Electroacoustics

Transformation of sound into electrical signals and the other way round. In particular loud-speakers and microphones are discussed.

WS 16/17
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Electroacoustics

Study of transformation of sound into electrical signals and the other way round

- Recording, storage, amplification, transmission, and reproduction of acoustics signals
- Part of electrical engineering as well as acoustics

Starting point

Telephone (Philipp Reis, Graham Bell, Antonio Meucci, around 1860)

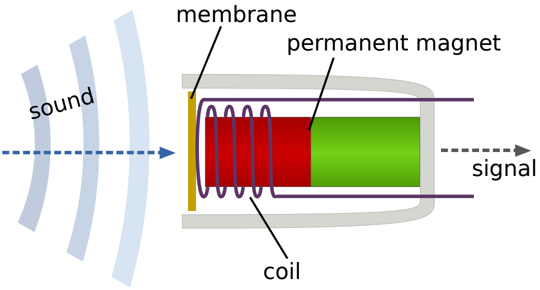
Further milestones

1876	Graham Bell	Telephone
1877	Thomas A. Edison	Carbon microphone
1898	Sir Oliver Lodge	Electrodynamic loudspeaker
1906	Lee De Forest	Electron tube
1917	C. Wente	Condenser microphone
1924	Siemens	Ribbon microphone and loudspeaker
1930	Neumann	Neumann bottle
1930-40	Firma Jensen	Bass reflex box
1936	Benjamin Olney	Labyrinth box
1962	G.Sessler/J.West	Electret microphone

Microphones

- Capture sound pressure
- Electro-magnetic transducers
- Directivity
- Frequency response

Dynamic microphone



[1]

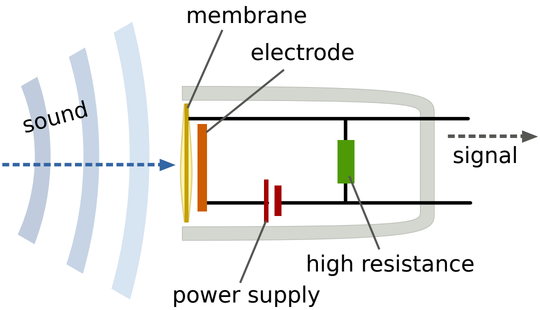
- **Principal:** electrodynamically induction
- Robust
- Applications in PA-area

Dynamic microphone

[2]

- **Principal:** electrodynamically induction
- Robust
- Applications in PA-area

Condenser microphone



[3]

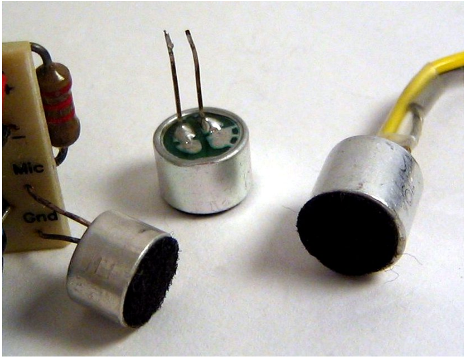
- **Principal:** charged capacitor
- Phantom power required
- High-class microphones

Condenser microphone

[5]

- **Principal:** charged capacitor
- Phantom power required
- High-class microphones

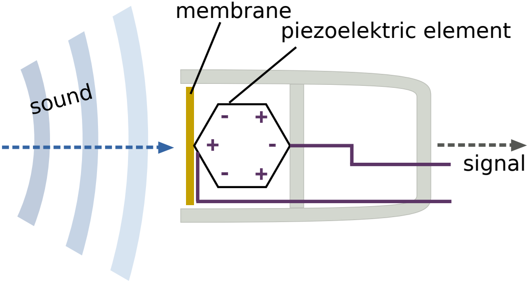
Electret-condenser microphone



[4]

- **Principal:** Bias voltage through electret foil
- Impedance transducer in capsule
- Very high market share

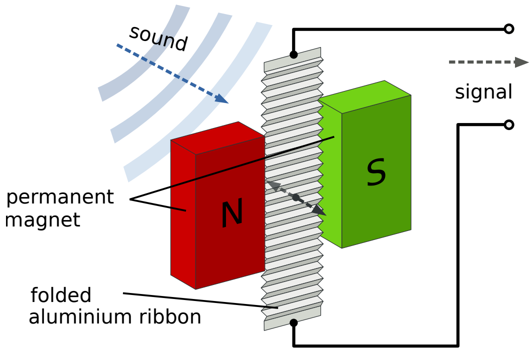
Piezo microphone



[6]

