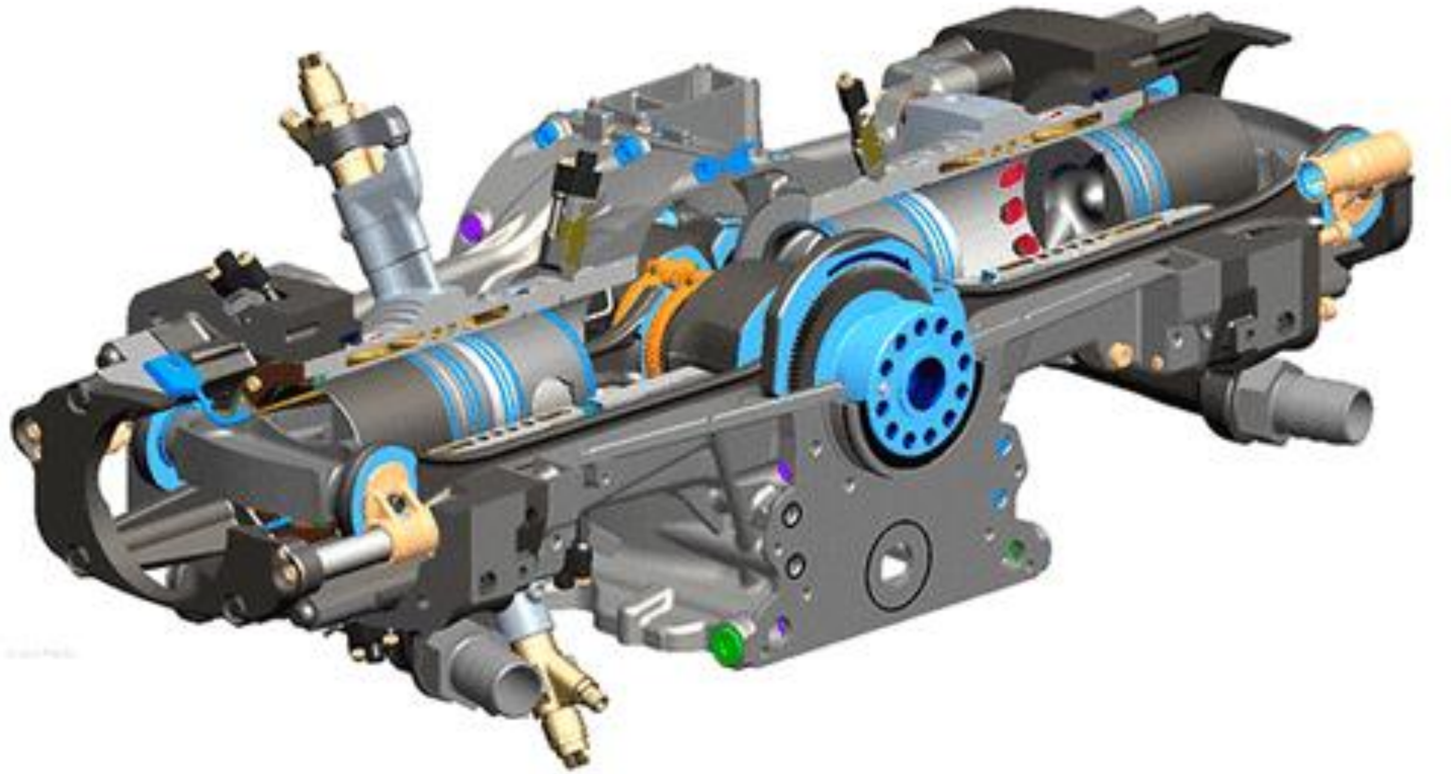
RAS MOTOR WORKSHOP

OCTOBER 4, 2020

Goals

- What kinds of motors are out there? What kind should I use?
- How do motors work?
- How do I know what size motor I should use?
- What else do I need to use a motor?
- How do I run a motor?

- Motors convert other forms of energy into mechanical energy.



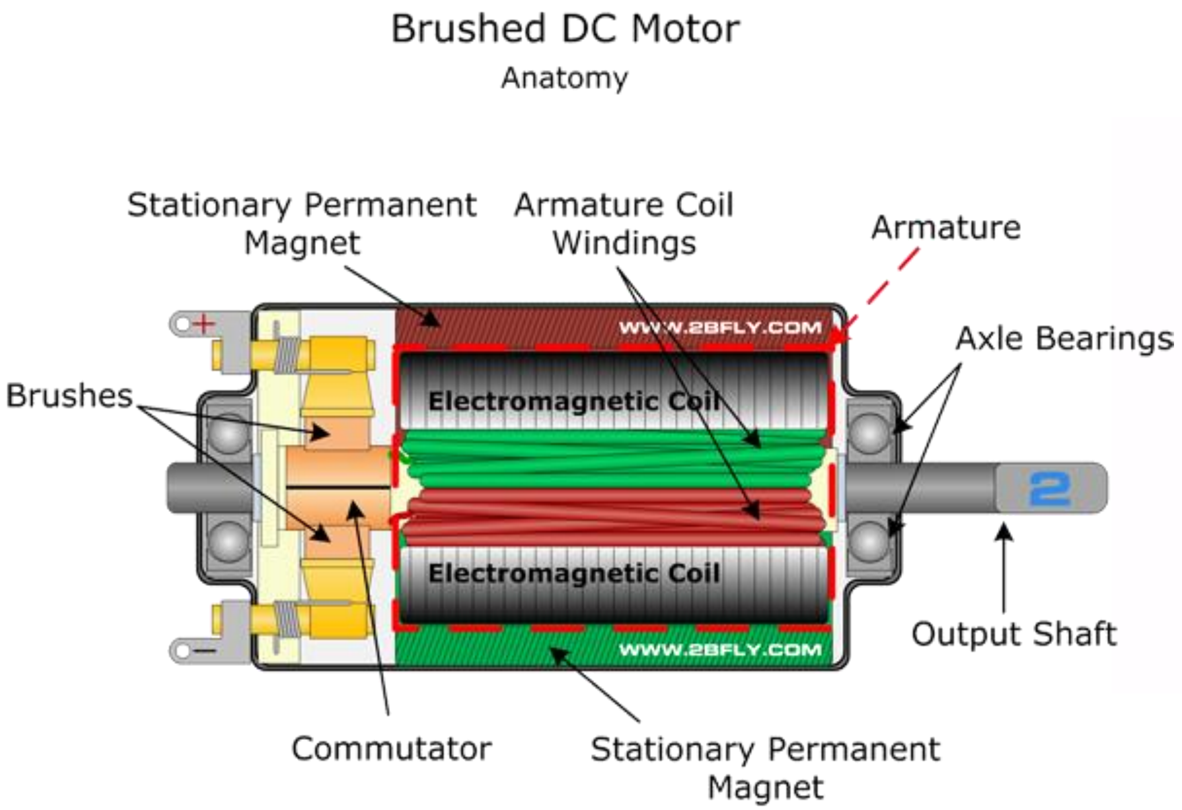
Types of electric motors

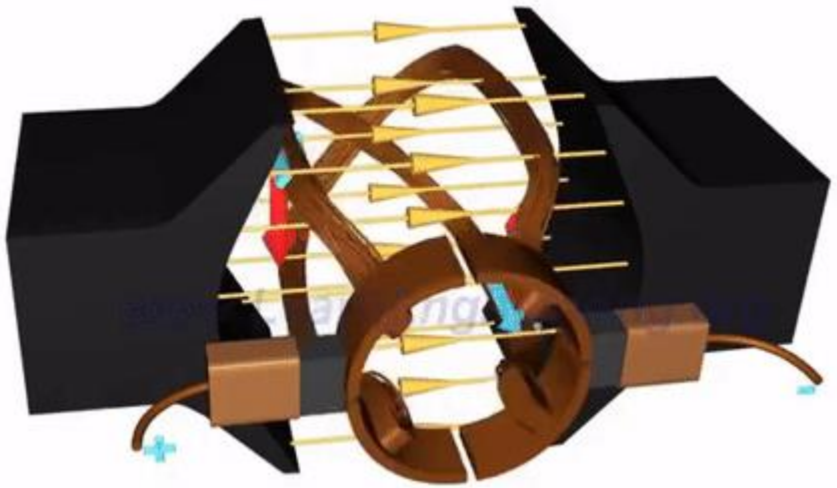
- DC motors
- Stepper motors
- Servo motors

DC Motors

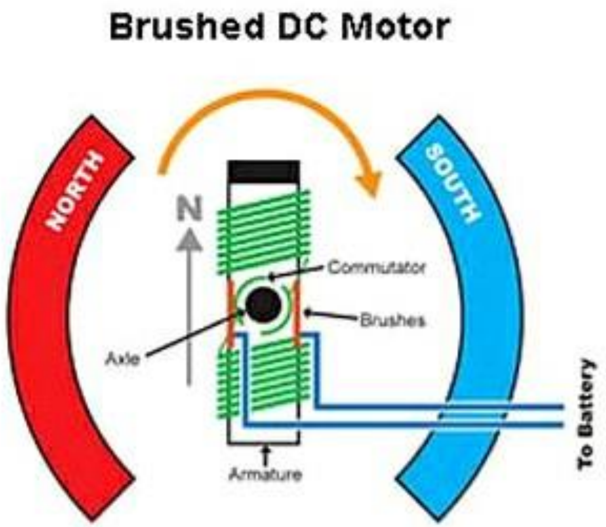
- Simple and cheap
- High speed
- Continuous rotation

