Batteries and Actuators

Fast Robots, ECE4160/5160, MAE 4190/5190

E. Farrell Helbling, 2/6/25

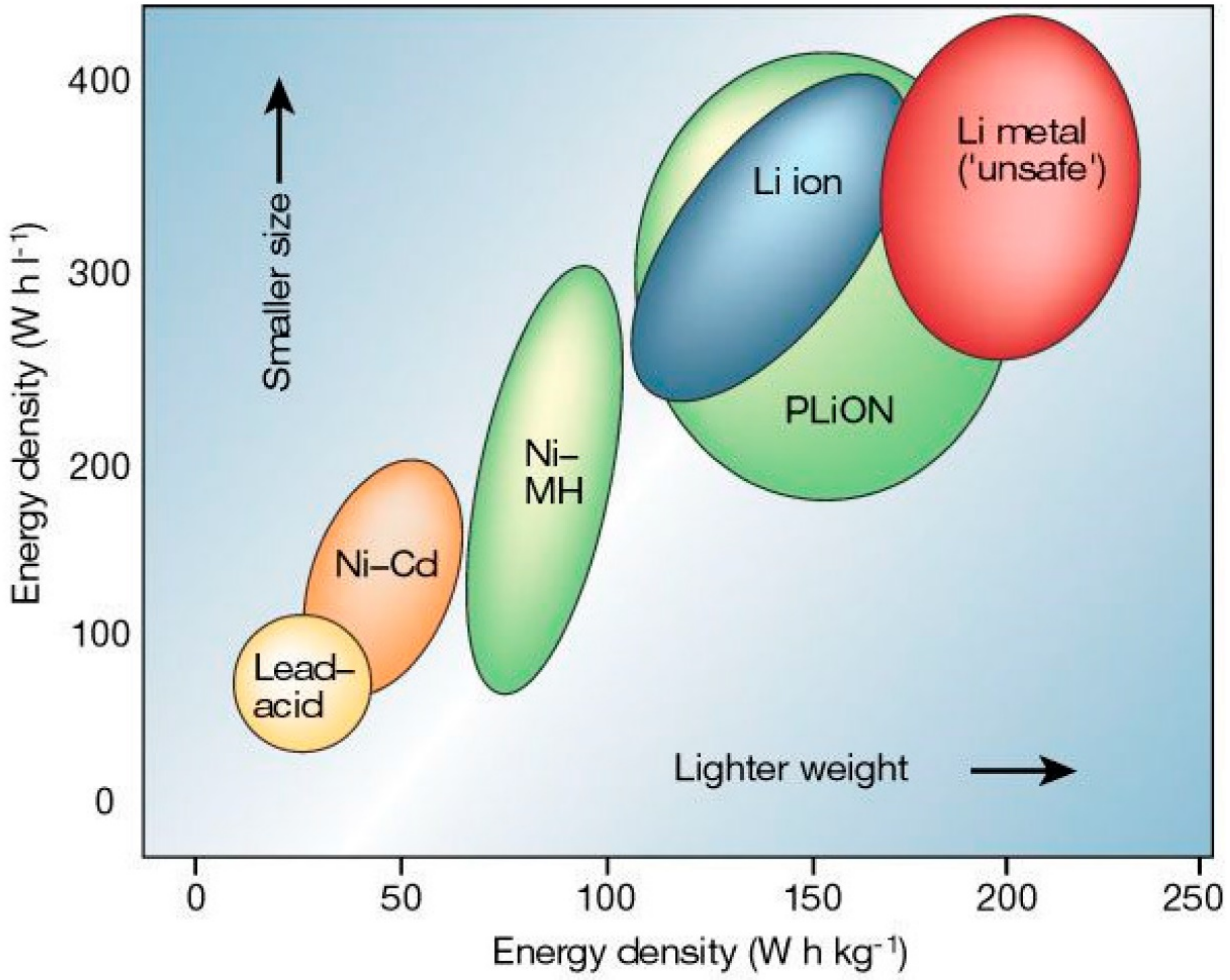
(Rechargeable) batteries

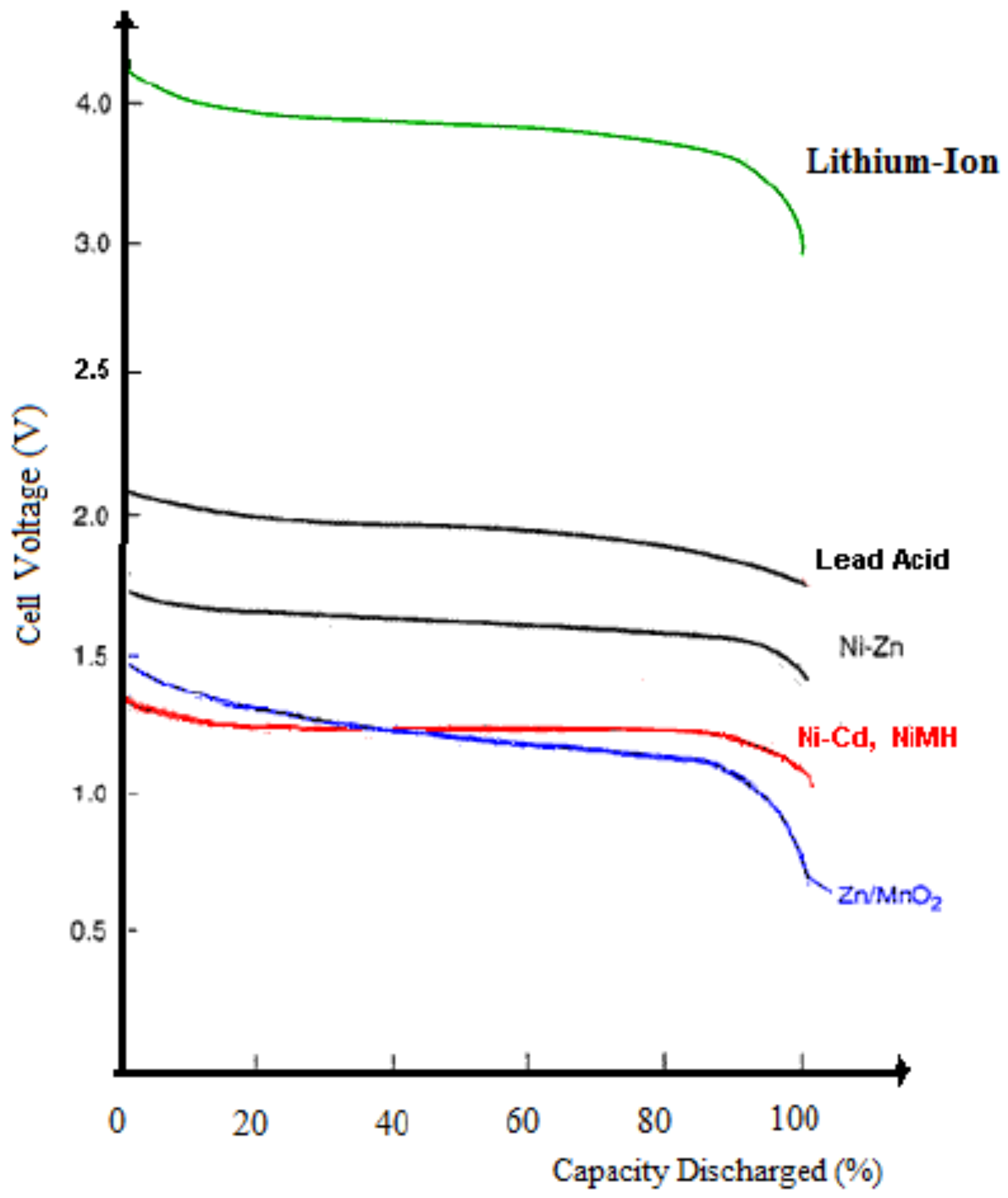
Important properties

What to look for when choosing a battery?

- Battery capacity
- Cell voltage
- Discharge curve
- Discharge rate (C)
- Charge rate
- Cycle times
- Aging/ “shelf life”
- Safety
- Environmental concerns
- Form factor/ weight
- Cost

MDPI, Energies

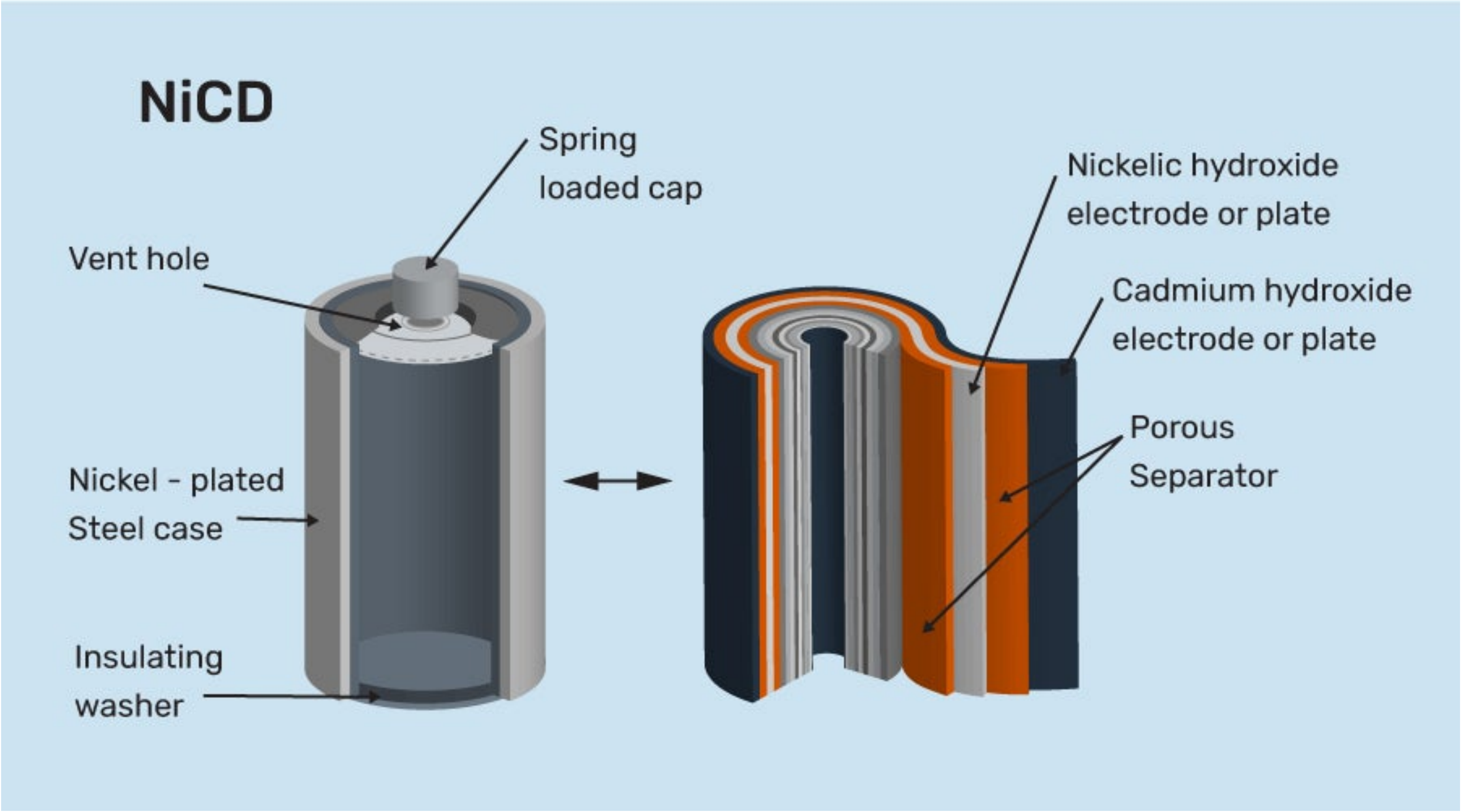




https://batteryuniversity.com/article/whats-the-best-battery

Rechargeable Batteries

- Lead Acid (SLA)
  - Cheap
  - Large power applications
  - Low energy density
- Nickel Cadmium (NiCd)
  - Mature tech, affordable
  - Fairly low in energy density
  - High discharge rate
  - Long cycle life
  - Better in rigorous working conditions
  - Periodic full discharge/ charge is critical
  - Contains toxic metals
- Nickel-metal Hydride (NiMH)
  - Higher capacity/ energy density than NiCd
  - Medium discarge rate
  - More robust
  - Reduced cycle life
  - No toxic metals
  - More expensive than NiCd

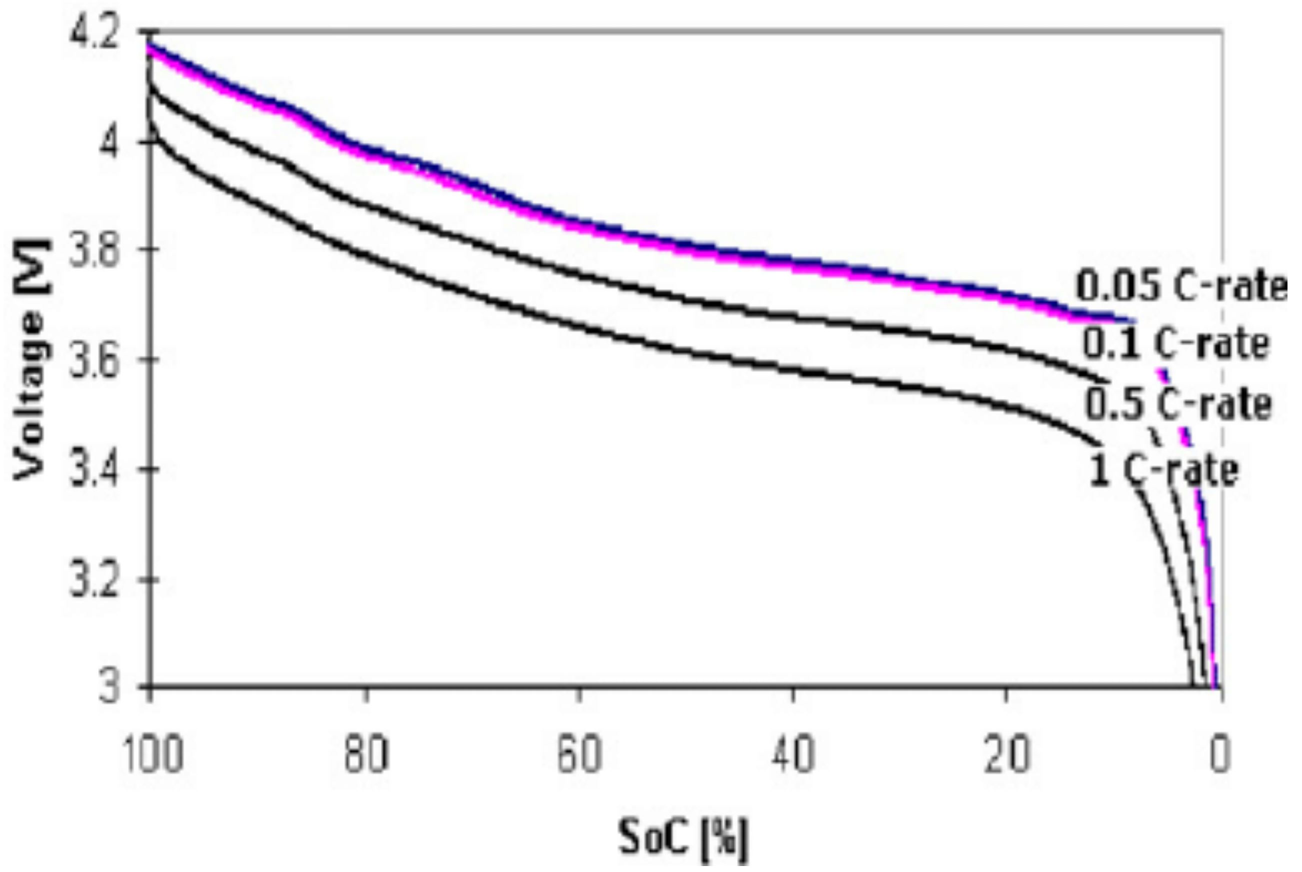


https://batteryuniversity.com/article/whats-the-best-battery

Rechargeable Batteries

- Lithium Ion (li-ion)
  - High energy density
  - Lightweight
  - Low-maintenance battery
  - Low self-discharge
  - Max discharge rate: 1-2C
  - High cell voltage (single cell batteries)
  - Form factor: prismatic and cylindrical
  - Protection circuits for charge/ discharge
  - Aging, safety concerns
- Lithium Polymer (li-po)
  - Lightweight
  - Free form-factor
  - Less safety concerns (dry/gel electrolyte)
  - Max discharge rate: 3-60C
  - Lower energy density than Li-ion
  - Costs more than Li-ion

What is this?



