ACOUSTIC BASICS

SIGNAL CHAIN

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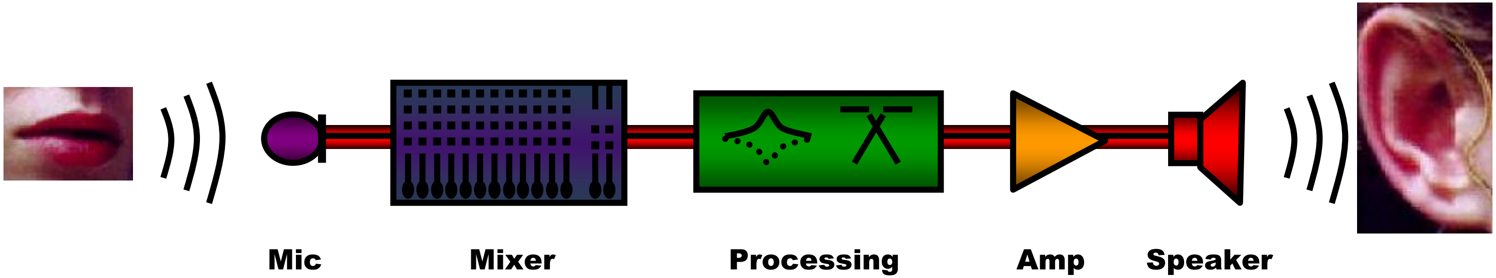
The Signal chain
Part I



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The Signal Chain in Total

Microphones

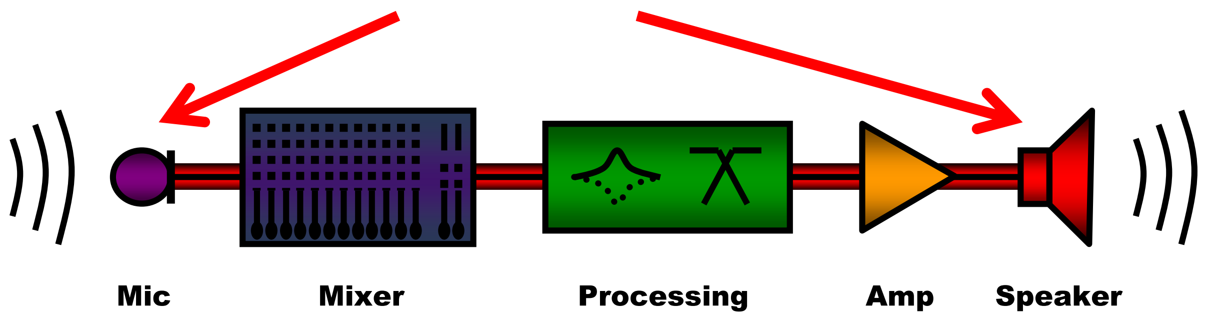
→ Mixing Consoles

→ Processing

→ Amplifiers

→ *Loudspeaker*

→ **Part I includes the in- and output side**



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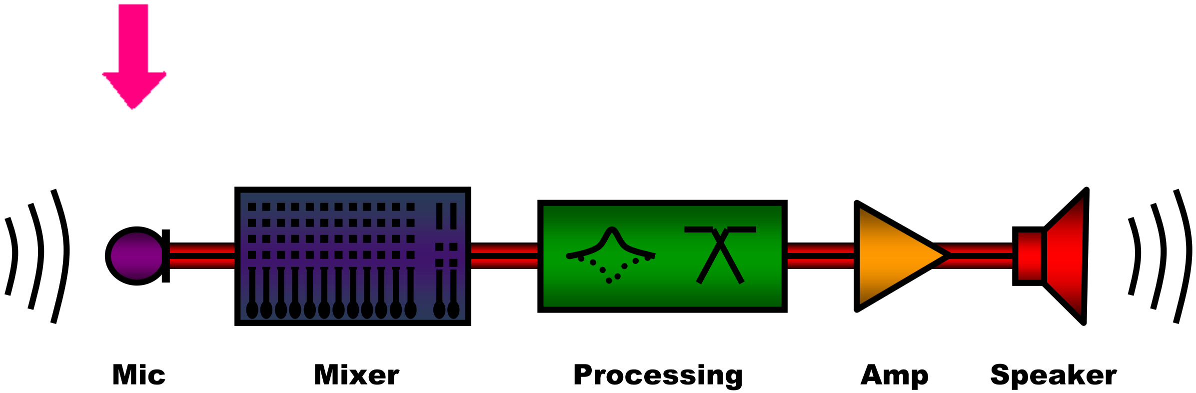
Signal Chain
Microphones



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Microphones
Overview

- ➔ Electroacoustical transducers:

  - Dynamic microphones
  - Condenser microphones

There are still some more types of microphones, but we will have a closer look to the above mentioned ones.

- ➔ General terms
  - Polar Pattern
  - Proximity-effect
  - Frequency response

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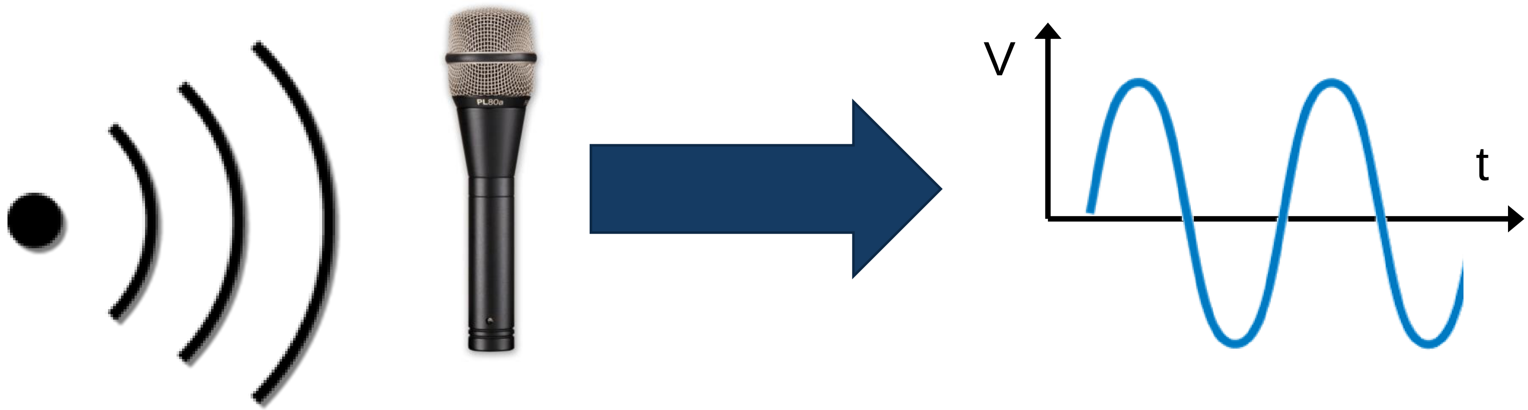
Microphones
Electroacoustical Transducer

➔ How the microphone converts sound into an electrical signal



acoustic signal ⇨ electrical signal

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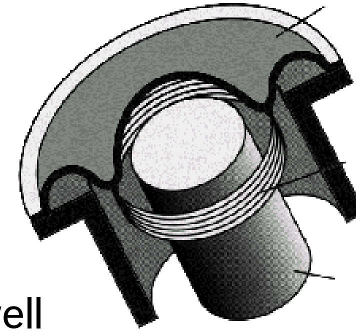
Microphones
Microphone transducer technologies

➔ Dynamic microphone:

➔ Pro´s and Con´s vs. Condenser microphone

- Simple Design, tend to be more affordable
- Large Size – Rugged
- Limited Frequency Response (Sound Quality)
- Handle extremes of temperature and humidity very well



➔ How is it working?

Sound waves set the diaphragm vibrating. The voice coil, which is connected directly with the diaphragm, moves in the magnetic field with a certain speed and an alternating voltage is inducted into the voice coil -> the acoustic signal is converted into a small electrical signal.

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Microphones
Microphone transducer technologies

- Condenser (=Capacitor) microphone:
- Pro´s and Con´s vs. Dynamic microphone
  - Requires Power (phantom or bias voltage)
  - High sensitivity (more natural/clearer sound)
  - Extended frequency response
  - Better transient response
  - More expensive
  - An additional microphone preamp is needed to match the output signal to the following signal processing. The preamp has two functions - convert impedance from about 1 MΩ to 150 Ω and bring the signal to "standard" - which means higher - mic level. The above mentioned phantom power supply is necessary to power the preamp circuit. If a low quality preamp is used, signal to noise ratio and dynamic problems can occur.
  - Flat frequency response and wide bandwidth are easier to achieve in comparison to a dynamic microphone.
  - The microphone cartridge can be built in smaller dimensions. It is the only choice if it comes to a subminiature lavalier microphone.

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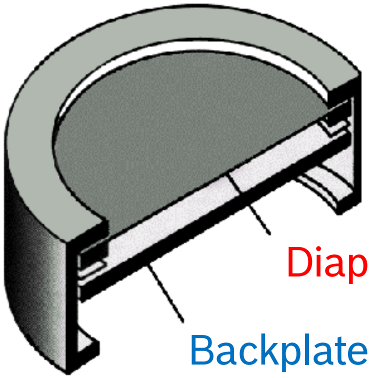
Microphones
Microphone transducer technologies

- Condenser (=Capacitor) microphone:

- **How is it working?**

  The plates (diaphragm / Backplate) are electrically charged, one positive and the other negative -> that means a capacitance is built up between the plates. If sound waves set the very thin gold-coated-plastic diaphragm, which is mounted just in front of the rigid backplate, in vibration, a change of the "basic" capacitance happens and in turn this results in a variable electric current flow -> the acoustic signal is converted into a small electrical signal.



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Microphones
Phantom Power

- Phantom power is a DC voltage (11 - 52 volts) which powers the preamplifier of a condenser microphone.

- Phantom power is supplied by

  - microphone mixer

    If a mixer supplies 48 volts of phantom, XLR pins 2 and 3 of the microphone cable carry 48 volts DC relative to pin 1. Mixers that supply phantom power contain current limiting resistors which act as control valves. If the microphone or cable is improperly wired, these resistors limit the flow of current to the microphone and thereby prevent damage to the phantom supply circuit.

  - separate phantom power supply

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Microphones
Phantom Power

- Phantom requires balanced circuit in which XLR pins 2 and 3 carry the same DC voltage relative to pin 1.
- The microphone cable carries the audio signal as well as the phantom voltage.
- A balanced dynamic microphone is not affected by phantom power.
- However, an unbalanced dynamic microphone (not common) will be affected. Although the microphone will probably not be damaged, it will not work properly.