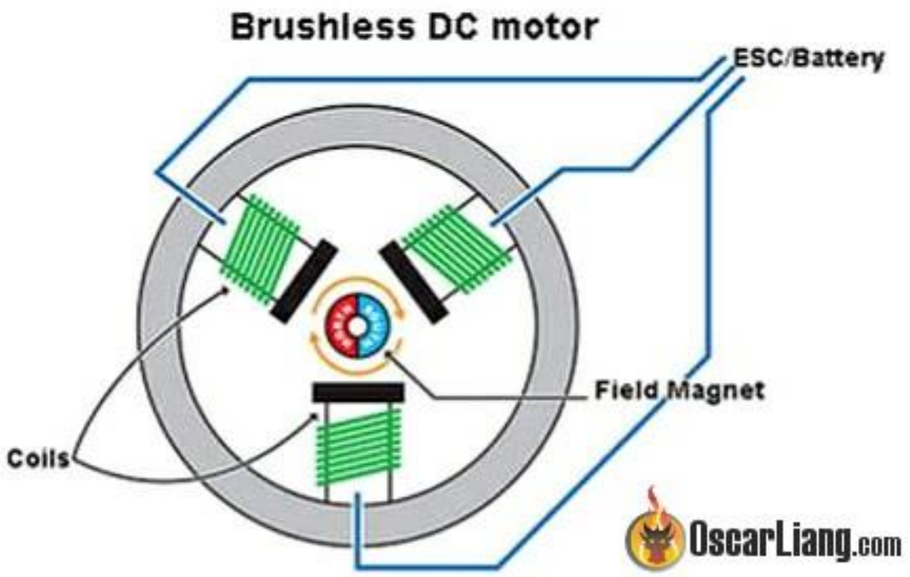
How do they work?





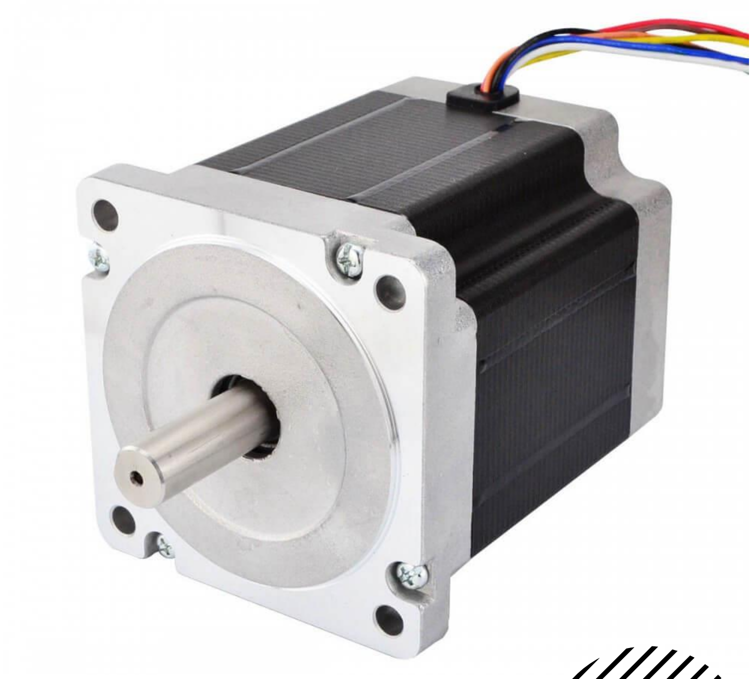
Brushed vs Brushless





- Cheaper
- Easier to program
- Generate more heat
- Shorter lifetime

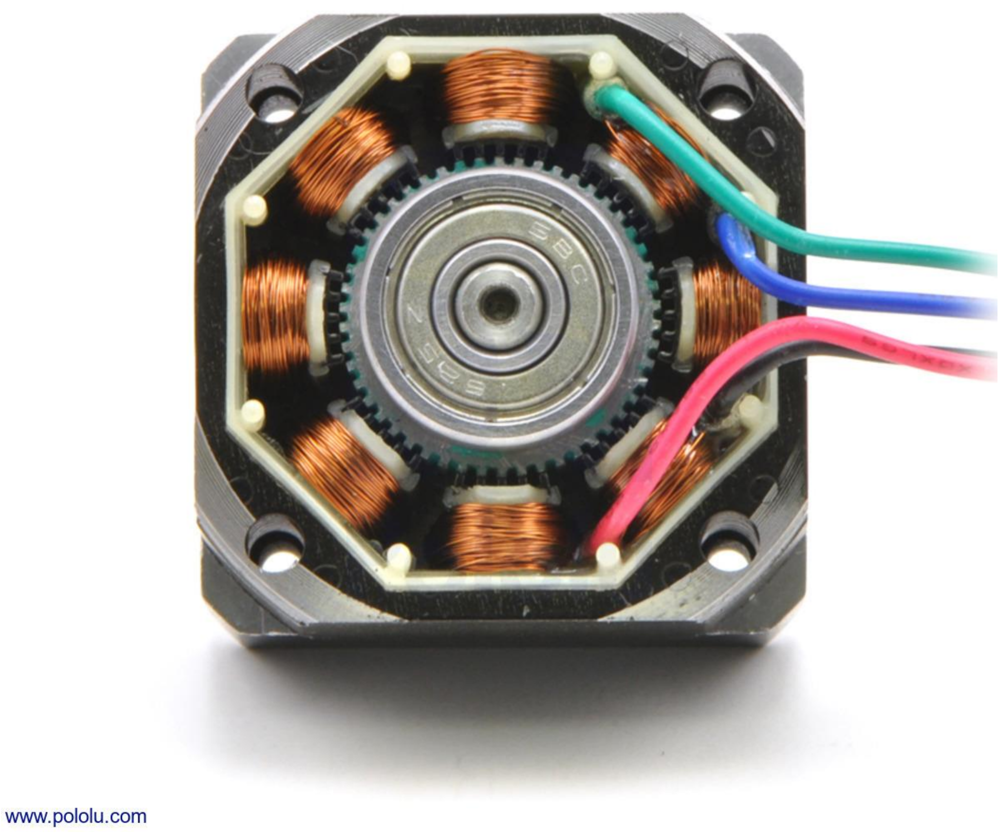
- More expensive
- More programming (ESC)
- Generate less heat
- Much longer lifetime

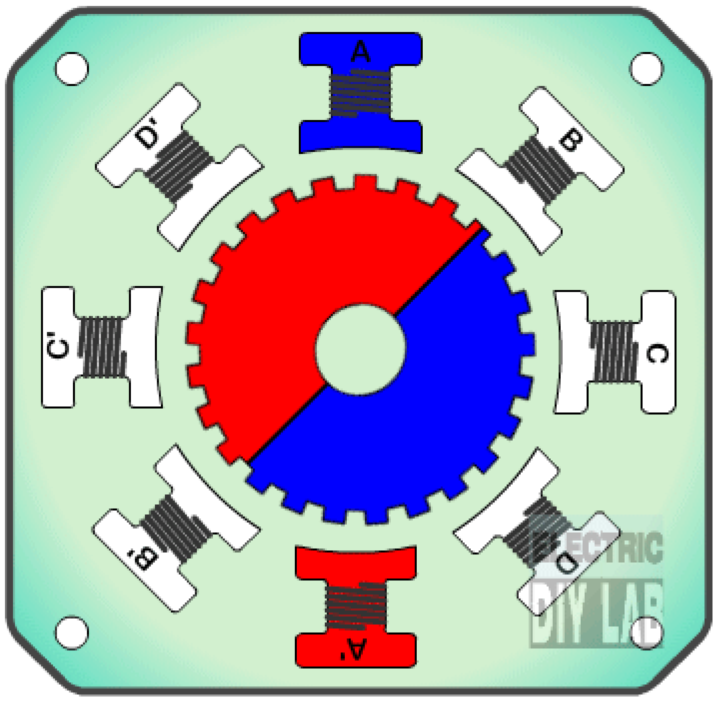


Stepper Motors

- Low speed
- High holding torque
- More complex than a DC motor
- Excellent position control
  - Resolution defined in terms of steps per revolution

How do they work?





Servo Motors

- DC motor with extra steps
  - Includes a gear box, control circuit, and position sensor
- High speed and high torque
- Limited rotation
  - Ex: 0-180°

How do they work?

So when do we use these?