https://batteryuniversity.com/article/whats-the-best-battery

Lithium and Cobalt

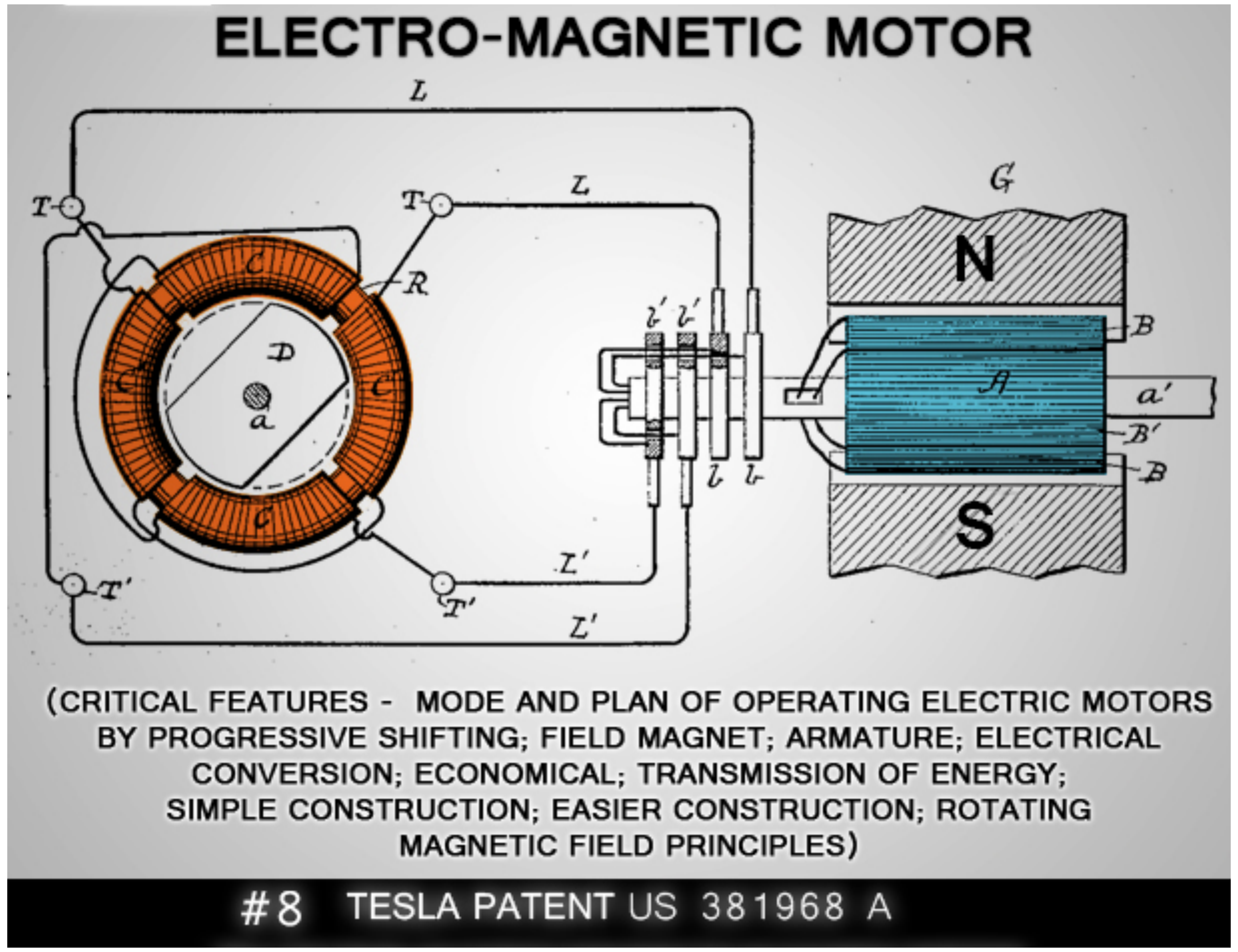
- Lithium is an extremely important commodity
  - Renewable energy storage, EVs, batteries
  - 80% is mined in Australia, Chile, and China
  - China controls ~50% of processing and refining
  - US mines and processes 1% (environmental concerns)
- Cobalt is used for the electrolytes
  - 70% of the world's Cobalt comes from the DRC
  - China has the largest footprint in critical minerals and infrastructure in Africa

Cobalt electrolytic and 1cm3 cube

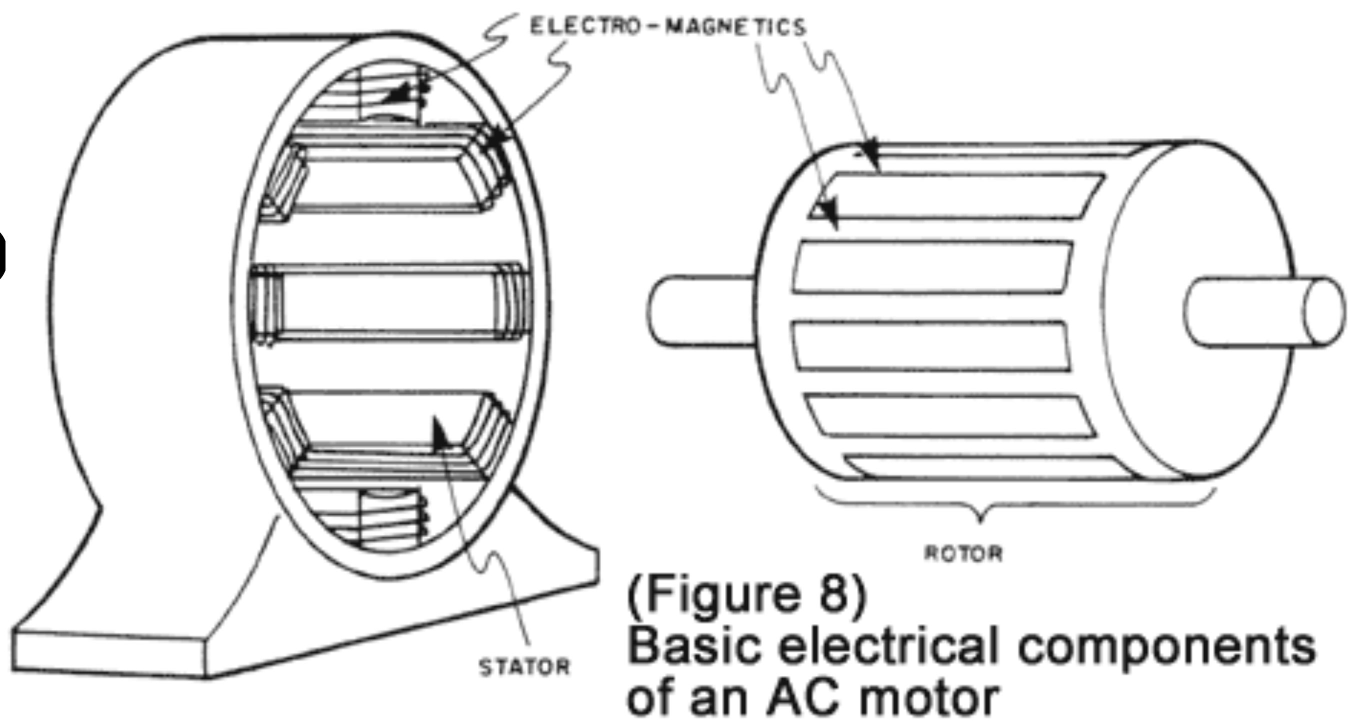
Electric motors

AC Motors

- High power/ torque
- Access to a mains/wall outlet
- Synchronous AC motors
  - Rotor turns as fast as the magnetic field fluctuates
- Asynchronous AC motors/ induction motors
  - Rotor turns slower than the field
  - Coil, frequency, and load dependent
- Simple, low cost, long lasting
- You'll need a variable frequency drive to change speed



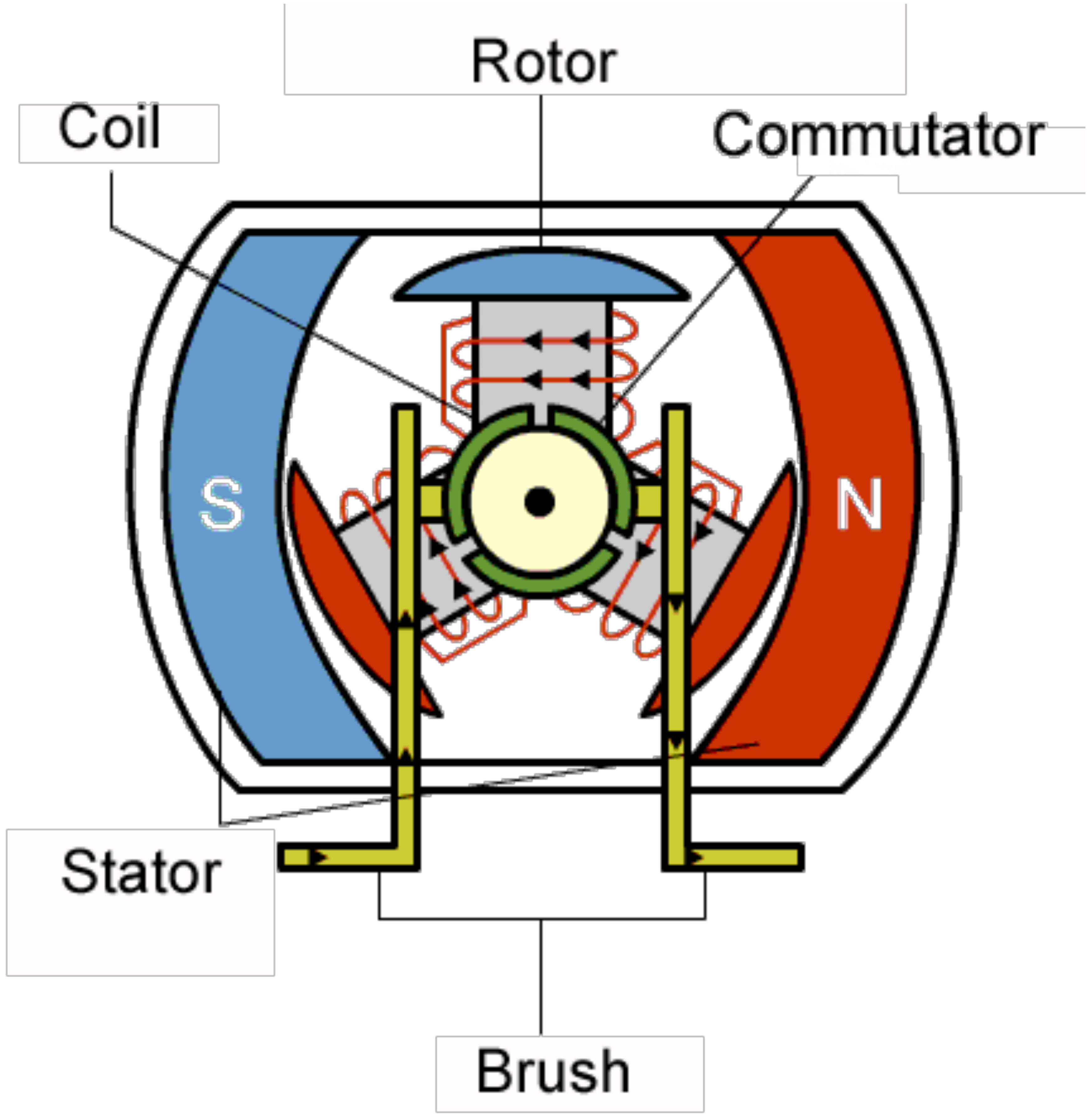
https://www.explainthatstuff.com/induction-motors.html



(Figure 8)
Basic electrical components of an AC motor

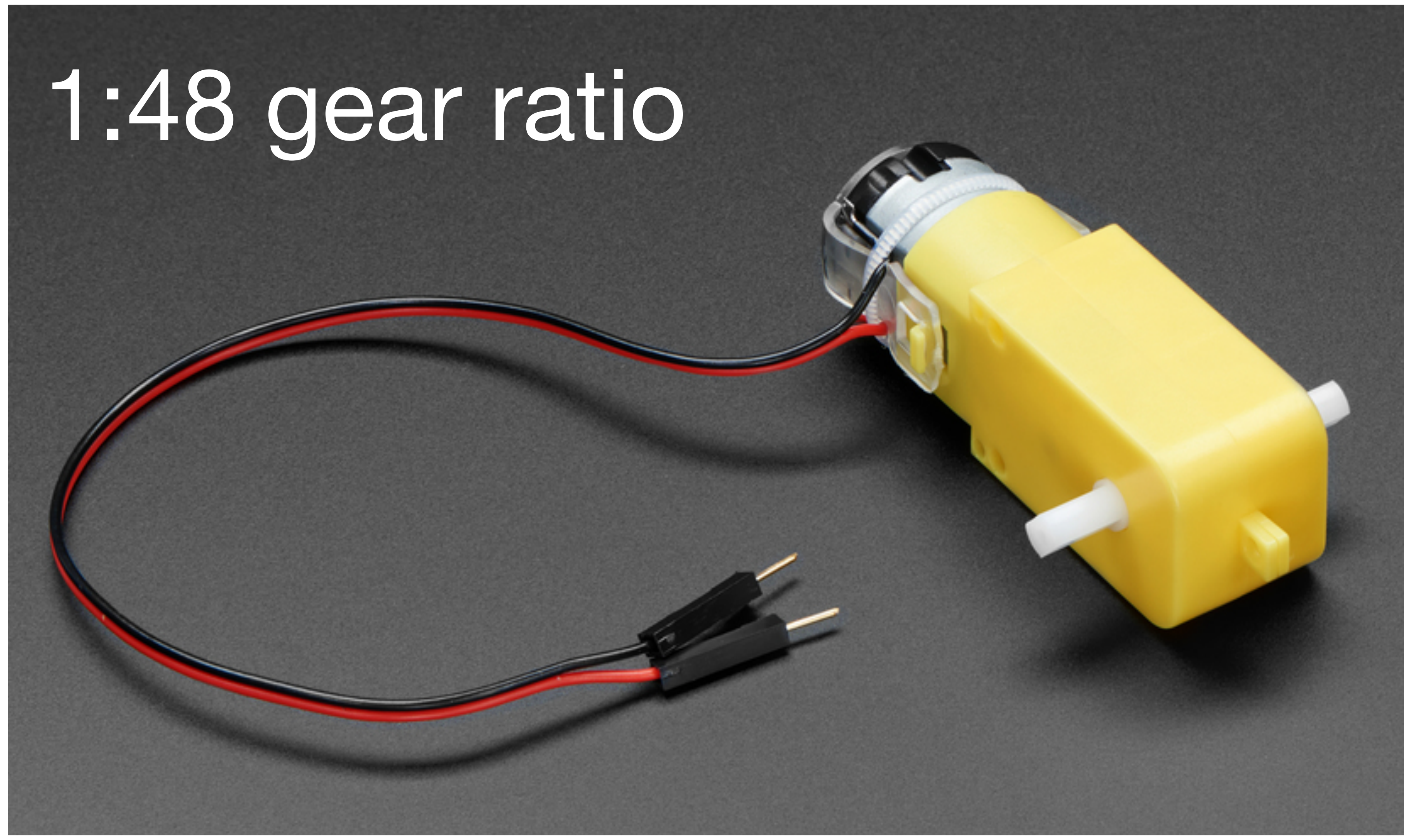
Brushed DC motor

- Brushes conduct current from source to armature
- Most commonly permanent magnet DC motors (PMDC)
- Pros
  - Inexpensive
  - Easy speed control (DC voltage)
  - Lightweight
  - Reasonably efficient
  - Great for low power, low form factor apps
- Cons
  - Mechanical wear
  - Electrical noise
  - Gearing is often needed

