University of Dhaka
Department of Computer Science and Engineering
CSE-2205: Introduction to Mechatronics

Lec-8: Sound Sensors

Mechatronics: Electronic Control Systems in Mechanical Engineering by W. Bolton

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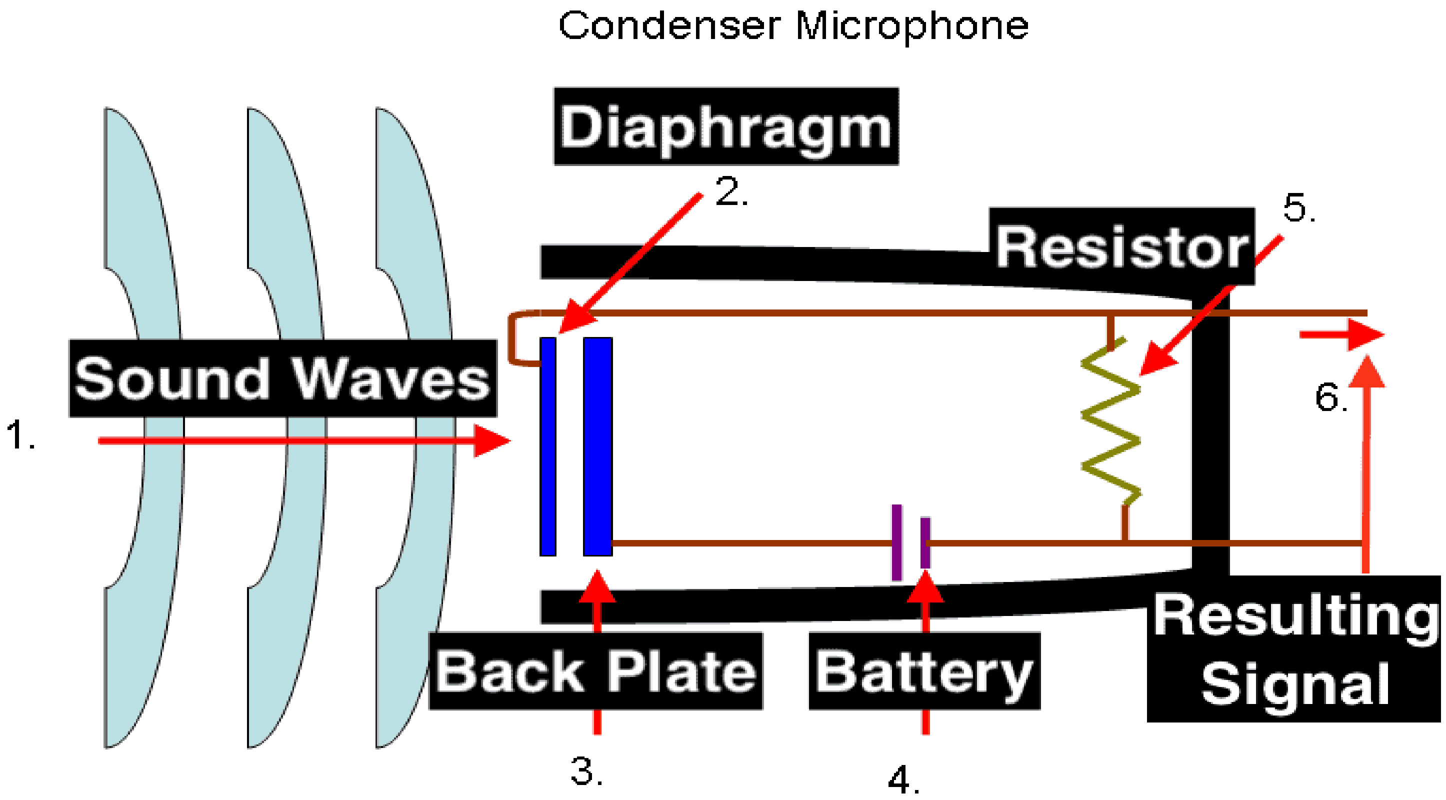
