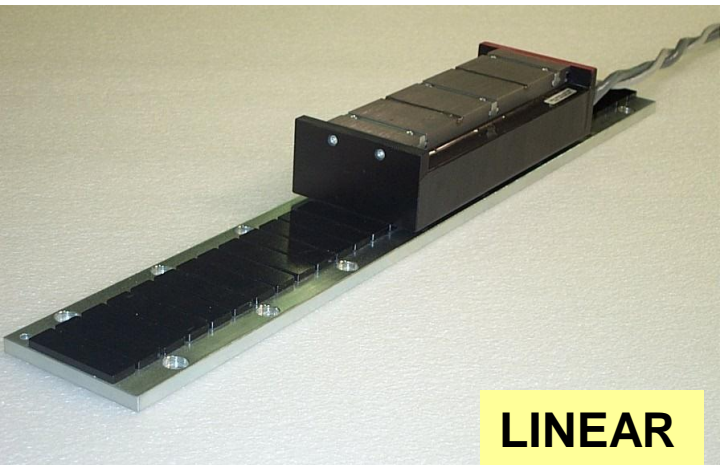


**Electric Motors  
and  
Motion Control**  
Ara Knaian

# Motors

- Motors convert electrical energy to mechanical energy
- Motors make things move



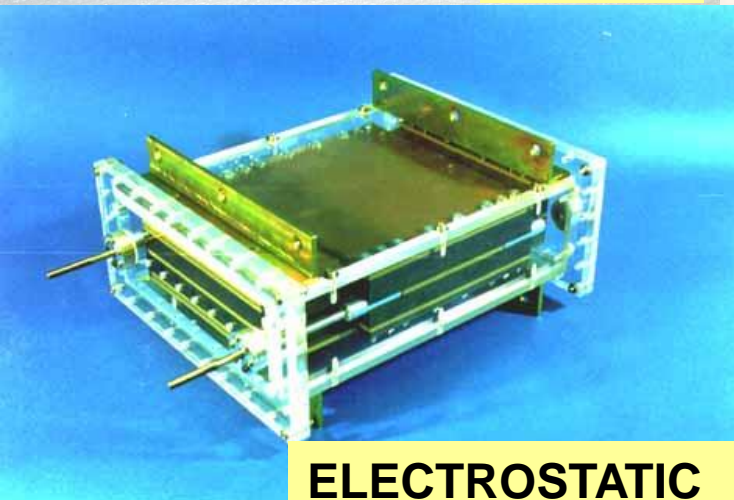