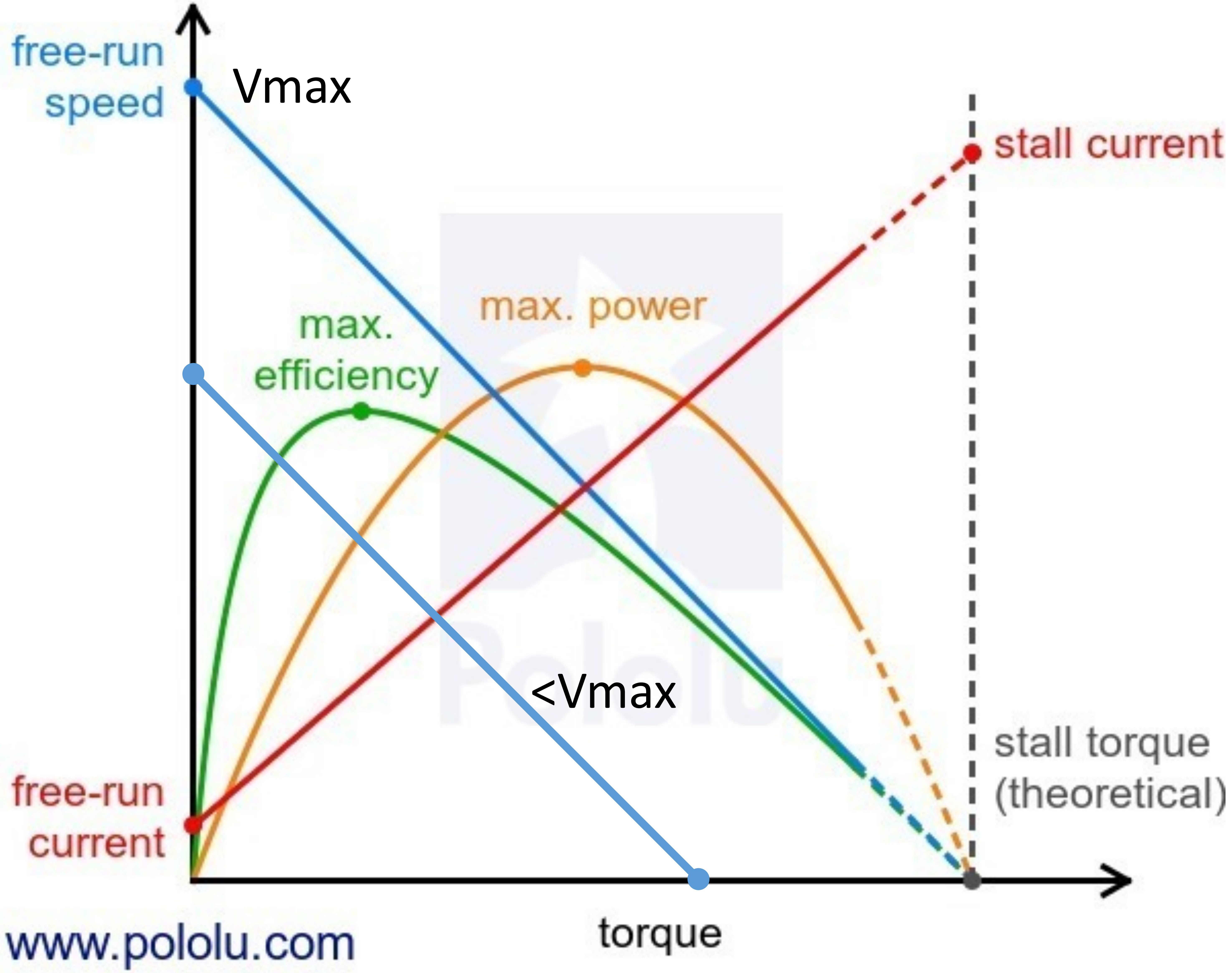


Brushed DC motor

Power = Torque x speed

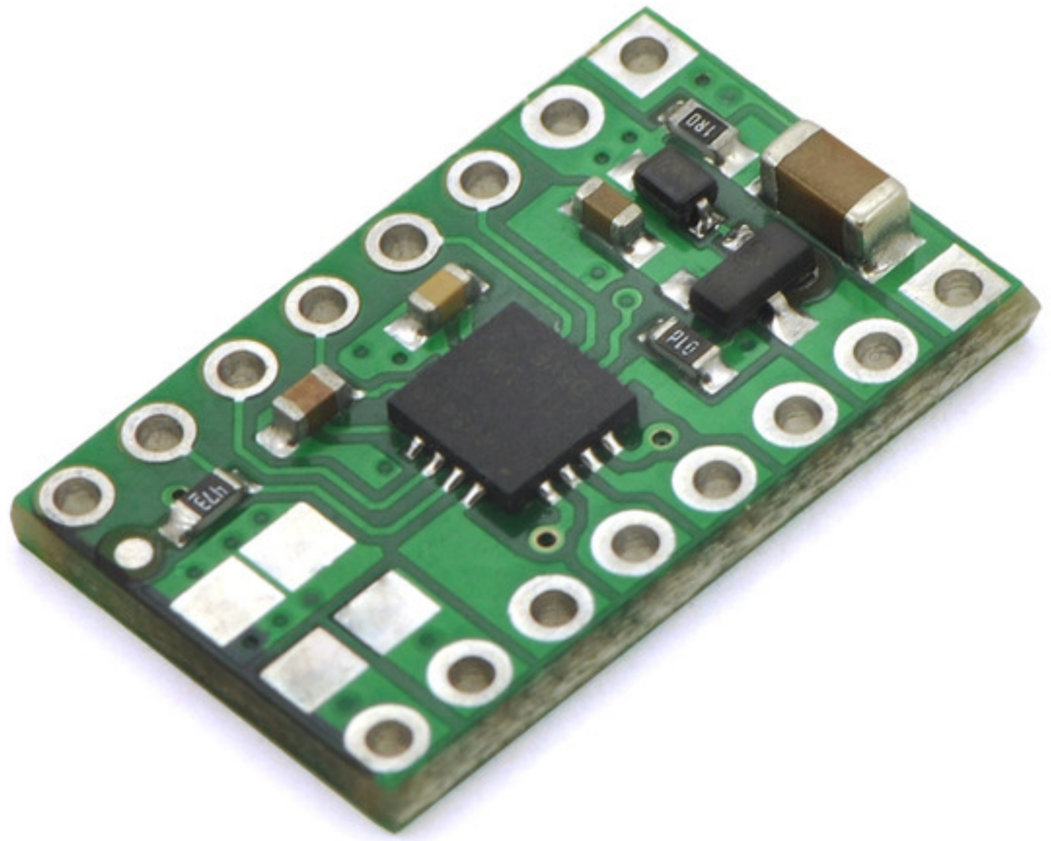


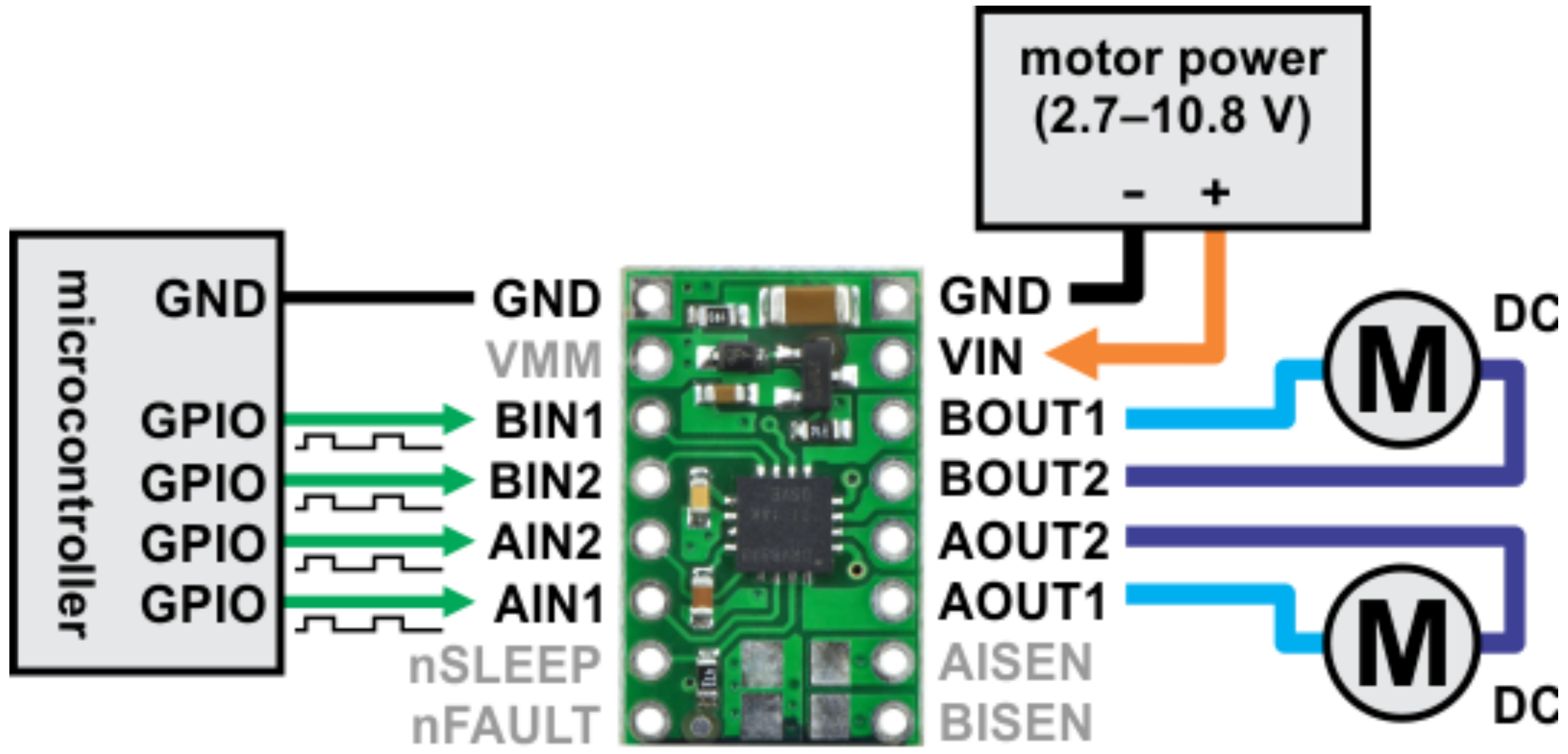
3VDC	0kgcm	150mA	120RPM
3VDC	0.4kgcm	1.1A	0RPM
6VDC	0kgcm	160mA	250RPM
6VDC	0.8kgcm	1.5A	0RPM



Brushed DC motor controllers

DRV8833 Dual Motor Driver Carrier





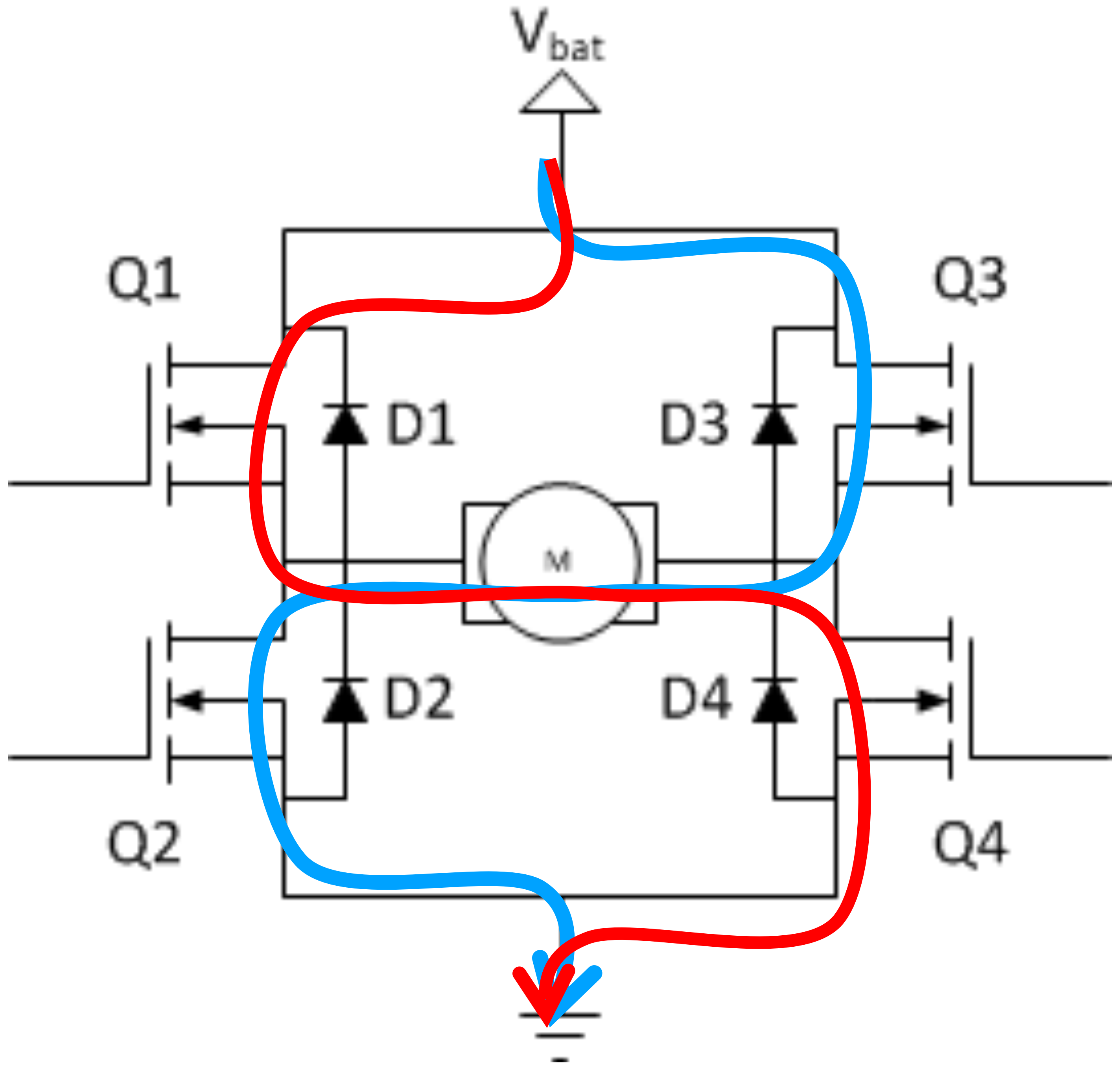


Table 1. H-Bridge Logic

xIN1	xIN2	xOUT1	xOUT2	FUNCTION
0	0	Z	Z	Coast/fast decay
0	1	L	H	Reverse
1	0	H	L	Forward
1	1	L	L	Brake/slow decay

https://www.pololu.com/product-info-merged/2130

Brushed DC motor controllers

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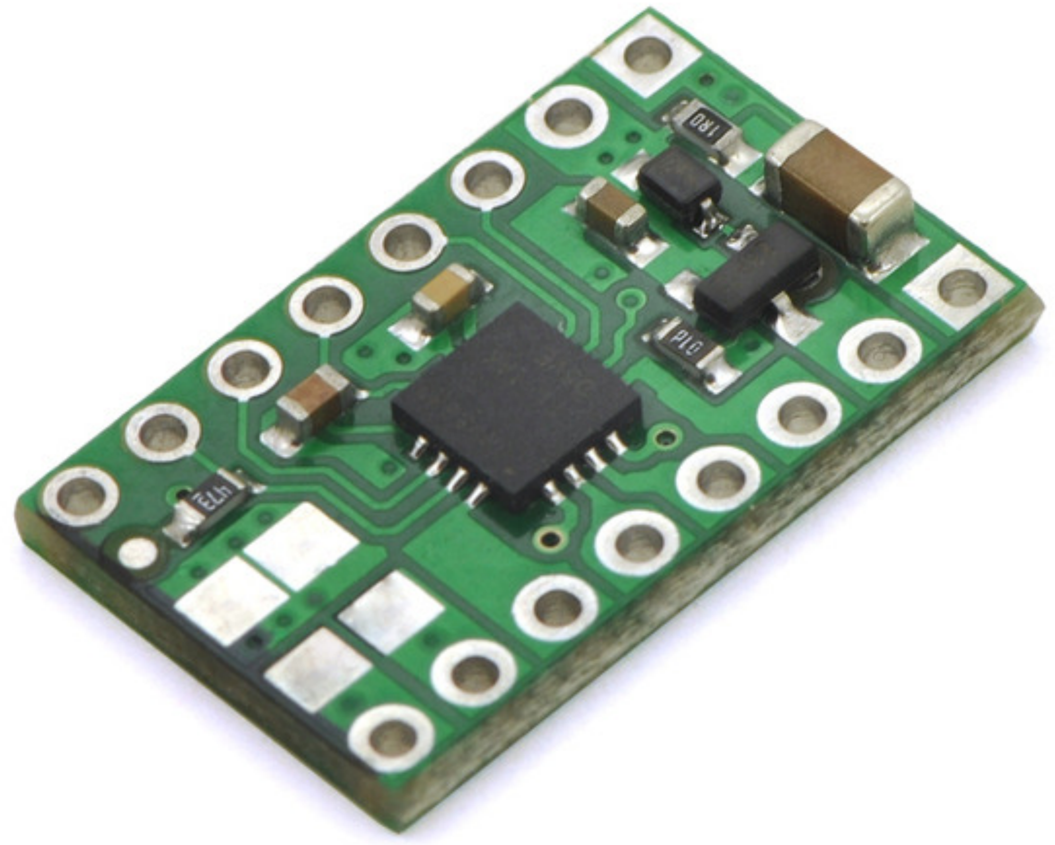