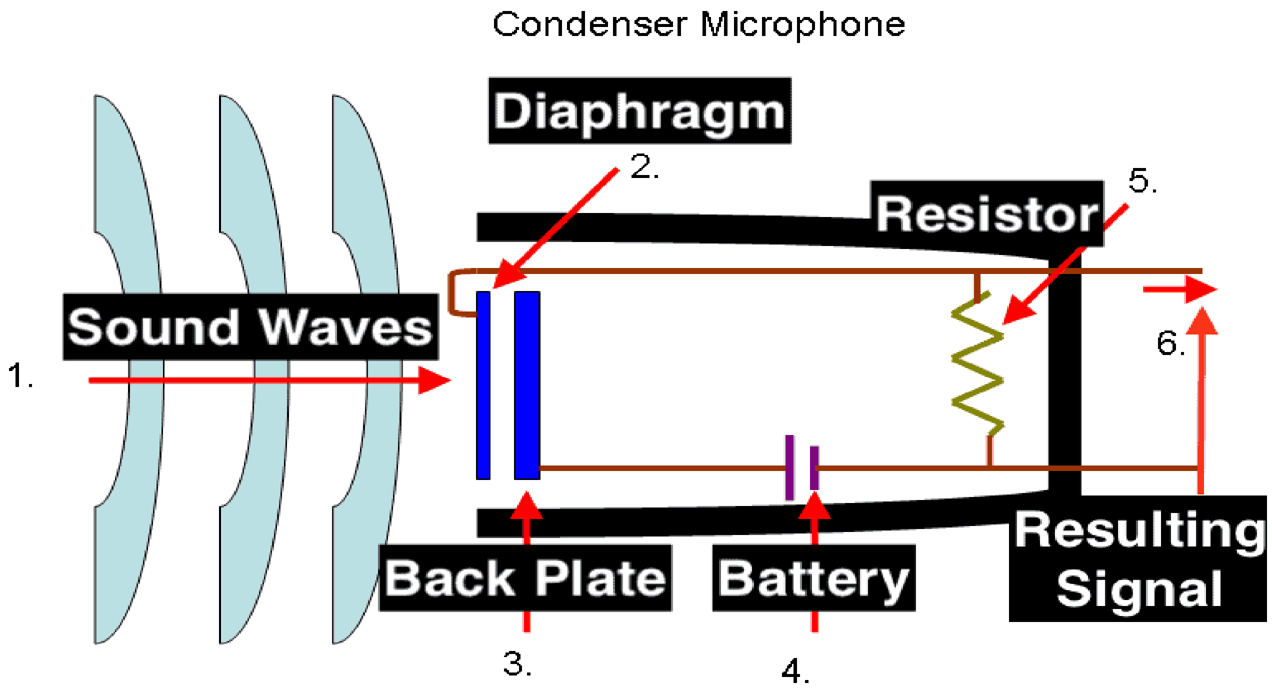
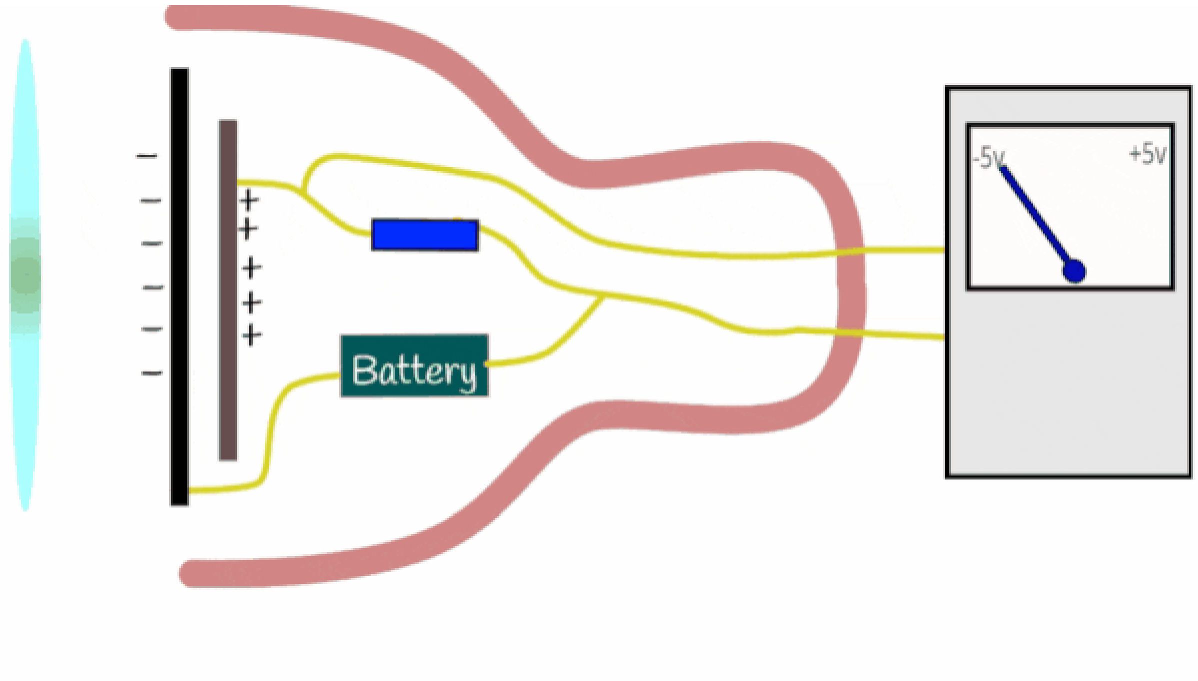
1. Condenser Microphones

Condenser microphones, also known as *capacitor microphones*, operate based on the principle of converting *sound waves into electrical signals* through *changes in capacitance*.