**LINEAR**



**DC BRUSH**



**INDUCTION**



**ELECTROSTATIC**

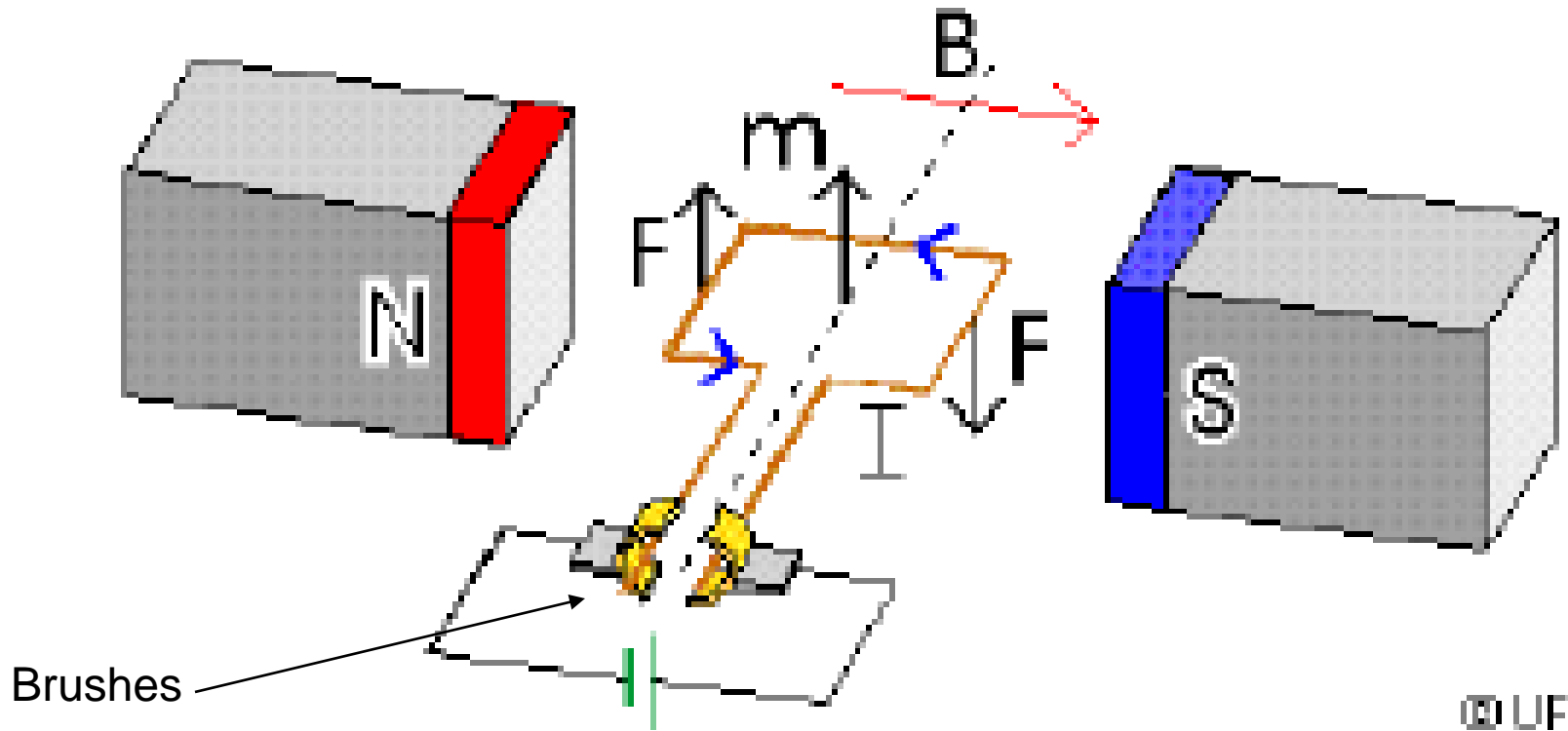


**STEPPER**



**UNIVERSAL**

# How a DC Motor Works

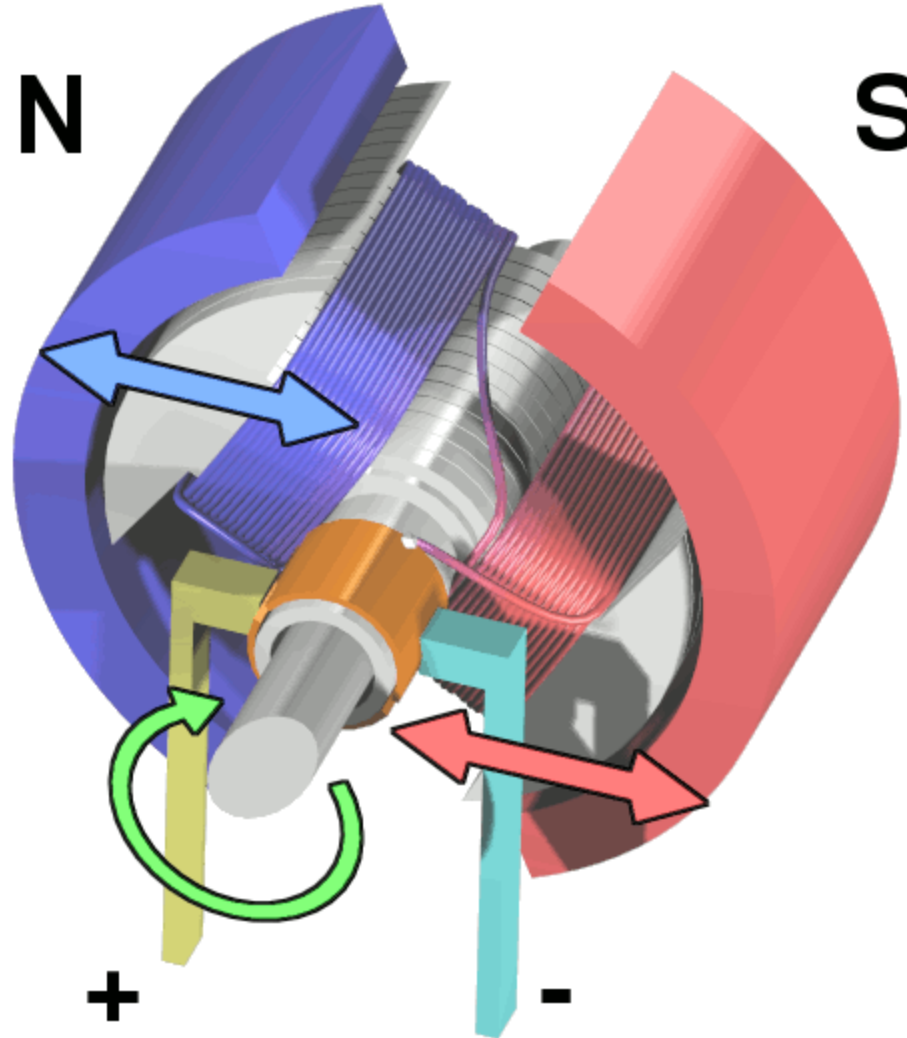


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$$\vec{F} = I\vec{L} \times \vec{B}$$