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Dynamic vs. Condenser Microphones

	Dynamic Microphones	Condenser Microphones
Construction	Simple	More complex
Cost	Less expensive	More expensive
Handling	Tolerates very rough handling	Requires careful handling
Sound Quality	Excellent over a wide frequency range	Very sensitive, smooth, natural sound even at the highest frequencies
Power Source	Does not require a separate power source	Requires phantom power or batteries
Environment	Good for live performance and some recording applications	Good for controlled environments, recording and some live applications

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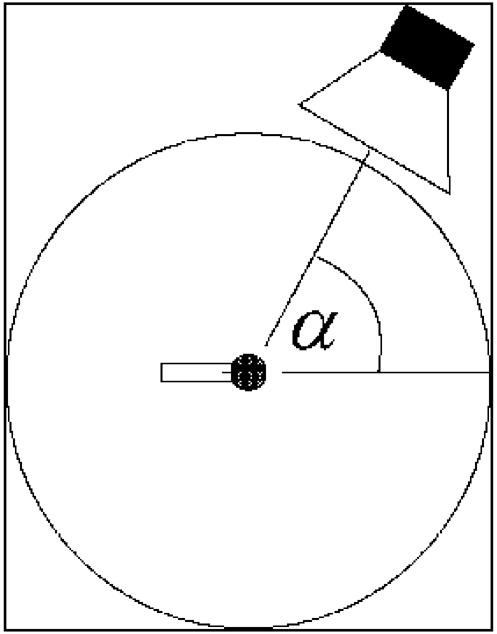
Microphones

Polar Pattern and Polar diagram

- A **polar pattern** is three dimensional. It demonstrates, how sensitive a microphone is to sound waves arriving from different directions. To measure the polar pattern, the microphone is rotated in front of a loudspeaker. The output signal is recorded in its relation to the angle between the microphone and the loudspeaker.

- A **polar diagram** is two dimensional and shows is a cross-section of the three dimensional polar pattern. That is the most common way in data sheets. The polar diagram provides information about the sensitivity of the microphone in relation to the angle between the sound source and the diaphragm / capsule of the microphone.



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Microphones
Directionality

- The closer you get to a sound source, the higher is the sound pressure level. This local change in sound pressure level is physically defined as a pressure gradient field. If a microphone points in the direction of a sound source, the sound pressure level in front of the microphone element is higher than behind of it.

- Pressure Gradient Microphones

  - have openings at the rear side of the microphone head. Through these openings sound waves can enter the cartridge rear.
  - The difference between the pressure upon the diaphragm from the front and the rear determines the output signal of the microphone.
  - In addition both components have different phase positions, which leads either to a positive or destructive interference.

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Microphones
Directionality

➔ The overall size of the rear side openings has a strong influence upon the resulting polar pattern. It determines the acoustical impedance of the openings.

○ no openings:	omnidirectional
○ midsize openings:	unidirectional
○ big openings:	bi-directional

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Microphones
Proximity-Effect

- In easy words the proximity effect increases low frequencies if a sound source is close or too close to a directional microphone. This effect does not show up with a non-directional microphone. The short-distance sound zone is responsible for this effect at pressure gradient microphones.

- **Reason for this effect:**
  If microphones are positioned very close to sound sources the bending of the wave front (spherical wave) compared to the wavelength gains more importance. Therefore the pressure gradient increases disproportional compared to the sound pressure level. There is an phase shift component caused by the spherical wave form additive to the existing phase shift of the rear sound. The result is:

  $\Rightarrow$ higher drive of the microphone diaphragm

  $\Rightarrow$ higher output signal

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Microphones
Proximity-Effect in practice

- The closer the microphone is moved to the sound source, the more low frequencies are boosted.
- At bigger distances (~more than 1 m) the voice sounds thin and without any bass.
- In „close talking“ mode the voice sounds full and deep.
- The proximity-effect can be used on purpose to let voices and instruments sound lower and fuller.
- On the other side the artist, e.g. singer has to show a high discipline in use of such microphones. For constant sound the distance between singer and microphone must be kept constant.

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Microphones

Frequency Response of Microphones

- The frequency response of a microphone is defined by:
  - the sound spectrum it can reproduce and
  - the variations of the output level within the frequency range.
- The frequency response is a major factor on the sound quality of a microphone.

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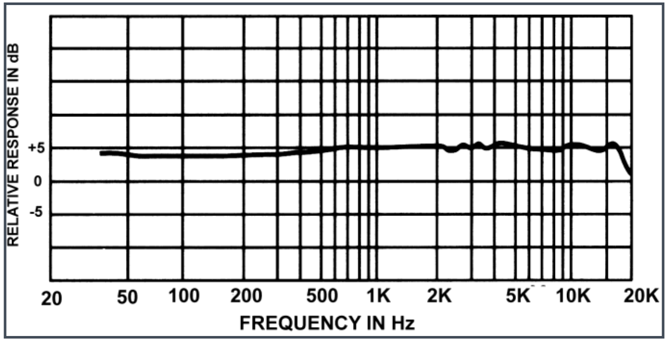
Microphones

Frequency Response of Microphones

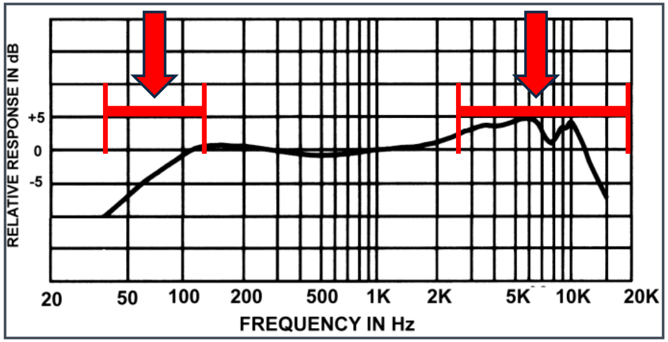
➔ **Flat Frequency Response**

- Uniform output at all frequencies
- Extended range typical
- Smooth overall shape



➔ **Shaped Frequency Response**

- Output varies with frequency
- Reduced range typical
- Some peaks or dips in response



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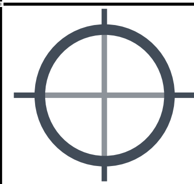
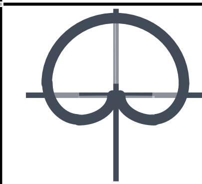
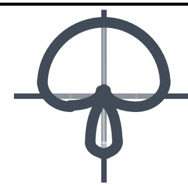
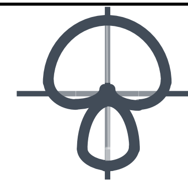
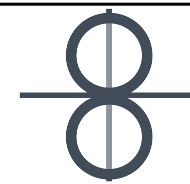
Microphones
Typical Polar Patterns - Overview

CHARACTERISTIC	OMNI-DIRECTIONAL	CARDIOID	SUPER-CARDIOID	HYPER-CARDIOID	BI-DIRECTIONAL
POLAR RESPONSE PATTERN					
COVERAGE ANGLE	**360°**	**131°**	**115°**	**105°**	**90°**
ANGLE OF MAXIMUM REJECTION (null angle)	**—**	**180°**	**126°**	**110°**	**90°**
AMBIENT SOUND SENSITIVITY (relative to omni)	**100%**	**33%**	**27%**	**25%**	**33%**
DISTANCE FACTOR (relative to omni)	**1**	**1.7**	**1.9**	**2**	**1.7**

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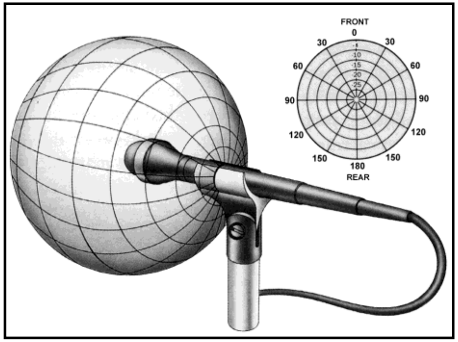
Microphones
Polar Pattern

→ Omnidirectional:

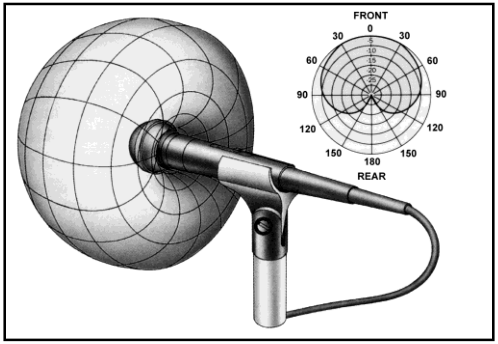
Equal Response at all angles



→ Cardioid:

Most sensitive at 0 degrees (on axis)

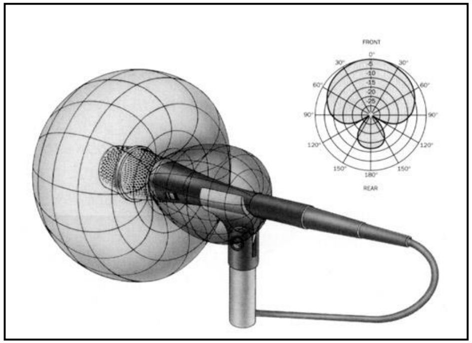
Least sensitive at 180 degrees (off Axis)



→ Supercardioid:

Most sensitive at 0 degrees (on axis)

Least sensitive at 126 degrees



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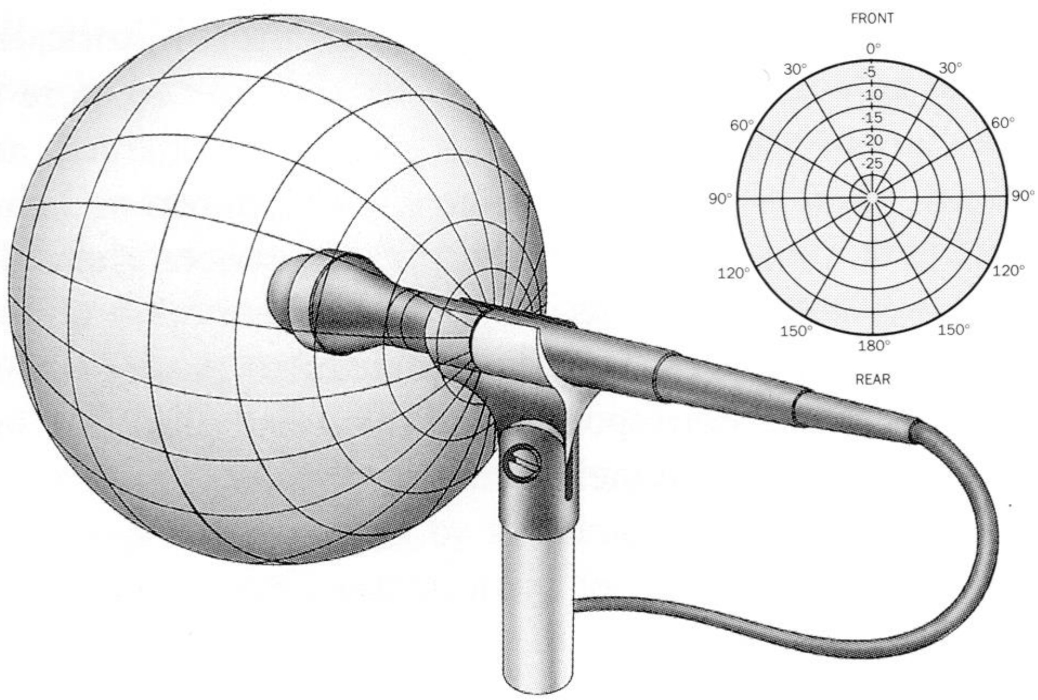
Microphones
Polar Pattern

- **Omnidirectional**
  Microphone is equally sensitive for sound sources out of every direction. There is no preference to any direction.
- Pressure Transducer
- No proximity effect



