Honeywell

Principles of Electroacoustics

Planning Principles for Voice Alarm Systems (VAS)

1 Principles of Electroacoustics

1.1 Basic physical concepts and units

Physical values are represented by a numerical value and a unit.
For example, the basic unit “ampere” is defined for the power of electric current. In this case, if one adds a numerical value such as ”2”, the product of the number and unit yield the physical value of 2 amperes.

Physical value = numerical value x unit

In practice, a large number of different unit systems exist in parallel. The International System of Units (SI system in reference to the French "Système International d´Unités”) clearly specifies the base units, making it a proper systematic basis.

The SI units system

Phys. Property	Unit	Symbol
Electrical current strength	ampere	A
Length	meter	m
Luminous intensity	candela	cd
Mass	kilogram	kg
Substance quantity	mole	mol
Temperature [1)]	kelvin degree Celsius	K °C
Time	second	s

1) Degrees Celsius is permitted within the scope of SI units (0 Kelvin = -273 °C).

Units for electrical systems / acoustics

Phys. Property	Unit and Symbol		Formula Symbol	Note
Electrical voltage	volt	V	**U**	---
Electrical field strength	---	V/m	**E**	---
Electrical power	watt	W	**P**	---
Capacitance	farad	F	**C**	1 F = 1 As/V
Magnetic flux	weber	Wb	Φ	1 Wb = 1 Vs
Magnetic induction	tesla	T	**B**	1 T = 1 Vs/m^2
Magnetic field strength	---	A/m	**H**	---
Inductance	henry	H	**L**	1 H = 1 Vs/A
Resistance	ohm	Q	**R**	---
Acoustics				
Sound absorption coefficient	---	---	α	---
Sound pressure	---	N/m^2 or 1 Pa	**p**	1 N/m^2 = 1 pascal
Sound pressure level	---	dB	L_P	$L_P = 20 \log (p_1/p_o)$
Sound intensity	---	W/m^2	**J**	
Acoustic radiation pressure	---	N/m^2	Π	---
Sound energy flux	---	m^3/s	**q**	---
Sound particle velocity	---	m/s	υ	---
Sound power	watt	W	P_A	---
Acoustic impedance, spec.	---	Ns/m^3	Z_S	---
Acoustic impedance	---	Ns/m^5	Z_A	---
Acoustic power	watt	W	P_{AK}	
Reverberation time	---	S	T_N	T_{N60} = Level at 60 dB
Reverberation radius		m	r_H	---
Loudness level	---	phon	L_N	---
Directivity factor	---	---	**Q**	Q = 1 (spherical) Q > 1 (directional)
Absorption area	---	m^2	**A**	---

1.2 Human hearing

The human ear consists of the pinna (external, visible ear), the external auditory canal, the eardrum and the actual hearing organ.

The eardrum separates the outer ear from the middle ear. The middle ear contains the three auditory bones of the hammer, anvil and stirrup, which transmit the received frequencies to the inner ear, i.e. the hearing organ. The inner ear consists of the fluid-filled cochlea.

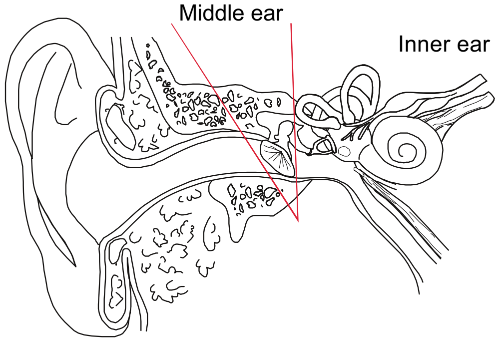


Fig.: Structure of the human hearing system (illustration)

The air vibrations received from the outside are converted into hydraulic sound waves in the fluid of the inner ear via the mechanical elements of the auditory bones. These “pressure waves” in turn stimulate a large number of hair cells, via which this information is transmitted to the corresponding nerve cells and carried on to the brain via the auditory nerve.

1.2.1 Auditory threshold and sensitivity

The human ear can only properly hear a specific range of frequencies and sound pressure levels. Hearing begins at roughly 20 Hz and ends at a frequency of about 20,000 Hz. The lower limit is referred to as the auditory threshold and the upper limit as the acoustic pain threshold.

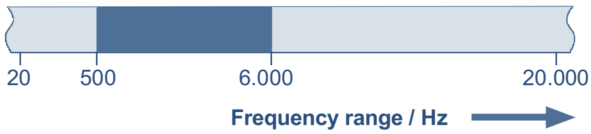


Fig.: Max. hearing range and optimal perceptual range

The hearing range depends on the age of the person (child or adult) and differs in practice for every individual. The highest sensitivity in the human ear lies in the range of about 500 Hz to 6,000 Hz. Frequencies in this range are perceived better and more strongly by human hearing than frequencies outside of this range.

The auditory threshold and the pain threshold are frequency-dependent. In the lower and upper frequency ranges, a significantly higher amount of acoustic energy must be applied to exceed the thresholds. In the middle frequency range, the energy required is lower, meaning that the pain threshold is also reached more quickly.

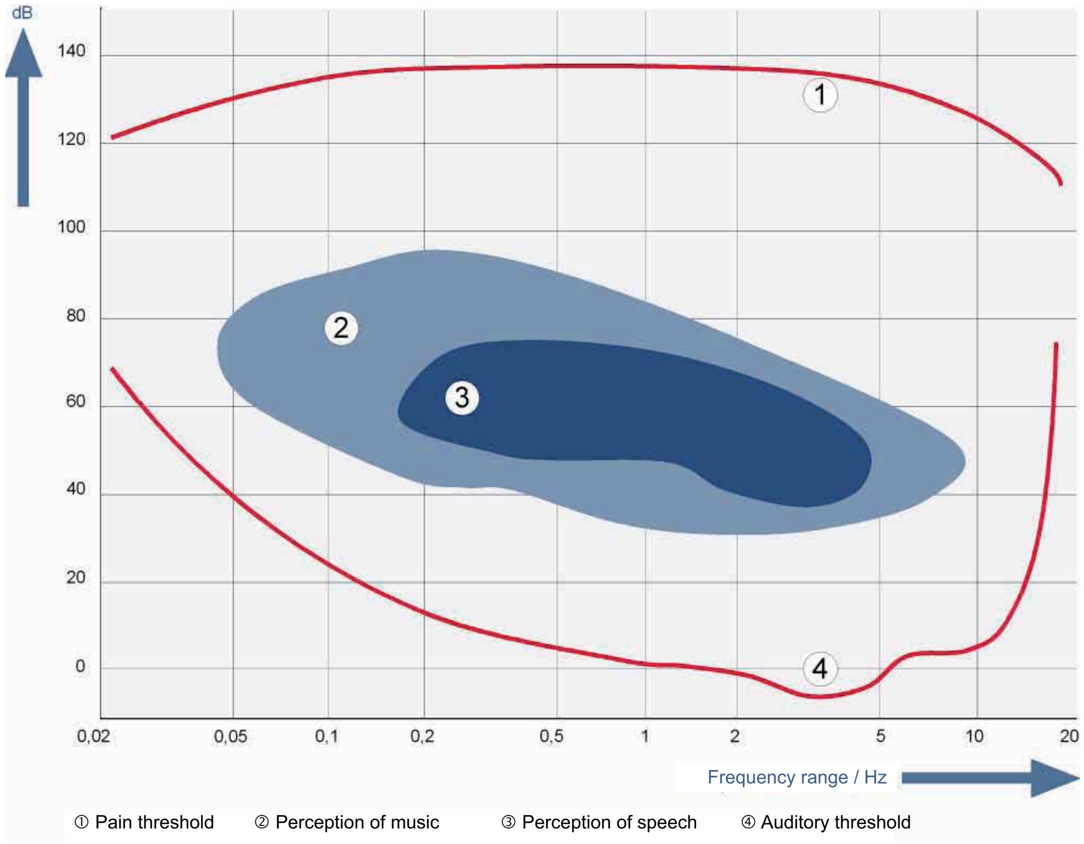


Fig.: Graph of human hearing capability

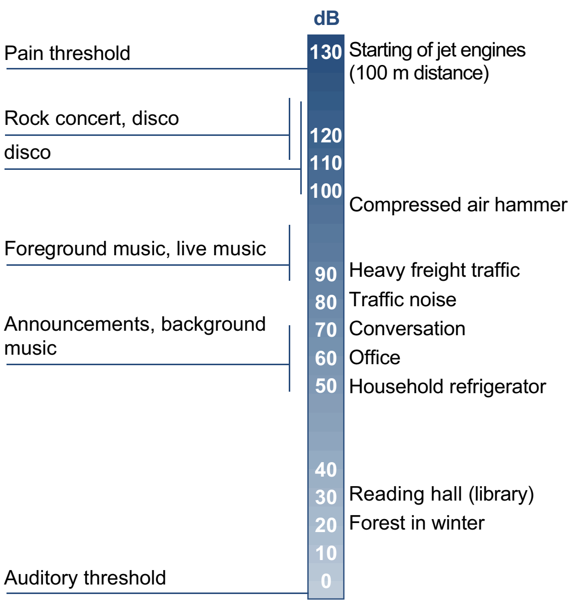
The diagram shows the hearing range of the human hearing system. The area in colour indicates the frequency range of human language. Within this range, language is easy to understand as long as external sources of interference, such as ambient noises lying in this frequency range, are not superimposed over the voice information, thereby reducing the quality of comprehension and perception.

If this interfering noise cannot be eliminated or reduced, it is necessary to increase the volume of the voice information and/or decrease the distance between the sound source (e.g. the loudspeaker) and the listener in order to reduce the influence of the interfering noise to the minimum possible level and ensure that the voice information can be comprehended.

The sound pressure level is indicated in decibels [dB].

A doubling of the sound power (watts) within the range of voice and music is noted as a barely perceptible increase in loudness (+ 3dB). A ten-fold increase in the sound power is perceived by the human ear as a doubling of the loudness.

This subjective perception must be taken into account in the transmission of voice information and music.



1.2.2 Loudness

The concept of "loudness" is a value that is based on human perception. Loudness relates the physical, measurable level or amplitude of the sound (e.g. as sound pressure or sound pressure level) to the volume subjectively perceived by a human.

Various procedures may be used to measure loudness, such as using the DIN loudness meter. Today's loudness level meters output the frequency-weighted sound pressure level (or more simply: weighted sound level) as the measurement result and are also capable of operating with various frequency-weighting curves (A, B, C and D). Evaluated levels are designated by the corresponding frequency weighting letters. For instance, dB (A) for A-weighting with curves of equal loudness levels at approx. 20-40 phon. In practice, it is generally sufficient to record only the internationally defined type A weighting curve and to indicate the corresponding sound level in dB(A).

The following diagram shows individual curves generated with a pure tone (sine wave). The loudness over each individual curve is perceived as identical despite the differing sound pressure levels and frequencies.

To evaluate the subjective perception of loudness, loudness is defined with a reference tone of 1 kHz in order to compare what sound pressure level a pure tone with a frequency of 1000 Hz must have in order for the same loudness to be perceived. The unit of loudness is the "phon". For example, a loudness of 60 phon corresponds to a sound of any frequency that is perceived as having the same loudness as a 1 kHz pure tone with a sound pressure level of 60 dB.

The diagram clearly shows the various sound pressure levels (dB) that must be reached in order to obtain an identically perceived loudness (phon) over the entire frequency spectrum from 10 Hz to 20 kHz. Examining the 40-phon curve at the frequency of 1 kHz and comparing this point with the frequency of 100 Hz, it can be seen that for 100 Hz a sound pressure level that is roughly +10 dB is required for the sound to be perceived at the same loudness.

Within the range of voice or music transmissions, an increase to the sound pressure level of +10 dB is perceived by human hearing as a doubling of the loudness.