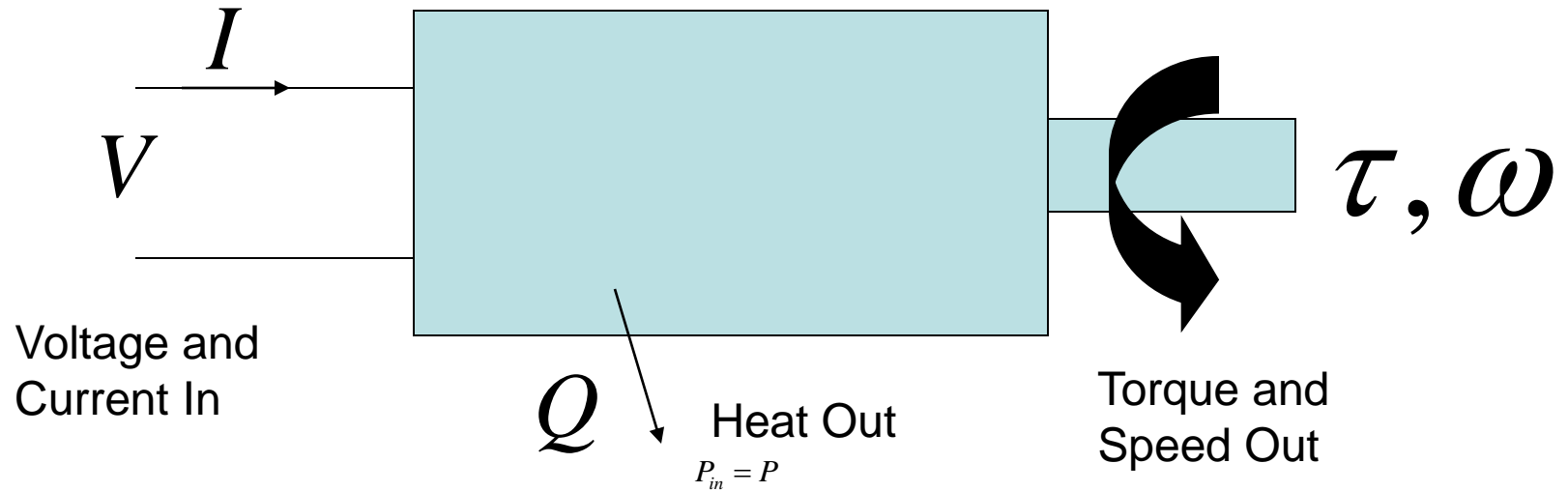
# How a DC Motor Works



# Motor Modeling

- Is this motor big enough?
- Will this thing move?
- What gear ratio should I use?
- How big should my power supply be?
- How hot will it get?
- How fast can I machine?
- What materials can I machine?