OMNIDIRECTIONAL MICROPHONE

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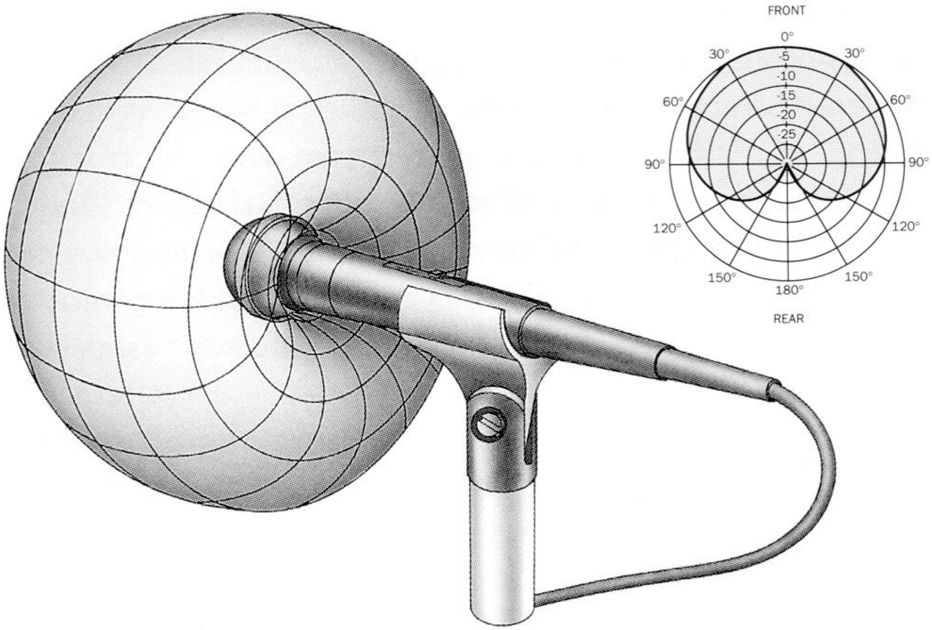
Microphones
Polar Pattern

- **Cardioid**
  Microphone is most sensitive for signals in front of the capsule (0°), signals coming from the rear side are picked up at a reversed level. Because of this directional preference, microphones of this type are used to pick up desired sound sources only.

- Pressure-gradient microphone

- Proximity effect



CARDIOID (UNIDIRECTIONAL) MICROPHONE

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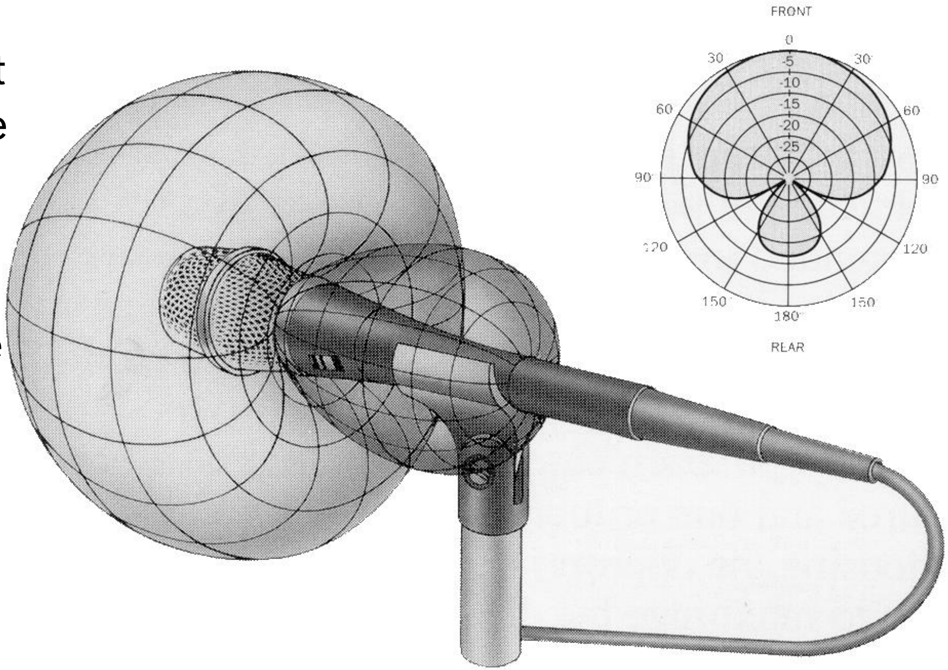
Microphones
Polar Pattern

- **Supercardioid**
  Microphone is most sensitive for signals in front of the capsule (0°) and least sensitive for sounds arriving at 126°. It is further less sensitive to ambience noise than an omnidirectional mic .

- Pressure-gradient microphone

- Proximity effect



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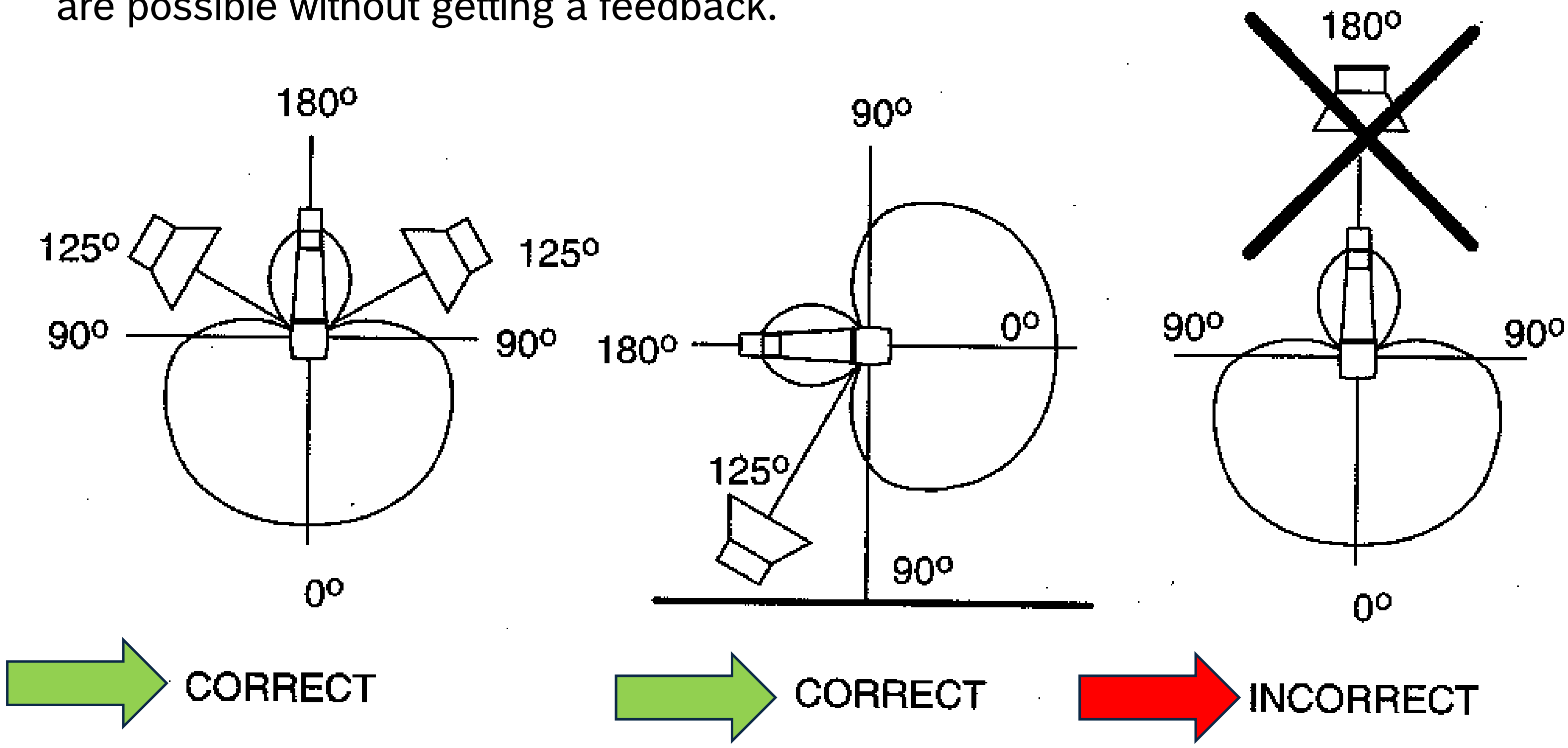
Microphones
Polar Pattern

- Practical example if it comes to monitor loudspeaker placement on stages with supercardioid microphones. With correct placement of the monitor higher levels are possible without getting a feedback.



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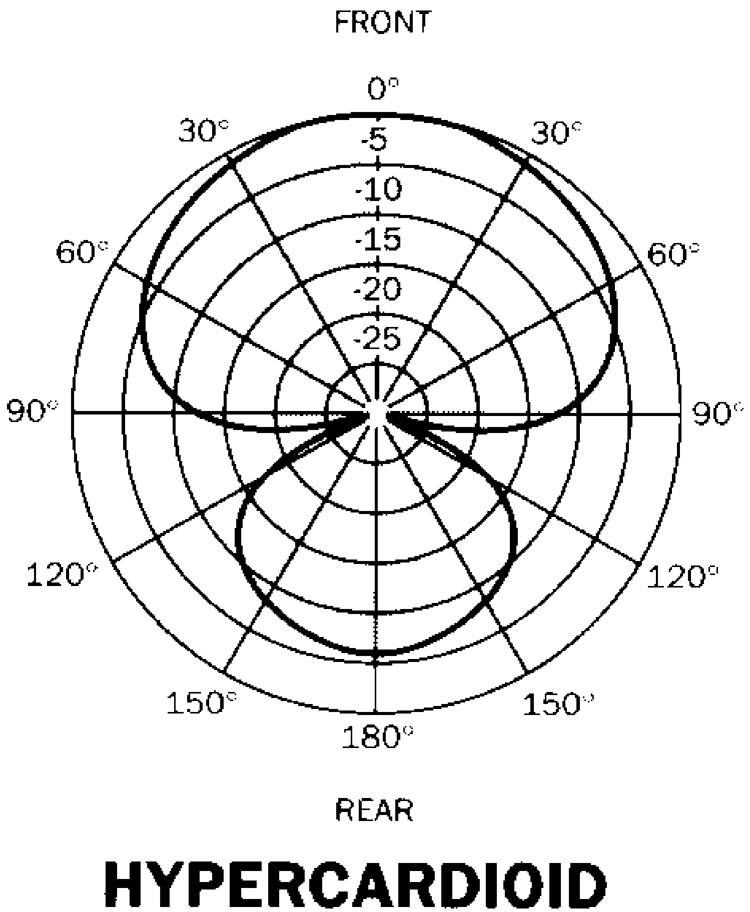
Microphones
Polar Pattern

- **Hypercardioid**
  Microphone is most sensitive for signals in front of the capsule (0°) and least sensitive for sounds arriving at 110°. Less sensitive to ambience noise than an omnidirectional microphone.

