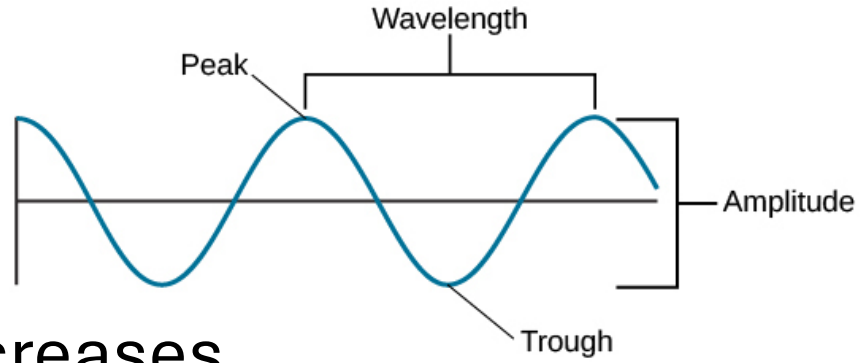
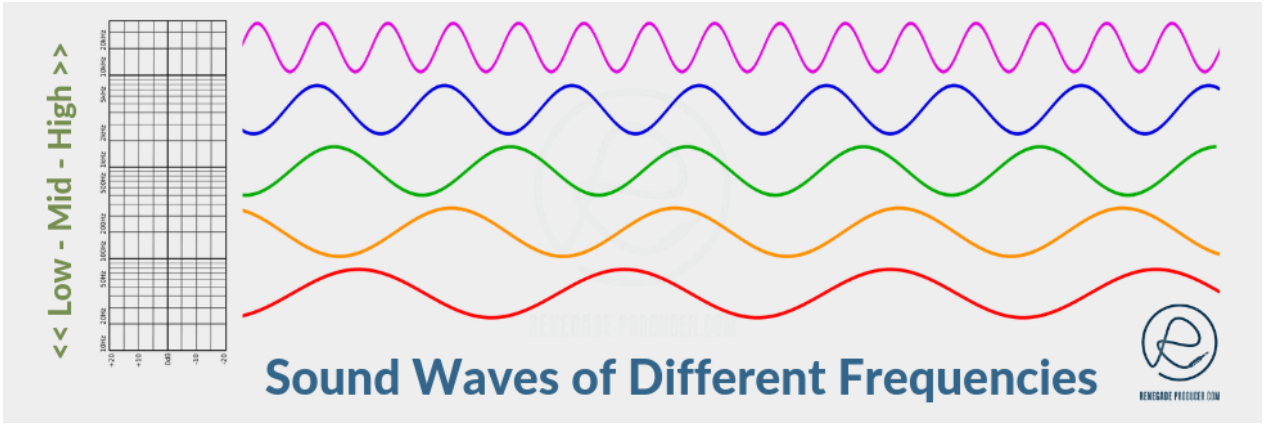
Topic 1: Acoustics and Energy

In Rooms and Loudspeakers

Wave Diagram



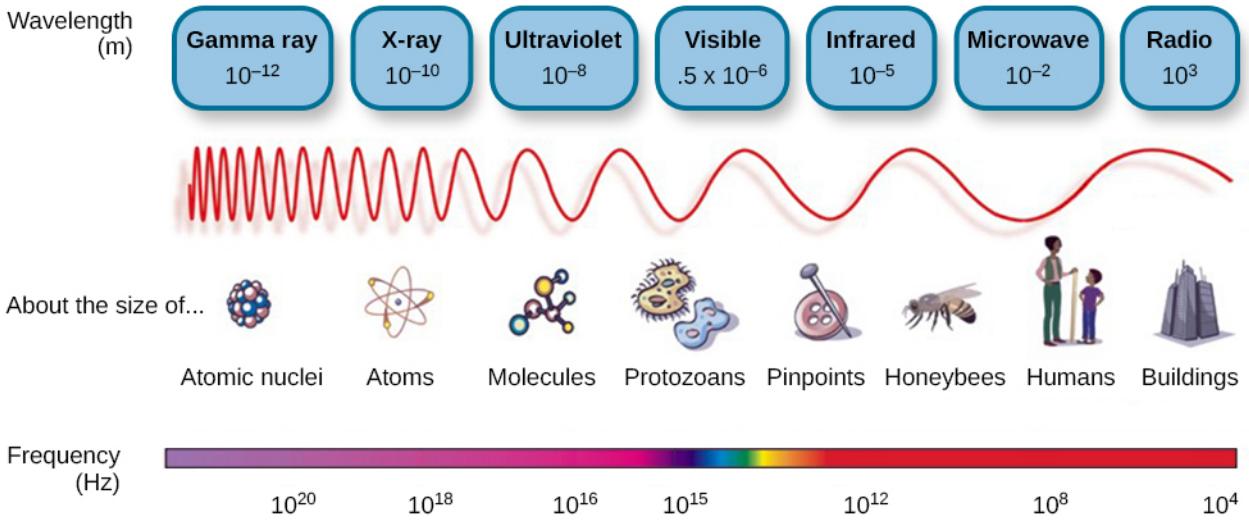
- Wavelengths get longer as frequency decreases
- Longer wavelengths require more energy to sustain
- Bass needs more energy



Vibration Frequency

- Mechanical energy
- Electro/Magnetic energy

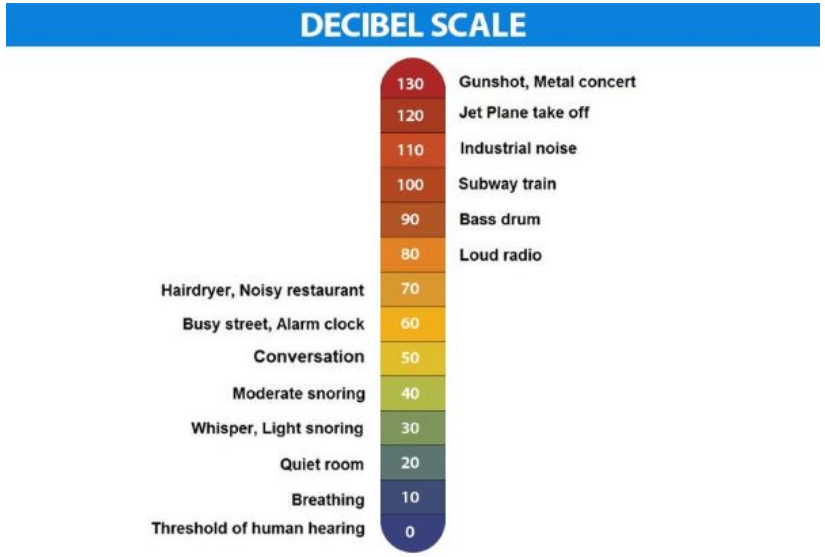
- In Loudspeakers…
- - Octave = ½ x Frequency
- - Octave = 2 x Wavelength
- - Octave = 4 x Energy



Decibel energy vs. Loudness

- +3dB = 2 x Energy
- +10dB = 10 x Energy
- 2x loud = 10 x Energy etc.

- In the Context of room size…
  - 2x Room (size) = 4 x Energy



dB	Energy Required	Perception of Volume
120	1,000,000,000,000E	4,096x
110	100,000,000,000E	2,048x
100	10,000,000,000E	1,024x
90	1,000,000,000E	512x
80	100,000,000E	256x
70	10,000,000E	128x
60	1,000,000E	64x
50	100,000E	32x
40	10,000E	16x
30	1,000E	8x
20	100E	4x
10	10E	2x
00	E	x

Energy Summary

- Louder requires more energy
- Deeper requires more energy
- Bigger rooms require more energy
- Rooms with greater damping (absorption) require more energy

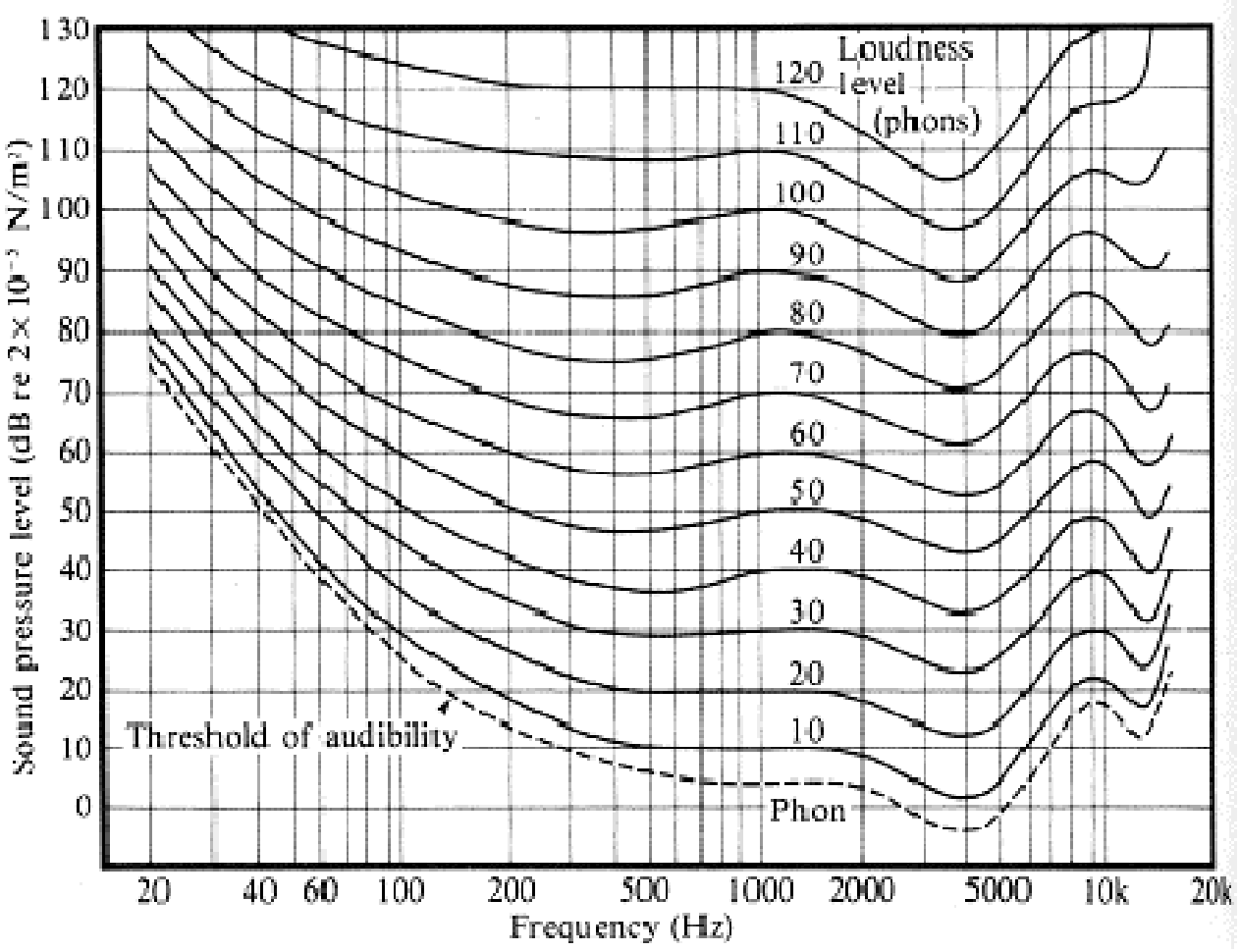
Topic 2: Acoustics

Physics of Sound

Human Hearing Range

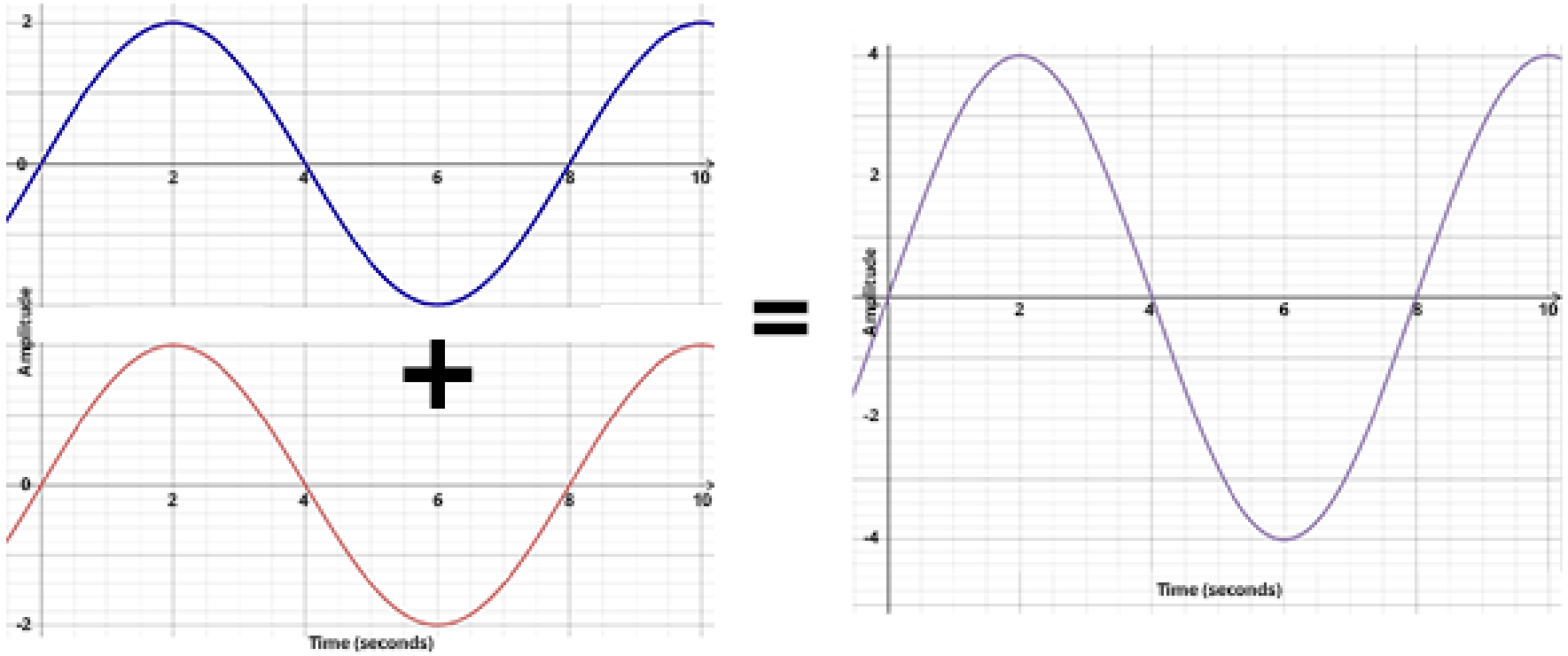
- 20 Hz – 20,000 Hz
- 20-300 Hz – Bass
- 300-3,000 Hz – Midrange
- 3,000-20,000 Hz – Treble

