DC Motors

Making things move

Keith Chester

@thekeithchester

https://github.com/hlfshell/DC-Motors---Making-Things-Move

Who am I?

- Degree in Robotics Engineering
- Runs Hardware Projects for Fusion Marketing
- Programmer
- Friendly neighborhood maker
- Organizer of node.jSTL, jSTL, Code for the People

hlfshell

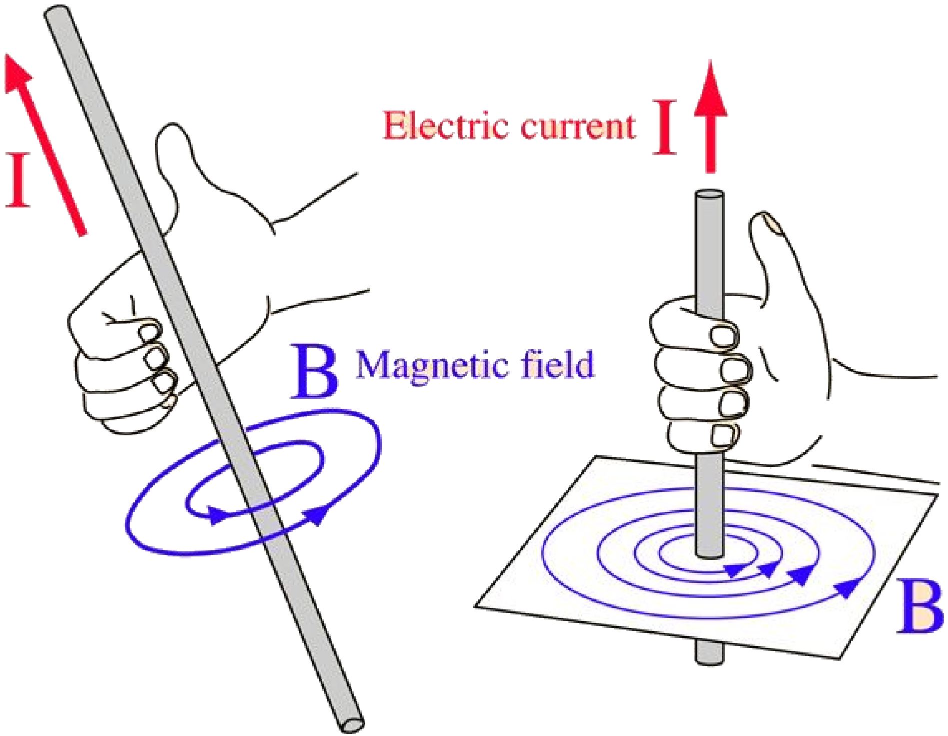
thekeithchester

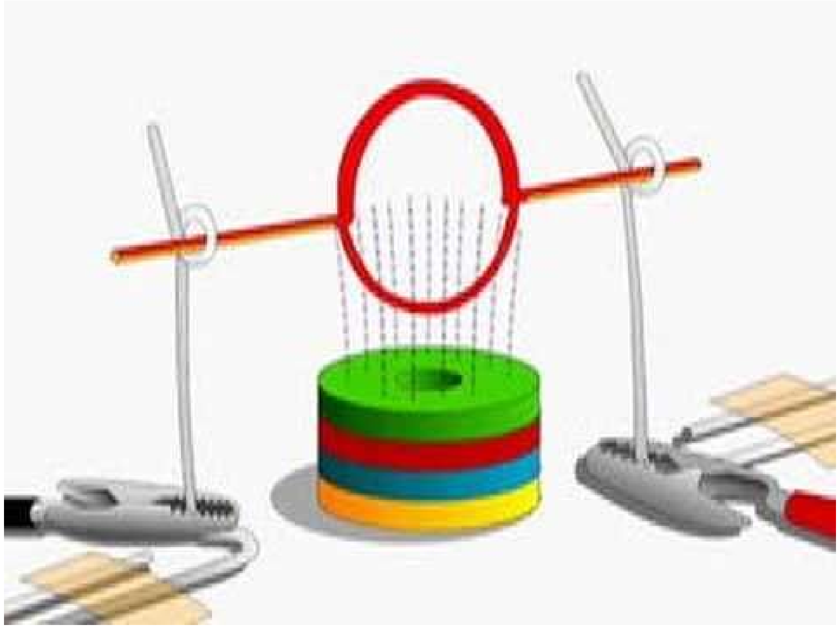
https://stltech.herokuapp.com
keithchester

What are we covering?

- Brushed DC Motors
- Controlling Motors
- Servo Motors
- Torque
- Positional Feedback
- Stepper Motors
- Brushless DC Motors
- *Calculating what motor we need*

The core concept - the simplest little motor





Brushed DC Motors

Brushed DC Motors

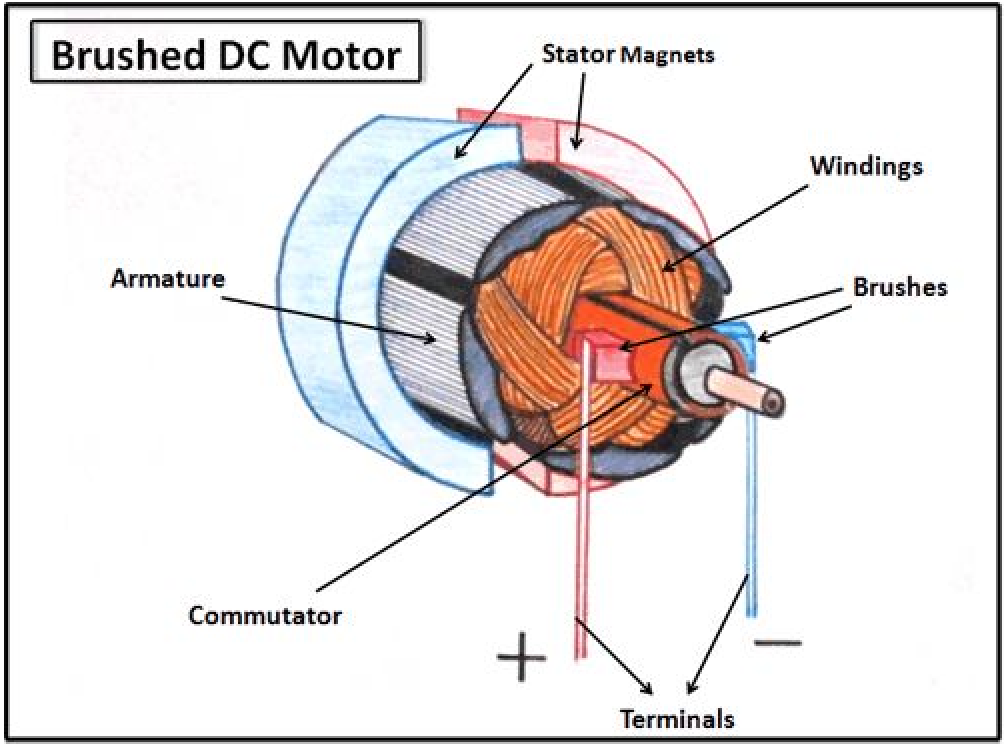
PROS

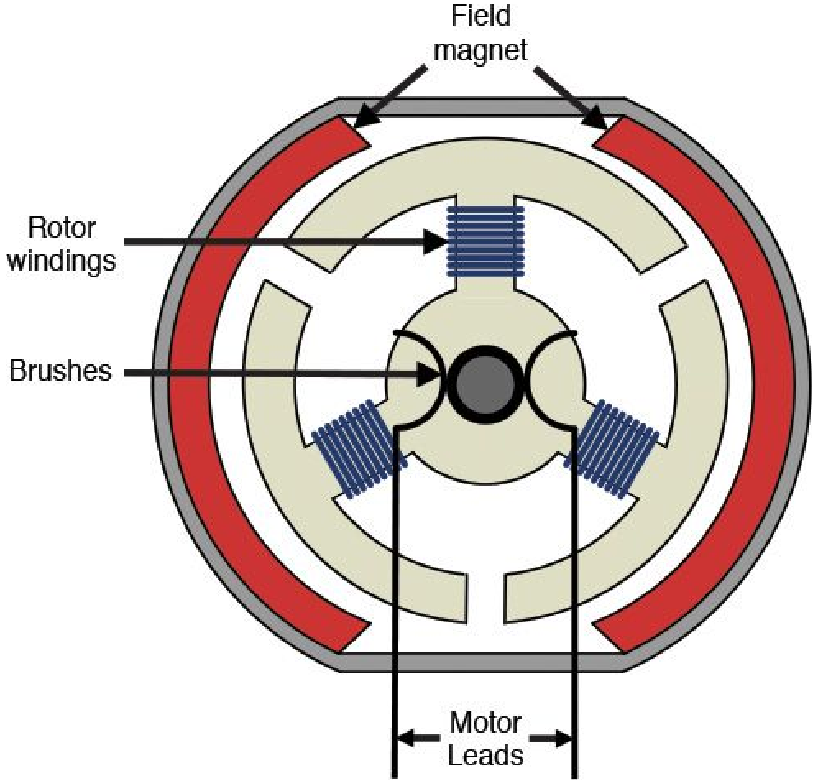
- Easy to control
- Easy to manufacture and thus cheaper
- Very common

