Motors and Speakers

Lecture 16

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Outline

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

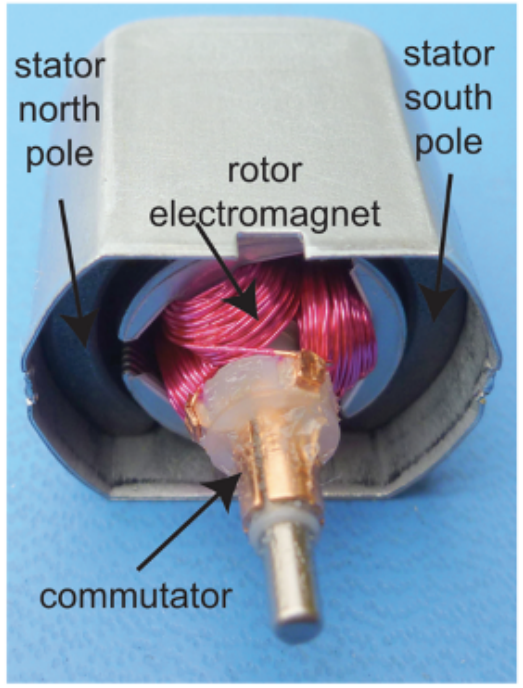
Learning Objectives

By the end of this lecture you will be able to…

- Describe how the most common kinds of motors work and what applications suit them.
- Describe the control signals required for various types of motors.
- Explain how a speaker works.

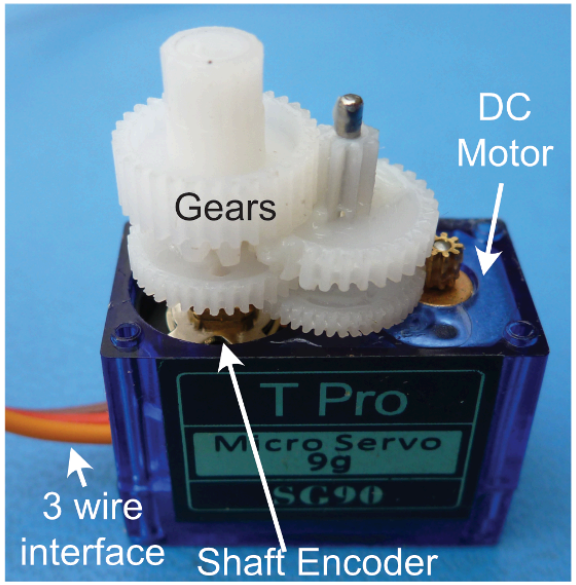
Main Types of Motors

DC (Brushed/Brushless)

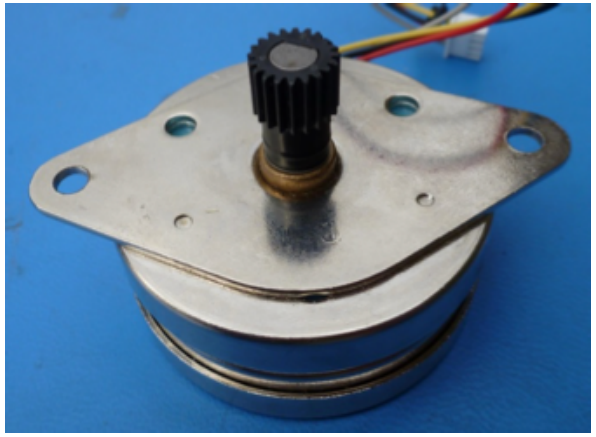


(b)