- Human speech – 100-6,000 Hz



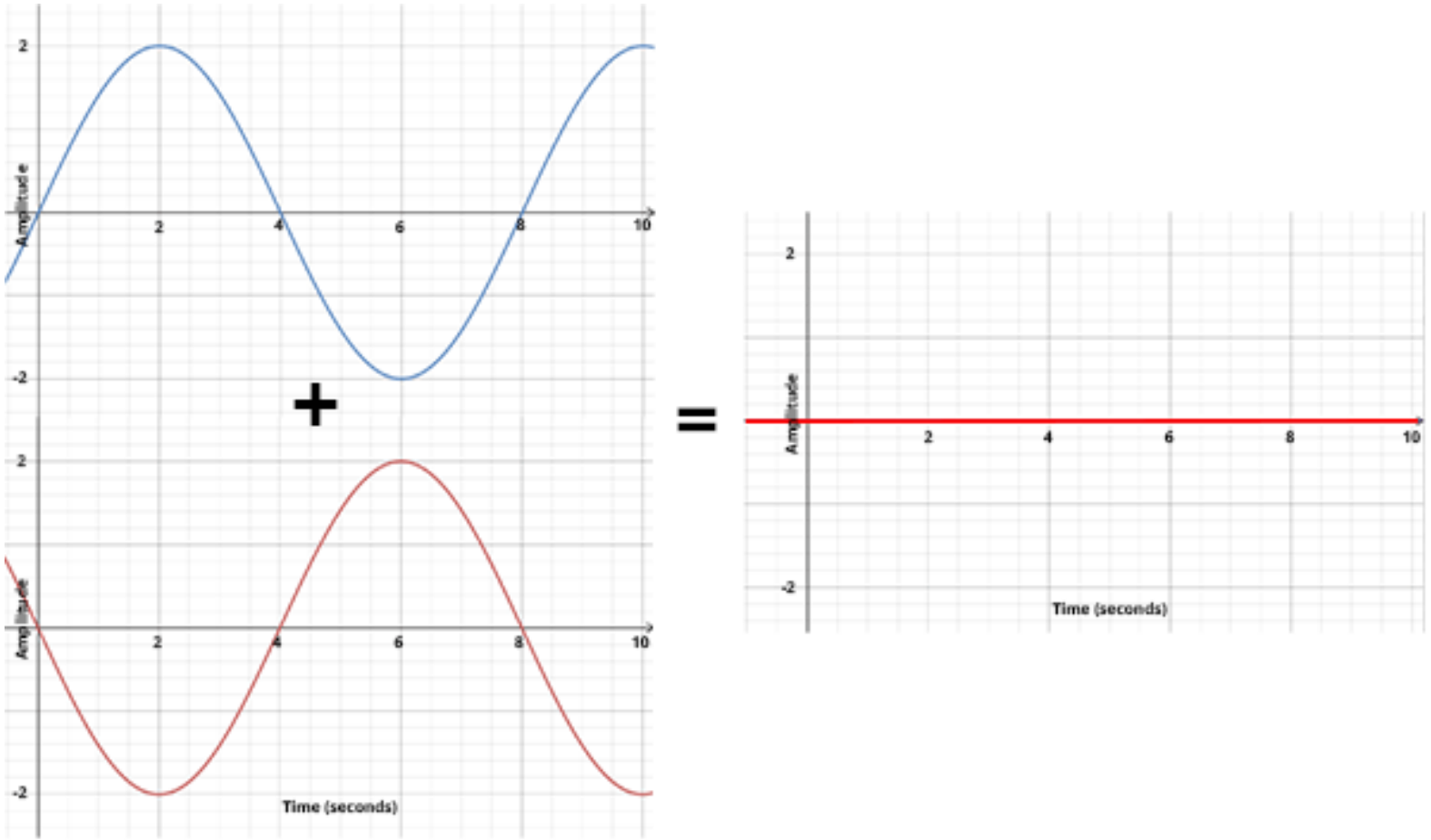
In-Phase waveforms

Peaks and troughs align which sums together and reinforces one another



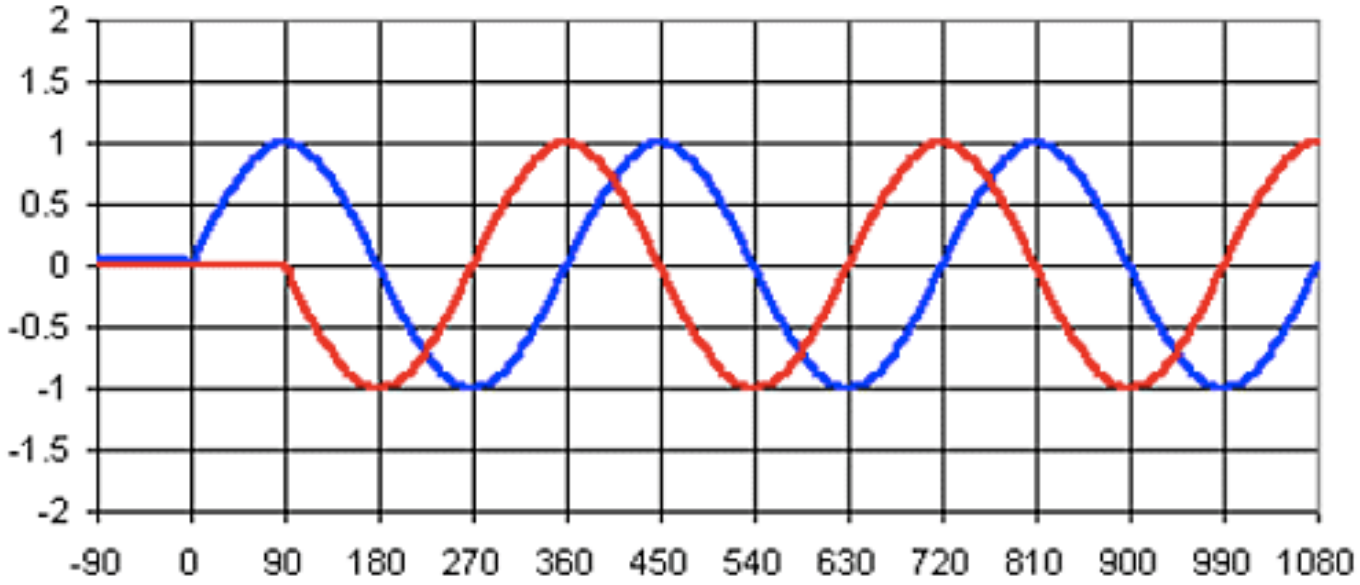
180 Degrees Out of Phase Waveforms

180 degrees out of phase waves sum together, cancelling one another



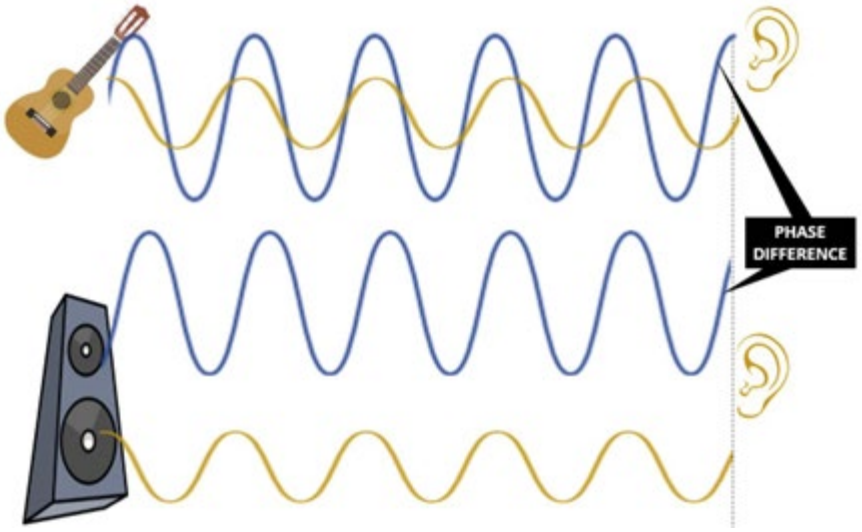
90 Degrees Out of Phase Waveforms

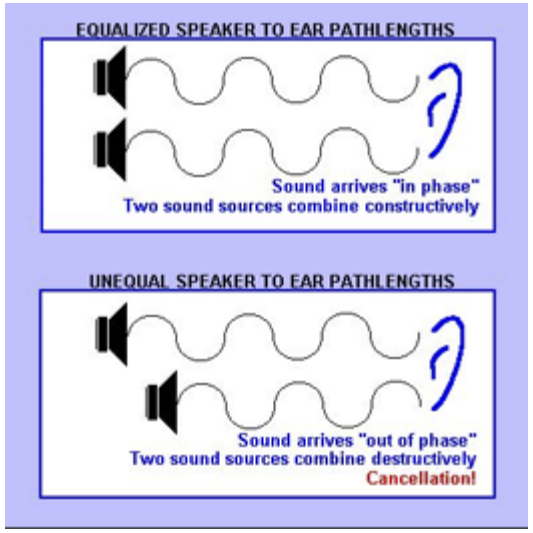
Fig 7 - Two Sine Waves:
Red = Phase Shifted 90 Degrees & Polarity Reversed



Phase Coherence in Speaker Context

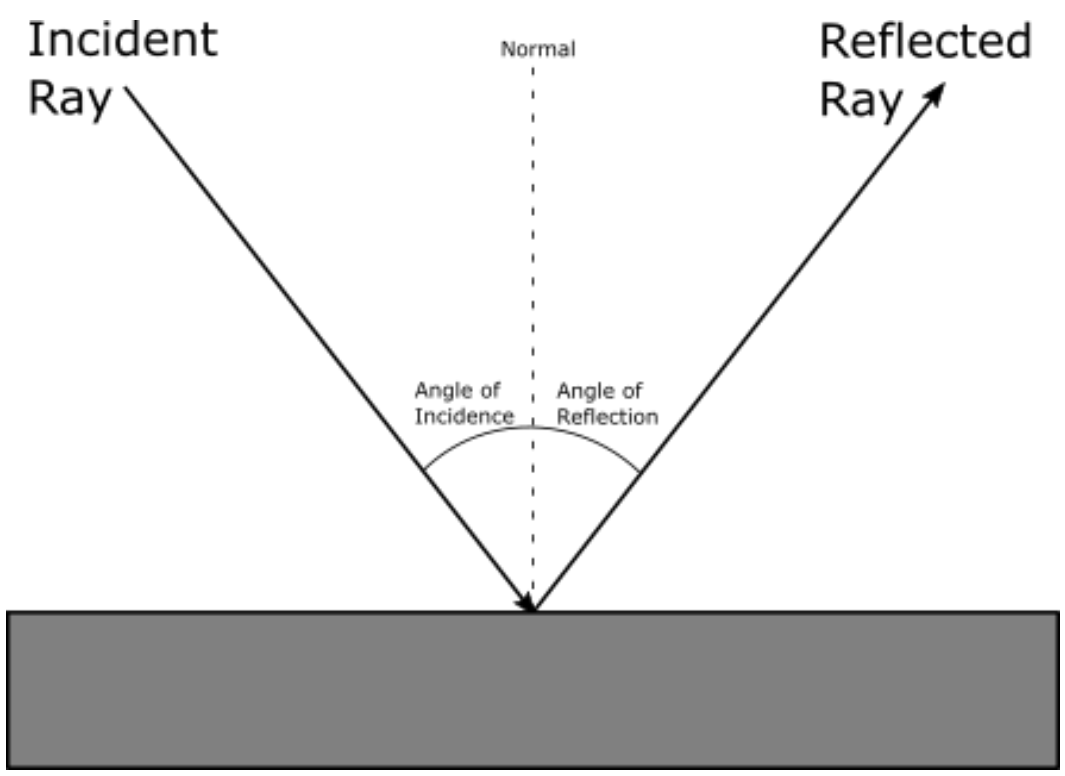
- Alignment of two sound waves

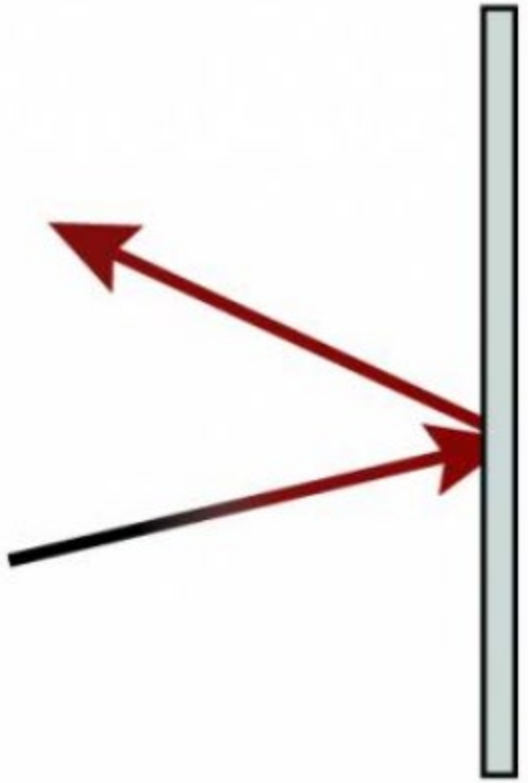




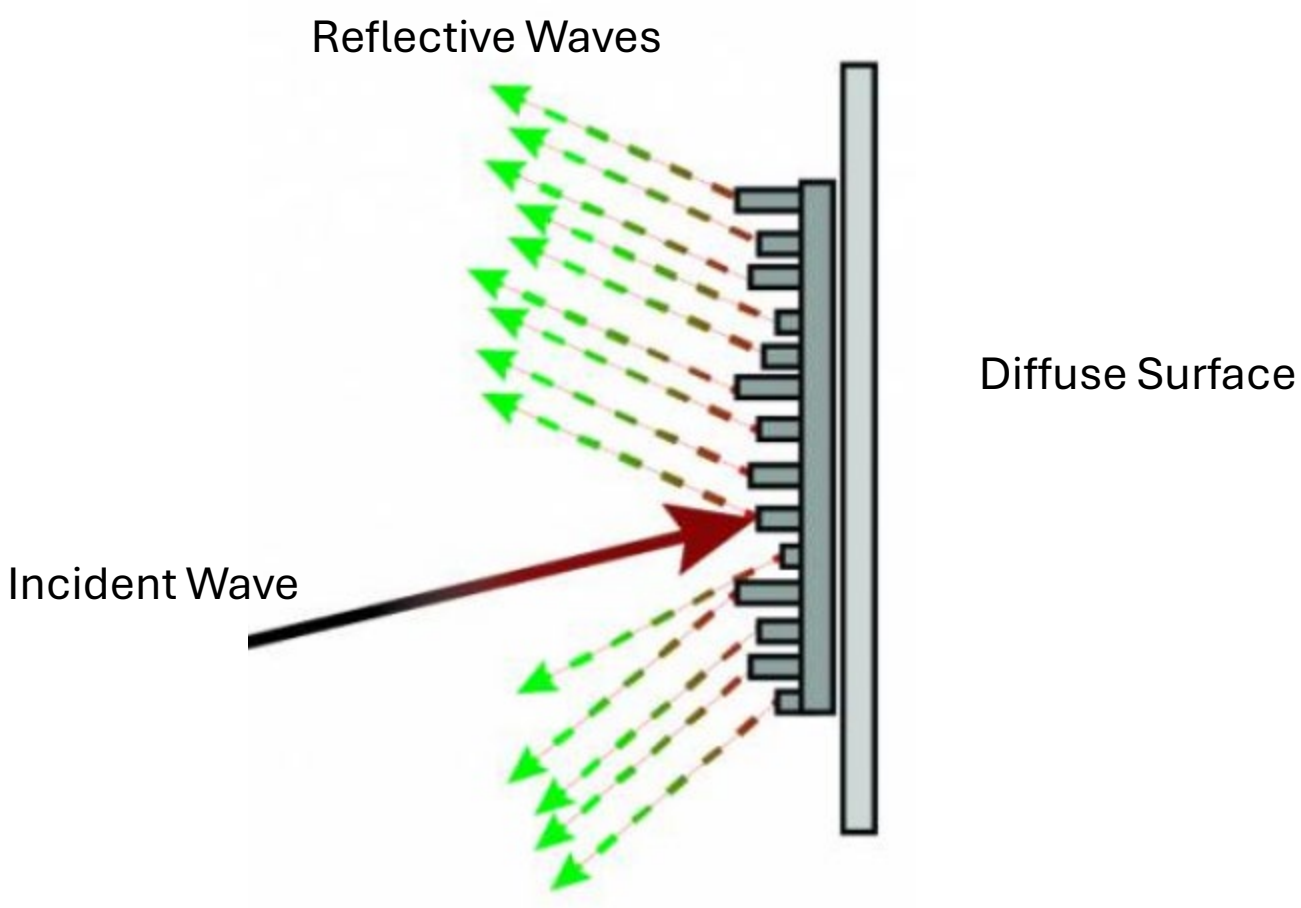
Sound Wave Reflectivity

Straight line reflection



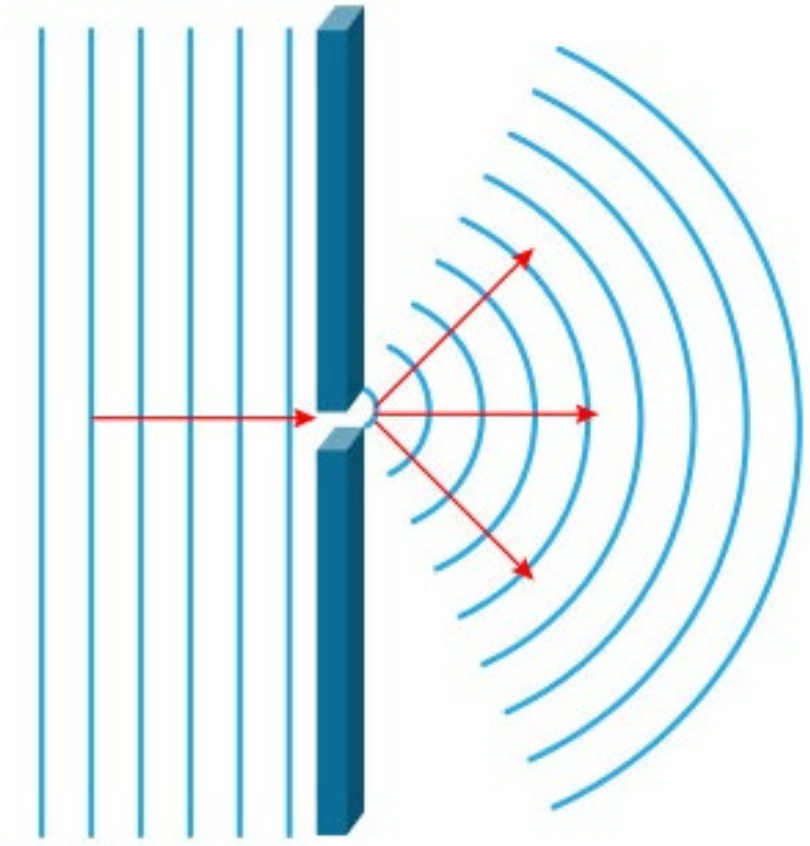


Diffusion



Diffraction Reformation

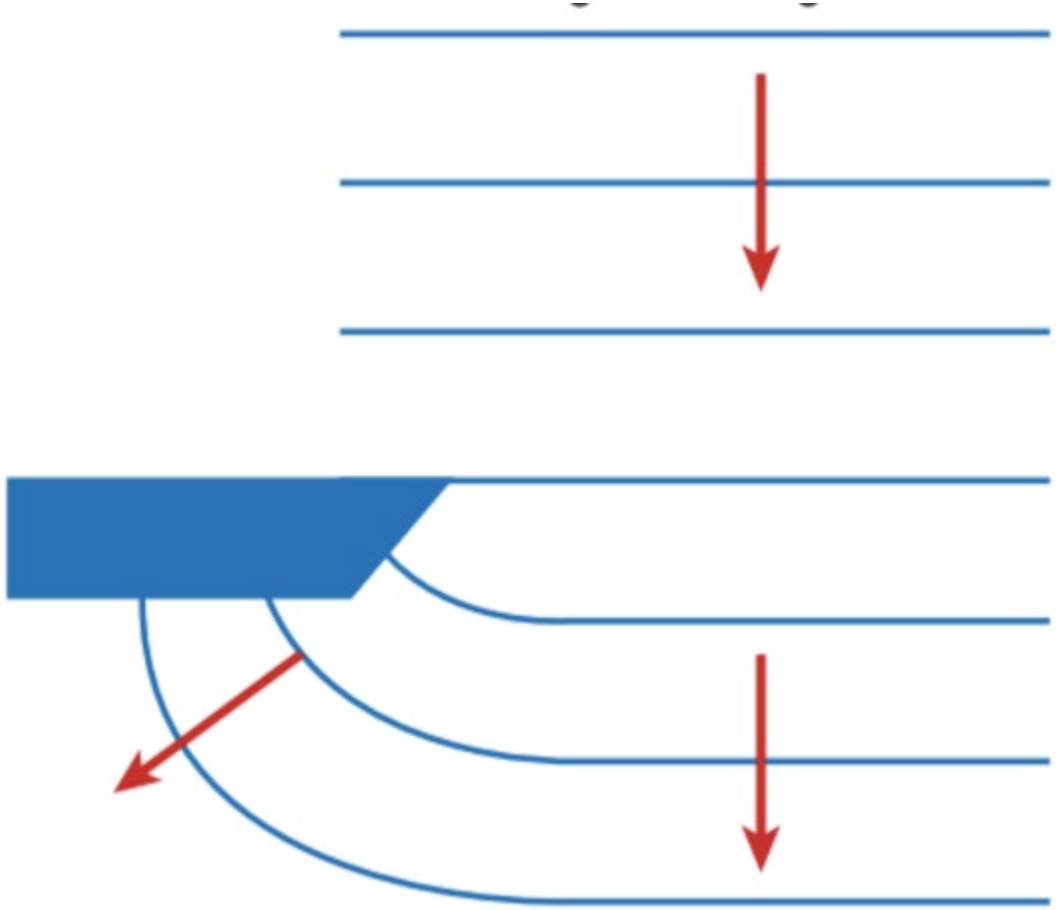
Barrier with small opening blocking waves



