Motors and Speakers

Lecture 18

Microprocessor-based Systems (E155)

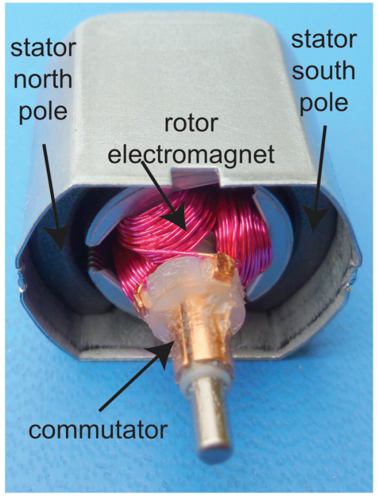
Prof. Josh Brake

Outline

- Motors
  - DC motors
    - Brushed
    - Brushless
  - Servo motors
  - Stepper motors
- Speakers

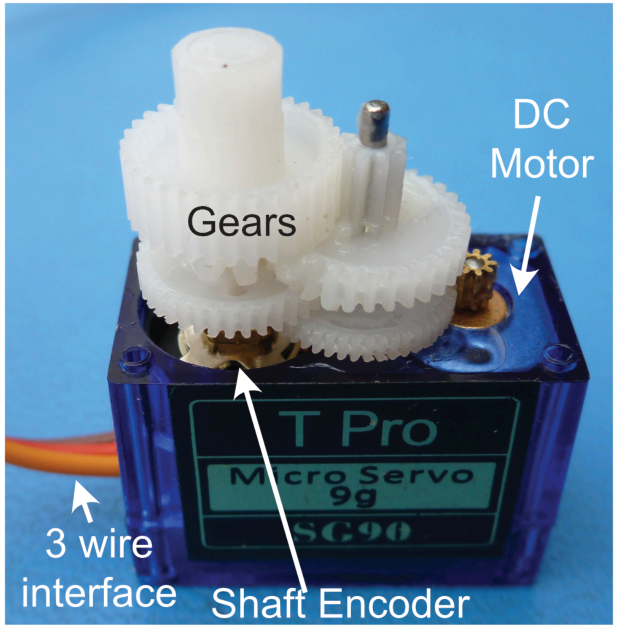
Main Types of Motors

- DC Motors
  - Brushed
  - Brushless
- Servo motors
- Stepper motors

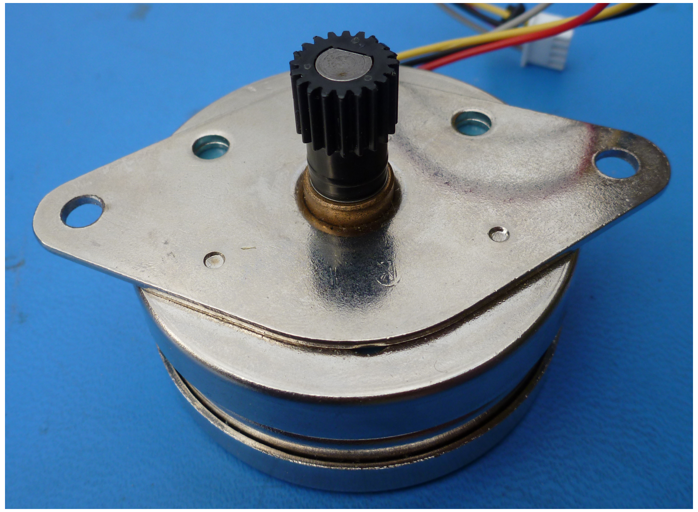


(b)