DC Motor

- Continuous rotation
- High speed applications

Stepper Motor

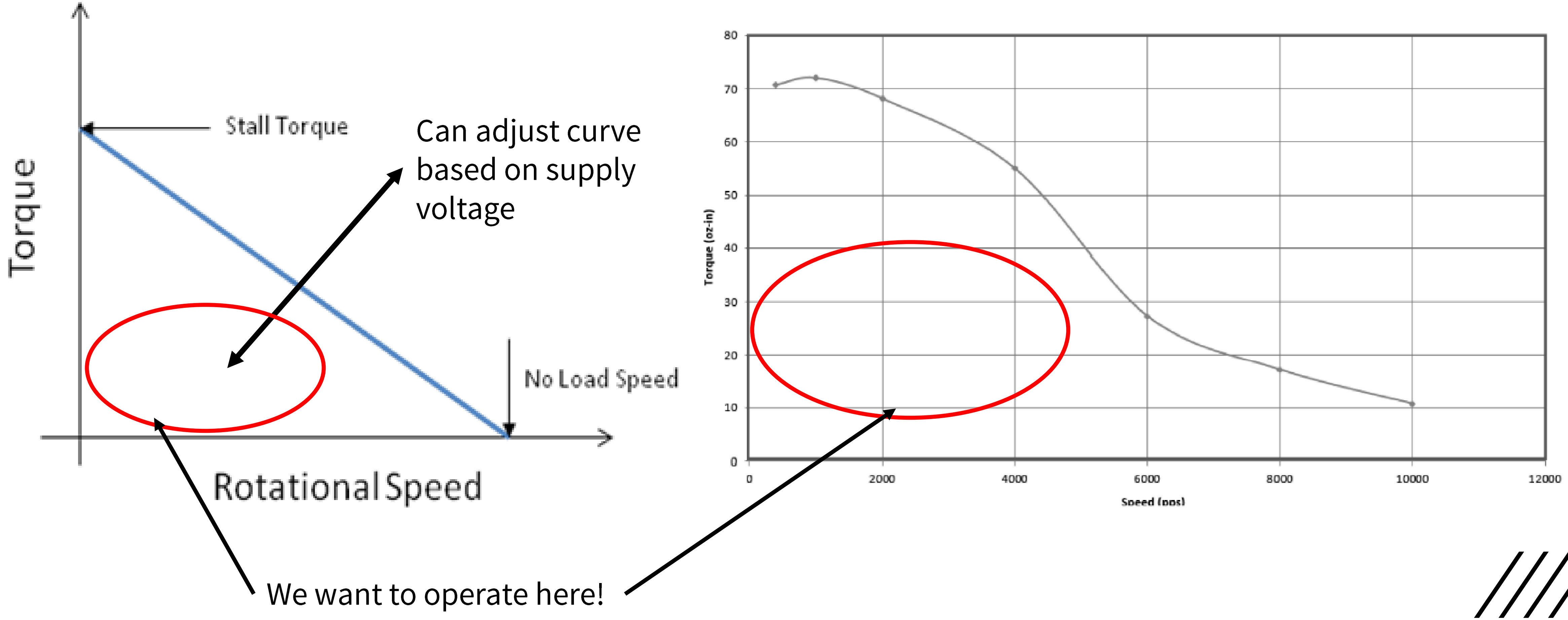
- Great for precise position control
- Low speed applications
- High holding torque

Servo Motor

- High speed AND high torque applications
- Limited angle of rotation

When selecting a motor, you want a motor which can satisfy your torque and speed requirements

- All motors have a trade-off between torque and speed



So how do we find these requirements?

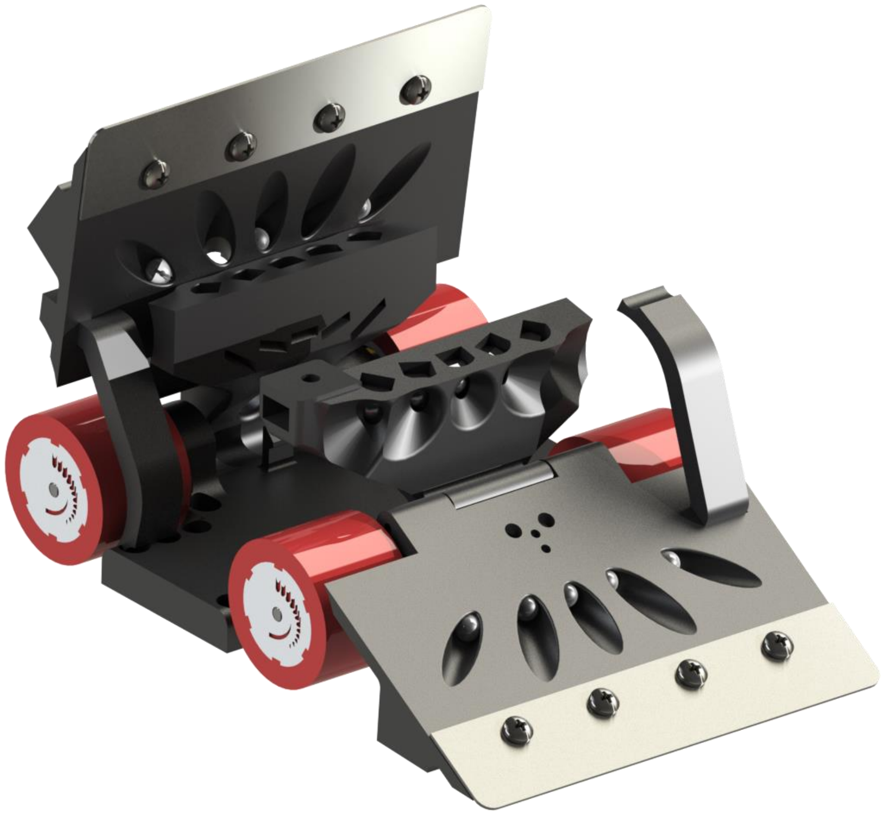
- Speed → How fast do you want to go? How quickly do you want to reach that speed?

- Torque → How much torque do you need to reach that speed?

Example: Sumobot!

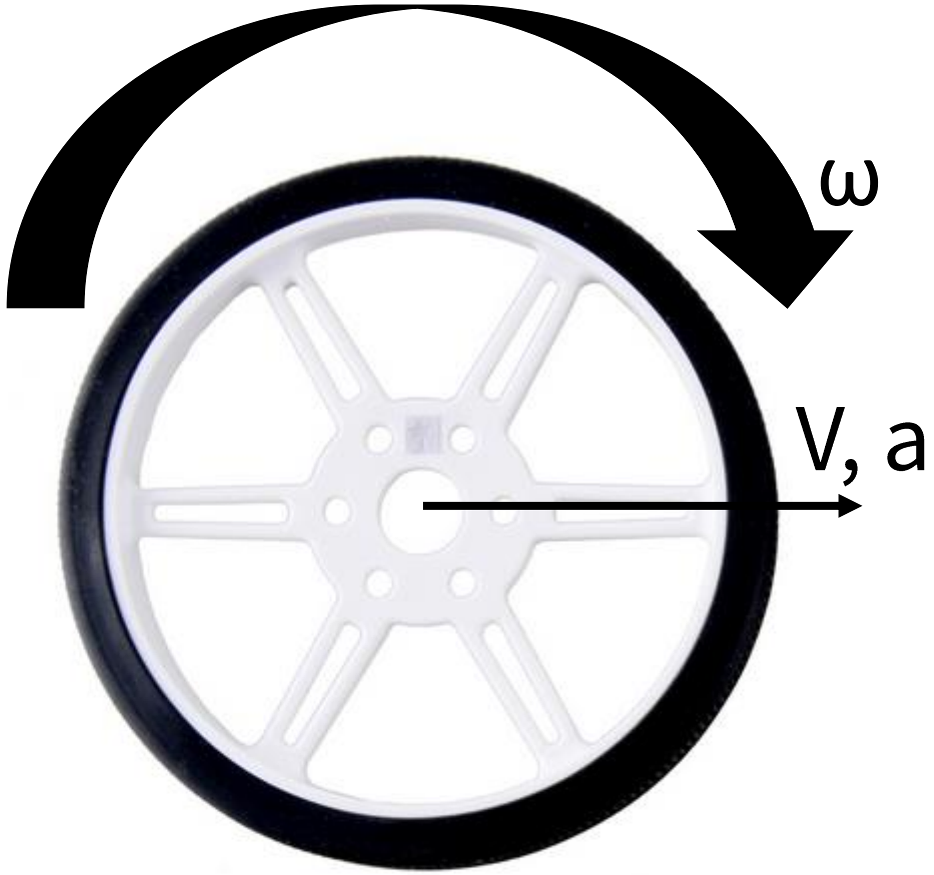
- Goal: To reach a max speed of 1 m/s in 0.25 seconds