CONS

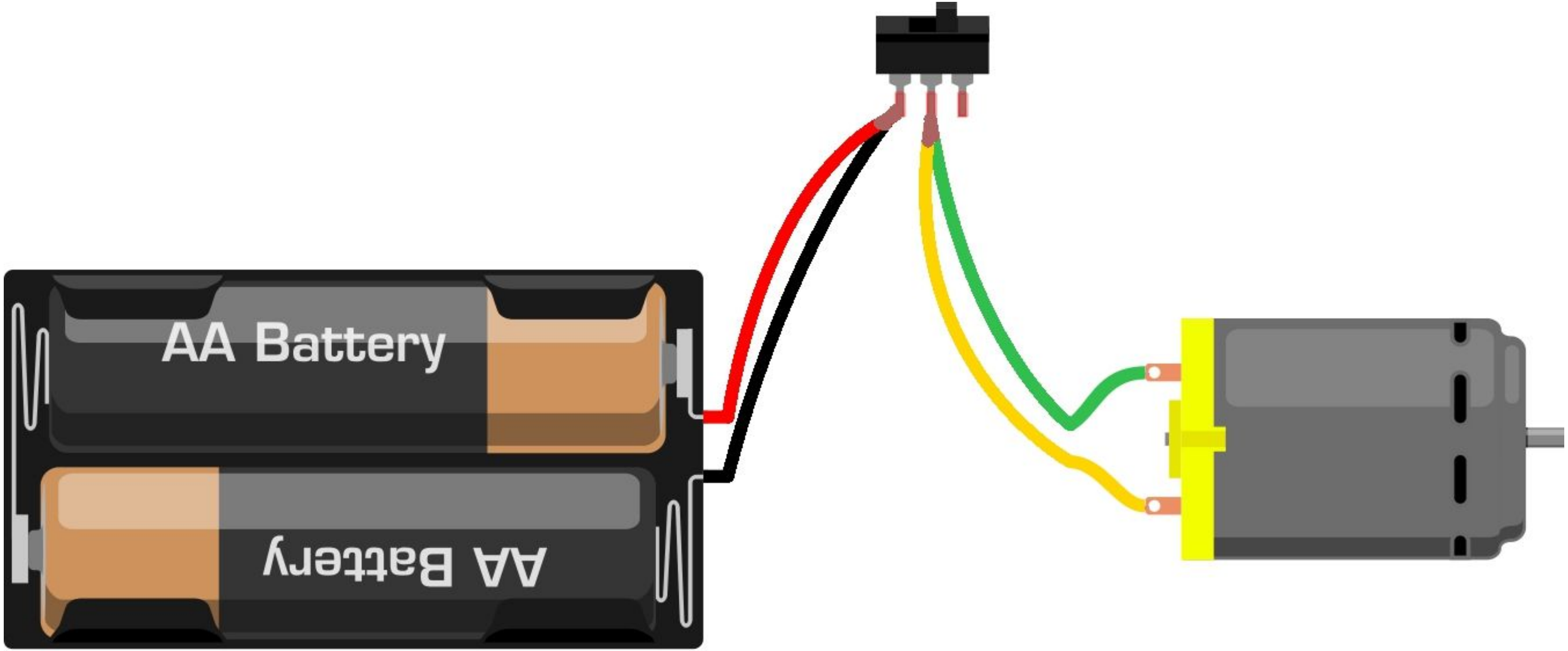
- Limited total lifespan or required maintenance due to brushes
- Not as efficient