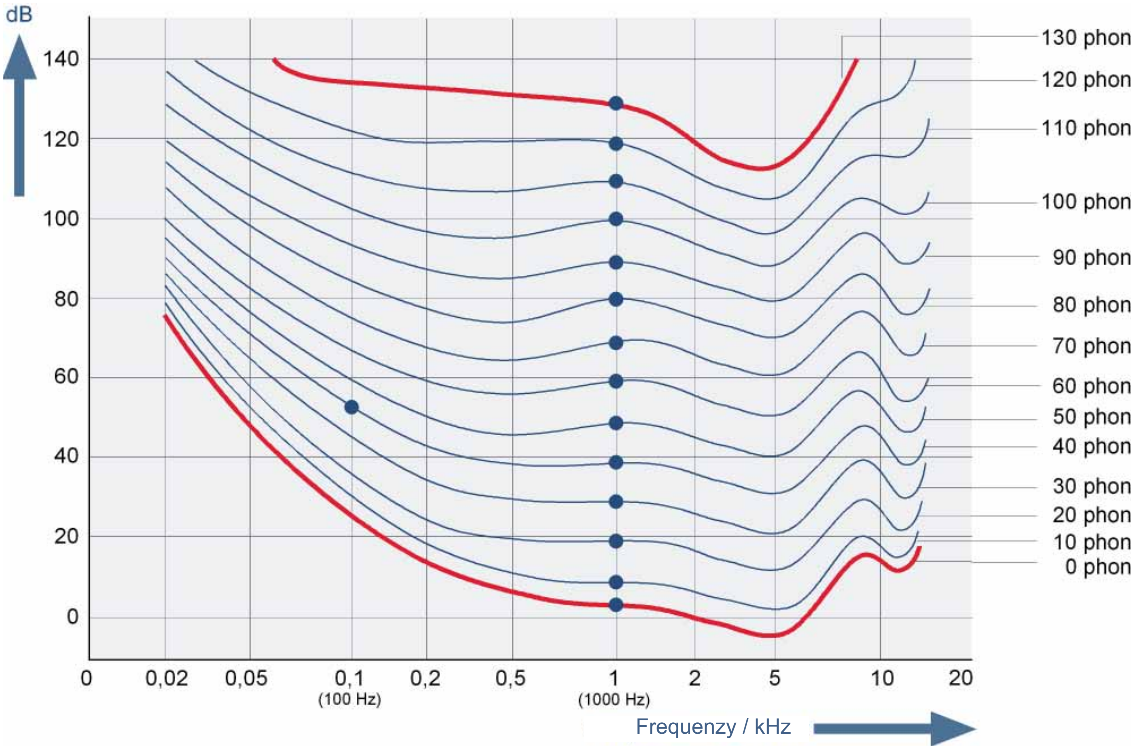


Fig.: Curves with identical loudness (phon value)

1.3 Understanding oscillations

An oscillation is a function that defines a physical condition based on time.
In event of a periodic condition change, the initial condition is repeated after a fixed interval of time.
In cases of differing time intervals, one refers to a non-periodic oscillation.

The propagation of sound waves in gases (e.g. air) and liquids essentially takes place only in the form of a longitudinal wave. Longitudinal waves are very often pressure waves.

The opposite is the transverse wave, such as shear waves and bending waves in solid bodies or electromagnetic waves.

1.3.1 Periodic oscillations

A sine oscillation corresponds to a pure tone (e.g. 1 kHz)

The number of repeating periods (T) per second is referred to as frequency (f).

The unit for frequency is Hertz [Hz]. For example, at a frequency of 1,000 Hz (= 1 KHz) each period is repeated exactly 1000 times per second.

$$\text{Frequency [f]} = \frac{1}{T}$$

$$1\ \text{Hz} = \frac{1}{s}$$

The time required for a complete periodic oscillation is referred to as the period duration (also cycle duration). The unit for period duration is the second [s].

The displacement (y) at a specific point in time (t) indicates the instantaneous displacement value, whereby the amplitude (peak value) defines the maximum displacement value.

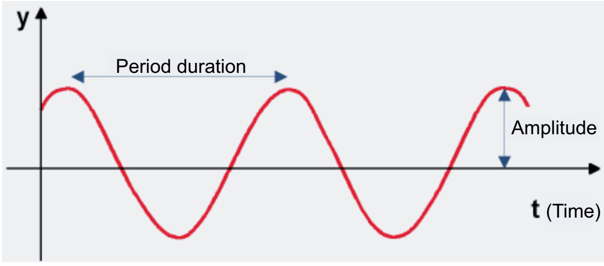


Fig.: Periodical sinusoidal oscillation (example)

Complex, composite and superimposed signals, such as music signals, can be mathematically reduced to sine waves using Fourier analysis (J.B. Fourier, 1786-1830).

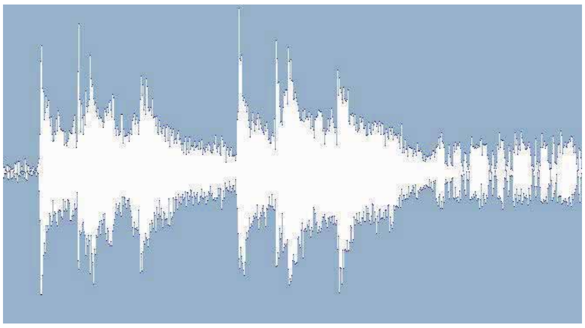


Fig.: Music signal or voice signal (example)

1.3.2 Superimposing of oscillations

Sound transmitted through a medium sets very small particles of material into motion.
With transmission of a pure tone (e.g. 1 KHz) through air, the air particles are set to oscillating, and the signal is also simultaneously attenuated (dampened) by this mechanical loss of energy. If one considers that a single particle cannot follow the various oscillations at the same time, this results in a diminishing or amplification of the individual sub-signals. Interference occurs.

Interference
Superimposing of at least two waves of any type according to the superposition principle.

The superposition principle describes the addition of waves, including addition with a negative sign (= subtraction).

Superposition principle
Addition of the amplitudes of a wave (not its intensity!)

If waves are amplified by the superposition principle, the superimposing of the waves is referred to as constructive interference.

Constructive interference
Amplification of the amplitudes.

If waves are diminished by the superposition principle, the superimposing of the waves is referred to as destructive interference.

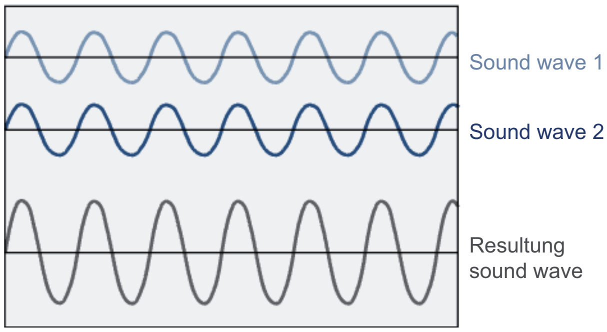
Destructive interference
Diminishing of the amplitudes.

If oscillations with identical phasing and identical amplitude are superimposed, the amplitude of the resulting oscillation is larger by a factor of the number of individual oscillations. For example, the amplitude value doubles in the case of two oscillations. This means that the amplitude of the resulting, "new" oscillation is twice as great as the amplitudes of the two individual oscillations.

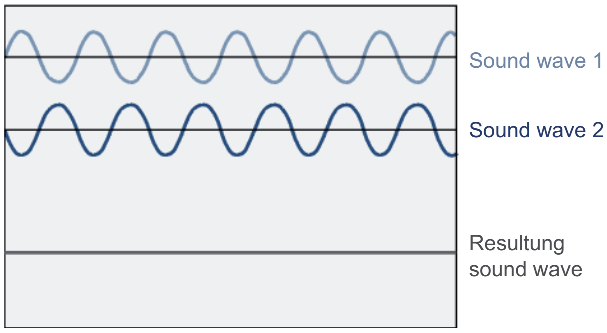
If the phasing is offset by 180°, the "positive" amplitude is balanced out by the "negative" amplitude (which is offset by 180°), and the resulting value is zero.

Superimposing of oscillations with identical frequency

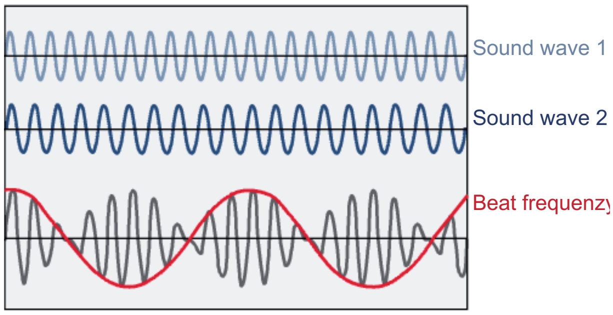
Constructive inferference



Destructive inferference



Interference with beat



When sound signals are transmitted in the environment, it can generally be assumed that different frequencies are being superimposed due to the presence of ambient noises.
The amplitudes of the individual oscillations as well as their phasing can differ significantly from the original oscillation.

Superimposing of oscillations with non-identical frequency

When two frequencies that differ only slightly from each other are superimposed according to the superposition principle, this is referred to as a beat.

Beat
Oscillation with periodically varying amplitudes.

The resulting wave with the new frequency is the envelope of the oscillation. The resulting beat frequency corresponds to the average of the two superimposed frequencies.

The interference between two waves of identical frequency that have opposite directions of propagation, results in a standing wave.

Standing wave
Interference of two waves with the same frequency and opposite directions of propagation.

1.3.3 Reflection and reverberation

Reflection describes the behaviour of a sound wave when it encounters an obstacle and is bounced back – reflected – by the surface of this obstacle. In the case of smooth surfaces, the law of reflection can be applied. A surface is considered smooth if its structure is smooth in relation to the frequency (wavelength) of the sound wave. Example for sound waves in the range of human hearing are glass surfaces such as windows, glass doors and/or building partitions made of glass (glass blocks). At very high frequencies, a surface that is considered visually smooth can behave physically like a surface with a certain degree of roughness.

The main reason for sound distortions in a closed room is reflections.

The law of reflection:
- The incident ray, the axis of incidence and the reflected ray lie in a plane.
- The angle of incidence is equal to the angle of reflection $\alpha = \beta$.

For sound waves in the range of human hearing

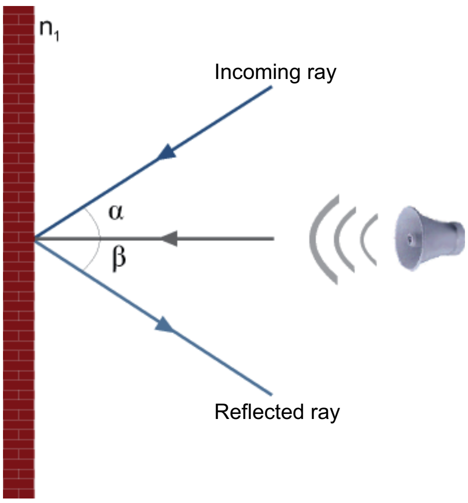


Fig.: Reflection of sound according to the law of reflection

(20 Hz to 20 kHz), it can be assumed in practice that the rule of "angle of incidence = angle of reflection" holds true for visually smooth surfaces. The reflection of a sound wave within rooms or buildings is of greater importance. In these cases, the sound wave could be reflected several times off ceilings and walls before it reaches the human ear. As a result of the differing travel distances of the sound wave, the wave also arrives at different times, resulting in reverberation. If the timing differences of the sound waves are very great, the reverberation can even be perceived as an echo.

Rays encountering rough surfaces and edges are reflected diffusely. The rougher a surface is, the more diffuse the scattering of the sound. The material and properties also play a role. Soft materials absorb more energy from sound waves. The largest share of reflected sound waves is reflected perpendicular to the surface, regardless of material and direction of incidence. This behaviour of diffusely scattered waves is defined mathematically in "Lambert's law".

Significance for the subjective acoustic perception of a specific noise (e.g. speech):

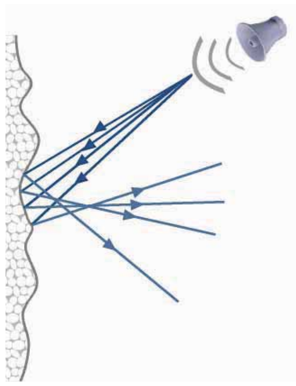


Fig.: Diffuse sound reflection

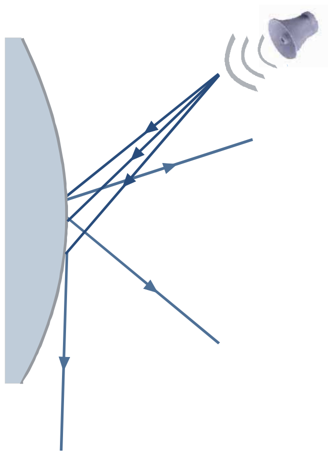


Fig.: Convex sound reflection

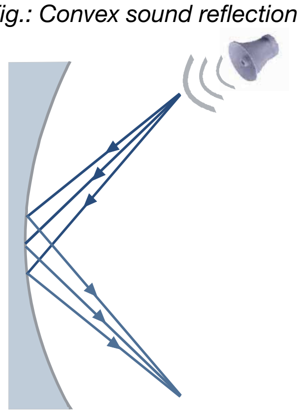


Fig.: Concave sound reflection

- The percentile share of direct reflections within the total sound level of the environment
- The differences in travel times of the reflections and the share they make up of the total sound level
- The intensity and spatial as well as temporal distribution (reverberation time) of the reverberation and its share of the total sound level

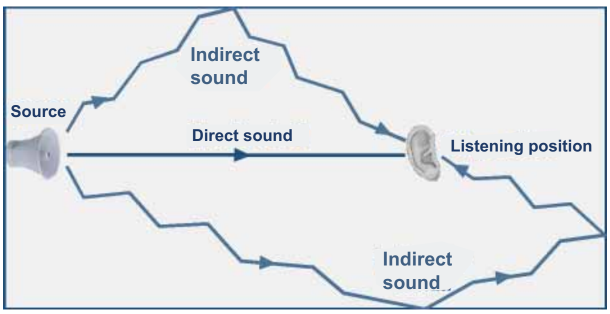
Reverberation
Continuous reflections of sound waves (sound reflections) in a closed room or in a naturally bounded region.