Figure e9.33 DDCA ARMed Edition p. 531.e44

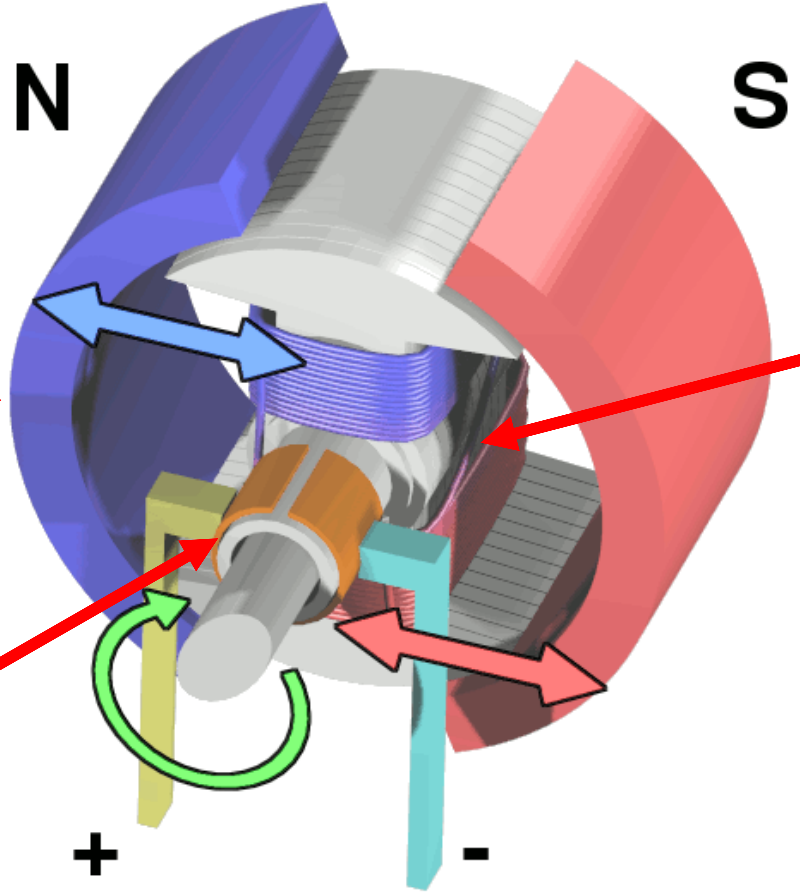


DDCA Figure e9.37 p. 531.e48

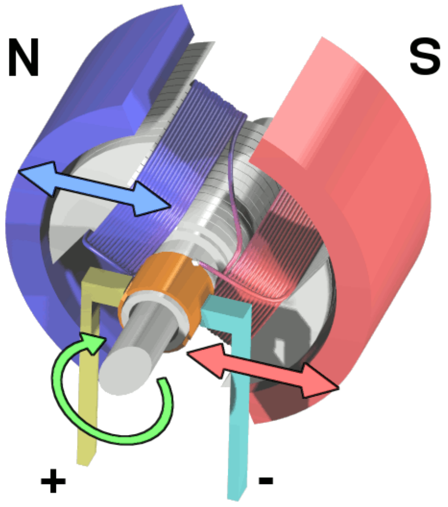


DDCA Figure e9.42 p. 531.e51

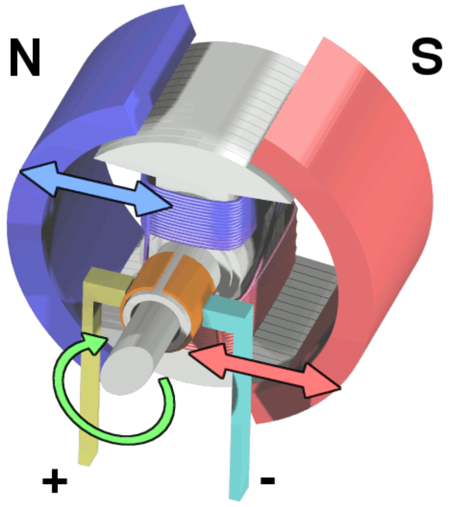
Typical DC Motor Architecture



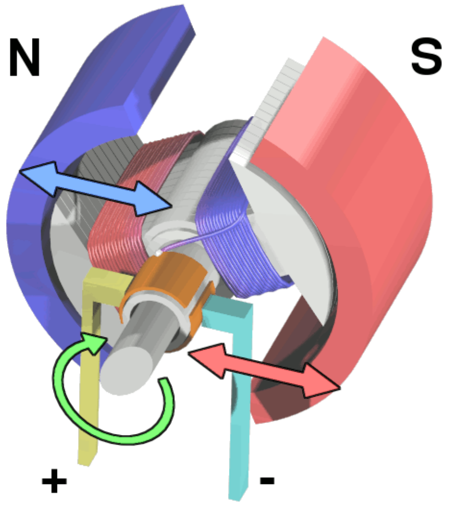
Brushed DC Motor Operation



Step 1

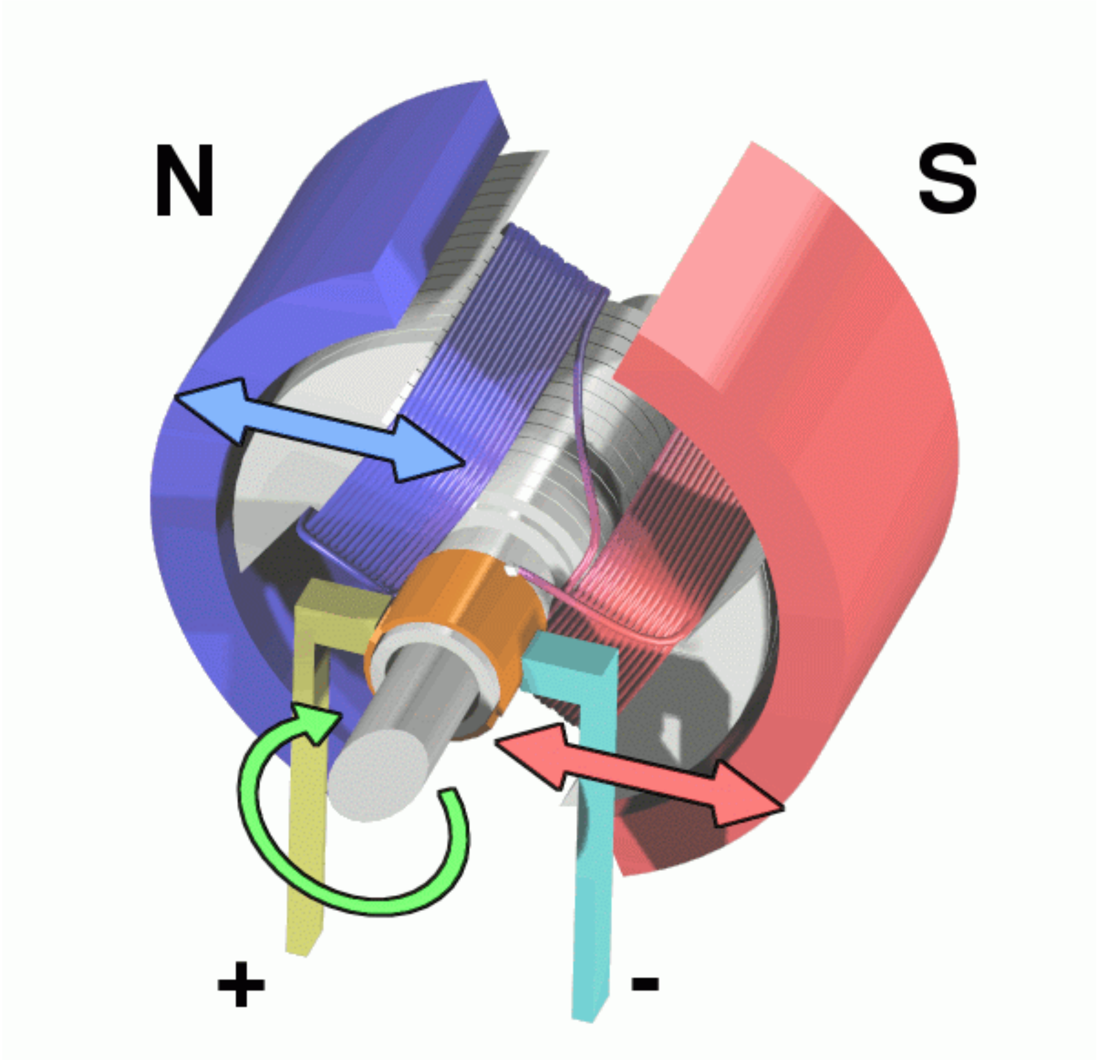


Step 2



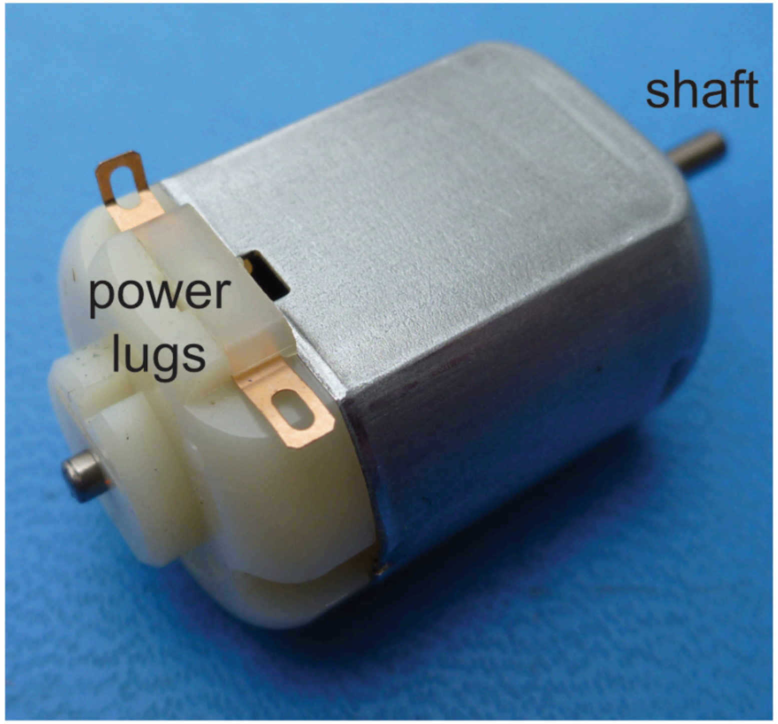
Step 3

DC Motor Animation

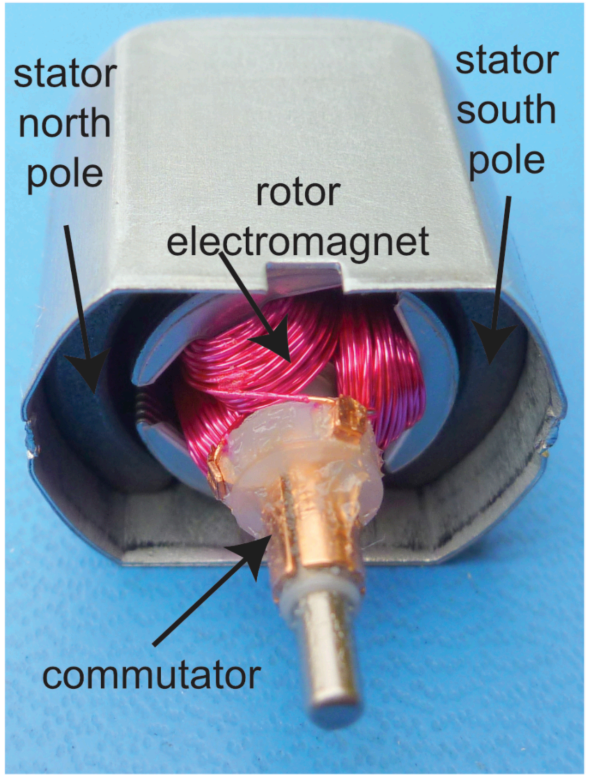