- Pressure-gradient microphone

- Strong proximity effect



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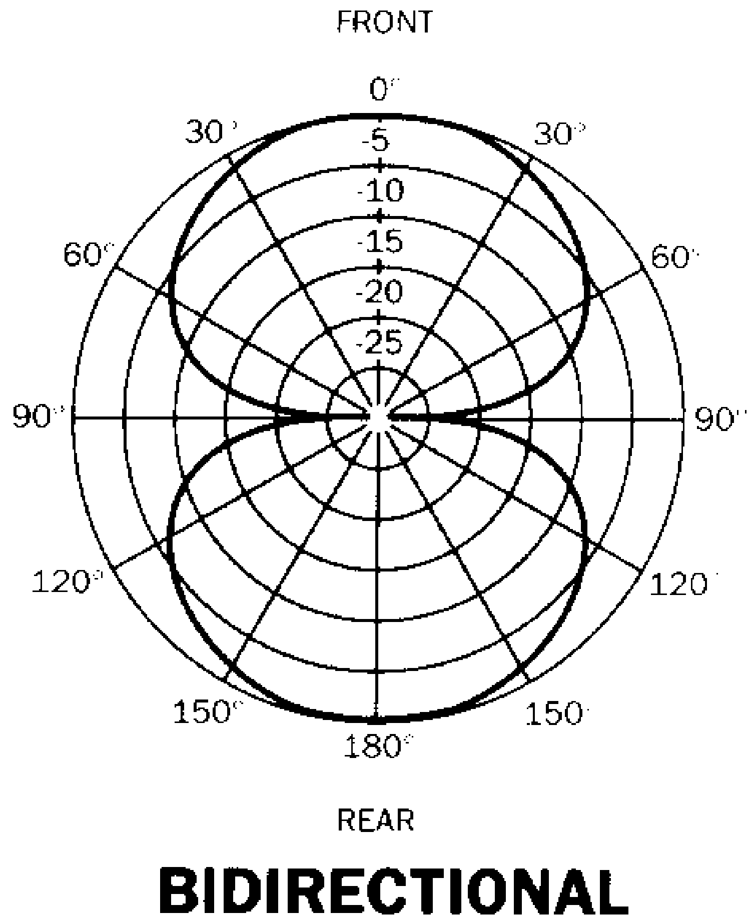
Microphones
Polar Pattern

- **Bi-directional / Figure of Eight** Microphone is very sensitive for sound sources in front of and behind the capsule (0° and 180°) and is least sensitive to sounds arriving at 90°. Less sensitive to ambience noise than an omnidirectional microphone.

- Pressure-gradient microphone

- Very strong proximity effect



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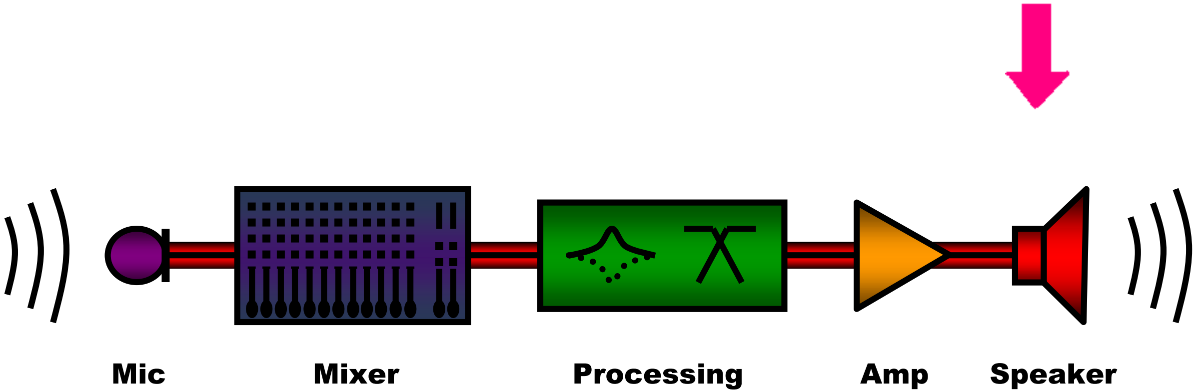
Loudspeaker



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Loudspeaker
General

- A loudspeaker is a converter from electrical energy into acoustical energy. By moving the cone synchronous to the electrical signal the electrical energy is transduced to the air by compression & decompression.

- **Typical conversion types are:**

- **Electromagnetic :**
  Alternating current moves coil in a static magnetic field - most common in Pro Audio applications

- **Piezo :**
  Piezoelectric material expands/contracts according to applied voltages

- **Electrostatic :**
  Two plates attract or distract each other depending on electrical charge relations

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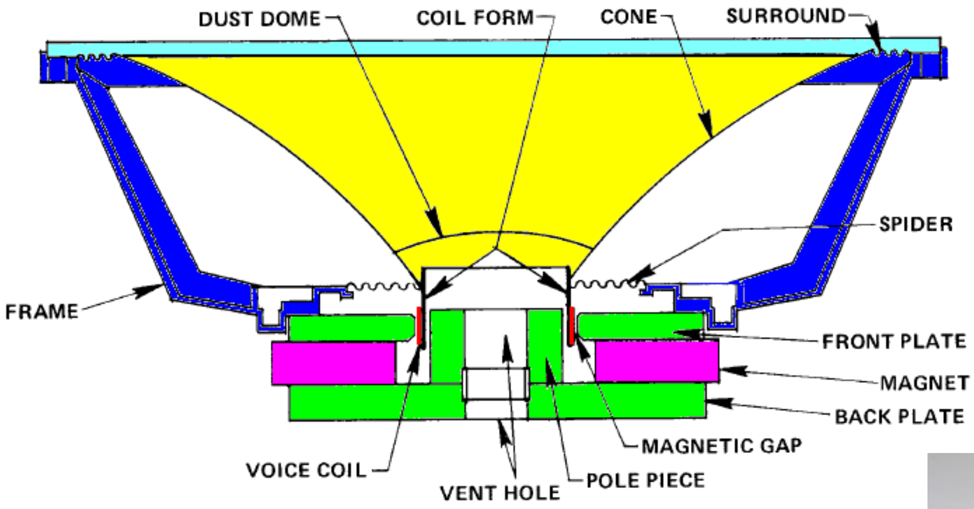
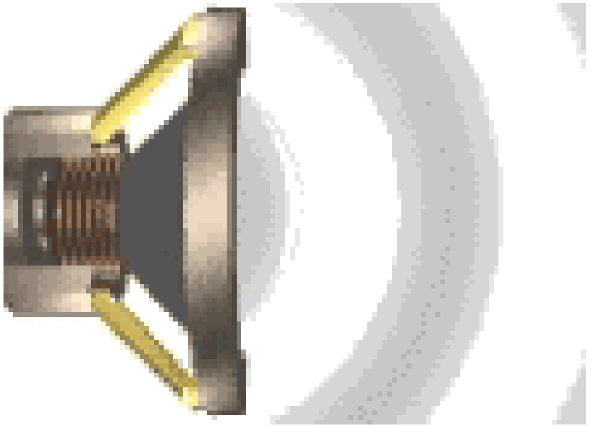
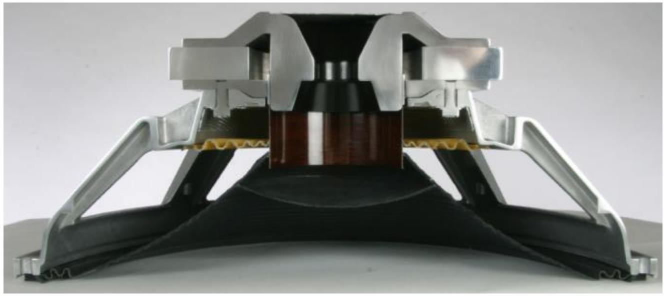
Loudspeaker
Cross section of a Cone Transducer

➔ Electromagnetic / „Electrodynamic“ Principle







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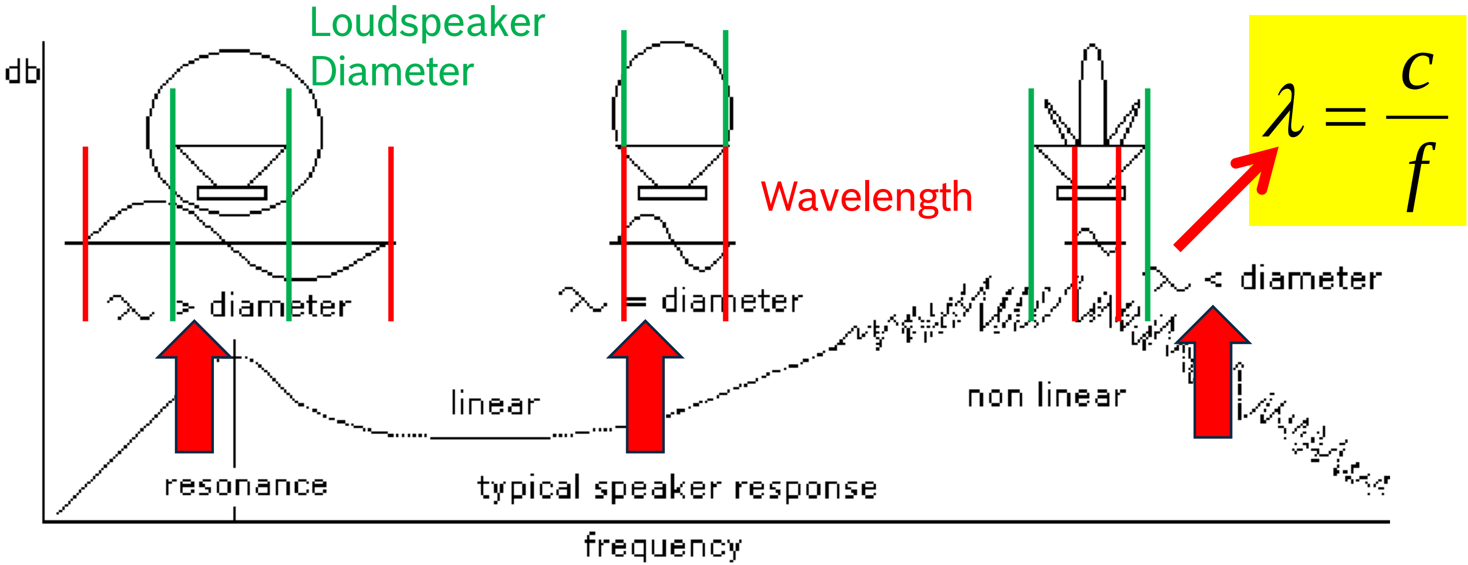
Loudspeaker
Bandwidth of loudspeaker chassis

- ➔ A single professional speaker chassis cannot reproduce the complete human hearing window with properties needed for professional concert sound applications. It refers to the relation of <u>wavelength to speaker diameter</u>. That is the reason for multiple ways / loudspeakers in professional applications to reproduce the audible frequency range.