Waves curve as they exit opening

Diffraction through small opening

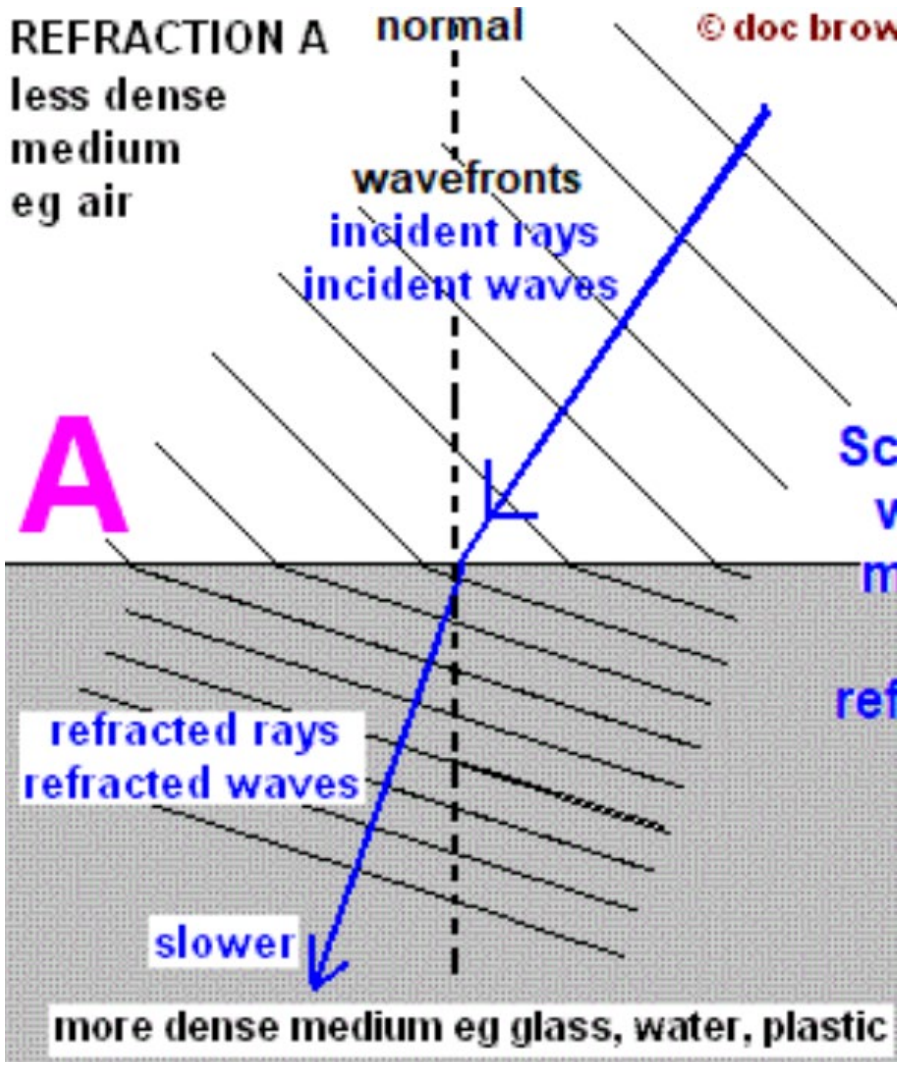
Diffraction Curve



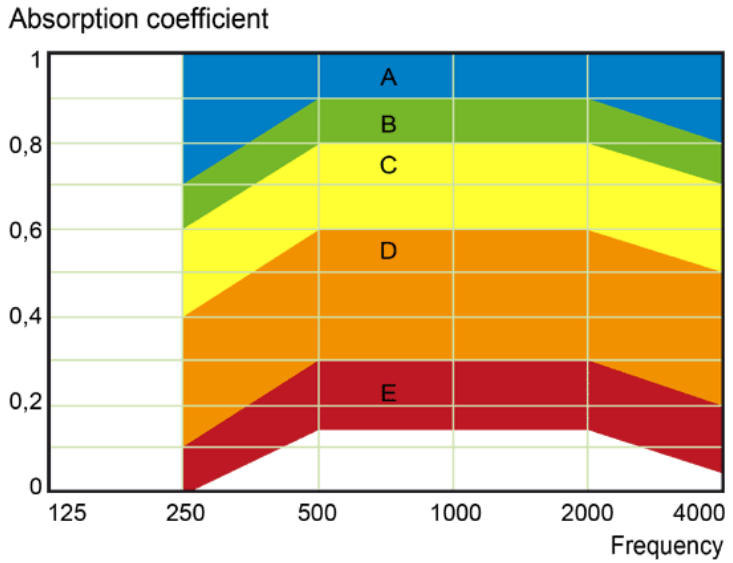
Object blocking path

Sound waves curve around object after they pass it

Solid Line Transmission



Absorption and NRC



- Higher NRC Values mean better absorption
- The **Noise Reduction Coefficient** (commonly abbreviated **NRC**) is a scalar representation of the amount of sound energy absorbed upon striking a particular surface. An NRC of 0 indicates perfect reflection while an NRC of 1 indicates perfect absorption.

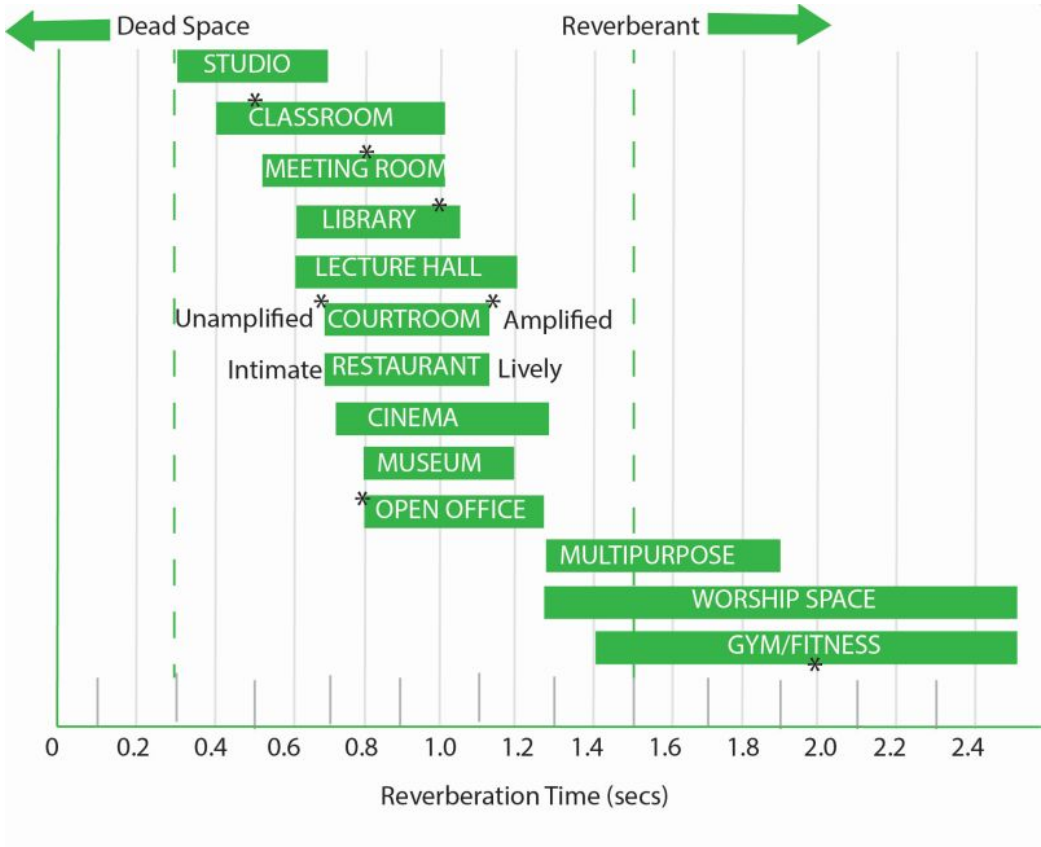
Materials NRC Ratings

Material Absorption Summary

Material	NRC Value	Thickness
Water surface	0.00	n/a
Brick or concrete	0.00 — 0.05	n/a
Marble or glazed tile	0.05	n/a
Drywall or glass	0.05 — 0.15	0.5"+
Wood paneling	0.10	1/4" + AS
Carpet	0.30 — 0.55	Heavy with pad
Thick curtain	0.60	Draped to half area
Wood with 3/16 perforations	0.65	1/2" + AS
Fabric wrapped panel	0.75+	1"+
Perforated metal (acoustic) panel	0.80+	2"+
Snow (freshly fallen)	0.90	4" thick
Fiberglass acoustic ceiling tile	0.95+	1"+

Room Reverberation

- Determines how a room can be used for certain practices
- Short reverb would be better for studio work
- Longer reverb would be better for choirs



Speech Intelligibility

- Takes into account 4 factors:
  - Room Geometry
  - Reverberation Time
  - S/N Ratio (Signal to Noise)
  - Background Noise Level

  - 1000 Hz – 4000 Hz contributes to 75% of speech intelligibility

How to get good Acoustics?

- 1) Watch out for SOUND REFLECTIONS. Straight surfaces reflect sounds back into the central space making sound clarity muddy.
- 2) Select ACOUSTICAL TREATMENT carefully. Different materials absorb sound frequencies differently. Make sure your acoustical treatments are absorbing the right sound frequencies.
- 3) Diminish ECHOES when necessary. Be aware that sounds traveling within 30 milliseconds of each other are perceived without echo. Sounds traveling after the 30 millisecond threshold become echoes of the original sound.

- 4) Don’t let other building systems get in the way. NOISE CONTROL is important to keep in check as other building systems (like HVAC systems) operate. Keep such clashing noises to a minimum.
- 5) Keep objects or other OBSTRUCTIONS out of the way. Objects that obstruct a sound path can block high frequency sounds. (Low frequency sounds can bend around objects.)
- 6) Get good PATTERN CONTROL. Make sure sound systems for a room get good sound coverage. This will prevent feed-back and other sound distortions.

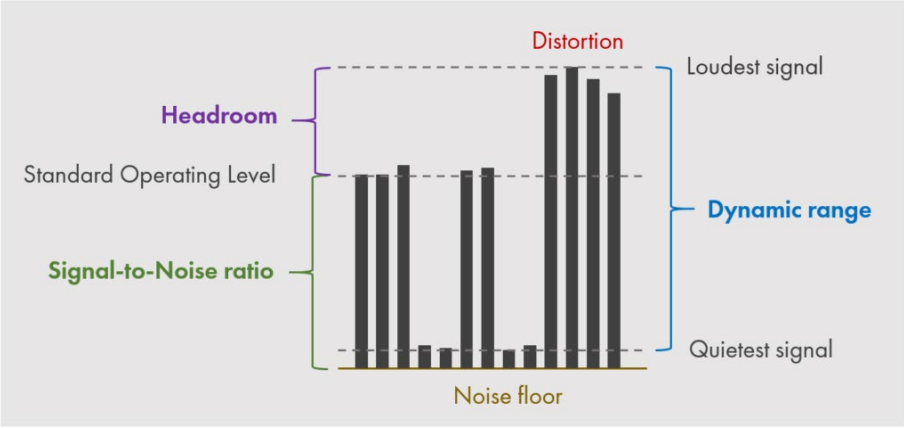
Topic 3: Loudspeaker Design Goals and Traits

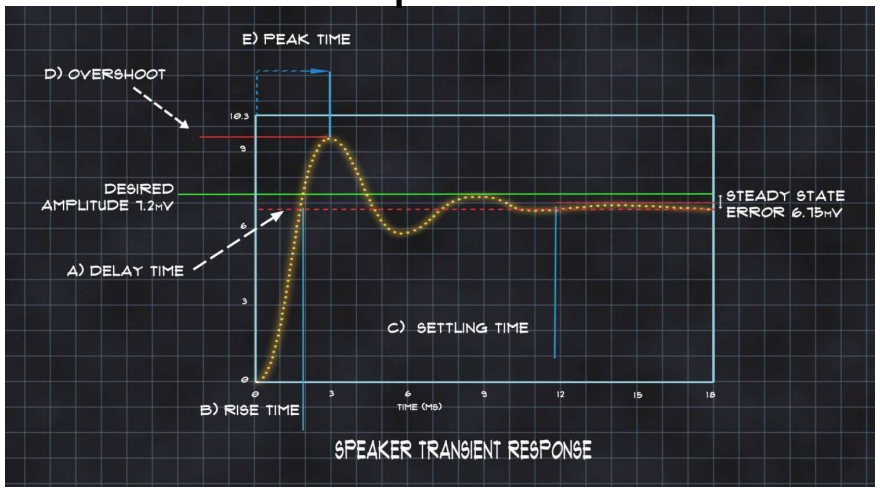
What Makes a Good Speaker?

- Depends on use
  - Ex. Mixing and Mastering, General listening, speech intelligibility, home theater, etc.
- Balance between visual aesthetic and sound quality
- Frequency Response: Accurate reproduction of a wide range of frequencies without significant peaks or dips.
- Low Distortion: Minimal harmonic and intermodulation distortion for faithful audio reproduction.
- Power Handling: Efficiently handles power from the amplifier without distortion or damage.
- Sensitivity: Converts electrical power into sound efficiently, producing higher sound levels with less power input.
- Build Quality: High-quality materials, sturdy enclosures, and well-designed components ensure durability and optimal performance.

Crucial Loudspeaker Traits

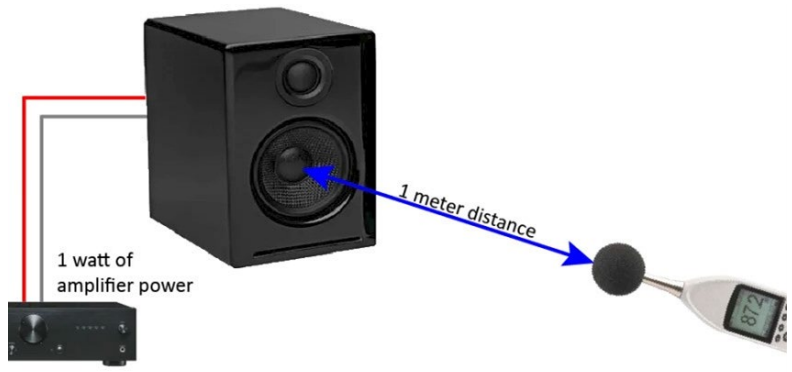
- Dynamic Range
  - Difference between the quietest and loudest sounds a speaker can reproduce without distortion or compression.
- Transient Response
  - How quickly and accurately a speaker can reproduce sudden changes in the audio signal, such as fast percussive sounds or sharp transients.





Crucial Loudspeaker Traits

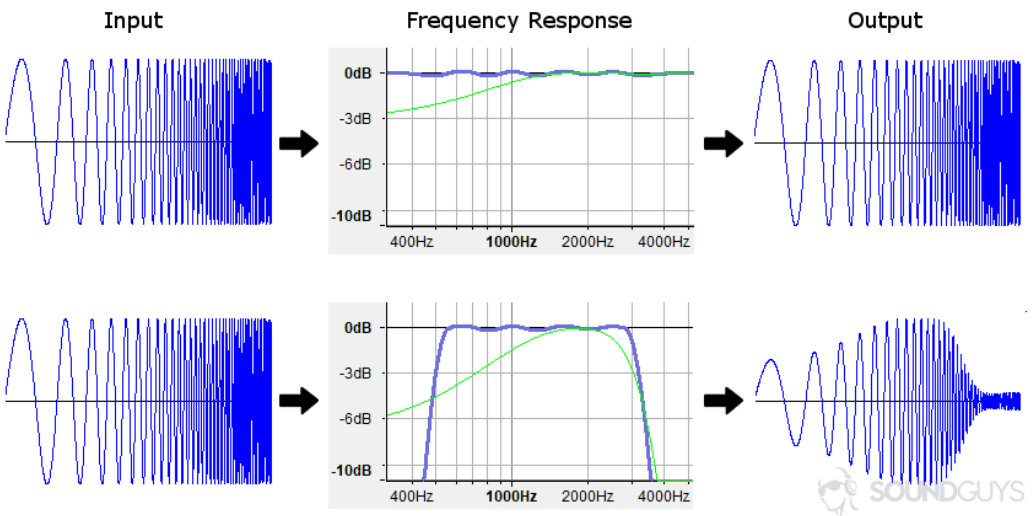
- Efficiency
  - How effectively a speaker converts electrical power into sound output.
  - Also known as “Sensitivity”



85 dB Sensitivity Rating		90 dB Sensitivity Rating	
Watts	dB Produced	Watts	dB Produced
1	85	1	90
2	88	2	93
4	91	4	96
8	94	8	99
16	97	16	102
32	100	32	105
64	103	64	108
128	106	128	111
256	109	256	114

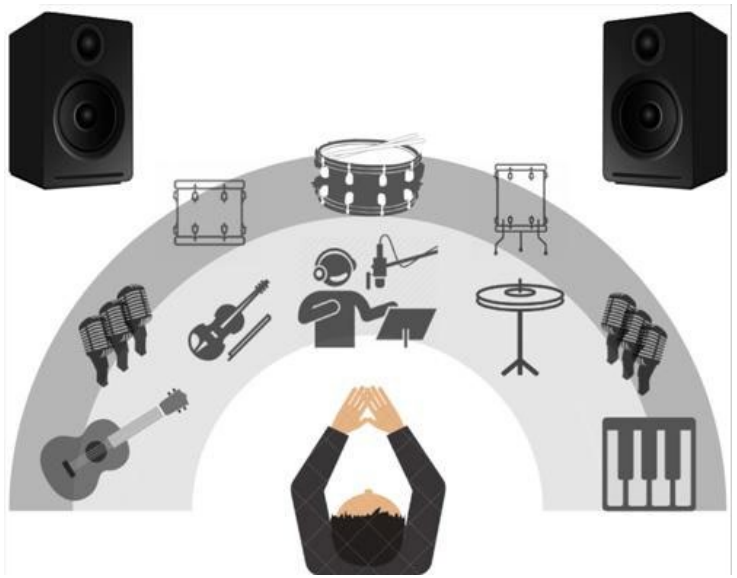
Crucial Loudspeaker Traits

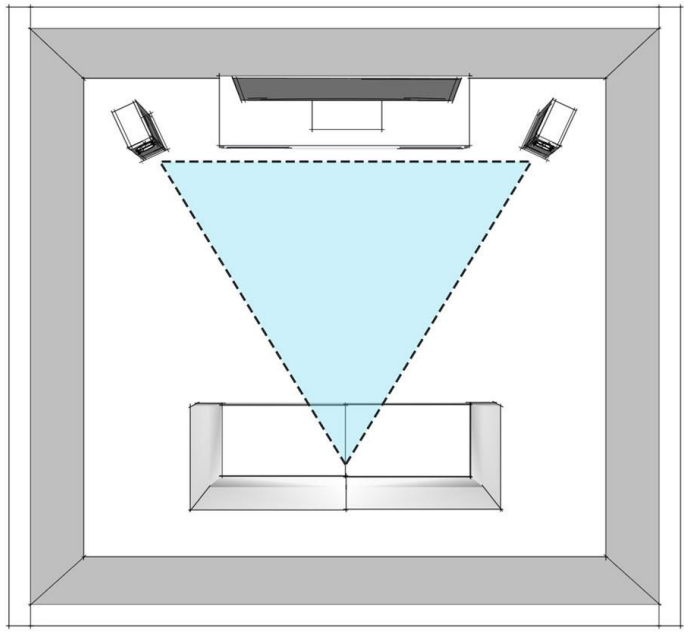
- Bass Response
  - A speaker's ability to accurately reproduce low-frequency sounds, typically those below 250 Hz.