"Basic Operation Illustration of a simple electric motor" by Wapcaplet CC BY-SA 3.0

Picture of a DC motor



(a)



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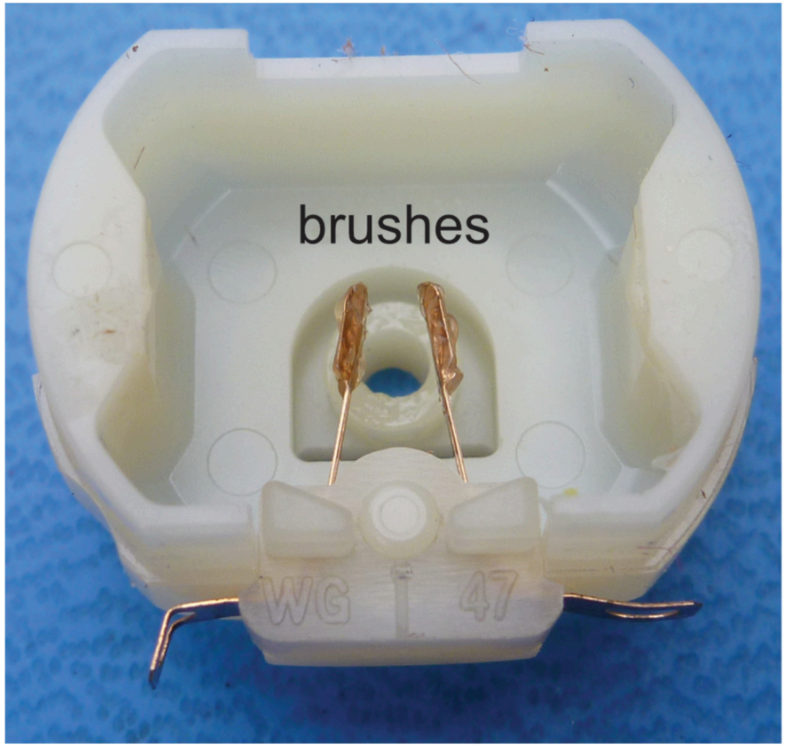


(c)

Figure e9.33 DDCA ARMed Edition p. 531.e44

Driving Brushed DC Motor

- Brushed DC motors
  - Use an H-bridge
    - Arrangement of switches to control the direction of current flow and thus the direction of rotation.
    - Can control the speed using pulse width modulation to turn the switches on and off