Brushed DC Motors - structure

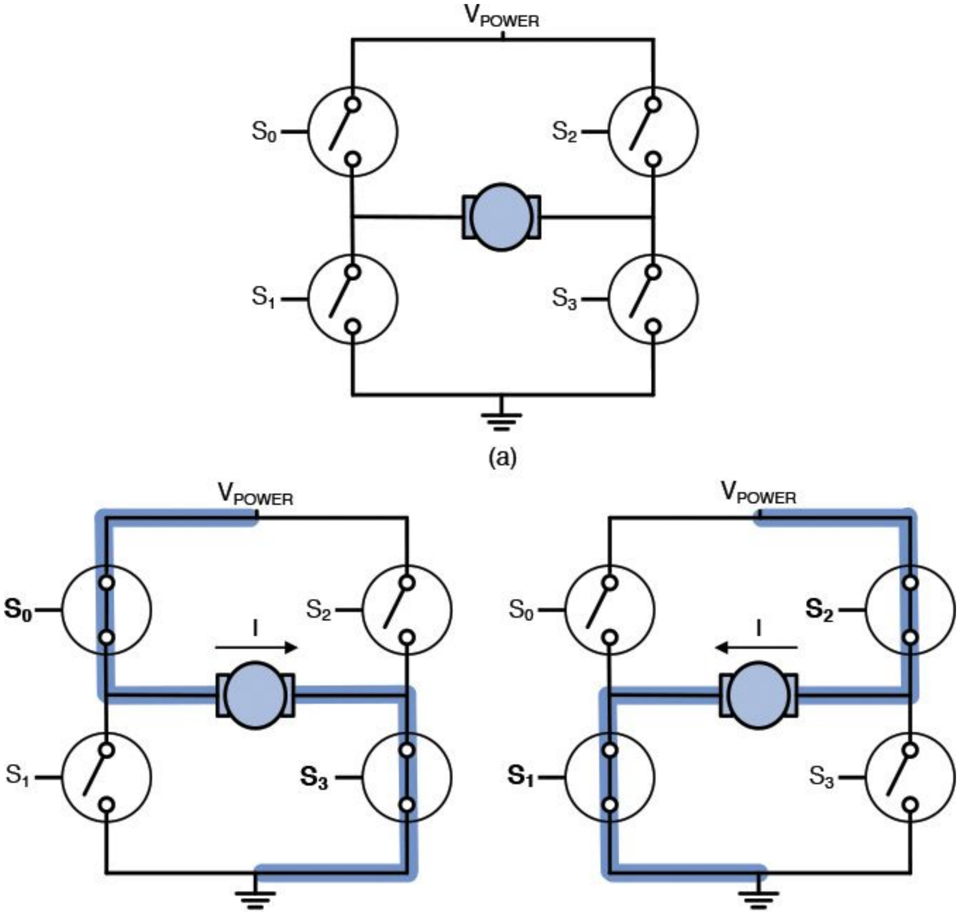




Controlling DC Motors - simple



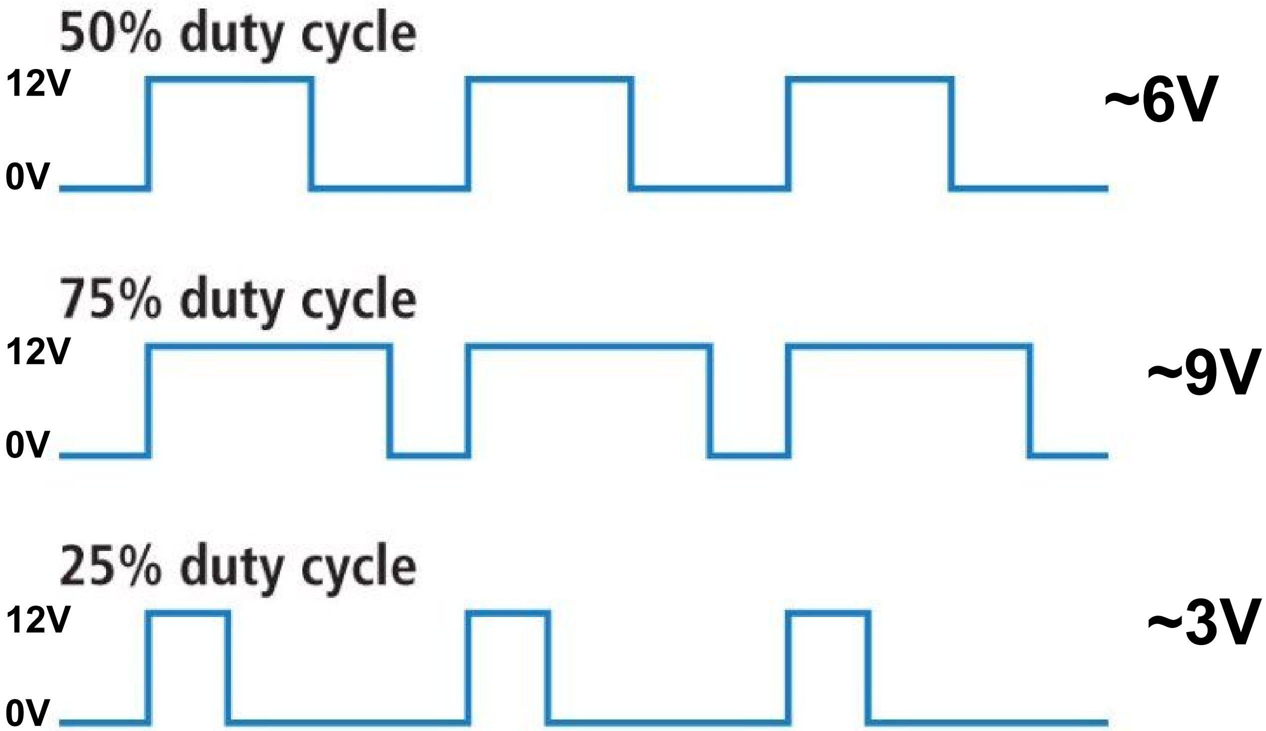
H-Bridges



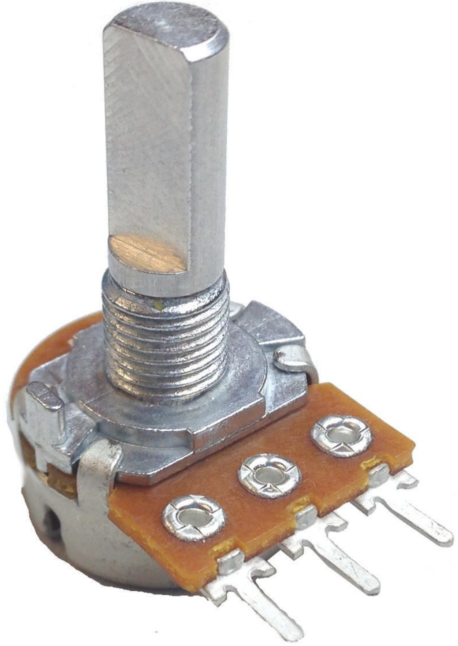
(a) (b) (c)

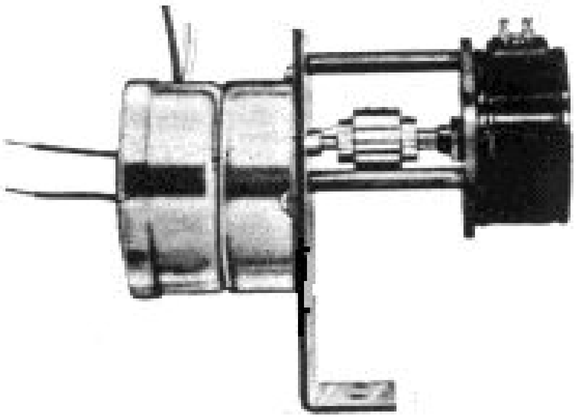
Motors For Makers
Matthew Scarpino

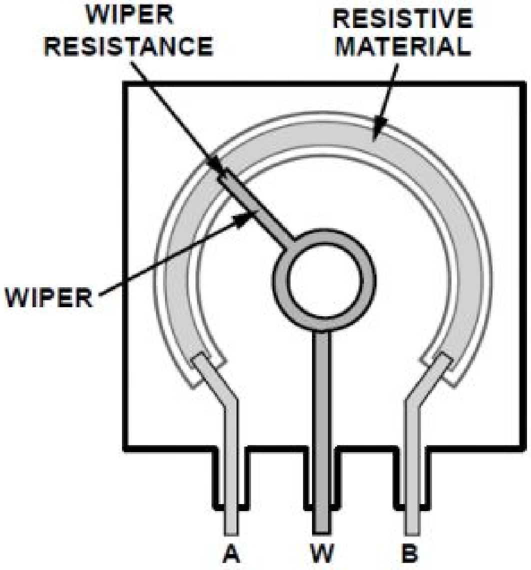
Pulse Width Modulation (PWM)