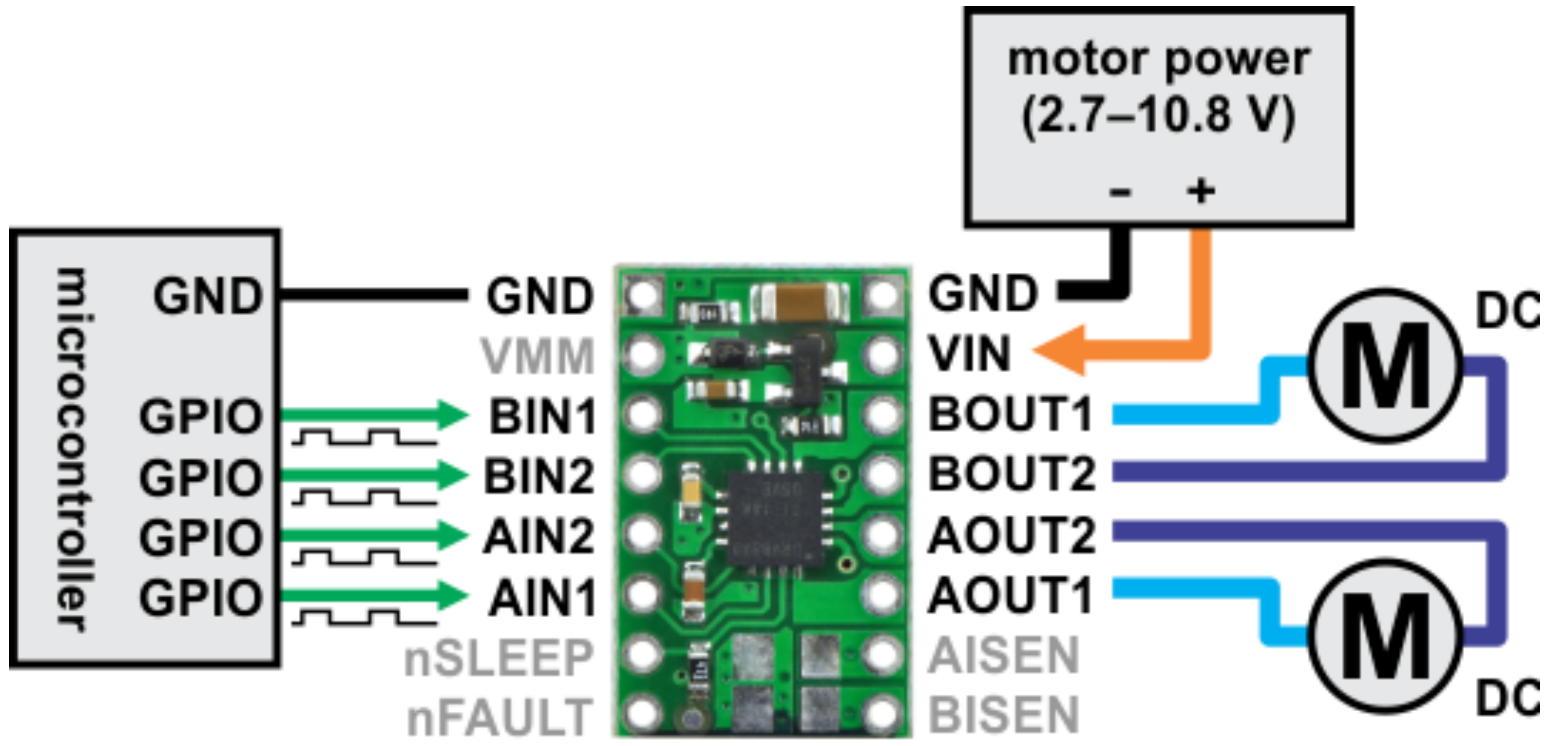

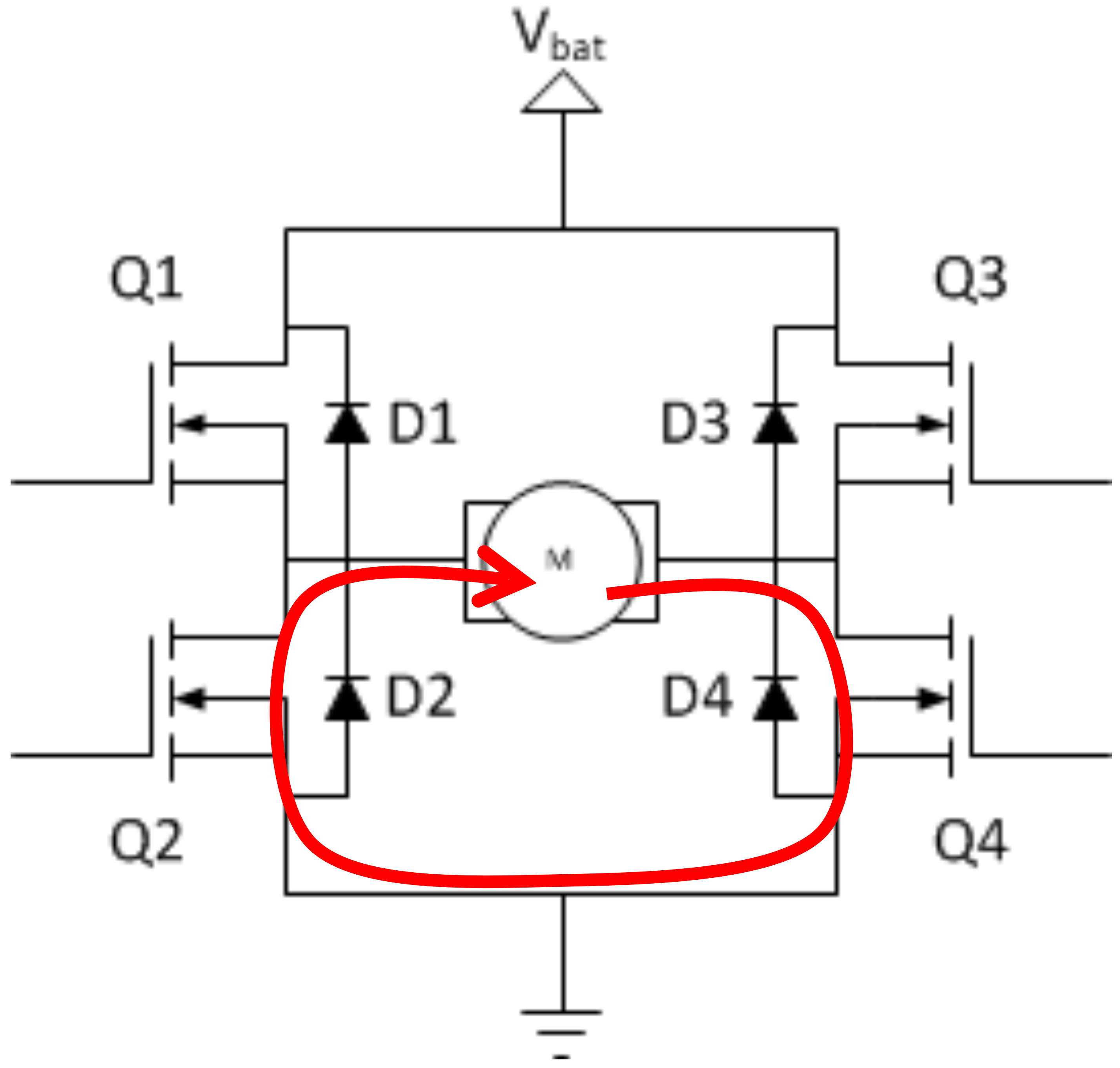

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Brushed DC motor controllers

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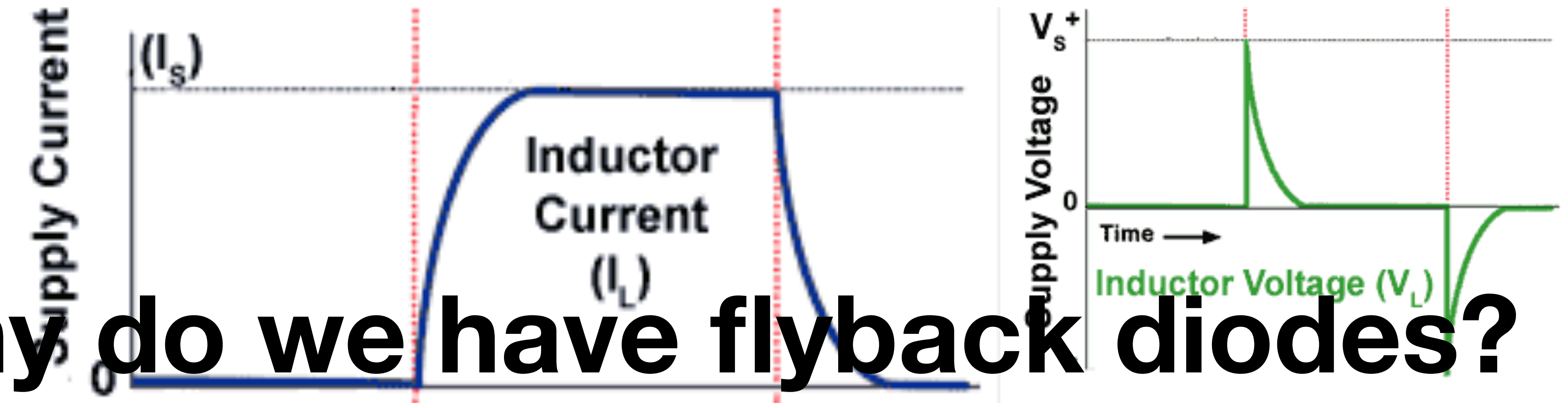
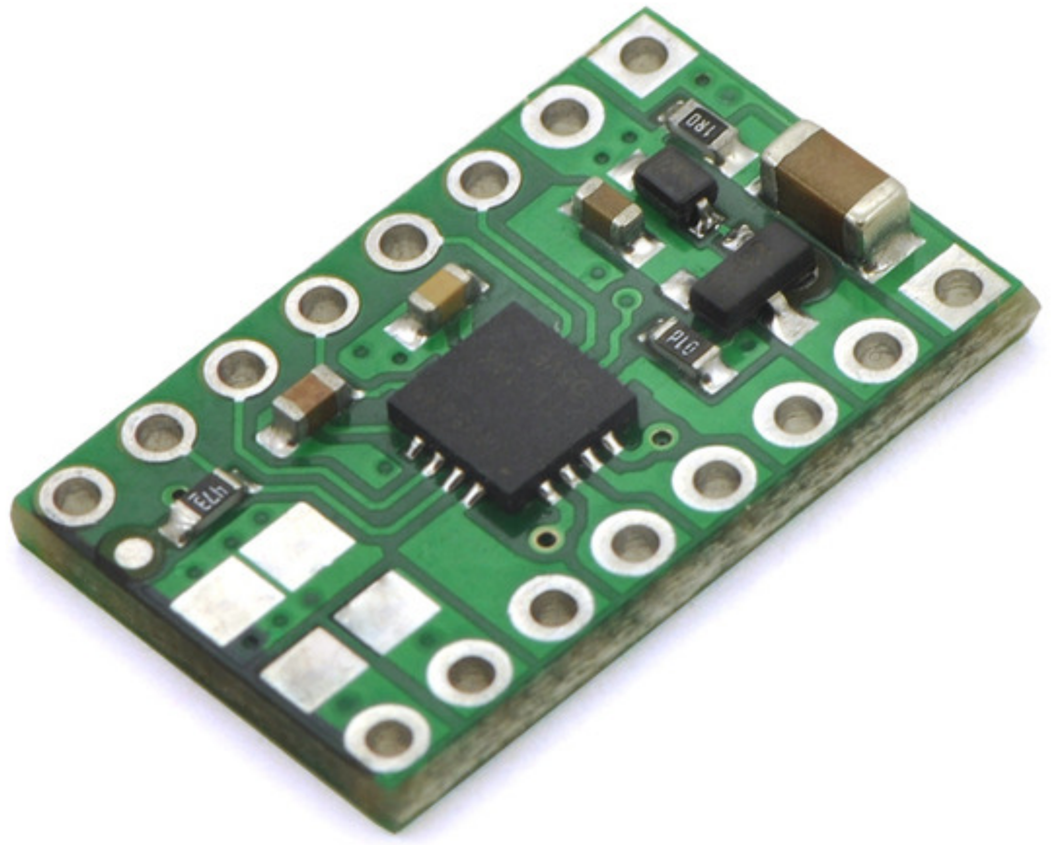
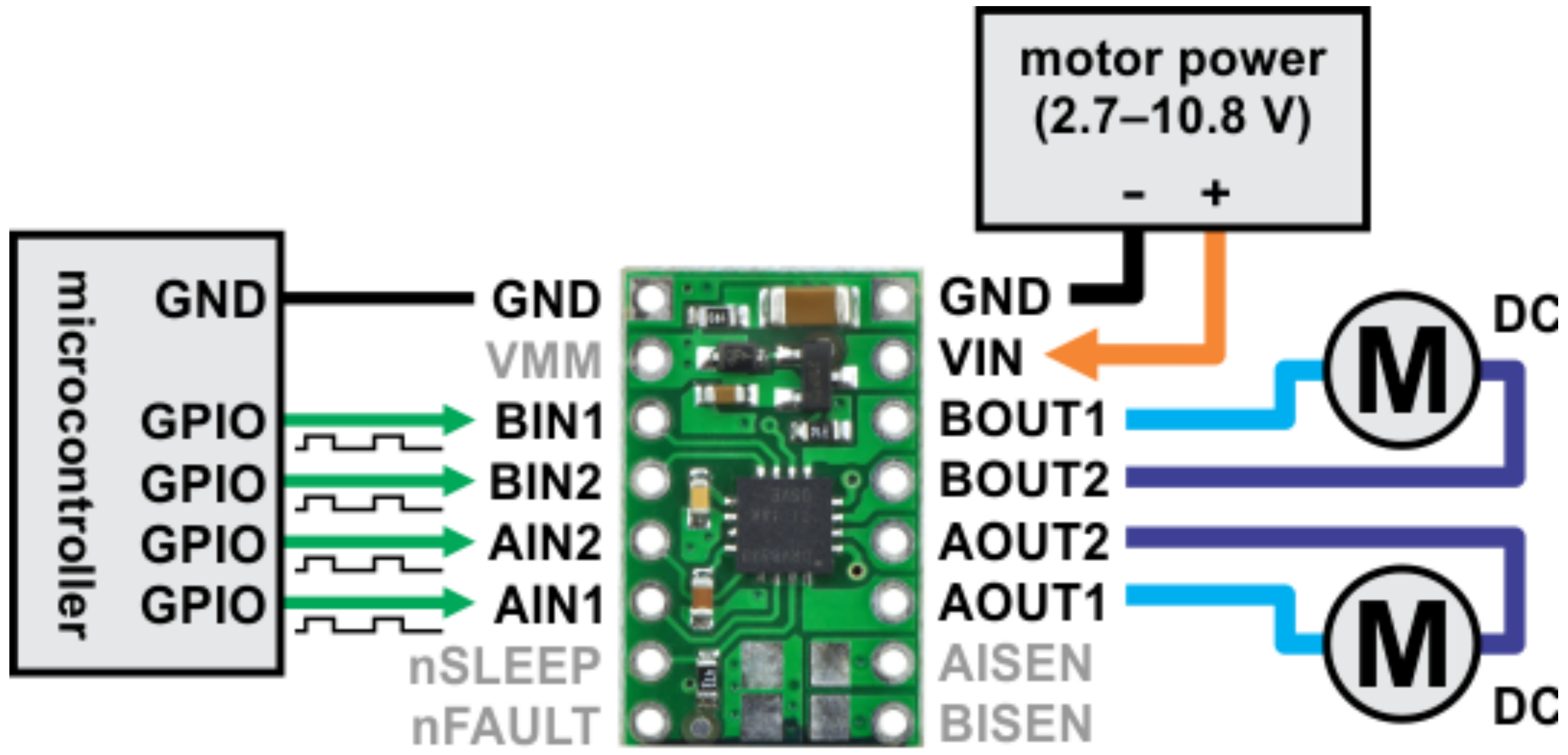
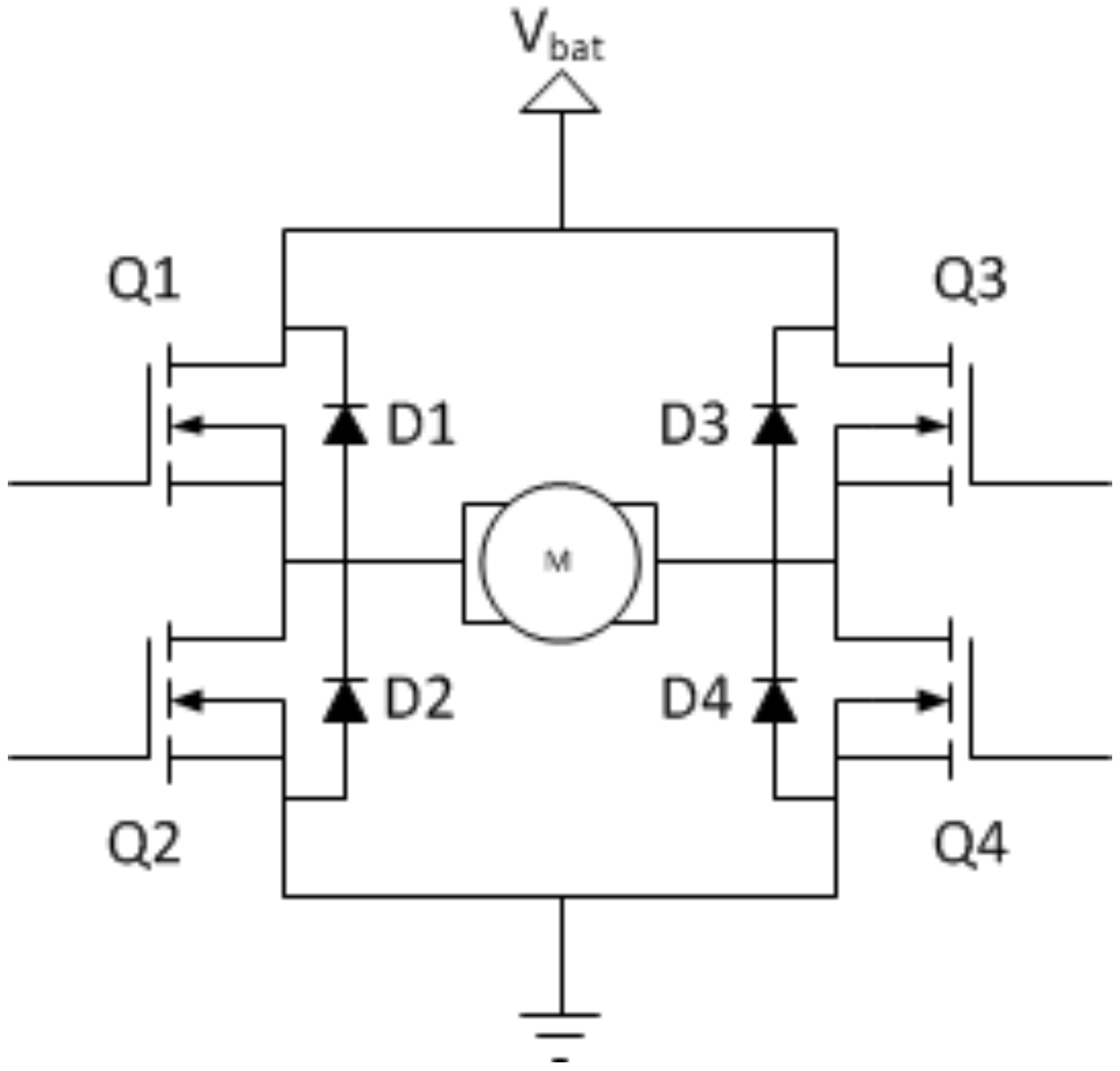


Why do we have flyback diodes?