Servo

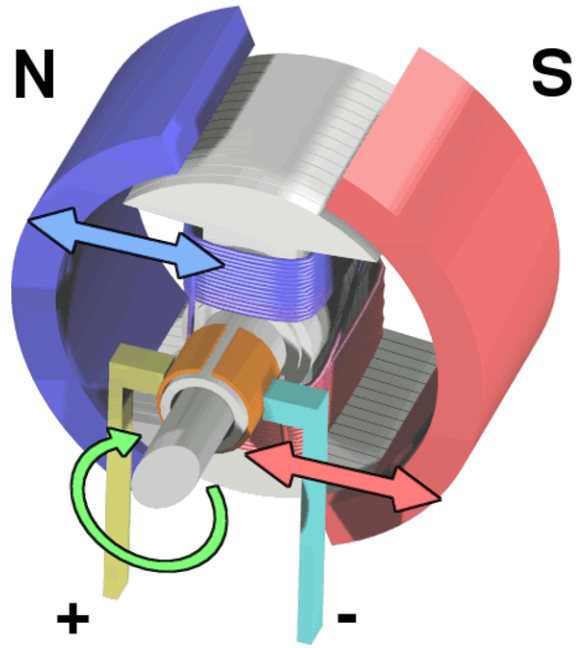


Stepper

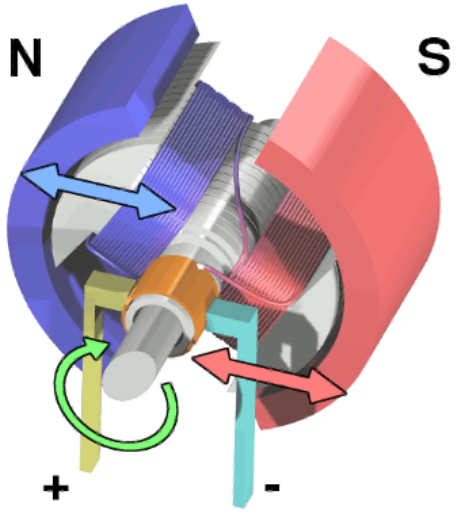


Typical DC Motor Architecture

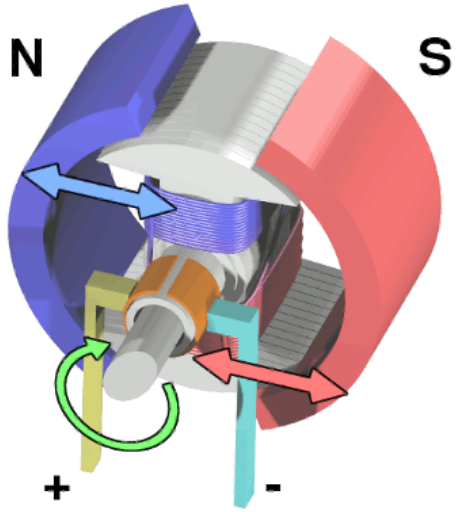
- Stator
- Rotor/Armature
- Commutator



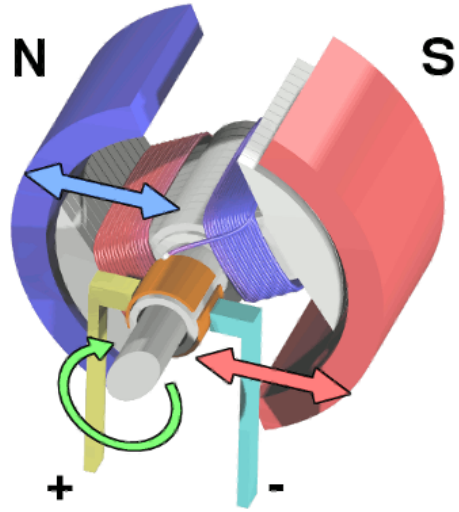
Brushed DC Motor Operation



Step 1



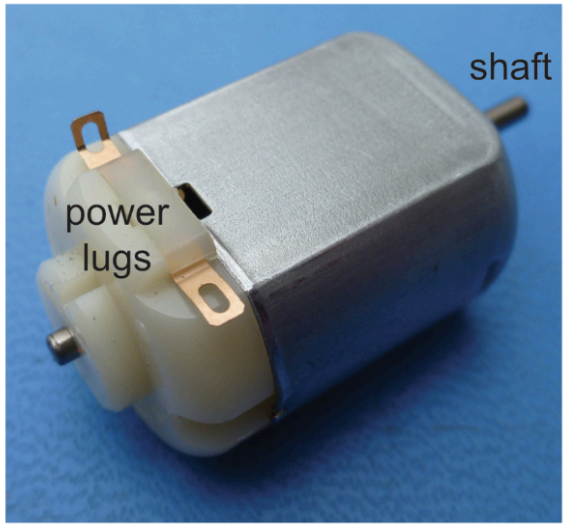
Step 2



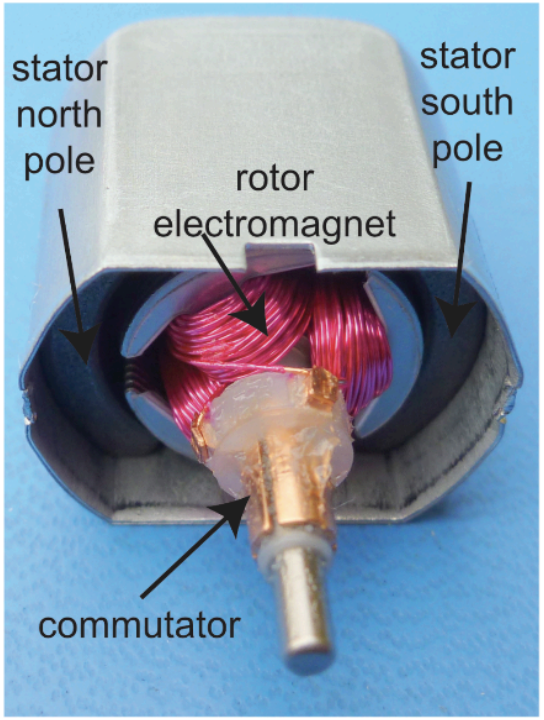
Step 3