Reverberation occurs, for example, in large (empty) rooms or buildings such as churches, rooms with a large proportion of tile and ceramic surfaces as well as caves. The comprehensibility of speech or the original sound signal can be significantly impaired by reverberation.

Reverberation time
Time after the sound source ceases during which the sound pressure level is reduced by 60 dB (corresponds to 1/1000th of the original sound pressure). For this reason, the reverberation time as often indicated as RT_{60}.

1.3.3.1 Reverberation time in rooms

In enclosed rooms, the reflection of sound waves off the walls and ceiling results in reverberation. The sound waves that reach the ear by indirect paths are delayed in time compared with the directly transmitted sound. The ratio between direct and indirect sound is called acoustic quality. The acoustic quality of a room is particularly good if no indirect sound is produced and as much direct sound as possible reaches the ear.



Recommended reverberation time (based on DIN 18041) for rooms in which high speechcomprehensibility must be ensured:

Hearing type	Reverberation time	Room size and room type
Normal hearing	0.3 to 0.8	Ø 200 m³, poorly reflective
	0.4 to 0.6	Training room / class room
	1.5 to 2	Concert hall with intentional reverberation effect
	1.1	Ø 350 m³, poorly reflective
	1.6	Ø 6,000 m³, poorly reflective
	1.9	up to 20,000 m³, poorly reflective
Hearing impaired	Ø 0.3	General recommendation

Calculation of the reverberation time

In order to calculate the reverberation time, it is necessary to know the absorption coefficient of the materials used in the given room.

The reverberation time is given in the unit “m^2 o.w.” The abbreviation “o.w.” stands for “open window”, which optimally absorbs sound as a large hole. The absorption coefficient α (alpha) of this “open window surface” has the value 1. All other materials are ranked in relation to this value and have absorption coefficients smaller than the absolute value 1.

The smaller the absorption coefficient of a material, the more strongly the sound wave is reflected. The absorption coefficient and thereby also the calculated reverberation time both depend on frequency.

The following table offers an overview of the absorption coefficients of various materials found in rooms and buildings at a frequency of 1 kHz.

Material	Absorption coefficient a at 1000 Hz
Air/m^3	0.00
Wall surfaces	
Brick wall, unpainted	0.03
Brick wall, painted	0.02
Brick wall, plastered, incl. wallpaper	0.05
Concrete wall, unplastered	0.03
Marble	0.02
Stucco	0.05
Wood panelling	0.08
Cork	0.04
Floors	
Linoleum	0.04
Parquet	0.05
Plank flooring	0.07
Carpet, minimum value	0.2
Carpet, heavy	0.5-0.7
Stone floor / tiles	0.01-0.03
Ceilings	
Concrete, bare	0.03
Concrete, incl. wallpapering	0.04
Plasterboard, closed and jointed	0.03
Mineral fibreboard with holes	0.75
Perforated sheet	0.80
Windows and doors	
Glass, single-pane	0.03
Glass, double-pane	0.03
Wood, full-surface	0.06
Room furnishings, decorations	
Thin curtains, outer curtains	0.25-0.4
Linen / cotton, thin	0.4-0.5
Curtains with folds	0.5
Velvet curtain, heavy	0.8-1.00
Chair, empty	0.13
Chair, occupied	0.45
Padded chair, empty or occupied	0.8
Leather chair, empty	0.55

Reverberation time calculation example:

Formula by W.C. Sabine (American scientist)

Reverberation time $T = \frac{0.163\ V}{A}$

A = total of areas n x absorption coefficient α

0.163 ➔ Sabine reverberation constant
T ➔ Reverberation time (in seconds)
V ➔ Room volume (in m^3)
A ➔ Total of the absorption values (all surfaces, objects in the room, etc.)

n ➔ Total area of the individual surface types (in m^2)

Calculation of room volume V:

V = length x width x height
V = 8 m x 15 m x 3 m = 360 m^3

Calculation of the individual surfaces:

The individual surfaces (A) with differing absorption coefficients (α) are:

A_{FLOOR}	= 120 m^2 x 0.05 (parquet)	= 6
$A_{CEILING}$	= 120 m^2 x 0.03 (plasterboard)	= 3.6
A_{WALL}	= 198 m^2 x 0.05 (wall, wallpapered)	= 9.9
	Total	= 19.5

The absorption coefficient (α) actually has the units (m/s) but is always given without dimensions.

According to W.C. Sabine's formula, the reverberation time is calculated thus:

$$T = \frac{0.163 \times 360\ m^3}{19.5} = 3.01\ s$$

Furnishings, such as curtains, furniture and window surfaces, doors or persons located in this room, have an additional influence on the reverberation time.

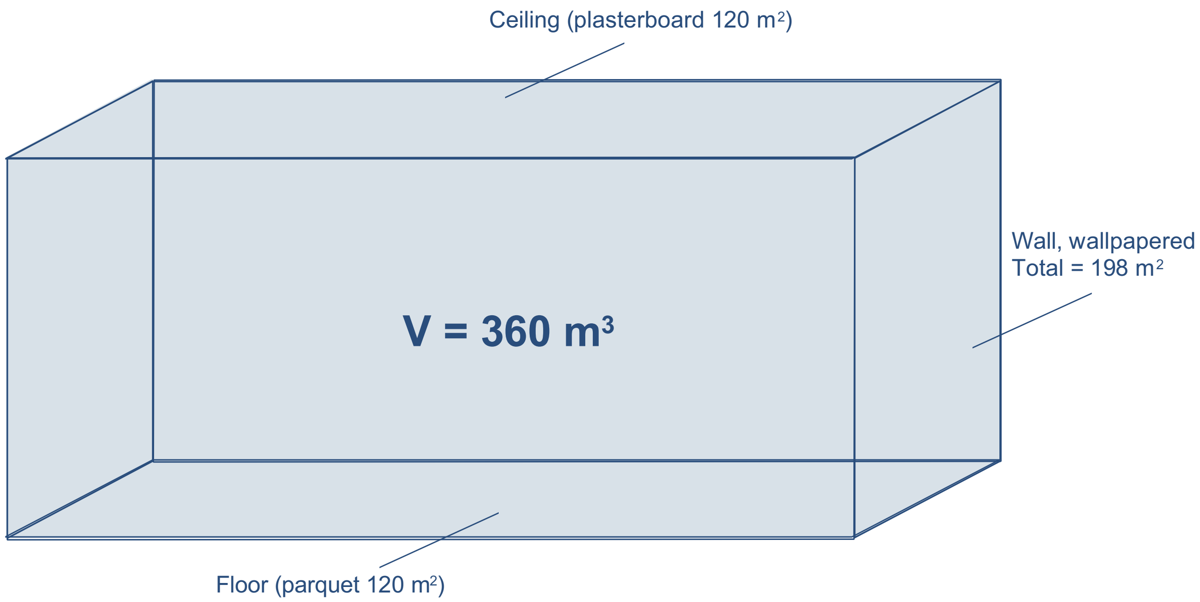


Fig.: An empty room with an area of 8 x 15 m and a ceiling height of 3 meters.

1.3.3.2 Reverberation radius

Due to reflection and the indirect sound in a room, a “frequency mix” arises that is superimposed over the direct sound. The loudness of the direct sound is not identical at all points in the room, rather it is inversely proportional to the square of the distance between the listening position and the sound source.

In the case of indirect sound, it can be assumed in practice that it has the same intensity at all points in the room – in contrast to direct sound. As a result, the share of indirect sound becomes larger than that of the direct sound as the distance from the sound source increases.

The reverberation ratio is the point or boundary in the room at which the indirect sound and the direct sound have the same physical size. The reference value is the directivity factor “Q”, which describes the omnidirectionality (Q=1) of a loudspeaker or a microphone, for instance. If the directivity factor is greater than 1, this describes a directionality.

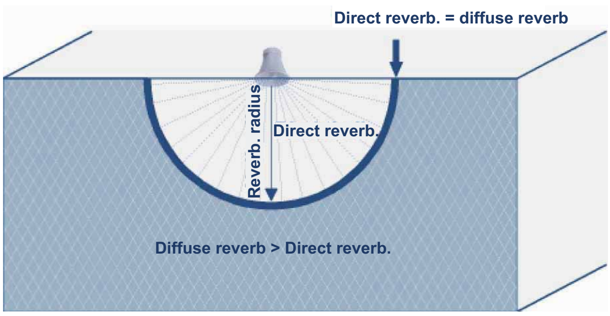


Fig.: Reverberation radius in a hall (diagram)

The following, simplified formula yields an approximate value that can be useful in practice.

$$r_H = 0.057\sqrt{\frac{V}{T}}$$

r_H	➔ Reverberation radius [m]
0.057	➔ Calculation constant
T	➔ Reverberation time (in seconds)
V	➔ Room volume (in m^3)

Sample calculation

Room volume V = 360 m^3

Reverb. Time T = 3.01 s

$$r_H = 0.057\sqrt{\frac{360m^3}{3.01s}} = \underline{\underline{0.623\ m}}$$

The reverberation radius for this sample room is only 0.623 meters.

This value can be used later for planning the positioning of microphones and loudspeakers.

Example calculations (approximated values)

The following table offers a rough guide for calculating the acoustic values based on room volume. The simplified calculation provided here cannot take into account all important parameters, such as the frequency dependence of the individual factors.

Room volume T [m³]	ROOM 1 Empty, acoustically unoptimised, e.g. warehouse or cafeteria			ROOM 2 Empty classroom with chairs, acoustically unoptimised		
	Absorption coefficient α_{TOTAL}	Reverberation time T_{60} [s]	Reverb. radius r_H	Absorption coefficient α_{TOTAL}	Reverberation time T_{60} [s]	Reverb. radius r_H
100	14	1.1	0.5	43	0.37	0.9
200	24	1.34	0.7	75	0.43	1.2
400	38	1.68	0.9	119	0.54	1.5
500	44	1.81	0.9	139	0.58	1.7
1000	70	2.29	1.2	220	0.73	2.1
2000	111	2.88	1.5	349	0.92	2.6
5000	205	3.91	2.0	643	1.24	3.6
10000	325	4.92	2.5	1021	1.57	4.5
20000	516	6.20	3.2	1621	1.97	5.7
50000	950	8.42	4.4	2986	2.68	7.7

1.3.4 Resonance and feedback

Due to resonance, it is possible in practice for an oscillatory system to escalate into many times the "original oscillation".

Resonance
Forced co-oscillation of an oscillatory system after periodic stimulation

Resonance arises when a "stimulating system" periodically perturbs a second system, which then also oscillates at the same frequency. A good example of mechanical resonance is a "swing".

In acoustics, resonance is used for the production of tones by musical instruments, for example. The occurrence of resonance is disadvantageous to the transmission of sound with high speech comprehensibility. In practice, for example, low frequencies with higher sound pressures can stimulate thin walls / ceilings or even large glass surfaces to resonate. Assuming that the sound pressure is not so strong that the resonance results in the destruction of the surfaces, the co-oscillation can however produce additional acoustic interference with the sound waves or the mechanical movement can generates background noise.

Feedback
Feedback refers in general to the signal-amplifying effect in which an output (e.g. acoustic signal) is directly or indirectly returned as an input to the original system.

In public address systems, feedback is disruptive and must be prevented.
Feedback occurs, for example, if a microphone is located too close to the loudspeaker that is emitting the signal from the microphone. The microphone receives the signal again from the loudspeaker with a certain delay. This gives rise to an electroacoustic loop that reinforces itself. In practice, this is perceived as a piercing whistling or a high unpleasant noise. The frequency of the resulting noise depends on the properties of the phase offset of the transmission path (air distance, loudspeaker and microphone properties, room walls, etc.).

In addition to irritating the listeners, the loudspeaker can even be destroyed in extreme cases.

Measures to prevent feedback

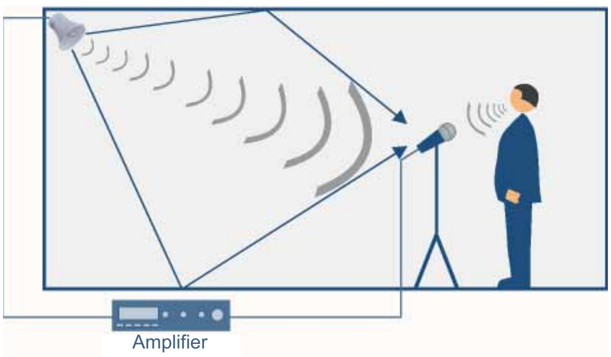


Fig.: Direct and indirect feedback of sound to the microphone

- Positioning microphones and loudspeakers such as to avoid a direct sound path between them as far as possible
- Special arrangements and linking of multiple microphones
- Changing the distance between the loudspeaker and microphone
- Shielding the microphone or using a different microphone type

In public address systems, the presence of people in the room can help to suppress feedback.