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Brushed DC motor controllers

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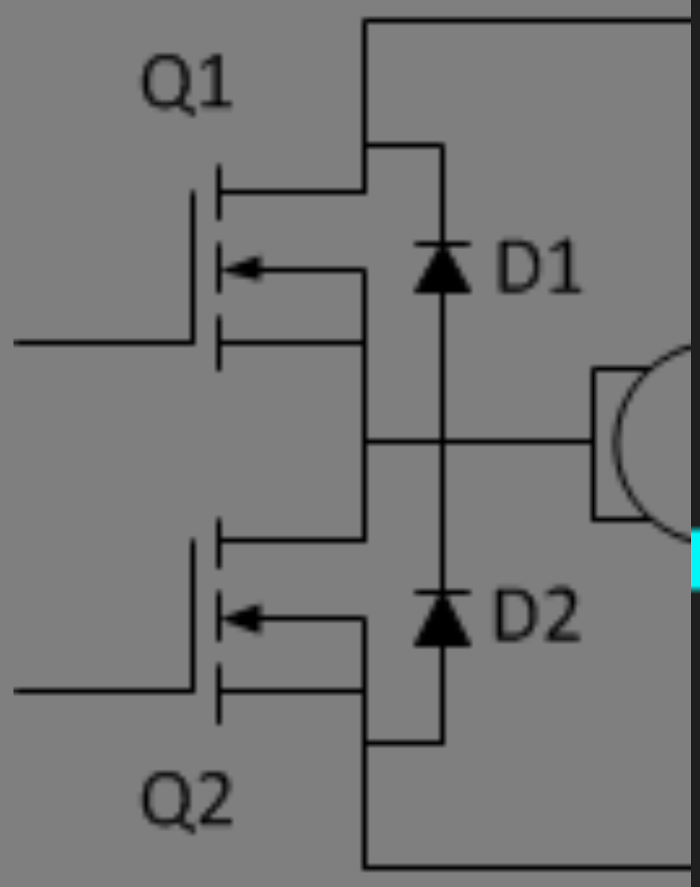
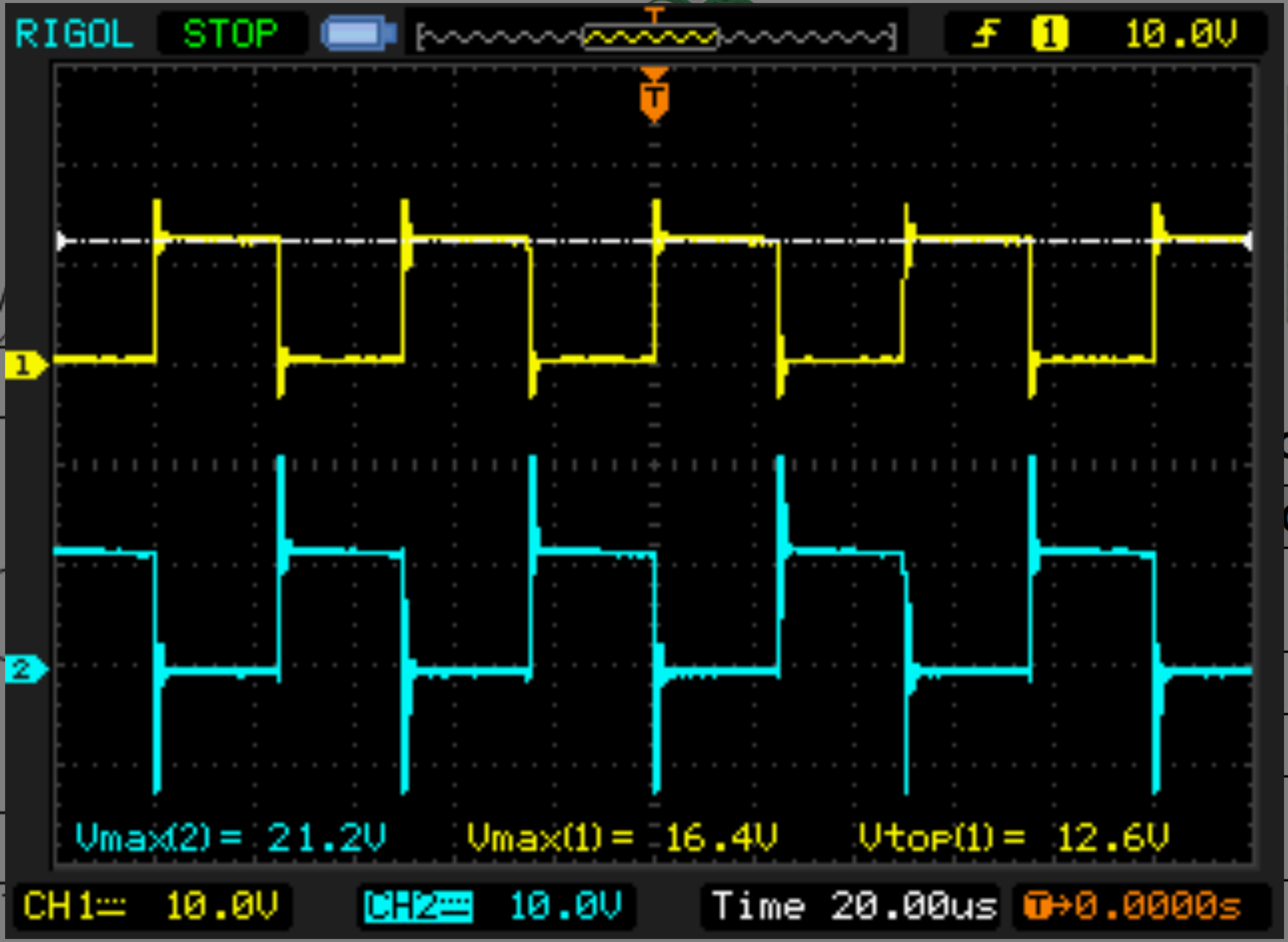
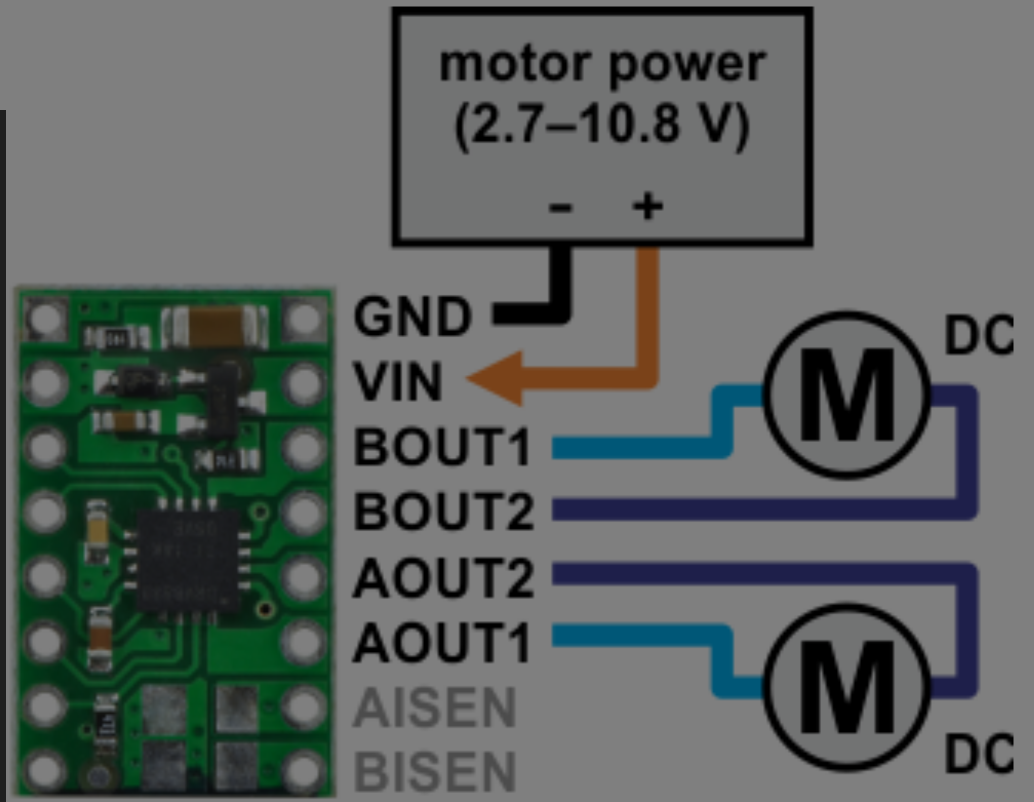






ogic

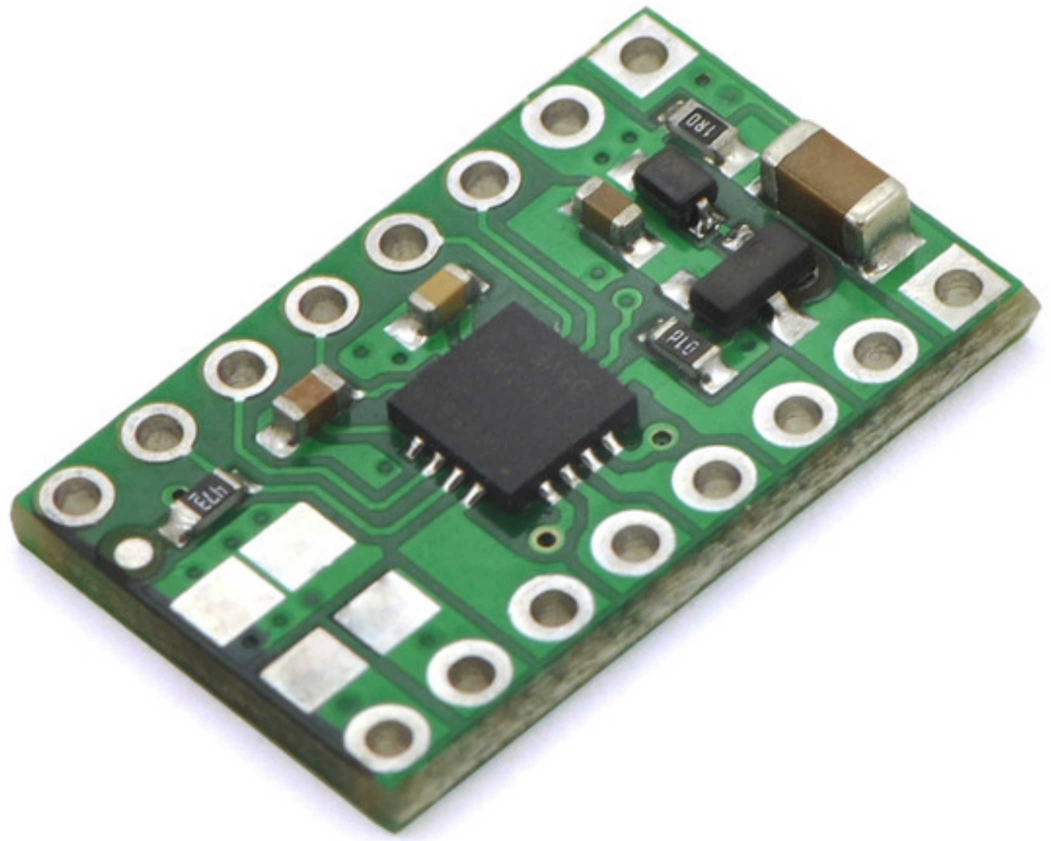
OUT2	FUNCTION
Z	Coast/fast decay
H	Reverse
L	Forward
L	Brake/slow decay

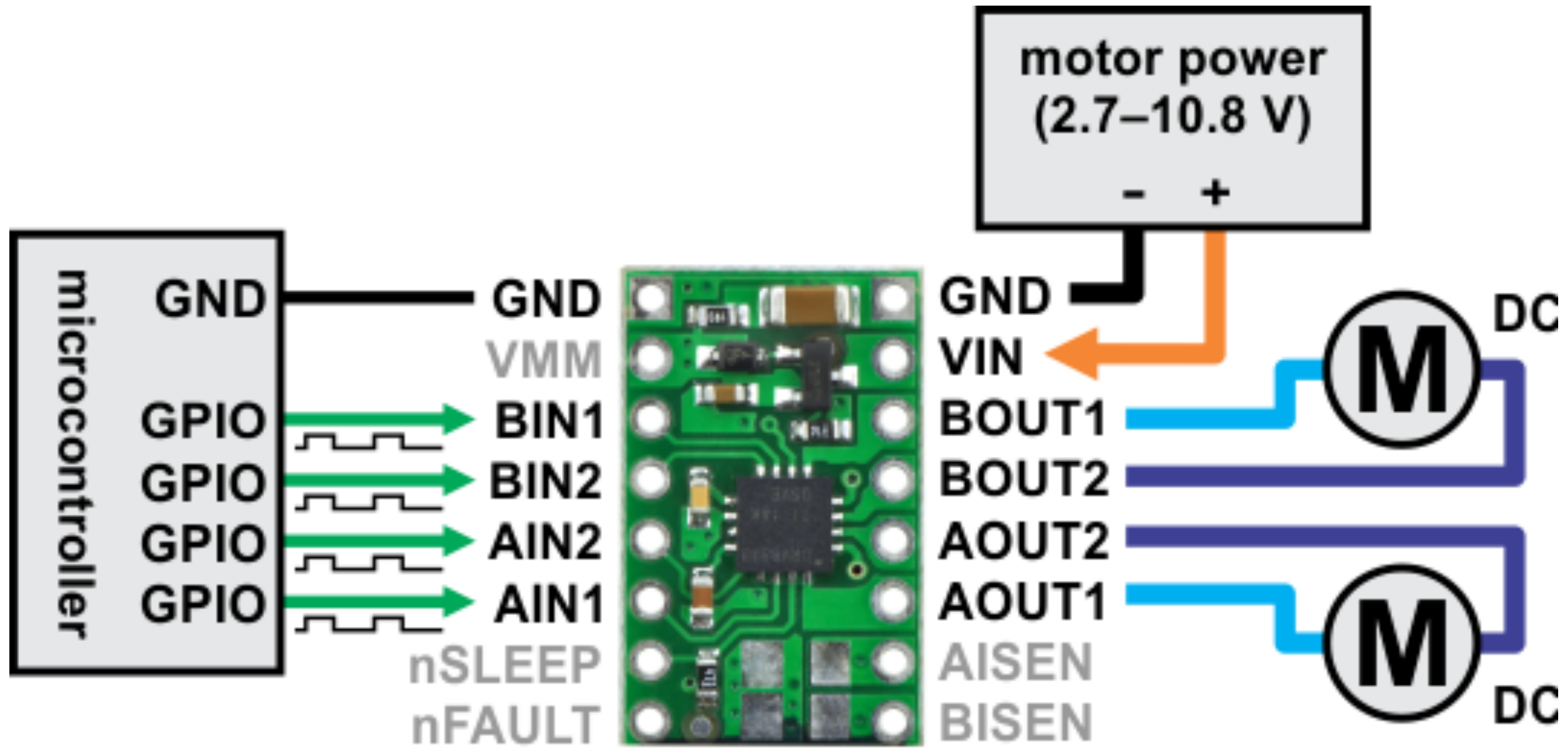
https://www.pololu.com/product-info-merged/2130

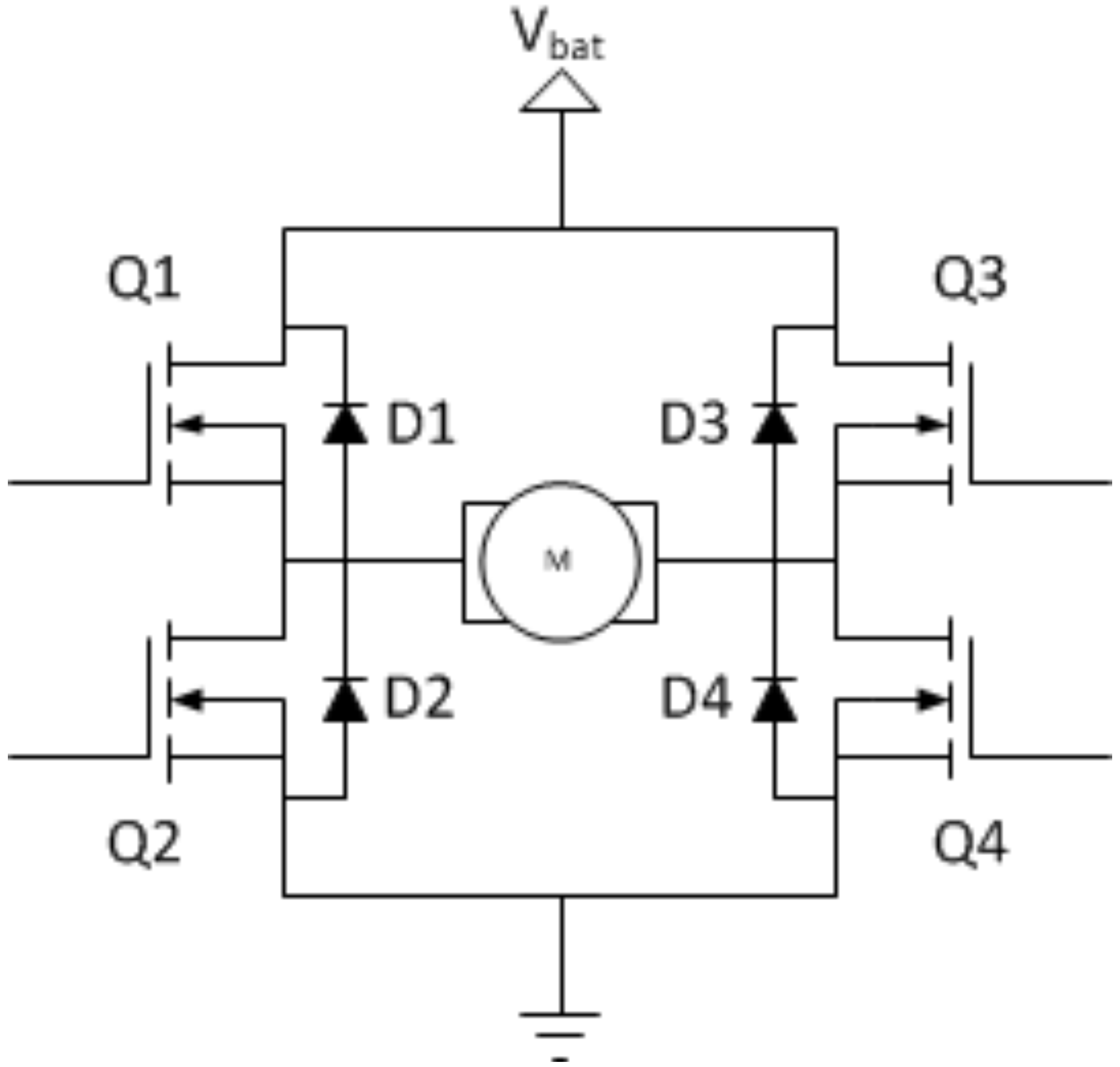
Brushed DC motor controllers

DRV8833 Dual Motor Driver Carrier

- VIN = 2.7-10.8V
- 3V compatible inputs
- Icon = 1.2A (per channel)
- Ipeak = 2A (per channel)
- Parallel couple two!