Sound Waves: Sound waves, *created by vibrations in the air*, enter the microphone and *hit the **diaphragm***.

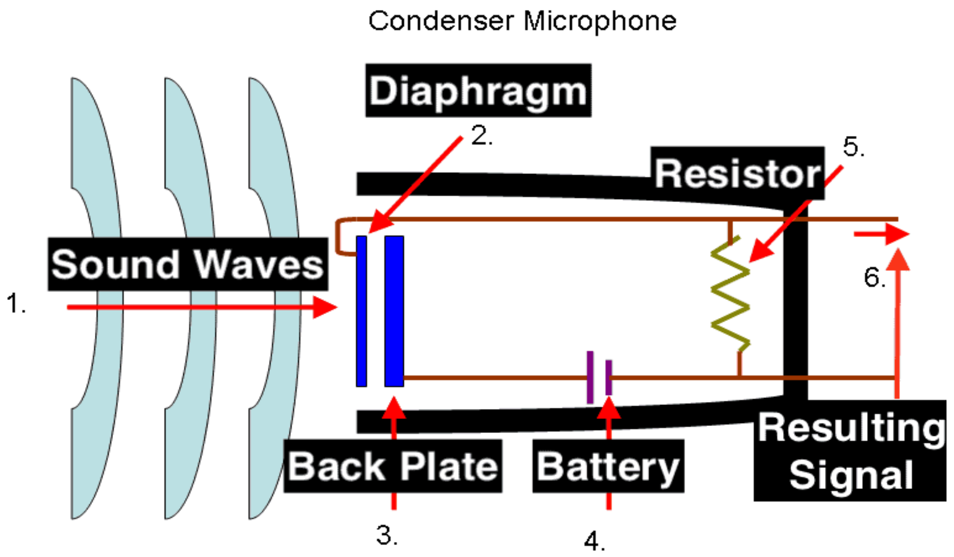




Diaphragm: The diaphragm is a *very thin, flexible material*, often made from a *metal-coated plastic or Mylar*, that acts as *one plate of a capacitor*. As sound *waves strike it*, the *diaphragm vibrates back and forth*.

Back Plate: Just *behind the diaphragm* is a back plate, *which is fixed and doesn't move*. This back plate, combined with the diaphragm, *forms a capacitor*.

When the *diaphragm moves due to sound waves*, the *distance between the diaphragm and back plate changes*, altering the capacitance.