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Loudspeaker
Frequency and wavelength

$$\lambda = \frac{c}{f}$$

c = speed of sound in air [m/s]
(344 m/s @20°C)
f = frequency [Hz]

→ Examples:

Frequency [Hz]		Wavelength [m]
100	→	3,44
1.000	→	0,344
10.000	→	0,0344

The relationship between wavelength and frequency for a range of frequencies is given in tabular form below

Frequency (Hz)	Wavelength (ft)	Wavelength (m)
20	56.50	17.20
31.5	35.87	10.92
40	28.25	8.60
50	22.60	6.88
63	17.94	5.46
80	14.30	4.30
100	11.30	3.44
125	9.04	2.75
160	7.06	2.15
200	5.65	1.72
250	4.52	1.38
315	3.59	1.09
400	2.83	0.86
500	2.26	0.69
630	1.79	0.55
800	1.413	0.430
1,000	0.130	0.344
1,250	0.904	0.275
1,600	0.706	0.215
2,000	0.565	0.172
2,500	0.452	0.138
3,150	0.359	0.109
4,000	0.283	0.086
5,000	0.226	0.069
6,300	0.179	0.055
8,000	0.141	0.043
12,500	0.090	0.028
16,000	0.071	0.022
20,000	0.057	0.017

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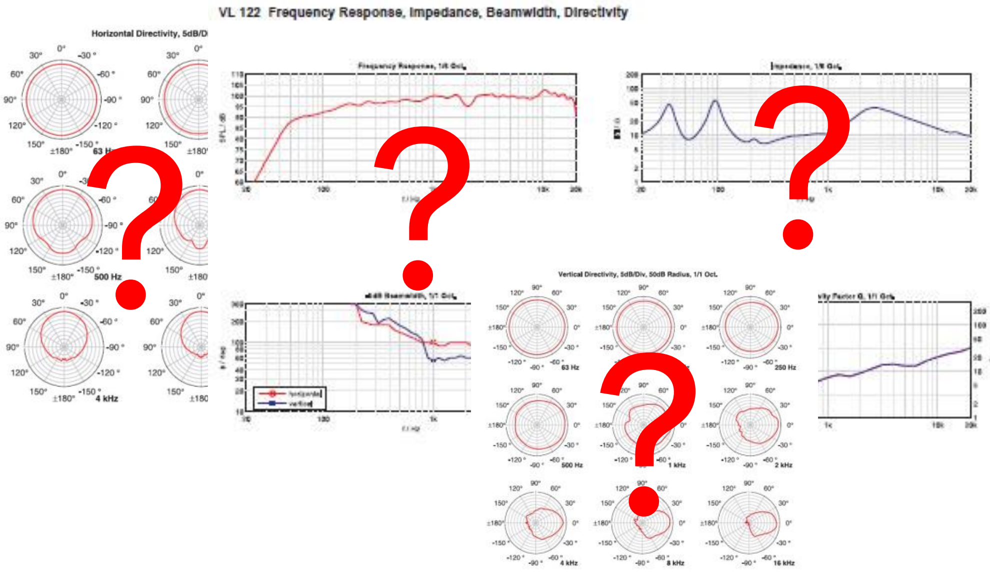
Loudspeaker
Properties - Specifications

- When we have a closer look into a datasheet of a professional loudspeaker we find a lot of information. What does it mean?



DYNACORD®

Technische Informationen

Architects and engineers specifications

VL 122

12" / 1.4"

2-Way Professional Speaker System

Features:

- *High-Power Multi-Functional 2-Way Cabinet*
- *400W 8 Ohms*
- *Rotatable CAD-optimized 90° x 45° Constant Directivity Horn*
- *Switchable to Biamped Mode*
- *Neodymium ND... Driver*
- *DND 12350 Woofer*
- *Voice Coil Tracking Protection*

Wir weisen ausdrücklich darauf hin, dass bei gehängten Lautsprecherboxen die einschlägigen Sicherheitsbestimmungen zu beachten sind. Es muss unbedingt qualifizierte Fachberatung in Anspruch genommen werden!

We expressly point out that the relevant safety regulations must be observed for „flying" loudspeaker systems. It is imperative that qualified expert advice is sought.

WARNING:
THIS LOUDSPEAKER SYSTEM CAN PERMANENTLY DAMAGE HEARING! USE EXTREME CARE WHEN SETTING SOUND PRESSURE LEVELS!

DANGER:
CONSULT A CERTIFIED STRUCTURAL ENGINEER BEFORE ANY ATTEMPT TO SUSPEND THIS LOUDSPEAKER! LOUDSPEAKER CAN FALL FROM IMPROPER SUSPENSION, RESULTING IN SEVERE INJURY AND DAMAGE OF PROPERTY. DO NOT SUSPEND OR MOUNT ANY OTHER PRODUCT OR DEVICE FROM THIS LOUDSPEAKER ENCLOSURE! USE GRADE 5 HARDWARE OR BETTER ONLY!

Specifications

TYPE / NAME	VL122
Order No.	D 113 103
Cabinet	Full-Range
Configuration	Passive 2-Way Switchable to biamped mode
Nominal impedance	8 Ohms
Rated power RMS	400 Watts
Program power	800 Watts
Peak power	1600 Watts
SPL 2,83 V / 1m 1W / 8 Ohm	99 dB
Max. SPL 1m (calculated with peak power)	131dB
Frequency range (-10dB) Full range	60Hz - 20kHz
Frequency range (-10dB) measured with H5000-RCM26 preset	50Hz - 20kHz
Coverage angle 1 kHz -6dB	90° * 45°
Passive crossover frequency	1.5kHz
Active crossover frequency	1.5kHz 24dB/Oct. Linkwitz-Riley, 1,5kHz Linear-Phase FIR
Voice coil tracking protection	Yes
Component HIGH Order No.	Electro-Voice ND6-8 Neodymium [illegible]
Component LOW Order No.	DND 12350 [illegible]
Connectors Full-Range	1+, 1-
Wired through	2+, 2-
Connectors Biamped	Lo 1+, 1- Hi 2+, 2-
Wired through	1+, 1-, 2+, 2-
Connector model	Speakon 2x NL4 MPR
Dimensions (WxHxD)	385x715x374mm (15.13" x 28.15" x 14.72")
Net weight	24kg (52.91 lbs)
Shipping weight	26kg (57.31 lbs)
Enclosure material	Birch plywood
Finish	Black, 2-component paint
Grille	Powder coated steel, acoustic foam
Handles	2
Warranty	36 Months
Optional Accessories	
SH-VL122 Dust-Cover	D113118
MB 122 UMH Mounting Bracket	D113114
RMA Rotatable Mounting Kit	D112807
TMA Tilt angle for MB122 UMH	D112815
TC-02 Truss clamp	D112808
FB-VL122 Flying Bracket	D113111
TC-TV Truss Clamp + TV Spigot	D112941
PM-TV Pole Mount + TV Spigot	D112942

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Loudspeaker
Properties - Specifications

- ➔ Efficiency
- ➔ Sensitivity
- ➔ Frequency Response
- ➔ Impedance
- ➔ Coverage Angle
- ➔ Directivity Index DI,Q
- ➔ Power Handling

Specifications

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Active crossover frequency	1.5kHz 24dB/Oct. Linkwitz-Riley, 1,5kHz Linear-Phase FIR
Voice coil tracking protection	Yes
Component HIGH Order No.	Electro-Voice ND6-8 Neodymium 361493
Component LOW Order No.	DND 12350 366559

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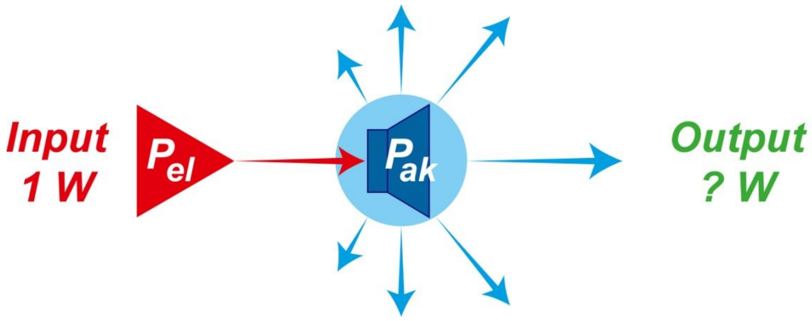
Loudspeaker

Efficiency η [eta]

- Efficiency:

The efficiency factor describes the ratio between electrical to acoustic energy, which is usually <u>not mentioned</u> in actual datasheets. Common loudspeakers have an efficiency of only a few percent (from about 0,5% up to 20%).



$$\eta = \frac{P_{el}}{P_{ak}}$$

> Important : Don´t mix the **efficiency** with On-axis **sensitivity!**

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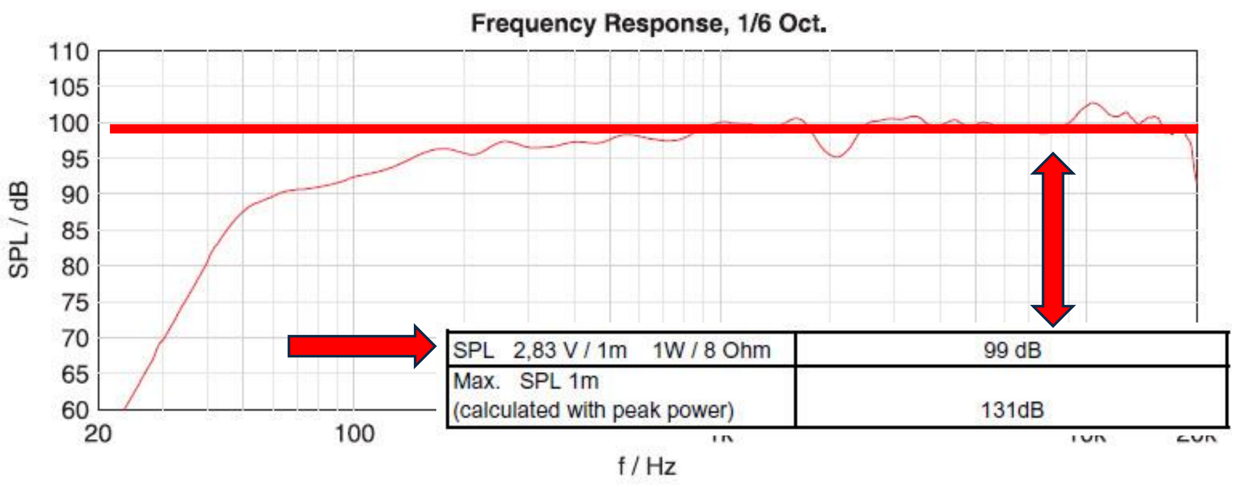
Loudspeaker

Sensitivity

- Loudspeaker sensitivity is typically rated at 1W/1m. 1W at 8 Ohms is the equivalent of 2,83V. In order to maintain 1W of power at 4 Ohms, the voltage must change to 2V. In a few cases the sensitivity is specified at other distances, so please read the specifications carefully, when you are comparing loudspeakers by datasheet.



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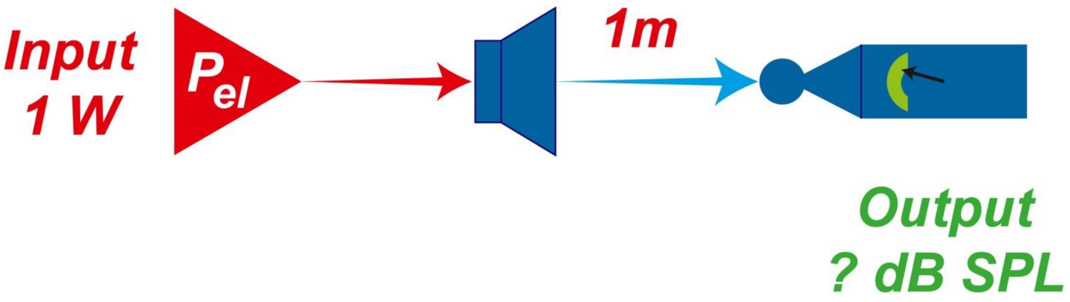
Loudspeaker
Sensitivity

→ Loudspeaker sensitivity is measured on axis only!