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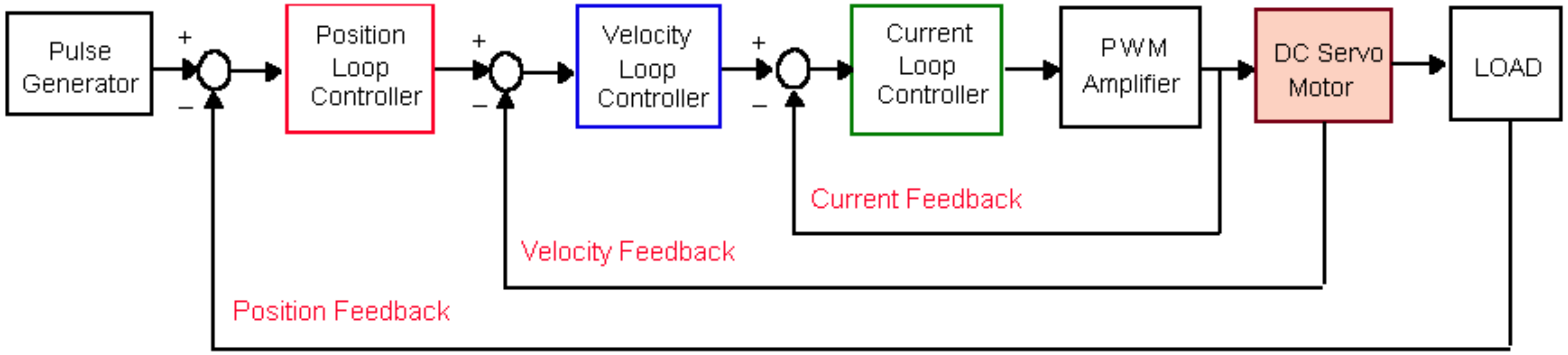
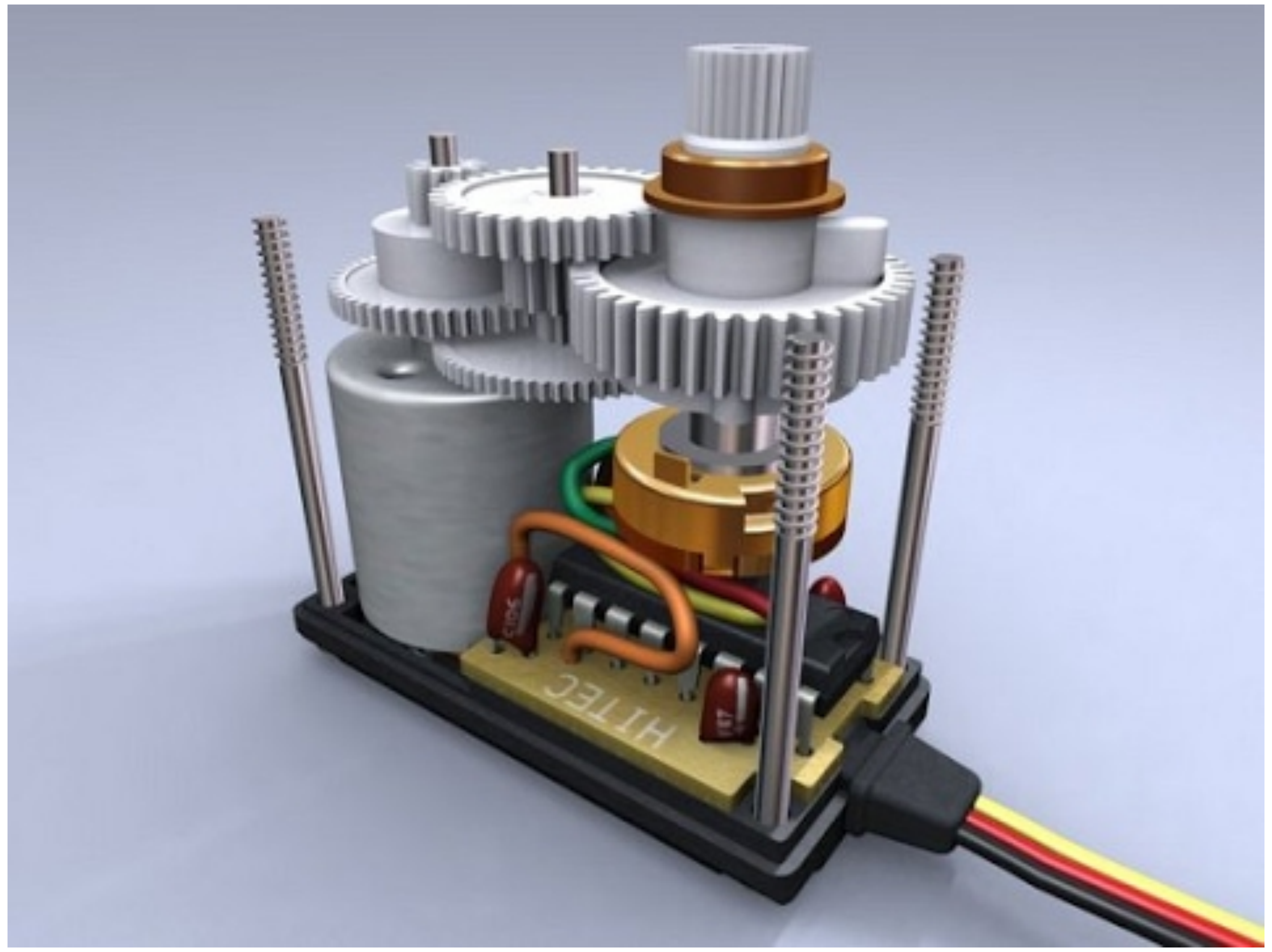
Servo motor

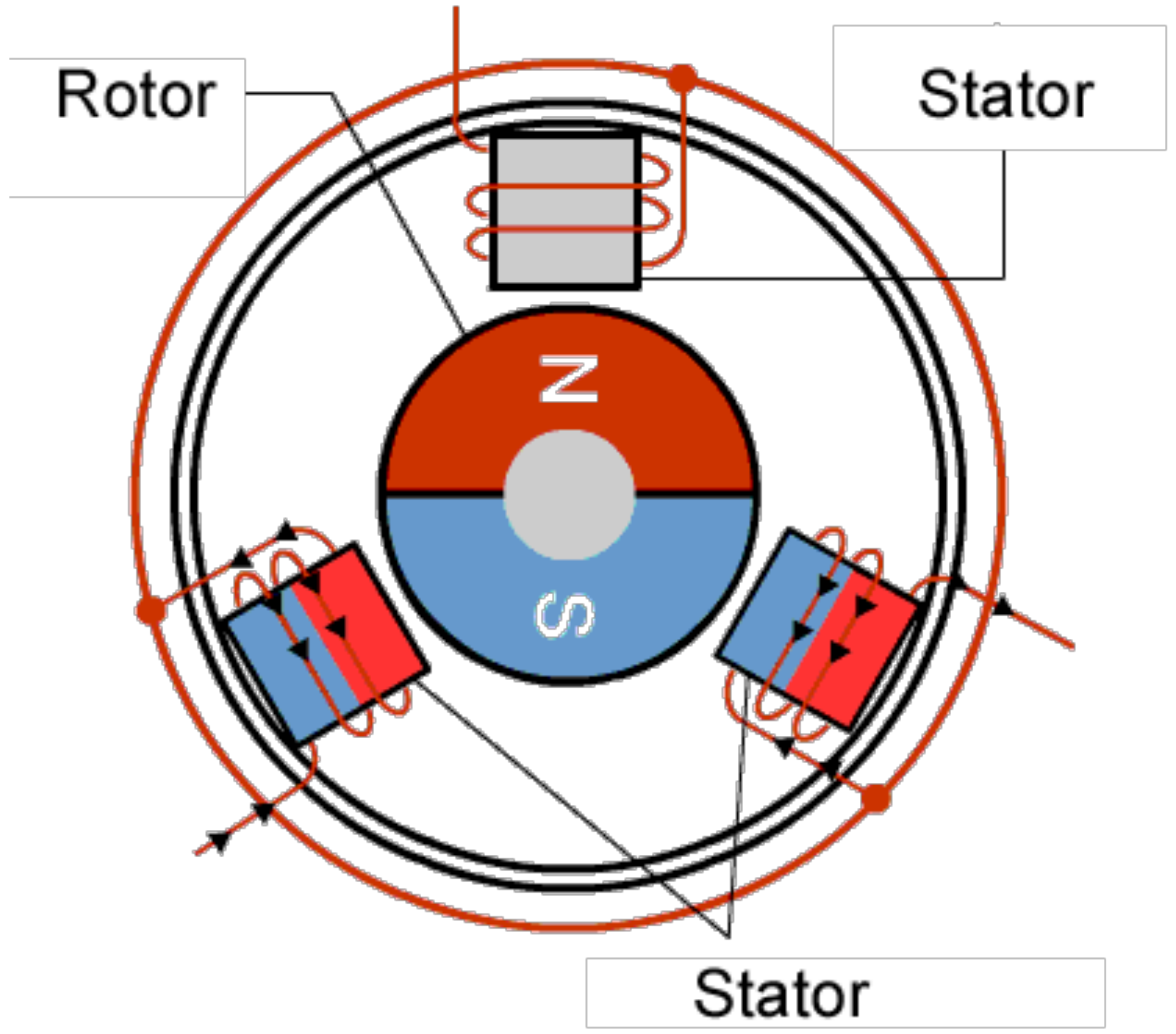
- Hobby-oriented PMDC motor
  - Duty cycle of a 50Hz 0-5V signal
- Continuous rotation servo
- Position controlled servo

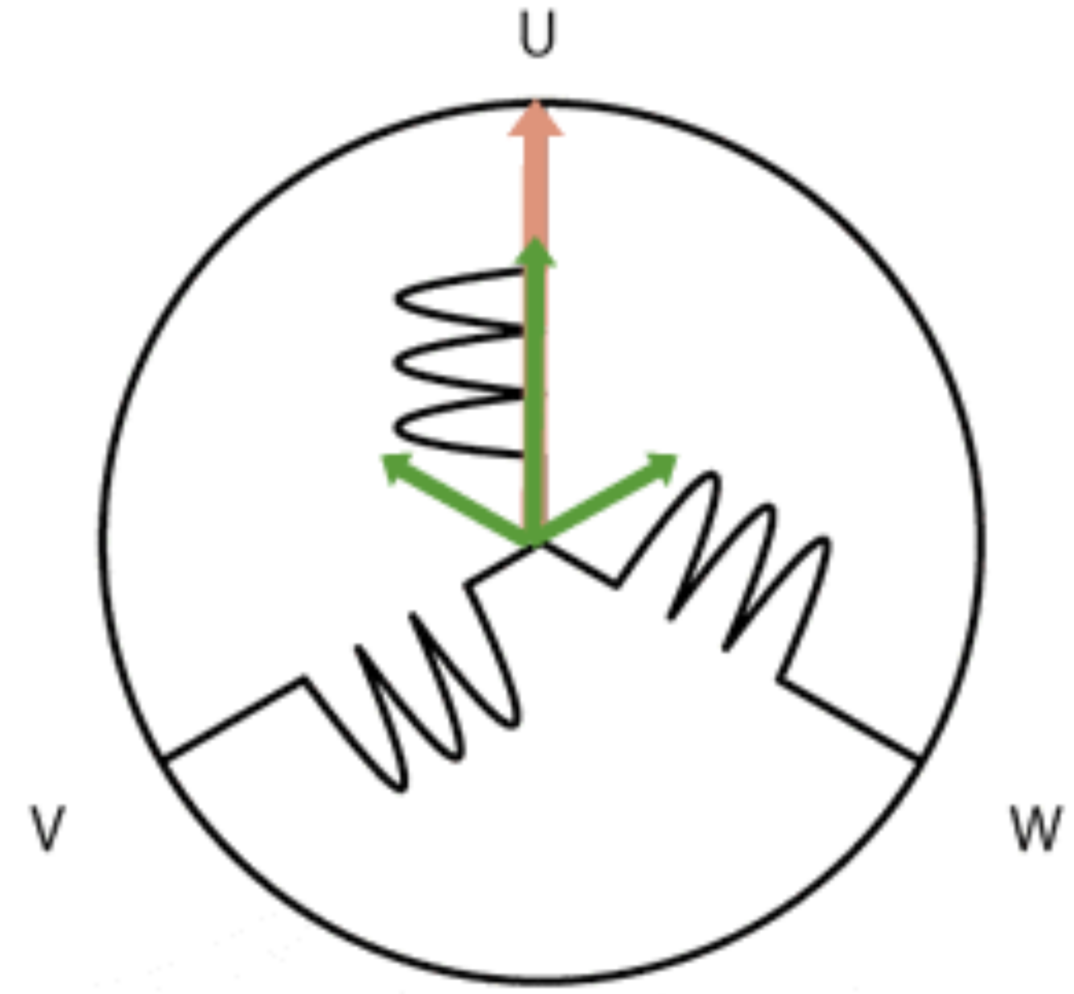




Brushless DC motor (BLDC)

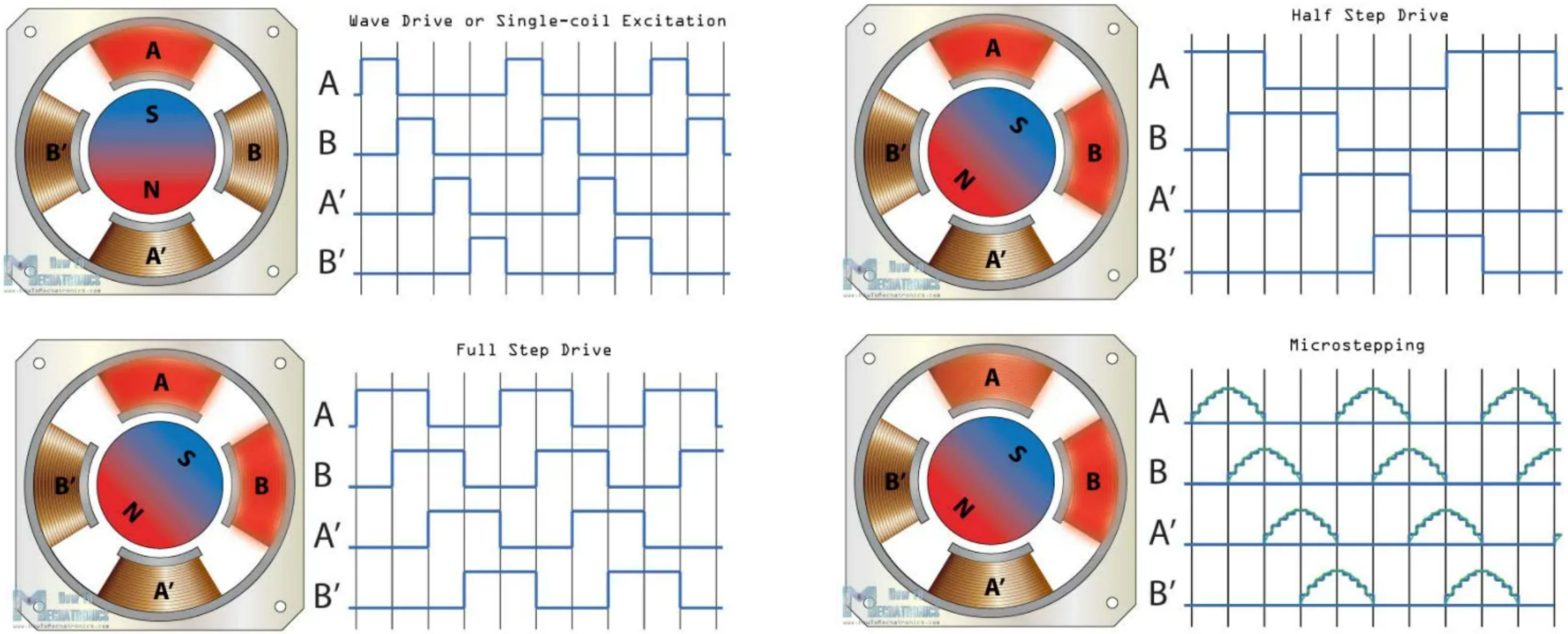
- Inside-out PMDC
- Higher efficiency (85-90% compared to 74-80% brushed)
- No wear, easier cooling, low EMI
- Higher power, high starting torque
- Precise control of torque and speed
  - Discrete control (easy, but jerky)
  - Sinusoidal control
- Position sensing
  - Sensors (hall effect, etc.)
  - Sensorless (back-EMF)
    - Lower speeds, worse control
    - Initialization





Stepper motor

- Good choice when low speed and high precision is needed
- Advantages: high torque compared to servos, constant holding torque, frictionless
- Disadvantages: low efficiency, torque declines rapidly with speed, low torque to inertia



Labs 2-4: Hardware integration

Hardware Labs

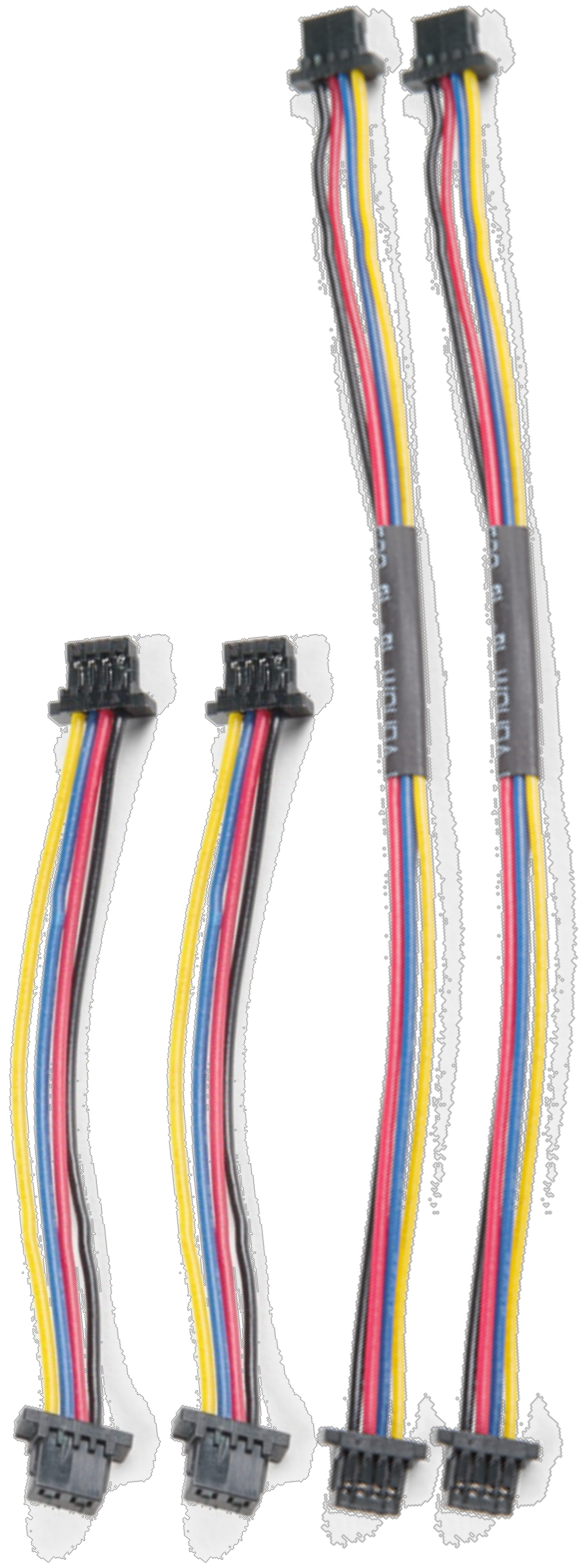
- Lab 2: IMU sensor
- Lab 3: ToF sensors and batteries
- Lab 4: Motor drivers and open loop control