$$C = \frac{\epsilon A}{d}$$

ϵ is the permittivity of the dielectric (air) between the plates,

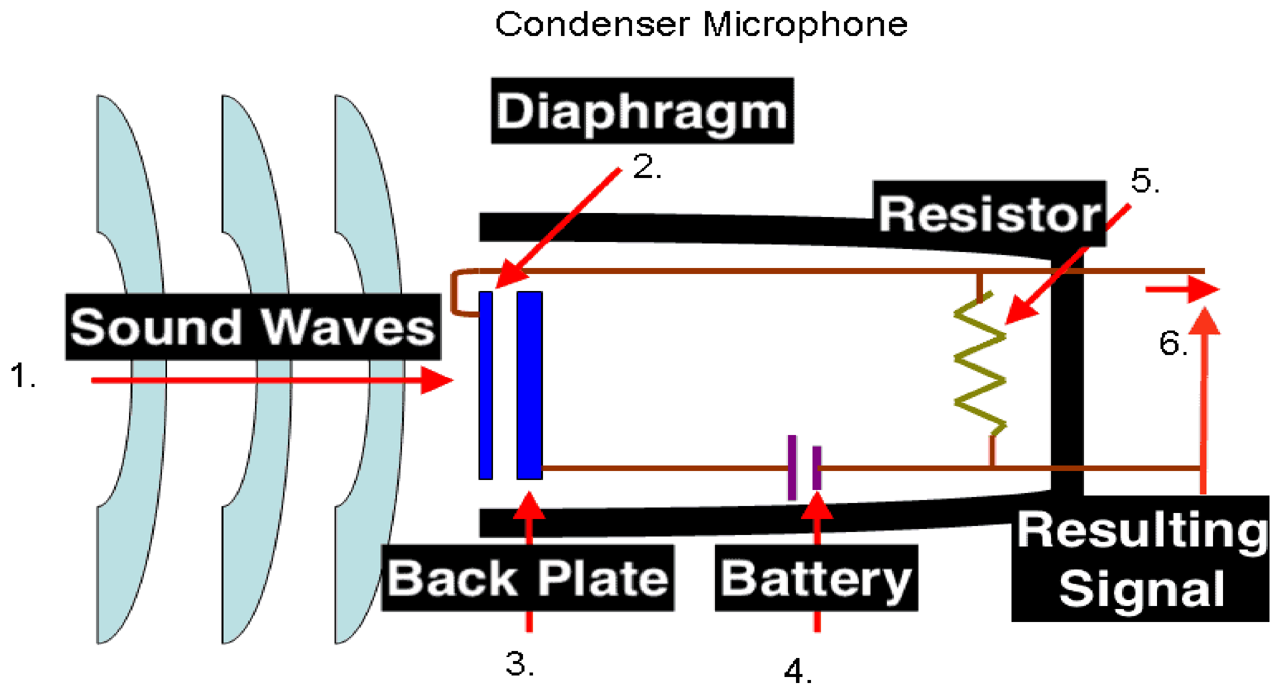
A is the surface area of the diaphragm,

d is the distance between the diaphragm and back plate.

$$C(t) = \frac{\epsilon A}{d(t)}$$

Battery: The microphone requires a **battery** or external power source, which is often referred to as "phantom power."

This power *<u>supplies a constant electric charge to the capacitor</u>* formed by the diaphragm and back plate.



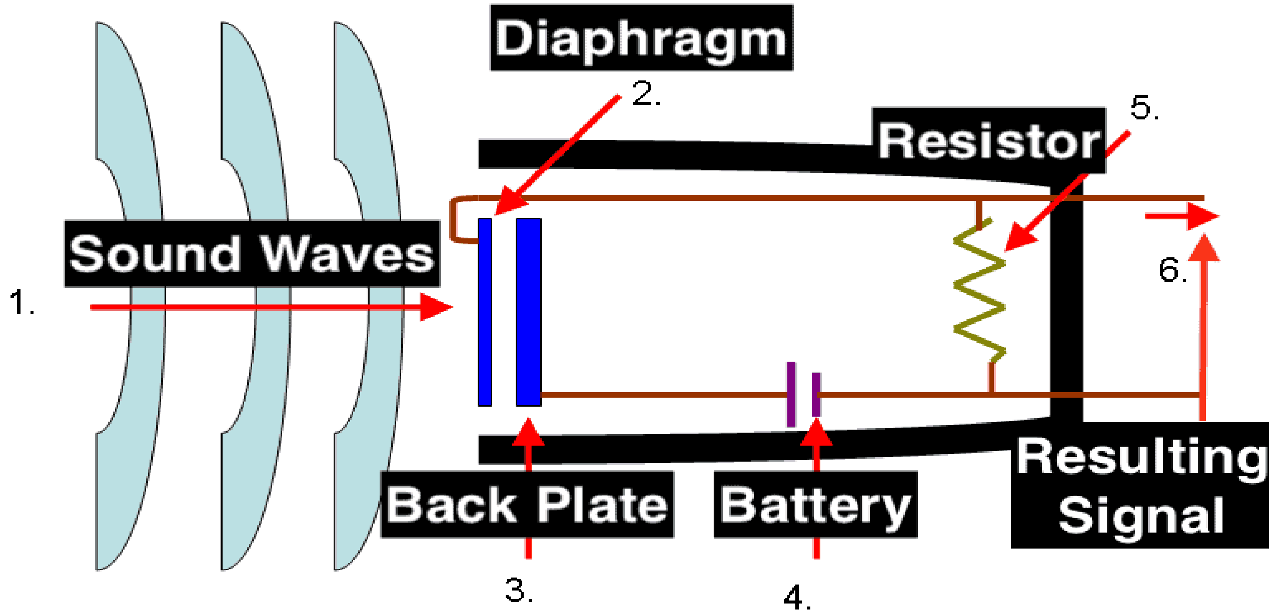
$$V_{Battery} = V_{Capacitor} + V_{Resistor}$$

Resistor: The power supply voltage is applied across a high **resistor** in the circuit, which helps maintain a steady current flow.