$$L_{sens} = ?\ dB\ SPL\ /\ 1W\ /\ 1m$$

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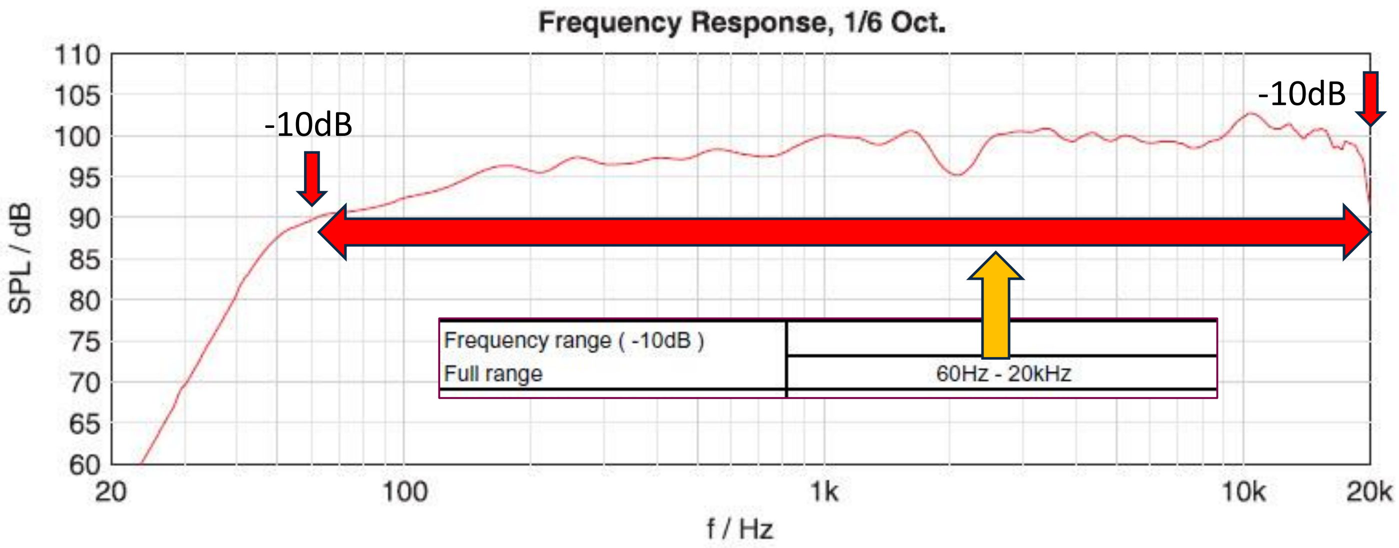
Loudspeaker

Frequency Response

- There are different kinds and possibilities to specify the frequency response or also called frequency range. If we look at our datasheet example it is specified within -10dB points, i.e. it shows the response of the loudspeaker, based on the sensitivity, where the level decreased by 10dB.



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Loudspeaker

Frequency Response

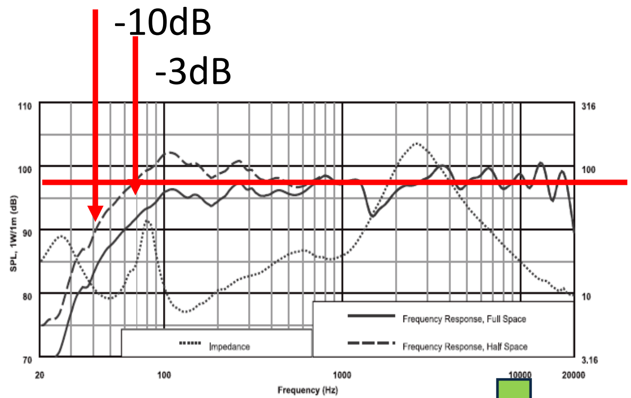
- Another example, where -3dB and -10dB values are specified, but in this case at half space measurement.

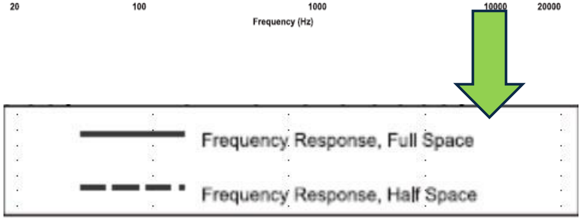
- Boundary loading a loudspeaker has a frequency dependent effect on the response of the system. Up to 6dB of boost in the low frequency range are possible.

- **Full space** – Loudspeaker in free space with no boundary nearby

- **Half space** – loudspeaker on one boundary

Freq. Response[1] (-3 dB):	58 Hz - 18 kHz
Freq. Range[1] (-10 dB):	39 Hz - 20 kHz
Rec. Hipass Frequency:	36 Hz
Axial Sensitivity:	98 dB (1W/1m)





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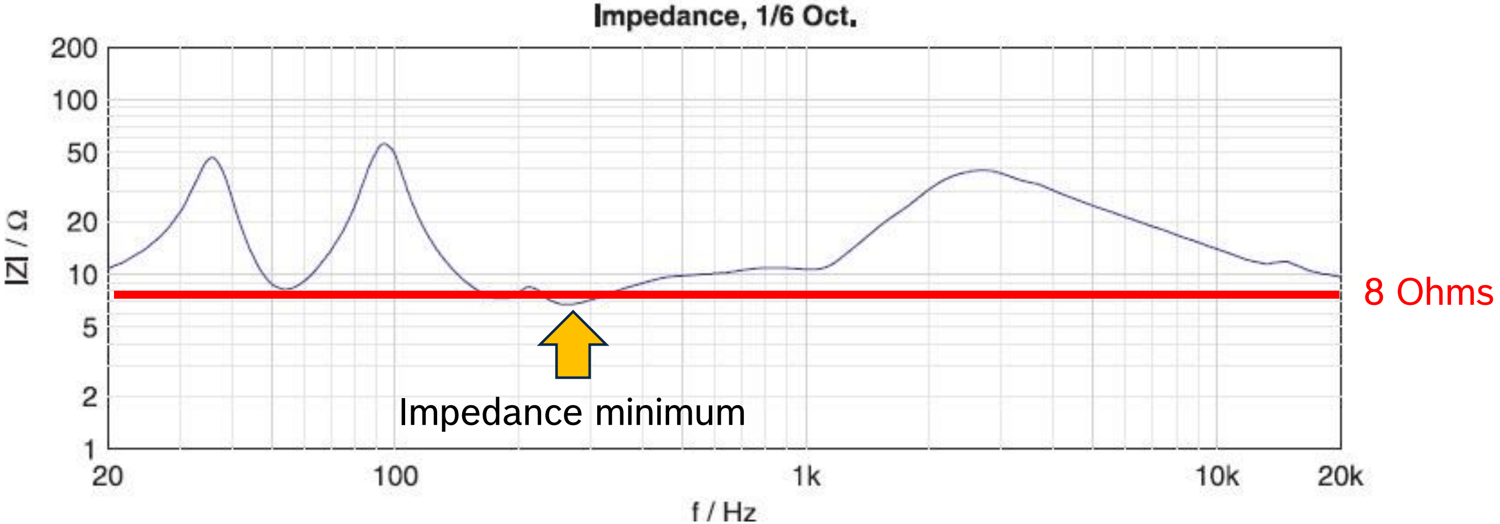
Loudspeaker

Impedance

- You can see that the impedance of a nominal 8 Ohm speaker is anything except constant 8 Ohms…

- The minimal impedance should not be less than 20% beyond the nominal impedance. It is a very important value when speakers are connected in parallel to an amplifier (minimum load capability).



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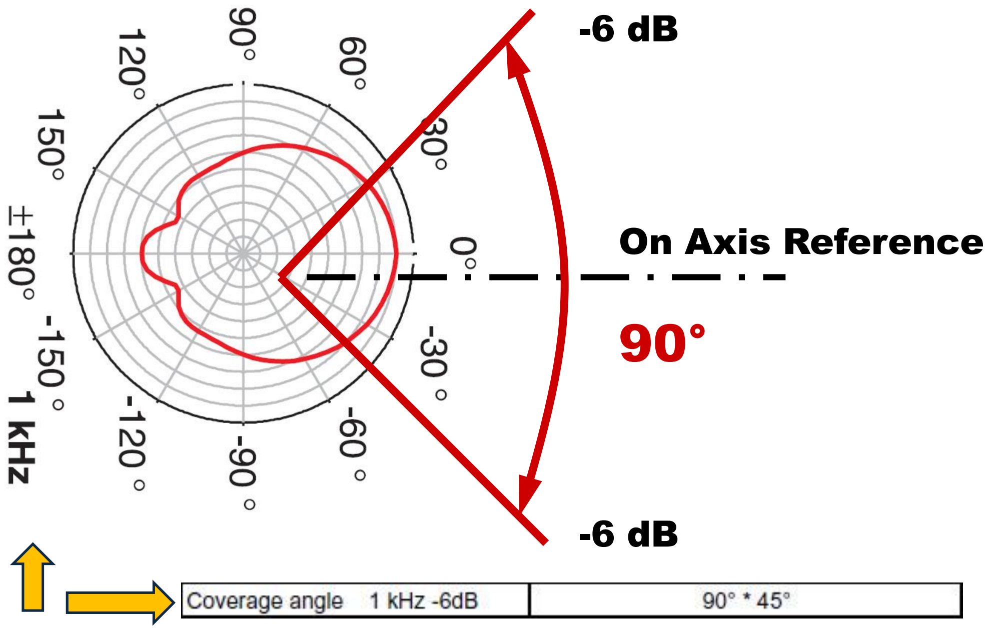
Loudspeaker

Coverage Angle

- The nominal coverage angle of a loudspeaker describes the angle of - 6 dB SPL at a certain frequency compared to on axis level vertical x horizontal.



Coverage angle 1 kHz -6dB	90° * 45°

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Loudspeaker

Directivity Q & Directivity Index DI

- **Directivity factor Q**:

  The Directivity factor Q is a numerical value depending on frequency, indicating the rate of acoustic power over all room directions.

- **Directivity Index DI**:

  The Directivity Index DI is the Directivity Factor Q expressed in decibel (dB).

- The increase of the directivity in one area of spehrical angle goes always with the decrease of the directivity in another area of spherical angle. Thus the emitted energy is more concentrated to the front.

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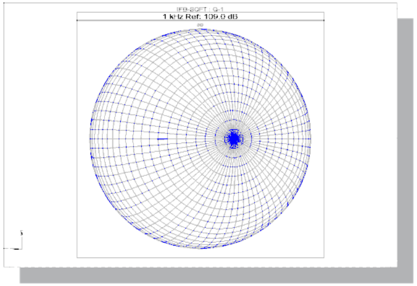
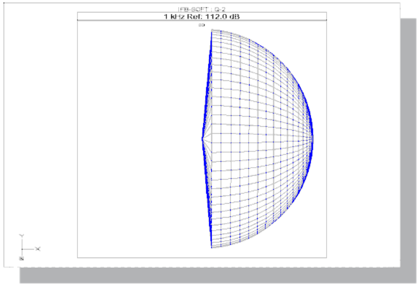
Loudspeaker

