Loudspeakers

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Outline

1. Loudspeaker Types
2. Loudspeaker Enclosures
3. Multiple drivers, Crossover Networks
4. Performance Measurements
Loudspeakers

- Microphone: acoustical sound energy $\rightarrow$ electrical energy
- Loudspeaker: electrical energy $\rightarrow$ acoustical sound energy
Moving-Coil

- Backwards dynamic mic
- Most common: transistor radios, PAs, studio monitors
- Permanent magnet with wire coil inside ring-shaped gap
- Magnet attached to speaker cone
- Electrical input $\rightarrow$ A/C current in coil $\rightarrow$ diaphragm vibration $\rightarrow$ sound waves
- Omnidirectional pattern
Moving Coil in Action
Electrostatic

- Backwards condenser mic
- Large, flat diaphragm between two oppositely charged plates (+) and (-)
- Electrical input to diaphragm alternates its charge, causing vibration.
- Expensive and harder to manufacture, usually lacking in bass response
- Figure 8 pattern
**Ribbon**

- Backwards ribbon mic
- Ribbon suspended between N pole and S pole magnets
- Electrical input applied to ends of ribbon induces alternating magnetic field, causing vibration
- Also more expensive to produce, low impedance and acoustical output
- Figure 8 pattern
Free-cone Dynamic Speaker Issues

- Back-to-front cancellation: sound wave emitted from rear of driver is opposite in phase (180°) to sound wave emitted from front, more prevalent at lower frequencies

- Free-cone resonance: speaker cone will vibrate more strongly at its natural “resonant frequency”
  - Causes distortion of signal: “ringing”, “boominess”
Speaker Enclosures

- Designed to reduce the free-cone problems of cancellation and resonance
- Also referred to as “baffles” or “cabinets”
- Several types: two of the most common are the “sealed” enclosure and the “bass-reflex” enclosure
Closed-box Enclosures

- Completely sealed, usually contains sound-absorbing material inside
- Soundwaves emitted from rear of driver do not reach open air
- Cheaper to manufacture, more common
Bass Reflex Enclosures

- Air inside bass port resonates at specified low frequency
- Reduces movement of speaker cone at bass port frequency ➔ increases efficiency and low frequency output
- Frequencies below resonant frequency are not acoustically loaded, can cause over-excursion of the speaker cone
Horn-loading

- Placing horn in front of diaphragm
- Usually has limited frequency range and uneven response
- Long-throw horn
  - Concentrates sound in the forward direction
  - Used in P.A.’s
  - Acoustical lens: diffracts sound over wider angle (better for people close to the speakers)
- Re-entrant horn
  - Driver facing backward, horn much shorter
  - Often used in hand-held horns, subway
Multiple-Driver Systems

- A single driver is not adequate for producing frequencies across the entire audible spectrum
- Tweeter - small, light, very responsive
  - 3 kHz - 20 kHz
  - Often uses convex “dome” construction
- Bass/mid driver - larger, heavier, less responsive
  - 30 Hz - 3 kHz
  - Require more power to drive greater mass
- Require “crossover” network to route frequency signals to the right driver
“Passive” Crossover Network

- Uses passive components to divide signal: resistors, capacitors, inductors
- Hi-pass filter: capacitor with lower impedance for high frequencies
- Low-pass filter: inductor with lower impedance for low frequencies
- Band-pass filter: Capacitor and inductor in series
“Active” Crossover Network

- Uses “active” electronic circuitry (i.e. transistors, valves) to divide audio signal
- Each driver has own power amplifier
- Downsides: more expensive, complex
- Benefits: Lower distortion, greater flexibility of design, better control of frequency response, clearer highs, tighter lows
Performance Measurements

- Impedance - standard is 8 Ω, but varies over frequency
- Most notable is the “bass hump” located at the system resonant frequency
  - Other dips/peaks due to inductive/capacitive elements in the crossover and drivers
- A bass-reflex enclosure
  - Significantly lowers the impedance at the bass port resonant frequency
  - But introduces a peak at the bass driver free-cone resonant frequency
- Other standard loudspeaker impedances include 4 Ω and 15 Ω
  - Lower resistance: Harder to drive, draw more current
  - Higher resistance: Easier to drive, draw less current ➔ but less power
Performance Measurements, pt.2

- Sensitivity: the effectiveness in converting electrical sound energy → acoustical sound energy
  - Most energy lost to heat, efficiency can range from 1% (typical hi-fi speaker) to 10% (horn-loaded system)
  - Standard measurement: 1 W input, 8 Ω resistance, SPL measurement 1m from speaker, i.e. 86 dB W\(^{-1}\)

- Distortion: tends to be 2nd-harmonic distortion - producing frequencies octave higher.
  - At lower freq ≈ 10%, mid-high freq ≈ 1%
  - Usually not perceptually relevant
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Performance Measurements, pt. 3

- **Frequency Response**
  - Ideally: 20 Hz to 20 kHz, flat response
  - Typical systems experience bass roll-off around 100 Hz
  - A good system may have only ±3 dB fluctuation in the rest of the spectrum

- **Power Handling**: # watts speaker can handle before unacceptable distortion
  - Speaker rated at 30 W, sensitivity of 86 dB W⁻¹
  - $10 \log(30 \text{ W}/1 \text{ W}) = 15 \text{ dB}$, $86 \text{ dB} + 15 \text{ dB} = 101 \text{ dB SPL (1 m from speaker)}$

- **Directivity**: angle of coverage of loudspeaker output
  - As waveforms increase in frequency, they become smaller relative to the speaker and enclosure size
  - Harder to diffract around the back of the enclosure ➔ forward-directional
  - Increase in off-axis phase cancellation ➔ narrower spread
Increasing forward-directionality

Decreasing spread
References

  • Chapter 4: Loudspeakers

• Images and diagrams from:
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