As the capacitance changes due to diaphragm movement, the *voltage across the capacitor also fluctuates*.

$$V(t) = \frac{Q}{C(t)} = \frac{Qd(t)}{\epsilon A}$$

Condenser Microphone

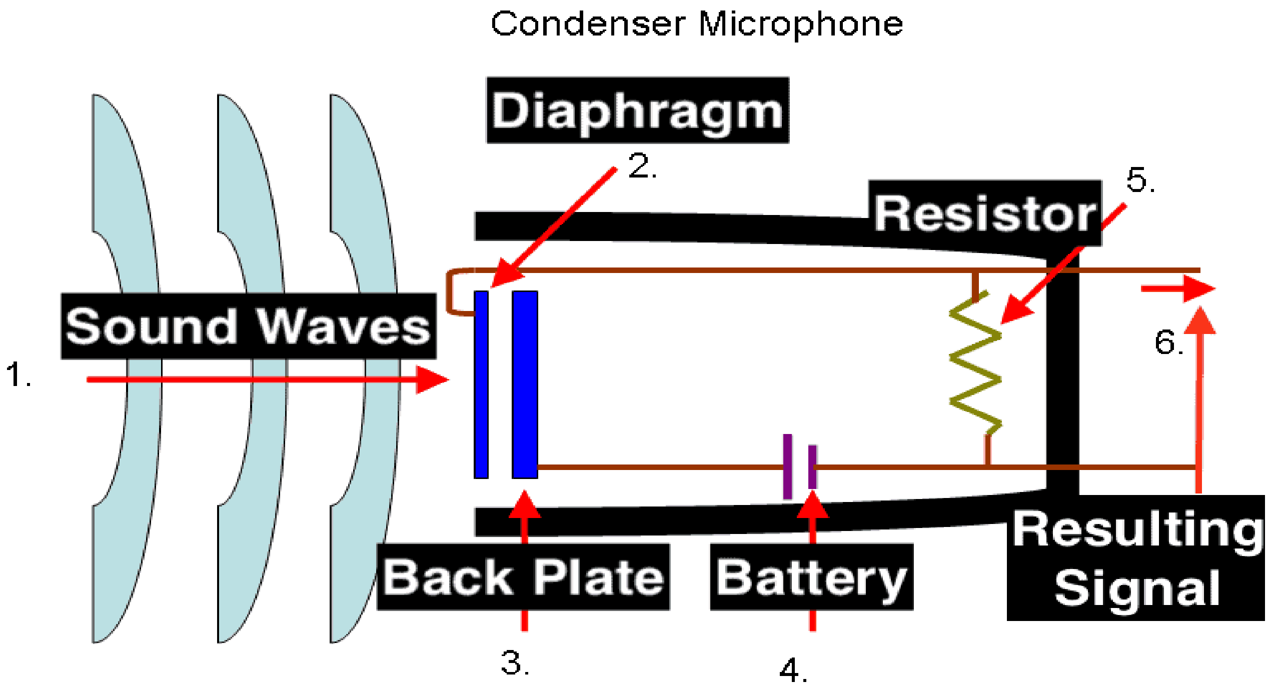


Resulting Signal: These *<u>fluctuations in capacitance create a corresponding voltage change</u>* in the circuit, which becomes the output signal.

<u>This signal is an electrical representation of the original sound wave</u>, where variations in voltage correspond to the variations in sound pressure hitting the diaphragm.

$$\Delta V \approx \frac{Q\,\Delta d}{\epsilon A}$$

$$V_{\text{Battery}} = V_{\text{Capacitor}} + V_{\text{Resistor}}$$



Permittivity $\epsilon = 8.85 \times 10^{-12}\,\mathrm{F/m}$,

Area $A = 1\,\mathrm{cm}^2 = 10^{-4}\,\mathrm{m}^2$,

Initial separation $d = 1\,\mu\mathrm{m} = 10^{-6}\,\mathrm{m}$,

Constant charge $Q = 10^{-8}\,\mathrm{C}$,

Then, initial capacitance C is:

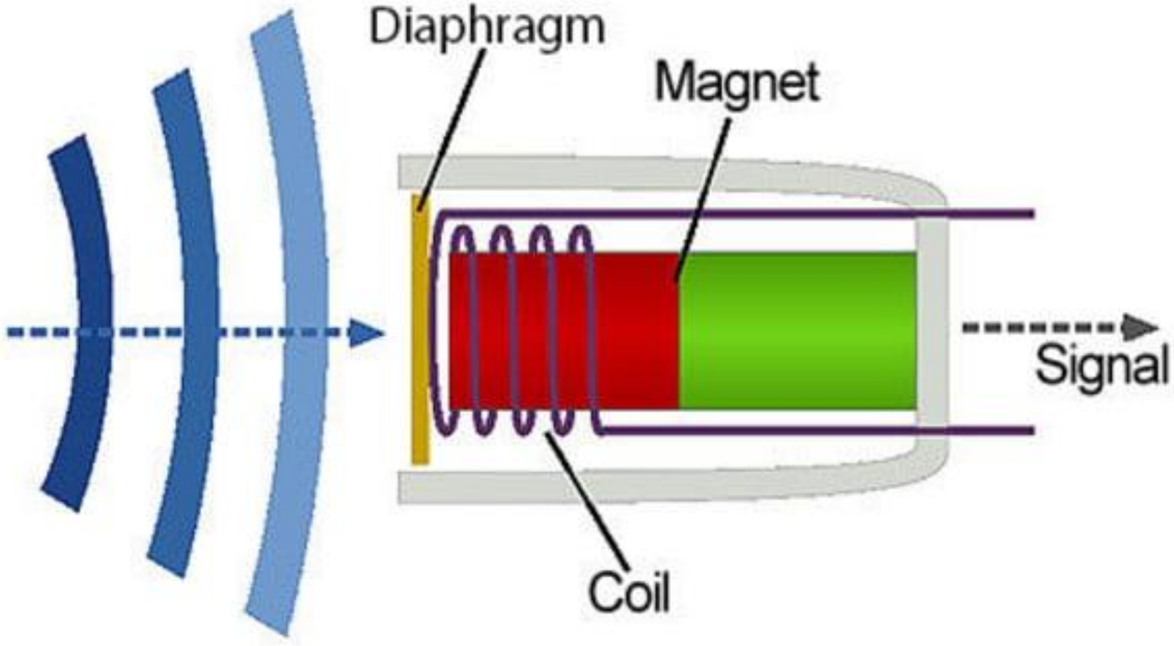
$$C = \frac{(8.85 \times 10^{-12}) \times (10^{-4})}{10^{-6}} = 8.85 \times 10^{-10}\,\mathrm{F}$$

If the diaphragm moves so that d changes by $\Delta d = 0.1\,\mu\mathrm{m}$, then the change in voltage ΔV would be:

$$\Delta V = \frac{(10^{-8}) \times (0.1 \times 10^{-6})}{8.85 \times 10^{-12} \times 10^{-4}} \approx 0.11\,\mathrm{V}$$