# Motor Modeling



Power In = Power Out

$$VI = Q + \tau\omega$$

$$VI \cong I^2 R + \tau\omega$$

# Motor Modeling

$$\overline{\mathbf{F}} = I \overline{\mathbf{L}} \times \overline{\mathbf{B}}$$



$$\tau = K_m I$$

# Motor Modeling

$$VI \cong I^2 R + \tau\omega$$

$$\tau = K_m I$$

Torque is proportional to current

In an ideal motor ( $R = 0$ ), speed is proportional to voltage

At constant voltage, speed goes down as torque goes up

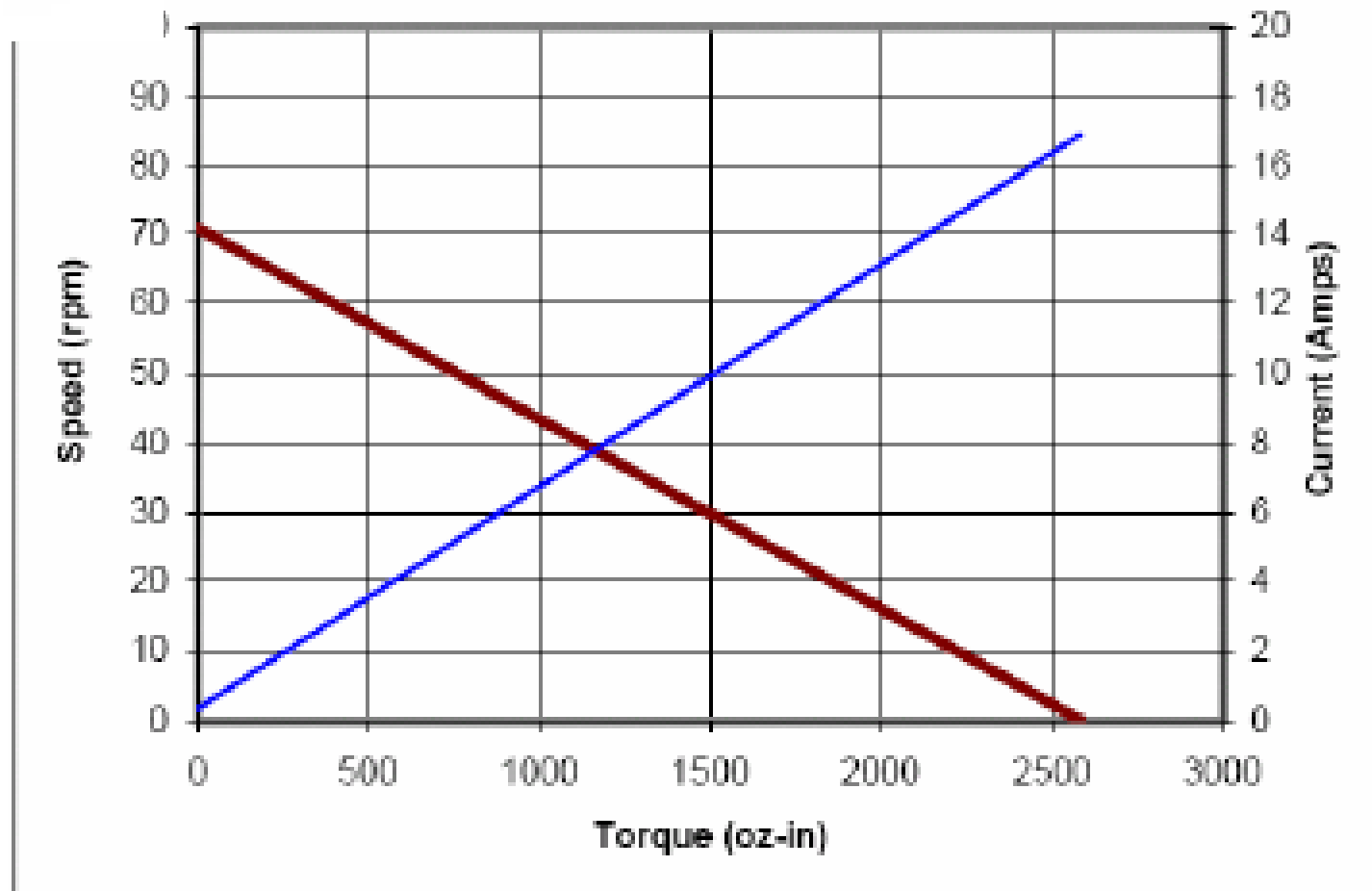


# Pittman Motor Data Sheet

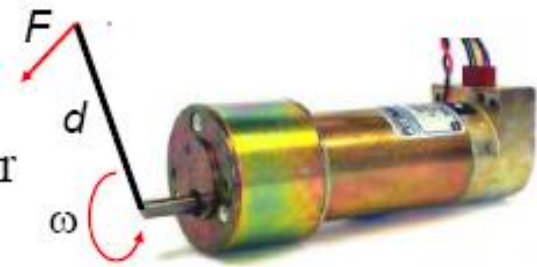