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

Picture of a Disassembled DC motor



(a)



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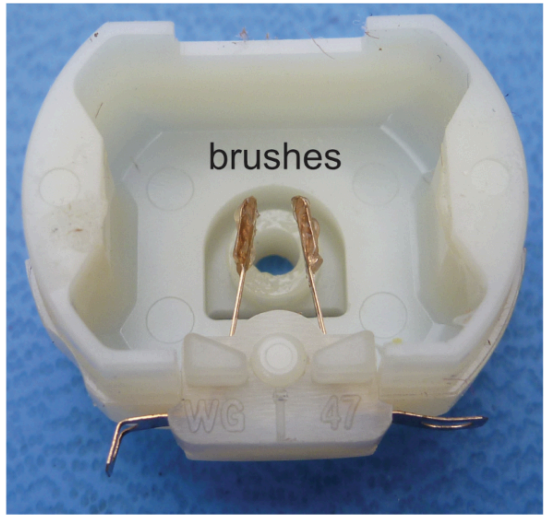


(c)

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

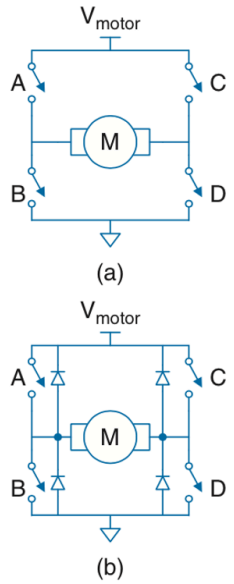


Figure e9.34 H-bridge

DDCA/ARMed Edition Figure e9.34 p. 531.e45
https://www.youtube.com/watch?v=YYMsS50x1UY