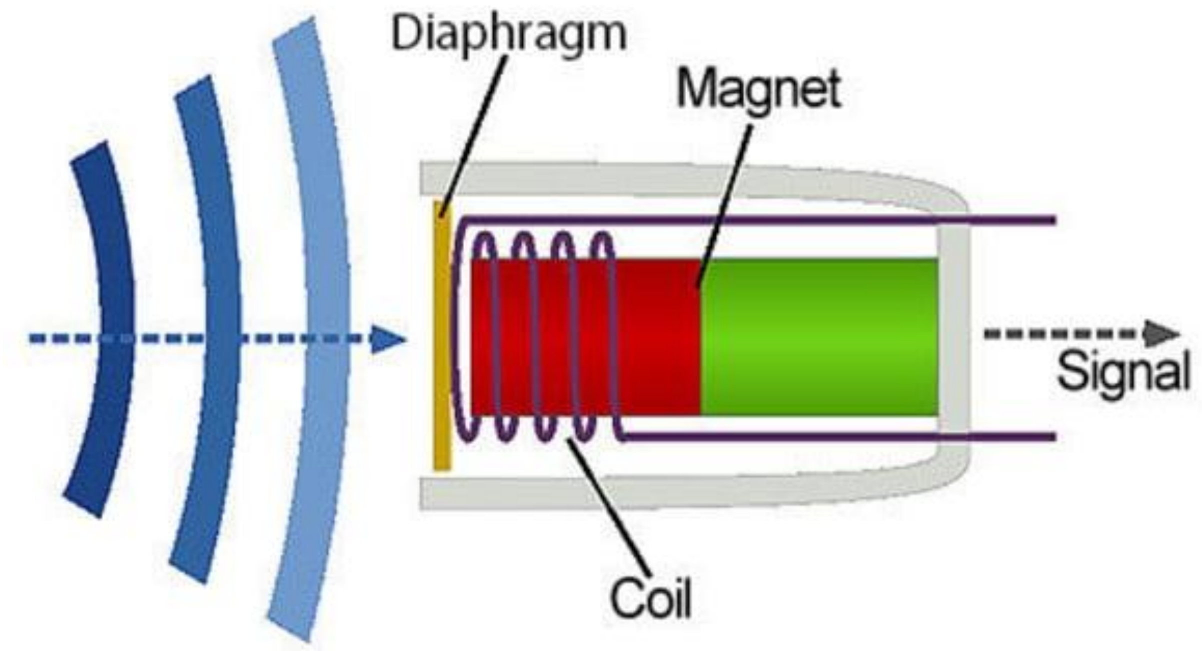
2. Dynamic Microphone

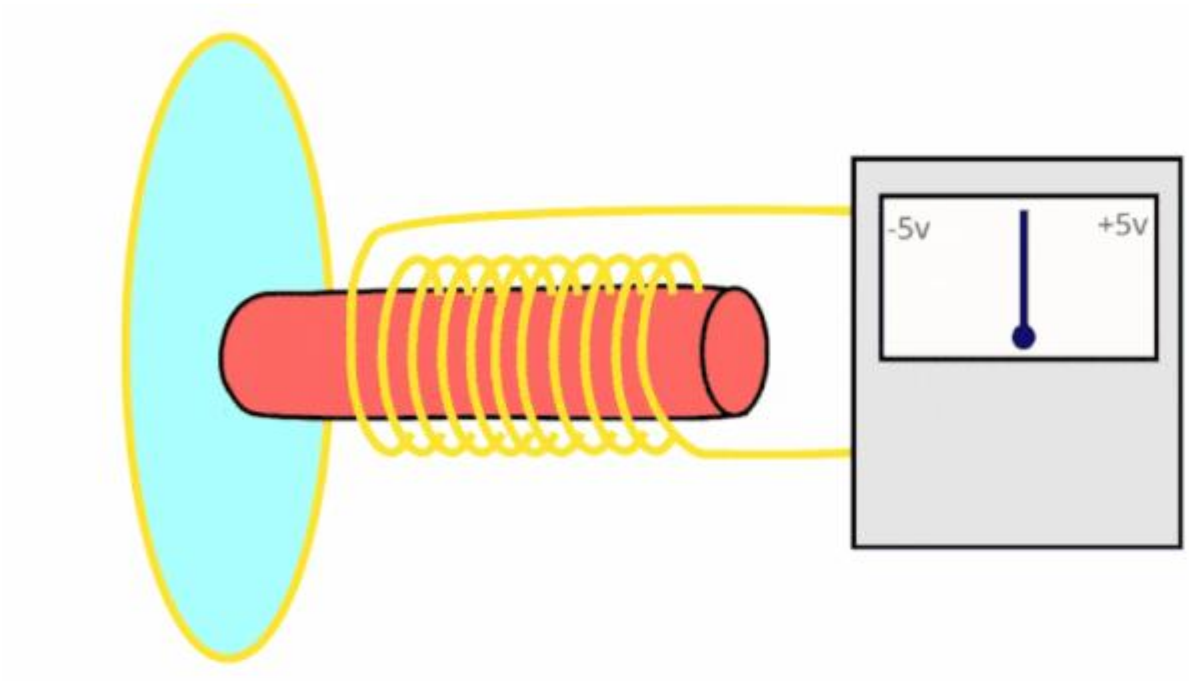
A dynamic microphone is a type of microphone that operates on the principle of *electromagnetic induction to capture audio*. It is a *durable and versatile* microphone commonly used for a wide range of applications, including live sound, broadcasting, recording, and public address systems.



Vibrating Diaphragm:

When sound waves from your voice or an instrument reach the microphone, they cause the ***diaphragm***, which is a thin, flexible membrane, to ***vibrate***. This ***vibration corresponds to the variations in air pressure*** created by the sound.