- Specs:
  - Mass: 600 g
  - Wheel diameter: 38 mm
  - Number of motors: 4



Determining speed

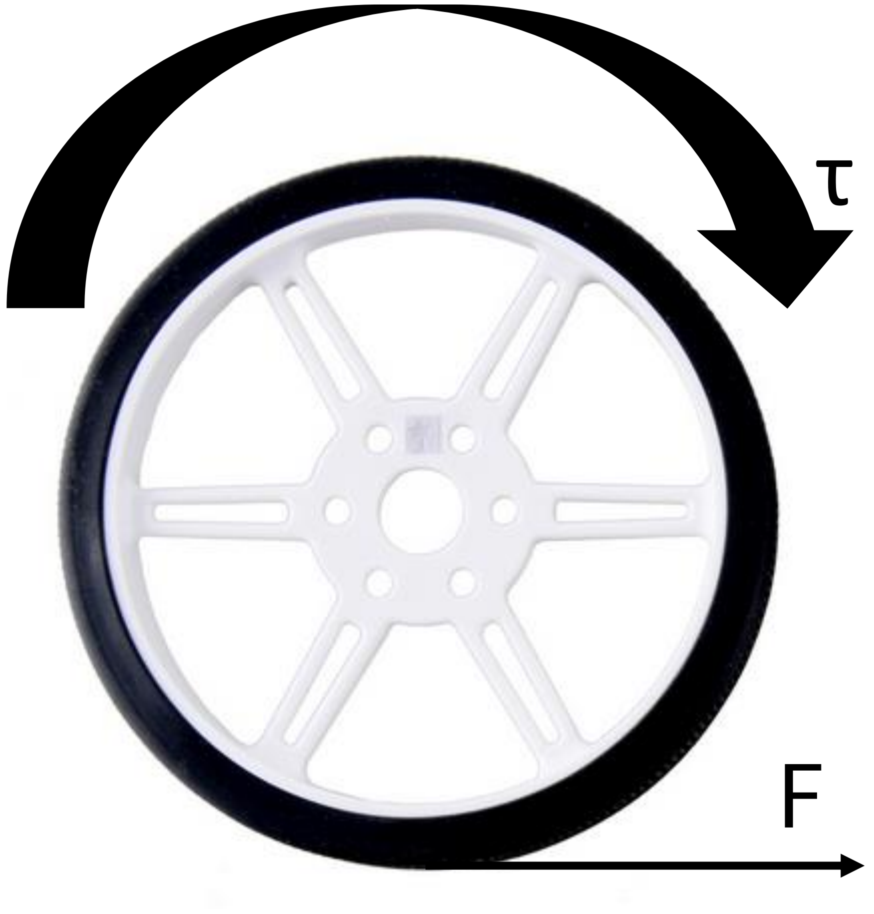
- V=ωR
- ω = (1 m/s) / (0.019 m) = 52.6 rad/s
- ω = (52.6 rad/s) * (60 s / 2π) = 502 RPM



Determining speed

- F = ma/4 (Force is split between four motors)
- a = (1 m/s) / (0.25 s) = 4 m/s2
- F = (0.6 kg) * (4 m/s2) / 4 = 0.6 N

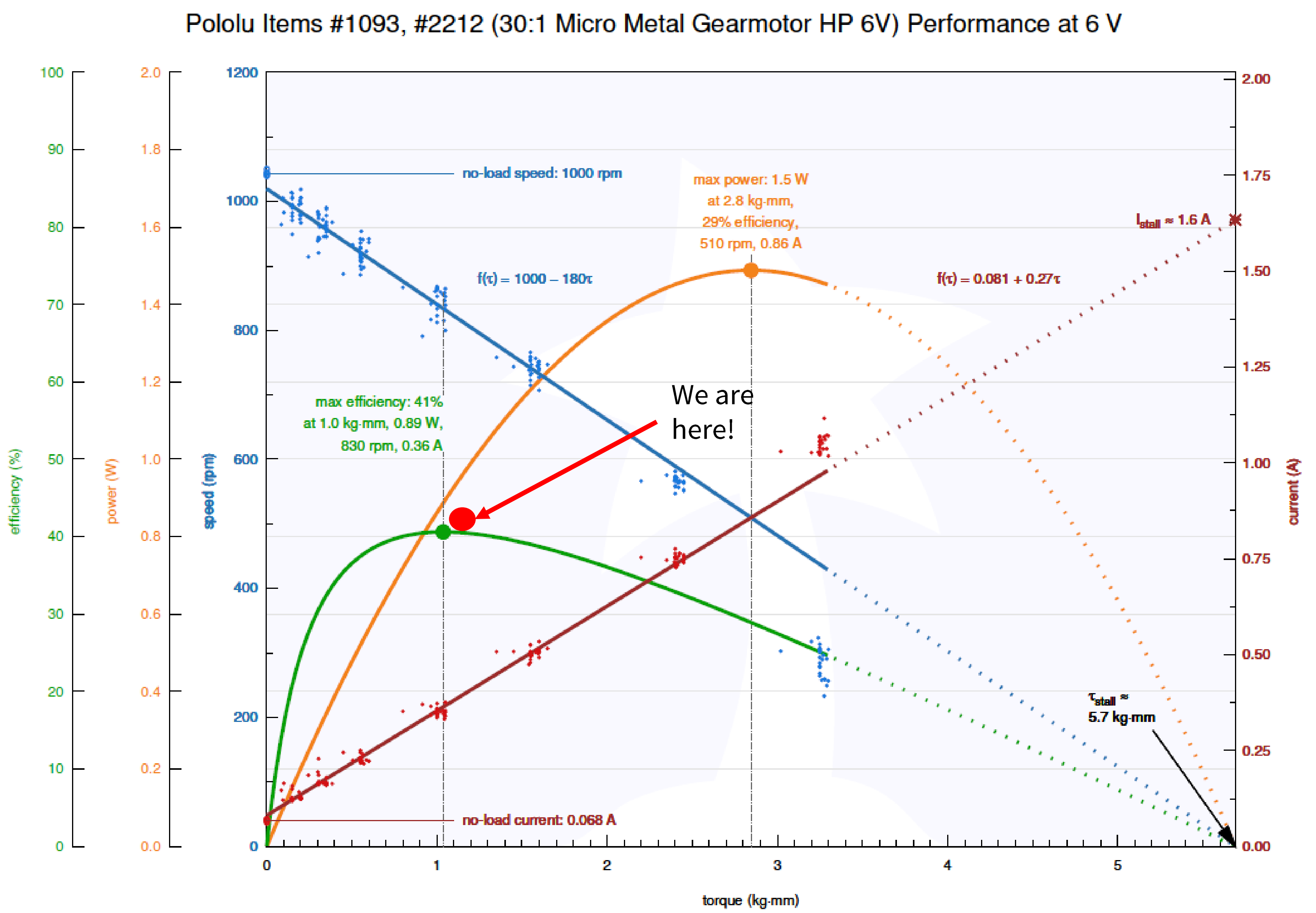
- τ = FR
- τ = (0.6 N)*(0.019 m) = 0.0114 N*m
- Convert to oz*in → τ = 1.6 oz*in