Crucial Loudspeaker Traits

- Imaging
  - The ability of a speaker system to create a precise and stable soundstage, where individual instruments and voices are perceived as coming from distinct locations within the stereo field.





Topic 4: Speaker Types

Types of Speakers

- Bookshelf Speakers
- Floor-standing Speakers
- In-wall Speakers
- In-ceiling Speakers
- Outdoor Speakers
- Portable Speakers
- Subwoofers
- Soundbars
- Satellite Speakers
- Studio Monitors.
- Computer Speakers
- Line Array Speakers

Subwoofers

- These are speakers that specialize in reproducing low-end information (Bass).

Subwoofers cont.

- Size: Subwoofers are typically larger in size compared to other speakers due to the need for housing larger drivers that can produce low-frequency sounds effectively.
- Driver: Subwoofers contain a specialized driver called a woofer, which is designed specifically to reproduce low-frequency bass sounds. The diameter of the woofer is usually larger than that of other speaker drivers, often ranging from 8 inches to 15 inches or more.
- Enclosure: Subwoofers are housed in an enclosure, which can be sealed or ported (vented). The enclosure helps control the movement of air generated by the woofer, enhancing bass response and preventing distortion.
- Weight: Due to their larger size and heavier construction, subwoofers tend to be heavier than other types of speakers, especially when equipped with powerful amplifiers and sturdy enclosures.
- Construction Materials: Subwoofers are often constructed using materials such as wood, MDF (medium-density fiberboard), or plastic for the enclosure, and reinforced materials for the driver cone to withstand the forces generated by low-frequency vibrations.
- Amplification: Many subwoofers come with built-in amplifiers (known as powered or active subwoofers), while others require external amplification (passive subwoofers). The amplifier provides the necessary power to drive the woofer and produce deep, powerful bass tones.

Soundbars

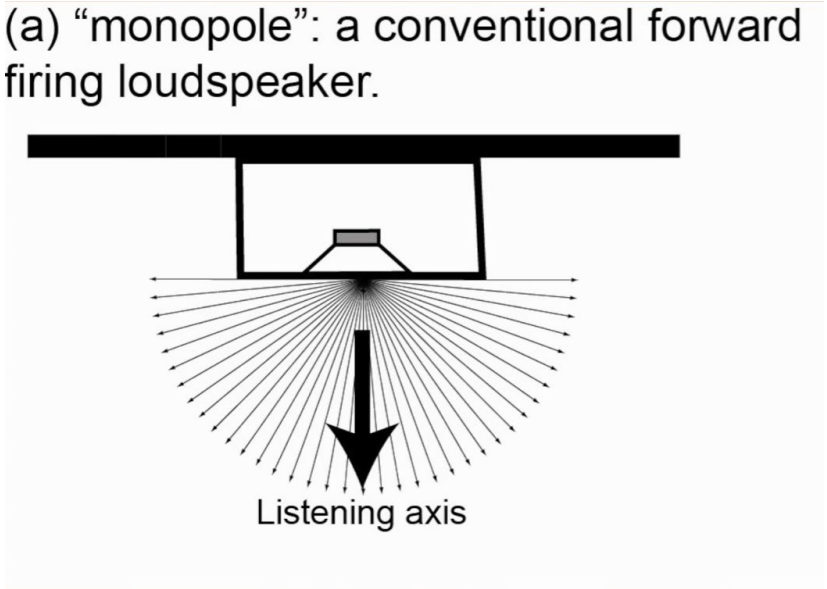
- Long, narrow speakers that offer an all-in-one audio solution, often used to enhance TV sound quality without the need for multiple speakers.

Soundbars cont.

- Shape and Size: Soundbars are long and narrow, resembling a rectangular box or cylinder. They are designed to sit in front of or underneath a TV, providing an all-in-one audio solution that doesn't take up much space.
- Speaker Drivers: Inside the soundbar, there are multiple speaker drivers arranged horizontally. These drivers can include woofers for bass, tweeters for high frequencies, and mid-range drivers for vocals and instruments.
- Enclosure: The enclosure of a soundbar is typically sleek and streamlined, often made of materials like plastic or metal. The design of the enclosure helps to distribute sound evenly across a room and can sometimes include built-in features like mounting brackets for wall installation.
- Connections: Soundbars usually have various input and output connections, such as HDMI, optical, or Bluetooth. These connections allow you to easily connect the soundbar to your TV, media player, or smartphone wirelessly or with cables.
- Controls: Most soundbars come with integrated controls on the unit itself or a remote control for adjusting volume, selecting audio modes, and controlling other settings.
- Subwoofer: Some soundbars come with a separate subwoofer unit, which can be wireless or wired, to enhance bass performance and provide a more immersive audio experience, especially for movie soundtracks and music.

Surround Sound Speakers - Monopole

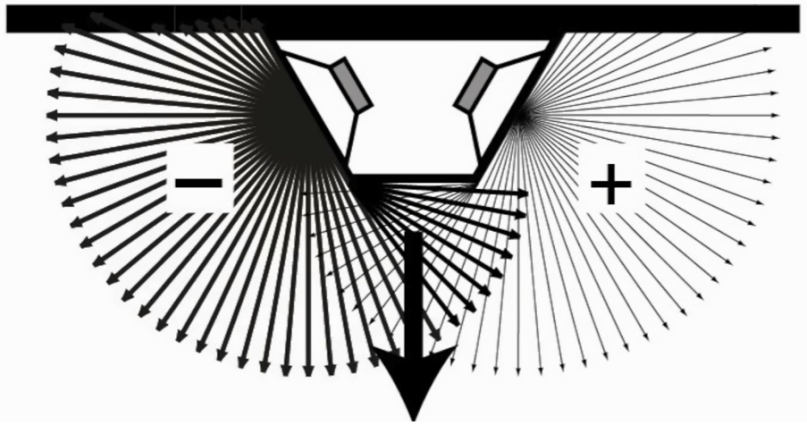
- This type of surround sound speaker is similar to regular speakers you might see at home.
- It's a single enclosure (the box) that emits sound primarily from the front, like most speakers.
- In a surround sound setup, these speakers are typically positioned in front of or behind the listener, providing direct sound that enhances the overall audio experience.



Surround Sound Speakers - Dipole

- Dipole surround sound speakers emit sound both forward and backward.
- They have two sets of drivers facing opposite directions within the same enclosure.
- This design creates a more diffuse sound field, which can enhance the sense of immersion in a surround sound setup.
- Dipole speakers are often used for side or rear surround channels in home theater systems.

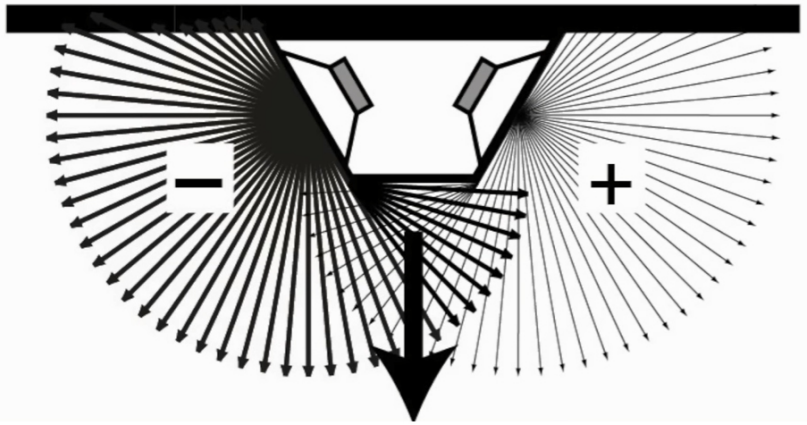
(b) “dipole”: a bidirectional out–of–phase loudspeaker.



Surround Sound Speakers - Dipole

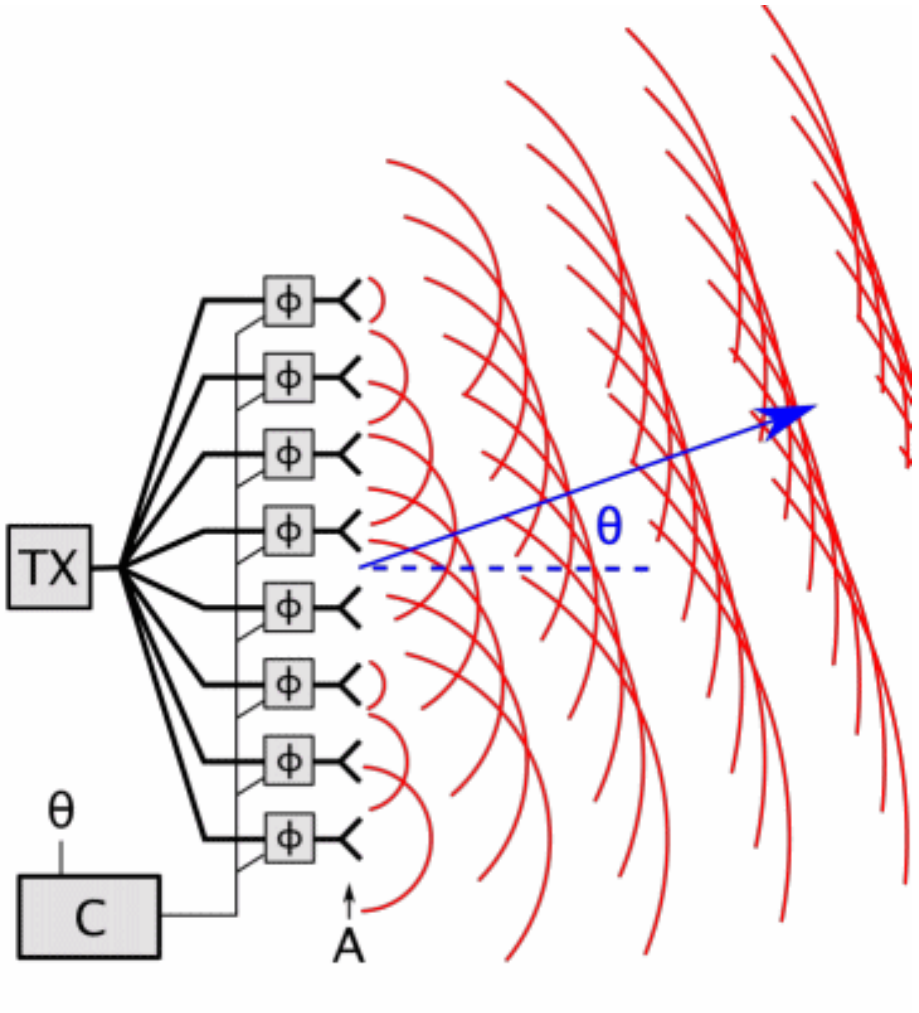
- Dipole surround sound speakers emit sound both forward and backward.
- They have two sets of drivers facing opposite directions within the same enclosure.
- This design creates a more diffuse sound field, which can enhance the sense of immersion in a surround sound setup.
- Dipole speakers are often used for side or rear surround channels in home theater systems.

(b) “dipole”: a bidirectional out–of–phase loudspeaker.



Line Arrays

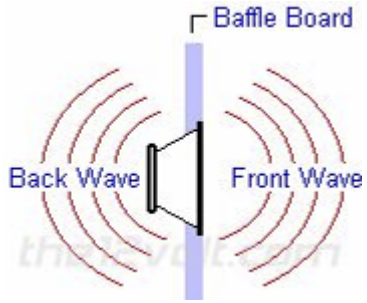
- Commonly used for live sound events
- Line array surround sound speakers consist of multiple smaller speaker units arranged vertically or horizontally in a line.
- This design helps to focus sound in a specific direction, providing more precise and controlled audio coverage in large venues or theaters.
- Line array speakers are commonly used in professional audio setups for concerts, theaters, and stadiums

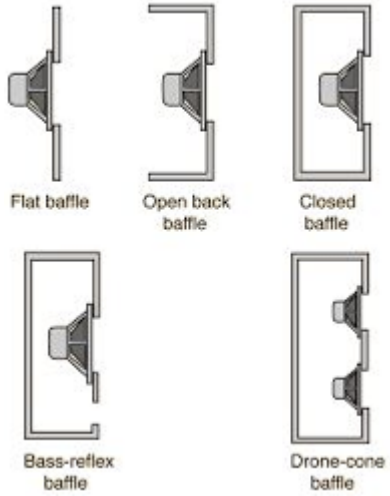


Topic 4.5: Bass Loading and Enclosures

Types of Enclosures: Open Baffle

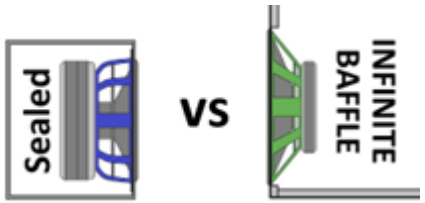
- No box contains the drivers
- Speaker is flat board





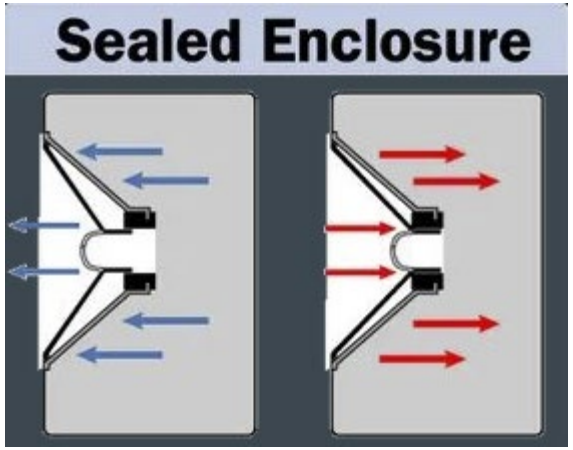
Types of Enclosures: Infinite Baffle

- A very huge, very big speaker
- So much air would be in that cabinet that a driver moving, wouldn't cause compression of air



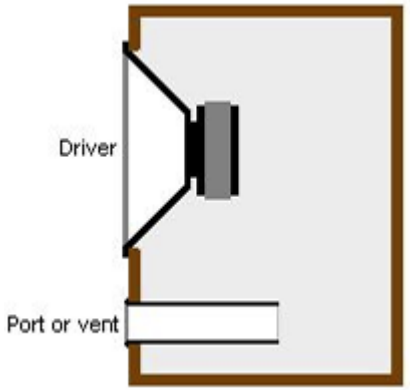
Types of Enclosures: Sealed

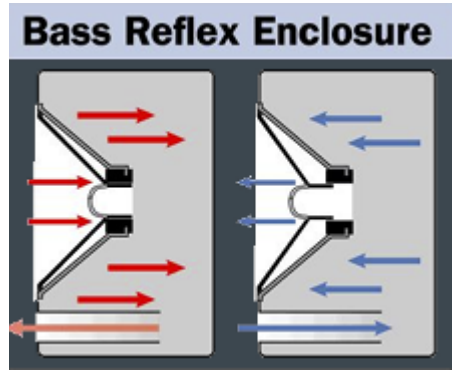
- All sound comes from the front of the speakers themselves
- Air is trapped inside cabinet
  - Acts as a spring to control movement
- Compact and easy to build
- Prevents sound waves from the back cancelling out the front
- Lots of internal air pressure
- Good power handling

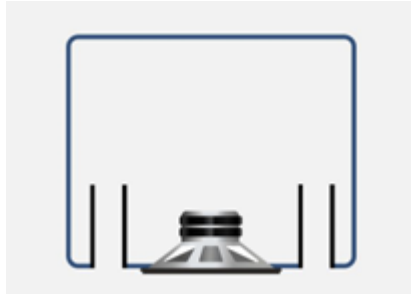


Types of Enclosures: Vented (Ported)

- Also called “Bass reflex enclosures”
- Has vent in front or rear side of cabinet
- Allows pressure to be equalized (Inside and outside)
- Used to tune cabinet to certain low frequencies based on how speaker is being used
  - Helps increase low frequency output

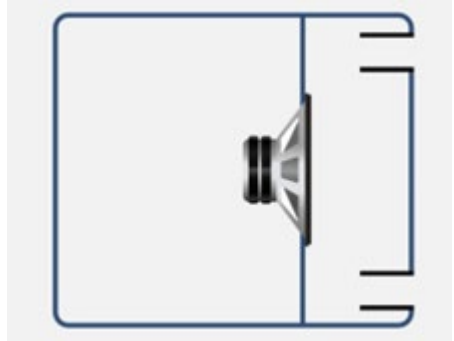


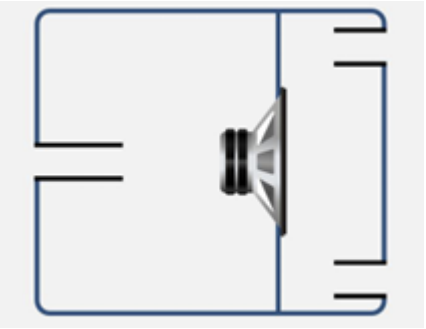




Bandpass

- Subwoofer enclosure that has two separate chambers instead of one
- Has filter that limits the high frequency response (effect is found in secondary chamber)
- Primary chamber can be vented or sealed
  - Can also be single or dual vented
- Produces low frequencies within a limited bandwidth
- Highly efficient





Topic 5: Subwoofers

What is a subwoofer?

