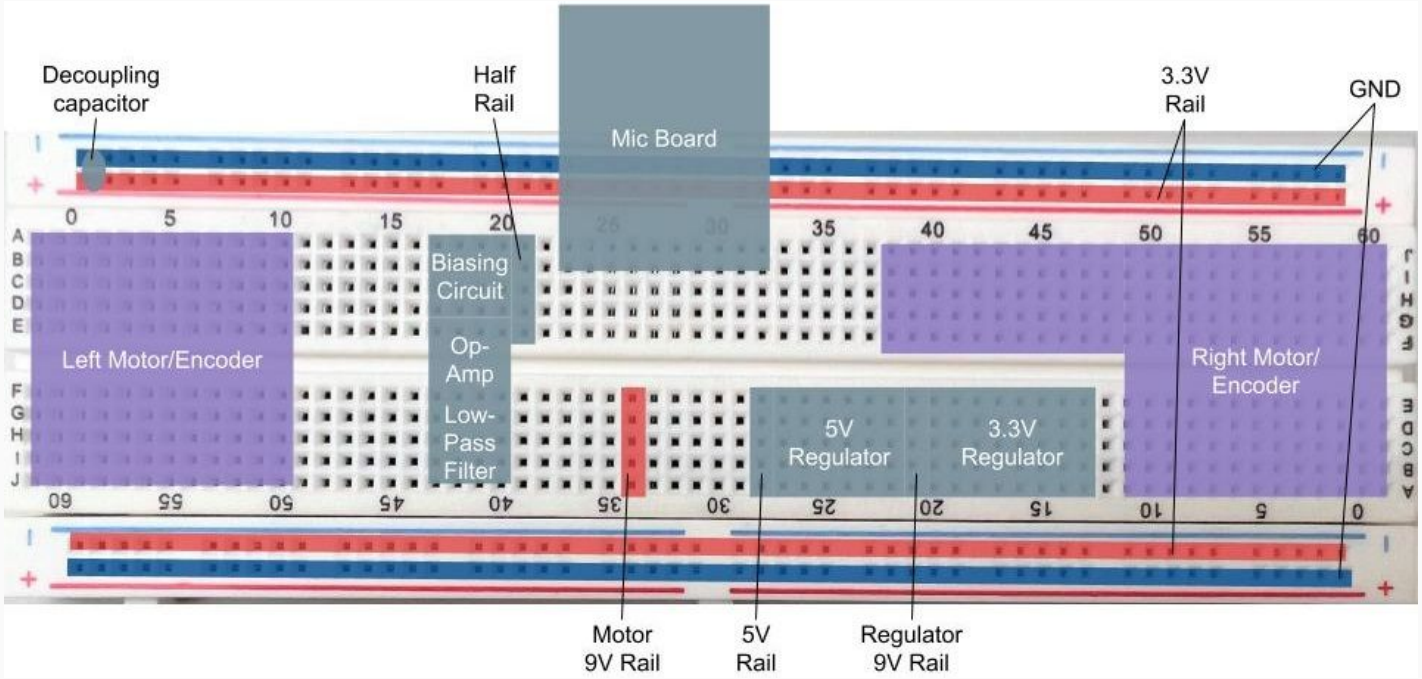
Testing Encoders

- Encoder “S” pins connected to voltage divider
  - Using resistors of ≥1k, divide the 3.3V max voltage down to between 2V - 2.5V
  - Can accomplish with one 1k ohm and one 2k ohm resistor
- Pass something between encoder legs or turn car wheel, red LED on encoder should blink if powered correctly
- encoder_test_0_ticks.ino
  - 4 phases: both wheels unpowered, L wheel powered, R wheel powered, both wheels powered
  - Test once with encoder wheels OFF
    - Checks if encoder readings are from noise or from actual car movement
  - Then test with encoder wheels ON
    - Rules out false negative

Arduino Stuff

- Make sure to connect one of your GND pins (any one works) to your breadboard negative (-) rail (which carries GND)
- DO NOT connect the 3V3 or 5V pin to anything for this lab!
- Pins can only tolerate voltages between 0V and 5V.

BREADBOARD LAYOUT



Lab 3 Checkoff

- **Follow ALL instructions clearly in ipynb!**
- Requirements for checkoff:
  - Have read lab note
  - Demonstrate both motors responding to changes in duty cycle
  - Demonstrate encoder tests passing
  - Desk should be cleaned.
  - **Be prepared to answer conceptual checkoff questions!**

Checkoff and help queues close 10 minutes before the end of section.

Let’s get into it!

Important Forms/Links

- Help request form: https://eecs16b.org/lab-help
- Checkoff request form: https://eecs16b.org/lab-checkoff
- Extension Requests: https://eecs16b.org/extensions
- Makeup Lab: https://makeup.eecs16b.org
- Slides: links.eecs16b.org/lab3-slides
- Anon Feedback: https://eecs16b.org/lab-anon-feedback
- Lab Groups: https://eecs16b.org/lab-groups

EECS Datahub is experiencing issues! If Lab 3 datahub doesn't work, try: https://links.eecs16b.org/lab3-temp-dh