Speed & Current vs. Torque

— Speed  
— Current

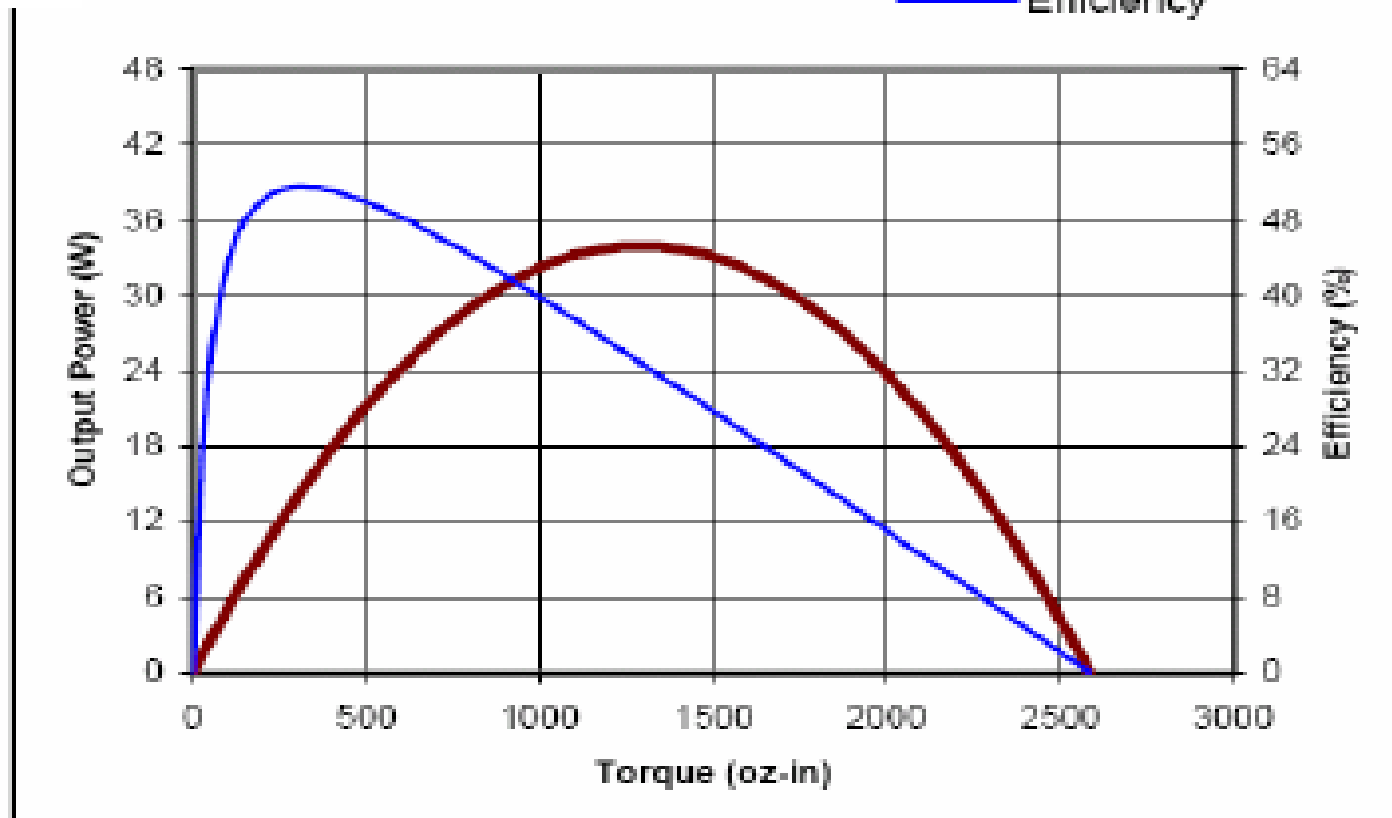


# Pittman Motor Data Sheet

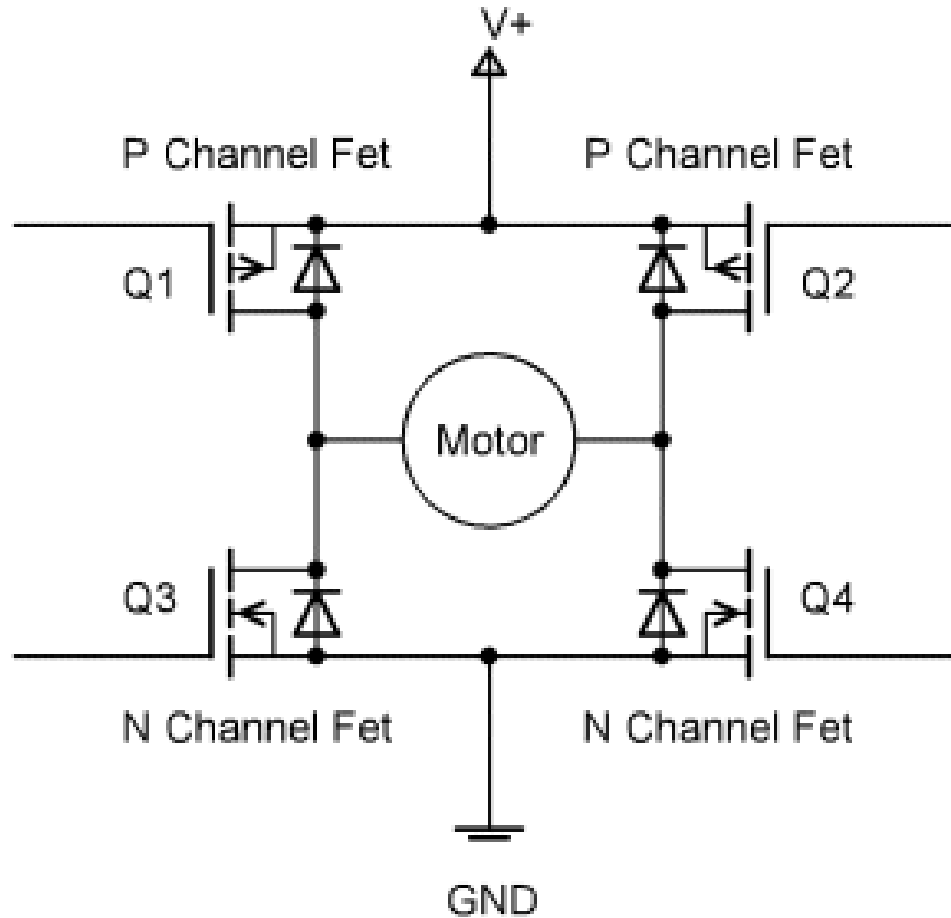


**Power & Efficiency vs. Torque**

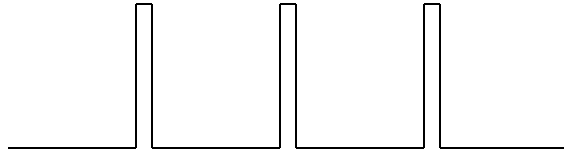
— Output Power  
— Efficiency (%)