Use your calculations to select a motor based on the torque-speed curves

- Continuous rotation → DC motor   Power supply → 6 V

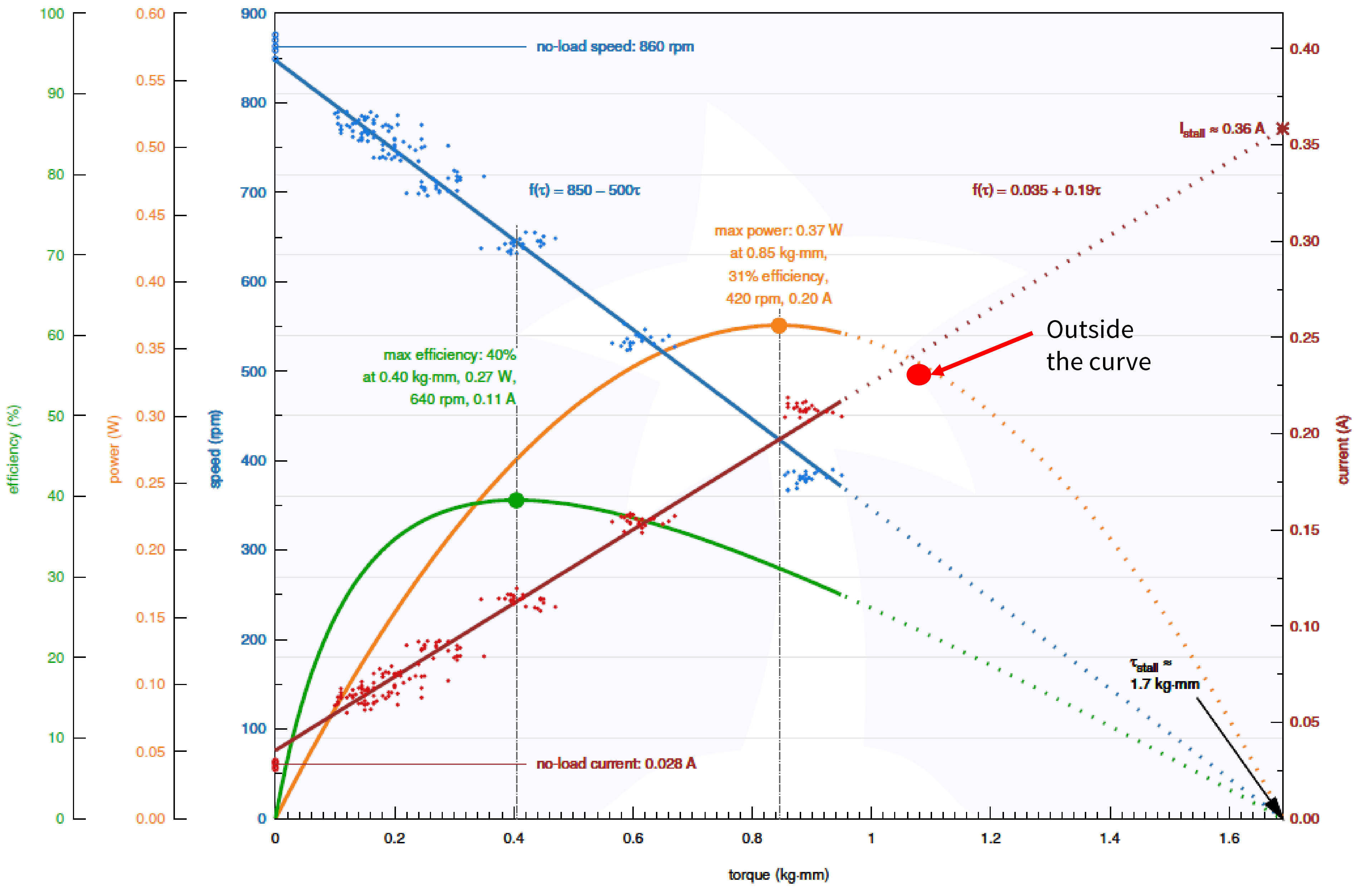
					Extrapolated Stall Torque			
Rated Voltage	**Motor Type**	**Stall Current**	**No-Load Current**	**No-Load Speed (RPM)**	**(kg · cm)**	**(oz · in)**	**Max Power (W)**	**Single-Shaft (Gearbox Only)**
6 V	high-power **(HP)**	1.6 A	0.07 A	6100	0.11	1.5	–	5:1 HP 6V
				3100	0.22	3.0	1.6	10:1 HP 6V
				2000	0.30	4.2	1.5	15:1 HP 6V
				1000	0.57	7.9	1.5	30:1 HP 6V
				590	0.86	12	1.3	50:1 HP 6V
				410	1.3	18	1.4	75:1 HP 6V
				310	1.7	24	1.3	100:1 HP 6V
				210	2.4	33	1.2	150:1 HP 6V
				150	3.0	42	1.1	210:1 HP 6V
				120	3.4	47	1.1	250:1 HP 6V
				100	4.0	56	1.1	298:1 HP 6V
				84	5.5	76	1.1	380:1 HP 6V
				31	12	170	–	1000:1 HP 6V


Pololu Items #1093, #2212 (30:1 Micro Metal Gearmotor HP 6V) Performance at 6 V
no-load speed: 1000 rpm
max power: 1.5 W
at 2.8 kg-mm,
29% efficiency,
510 rpm, 0.86 A
I_{stall} ≈ 1.6 A
f(τ) = 1000 – 180τ
f(τ) = 0.081 + 0.27τ
max efficiency: 41%
at 1.0 kg-mm, 0.89 W,
830 rpm, 0.36 A
We are
here!
$τ_{stall}$ ≈
5.7 kg-mm
no-load current: 0.068 A
efficiency (%)
power (W)
speed (rpm)
current (A)
torque (kg-mm)

- Note: Just because a motor can meet the torque or speed requirement does not mean it can reach both!

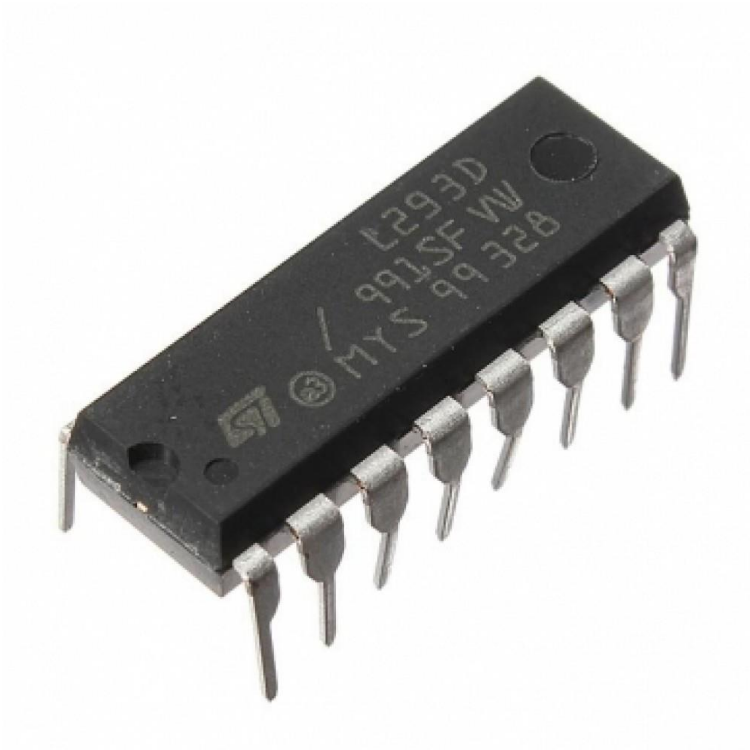
Rated Voltage	Motor Type	Stall Current	No-Load Current	No-Load Speed (RPM)	Extrapolated Stall Torque (kg · cm)	Extrapolated Stall Torque (oz · in)	Max Power (W)	 Single-Shaft (Gearbox Only)
6 V	low-power **(LP)**	0.36 A	0.02 A	2500	0.05	0.7	–	5:1 LP 6V
				1300	0.10	1.4	–	10:1 LP 6V
				860	0.17	2.4	0.37	15:1 LP 6V
				450	0.29	4.0	0.31	30:1 LP 6V
				270	0.44	6.1	0.29	50:1 LP 6V
				180	0.64	8.9	0.29	75:1 LP 6V
				130	0.74	10	0.25	100:1 LP 6V
				90	1.1	15	0.25	150:1 LP 6V
				65	1.6	22	0.25	210:1 LP 6V
				54	1.7	24	0.23	250:1 LP 6V
				45	2.0	28	0.22	298:1 LP 6V
				36	2.9	40	0.27	380:1 LP 6V
				13	5.5	76	–	1000:1 LP 6V

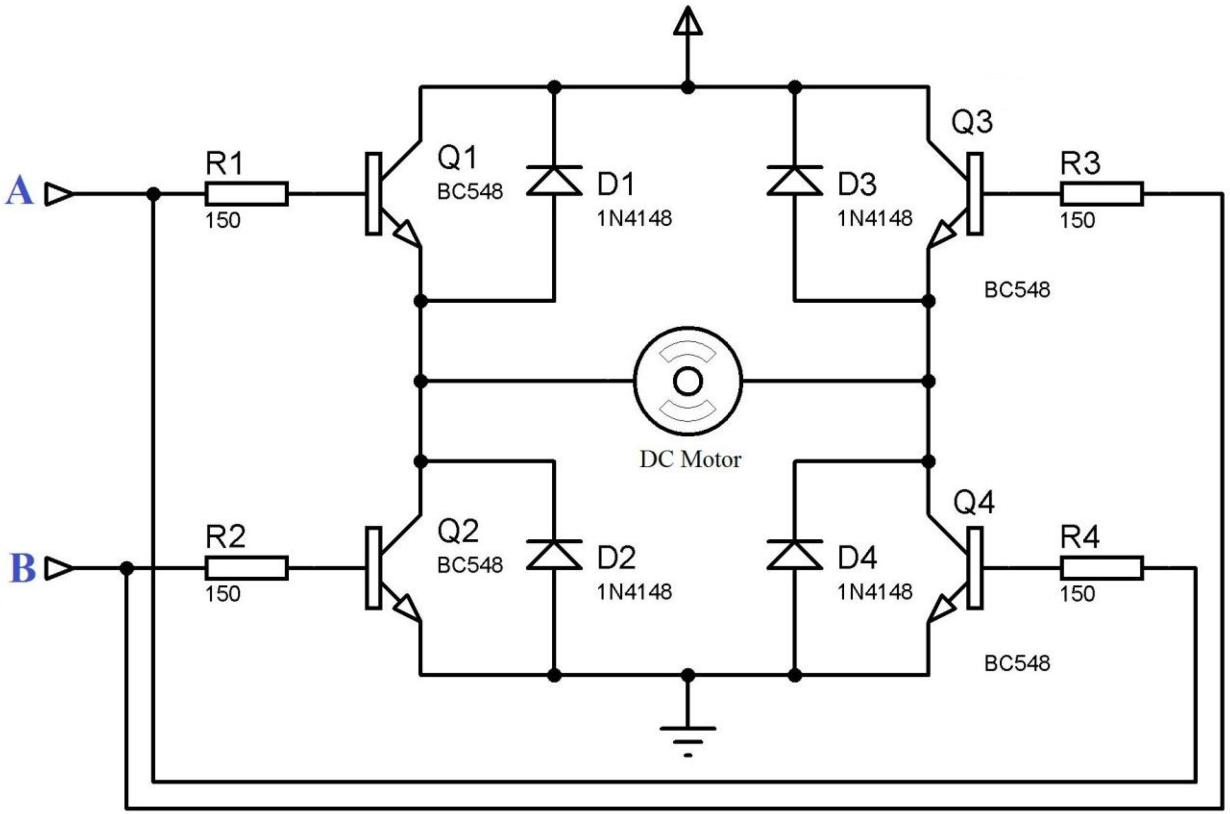
Pololu Items #4780, #4781 (15:1 Micro Metal Gearmotor LP 6V) Performance at 6 V