- **Principal:** piezo-electrically effect
- Pressure moves electrical particles
- Low quality

Ribbon microphone



[7]

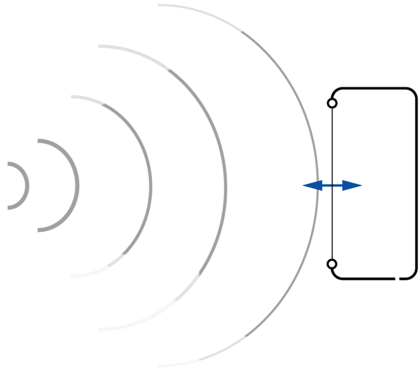
- **Principal:** electrodynamically induction
- Combination membrane/transducer
- Pressure-gradient microphone

Ribbon microphone

- **Principal:** electrodynamically induction
- Combination membrane/transducer
- Pressure-gradient microphone

Pressure microphones

Membrane in front of a closed cavity

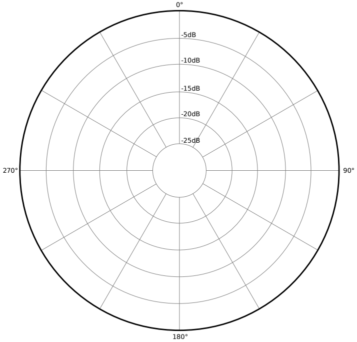


Adapted from [8]

- Closed capsule behind membrane
- Capillary opening

Pressure microphone

Directivity: omnidirectional

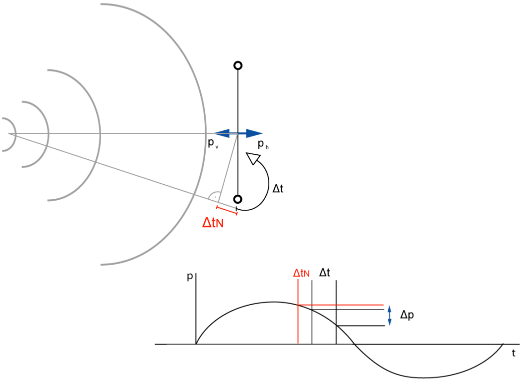


[9]

- Directivity $A(\alpha) = 1$
- Wave length $<$ size of membrane
- Sensitivity increases with size of membrane

Pressure-gradient microphones

Membrane is open at both sides

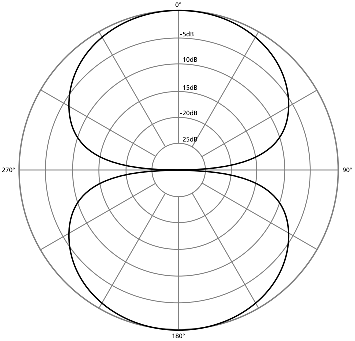


Adapted from [10]

- Increased sensitivity for near point sources (proximity effect)
- High-pass characteristic at far-field of source

Pressure-gradient microphones

Directivity: eight



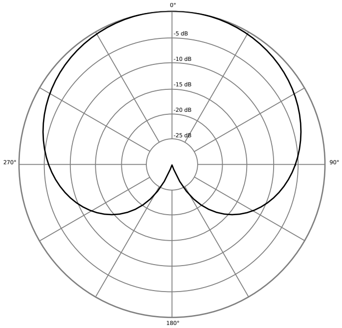
[11]

- Directivity $A(\alpha) = \cos(\alpha)$

Combinations of directivities

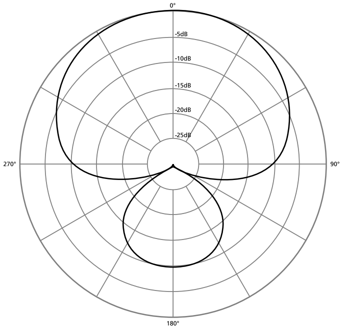
Different directivities are possible through combinations

$$A(\alpha) = a + b\cos(\alpha), \text{ with } a + b = 1.$$



[12]

Cardioid, $a = 0.5$, $b = 0.5$



[13]