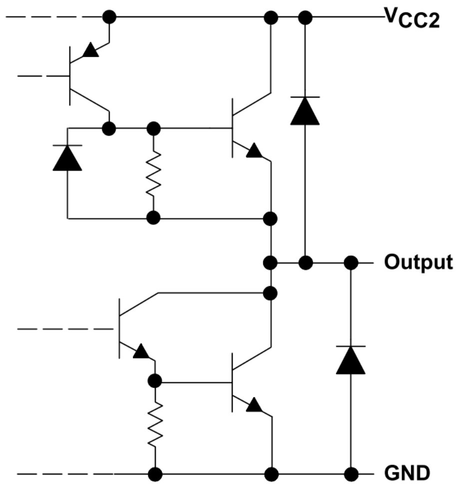


Figure 5. Typical of All Outputs

SN754410 Datasheet

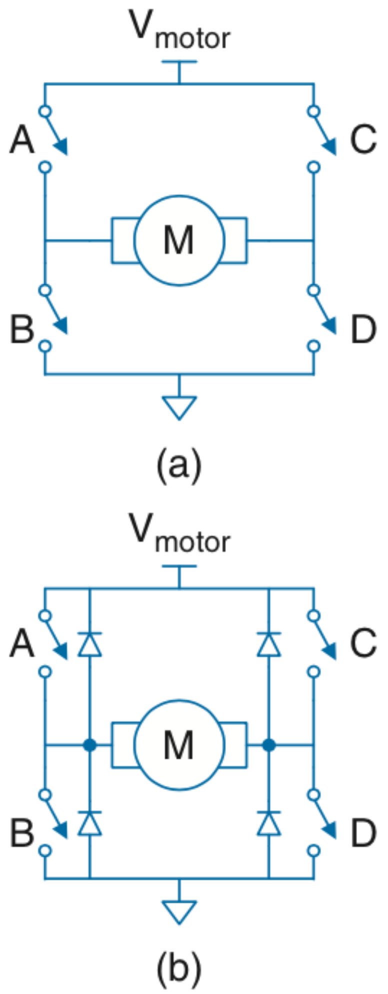


Figure e9.34 H-bridge

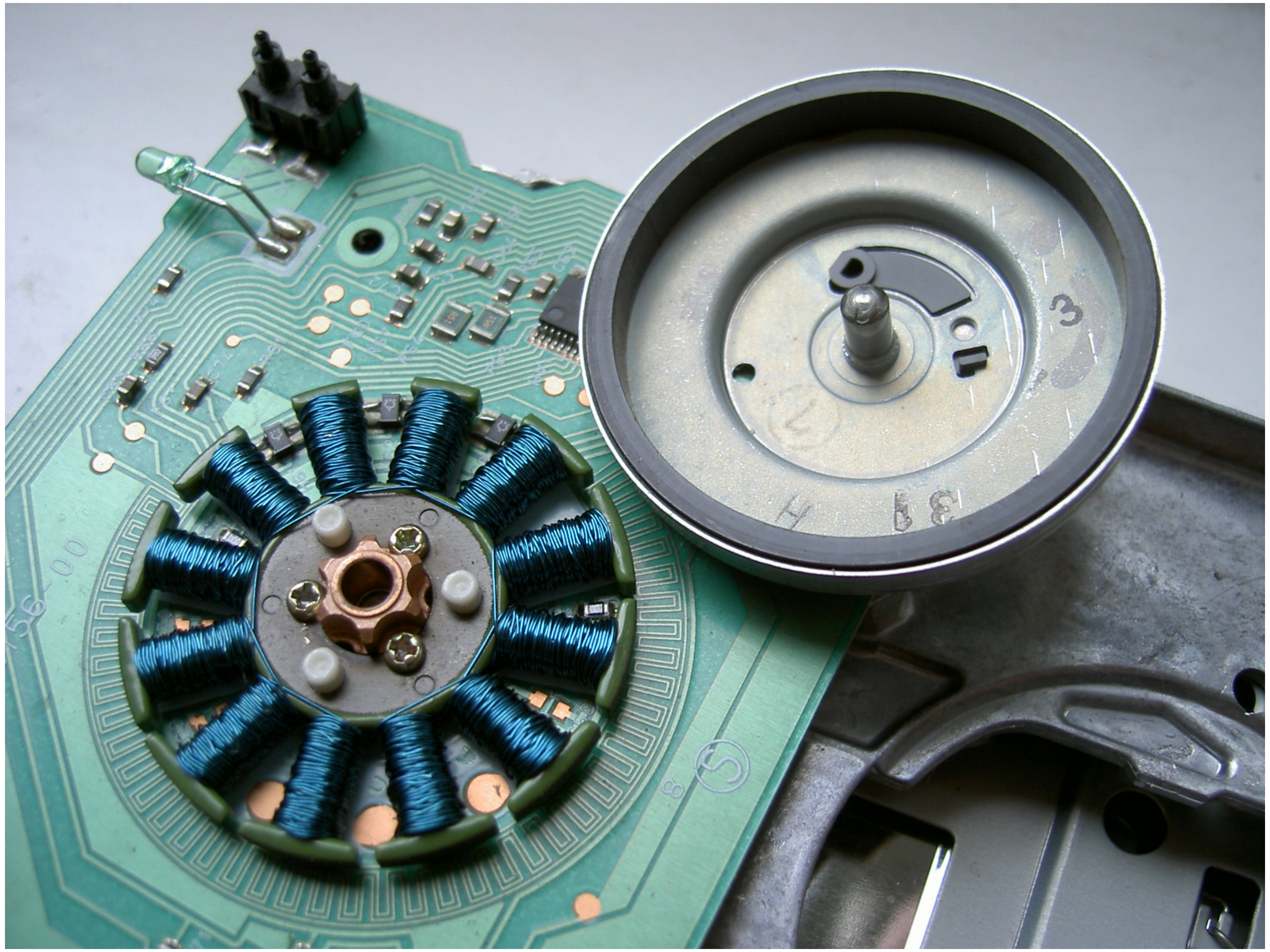
DDCA/ARMed Edition Figure e9.34 p. 531.e45