- Subwoofers are loudspeakers designed to produce bass and sub-bass.
- Frequency range is generally 20-200 Hz
- Always used with other regular speakers
- Connected to an amp, which provides power

Single Woofer setup vs. Multi Woofer setup

- Convenience, multiple small subwoofers take up less space than one giant one.
- Bass is omnidirectional

- The more subs, the greater power load is taken off one another.
- Typically not used for directing the bass in a certain direction. (Bass is omnidirectional)

Subwoofer integration with main speakers

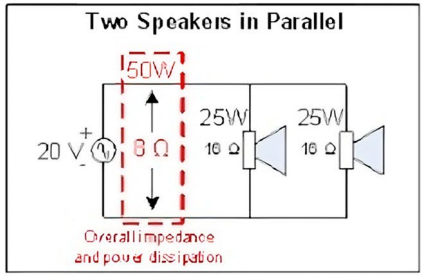
- Using crossovers, different frequency ranges can be distributed to different speakers that can handle low, mid, and high frequencies optimally.
  - Give main speakers mid and high frequency playback
  - Leave sub/subs to play low frequencies

Topic 5.5: Woofers and Midrange in depth

More in depth look at woofers...

Mechanics

- Two Speakers in Parallel
  - Impedance decreases
  - Volume increase from more flow through circuit
- Two Speakers in Series
  - Impedance increases
  - Volume decrease due to voltage drop in circuit

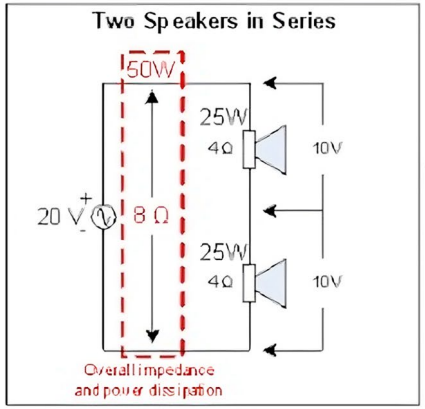


Formula for calculating the equivalent overall impedance of speakers wired in parallel

Z(total) = Equivalent Overall Impedance

Z(1) = Impedance of speaker one

$$Z(\text{total}) = \frac{1}{\frac{1}{Z(1)} + \frac{1}{Z(2)} + \frac{1}{Z(3)} + \dots}$$



Formula for calculating the equivalent overall impedance of speakers wired in series

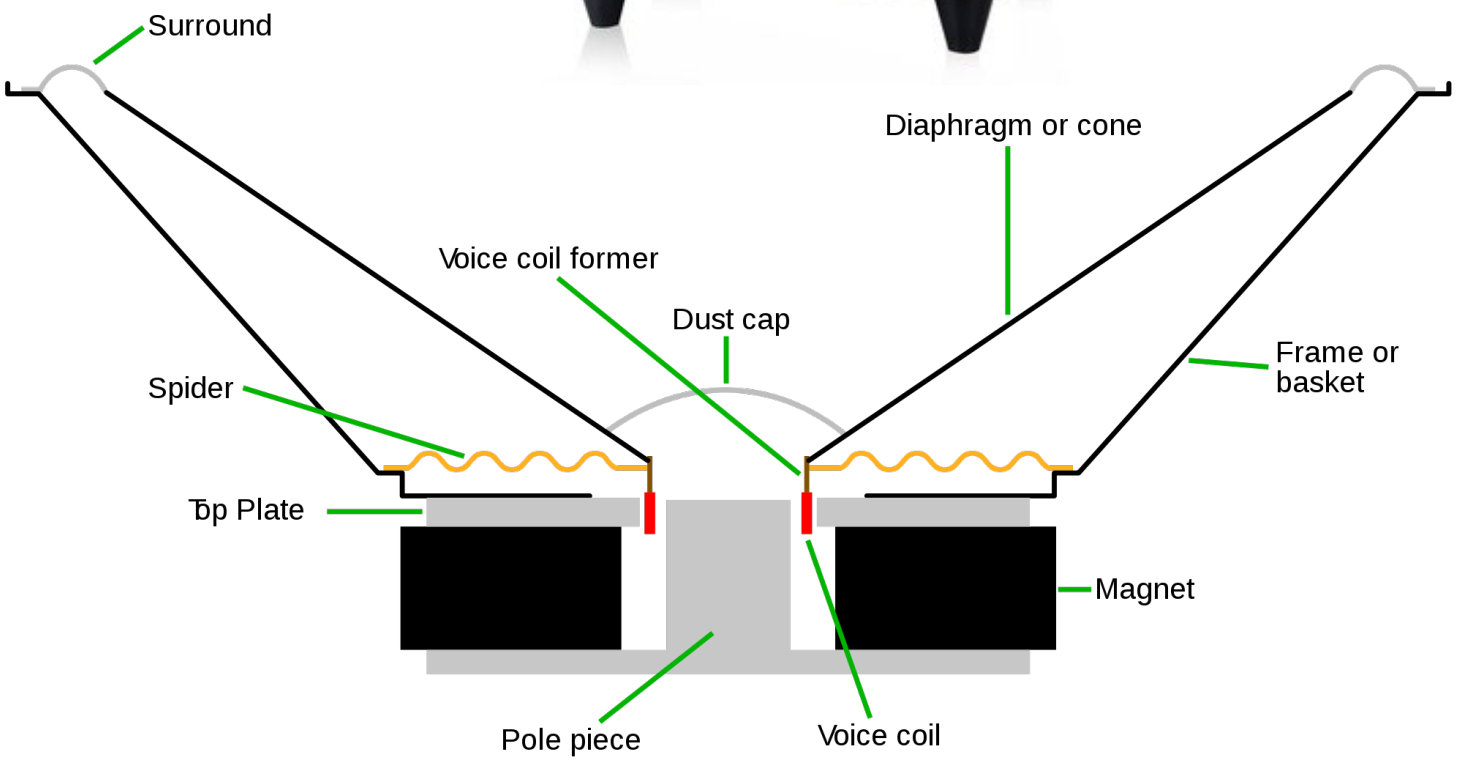
Z(total) = Equivalent Overall Impedance

Z(1) = Impedance of speaker one

$$Z(\text{total}) = Z(1) + Z(2) + Z(3) + \dots$$

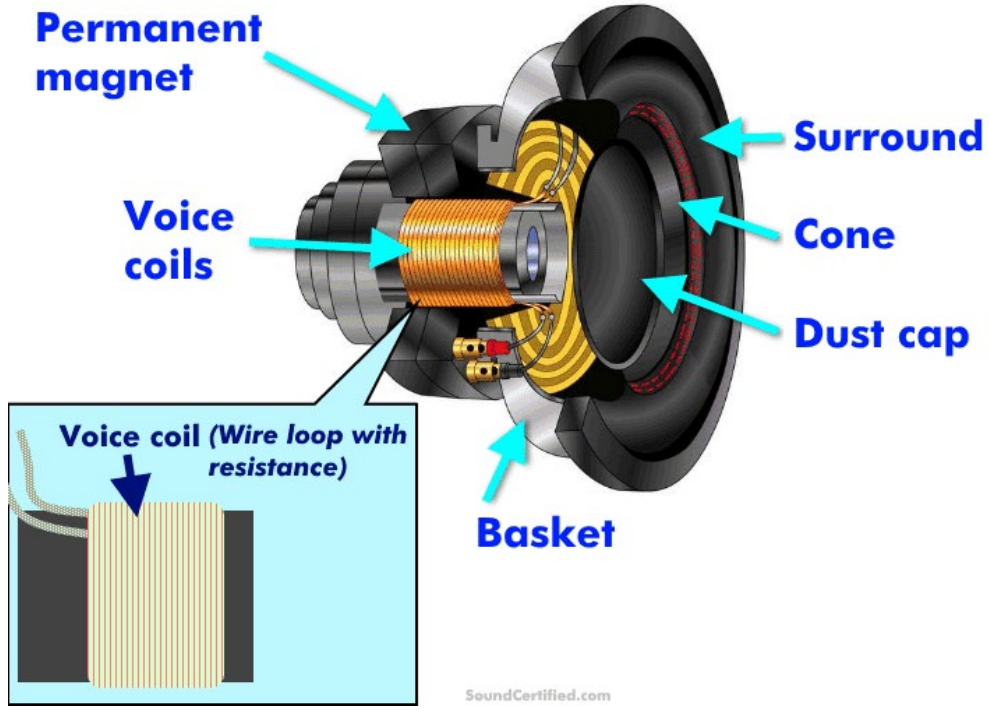
Suspension

- Provides flexibility for diaphragm to move back and forth



The Motor

- Drives diaphragm movement



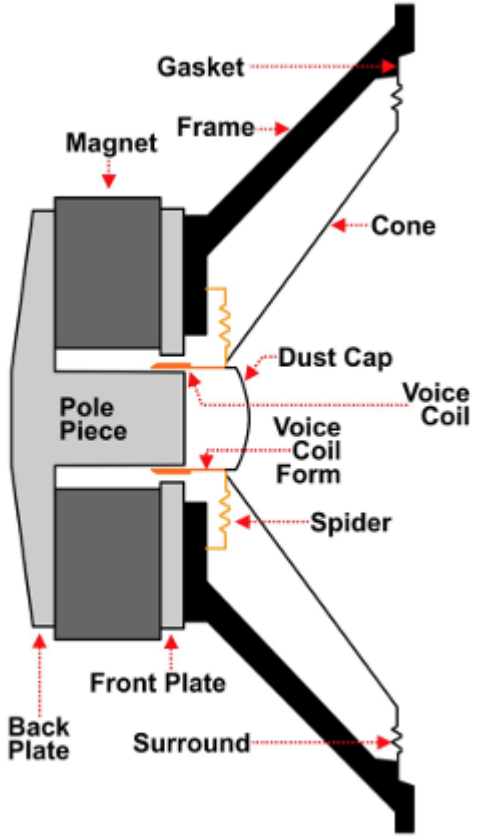
Cone Material

- Paper
  - Lightweight and damping
- Kevlar
  - High strength to weight ratio
- Aluminum/Metal
  - High rigidity and low resonance and good transient response
- Carbon Fiber
  - Lightweight and high stiffness

Topic 6: Tweeters

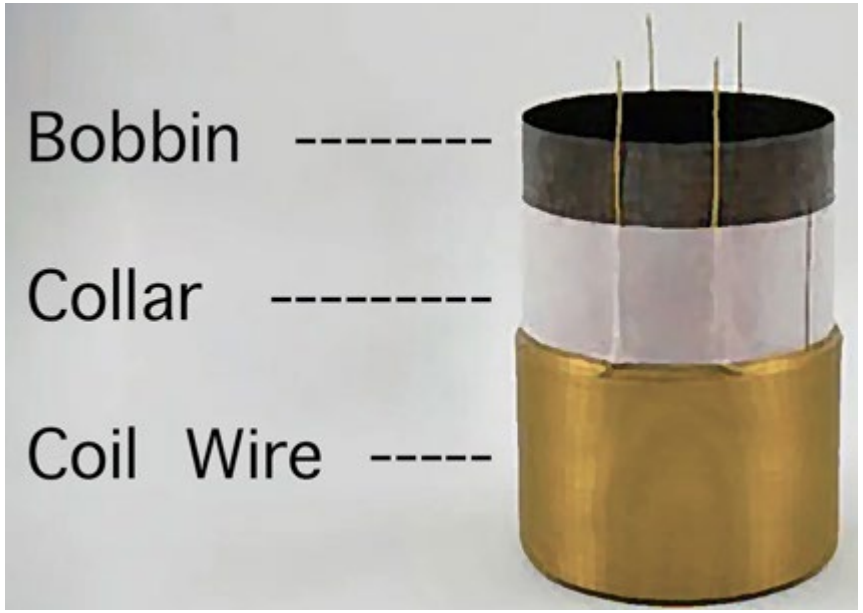
Voice Coil

- A winding of a wire, usually copper or aluminum that is wrapped around a former (bobbin) and then attached to the apex of a speaker cone
- Produces a varying magnetic field, works against a magnet’s fixed magnetic field.
- Forces move coil off center position. ○ Mechanical movement is (hopefully) analogous to electrical waveform supplied by the amplifier's output to the voice coil
- Since the coil is attached to a diaphragm, the voice coil’s vibratory motion transmits to the diaphragm.



Voice Coil

- Passing too much current through the coil can cause it to overheat.
- Ribbon-wire provides a higher packing density in the magnetic gap than coils wrapped with round wire.
- Surface-sealed bobbin & collar materials
- Excessive input power at low frequencies can cause distortion and possibly mechanical damage



Diaphragm Materials

- Tweeter materials are usually more rigid and thin to produce higher frequencies.
- Warm or Detailed
- Don’t want ringing so need well-damped material

What makes a good tweeter?

- Light & stiff
- Good dampening

Topic 7: Crossovers

What is a crossover?

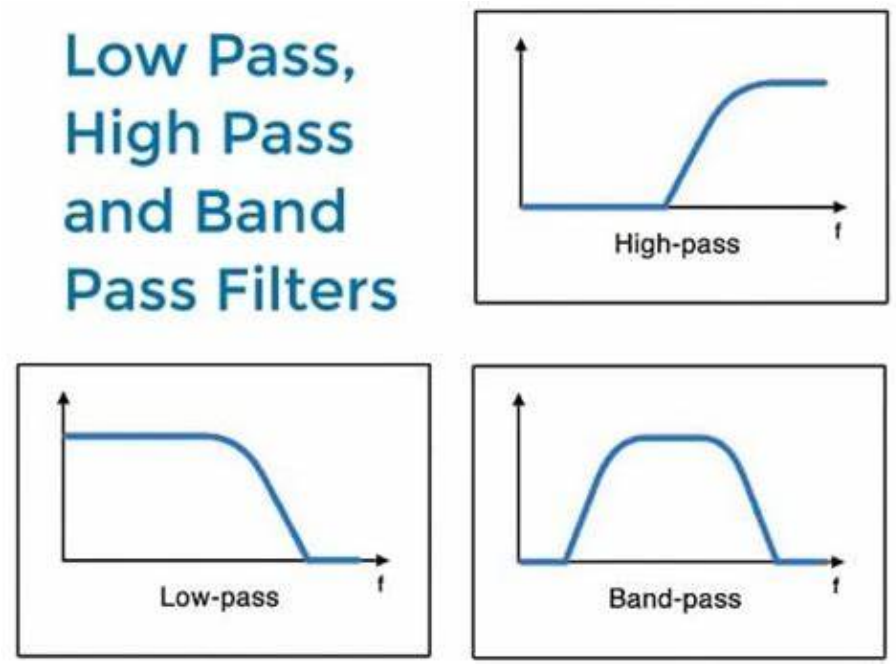
- The process of splitting an audio signal and sending specific filtered frequencies to multiple speakers that will more efficiently handle the frequency range sent.

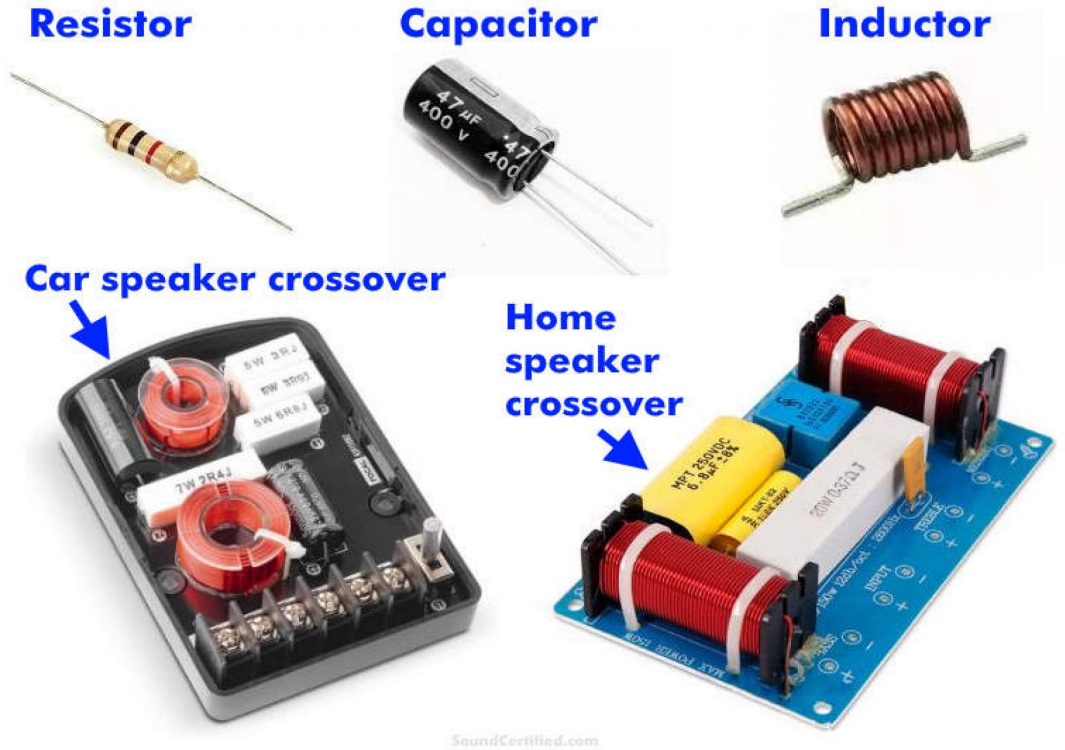
- Passive or Active
  - Passive does not require power
  - Requires power from amplifier

- Contains filters that direct low, mid, and high frequencies to specific outputs.
  - Sub
  - Woofer
  - Tweeter

Capacitors, Inductors & Resistors

- Capacitor: High Pass Filter
- Inductor: Low Pass Filter
- Resistor: Balances output level across all drivers. (Controls Impedance)





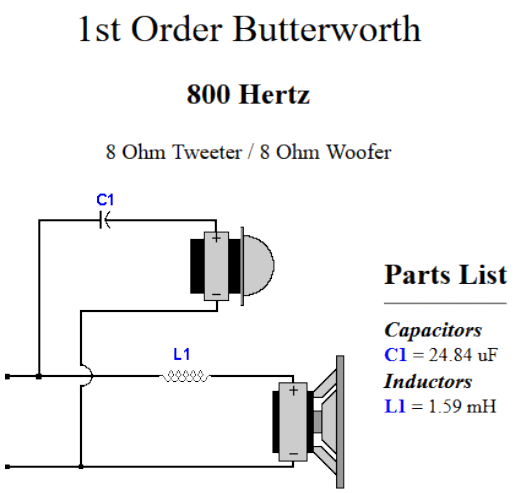
Order of Crossover 1st – 4th

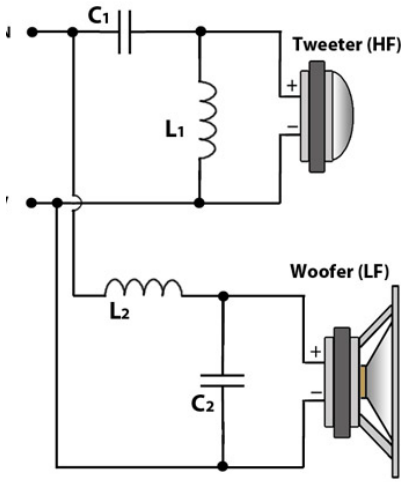
First-order (6 dB/octave): Gradually attenuating frequencies beyond the crossover point.