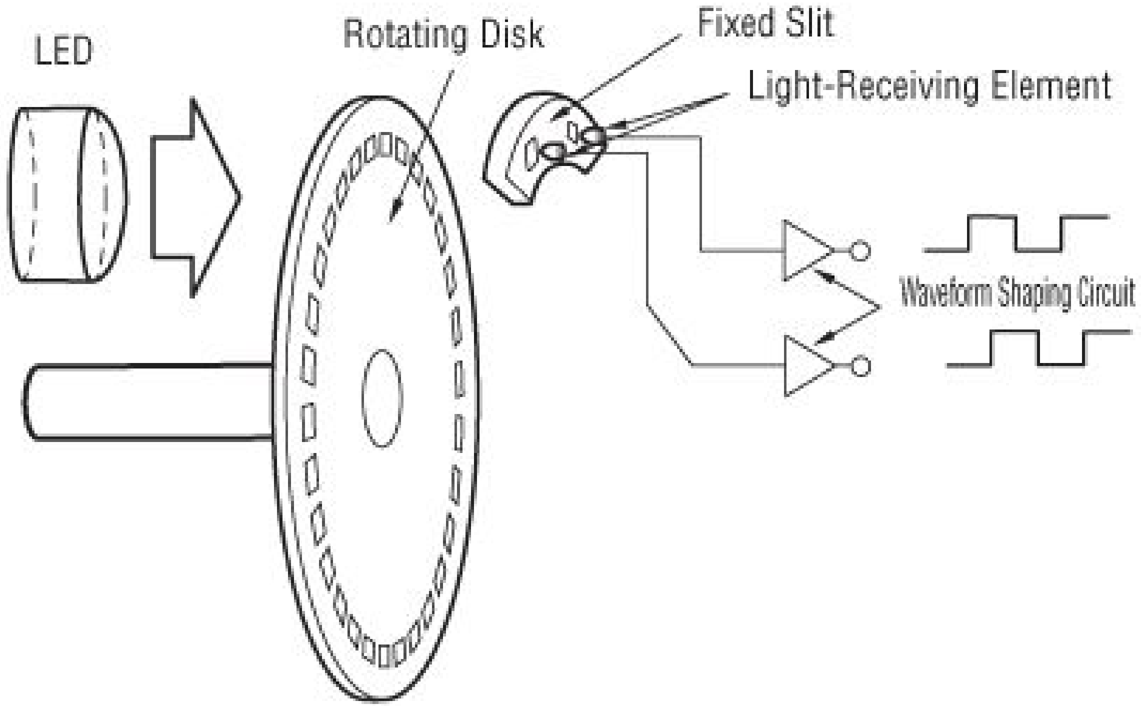
Positional Feedback -Potentiometers



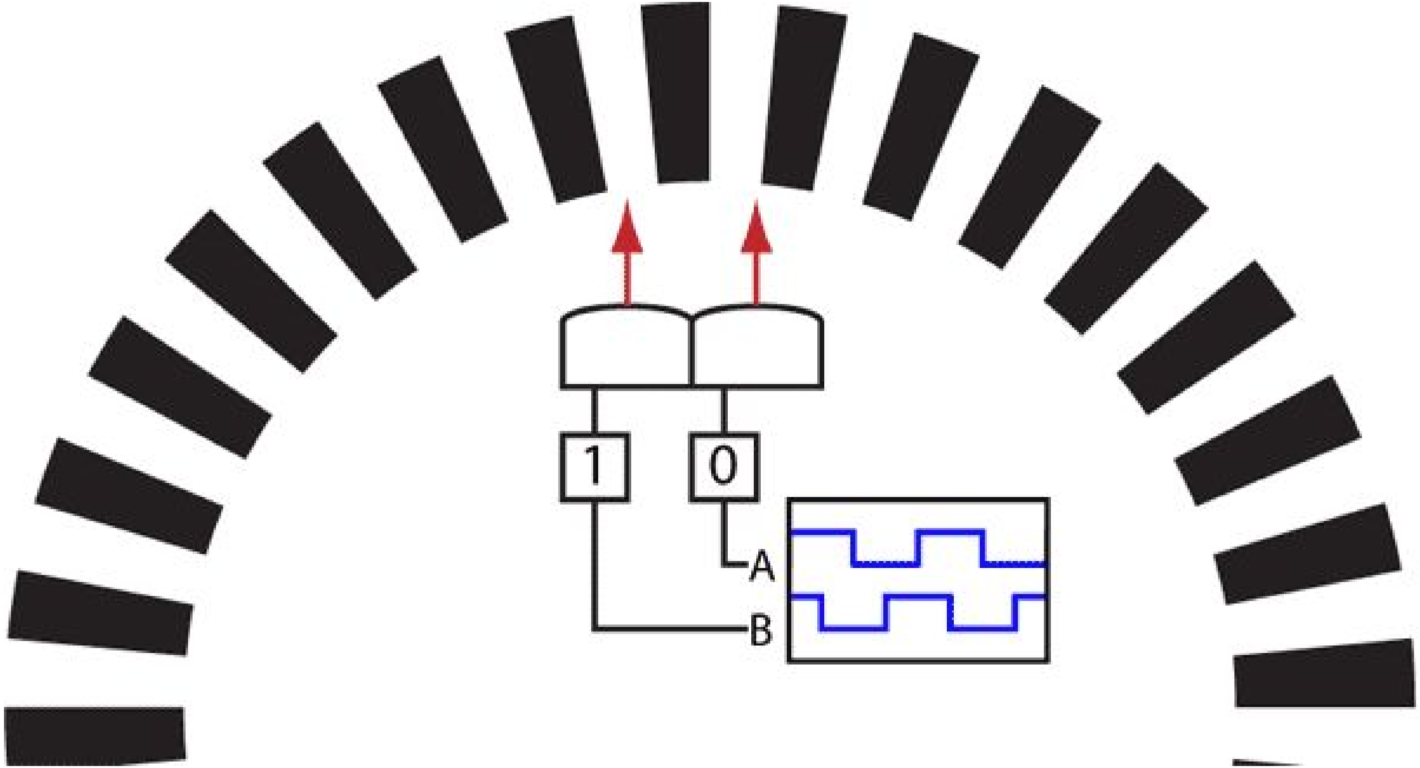




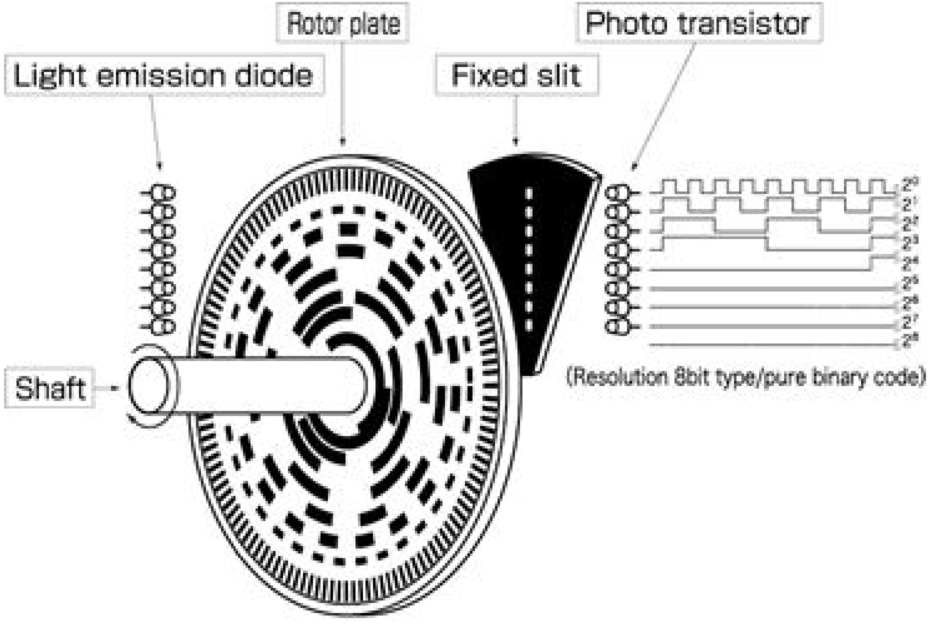
Positional Feedback - Encoders



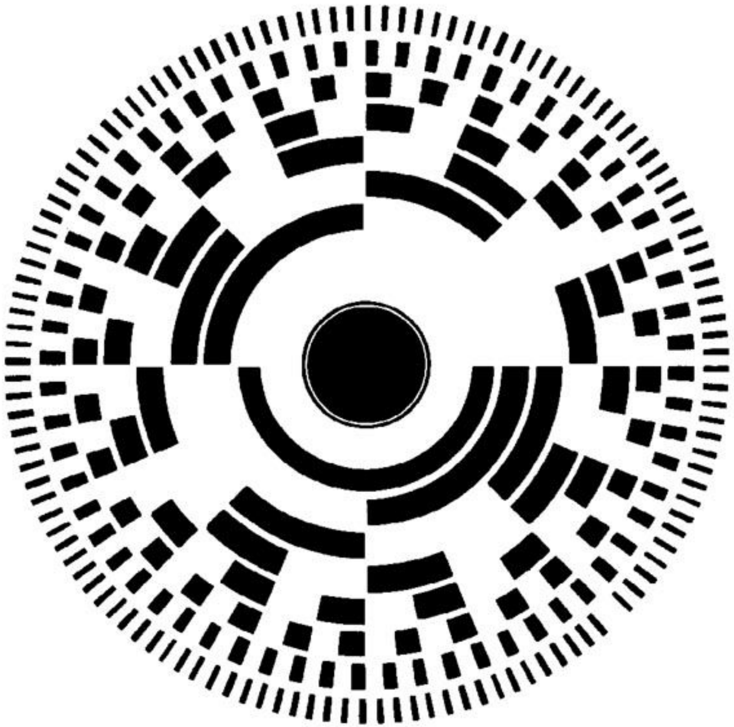
Quadrature Encoders



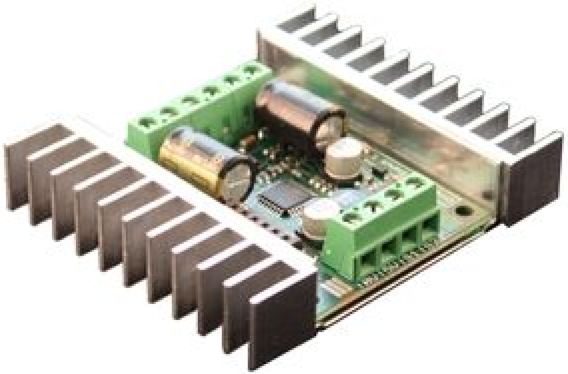
Absolute Encoders

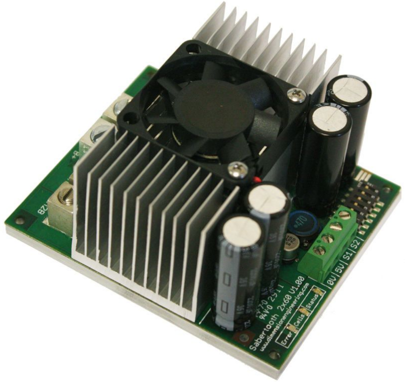


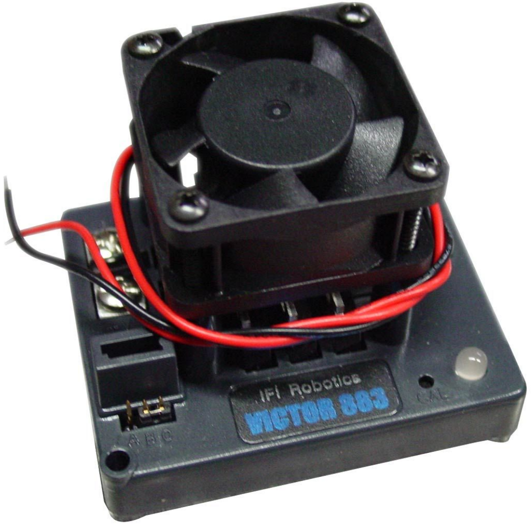
Absolute Encoder Simplified Structure



Motor Controllers







Servo

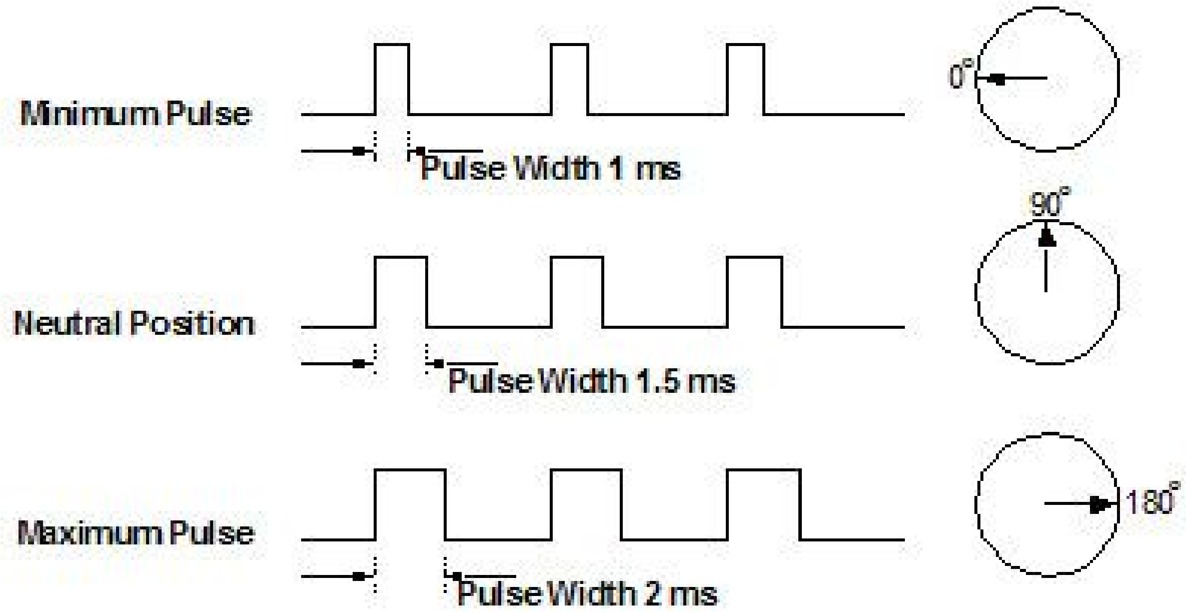
noun - sərvō -