Brushless motors

- Brushed motors suffer from several disadvantages
  - Friction from brushes
  - Mechanical wear on brushes
  - Resistance of sliding brush
  - Abrupt switching of current can generate noise
- But we still need a way to switch the direction of the current flow to keep the motor spinning
- Solution: use an electrical solution to switch the current direction

Brushless Motors

- No brushes! Commutation is done electrically.
- Notice that the coils are now in the stator and the magnet is in the rotor.
- In this particular motor the rotor is on the outside of the stator



Driving Brushless DC Motor

- Brushless motors
  - Need to control and synchronize the current flow through the coils in the stator
  - Use hall effect sensors to detect the orientation and rotation speed of the rotor and then synchronize the drive signals
  - Similar idea to what we will discuss for stepper motors

Shaft Encoders

- Even if we send the same exact signal to two DC motors, it is unlikely they will spin at exactly the same speed
- Can use a shaft encoder to measure the actual rotation speed
- Using two LED/sensor pairs spaced by half a slot the direction can also be measured via quadrature outputs

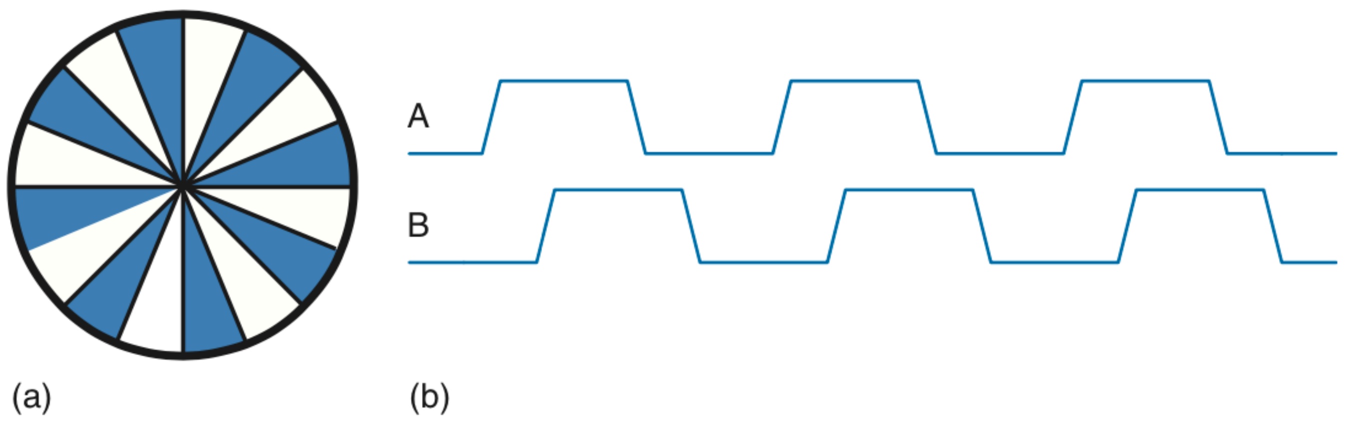


Figure e9.36 **Shaft encoder (a) disk, (b) quadrature outputs**

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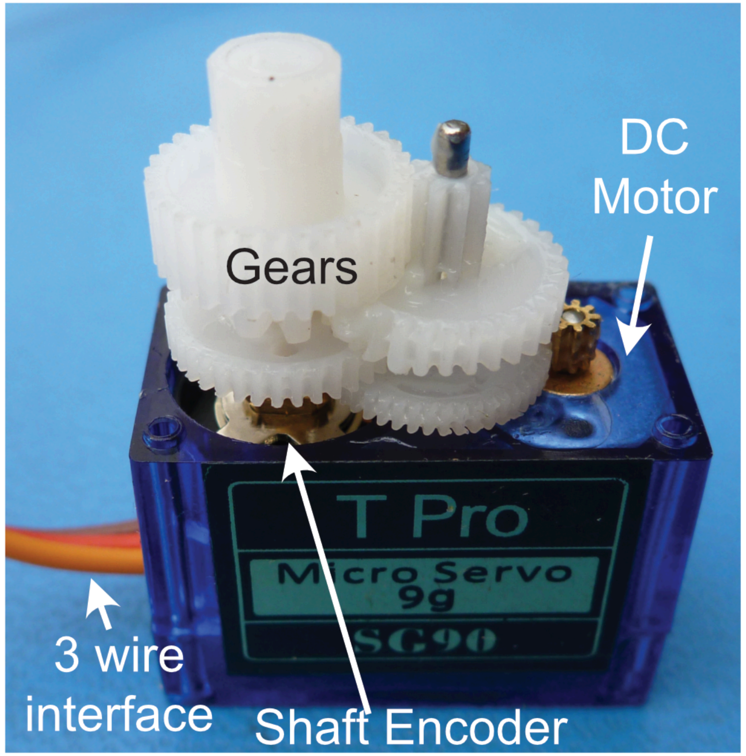
Servo motor

- DC motor plus encoder to sense position (normally implemented with a rotary potentiometer)
- Controlled with PWM signal to drive the servo to a particular position (normally within 0 to 180 degrees)
- Separate power and logic signals in 3-wire interface
- Can also remove the physical stop and replace the potentiometer with a fixed voltage divider to make a continuous rotation servo.