Supercardioid, $a = 0, 37$, $b = 0.63$

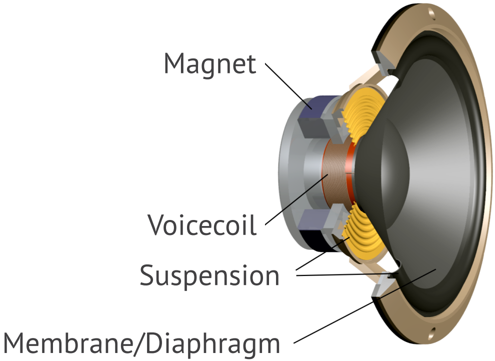
Important microphone parameters

- **Sensitivity:** output voltage in mV/Pa
- **Maximum sound pressure level:** Maximum level without considerable distortions
- **Inherent noise**
- **Frequency response:** high pass, …
- **Directivity:** omnidirectional, eight, cardioid, …
- **Non-linear distortions:** distortion factor (German: “Klirrfaktor”)
- **Impedance:** Electric output impedance, capacity

Loudspeakers

- Generate sound pressure
- Directivity
- Frequency response

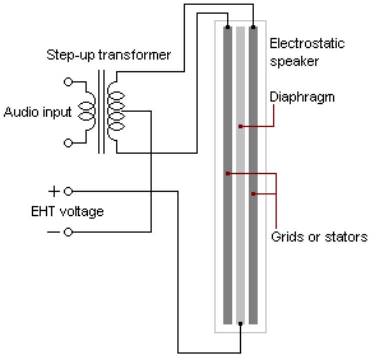
Electrodynamic cone loudspeaker



Adapted from [14]

- Very common type of loudspeaker
- Behaves like as a dipole radiator
- Directivity depends on membrane diameter

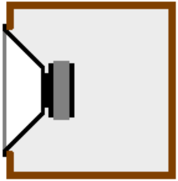
Electro-static loudspeaker



[15]

- Use electro-static attractive force
- Electric charge for linear frequency response
- Lightweight membrane, dipole radiator
- Relatively poor reproduction of low frequencies

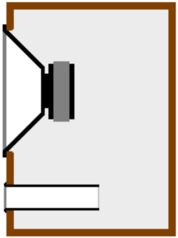
Sealed loudspeaker enclosure



[16]

- **Principle:** Cancellation of reward sound
- Absorbing material in enclosure
- Air cushion changes loudspeaker characteristics

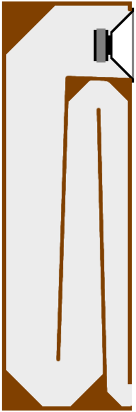
Bass reflex enclosure



[17]

- **Principle:** Helmholtz resonator
- Matching tube diameter/length
- Amplification of low frequencies

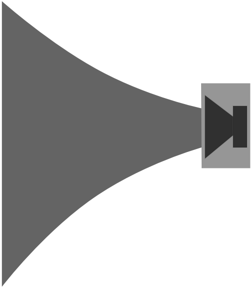
Transmission line enclosure



[18]

- **Principle:** tube with open end
- Standing wave in tube
- Radiation at resonance frequency

Horn loudspeaker



[19]

- **Principle:** Acoustic impedance transformation
- Improved efficiency factor
- Complex construction

Horn loudspeaker

[20]

- **Principle:** Acoustic impedance transformation
- Improved efficiency factor
- Complex construction

Sound pressure level of a point source

$$L = 10\lg P - 20\lg r + 10\lg \frac{\rho_0 c}{4\pi p_0^2}$$

- Doubling of distance at constant power: $-6\,\mathrm{dB}$
- Doubling of power at constant distance: $+3\,\mathrm{dB}$

Maximum sensitivity at $P = 1\,\mathrm{W}$ and $r = 1\,\mathrm{m}$:

$$L = 10\lg \frac{\rho_0 c}{4\pi p_0^2} = 109.1\,\mathrm{dB}$$

Important loudspeaker parameter

- **Frequency range:** low-, medium-, high-frequency
- **Frequency response:**
- **Sensitivity:** sound pressure level in 1 m distance at 1 W electric input power
- **Electric robustness:** long and/or short term robustness
- **Directivity:** varies with frequency
- **Nonlinear distortions:** distortion factor (German: “Klirrfaktor”)
- **Impedance:** typically 4 Ω or 8 Ω

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