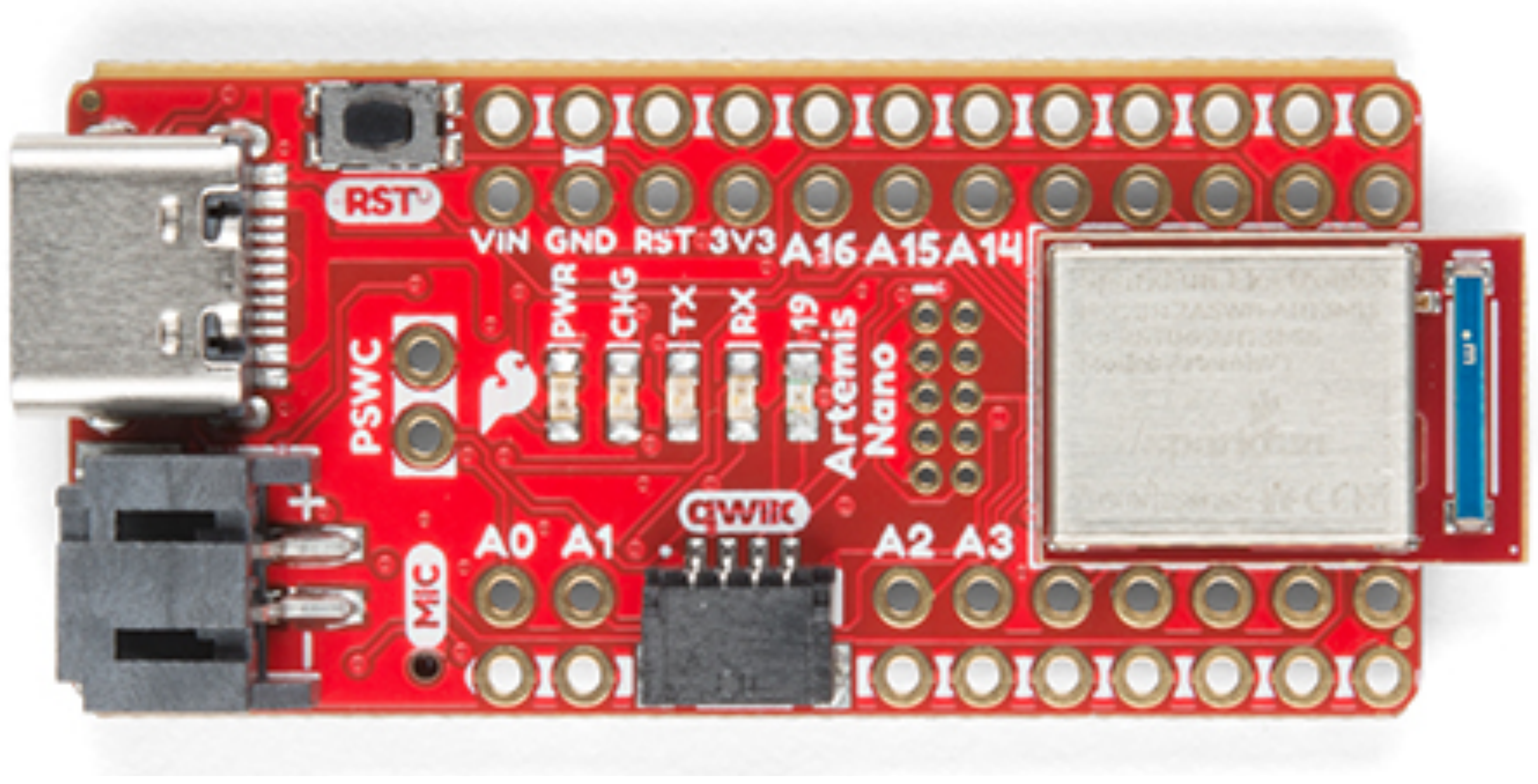
Hardware Labs

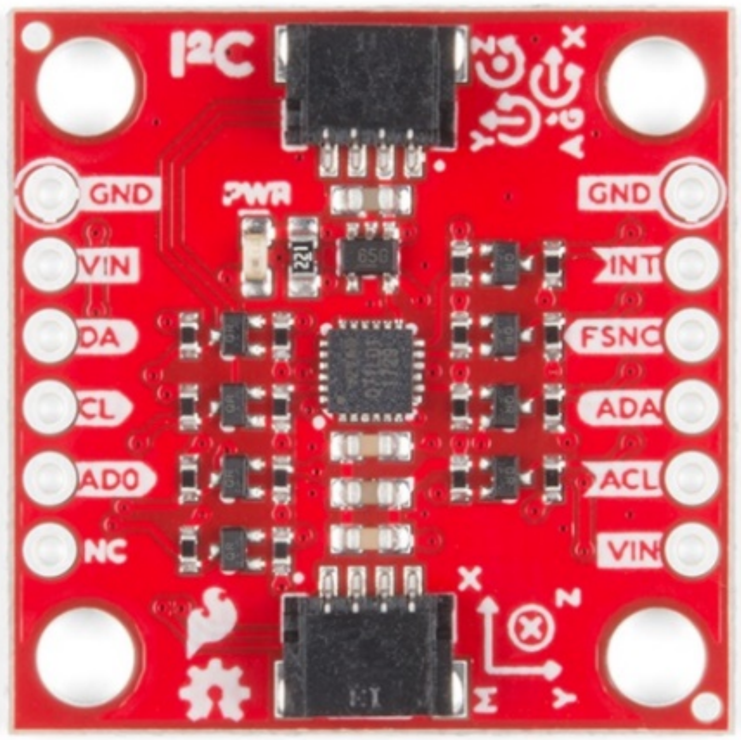
Things to consider

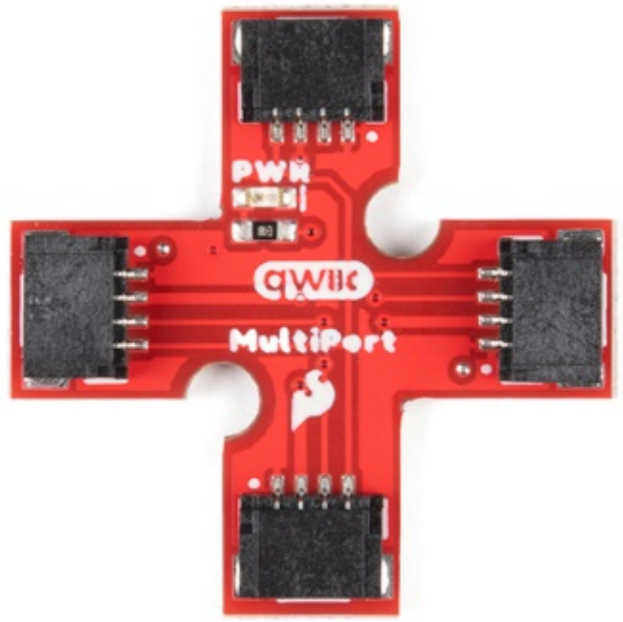
- Where/ how do you place components?
- Routing paths (w. EMI considerations)
- Color coding
- Permanent solder joints/ detachable connections?
- Single core or braided wires?
- Which side of the breakout boards do you solder to?
- What cable will you use where? Which will you cut for the ToF sensors?
- Identify the colors of the signals in the QWIIC cable (GND, VCC, SDA, SCL)
- In lab 3 and 4, focus on getting your soldering done if you don't have access outside of lab!

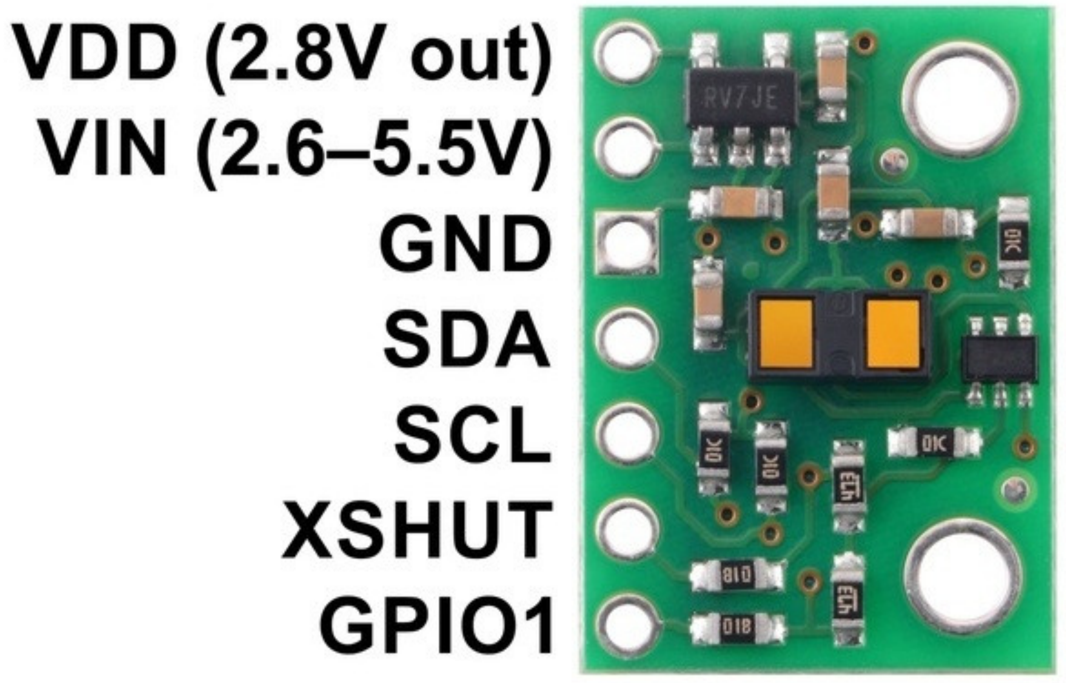
Hardware

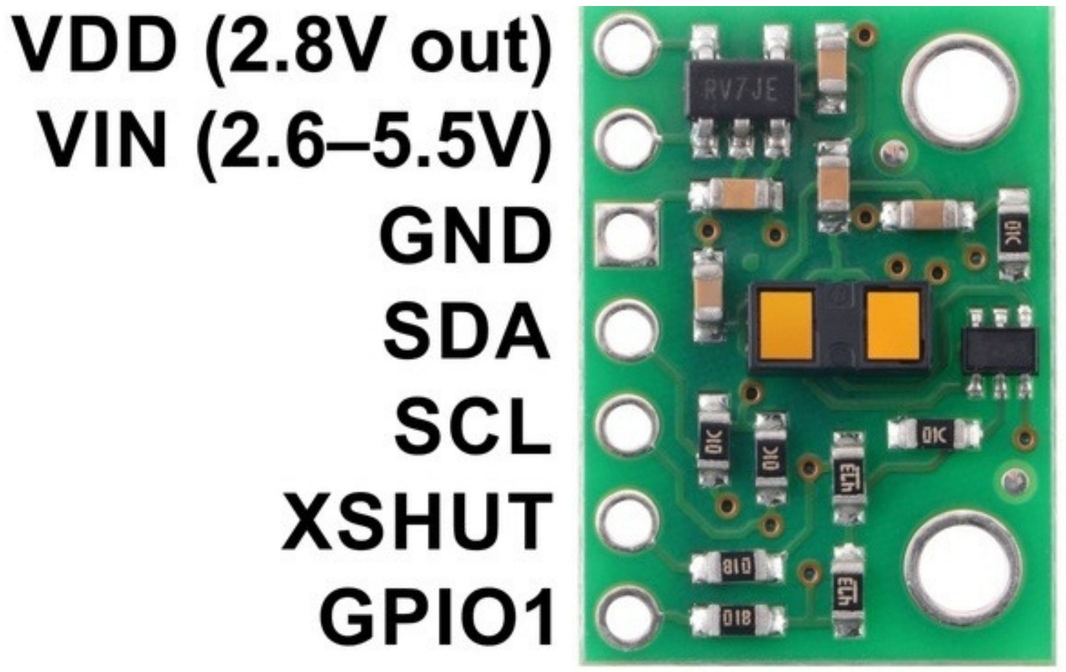



RST
VIN GND RST 3V3 A16 A15 A14
PSWC
PWR CHG TX RX 19
Artemis Nano
qwiic
MIC
A0 A1 A2 A3


I2C


PWR
qwiic
MultiPort


VDD (2.8V out)
VIN (2.6–5.5V)
GND
SDA
SCL
XSHUT
GPIO1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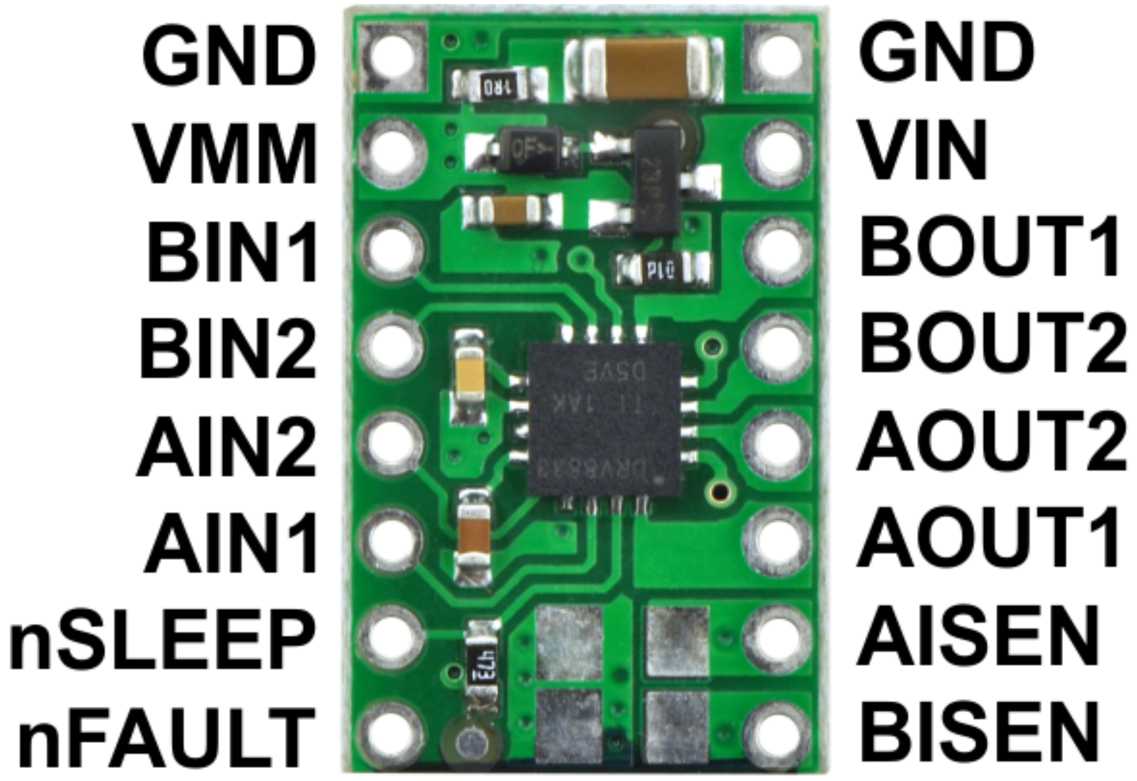
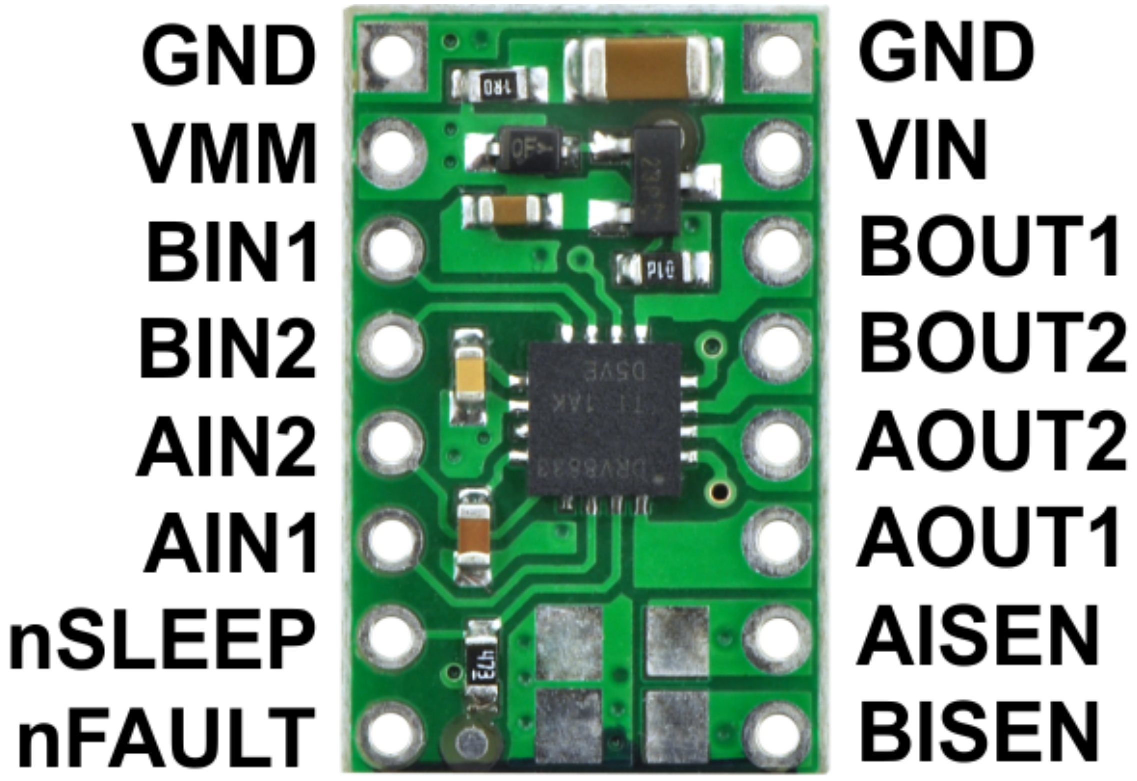