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Driving Servo Motor

- Standard servo is controlled pulses between 1 and 2 ms at a frequency of ~50 Hz.
  - 1 ms pulse = 0 degrees
  - 1.5 ms pulse = 90 degrees
  - 2 ms pulse = 180 degrees
- Continuous rotation servos change speed based on length of pulse

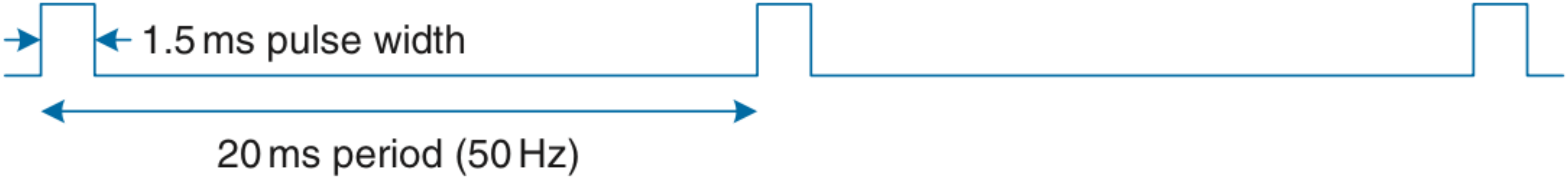

Figure e9.38 Servo control waveform

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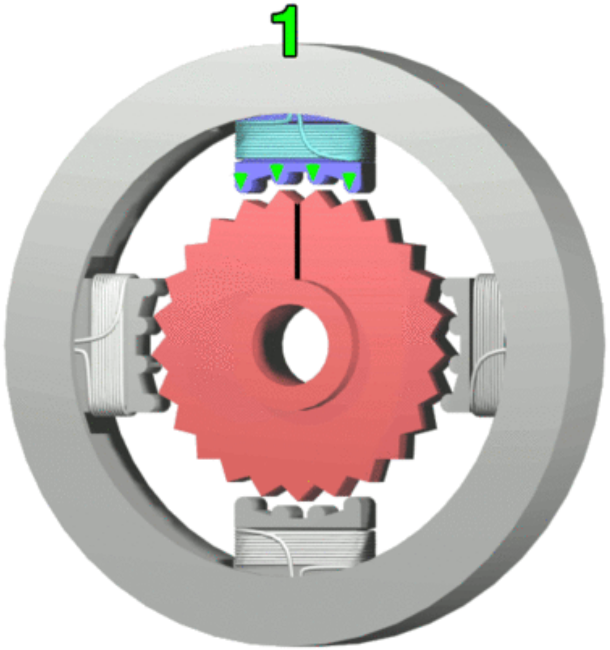
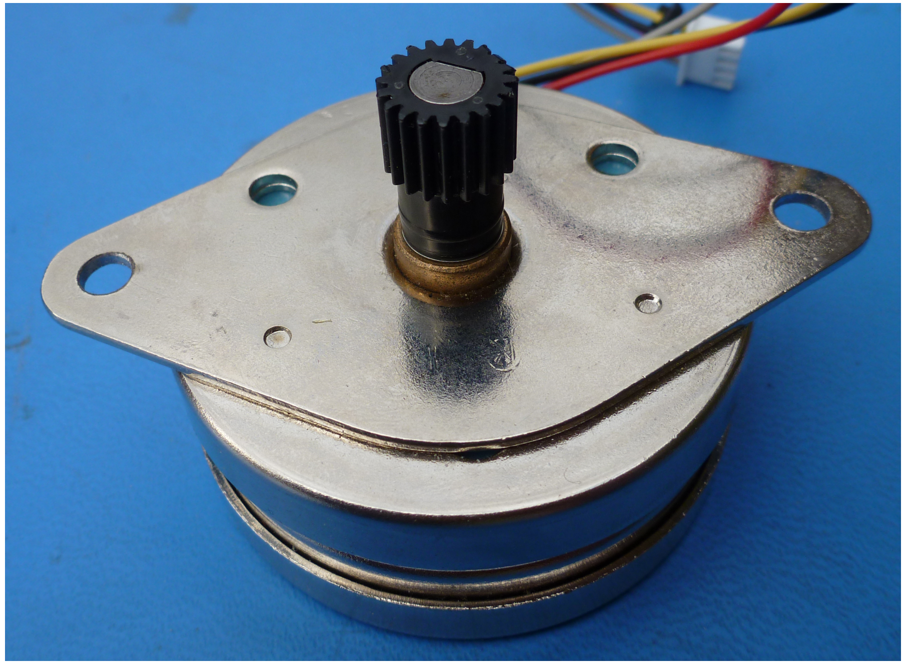
Stepper Motor

- Brushless motor with electromagnets with teeth





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Stepper motor by Wapcaplet; Teravolt. GFDL