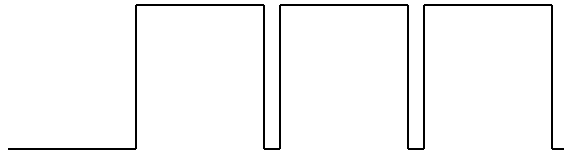
# Bidirectional Motor Drive: H-Bridge



# Speed Control: PWM

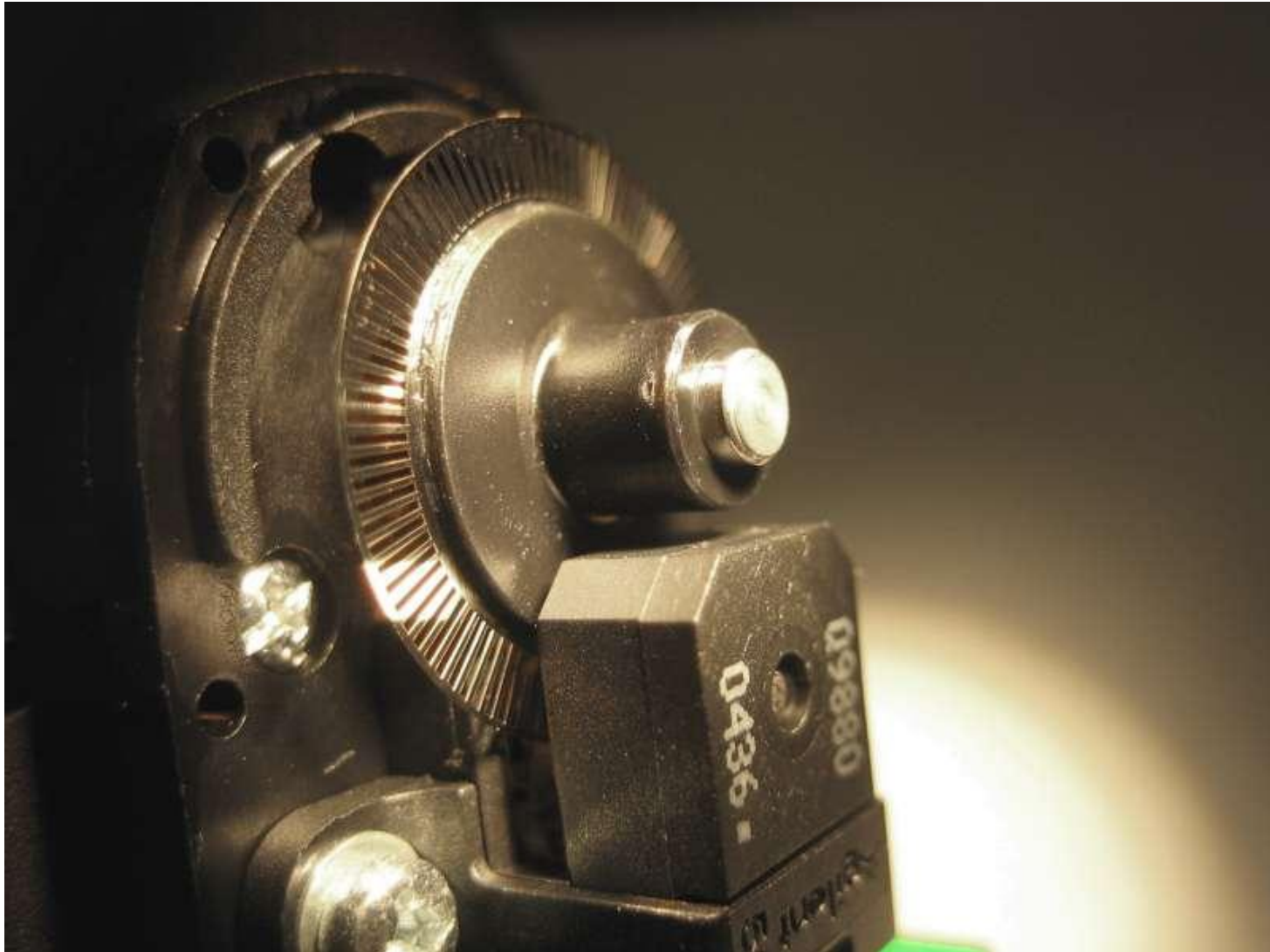


Like Low Voltage  
(slow)