While an empty room may exhibit high feedback, the presence of listeners or persons in the room could dampen the sound enough to reduce the feedback. In principle, however, one should always assume the worst conditions (e.g. an empty room).

1.4 Sound and sound levels

Sound is the noise or the tone as it can be perceived by the sense of hearing of a person or animal. The propagation of sound is only possible in connection with a material (air, water, solid bodies, etc.). Sound cannot propagate in an airless room (vacuum), meaning that no transmission of sound is possible.

Sound is produced when a body is stimulated to oscillate. In the case of human speech, this is done with the vocal chords; in acoustics, it could be done by loudspeakers, which cause the air to oscillate by means of the mechanical motion of the diaphragm, thereby generating a sound wave.

The sound, or sound wave, is defined by a number of factors that allow for calculation of its properties.

1.4.1 Speed of sound

The speed with which a sound wave propagates is referred to as the speed of sound. This depends significantly on the medium through which the sound wave moves.

The speed of sound [c] is the product of the wavelength [λ] and the frequency [f].

$$c = \lambda \times f$$

Speed of sound

Air ➔ 343 meters per second (at 20 °C)

Water ➔ 1,407 meters per second (at 0 °C)

1.4.2 Sound pressure and sound pressure level

As sound waves propagate through air, the oscillating air particles cause changes in the air density. This local and temporary change in air pressure is referred to as sound pressure [p]. The unit of sound pressure is [N/m^2] or the pascal (1 N/m^2 = 1 P).

Sound pressure [p] can be measured relatively easily with a microphone. Microphones (like the human hearing organ) are sound pressure receivers due to their physical design. The more accurate term is alternating sound pressure since the concept does not involve a static value. In practice, however, this term is largely ignored.

At the human auditory threshold, the sound pressure amplitude has a value of 2 x 10^{-5} N/m^2 (= 20 μPascals). This corresponds to a sound pressure level of 0 dB. A sound pressure of roughly 20 N/m^2 (= 20 pascals) is already perceived as unpleasant at a frequency of 1 kHz.

The effective value of the sound pressure is always used for calculating the sound pressure level. The sound pressure level (absolute value) is designated with the letter "L".

The sound pressure level from the auditory threshold (0 dB or 2 x 10^{-5} N/m^2) up to the pain threshold (130 dB) extends across six orders of magnitude.

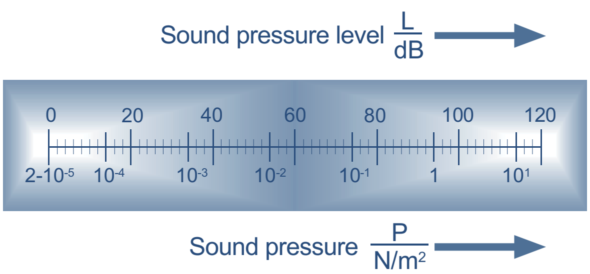
Decibels

Values given in dB refer to a power ratio (10 x log). These decibel values must be squared for calculation of the level ratio for the sound pressure in order to compare this with the power ratio. When using decibels, this is accomplished by multiplying by a factor of 2 (2 x 10 log).

$dB_{POWER\ RATIO}$ ➔ **10** x $\log_{10}$ ....

$dB_{LEVEL\ RATIO}$ ➔ **20** x $\log_{10}$ ....

When using decibels, it is easy to add or subtract the individual values for the power ratio and the ratio of the sound pressure level.



Energy ratio	Sound pressure level
$L = 10 \log_{10} \frac{P_1}{P_2}$ (dB)	$L = 20 \log_{10} \frac{p_{EFF}}{p_0}$ (dB)
L = absolute sound pressure level [dB] P1 = power P2 = power (reference value)	L = absolute sound pressure level [dB] p_{EFF} = sound pressure (effective) p0 = reference sound pressure (pure tone 1 kHz, auditory threshold)

Power and level ratios

The table shows that a doubling of the sound pressure “p” also means a concurrent increase of the sound pressure level “L” by +6 dB

Level [dB]	Energy ratio	Sound pressure
0	1	1
1	1.25	1.12
2	1.6	1.25
3	2	1.4
4	2.5	1.6
5	3.15	1.8
6	4	2
12	15.8	4
20	100	10
30	1,000	32
40	10,000	100
50	100,000	316
60	1,000,000	1,000
80	100,000,000	10,000
100	10,000,000,000	100,000
120	1,000,000,000,000	1,000,000

+ 6 dB (0 → 6)

+ 6 dB (6 → 12)

Examples of sound pressure levels of specific noises

Description	Sound pressure [N/m2]	Sound pressure level [dB]	Energy ratio [□]
Theoretical limit for a sound wave (at 1 bar air pressure)	100,000	194 dB	
Pain threshold	100	134 dB	10,000,000,000,000
Possibility of hearing damage	20	120 dB	1,000,000,000,000
Pneumatic hammer, 1 m distance	2	100	10,000,000,000
Disco Car, 10 m distance	1.8-2.0 0.2	90-100 70	1,000,000,000 10,000,000
TV, 1 m distance	0.02	60	1,000,000
Conversation, 1 m distance	0.0063	50	100,000
Quiet room / night	0.00063	30	1,000
Calm breathing	0.000063	10	10
Auditory threshold	0.000020	0	1

1.4.3 Sound production and propagation

A sound or a sound wave is produced when a material or a body is stimulated to free or forced oscillation. Most sound emitters utilise the transformation of mechanical or electrical energy in order to produce sound.

Mechanical sound producers (examples)
- Guitars, drums, flutes, trumpets
- Pianos
- Bells
- Hammer strikes
- Diaphragms
- Whistles
- The human voice

Electrical sound producers (examples)
- Loudspeakers
- Telephones

The human voice
The production of sound for human speech takes place via the vocal chords in the larynx and lies within the frequency range from 300 Hz to roughly 3,500 Hz. With a singing voice, such as a bass, it is possible to reach a frequency of approx. 90 Hz. A soprano voice has a frequency of roughly 1500 Hz.

The voice of every human is unique. This is due to the size of the oral and nasal cavities as well as the tongue size and position. The pronunciation of the five vowels (a, e, i, o, u) is characteristic for the sound of a voice.

In speech transmission, only the main frequency range from 300 Hz to 3.5 kHz is typically taken into consideration in practice. High-quality transmission of this frequency range allows for high speech comprehension and does not pose high demands on technical equipments (such as telephones).

Sound propagation

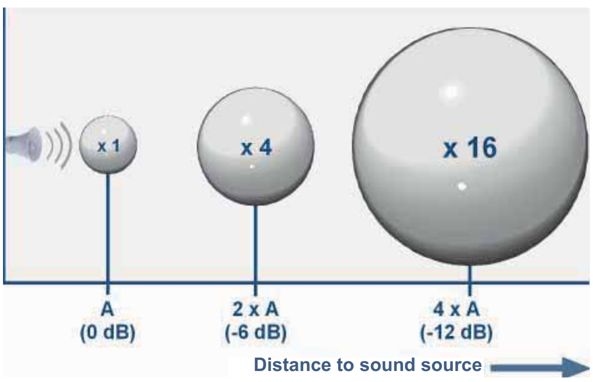


Fig.: The "sphere surface" for sound propagation (diagram)

Sound propagation is influenced by all the properties of sound. External factors, such as air pressure (height above sea level) and temperature, also play a role.
The sound wave propagates in air at the speed of 343 m/s (at 20 °C), which corresponds roughly to a speed of 1235 km/h.

Temperature (Air)	Propagation speed	Time for 1 meter	
-10 ° C	325 m/s	3.09 ms	corresponds to Ø 3 ms
0 ° C	331.5 m/s	3.03 ms	
10 ° C	337.5 m/s	2.97 ms	
20 ° C	343 m/s	2.915 ms	
30 ° C	349 m/s	2.865 ms	

ms = millisecond (1/1000th of a second)

Assuming a point-shaped sound source, the propagation takes place evenly toward all sides of the room. This means that all particles have the same distance to the sound source, i.e. are located on the surface of a sphere whose centre is the sound source. Sound waves that propagate uniformly in all directions are therefore referred to as spherical waves. Such spherical waves represent an idealised concept. As the surface of the sphere “grows” at increasing distance from the sound source, the sphere surface becomes increasingly large, meaning that the energy density and sound pressure decrease. In somewhat simplified terms, the sphere surface at twice the distance (2xA) would be 4 times greater, and the sound pressure level would be reduced to half the original value (- 6dB).

In practice, this means that the sound pressure level, such as produced by a loudspeaker, is halved when the distance to the sound source is doubled.

With a loudspeaker with a sound pressure level of 90 dB (1 m) located in a 5-m high room, the sound pressure level available at the ear level of the listener is only roughly 80 dB.

At the farthest points in the room, the sound pressure level is even less than 75 dB. This idealised representation can be influenced in practice by many factors, such as reflections, the furnishing of the room, etc.

Distance to sound source	Sound pressure	Note
1 m	0 dB	Reference point for value (e.g. 90 dB at 1 m distance)
2 m	-6 dB	Corresponds to half the original sound pressure
4 m	-12 dB	Corresponds to one-fourth of the original sound pressure
8 m	-18 dB	
16m	-24 dB	
32 m	-30 dB	Corresponds to 1/32nd of the original sound pressure

In order to compensate for this decrease in the sound pressure level, either the sound source can be moved closer to the listener (or vice versa) or the number of individual sound sources can be increased.

The diagrams show that the sound pressure level drops off steeply in the first few meters. If the distance is doubled from 1 m to 2 m, the sound pressure level falls by 6 dB. With increasing distance to the sound source, the reduction is then proportionately significantly lower. If the distance is doubled from 8 m to 16 m, the sound pressure level likewise falls by 6 dB.

Windows, doors or partition walls

Even if the sound propagation is unhindered, the sound pressure falls the farther away from the sound source one stands. In practice, furnishing elements such as windows, doors and partition walls (including decorative walls) have a considerable influence on the propagation of sound.

For example, windows and doors or a partition wall (room divider) can lower the sound pressure in a room by about 40 dB. In addition, other disruptive noises would enter into the room from the “outside”.

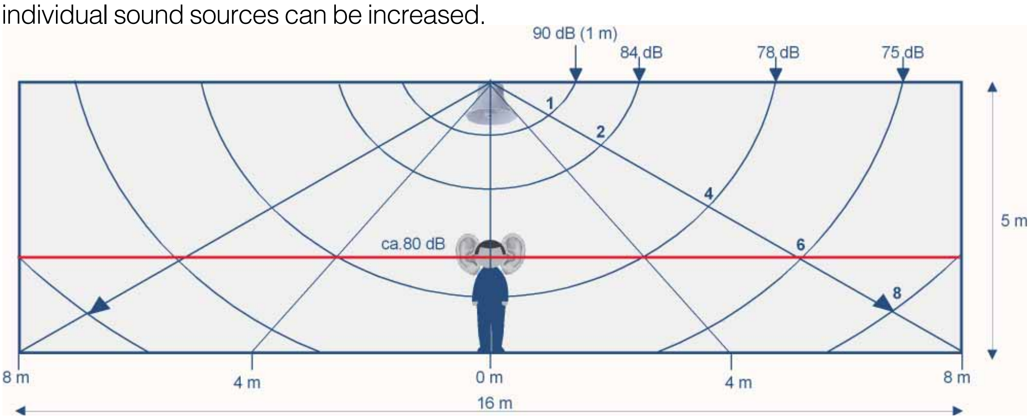


Fig.: Decrease in sound pressure level based on distance

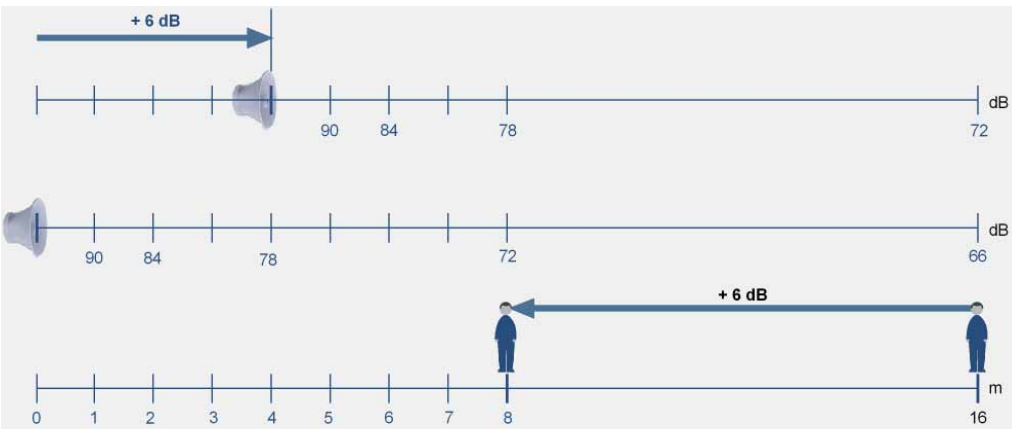


Fig.: Increase in the sound pressure level by changing the position

1.4.3.1 Room sound

Room sound refers to the sound waves in an enclosed room that return to the recipient after multiple sound reflections.