Stepper Motor Operation

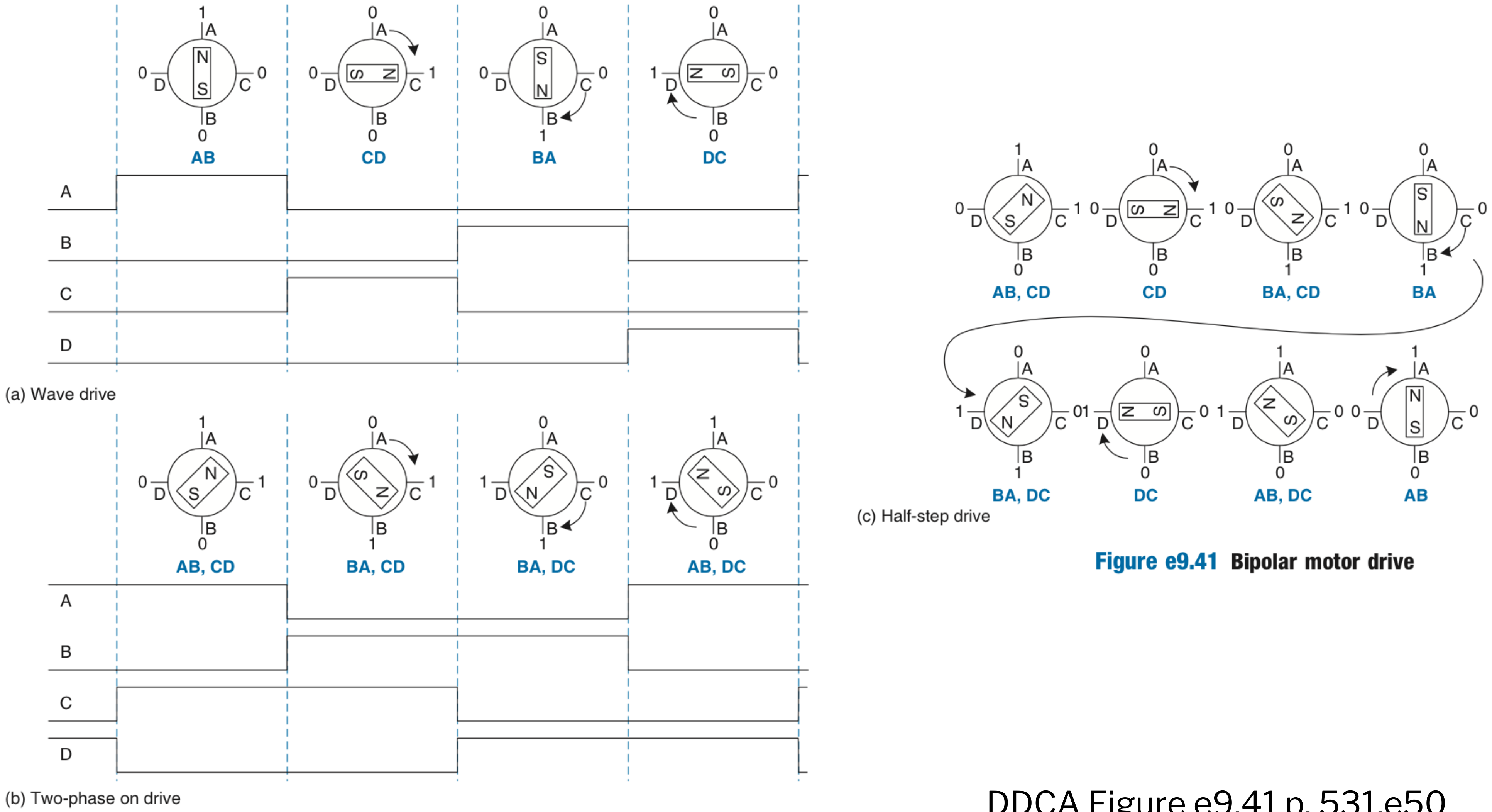

Figure e9.41 **Bipolar motor drive**

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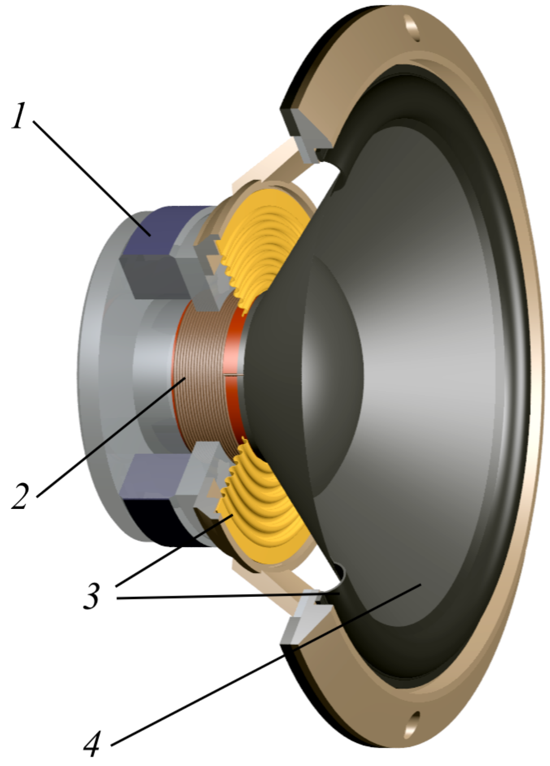
Speakers

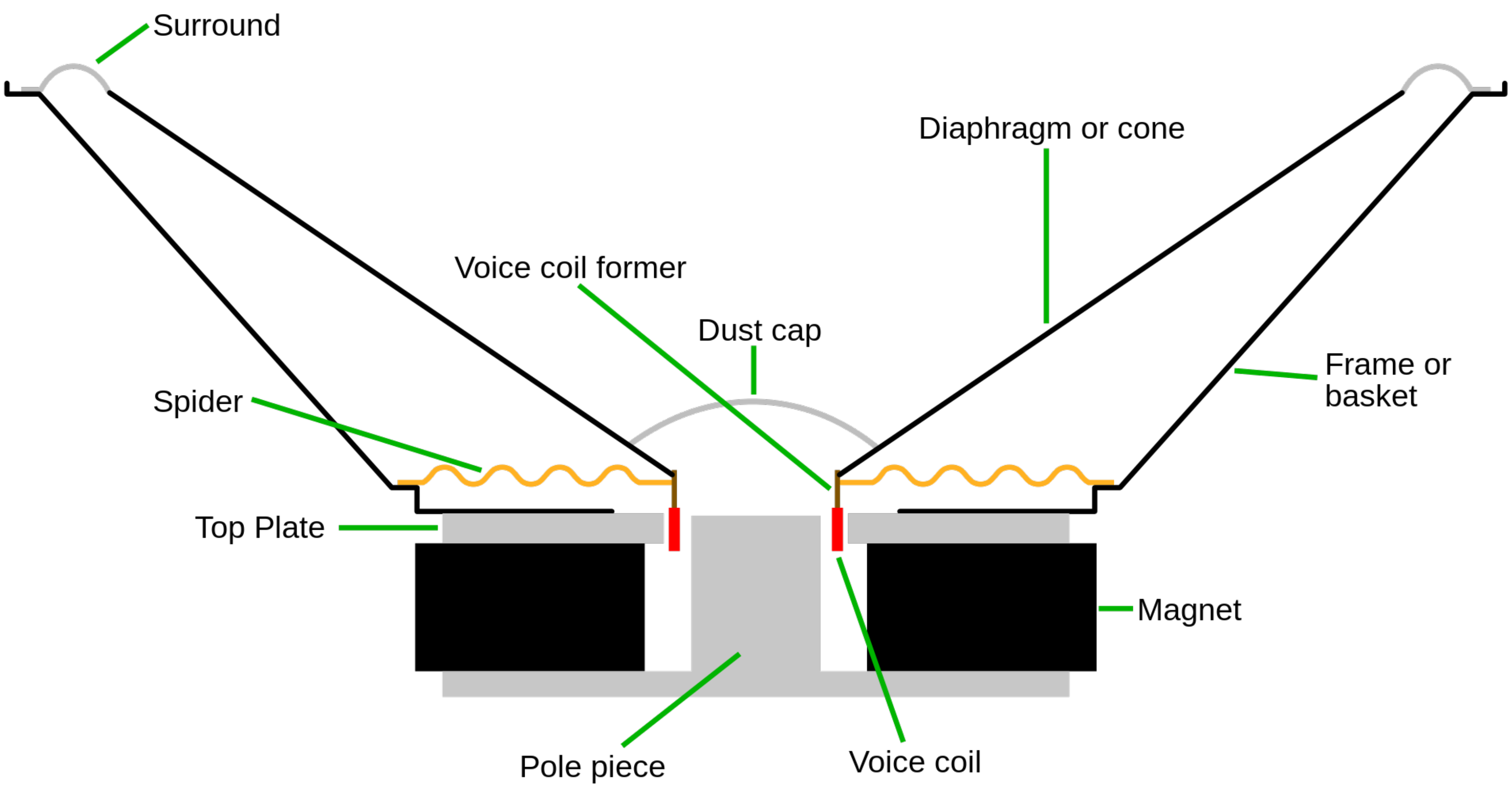
- Purpose: Convert electrical energy to mechanical vibration
- Drive current through the voice coil, creating a variable magnetic field.
- This in turn vibrates the diaphragm back and forth against the magnetic field from the permanent magnet to generate acoustic waves