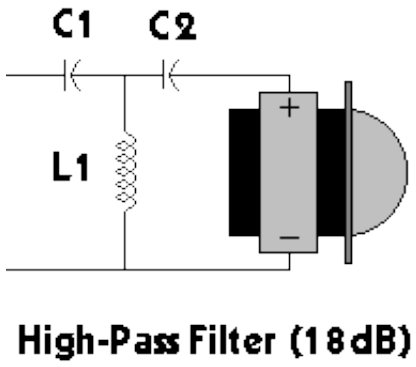
Second-order (12 dB/octave): Steeper slope, providing better separation between frequency ranges

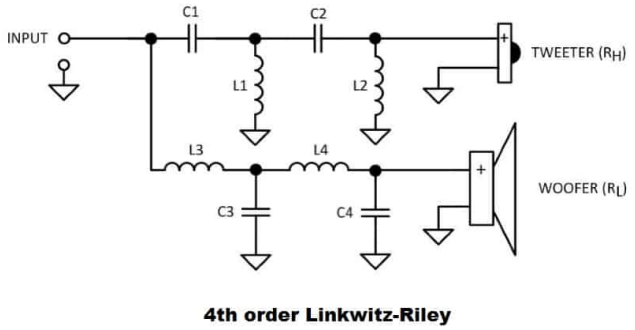
Third-order (18 dB/octave): Even steeper than the second-order. ensures more distinct separation between drivers

Fourth-order (24 dB/octave): Sharpest slope, allowing precise control over the frequency response









Types of Crossovers

- Linkwitz-Riley: Combo of 2 butterworth filters, no 3dB peak.
- Butterworth: Digital, 3dB peak at crossover point.

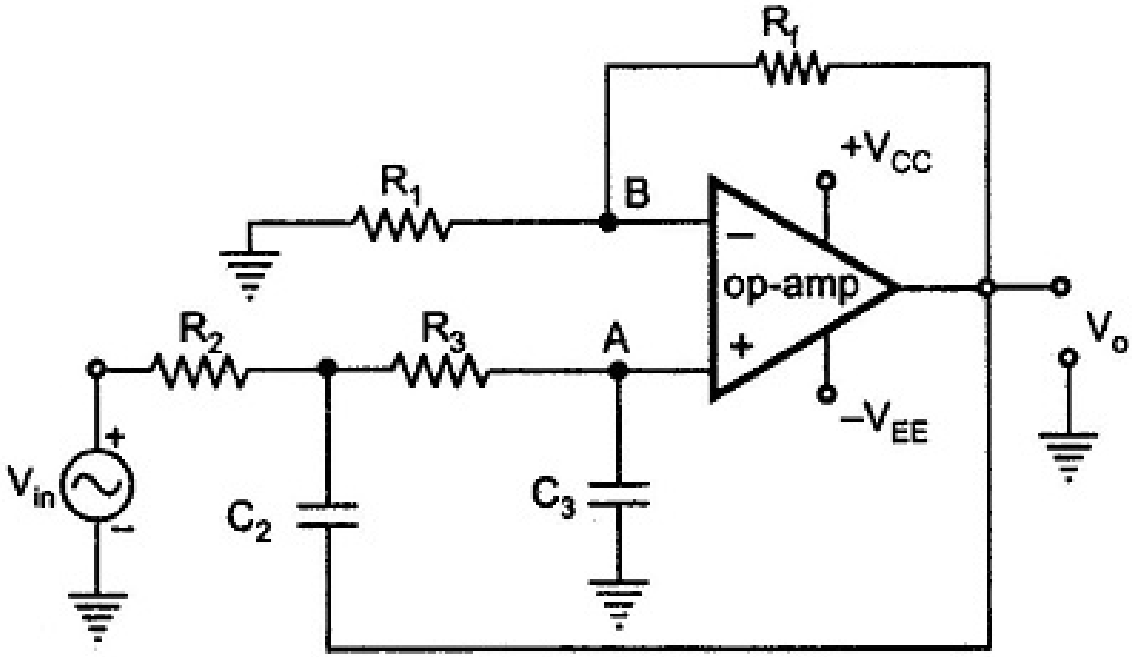


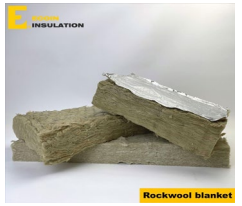
Fig. 2.76 Second order low pass butterworth filter

Topic 8: Cabinet Design

Cabinet Resonance

- Cabinet Resonance- When the mid- bass driver or subwoofer exerts pressure on the cabinet walls causing them to resonate and add unwanted sounds
- When the speaker driver moves it pumps air in the cabinet, this puts pressure on the cabinet walls causing them to flex and vibrate.
- The more mass you add, the heavier the damping
- = less resonance

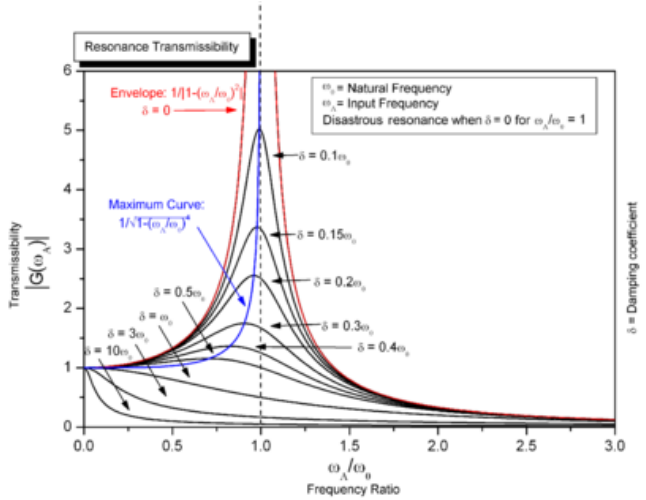
- To avoid, use dampening materials or add mass.
  - Polyfil
  - Fiberglass
  - Rockwool
  - Foam
  - Felt

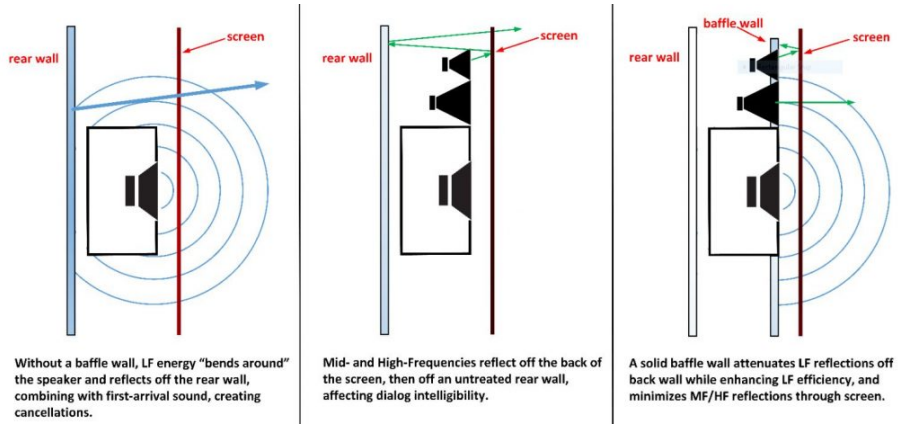


Panel Thickness and Resonant Frequency

- The thinner the panel the more you're hearing the resonance of the case.
- The thicker the panel the more you're hearing of the driver output.

- Resonant Frequency - Where the audio peaks in the resonance
- Internal Volume- How loud it is within the casing without damping





Bracing

- Bracing pushes resonant frequency higher
- Physical EQ
- Triangular bracing is most effective

Figure 2
R11 Cabinet construction

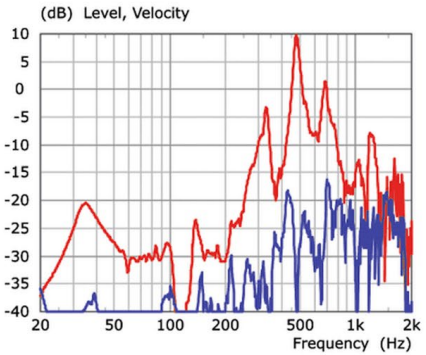
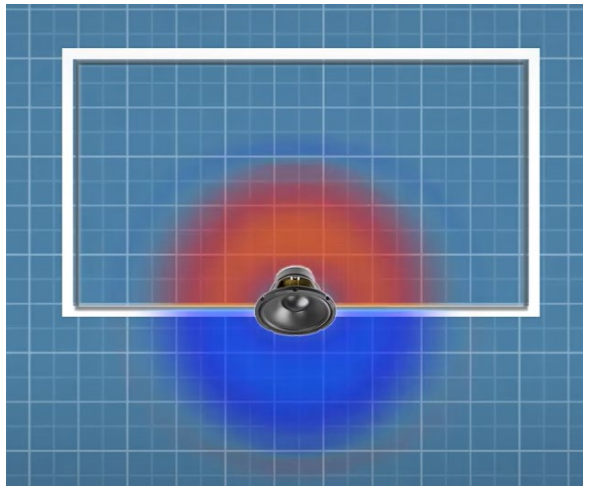
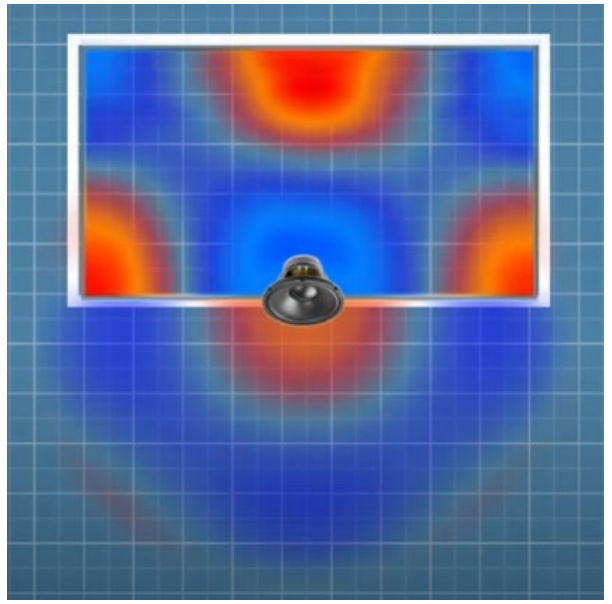


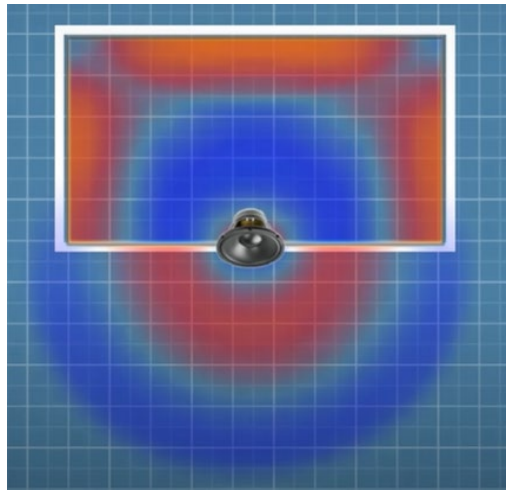
Figure 3
Panel vibration — without damping — with damped bracing

Internal Reflection

- When drivers move back and forth, they send sound both forwards and backwards
- Sound waves bounce off the back of the cabinet and hit the back of the driver, creating coloration / bias
- Irregular-shaped cabinet would help disperse / redirect rear sound waves

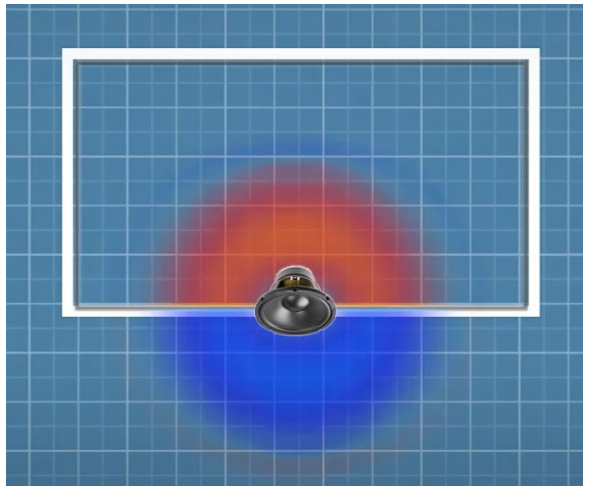


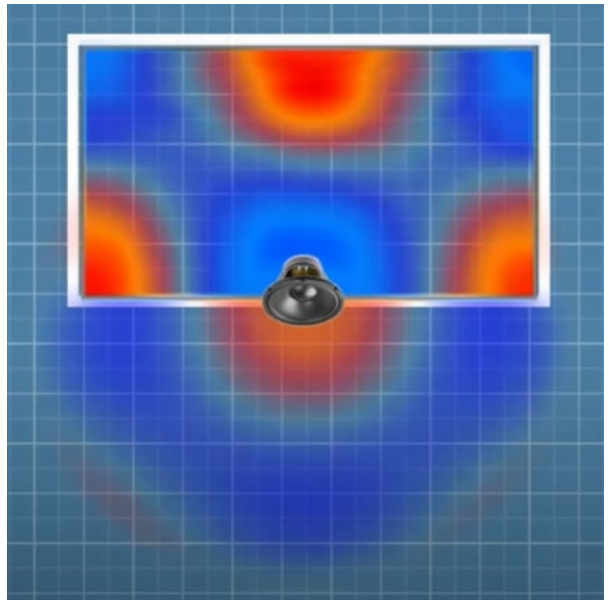


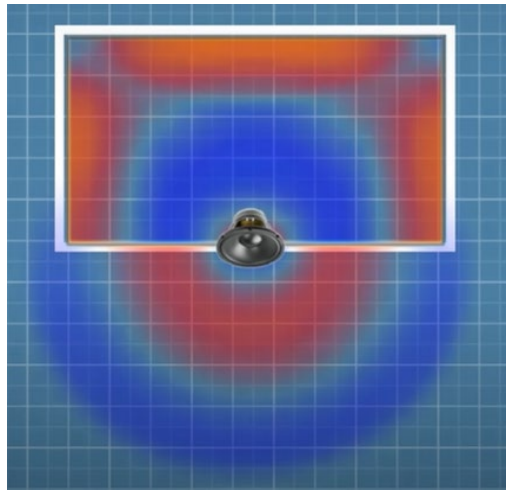


Internal Reflection

- When drivers move back and forth, they send sound both forwards and backwards
- Sound waves bounce off the back of the cabinet and hit the back of the driver, creating coloration / bias
- Irregular-shaped cabinet would help disperse / redirect rear sound waves







Topic 9: Transducer types

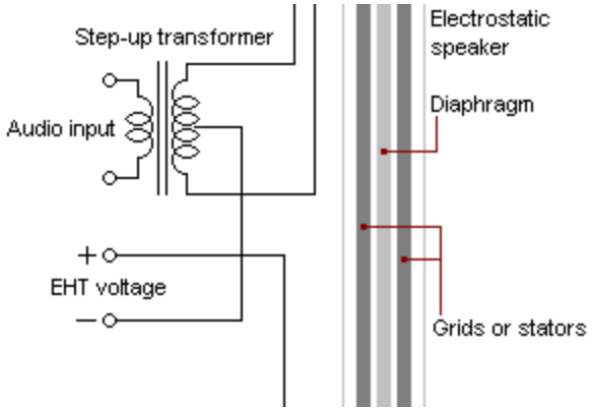
What are transducers

- A sound transducer is a device that can convert Sound Signals into electrical signals or electrical signals into sound signals
- Input Sound Transducers: Microphones, guitar pickups

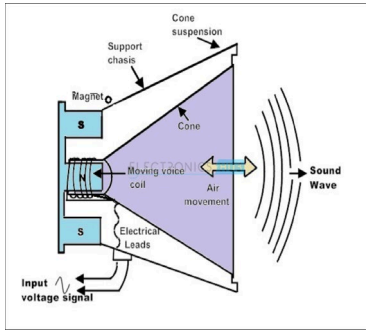
- Output Sound Transducers: Speakers

Types of Transducers

- Electrostatic:
  - Conductive diaphragm placed between two conductive plates
  - Uses positive and negative polarity switching to create vibrations
- Ribbon:
  - Strong and lightweight metalized film ribbon suspended between a set of high power magnets.
  - No voice coil
- Dynamic Cone:
  - Consists of a voice coil attached to a diaphragm

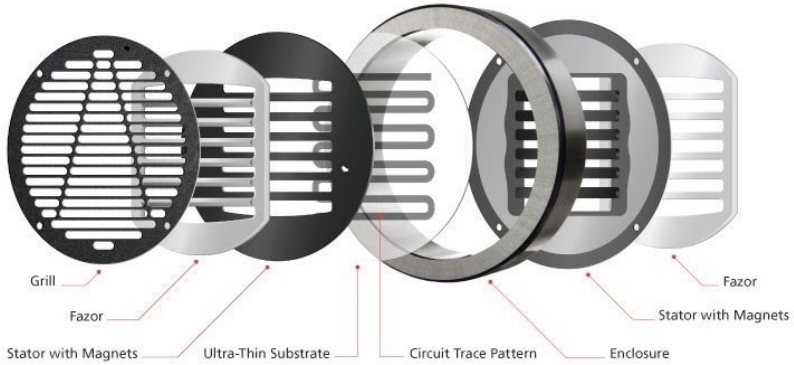


▲ Ribbon driver

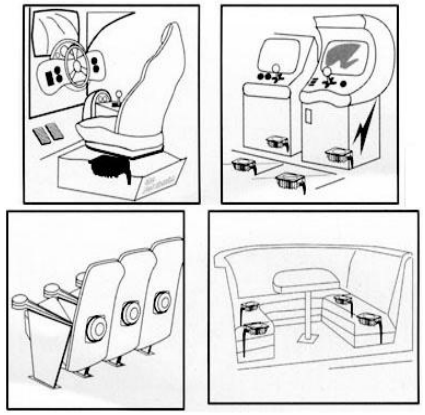


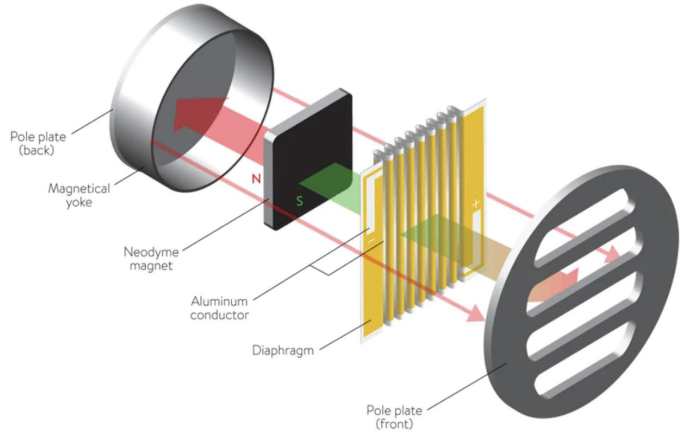
Motor Types

- Planar:
  - Planar magnetic drivers are electrostatic drivers that use a flat diaphragm to produce sound.