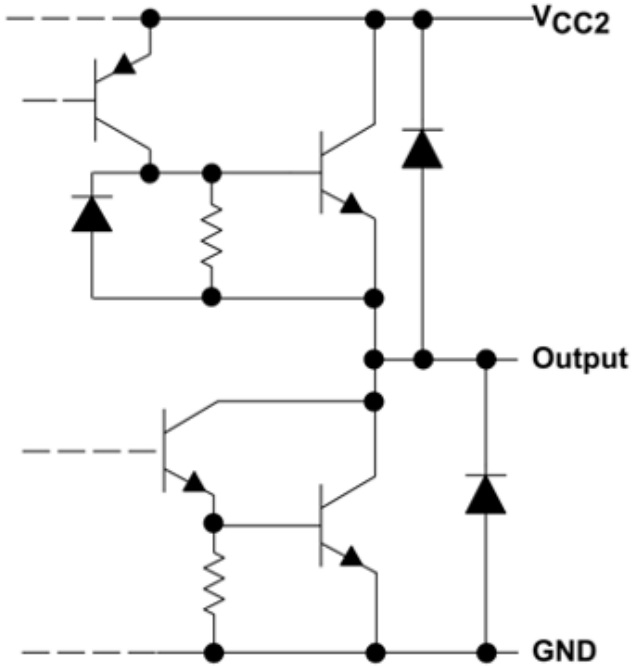


Figure 5. Typical of All Outputs

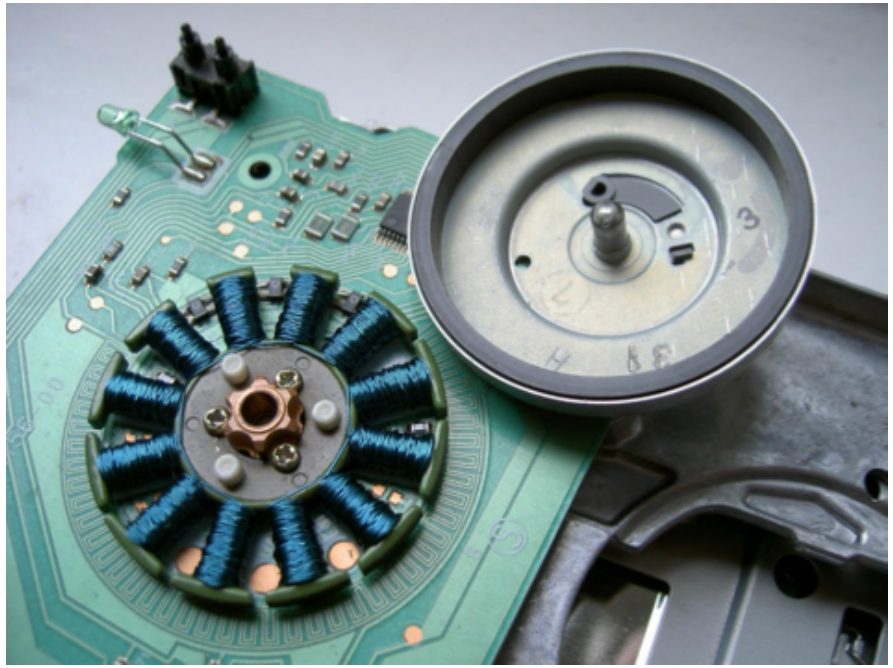
SN754410 Datasheet

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



“Floppy drive spindle motor open” by Sebastian Koppehel CC BY 3.0

Driving Brushless DC Motor

- 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

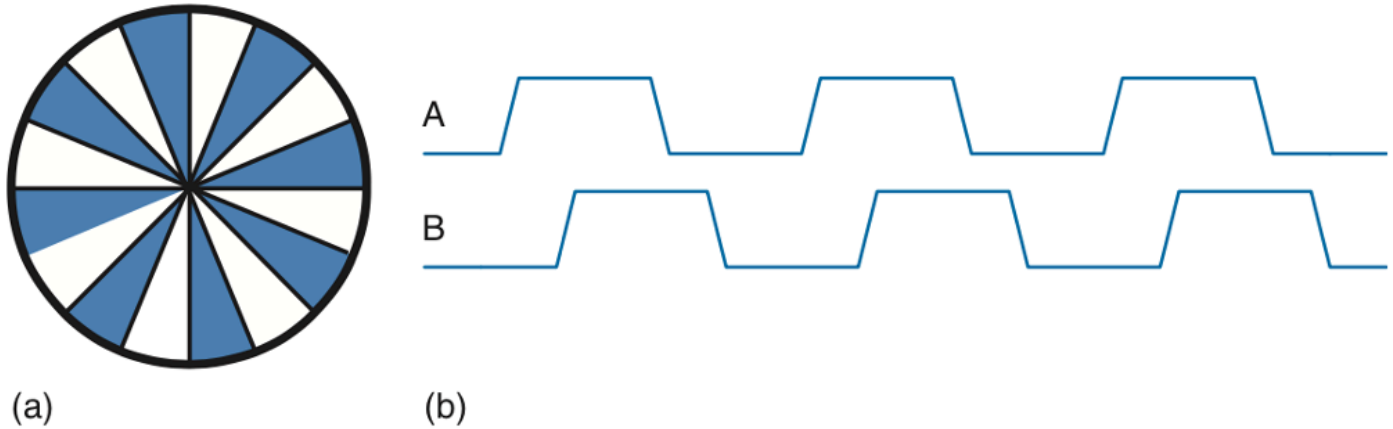