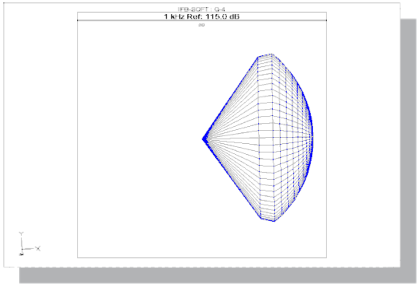
Directivity Q & Directivity Index DI



Q= 1
DI= 0 dB



Q= 2
DI= 3 dB



Q= 4
DI= 6dB

$$D_I = 10 \log Q$$

→ For equal speaker efficiency : The higher directivity, the higher sensitivity

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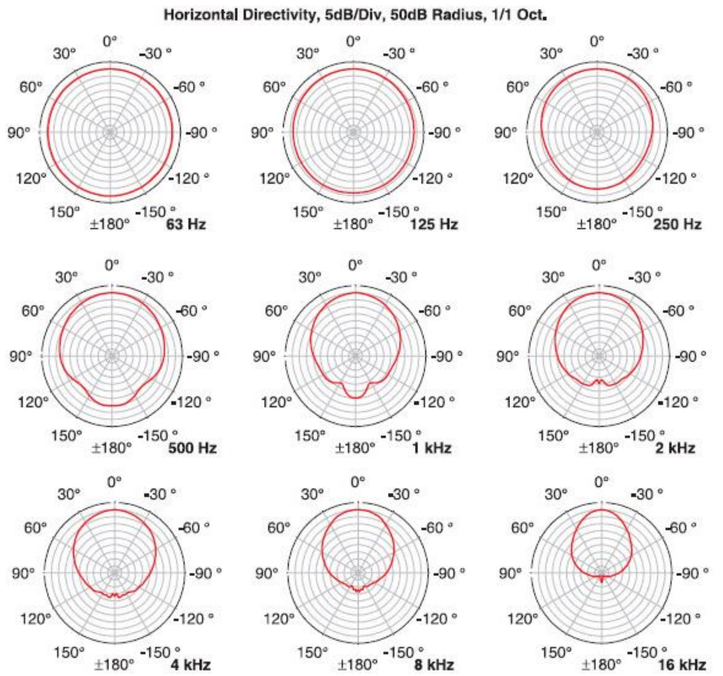
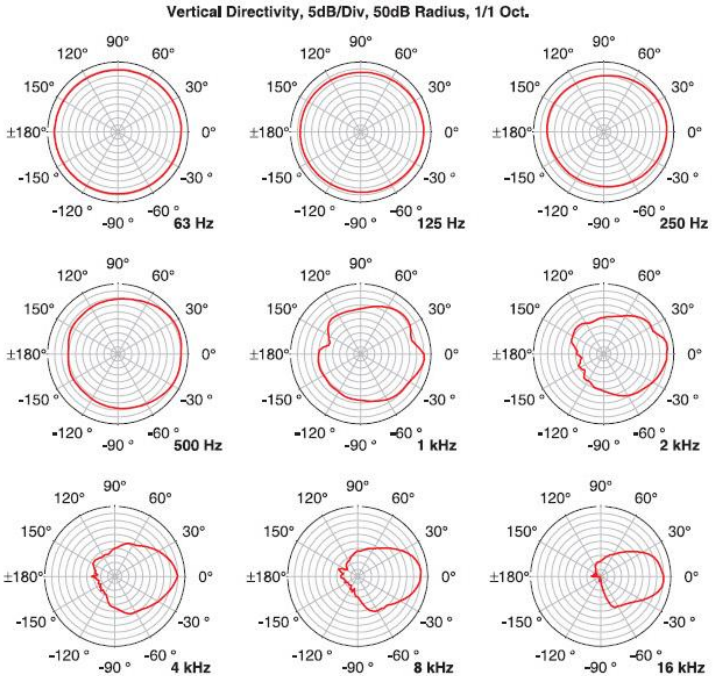
Loudspeaker

Polar Plots – Horizontal and vertical Directivity

➔ The polar plots represent a vertical and a horizontal slice of the entire spherical SPL data.





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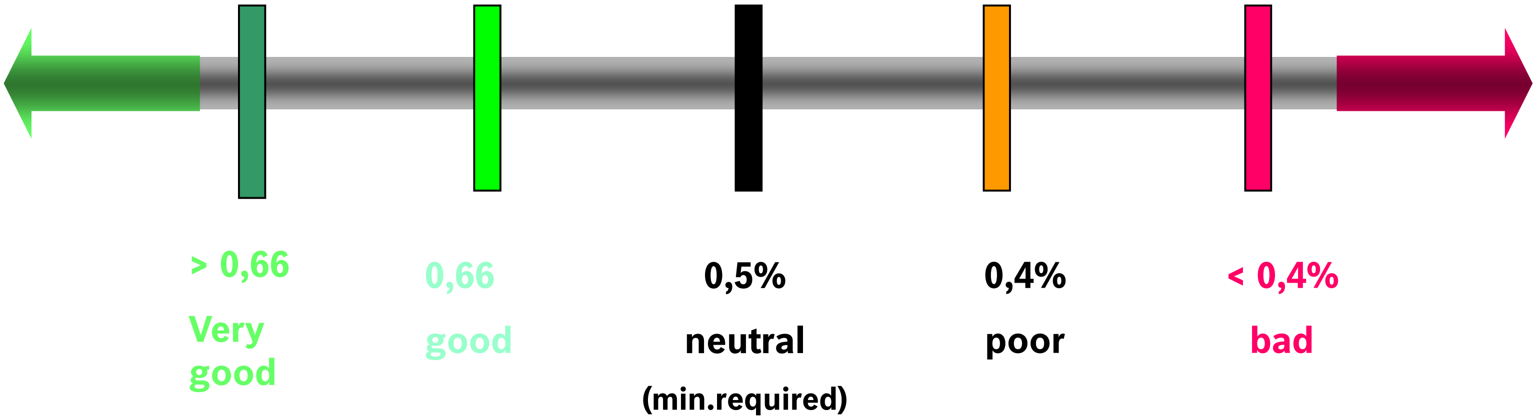
Loudspeaker

Directivity Q

- **Why is the Directivity of a loudspeaker such an important factor for planning sound systems?**

The following examples show the relationship between speech intelligibility (STI) and the directivity factor Q in the same room with equal conditions.

- STI values are in between 0 and 1:



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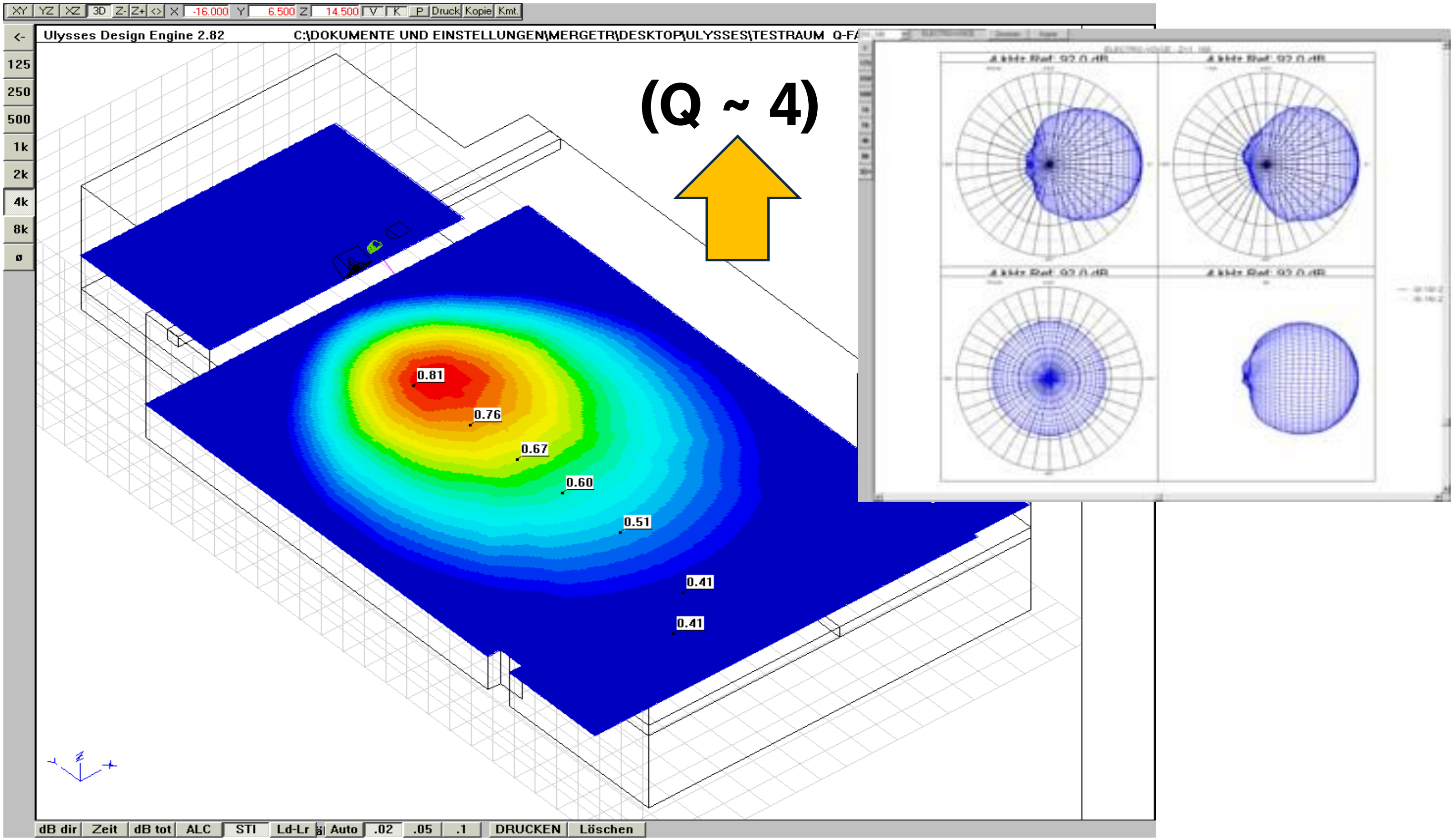
Loudspeaker
Directivity Q



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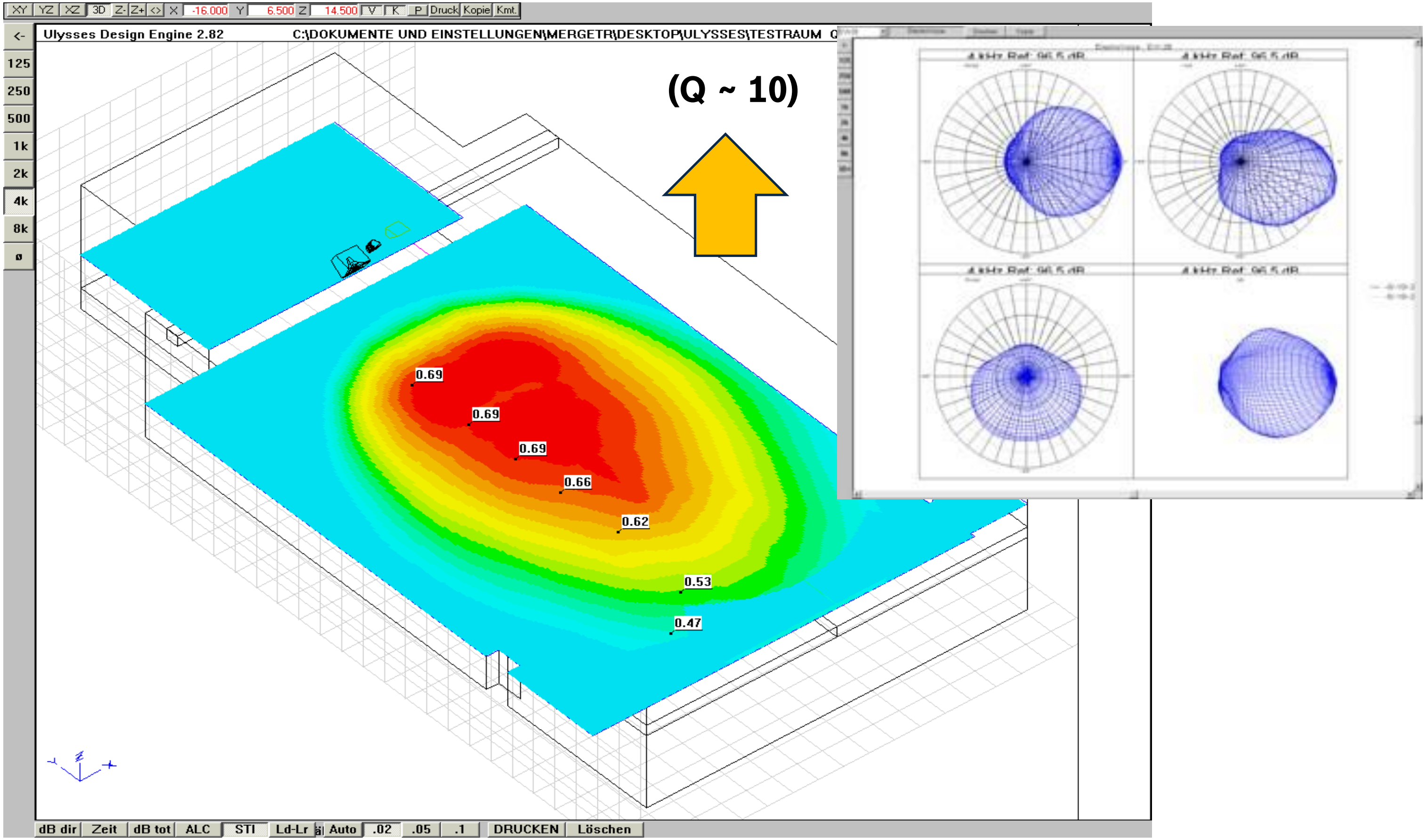
Loudspeaker