An electrical motor with *integrated* positional feedback and control systems

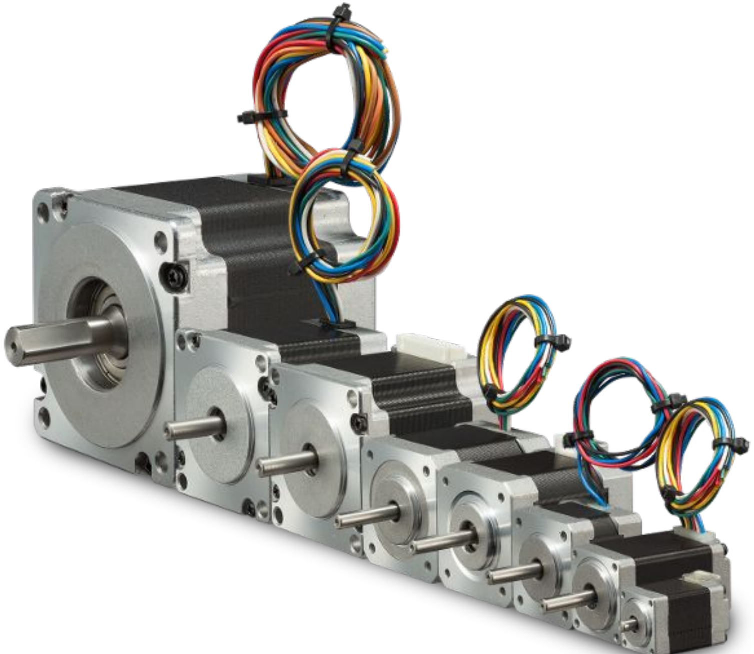
Hobby Servos

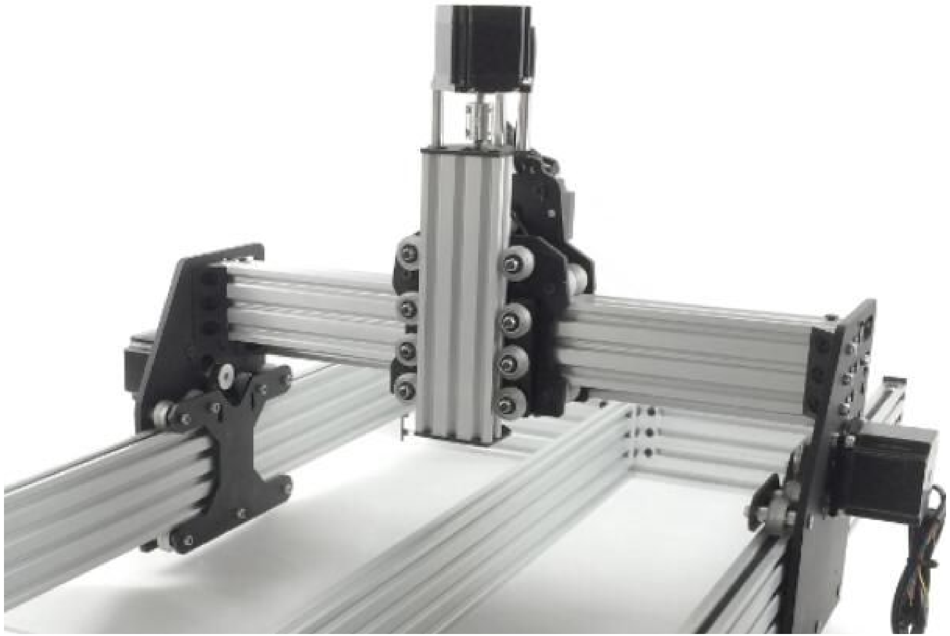
from Sparkfun

“Servo signal”



Stepper Motors





Stepper Motors

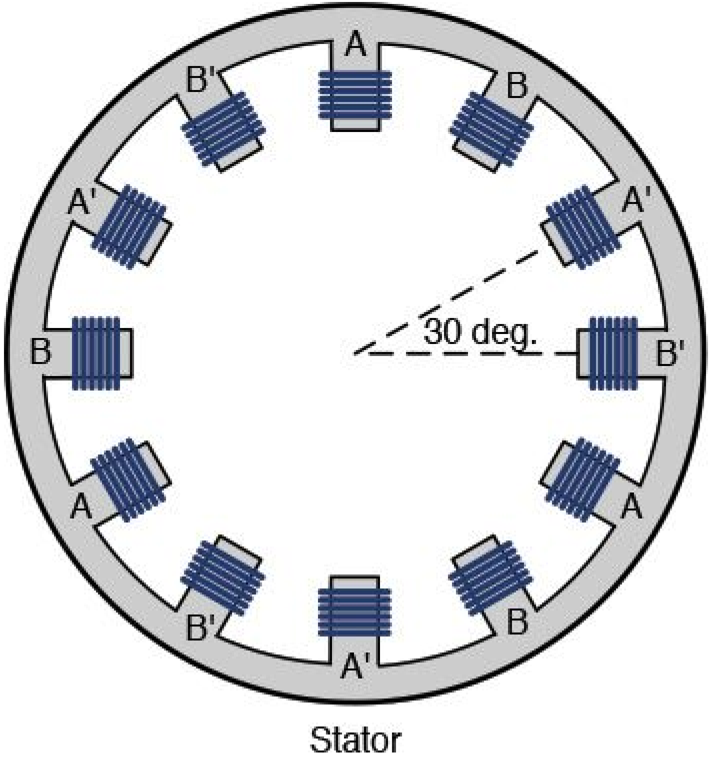
PROS

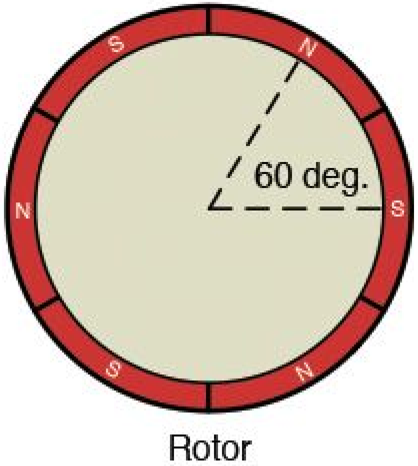
- Precision Movement Control
- Easy to control movement
- Cheap due to 3d printers

CONS

- “Holding” torque takes tons of current
- Not fast or as torquey to equivalent weighted motors
- “Dumb” without additional sensors still