GND
VMM
BIN1
BIN2
AIN2
AIN1
nSLEEP
nFAULT
GND
VIN
BOUT1
BOUT2
AOUT2
AOUT1
AISEN
BISEN


GND
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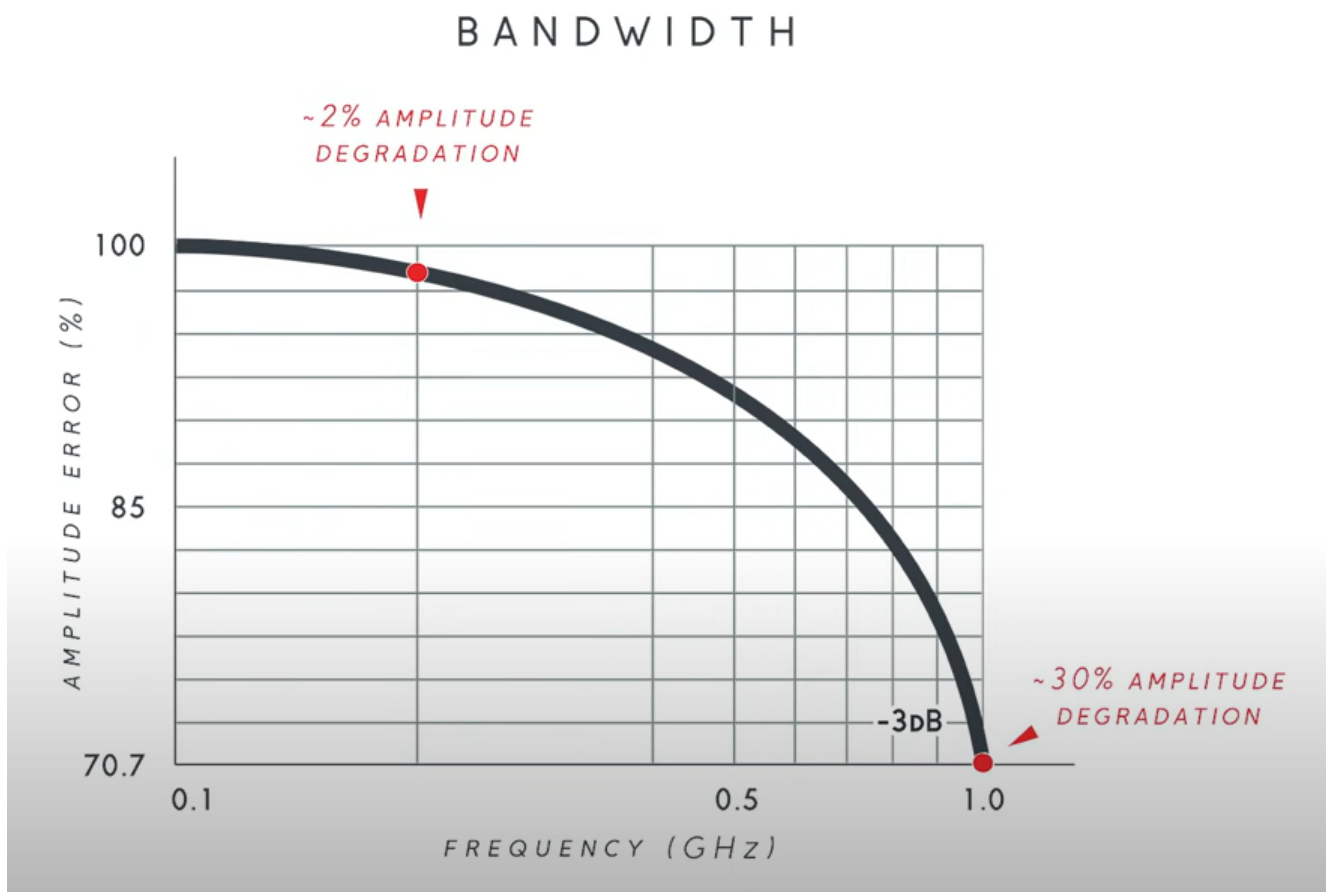
nFAULT
GND
VIN
BOUT1
BOUT2
AOUT2
AOUT1
AISEN
BISEN

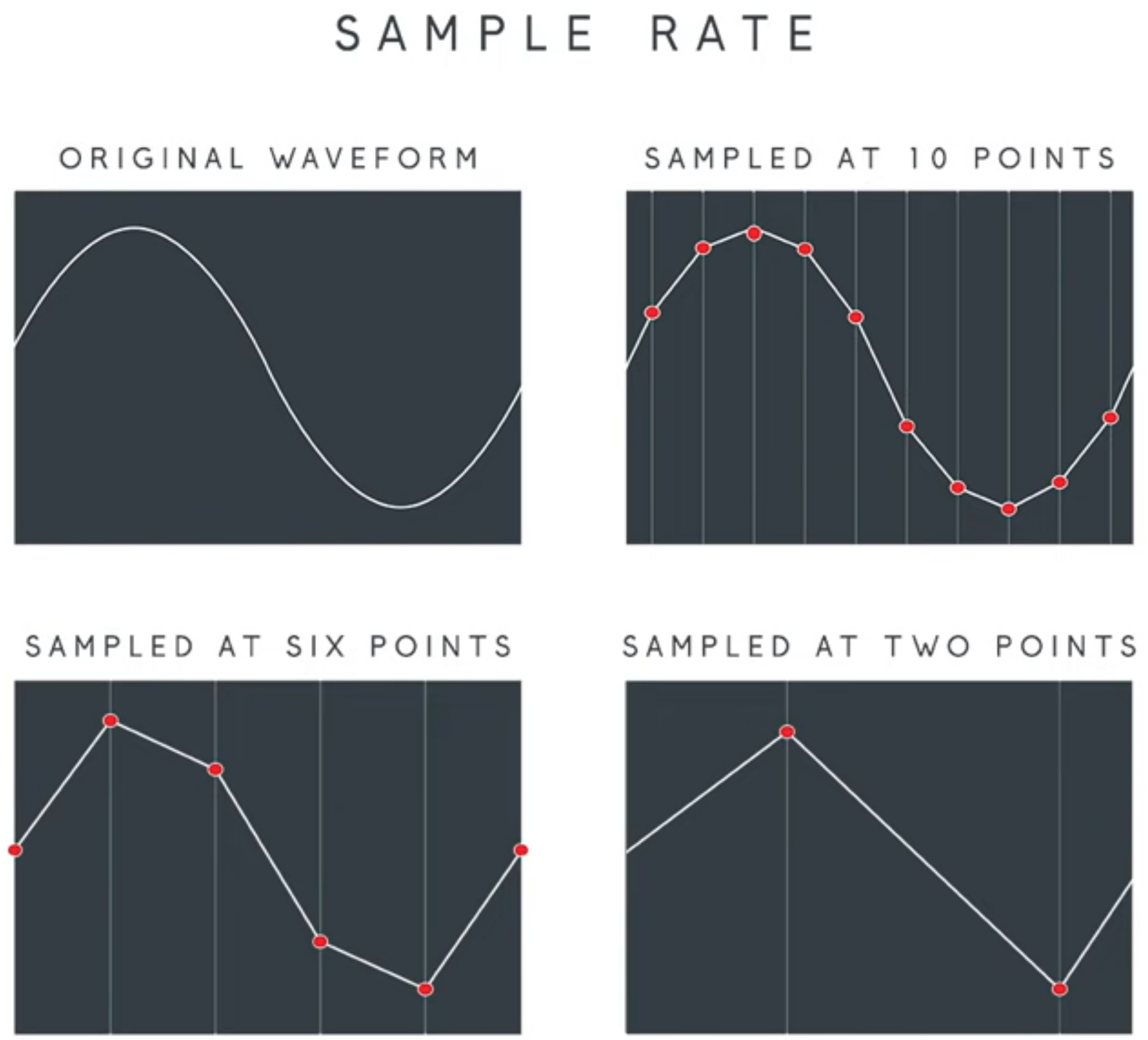
Oscilloscopes

Oscilloscope setup

Oscilloscope setup

- Bandwidth
- Sample rate
- Resolution

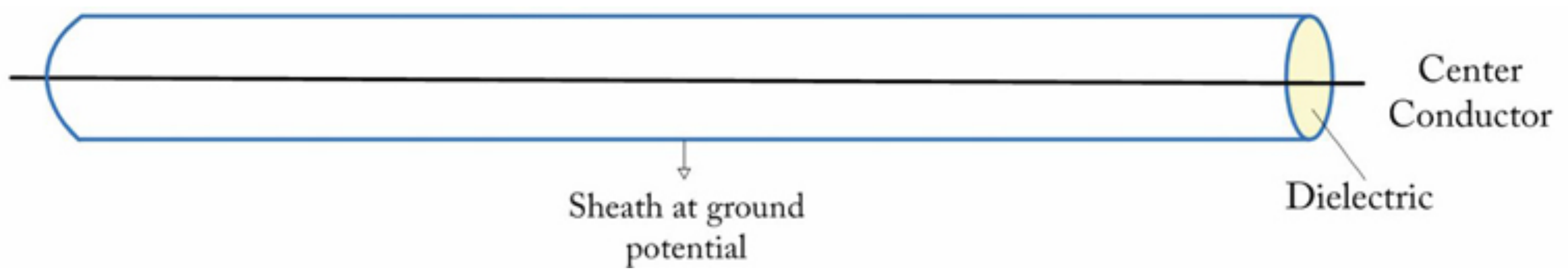




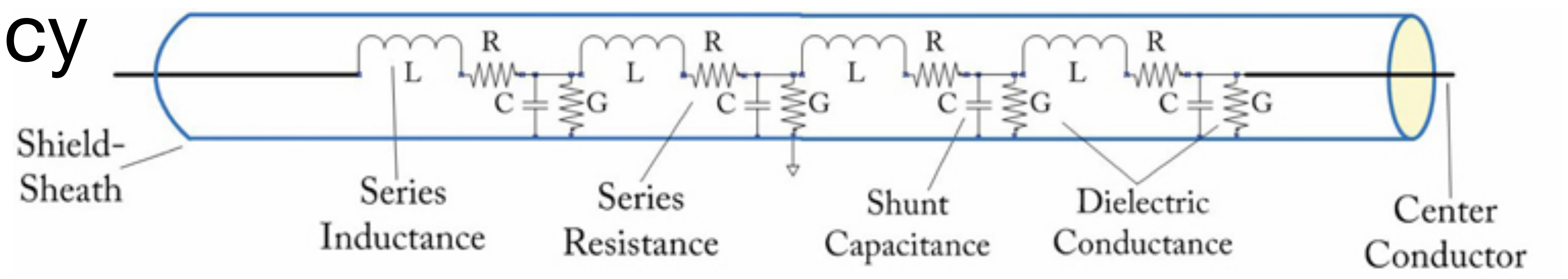
Oscilloscope Probes

- Scope inputs resemble a 16pF capacitor in parallel with a 1MOhm resistor
- At high frequencies the coax cable acts as a low pass filter
- 1x attenuation for low amplitude, low frequency signals
- 10x attenuation for load-sensitive circuits, high-frequency or high-amplitude signals

Low frequency coax cable



High frequency circuit



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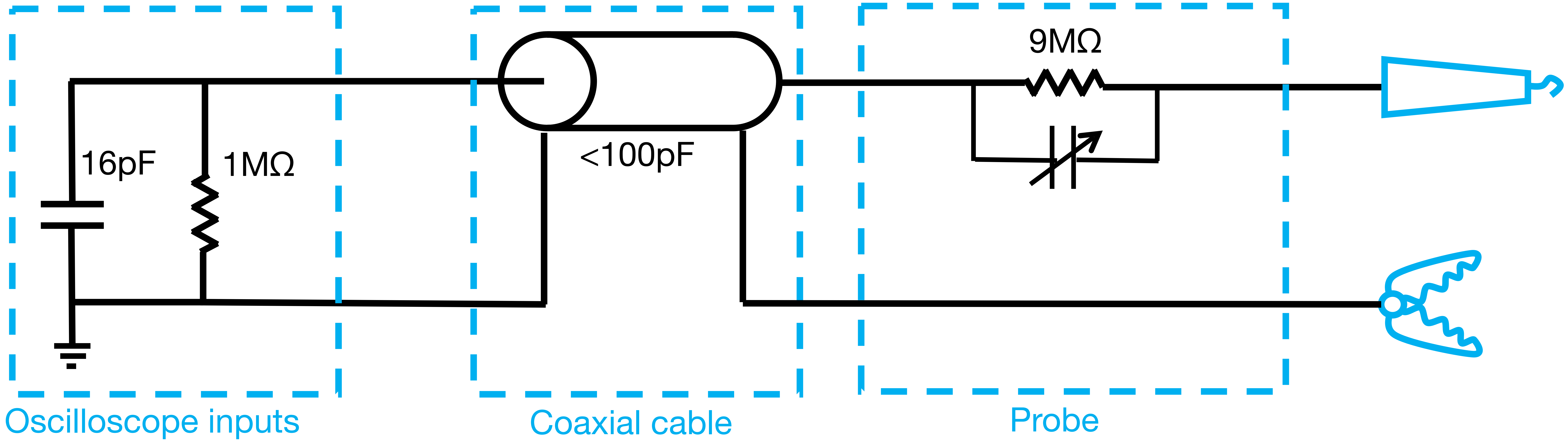
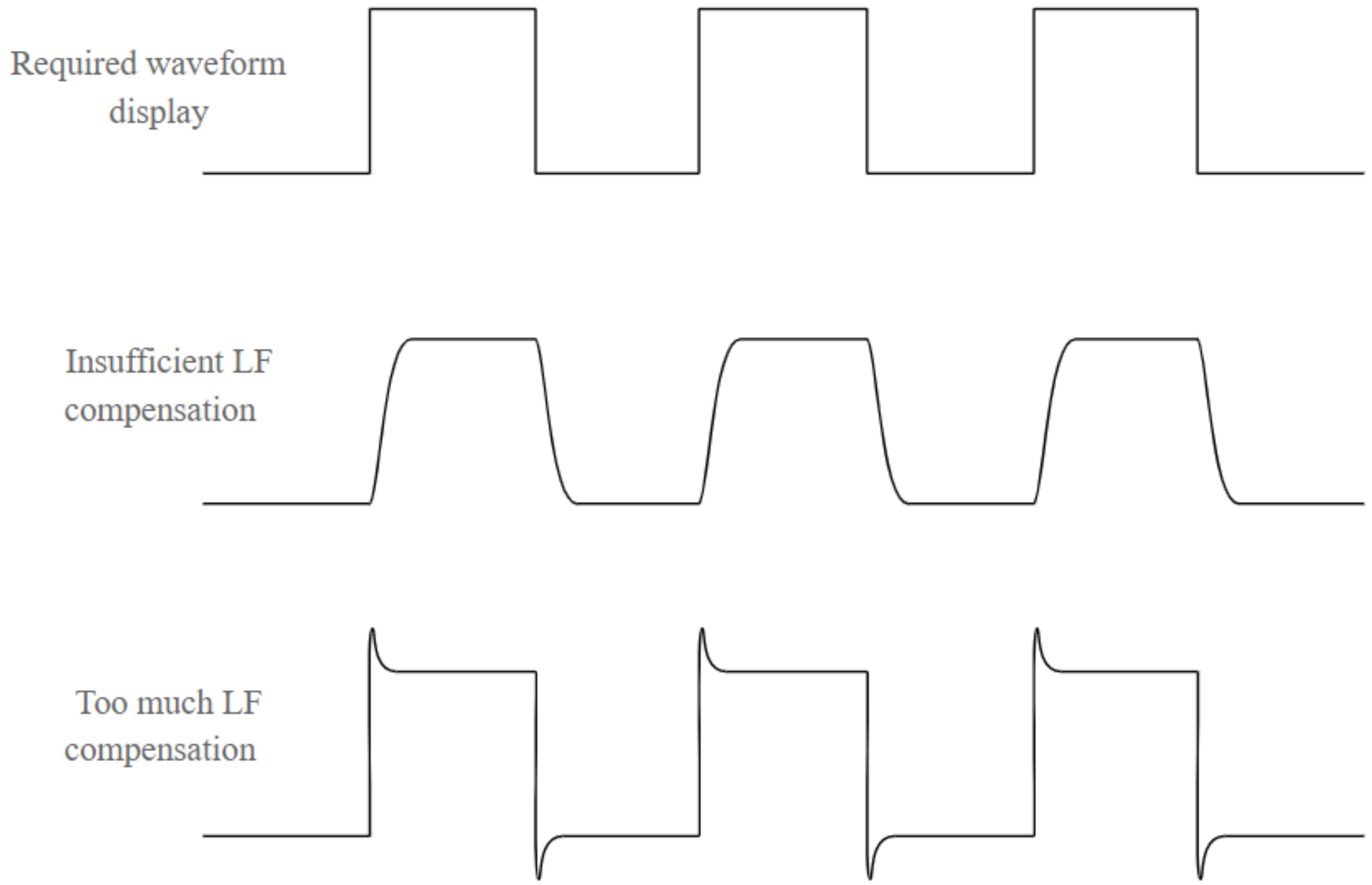


Oscilloscope Probes

- 10x probe calibration
  - Use the built-in square wave generator
  - Adjust capacitor until the square wave looks square!



Oscilloscope setup

Class Action Items

- Lab 2 is due Tuesday 8am for Lab 401, Wednesday 8am for Labs 402, 403
- If you choose to drop the class, please let me or the teaching staff know so you can give us back the supplies!
- Check the calendar for open hours
- Feel free to charge your batteries in lab during lab times/ open hours as you feel comfortable.
- We are going to cut the cable on your 650mAh/ 750mAh batteries next lab so you can charge through the Artemis!