The first sound wave perceived is decisive for orientation by the human hearing system. This is generally the direct sound wave. Indirect sound waves (reflections) can also influence the orientation if the travel delay with respect to the direct sound wave is less than 50 milliseconds (ms).

For larger travel time differences, it is possible that both observations are perceived as different events. In this case, one refers to an acoustic echo that negatively influences the objective perception of the sound wave and makes the original signal harder to comprehend.

The comprehensibility or quality of the transmission of sound waves within a room is significantly influenced by:

- The size of the room (room volume)
- Geometric shape (rounded surfaces, ratio between floor and wall surfaces)
- Furnishing (tiles, carpet, curtains, chairs, etc.)
- Number of window surfaces
- Entrances, doors (especially if open)
- Position of the sound source (e.g. tower or ceiling loudspeaker)
- Type of sound source
- Background sound level (disrupting noises or traffic)
- Reverberation time

1.5 Microphones

A microphone converts sound into electrical impulses. Microphones are used in electroacoustics to generate electrical audio or voice signals.

The technical data of a microphone always refers to a sound pressure of 1 Pascal (= 1 N/m²) and a distance to the sound source (e.g. a speaker) of 0.3 meters.

1.5.1 The conversion principle

Two types of microphones are preferred in public address systems. These differ in their conversion principles. On one hand, we have dynamic microphones and, on the other, electrostatic converters such as capacitor microphones.
The physical characteristics and microphone properties are significantly influenced by the type of energy conversion.

Dynamic microphones
Dynamic microphones are available as pressure microphones and pressure gradient microphones. This design also determines the directional characteristic.

Applications / suitability
- No power supply required
- Suitable for high sound pressure (e.g. public address systems, live music)
- Mechanically robust
- Can be connected directly to soundboards
- Low acquisition costs
- Preferred for close-up recordings (speaking distance)

In a moving-coil microphone, the diaphragm is connected to the moving coil. The sound pressure acts on the diaphragm, which in turn moves the moving coil constantly within the field of a permanent magnet. This generates an induced voltage at the terminals of the moving coil.

Applications / suitability
- No power supply required
- Not suitable for high sound pressure
- Sensitive to movement and wind
- Good frequency response
- Preferred for close-up recordings (speaking distance)

The principle of the moving coil microphone allows for particularly good reproduction of deep tones; however, this conversion principle is less well suited to high frequencies.

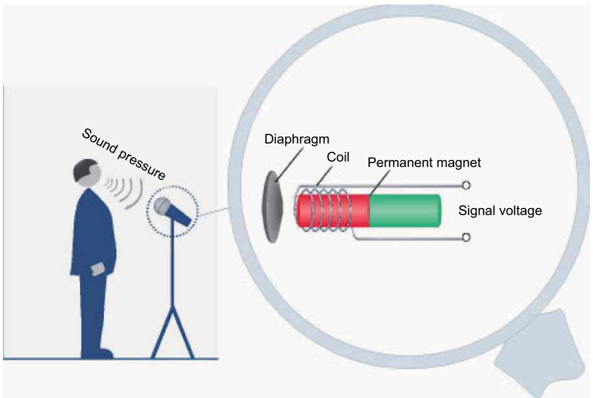


Fig.: Diagram of a moving coil microphone

Unlike a moving coil microphone, a ribbon microphone makes use of a folded strip of aluminium, which is moved within the field of a permanent magnet by the sound pressure. This very light and flexible ribbon allows for a nearly linear frequency response within its operating range.

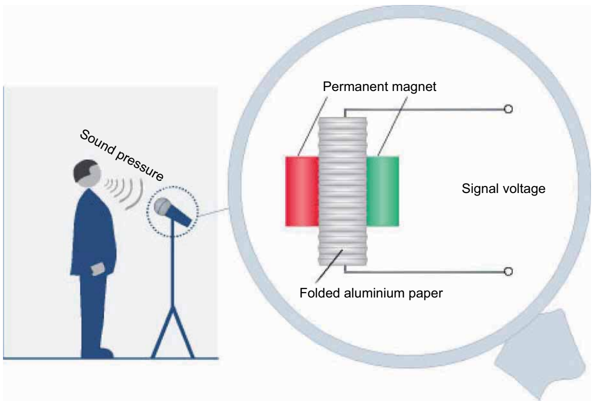


Fig.: Diagram of a ribbon microphone

The operating principle of the ribbon microphone results in a “figure-eight” directional characteristic. Due to the mechanical properties of the ribbon, higher frequencies can also be reproduced well; however, it is relatively unsuited for lower frequencies.

Capacitor microphone
The capacitor microphone makes use of a (plate) capacitor to generate electrical signals. An external electrical power supply is required to operate a capacitor microphone. This is provided in the form of phantom power.

Capacitor microphones are available as pressure microphones and pressure gradient microphones. This design also determines the directional characteristic.

Applications / suitability
- External power supply required
- Partially adjustable directional characteristic
- Large dynamic range
- Unsuited for high sound pressure (mechanically and acoustically very sensitive)
- Good impulse response, high quality output signal

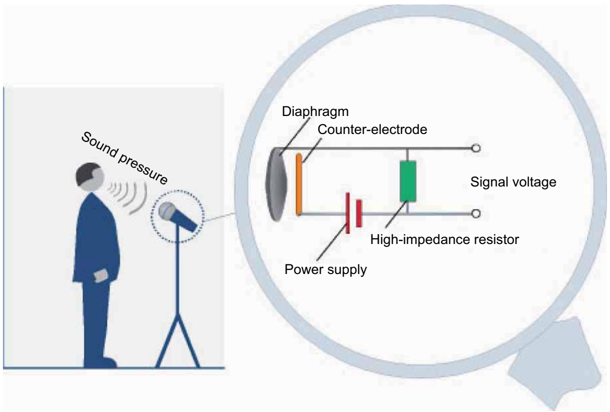


Fig.: Diagram of a capacitor microphone

The sound pressure stimulates a conductive diaphragm to oscillate. This diaphragm electrode is positioned with an insulating layer (thin air gap / dielectric) in front of a second (capacitor) plate. An external voltage is connected to this capacitor, and the capacitor is polarised. As the diaphragm oscillates, the distance between the two "plates" changes and thereby also the electric field. This generates an alternating current that causes a voltage drop at the high-impedance internal resistor (≥100 MΩ). This process is used to generate the signal voltage.

Electret capacitor microphone
The electret capacitor microphone operates according to the same principle as the "normal" capacitor microphone.
The mechanical design differs in terms of the insulating layer between the two "capacitor plates". This microphone receives its name from this electret film. Electrets are made of special materials and treated so that they exhibit a permanent electric field. As a result, no external voltage is required for polarisation of the capacitor.

Applications / suitability
- Inexpensive, robust, small
- No external power supply required
- Very low current consumption
- Wide range of variants
- High input resistance at amplifier required
- Moderate signal quality

1.5.2 Phantom power

Phantom power is required for supplying power to and polarising capacitor microphones and typically lies within a range from 9 to 48 V DC.

Electret capacitor microphones are generally operated without this power.

Phantom power is also not needed in the case of dynamic microphones. When connecting a dynamic microphone, it does not matter whether the phantom power of the amplifier is switched on or off.

The positive pole of the power supply to the capacitor microphone is connected to both poles of the signal line via a decoupling resistor. The cable shielding of the line is connected to the negative pole. As a result, no voltage can be measured between the two wires of the signal line, which is why this is referred to as "phantom voltage". The voltage can only be measured from one of the signal wires to the cable shielding.

The phantom voltage is supplied symmetrically (!), and it is possible to connect multiple microphones to a single power source. Microphones supplied with phantom voltage can only be operated on symmetrical amplifier inputs.

1.5.3 Characteristics of a microphone

Frequency response
Frequency response is a graphical representation of the sensitivity of a microphone.

Different distances between the microphone and the sound source (speaker, singer) can require a different frequency response and therefore a different type of microphone.

What is important is the frequency range to be transmitted for human hearing of 20 Hz – 20 kHz. Ideally, no natural resonances should arise in the diaphragm to ensure that the sound can be reproduced in high quality.

The size and weight of the diaphragm as well as, for example, the inertia of the coil in a moving coil microphone influence the application range for the microphone.

Impedance
In electrical engineering as well as with regard to the electromagnetic and acoustic propagation of waves, impedance is the complex alternating-current resistance "Z" of a linear, passive, two-terminal circuit.

Faulty adaptation of the impedance between a microphone and the input of an amplifier (or the signal line) can cause reflections and resonances. These "disruptions" result in a non-linear frequency response.

In practice, dynamic microphones have an impedance of about 600Ω and capacitor microphones have an impedance of about 50-250Ω, while electret capacitor microphones exhibit a high impedance of 1-5 kΩ.

The higher the resistance of the microphone output, the greater the influence of the connected cable capacity. Longer connection cables exhibit higher attenuation particularly for higher frequencies.

Distortion factor
The distortion factor is the measure of the non-linear distortions caused by the microphone up to a maximum value of 1.

The smaller the distortion factor, the better the linear frequency response of the microphone.

In the case of dynamic microphones, non-linear distortions arise in practice only at very high sound pressure levels. These distortions are usually caused by the physical properties of the diaphragm.

Capacitor and electret microphones are more susceptible to non-linear distortions due to their design.

Sensitivity
The sensitivity of a microphone defines which voltage (in mV) is output at the standard sound pressure of 1 Pa (= 1 N/m^2).

The larger the diaphragm used in the microphone, the higher the sensitivity, whereby a doubling of the sound pressure does not necessarily mean a doubling of the voltage value.

Typical values:

Dynamic microphones:
1.5 mV/Pa (corresponds to -56 dB)

Capacitor microphones:
10 mV/Pa (corresponds to -40 dB)

In the technical data for microphones, sensitivity is generally indicated in decibels in order to permit a simple calculation of the amplifier power. The value -40 dB means that the microphone signal must be amplified by +40 dB in order to correspond to the 0 level of a soundboard input, for example.

Interference susceptibility

In addition to reflections and the resulting interferences or positive feedback, an undesirable "humming" can often be heard in practice. This interference noise is primarily caused by the connection of the microphone or the cable design. This involves electromagnetic interference that is picked up by the connection cable. The longer the connection cable, the higher the possibility of receiving interference signals, i.e. the interference susceptibility is higher.

To avoid such interference, only shielded connection cables should be used. By virtue of their design, coaxial cables are already largely protected against external electromagnetic influences.

In practice, "ground loops" in the cable lines are usually responsible for such humming noises (interferences). Such interference influences can be avoided by a symmetrical cable arrangement with a ground wire separate from the cable shielding. The quality of the microphone cable and its physical properties are of great importance here.

Directional characteristic

Directional characteristic refers to the size of the resulting signal amplitudes (signal voltage) depending on the direction of incidence of the sound pressure. The directional characteristic of a microphone is frequency-dependent. To determine the directional characteristic, a sound source with a pure tone of 1 kHz is emitted at a distance of 1 m in the axis of symmetry. The human ear can be compared with "cardioid" directional characteristic.

In principle, one can differentiate between the following two types of microphones:

Pressure microphones
Spherical characteristic

Pressure gradient microphones
Figure-eight characteristic, directional microphone

The "directivity" value is generally only given in practice for the axis of symmetry. The value is given in decibels [dB]. The outer point on the axis of symmetry at 0° is the reference point and is designated as 0 dB.