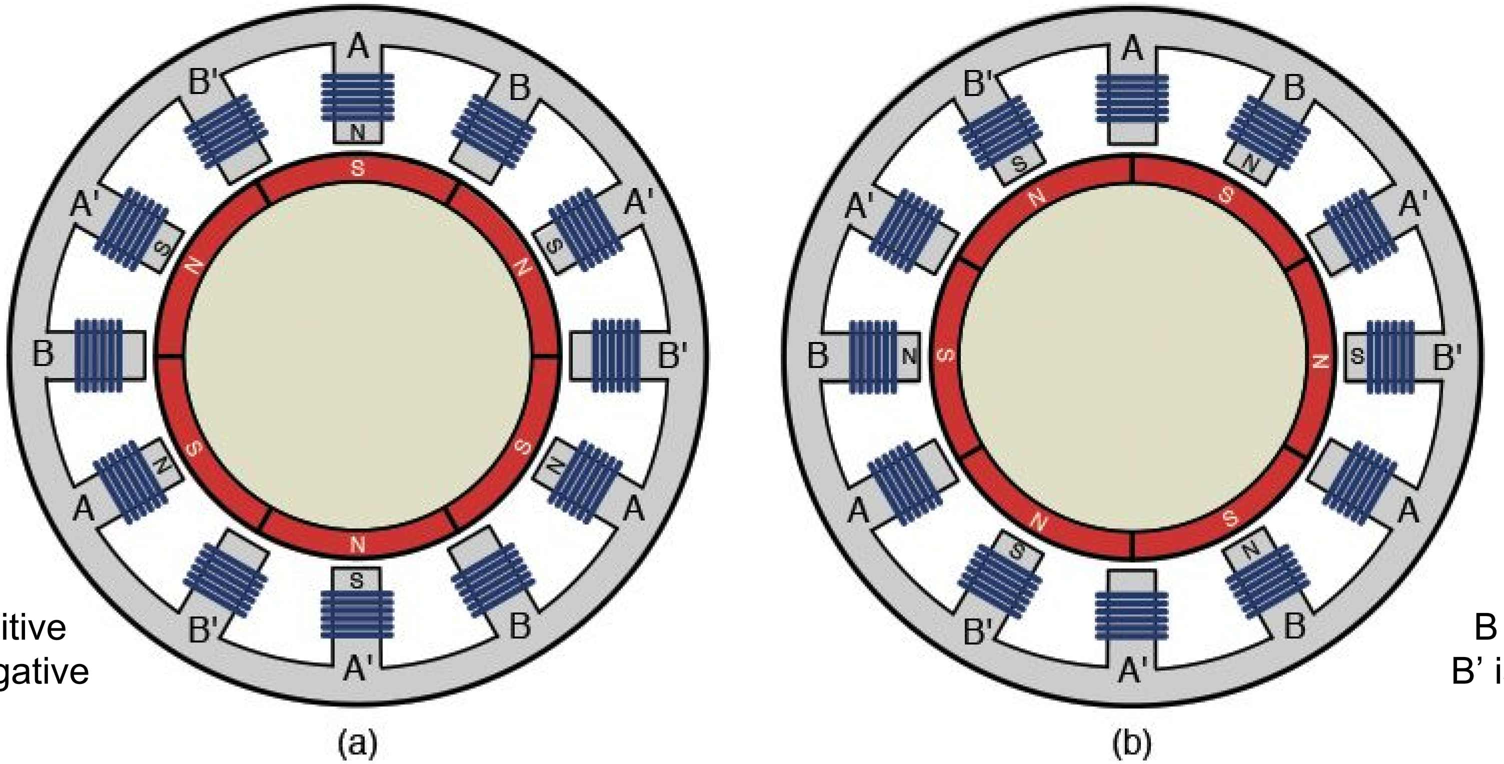
Stepper Motors - Structure





Motors for Makers

Stepper motors - “pulses” = “steps”



A is positive
A’ is negative

B is positive
B’ is negative

Stepper Motors - step types

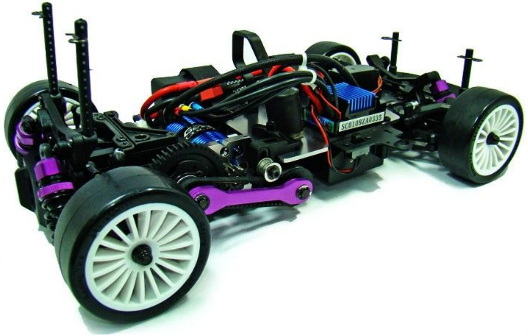
Full Step One Phase - what we just covered

Full Step Two Phase - both phases are on, motor goes *between* windings. Twice as much current, 30-40% more torque

Half Step - Alternates between one and two phase activations - *half the step angle*, 20% *less* torque

Microstep - Current is delivered in a sinusoidal wave, reducing step size to a tiny fraction of original. Smoothest possible motion. 30% torque reduction and slower

Brushless DC Motors - BLDC



Brushless DC Motors

PROS

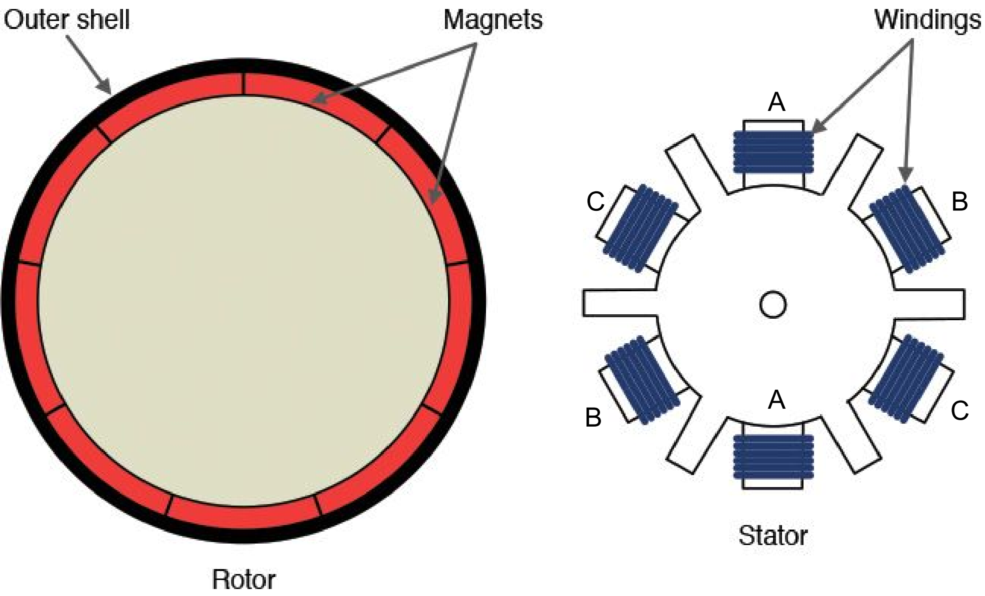
- High speed and high torque
- Far less maintenance / longer lifetime
- More efficient

CONS

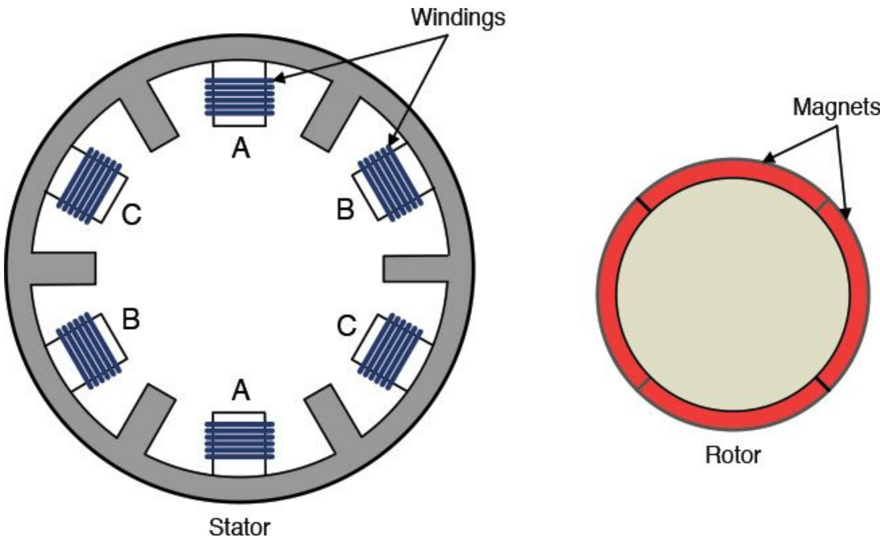
- More complex to control
- Higher price, though dropping