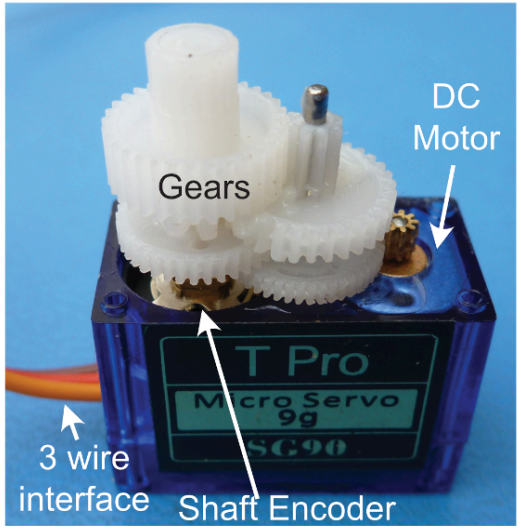


Figure e9.36 Shaft encoder (a) disk, (b) quadrature outputs

DDCA Figure e9.36 p. 531.e48

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.



DDCA Figure e9.37 p. 531.e48

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.

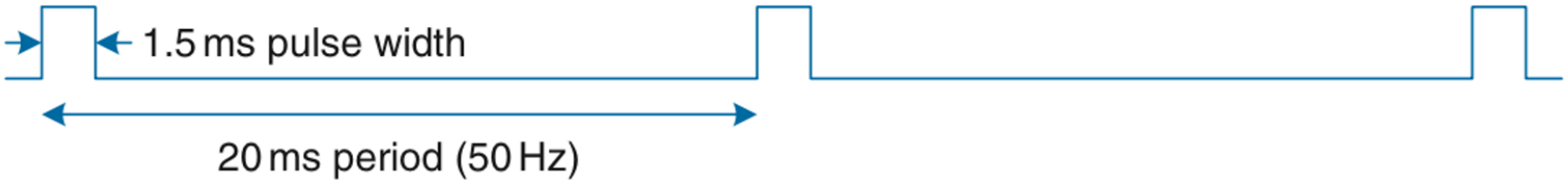
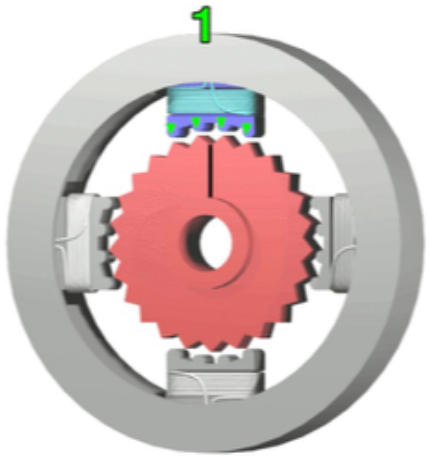