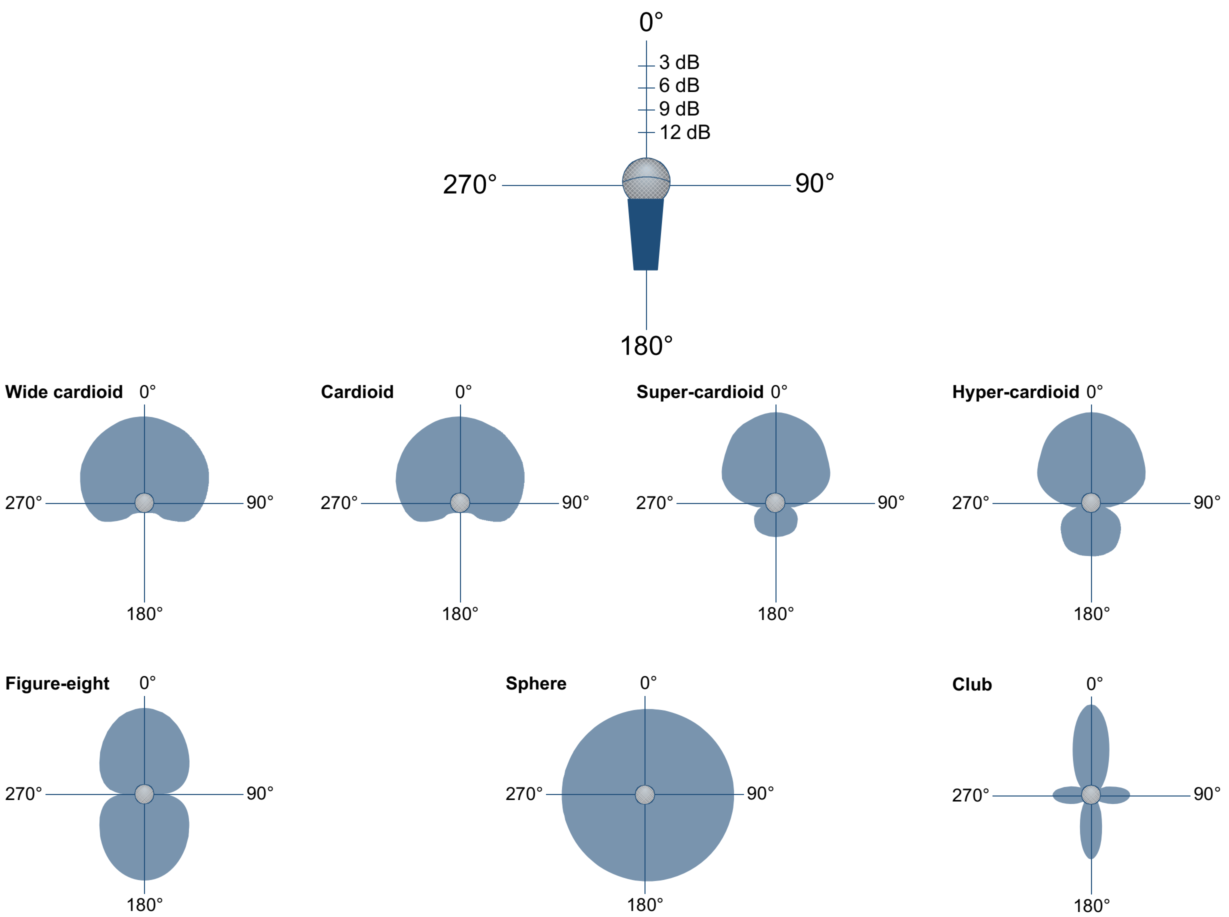


Fig.: Microphone characteristics

1.6 Loudspeakers

A loudspeaker is an electromechanical component by which electrical signals, such as the output signal voltage generated with a microphone, are converted back into sound waves.

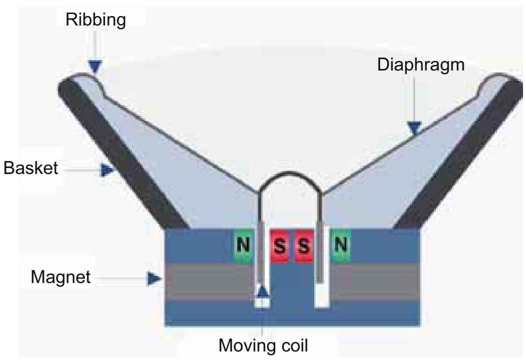
Loudspeakers (also sound transducers) exist in a wide variety of shapes and designs. Various physical processes are used to convert the electrical signal into a pressure wave.

Loudspeakers for voice alarm systems according to DIN VDE 0833-4 must satisfy the product standard EN 54 – 24.

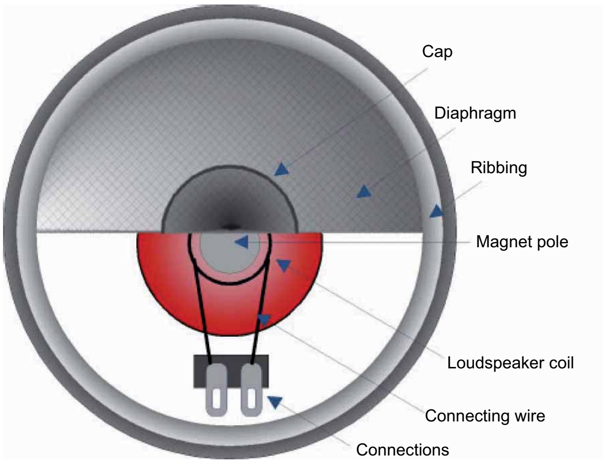
Loudspeaker types (examples)
- Electrodynamic sound transducers
- Magnetostats
- Electrostats
- Piezoelectric loudspeakers (ferromagnetic loudspeakers)
- Pressure chamber loudspeakers / horn loudspeakers / megaphones

Electrodynamic loudspeakers
The electrodynamic conversion of sound in this type of speaker is the reverse of the physical process in an electrodynamic microphone. The electrodynamic loudspeaker consists of a diaphragm connected to a central moving coil. This coil is located within the magnetic field of a permanent magnet. If the output (alternating) voltage of an amplifier is connected to this coil, the result is an alternating electromagnetic field that causes the diaphragm to move, thereby producing a sound pressure.

Depending on the frequency range, smaller or larger and softer or harder diaphragms are used.



This diaphragm is connected to the housing via a “rib”. This rib is made of an elastic material that allows for the movement of the flattened dome.
Electrodynamic loudspeakers are excellently suited for producing a high sound pressure.



Due to the large diaphragm surface and the associated inertia, the dynamic loudspeaker is not particularly well suited for high frequencies. Depending on the design, however, good results can be achieved in this area. Electrodynamic loudspeakers for simple applications can be produced inexpensively. This process is frequently also used for headphones.

In public address systems, the electrodynamic loudspeaker is one of the most frequently used designs.

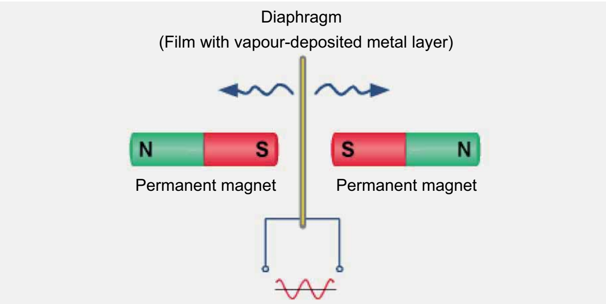
Magnetostatic loudspeakers

Magnetostats are sound transducers that do not have a moving coil but rather an "electrical driver" that is distributed over the entire surface of the diaphragm (film magnetostat) or a ribbon that is simultaneously used as diaphragm.

The diaphragm generally consists of a thin film (e.g. plastic) that is applied to a textured metal layer. This diaphragm is situated at the centre between multiple permanent magnets and has connecting contacts for the output (alternating) voltage of an amplifier. This voltage in the metal layer of the film (or ribbon), in connection with the one in the field of the permanent magnets, causes an alternating movement, thereby generating a sound pressure.

Magnetostatic loudspeakers are also referred to as planar speakers due to the large diaphragm surface. The application range of magnetostats of medium to high frequencies lends itself primarily to music reproduction and high-end audio technology.

Electrostatic loudspeakers



In an electrostatic loudspeaker, the diaphragm is driven by an electrostatic field.

This conversion principle makes use of the physical effect of repulsion between identical charges (and the reverse). In principle, this sound transducer can be compared to a plate capacitor, the plates of which have different electrical charges. Between these two electrically charged surfaces is the diaphragm, onto which an electrically conductive layer is applied by vapour-deposition (as with a magnetostat), and which has connection terminals for the output (alternating) voltage of an amplifier.

This voltage in the metal layer of the film, in connection with the electrostatic field of the plates, causes an alternating movement, thereby generating a sound pressure.

A very high external voltage is required for this type of sound production. In transistor devices, this high voltage is generated by transformation. Typically, however, electrostatic loudspeakers are driven by tube amplifiers.

Electrostatic loudspeakers have excellent impulse behaviour, and in practice due to their expensive design, are used only for the reproduction of higher frequencies in high-end audio equipment.

Piezoelectric loudspeakers

The core of a piezoelectric loudspeaker is a crystal. The output (alternating) voltage of an amplifier is connected to this crystal, and the crystal is deformed and set into motion by this voltage.

Piezoelectric loudspeakers are only used for the higher frequency range as tweeters or midrange speakers.

- High impedance – lower power consumption

Pressure chamber loudspeakers

In a pressure chamber loudspeaker, the diaphragm acts on a very small space – the pressure chamber.

In this pressure chamber, the speed of the air particles is increased by the small chamber cross-section.

This principle improves the efficiency considerably compared with other designs.

By shaping the loudspeaker housing like a horn or funnel, the sound coupling is further increased and a directional effect is achieved. Due to the high sound pressure that can be achieved and the adequate frequency range that can be produced, pressure chamber loudspeakers are ideal for providing sound coverage over large areas (even outdoors) and halls.

Pressure chamber loudspeakers are generally resistant to weather and very robust.

Frequency response
The frequency response describes the non-linear distortions and the associated alteration of the tone in the reproduction of signals.
A loudspeaker outputs the “input signal” with varying sound pressure depending on the respective frequency. Ideally, a loudspeaker should be able to reproduce the complete frequency spectrum of human hearing. However, the unavoidable tone alteration that occurs in practice is only a significant factor for applications in which a high-quality reproduction is required (music playback, concerts, etc.).

Pulse fidelity
The capability of a loudspeaker to process an impulse is referred to as pulse fidelity (also impulse response). The more accurately the (signal) impulse is reproduced by the sound transducer, the better the sound quality.
The number of oscillations with which the loudspeaker follows the driving signal and its behaviour over time are decisive here. The pulse fidelity of dynamic loudspeakers, for instance, is significantly influenced by the strength of the diaphragm and the ribbing

Distortion factor
The distortion factor is a rating of the level-dependent distortions of signals. In the transmission of frequencies, parasitic oscillations, reflections, overtones, etc. that did not exist in the original oscillation are always produced. The main cause is the non-linearity of the electromechanical converter.

A distortion factor of max. 1% is practical imperceptible by the human ear. Only from a value of about 3% are the distortions perceived as unpleasant and irritating.

Electrical load capacity
The load capacity of a loudspeaker is the maximum electric power consumption (in watts, W) at which it can be operated without distortions and damage.

The loud capacity is an important value for selecting a loudspeaker in connection with the power of the amplifier to which it is connected. The output power of the amplifier should be adapted to the loudspeaker and should never exceed the load capacity.

Regardless of the output power of amplifiers, loudspeakers can be destroyed by strong distortions (distortion factor). In practice, this means that even low-quality amplifiers with low output power that are operated in their upper power range can also destroy loudspeakers that exhibit a significantly higher load capacity according to the technical data.

Efficiency
The efficiency of a loudspeaker reflects how effectively the electrical energy is converted into sound pressure.

The higher the efficiency (indicated in %), the less energy is required to achieve a given sound pressure. Put another way, the loudspeaker operates with low losses and can produce a required sound pressure even with very low amplification. A connected amplifier can therefore be operated within its optimal operating range and not near its operating limits. The efficiency of the loudspeaker also has an influence on the possible operating time in the case of battery-powered devices.

A loudspeaker with a lower efficiency requires a higher amplification power, and the heat introduced to the speaker by the higher energy must in turn be dissipated to prevent damage.