BLDC - structure

* Three phase motors



Outrunner BLDC



Inrunner BLDC

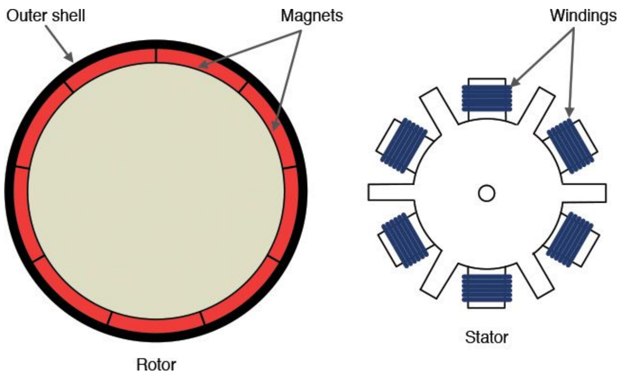
Motors for Makers

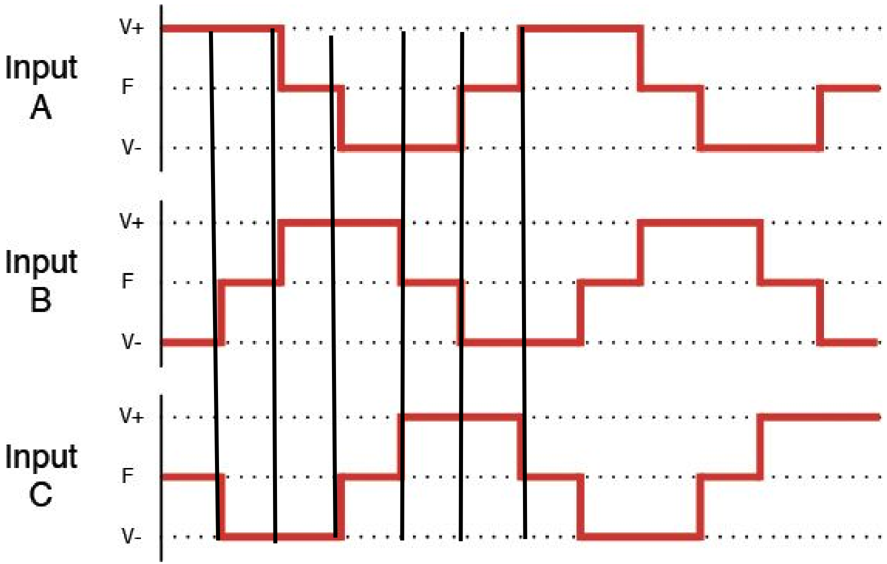
Inrunners vs Outrunners

Inrunners - *very* high speed - very low torque

Outrunners - *very* high torque, used in drones/remote control cars

BLDC - Controlling BLDCs

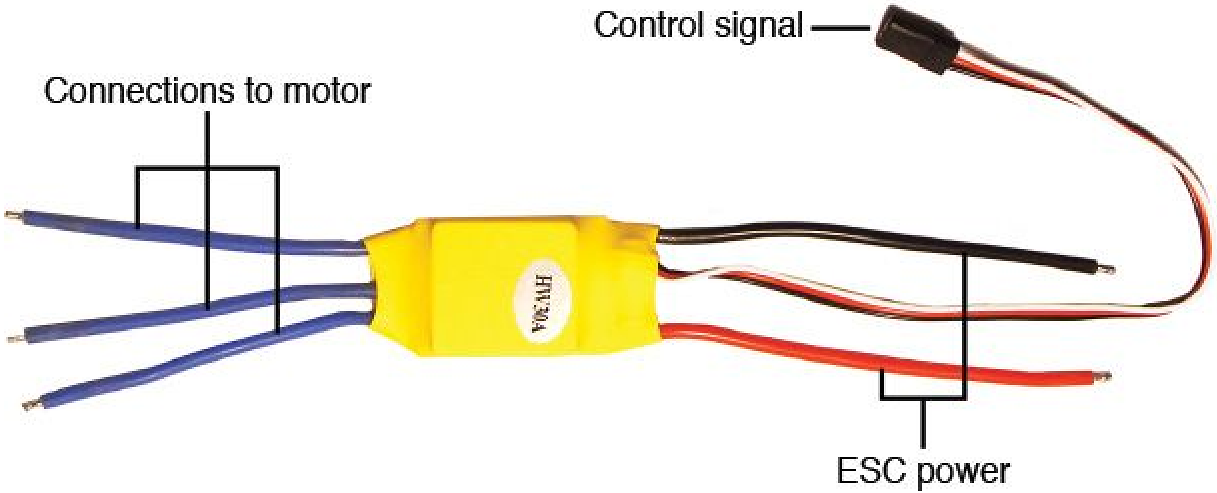




6 steps- 360 degrees
1 step - 60 degrees

Orientation of the motor matters for the phase

ESCs - Electronic Speed Controllers

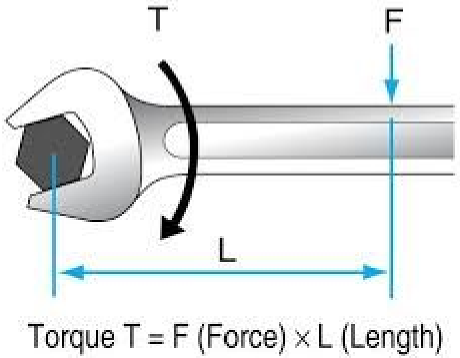


Programming ESCs

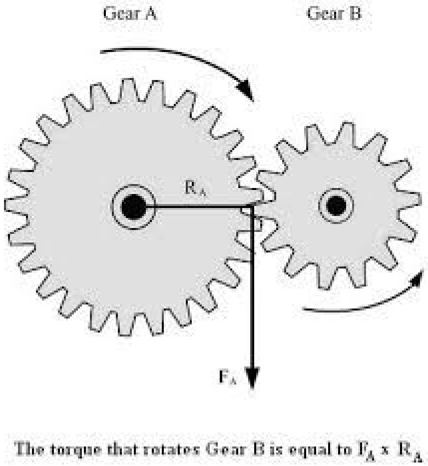
- Auto-cutoff
- Brake
- Battery type (*NiMH, LiPO, NiCd, LiFePO4*)
- Timing - how quickly pulsing to the BLDC occurs
- Acceleration
- Reverse
- Reverse Delay
- Current limiting

Torque

$$\tau$$

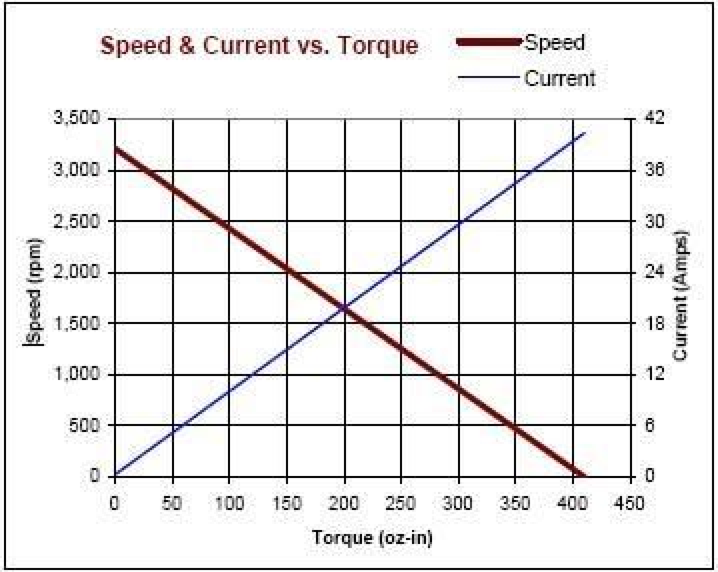


T
F
L
Torque T = F (Force) × L (Length)

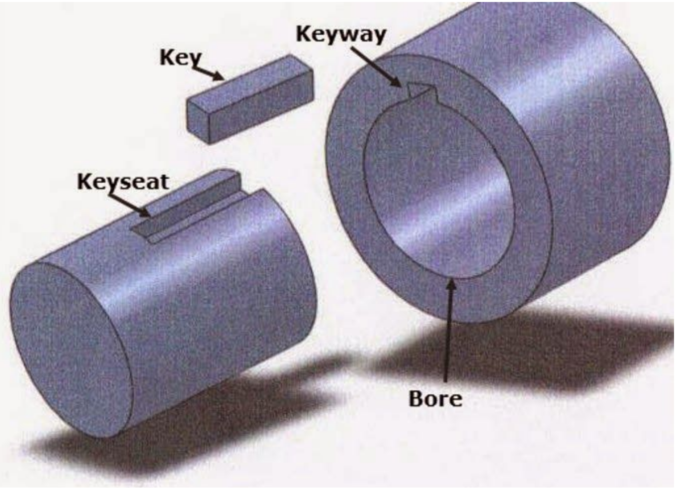


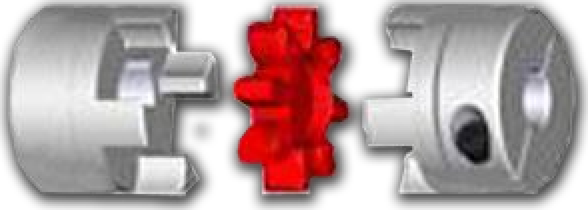
Gear A
Gear B
R_A
F_A
The torque that rotates Gear B is equal to F_A x R_A