You typically need a motor driver to regulate speed and direction of your motor

- Example: H-bridge for DC and stepper motors





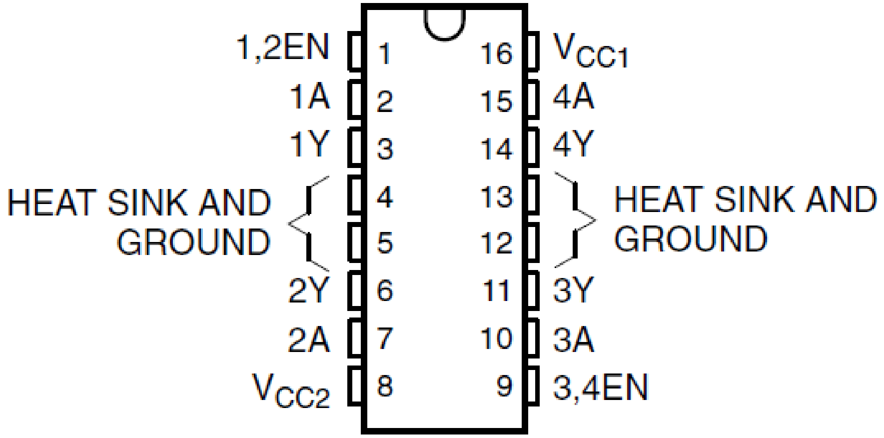
Check the current rating of your motor to pick the correct controller

Our motor's operating current: ~0.38 A

H-bridge specs:

- Featuring Unitrode L293 and L293D Products Now From Texas Instruments
- Wide Supply-Voltage Range: 4.5 V to 36 V
- Separate Input-Logic Supply
- Internal ESD Protection
- Thermal Shutdown
- High-Noise-Immunity Inputs
- Functionally Similar to SGS L293 and SGS L293D
- Output Current 1 A Per Channel (600 mA for L293D)
- Peak Output Current 2 A Per Channel (1.2 A for L293D)
- Output Clamp Diodes for Inductive Transient Suppression (L293D)

L293 . . . N OR NE PACKAGE
L293D . . . NE PACKAGE
(TOP VIEW)

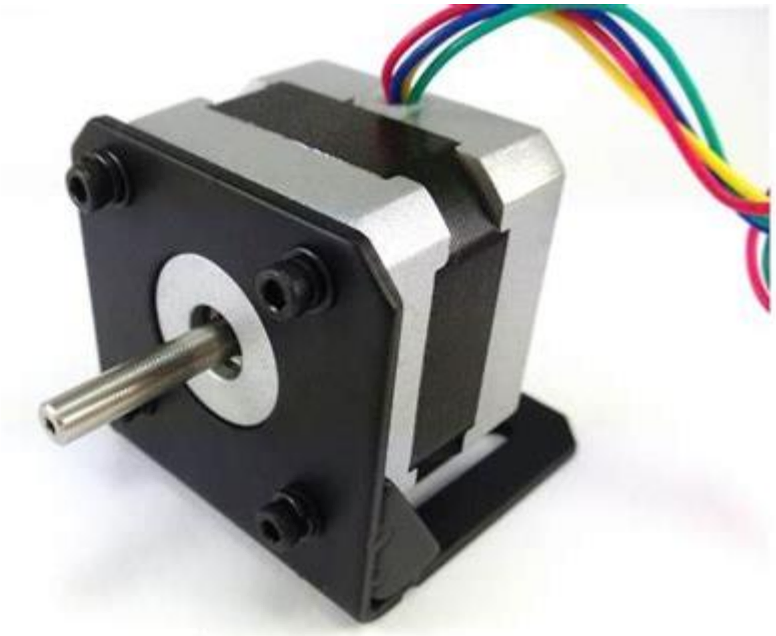


- You may need other mechanical components to install your motor

Wheel hubs

Shaft adapters

Mounting bracket

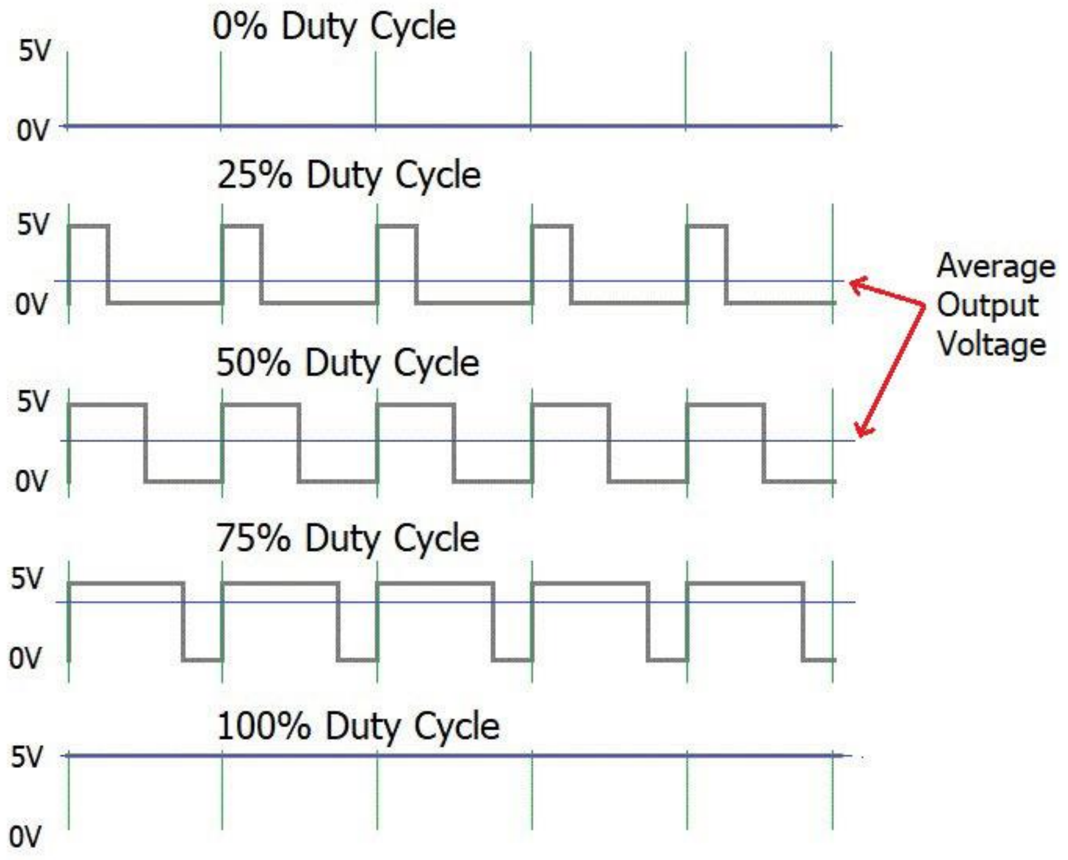


DC Motor Control: Direction and Speed

- Direction: H-bridge receives a digital HIGH or LOW, which each correspond to a different direction
- Speed: Pulse Width Modulation supplies a voltage to dictate the rotational speed

DC Motor Control: Pulse Width Modulation (PWM)

- Digital pins can only provide a HIGH or LOW output
- PWM sends out pulses of the HIGH and LOW
- Creates an average voltage for the motor