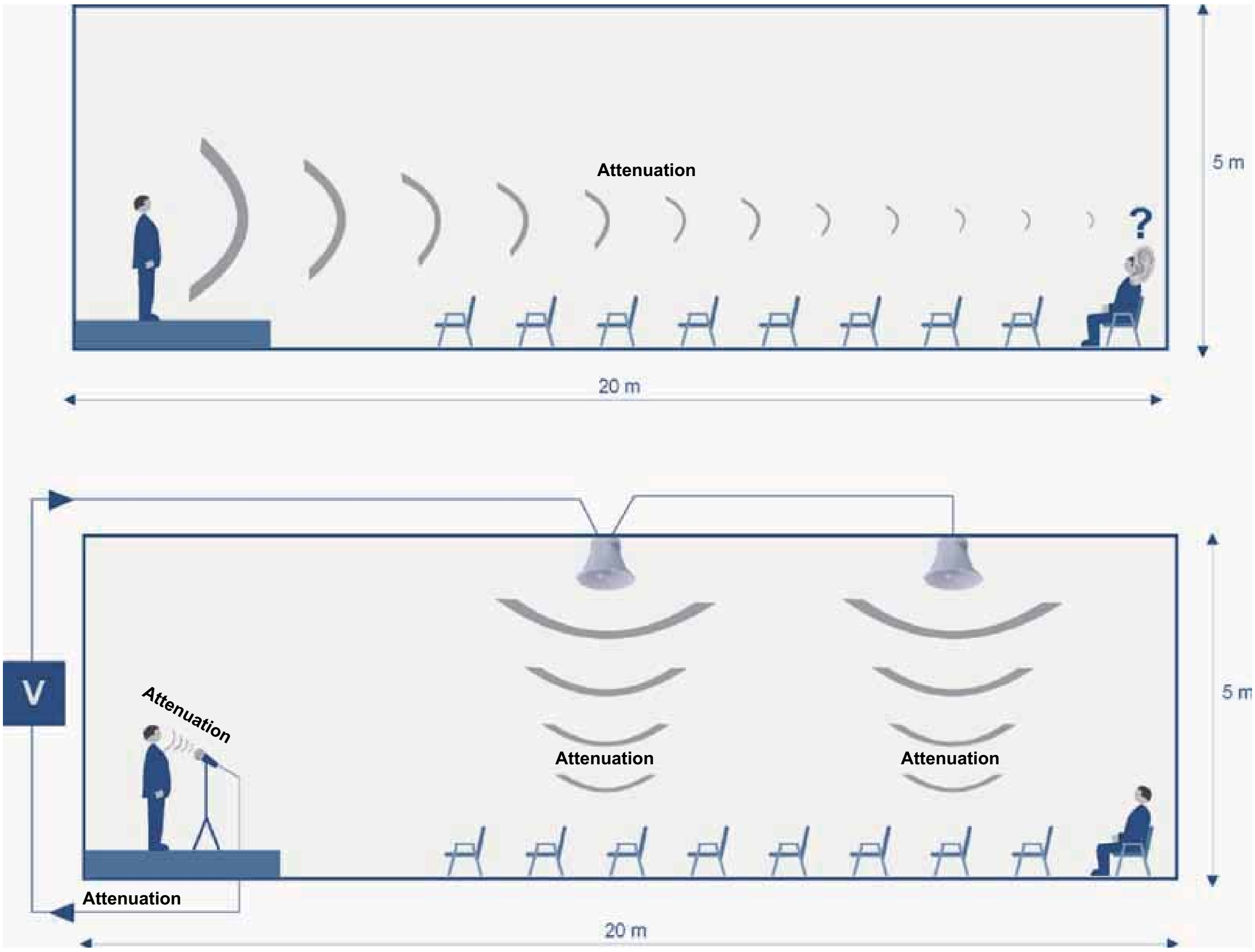
Public address systems require high comprehensibility of the information even at a high sound pressure level for announcements and alarms. Due to their functioning principles and high efficiency, pressure chamber loudspeakers are ideally suited for this.

1.7 Amplifiers

An amplifier is an active component that increases the output signal of a sound source (e.g. microphone) and passes its output signal to a sound transducer (e.g. loudspeaker).

Ideally, the amplification factor over the entire frequency range (e.g. hearing range of 20 Hz – 20 kHz) is uniformly good to avoid corruption of the original signal. This transmission range is determined by the lower cut-off frequency and the upper cut-off frequency. Beyond these cut-off frequencies, the amplifier is no longer operated within its optimal range and distortions result.

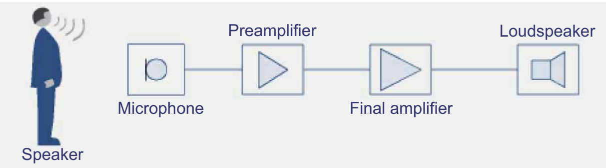
Filter stages can be used to smooth out flawed sound reproduction or to adjust the sound to personal tastes or acoustic requirements of the room. In practice, this is a tone control system of the amplifier itself (highs, mids, lows) or a soundboard or equalizer



Preamplifier / final amplifier

In order to run the (power) amplifier within its optimal operating range, the amplifier stage is often divided into a preliminary stage and a final stage. This division can be implemented with two separate devices or even within the same housing.

The interaction between these two amplifier stages encompasses important factors such as the frequency range, frequency response, input voltage and impedance. Due to the electrical operation of the preamplifier, the share of undesired harmonic oscillations is extremely small.



In public address systems, low noise levels and overmodulation resistance are of great importance. Generally only the smaller signal voltages of a microphone are available here, which must be amplified to a very high output level by the amplifier.

With the division into preliminary and final amplifier stages, the microphone signal can be adjusted by the preamplifier and ideally prepared for the input of the final amplifier. This largely avoids the pronounced amplification of undesired signals.

Amplifiers are devices used in audio technology to drive a loudspeaker and that must satisfy specific, minimum electrical requirements. In the case of audio technology, for example, this means an output power of at least 1 watt on a low-resistance device output (e.g. 4 oder 8 Ω).

1.7.1 Characteristics of an amplifier

Output power

The output power (in watts) refers to the total output power of the amplifier. Amplifiers are developed for a specific impedance or output voltage. In low-impedance amplifiers (audio technology, high fidelity), load impedances of 4 to 8 Ω are typical.

In public address systems, one makes reference to the output voltage (e.g. 100 V) because the impedance is adjusted by the pulse transformer built into the loudspeakers. The load connected to an amplifier (in watts) may not exceed the output power of the amplifier.

Example:
A 100-V amplifier with an output power of 240 W is capable of driving a maximum of 40 loudspeakers (suitable for 100-V technology) with an individual power of 6 W each.

Amplifiers in public address systems frequently offer multiple “loudspeaker outputs”. One refers here to loudspeaker zones over which the total output power of the amplifier is distributed.

Example:
A 100-V amplifier with an output power of 240 W and 4 zones provides an output power of 60 W per zone. It is then possible to connect 6 loudspeakers of 10 W each or 10 loudspeakers of 6 W each to each output.

In principle, an amplifier should not be operated near the limit of its range. In addition to the interferences expected there (distortion, noise, etc.), the thermal load also plays a major role. Amplifiers with larger output powers must be sufficiently well ventilated or have integrated “forced ventilation” that cools the amplifier with controlled fans or even “throttles” it electronically.

Output type
The output type determines what types of loudspeakers can be connected to an amplifier. Typical output types of 100-V amplifiers used in public address systems are 100 V, 70 V and 50 V. Suitable loudspeakers (pulse transformers) with the respective voltage (energy transformation) can be connected to these outputs.

Most amplifier types also support an output for connecting passive loudspeakers with 4 to 16 Ω impedance.

Distortion factor
The distortion factor (in %) indicates the size of the undesired distortions produced by non-linear components of the amplifier and the amplification principle. The distortion factor in equipment used in public address systems is generally less than 1% and therefore negligible.

For devices that are intended to alter the sound (mixers, equalizers), a distortion factor is generally not indicated

Frequency response
The frequency response of an amplifier describes its capability to amplify the input signal within a range without significant distortions or tone alterations. What is important is the frequency range transmitted for human hearing of 20 Hz – 20 kHz.

For audio devices, (e.g. high fidelity amplifiers) developed specially for high-quality reproduction of music signals, the frequency response is an important factor for selecting a device depending on individual audio quality expectations and personal hearing capability.

The frequency response of 100-V amplifiers generally covers this entire range in practice. For use in voice alarm systems, however, the very low frequencies (< 100 Hz) and the very high frequencies (> 15 kHz) are generally not important. It is important here to be able to reproduce high quality in the "large middle range".

Efficiency
Efficiency is the relationship between effective power (audio power) and the total power consumed.

$$\eta = \frac{P_A}{P_G}$$

Amplifiers of class AB have an efficiency of approx. 50 %. For example, at 2 x 250 W and an efficiency of 50%, these would consume up to 1000 W. This corresponds to an audio power of 500 W and a loss of 500 W, which is converted into heat.

When using a class D amplifier, the advantage lies in the reduced power loss.
In comparison, the power loss is only 125 W with the same audio power as in the previous example. This corresponds to an efficiency of 80% and a consumption of up to 625 W.

Class D amplifiers:
2 x D250 (580231)
2 x D400 (580232)

1.7.2 100-volt technology

100-V technology is primarily used in public address systems of VAS systems (ELA) or PA systems. Using this technology, it is possible to carry out cabling of the individual loudspeakers with a very low cable cross-section and still to transfer the required energy.

The output signal of the amplifier is transformed up to 100 V for the loudspeaker using a pulse transformer.

Both special pulse transformers and special amplifiers (with integrated pulse transformers) that already provide the required 100 V power at their output are available for this.

The loudspeakers are connected in parallel, in con-

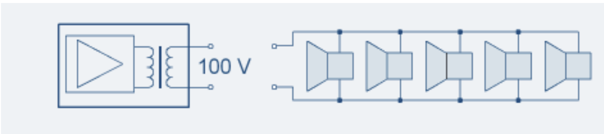


Fig.: Connection to loudspeakers in 100-V technology

trast to audio technology. Each loudspeaker in turn has its own pulse transformer (integrated or connected before the speaker) for individually adjusting the voltage and impedance. The transmission takes place symmetrically over unearthed signal lines with a small cable cross-section.

In principle, there is no limit to the number of loudspeakers for a VAS system in 100-V technology. Various loudspeaker types with different outputs can also be connected in parallel to one amplifier.

In order to calculate the required amplifier power, the individual powers of the connected loudspeakers can simply be added together.

The 100-V technology does not have to be operated at a voltage of 100 V. Most pulse transformers have inputs for the internationally used voltages of 100 V, 70 V and 50 V.

However, this reduces the energy to one-half (at 70 V) or to one-fourth (at 50 V) of the power of a 100-V supply.

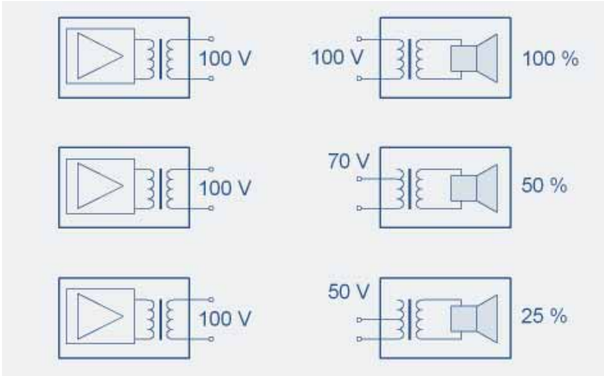


Fig.: Connection of loudspeakers with a different voltage (70 V or 50 V)

Because every loudspeaker is preceded by its own pulse transformer, the volume of each loudspeaker can be adjusted individually. It is also possible to switch off individual loudspeakers or loudspeaker groups without impairing the system. Most power transformers are single-channel, i.e. designed for mono-operation. To implement stereo, it is necessary to double all the equipment (amplifiers and pulse transformers).

Typical terminal assignment

In practice, the power of the loudspeaker can be "selected" based on the corresponding connection terminal. For example, the following power values are possible on a 6-watt loudspeaker.

Advantages of 100-V technology

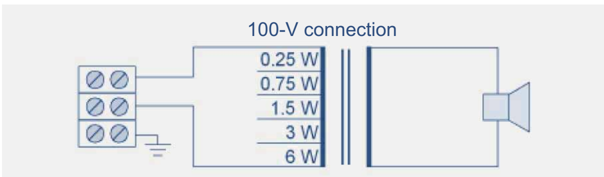


Fig.: Selecting the power (example)

- Ideally suited for announcements and acoustic alarms
- High number of loudspeakers can be achieved
- Easy extension or increasing of the number of loudspeakers (parallel connection)
- Low cable diameter of the loudspeaker supply line
- Low line losses due to high voltage
- Long cable lengths/distances are possible
- Individual volume regulation possible for each loudspeaker

Honeywell

System Design Principles for Voice Alarm Systems (VAS)

and

combined Voice Alarm and Puplic Address Systems

2. System Design Principles for VAS

2.1 General

History

In the 1970s, Lloyd's Register issued safety guidelines for ships, which also included requirements for voice alarm systems. The classification was the basis for the stipulation of the corresponding insurance premiums.

1991

The Lloyd's Register safety guidelines were adopted by the British Standards Institute in 1991 as BS7443 (Public Address Voice Alarm Systems).

1998

…Saw the replacement of BS7443 with the European Standard EN60849, which became mandatory in the EU in 2002 following a waiting period of 4 years. The EN60849 is a combination of an application and a system standard norm for VA (Voice Alarm) systems that have no connection to fire panel. You find in this norm detailed description like:
quality of speech transmission, standby times, etc. But you will not find any detailed test procedures which means that certifications for VA systems are based on specific projects and mor or less subjetiv cretirias (from whom the system is tested) only.