Torque VS Current

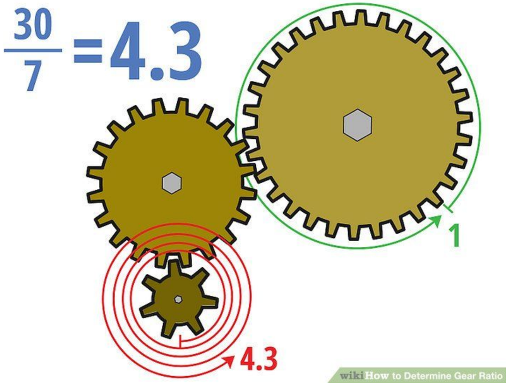


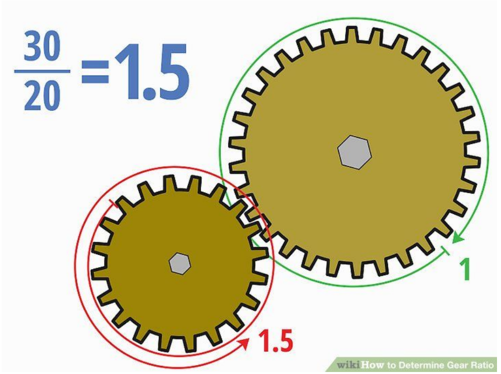
Shaft Connections

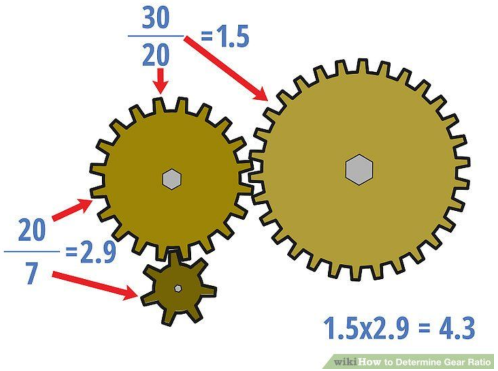




Gearing


30/7 =4.3
1
4.3
wikiHow to Determine Gear Ratio


30/20 =1.5
1
1.5
wikiHow to Determine Gear Ratio


30/20 =1.5
20/7 =2.9
1.5x2.9 = 4.3
wikiHow to Determine Gear Ratio

Challenge - let's specify a motor

- Robot + payload = 50 lbs
- I want to go up at least a 10 degree incline
- I want to go at least walking speed (3.1 mph)
- Accelerate to its speed within 2 seconds
- We'll use 10 inch wheels

WARNING

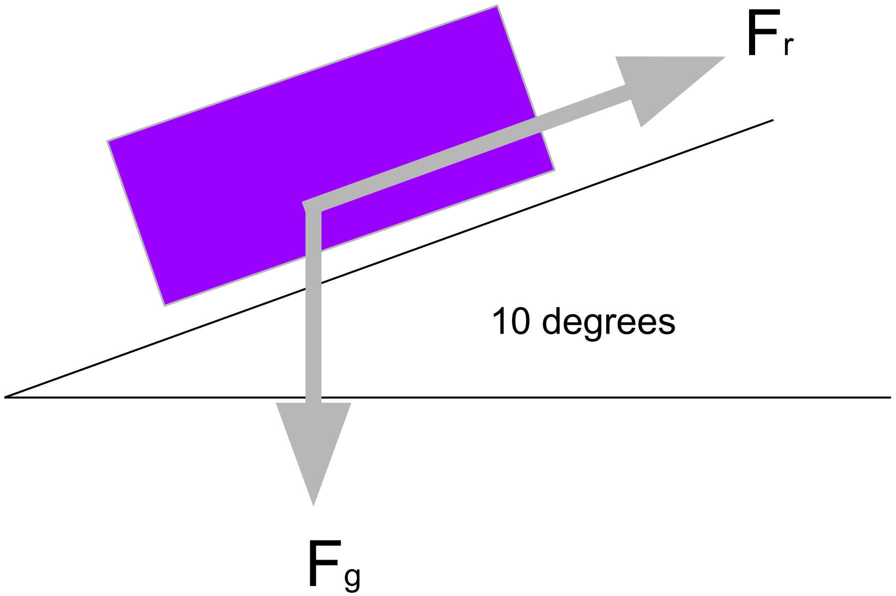
not overwhelming math ahead

The Formulas

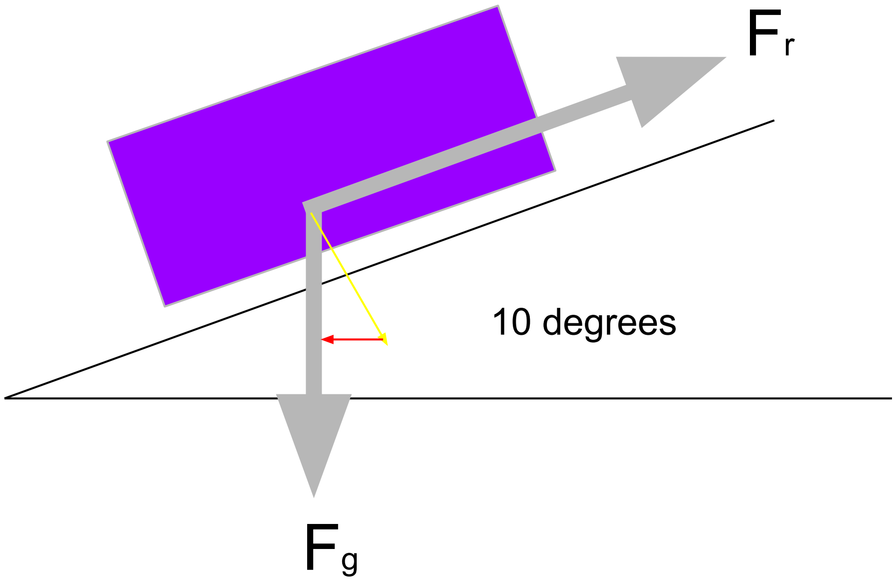
$P = I * V$ $T = F * r$ $v_f = a * t + v_0$

$P = T * \omega$ $F = m * a$ $g = 30.48 \ f/s^2$

Draw a Free Body Diagram



Forces happening



$F_{gy} = m * g * \cos(\Theta)$

$F_{gx} = m * g * \sin(\Theta)$

$F_r =$ Force from motor

We must overcome!

$F_{gx} = m * g * \sin(\Theta)$

$T = F_r * r$

$T/r = F_r$

$F_r - F_{gx} = F_{total}$

$(T/r) - m*g*\sin(\Theta) = m*a$

$T/r = m*a + m*g*\sin(\Theta)$

$T = m*(a+g*\sin(\Theta))*r$

Convert Requirements (trust me)

Freedom Units	**Sensible Metric Units**
50 lbs	22.680 kg
3.1 mph	1.38 m/s
Gravity	9.8 m/s²
10” wheels	0.254 meter wheels

He Did The Math

$$T = m*(a+g*sin(\Theta))*r$$

$v_f = a * t + v_0$
1.38 m/s = a * 2 + 0
1.38 m/s = 2 * a
a = 0.69 m/s²

T = 22.68 * (a + 9.8 * sin(10)) * 0.254

T = 22.68 * (0.69 + 9.8 * sin(10)) * 0.254

T = 22.68 * (0.69 + 1.702) * 0.254

T = 22.68 * 2.392 * 0.254

T = 13.80 Nm

13.80 / 2 = 6.89 Nm

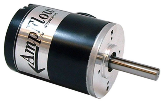
Torque conversions

kg/cm	70.26
oz/in	975.71
lb/ft	5.08

RPM to MPH with 10” wheels

100 rpm	2.98 MPH
250 rpm	7.45 MPH
500 rpm	14.88
1000 rpm	29.8 MPH

Motor Shopping

	http://www.andymark.com/CIM-Motor-p/am-0255.htm	$28	2655 rpm	172 oz-in
	http://www.andymark.com/product-p/am-pgseries.htm	$55	75 rpm	6335 oz-in
	http://www.andymark.com/NeveRest-p/am-neverest.htm	$28	105 rpm	593 oz-in
	http://www.robotmarketplace.com/products/0-pdx26.html	$85	900 rpm	2320 oz-in
	http://www.robotmarketplace.com/products/0-e30-150.html	$79	5600 rpm	710 oz-in

But what if we geared down...?

2655 rpm @ 10 inches = 79.8 mph!!!

Geared down 10:1:

265.5 rpm @ 10 inches = *7.9 mph*
...also giving us 1720 oz/in!

Wait a minute… what’s stall torque anyway?
… and no-load rpm?
… and efficiency?

Places to shop

- Andy Mark - http://www.andymark.com
- Robot Marketplace - http://www.robotmarketplace.com
- Robot Shop - http://www.robotshop.com
- Trossen Robotics - http://www.trossenrobotics.com
- Super Droid Robots - https://superdroidrobots.com

Questions?