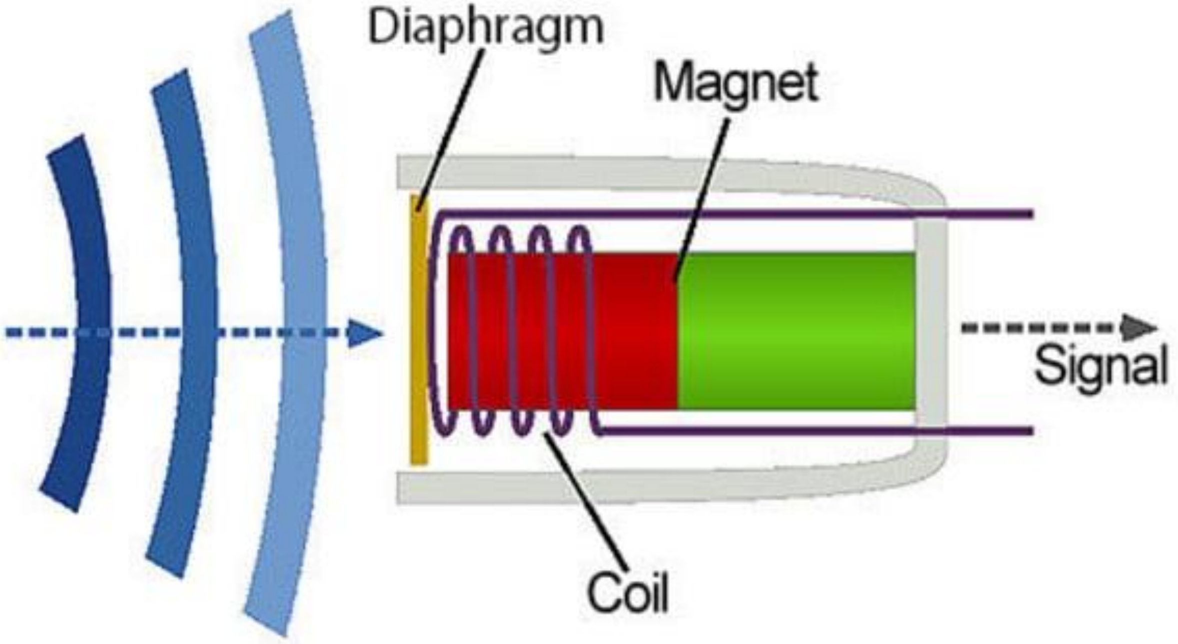




Voice Coil and Magnetic Field:

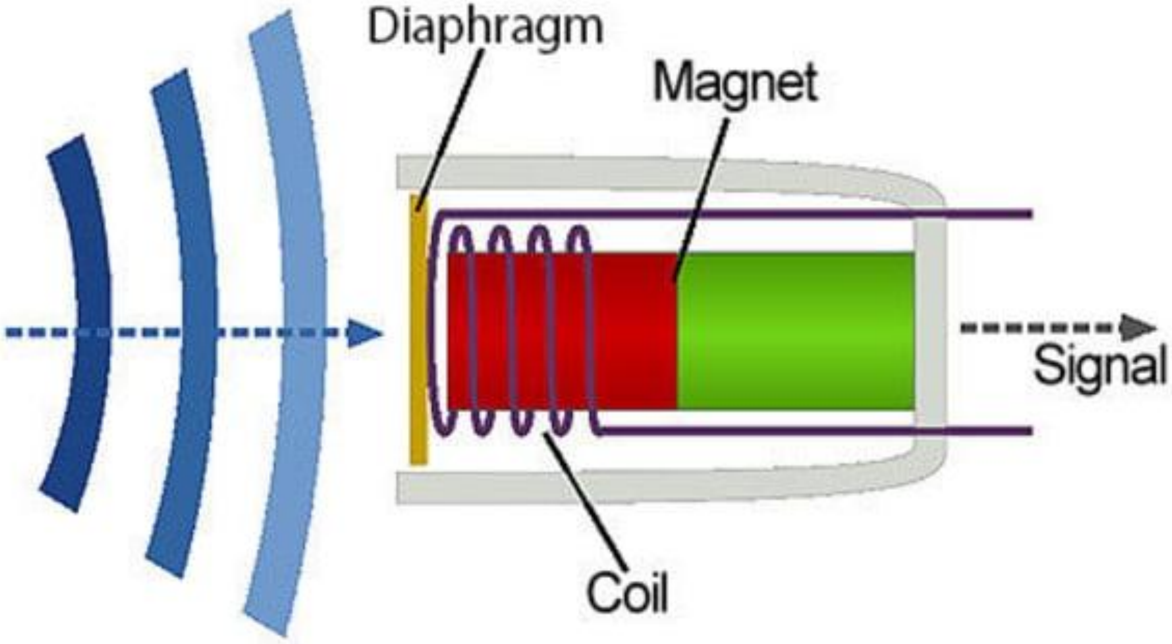
Inside the microphone, there is a *coil of wire called the voice coil*, which is *attached to the back of the diaphragm*. Surrounding the voice coil is a *permanent magnet that creates a constant magnetic field.*

$$\Phi = B \cdot A$$



Electromagnetic Interaction:

As the *<u>diaphragm vibrates</u>*, it moves the attached voice coil *<u>back and forth within the magnetic field</u>*. This motion of the voice coil inside the magnetic field results in a *<u>change in the magnetic environment experienced by the coil</u>*.



Electromagnetic Induction:

According to Faraday's law of electromagnetic induction, when a conductor (in this case, the voice coil) *moves within a changing magnetic field*, it *induces an electrical current in the conductor*. In this case, the motion of the voice coil within the magnetic field leads to variations in the magnetic field strength experienced by the coil, resulting in the generation of an electrical current.

$$V = -N\frac{d\Phi}{dt}$$

N is the number of turns in the voice coil,

$\frac{d\Phi}{dt}$ is the rate of change of magnetic flux through the coil.