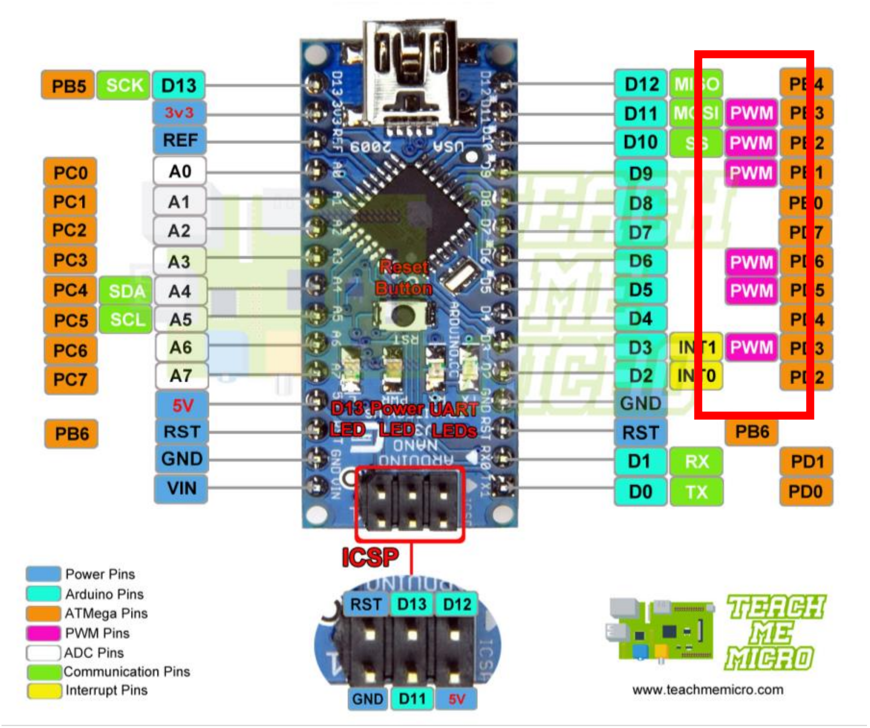
Hardware vs. Software PWM

Hardware PWM

- Microcontroller has built in PWM pins you can use

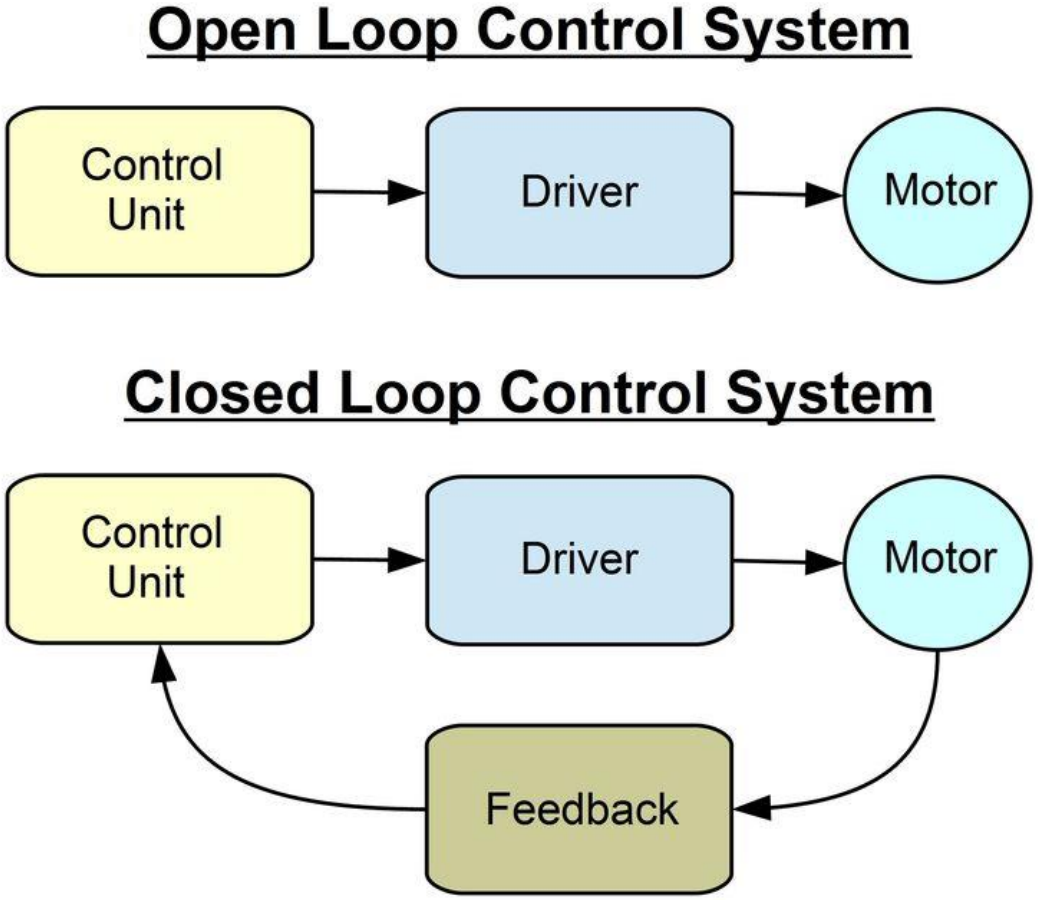
Software PWM

- You can use the controller's timer to make your own PWM loop



LET'S LOOK AT AN EXAMPLE

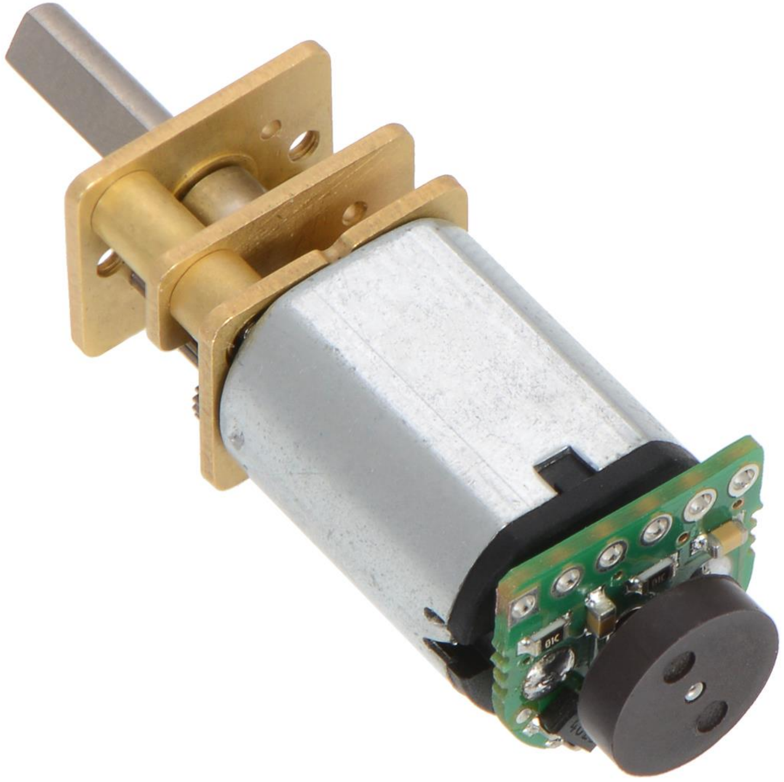
- The current setup is an open loop setup, there is no feedback

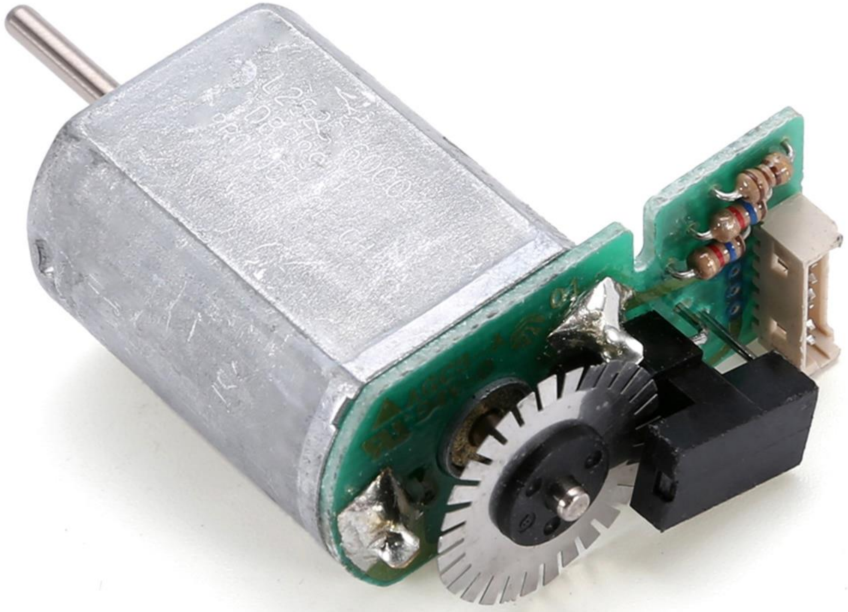


Without feedback, we cannot be sure that this motor is doing exactly what we want it to do.