1. Magnet
2. Voicecoil
3. Suspension
4. Diaphragm

"Loudspeaker bass" by Svjo CC BY-SA 3.0 link

Cross-sectional view



"Speaker cross section" by Iain CC BY-SA 3.0 link

Driving a speaker: LM386 Analysis

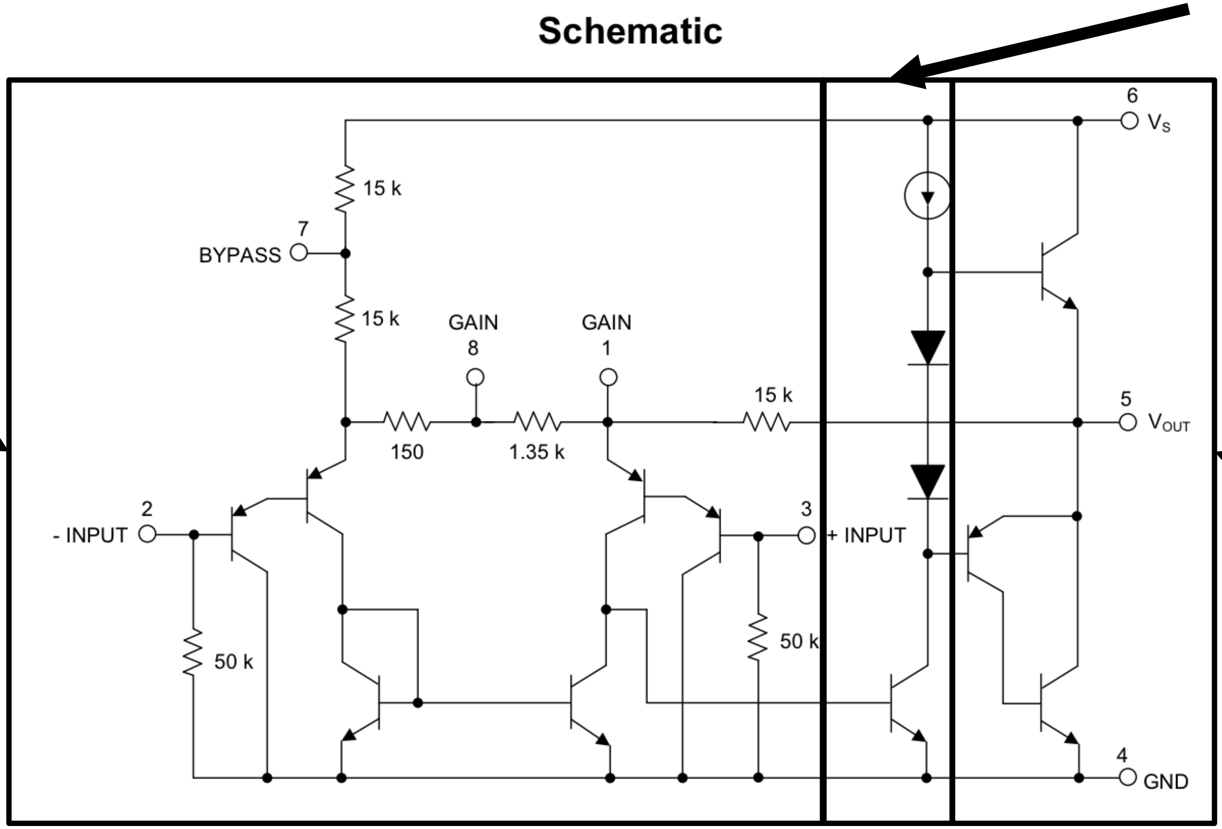
- Cannot drive directly from an MCU output since lots of current is required.

Voltage Amplification Stage

Common emitter amp

Input Stage

PNP emitter follower



Output Stage

Push-pull class AB

LM386 Datasheet (link)

https://www.electrosmash.com/lm386-analysis

Summary

- 4 main types of motors
  - DC brushed – simple but mechanical solutions create reliability issues
  - DC brushless – less mechanical issues but more complicated control
  - Servo – for closed-loop control
  - Stepper – many discrete steps
- Speakers
  - Designed to optimize transfer of electrical energy to acoustic waves
  - LM386 amplifier follows typical power amplifier design
    - Input amplification
    - Voltage amplification
    - Current amplifier