Directivity Q



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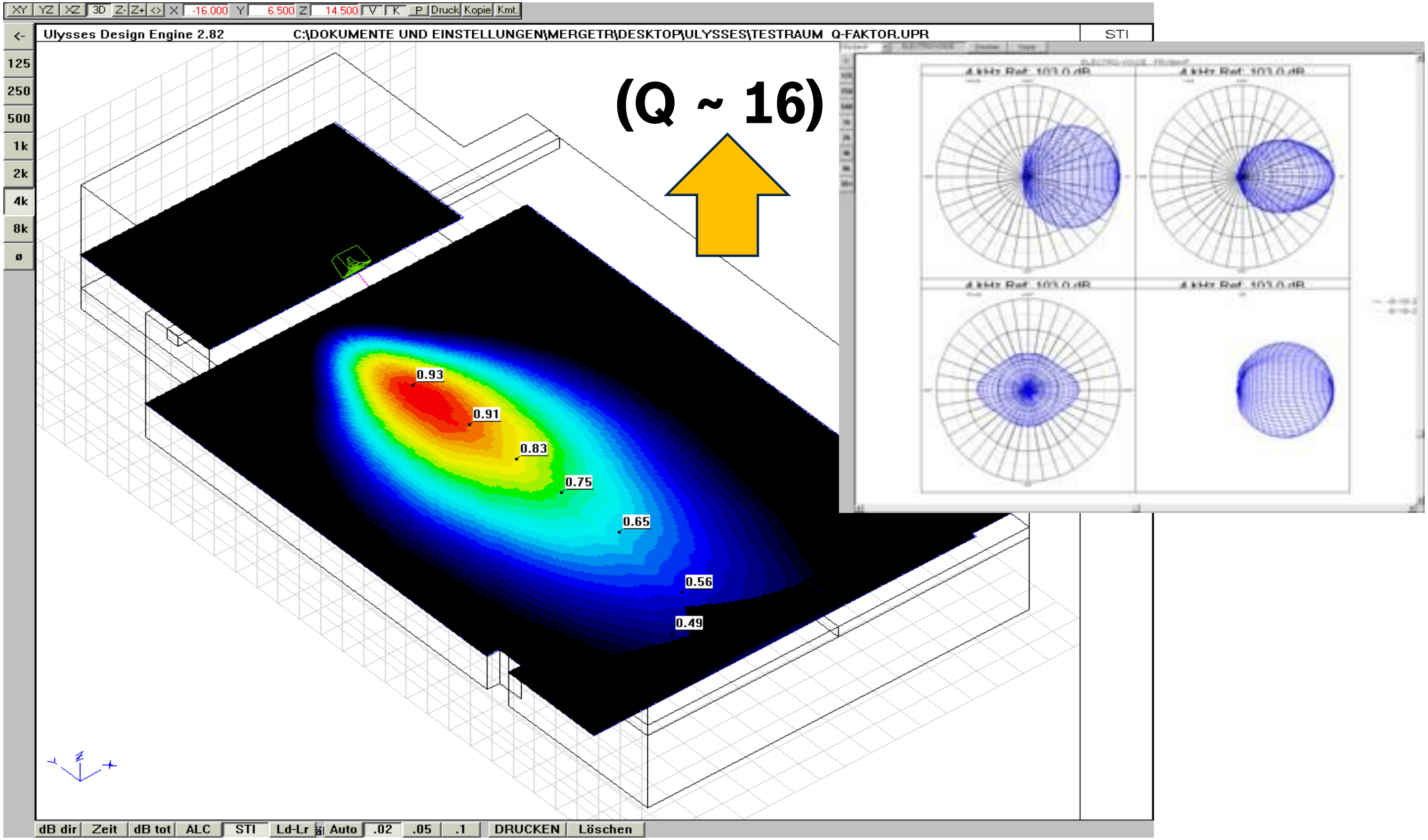
Loudspeaker

Directivity Q



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Loudspeaker

Power Handling

- There are several methods to specify the power handling of loudspeakers. Following two of the most important/common ones:

AES2-1984 used for individual transducers (woofers and compression drivers). Uses filtered pink noise one decade apart, specific to the device under test. Two hour test procedure duration.

EIA RS-426a used for loudspeaker systems. Uses filtered white noise to resemble typical program content in music. Eight hour test procedure duration.

- But as mentioned there are some more…On the next page a comparison of different standards, just to show how different these methods can be.

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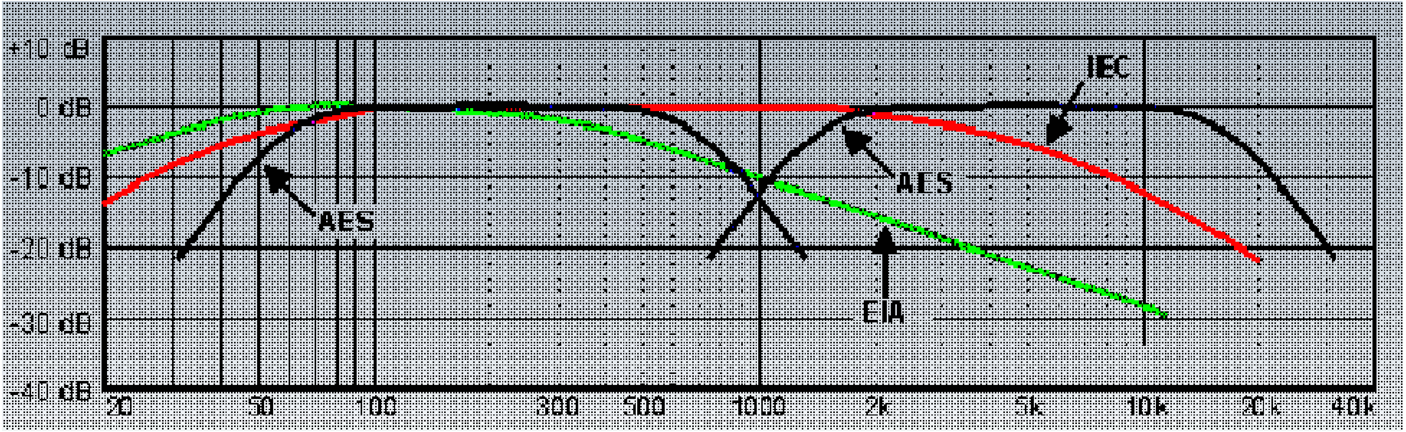
Loudspeaker

Power Handling – Overview

AES2-1984
Audio Engeneering Society
- Pink Noise
  BW: 1 Decade
- 6 dB Crest Factor
- 2 h

EIA RS-426-A (1980)
Electronic Industries Association
- Pink Noise
  LP-Filter
- 6 dB Crest Factor
- 8 h

IEC268-1 (1985)
International Electro-technical Commission
- Pink Noise
  IEC-Filter (Music)
- 6 dB Crest Factor
- 100 h



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Loudspeaker

Power Handling

- Datasheet specifications:

Rated power RMS	400 Watts
Program power	800 Watts
Peak power	1600 Watts

- Average Power or **RMS Power (long term)**
  Calculation with RMS voltage

- **Program Power (mid term)**
  Commonly used as doubled average power

- **Peak Power (short term)**
  Calculation with peak voltage (e.g. 6 dB Crest Factor -> Peak = 4 x RMS)
  Maximum SPL values of loudspeakers in datasheets are usually only calculated values with Peak power.

Max. SPL 1m (calculated with peak power)	131dB

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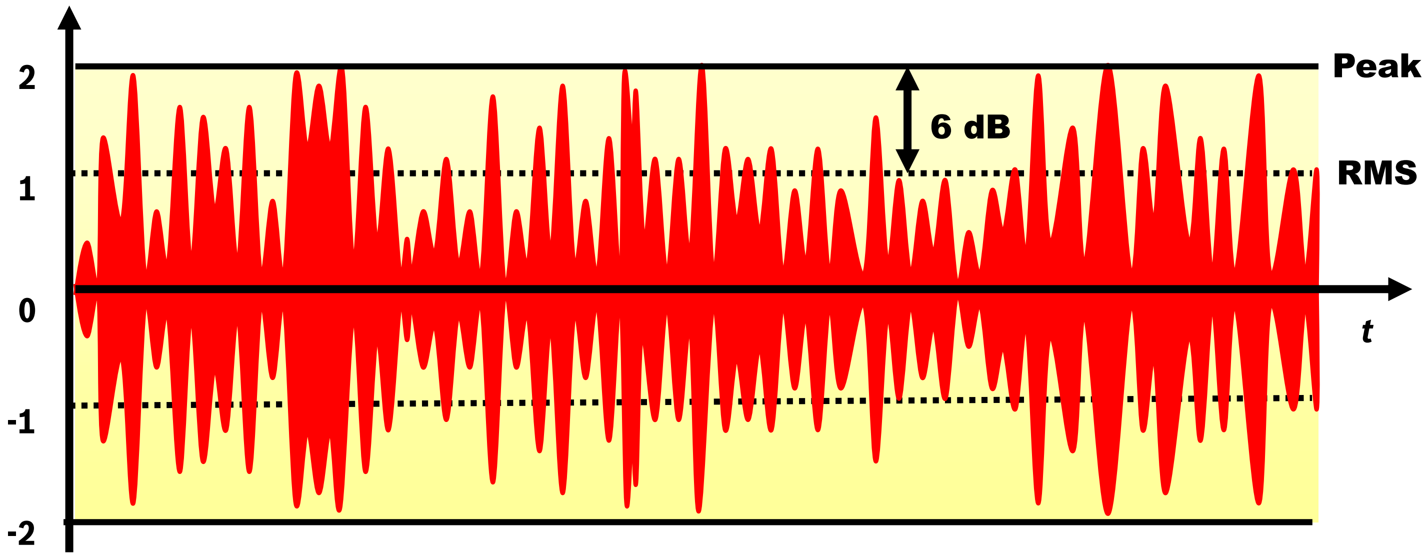
Loudspeaker

Crest Factor

➔ The Crest factor describes the ratio of peak vs. long term RMS value (root mean square) of a signal.



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