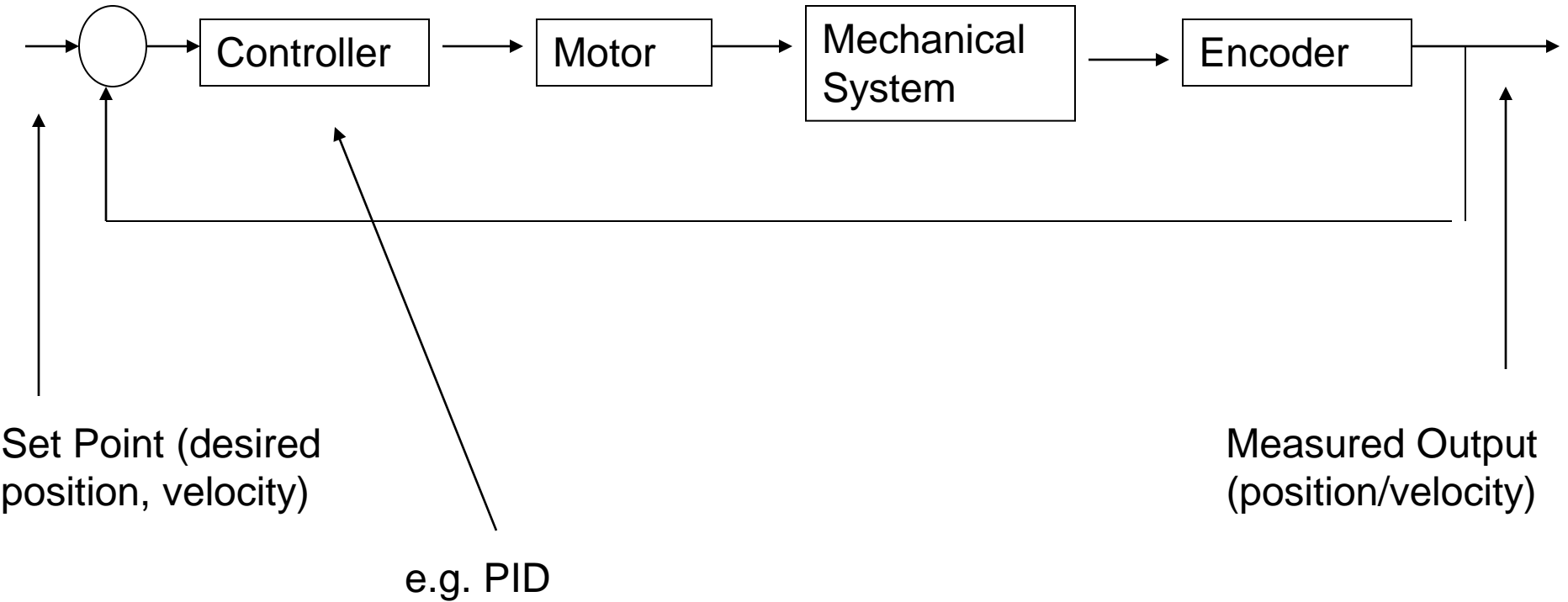


Like High Voltage  
(fast)

# Rotary Shaft Encoder



# Motor Control: Linear Servo Loop



# Practical Motor Controller Block Diagram