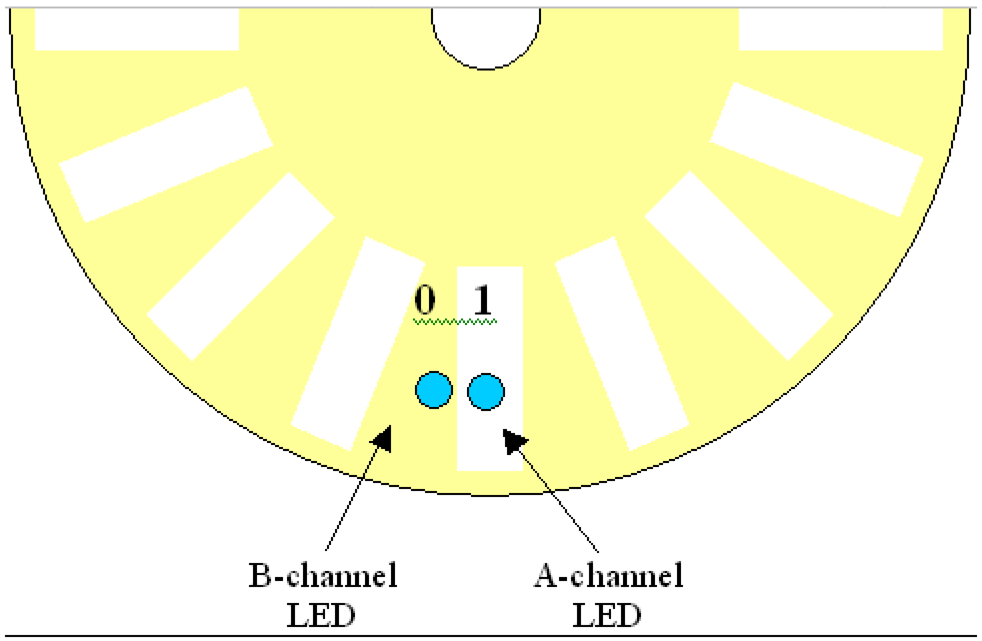
- How far have we actually moved?
- Are all the motors moving at the same speed?

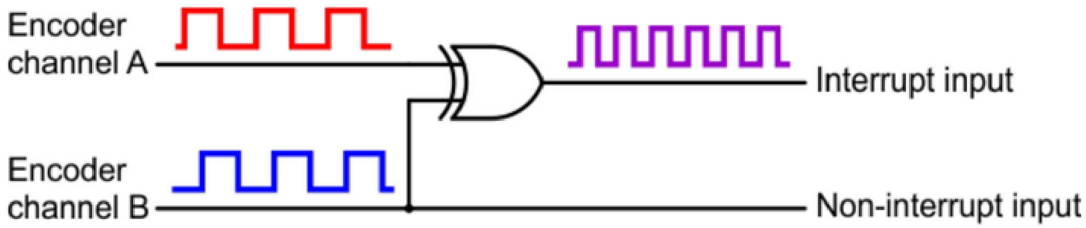
- We can use encoders to measure the motor’s true velocity and our position

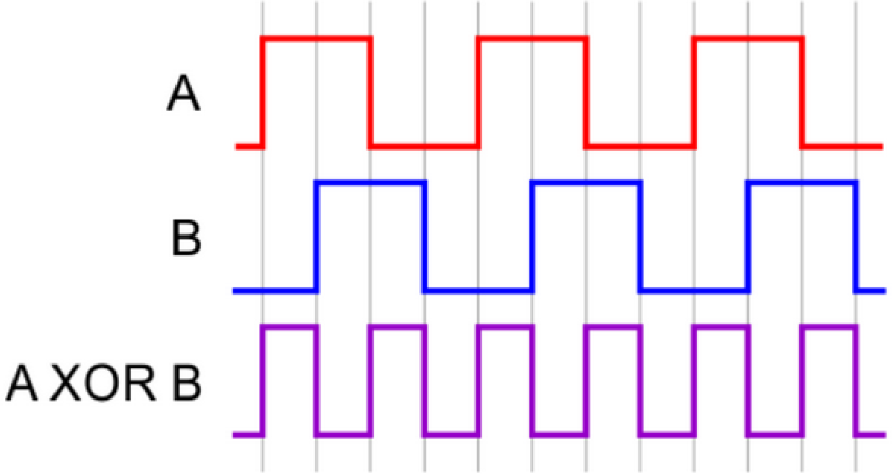




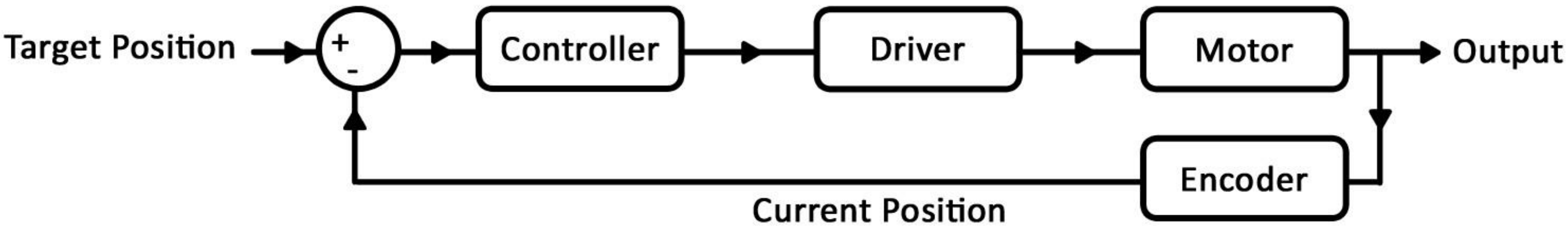
- Encoders count the number of rotations of the output shaft

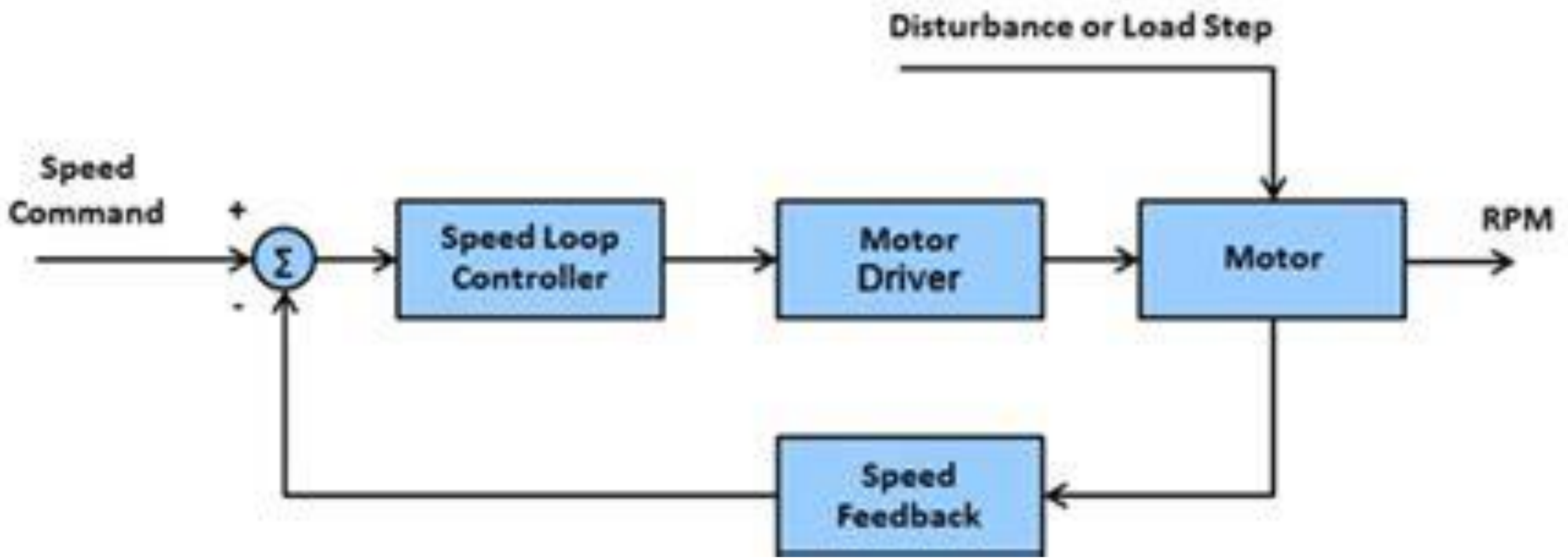






- We can convert that output into velocity and position data to close the loop





Let’s Recap

- There are several electric motors you can use depending on the project (DC, stepper, or servo)
- Use a torque analysis to properly size your motor
- Set up a PWM signal to control DC motor speeds
- Use an encoder (or similar sensor) to track position and motor speed for a closed feedback loop

Some websites to get you started:

- Pololu (General Robotics): https://www.pololu.com/
- Sparkfun (General Robotics): https://www.sparkfun.com/
- Odrive (Brushless Controllers): https://odriverobotics.com/shop
- Servocity (Servos and DC Motors): https://www.servocity.com/
- Stepper Online (Stepper Motors): https://www.omc-stepperonline.com/

QUESTIONS?

Glossary

- Torque – A force’s tendency to produce rotation
  - Torque = (Force) x (Radius)
- Angular speed – How quickly an object rotates
- Efficiency – How much of the input power is used to generate rotation vs. dissipated as heat or noise