Figure e9.38 Servo control waveform

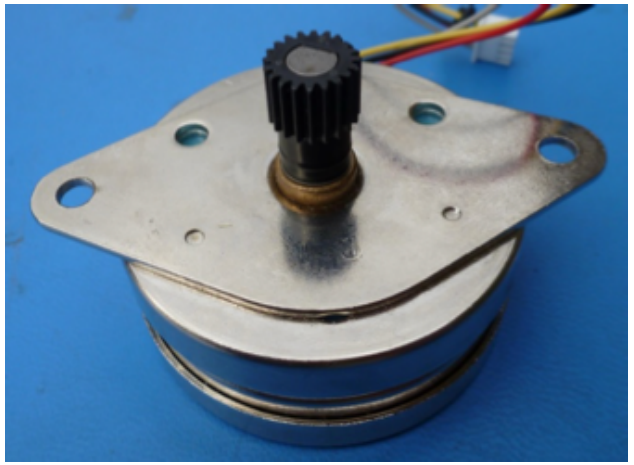
DDCA Figure e9.38 p. 531.e49

Stepper Motor

- Brushless motor with electromagnets with teeth

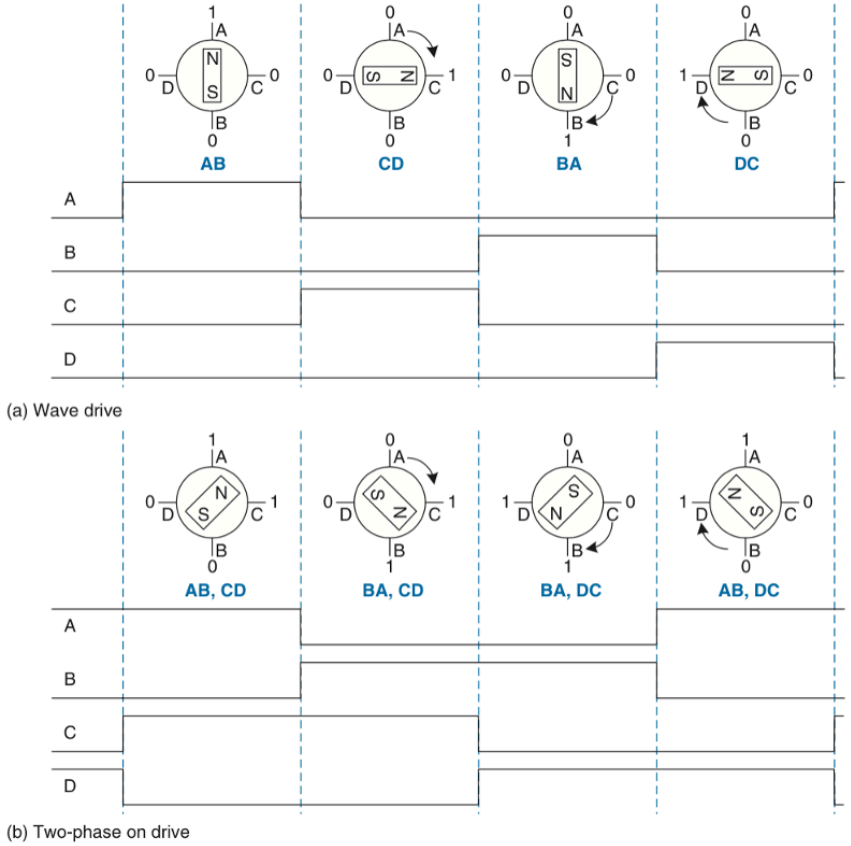


Stepper motor by Wapcaplet; Teravolt. GFDL



DDCA Figure e9.42 p. 531.e51

Sttper Motor Operation



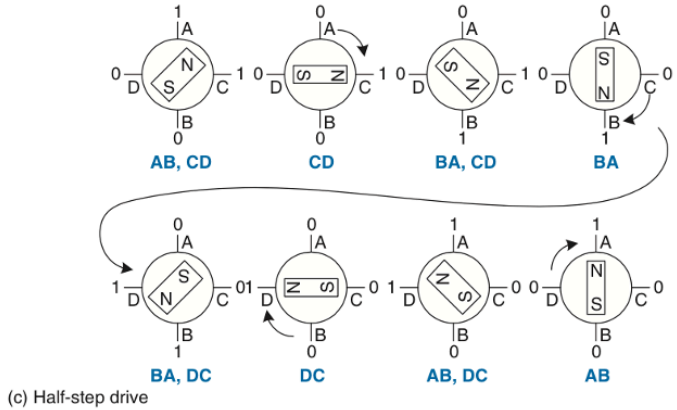
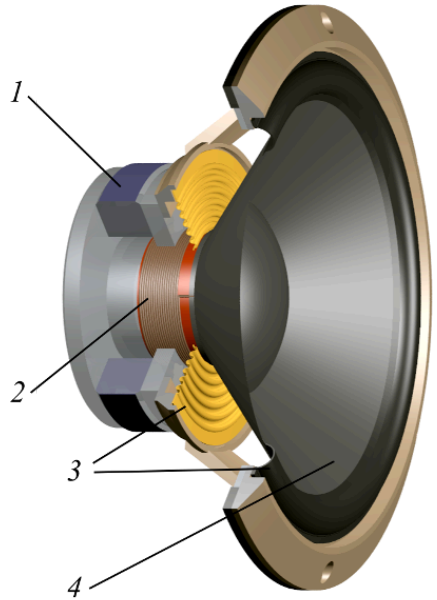