- Air Motion Transfer:
  - Electromagnetic Driver





- Tactile Transducers:
  - Attached to seating to increase bass sensation.
  - Allows listener to “Feel” the bass more

Topic 10: Thiele Small Parameters (TS Parameters)

What are T/S Parameters?

- Thiele-Small parameters are a set of measurements used to define the mechanical, electrical, and electromechanical properties of loudspeakers and speaker design.
  - They provide information about the design and performance of a speaker.
  - How big the housing should be.
  - How long should the bass reflex opening should be.

Common TS Parameters

- Resonant Frequency (Fs)
- DC Resistance (Re)
- Mechanical Q Factor (Qms)
- Electrical Q Factor (Qes)
- Total Q Factor (Qts)
- Mechanical Resistance (Rms)
- Equivalent Volume of Air (Vas)
- Sensitivity (SPL)
- Effective Piston Area (Sd)
- Linear Excursion (Xmax)

Which parameters matter for woofers?

- Resonant Frequency (Fs): This is the frequency where the speaker/subwoofer plays with the least effort in a free air situation. This also determines the lower frequency limit of the driver’s usable range.
- This is less important for tweeters since they operate at higher frequencies.
- Excursion Distance Before Distortion (Xmax): The Xmax is the maximum distance of travel before DISTORTION.

Power Handling

- Power handling refers to the maximum amount of electrical power a speaker can handle without being damaged. It's typically specified in terms of both continuous (RMS) power and peak power.
- Exceeding the rated power handling can lead to distortion, overheating, or even physical damage to the speaker.

Sensitivity

- Sensitivity, often expressed in decibels (dB), measures the sound pressure level (SPL) produced by the speaker when driven by a standard input power level.
- Sensitivity is measured with an input power of 1 watt and at a distance of 1 meter from the speaker.
- A higher sensitivity rating indicates that the speaker produces louder sound for the same input power compared to a speaker with lower sensitivity.
- Sensitivity influences efficiency

85 dB Sensitivity Rating		90 dB Sensitivity Rating	
Watts	dB Produced	Watts	dB Produced
1	85	1	90
2	88	2	93
4	91	4	96
8	94	8	99
16	97	16	102
32	100	32	105
64	103	64	108
128	106	128	111
256	109	256	114

Sensitivity and Power Handling Relationship

- Efficiency: A speaker with higher sensitivity generally converts more electrical power into sound energy efficiently.
- Power Requirements: Speakers with higher sensitivity require less power to produce a given volume level than speakers with lower sensitivity.
- System Design: A speaker with high sensitivity might be paired with a lower-powered amplifier and vice versa.

Speaker Efficiency (dB)	Amplifier RMS Power (Watts)									
	1	2	4	8	16	32	64	128	256	512
80	75	78	81	84	87	90	93	96	99	102
83	78	81	84	87	90	93	96	99	102	105
86	81	84	87	90	93	96	99	102	105	108
89	84	87	90	93	96	99	102	105	108	111
92	87	90	93	96	99	102	105	108	111	114
95	90	93	96	99	102	105	108	111	114	117
98	93	96	99	102	105	108	111	114	117	120
101	96	99	102	105	108	111	114	117	120	123
104	99	102	105	108	111	114	117	120	123	126
107	102	105	108	111	114	117	120	123	126	129
110	105	108	111	114	117	120	123	126	129	132
113	108	111	114	117	120	123	126	129	132	135
116	111	114	117	120	123	126	129	132	135	138
119	114	117	120	123	126	129	132	135	138	141

Compliance (Cms) and Bass Loading

- Refers to how easily a speaker's cone can move back and forth in response to changes in air pressure.
- The compliance of the woofer affects how it behaves in different types of enclosures used for speakers, particularly in ported and sealed.

Topic 11: Loudspeaker Specifications

Revisiting Power Handling

- Peak: the absolute most amount of power run through the system
  - Refers to overall most watts possible
  - Not long term
- RMS (root mean square) : the average of how high the power can be run "comfortably“
  - Refers to continuous use
  - Equation to see values over time

Root Mean Square

$$x_{rms} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2} = \sqrt{\frac{x_1^2 + x_2^2 + \ldots + x_n^2}{n}}$$

Units of Measurement

- dB = unit of volume
- KHz= unit of frequency
  - The cycle of a specific frequency
- Meter = unit of distance
  - Related to distance sound waves move
- Watt = unit of Power
  - Amp sending too many watts can destroy speaker
  - Too little can cause clipping

1 Watt at
1 KHZ
+
mic 1
meter away

Pro vs. Home Audio

- HOME - REGULAR
  - Ease of Use
  - Pleasurable frequency curve.
  - Boost in bass and treble
  - Not accurate because of this
- PRO - STUDIO
  - Accurate, Flat, sound reproduction
  - Durability

Consumer preferences

- Size
  - 6×9-inch, 6.5-inch, 5 1/4-inch, 4-inch, and 3.5-inch.
  - Common sizes include 6.5", 8", and 12"
  - These common speaker sizes produce a diverse range of tones.
  - Not accurate because of this
- Visual aesthetic
- Enclosure material
- Bass/punch

Vented vs Sealed dispersion

- Vented allows for more reinforcement of low bass frequencies giving the illusion of more bass.

- Sealed allows for more controlled and “tight” low end response without any extra bass reinforcement.

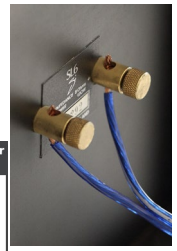
Types of connectors

- SpeakOn

- Banana plug

- ¼” Phono

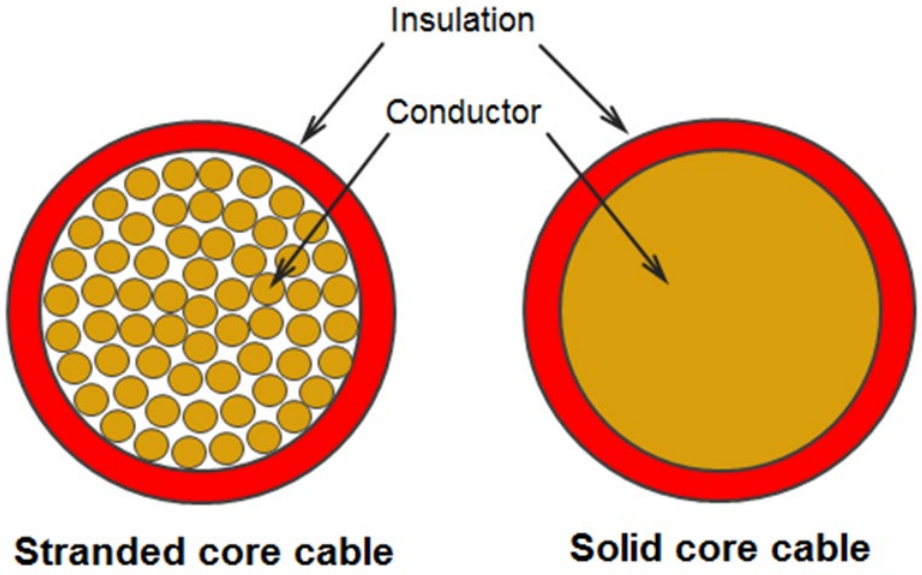
- Bare wire



- XLR

Stranded vs. Solid core

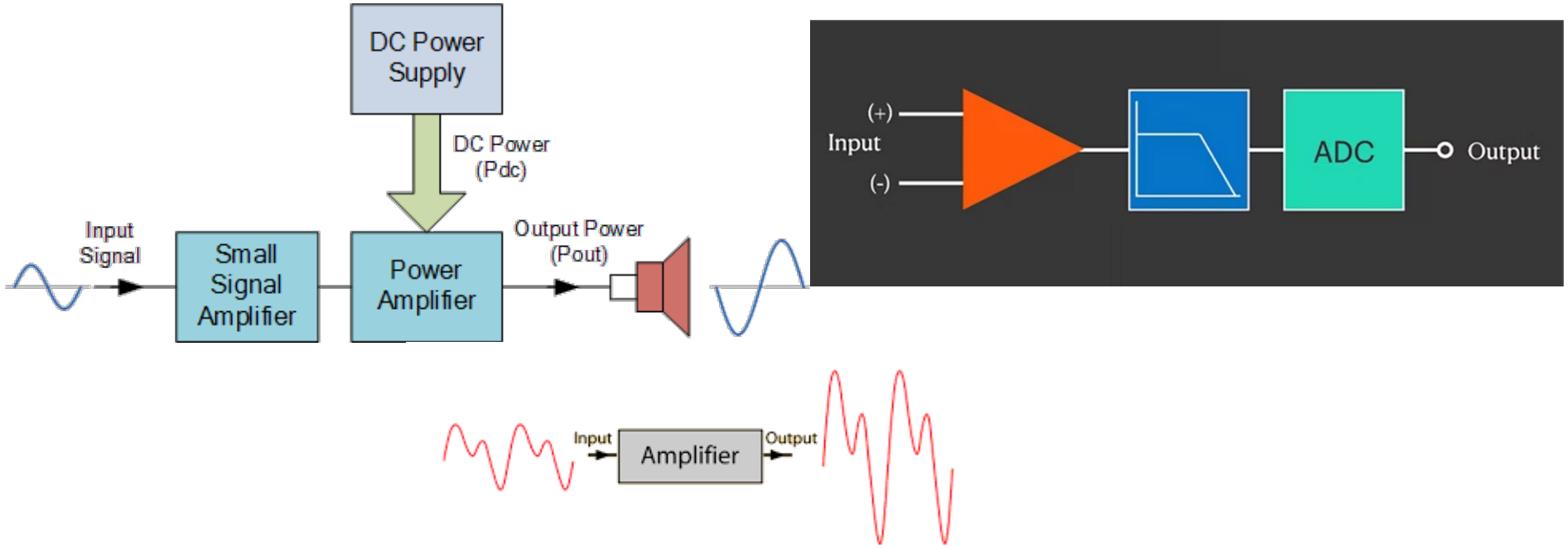
- Stranded core has many ‘outside’ circumferences, which reduces high frequency losses
- Solid core can only bend a few times before it cracks and breaks.
- Stranded core wire is way more flexible and is exclusively used as speaker wire



Topic 12: Amplifiers and Signal Processing

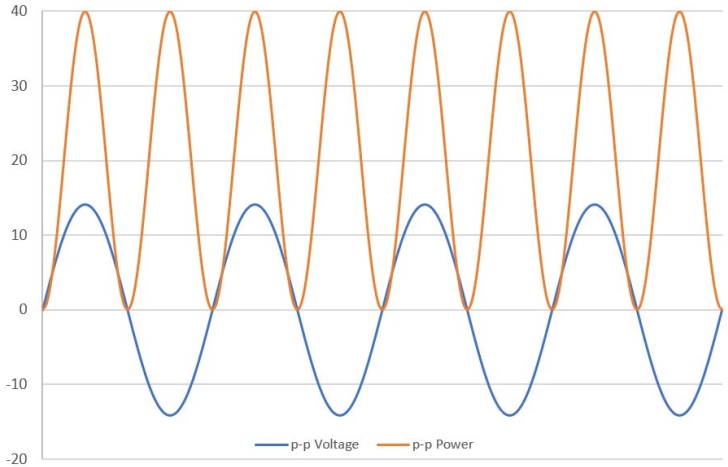
Amplifiers

- Increase voltage, current, or power of a received signal.



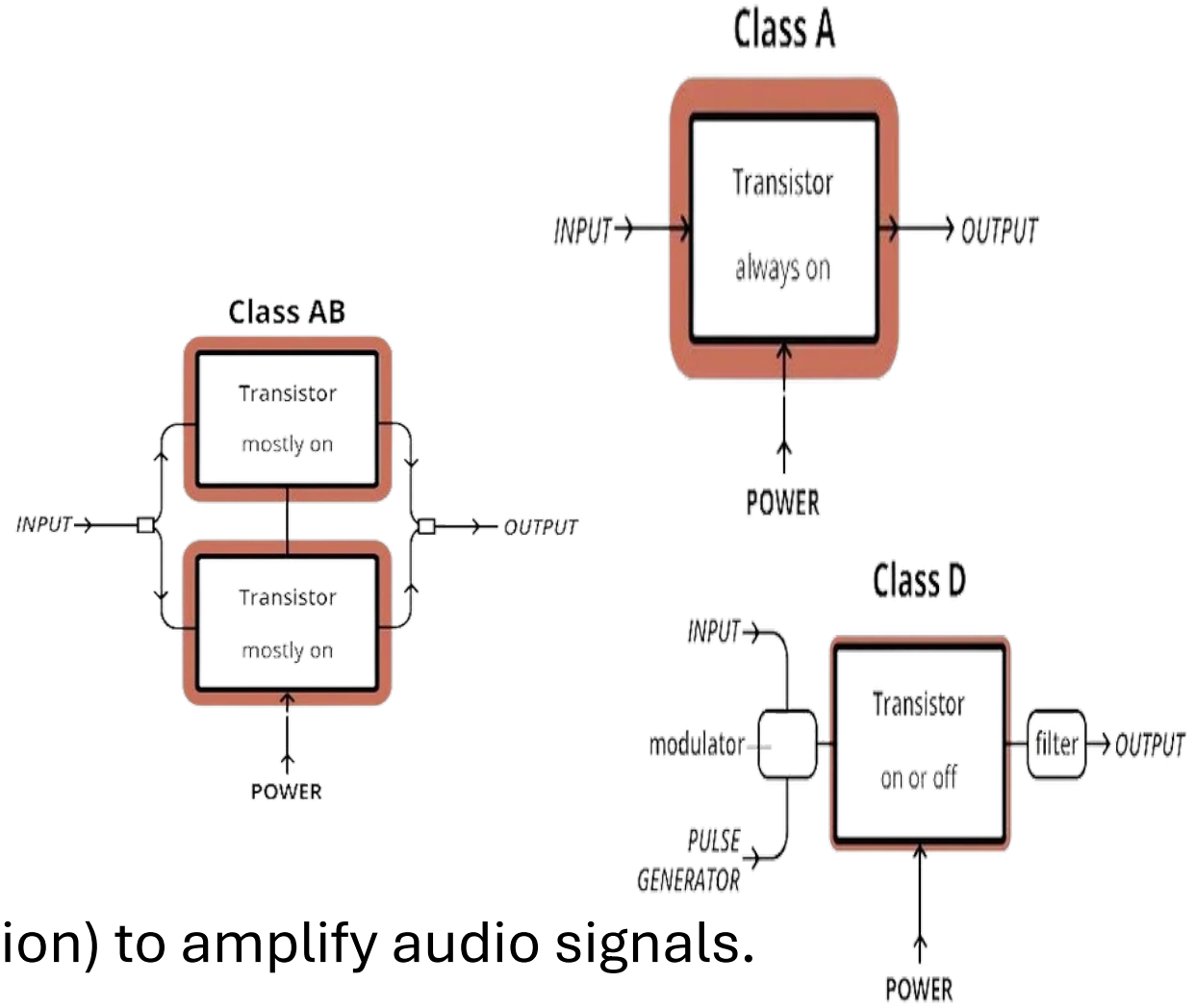
Power Supply

- A power supply allows enough power to get to an amp and will also can reduce noise and interference
- Amplifier power is calculated
- Voltameter is measured in volts
- Ammeter measured in amps
- Ohmmeter measures resistance in Ohms
- Power (watts) = Voltage squared by Resistance
- Take the voltage (blue) a square it, then divide that by the constant, and we get the power output (orange)
- Calculator for Amp Power
- Amplifier power is basically the average continuous



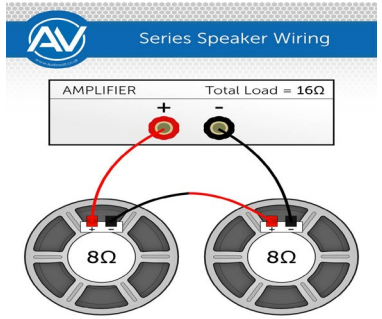
Amplifier Types

- Class A
  - Hi-Fi
  - Always run at full-power
  - Expensive
- Class AB
  - Hi-Fi
  - Running more than half the time
  - Don’t turn on and off abruptly
  - High efficiency
- Class D
  - Utilizes PWM (Pulse Width Modulation) to amplify audio signals.