Figure e9.41 **Bipolar motor drive**

DDCA Figure e9.41 p. 531.e50

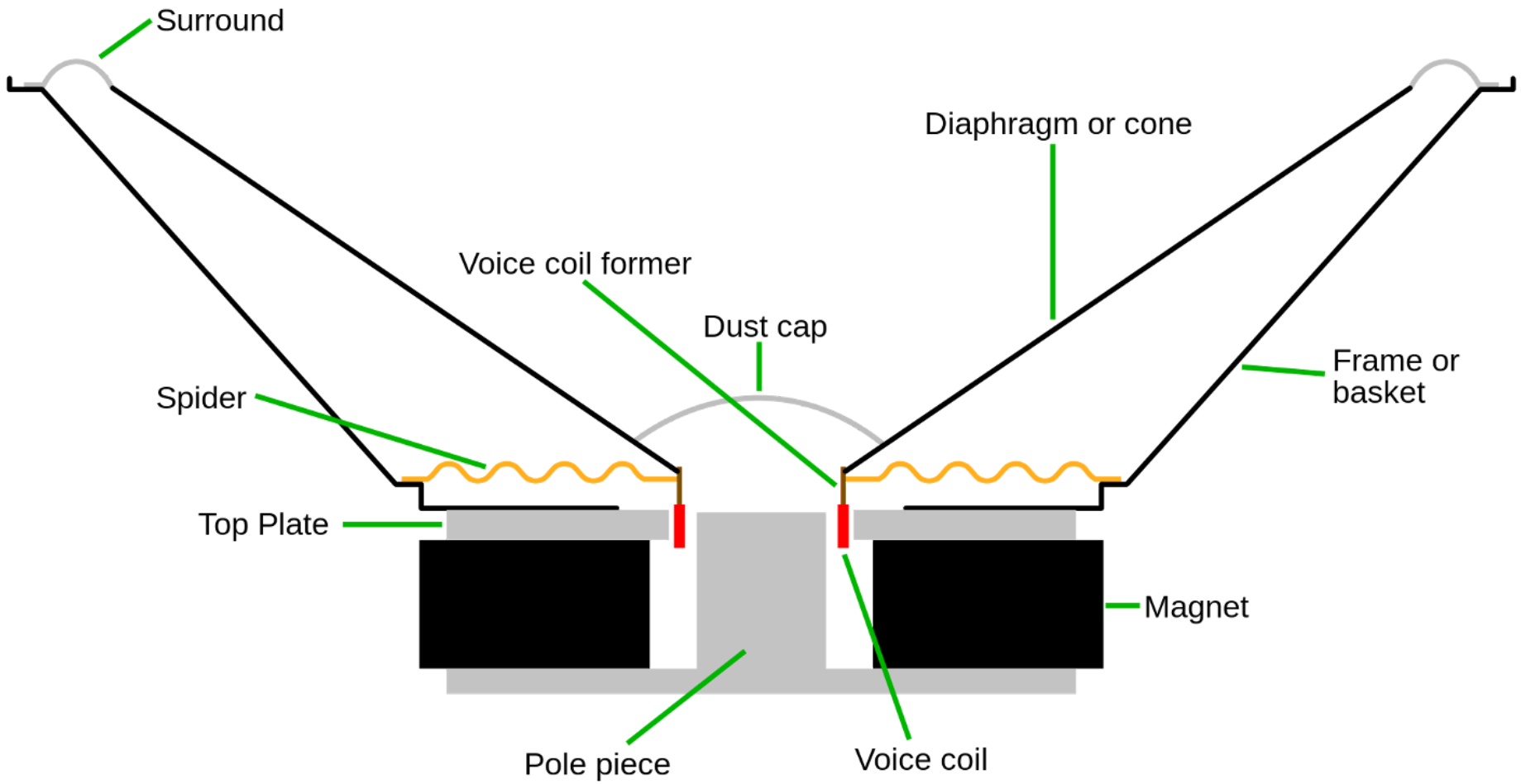
Speakers

- 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



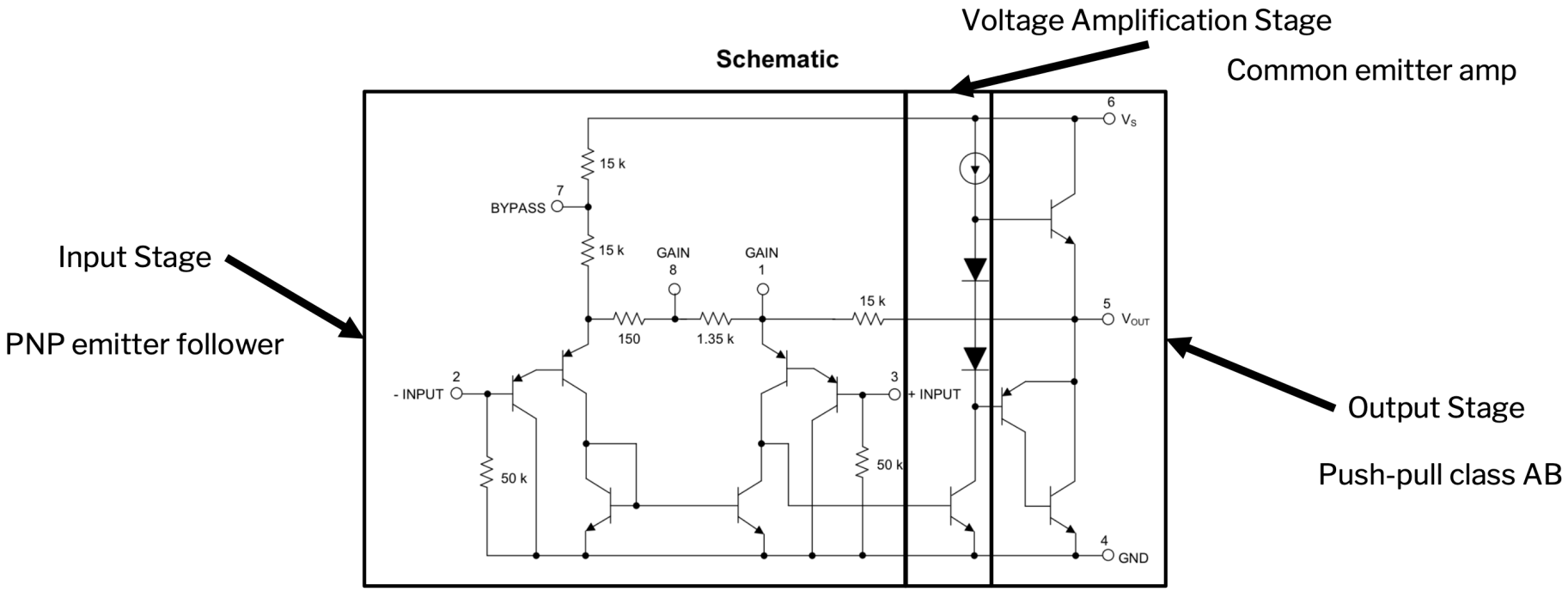
1. Magnet
2. Voicecoil
3. Suspension
4. Diaphragm

Cross-sectional View



Driving a Speaker: LM386 Analysis

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



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

LM386 Datasheet

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