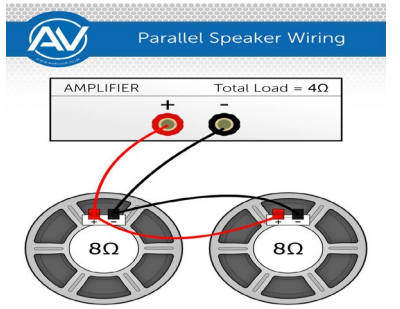


Parallel vs. Series Wiring

- Wiring in series increases the impedance. This is calculated by multiplying the number of speakers by their impedance. For example:
  - 2x speakers @ 8Ω = 16Ω
  - 2x speakers @ 4Ω = 8Ω
  - 4x speakers @ 4Ω = 16Ω



- Wiring in parallel reduces the impedance. This is calculated by dividing the number of speakers by their impedance. For example:
  - 2x speakers @ 8Ω = 4Ω
  - 2x speakers @ 16Ω = 8Ω
  - 4x speakers @ 16Ω = 4Ω

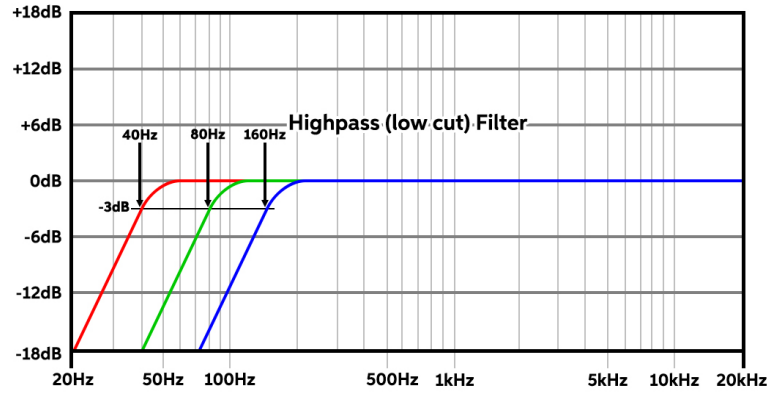


Signal Processing

- Some amplifiers have built in signal processing.
  - Crossovers
  - Low Cuts
  - Delays
  - Limiters

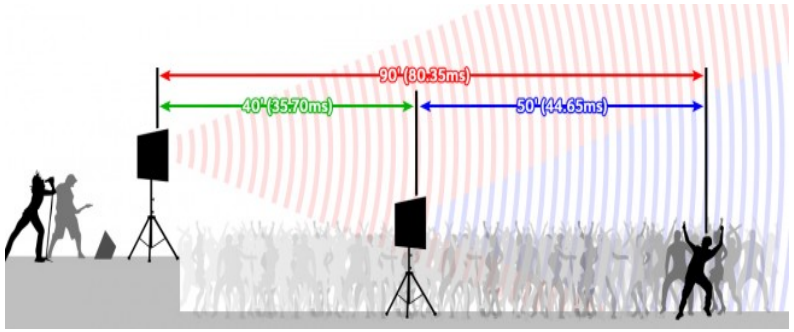
Low Cut / Bass Cut

- Can be either a function of EQing or the crossover itself
- Removes lower frequencies from a speaker to avoid trying to reproduce bass that is too low for it to play without distorting
- The louder you get, the higher the low cut needs to be to avoid overdriving the woofer, even with subwoofers



Delays and Time Alignment

- Delays can delay the audio signal for a specific amount of time before allowing it to pass.
- Them amount of delay can be either expressed in time or distance
- Short delays are smaller values used for time alignment of individual drivers within a single speaker. Typically < 1’
- Long delays are larger values used to time align one speaker to another speaker. Can be any distance up to hundreds of feet.



Delays and Time Alignment cont.

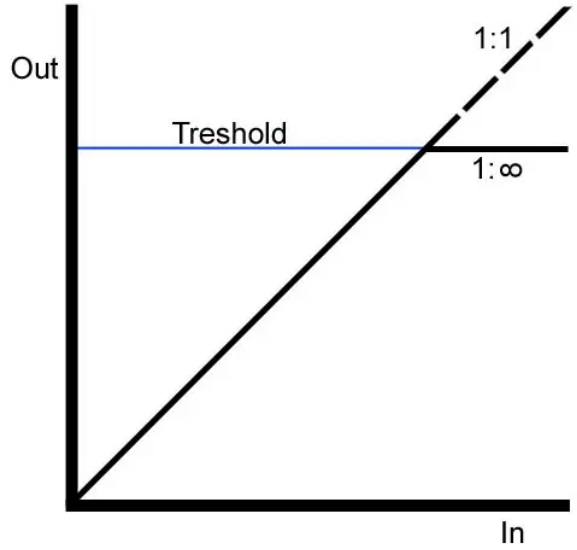
- Time alignment is a means of delaying one speakers input signal relative to another so that the sound from each speaker arrives to you at the same time

- Can delay full range speaker or individual drivers to compensate for differences in distance between one another.

- Delays can allow for out-of-phase waveforms to be pushed back into phase coherency.

Limiter

- Cap peak signal getting to the amplifier(s)
- Used to keep speakers from being played to loud, either for their protection or for audience protection
- Keeps inexperienced system operators from blowing up speakers or hurting the audience



Topic 13: Room Acoustics and Speaker Placement

What are room acoustics?

- The behavior of sound in an enclosed space.

- Dependent on:
  - Architecture of room
  - Surface materials
  - Room size and dimensions
  - Room noise bleed

Room size and dimensions

- Certain ratios between dimensions can distribute sound modes more evenly and minimize the impact of standing waves and resonances.
- Specific ratios have been shown to mitigate problematic sound wave behavior.
  - Golden ratio: 1 x 1.6 x 2.56

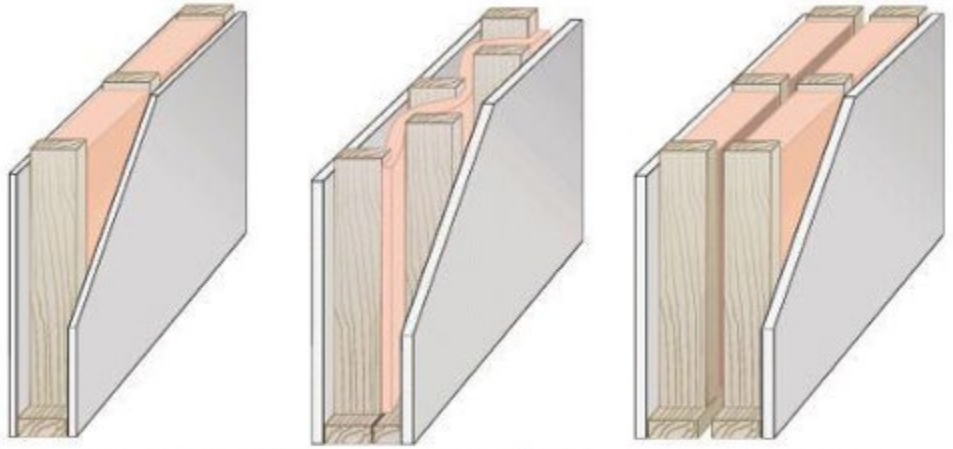
W	H	L	cu.ft.	m^3	
9' | 2.74m	11' | 3.35m	10' | 3.04m	990	27.09	[RED] Find a larger room. Extensive low frequency treatment required
10' | 3.04m	11' | 3.35m	11' | 3.35m	1210	34.12	
11' | 3.35m	11' | 3.35m	12' | 3.65m	1452	40.96	
12' | 3.65m	11' | 3.35m	13' | 3.96m	1716	48.42	
13' | 3.96m	11' | 3.35m	14' | 4.26m	2002	56.51	
14' | 4.26m	11' | 3.35m	15' | 4.57m	2310	65.21	[YELLOW] Treatable/large areas of coverage. Good low, middle, and high end.
15' | 4.57m	11' | 3.35m	16' | 4.87m	2640	74.55	
16' | 4.87m	11' | 3.35m	17' | 5.18m	2992	84.51	
17' | 5.18m	11' | 3.35m	18' | 5.48m	3366	95.09	
18' | 5.48m	11' | 3.35m	19' | 5.79m	3762	106.29	
19' | 5.79m	11' | 3.35m	20' | 6.09m	4180	118.12	
20' | 6.09m	11' | 3.35m	21' | 6.40m	4620	130.56	[GREEN] Minimal EQ required. Strong low, middle, and high end.
21' | 6.40m	11' | 3.35m	22' | 6.70m	5082	143.64	
22' | 6.70m	11' | 3.35m	23' | 7.01m	5566	157.33	
23' | 7.01m	11' | 3.35m	24' | 7.31m	6072	171.66	

Noise Bleed

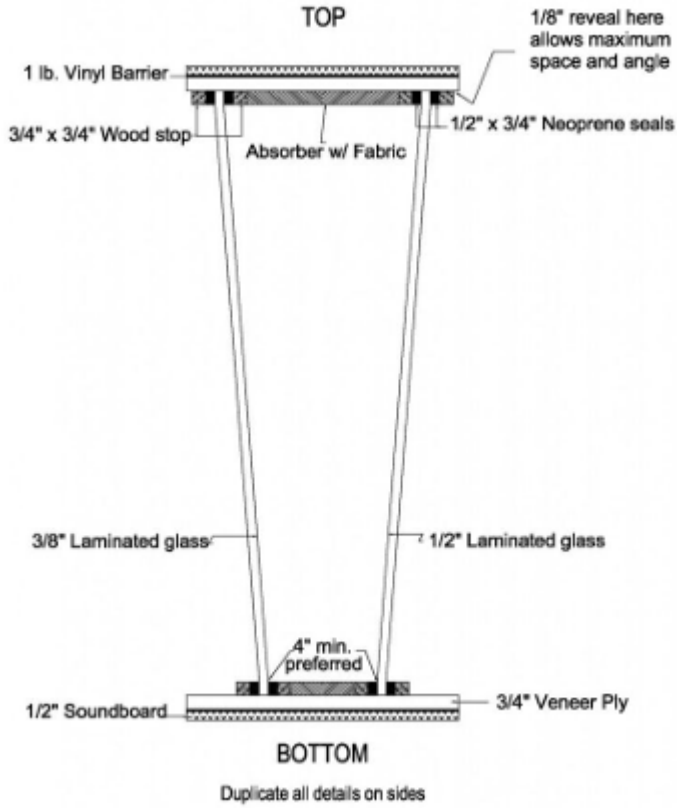
- Noise - Unwanted Sound
- Noise Floor - The constant level of noise in a room, added up from all noise sources
- Noise From Outside
- Noise From Inside
- Noise Criteria (NC) - a rating system for background noise levels

Reducing Bleed

- Walls
  - Insulation
  - Double Studs
  - Soundproofing
- Floor
  - Concrete
  - Floating floors
  - Carpets
  - Risers
- Ceiling
  - Carpeting above
  - Insulation
- Windows
  - Double Pane
  - Sound Dampening around edge
- Doors
  - Double lock
  - Weather stripping
  - Heavy doors



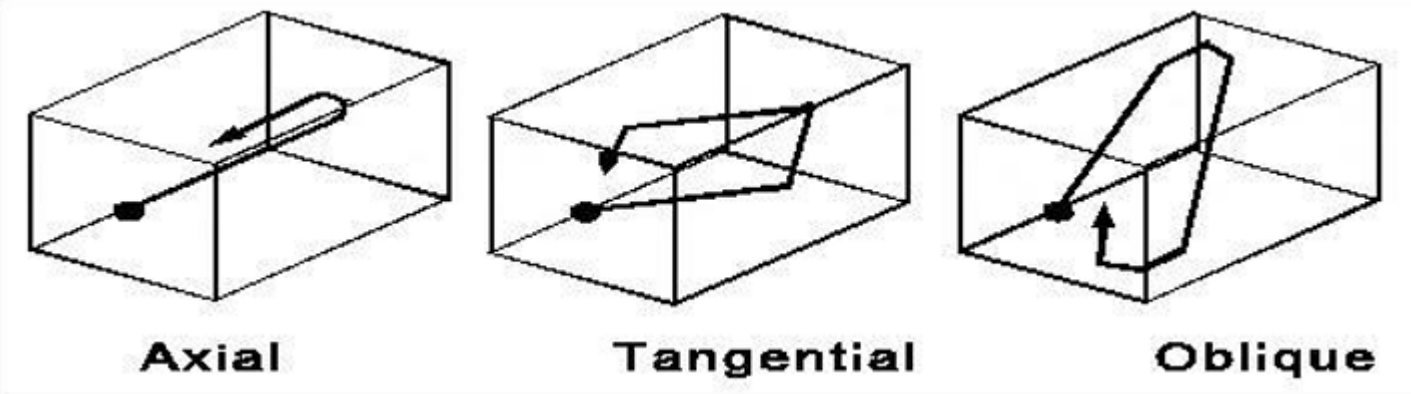
Conventional wall (coupled) Staggered stud wall. Shown is 2x4 studs offset on a 2x6 base plate Double stud walls. Two separate rows of studs with drywall only on the outside



Room Modes and Materials

Floor materials	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Carpet	0.01	0.02	0.06	0.15	0.25	0.45
Concrete (unpainted, rough finish)	0.01	0.02	0.04	0.06	0.08	0.1
Concrete (sealed or painted)	0.01	0.01	0.02	0.02	0.02	0.02
Marble or glazed tile	0.01	0.01	0.01	0.01	0.02	0.02
Vinyl tile or linoleum on concrete	0.02	0.03	0.03	0.03	0.03	0.02
Wood parquet on concrete	0.04	0.04	0.07	0.06	0.06	0.07
Wood flooring on joists	0.15	0.11	0.1	0.07	0.06	0.07

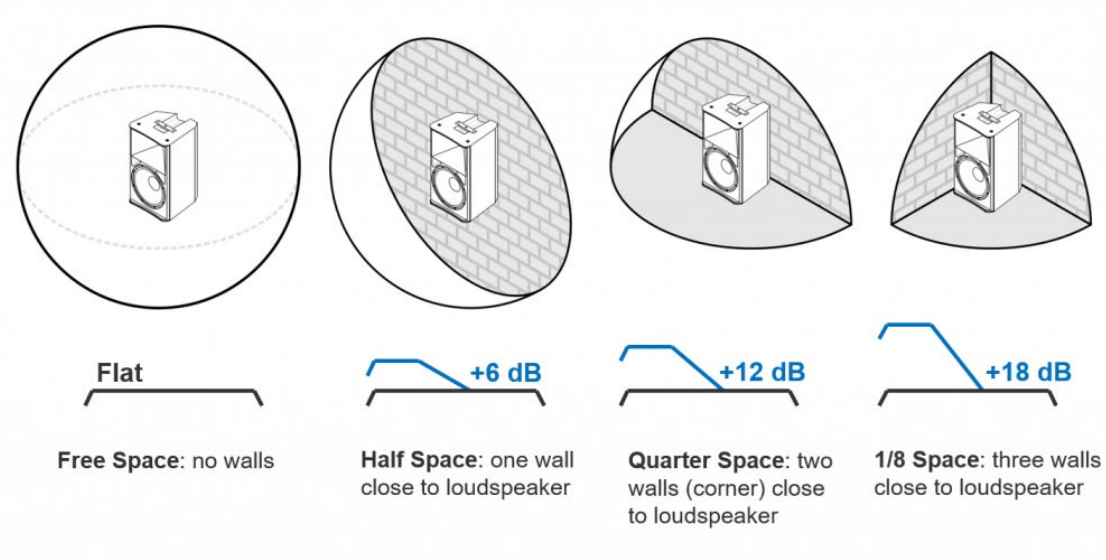
- Axial
- Tangential
- Oblique



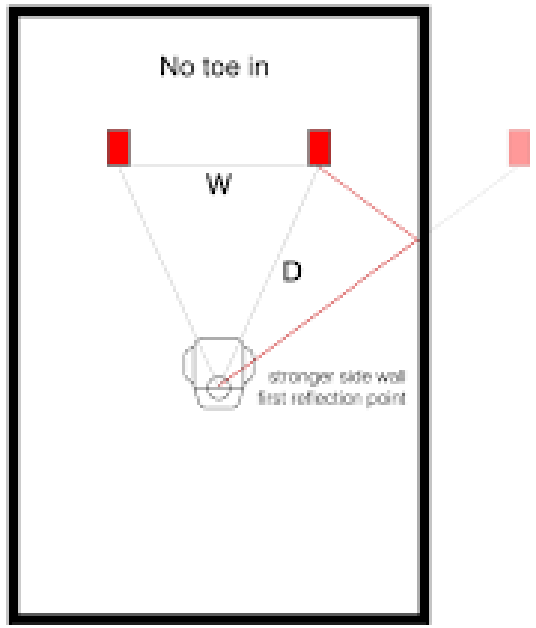
- Non-Parallel walls
  - Break up standing waves
- Different materials have different absorption properties.
  - Acoustic foam and diffusers
  - Strategically placed to mitigate room

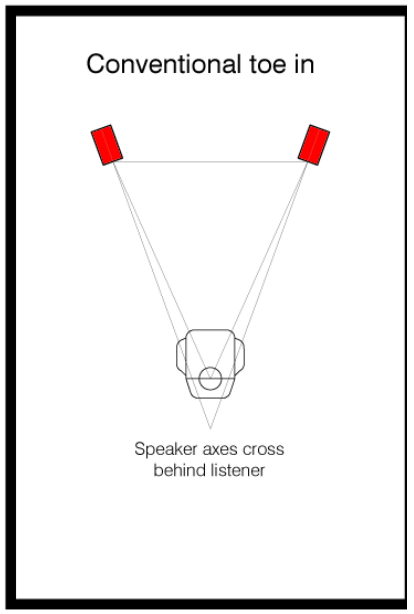
Speaker placement

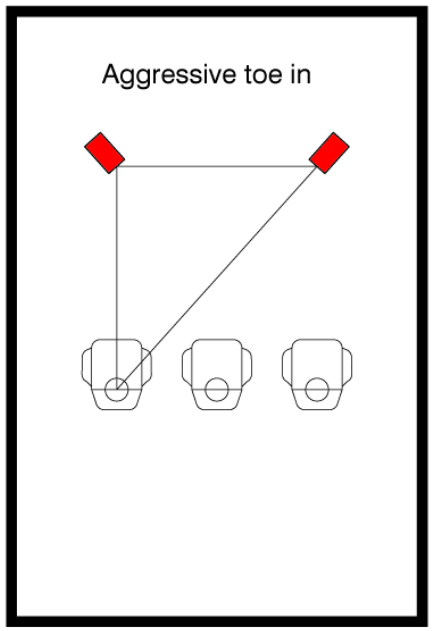
- Whole space: Speakers are placed away from walls and corners, and no EQ is necessary
- Half space: Speakers are close to one wall, and the bass should be rolled off by 2 to 6 dB
- Quarter space: Speakers are placed near corners, and the bass should be rolled off by 4 to 12 dB



Speaker Alignment Positions







Dispersion

- Narrow dispersion is undesirable
- Dispersion changes with frequency
  - Low frequencies have wider dispersion
  - High frequencies are more directional