2003

…Saw the addition in Germany of DIN/VDE 0833-3 followed by VDE (German Association for Electrical, Electronic & Information Technologies) 0833-4 (draft) in 2005. This standard describes the installation, scope and networking of voice alarm systems and is only used in Germany. Application standards only such like VDE 0833 are based in Europe are currently on national law. E.g. in Austria we find the "TRVB S 158" or in UK the BS 5939-9. In fact application norms still differ from country to country but you find a lot of common reqirements.

2008

...Also saw the introduction of a product standard for VAS systems in the form of EN54-16. This exclusively describes the central control equipment. Initially assigned a transitional period, EN54-16 has been in force in Europe since April 2011 and is binding for VAS systems that are connected to an FACP. EN54-16 also describes in detail the functions, product quality and testing procedures for standardised testing. This means therefore that manufacturers must have their products inspected by an independent testing institute. For its part, the testing institute must also possess the proper certification. A VAS that has been certified according to EN54-16 therefore satisfies high functional and qualitative requirements, offering planners of a VAS a good basis for specifying suitable systems. In addition to EN54-16, the standards EN54-4 and EN54-24 have also been passed. These two norms have also been in force without restrictions since April 2011.

EN54-4 describes the emergency power supply of a VAS, and EN54-24 describes the loudspeakers for a VAS application. Just like EN54-16, it specifies requirements for the functionality, product properties and quality. Certification processes similar to EN56-16 are also described. This means that using loudspeakers certified according to EN54-24, guarantees that important product properties from the data sheet, such as frequency response (range and uniformity) or sound pressure, are actually achieved. The use of EN-54-24-certified loudspeakers therefore ensures high quality public address systems not only for VAS projects.

Aim of EN60849:

- Protection of human life, alerting and evacuation of people with clear spoken texts. If possible use spoken texts that guide people towards the escape.

- Guidelines for the standardised planning and design of voice alarm systems (VAS) in particular planned and documented speech comprehensibility.

- Definition of the terms and the general system requirements as well as monitoring and environmental conditions.

Aim of protection

Quickly informing and alerting the people affected and operating staff if there is an event. Examples of this include fire alarms, evacuation instructions and also reassurance messages and all-clears.

The voice alarm system (VAS) is mainly used in combination with a fire alarm control panel (FACP) for emitting alarms. In practice, the VAS is also used for the tasks of public address systems as well.

Examples of this include spoken messages such as advertising or calling people in airports, announcements in stations or playing background music.

The different messages are emitted according to a predefined valency (priority). Messages with a higher priority, such as fire alarms, always take priority over messages of lower priority, such as background announcements.

According to applicable law, planning and design work on security systems is subject to the Product Liability Act. Possible infringements are subject to a limitation of 30 years. Many other countries have similar regulations and laws, meaning that planning must be performed very carefully. It is also useful to employ quality assurance standards such as EN54-16.

Reference sources for standards

DIN standards, DIN-EN standards without VDE
Beuth Verlag GmbH
Burggrafenstraße 6
10787 Berlin, Germany
www2.beuth.de

VDE standards, DIN-VDE standards
VDE publishing house
Bismarckstraße 33
10625 Berlin, Germany
www.vde.de
www.vde-verlag.de

2.1.1 Standards, guidelines

Use of voice alarm systems (VAS)
VAS are used in buildings in which people have to be alerted or areas evacuated via emergency systems.

In this manual, the focus is on the planning of a VAS and the further applicable standards and provisions.

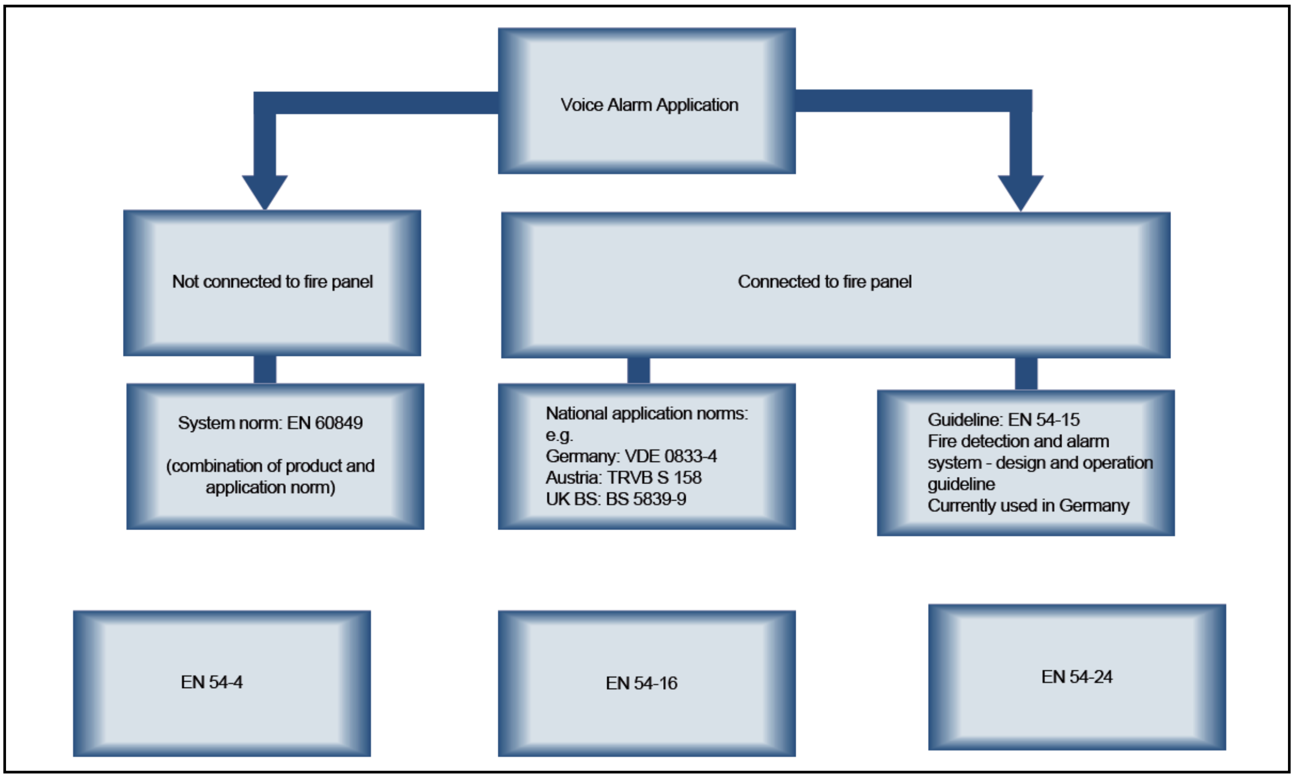


Fig.: Application of Voice Alarm Systems (VAS)

Some of the standards, guidelines and regulations which must be applied in Germany are named below. The current and valid versions of each of these must be observed during the planning and installation as well as the operation of a fire alarm system or an emergency system / VAS. The relevant standards in Europe and around the world are indicated.

DIN VDE 0833	Hazard alarm systems for fire, intruder and hold-up
Part 1	General determinations
Part 2	Determinations for fire alarm systems (FAS)
Part 3	Determinations for intruder and hold-up alarm systems
Part 4	Determinations for systems with voice alarms in the case of fire
DIN 4066,	Information signs for the fire service
DIN 14675	Fire alarm systems – Assembly and operation
DIN 33404-3	Acoustic hazard signals, uniform emergency signal
DIN EN 54-1	Fire alarm systems – Introduction
DIN EN 54-3	Fire alarm systems – Fire alarm equipment - Acoustic signal devices
DIN EN 54-4,	**Fire alarm systems – Power supply equipment**
DIN EN 54-16	**Fire alarm systems – Components for voice alarms in fire alarm systems, voice alarm control panels (draft)**
DIN EN 54-24	**Fire alarm systems – Components for voice alarms in fire alarm systems, loudspeakers (draft)**
DIN EN 60268-16	**Electro-acoustic devices – Objective assessment of the speech comprehensibility via the speech transmission index**
DIN EN 60849	**Electro-acoustic emergency warning systems**
DIN EN 61672	Electro-acoustic – Sound level meter
DIN EN ISO 9921	Ergonomics – Assessment of speech communication
DIN VDE 0800-1	Telecommunications – General terms, requirements and tests for the safety of the systems and devices
DIN VDE 0815	Installation cables and lines for telecommunications and information systems
DIN VDE 0845-1	Protection of telecommunications systems against lightning, electrostatic charges and overvoltages from electric power installations – Measures against overvoltages
Sample guideline for cabling systems	Sample guideline on technical fire protection requirements for cabling systems The respective implementations apply in the individual federal states (guideline for cabling systems)
Guideline for cabling systems	See sample guidelines for cabling systems
94/9/EC (ATEX)	Directive of the European Parliament and the Council of 23 March 1994 on the approximation of laws of the Member States concerning equipment and protective systems for intended use in potentially explosive atmospheres
VdS 2095	Guidelines for automatic fire alarm systems; planning and installation
VdS 2341	VdS publications on loss prevention and technology

2.1.2 Construction supervision legislation of the federal states

Construction supervision legislation/construction inspection legislation is regional law. Accordingly, the individual federal states are responsible for decreeing construction ordinances. According to the division of the Federal Republic of Germany into 16 federal states, there are 16 construction ordinances which may differ in terms of content. They are only legally binding in the respective federal state.

Construction law is regional law

There may also be additional fire protection requirements for construction systems due to their particular type and use. Additional ordinances for construction systems of a particular type and use exist for:

- Systems with radioactive substances
- Building sites
- Accommodation, public houses, hotels
- Temporary structures
- Garages
- Commercial buildings and department stores
- Residential buildings
- High-rise buildings
- Wooden constructions
- Nurseries
- Hospitals
- Stockyards, display areas and exhibition sites
- Schools
- Air-supported structures
- Assembly points and shops,
- Circuses

In some of the stated standards and ordinances, the construction authorities require the use of a fire alarm system to comply with the standard/ordinance and ensure the provision of the sufficient level of fire protection. In special cases, the construction supervision authorities can also insist on the use and operation of further additional fire protection equipment and also alarm equipment.

Applications for the preparation of construction approvals are submitted to the responsible construction authorities with the corresponding construction plans, the applicable static specifications and an exact description of operation which specifies the future use, the number of occupants or employees etc. Compliance with the stated standards, ordinances and guidelines is mandatory for the planning and construction of fire alarm systems, as well as the preparation of a fire protection plan. In addition to the requirement of the construction authorities for fire alarm systems / voice alarm systems (VAS), the recognised technical rules for the planning, construction and operation of these systems and local requirements must also be considered.

VAS required by the construction regulations
The functioning of cables required for the alarm must remain guaranteed even if there is a fire (see DIN VDE 0833-4 and guideline for cabling systems).

VAS not required by the construction regulations
Cables which are required for the functioning of the alarm must, if required and if these cables do not lead through rooms with only a low fire load, be designed to maintain their function for at least 30 minutes. An exception to this is made for cabling systems within one fire section in a floor of a building. The cables leading into these areas must be designed to maintain function.

Ordinance on Places of Assembly
The Ordinance on Places of Assembly is a state-specific ordinance for the construction and operation of places of assembly. In practice, the example decrees which this contains are adopted into the legislation of the respective federal state. In principle, the following recommendation can be made for the construction of a VAS:

- Obligatory for buildings with a floor area of more than 1.000 m^2.

- Obligatory for places of assembly such as multi-purpose halls and sports stadiums which can hold more than 5.000 visitors including an additional priority circuit for the incident command, as well as an uninterruptible emergency power supply. Existing VAS must be adapted in line with the legally valid regulations within a period of two years.

Regulation on sales outlets
In showrooms and shopping centres larger than 2.000 m^2 alarm equipment must be available, which alerts all employees and which can be used to give instructions to employees and customers.

2.1.3 IP ratings
As per IEC 529 / DIN 40 050

The rating of electrical equipment using appropriate casing is specified using an abbreviation which consists of the letters IP and two, or sometimes three, figures.

The first figure specifies the degree of protection on contact and from foreign bodies, and the second figure specifies the protection against moisture.

Impact protection, the third figure, is not usually specified.

Example: Amplifier

Power amplifier in standard housing or 19" installation

Typical value: IP30

The interior of the device is protected against direction contact/against the penetration of foreign bodies larger than 2.5 mm.

There is no protection against the penetration of moisture.

This device is exclusively suitable for operation in dry areas with a corresponding room climate.

IP	1st position Contact and foreign body protection	1st position Moisture protection	3rd position Impact protection against impact energy up to ...
0	---	---	---
1	... Foreign bodies > 50 mm	... Dripping water falling vertically	... 0.225 J = strike of 150 g from a height of 15 cm
2	... Foreign bodies > 12 mm	... Dripping water falling at a slant	... 0.375 J = strike of 250 g from a height of 15 cm
3	... Foreign bodies > 2.5 mm	... Spray	... 0.5 J = strike of 250 g from a height of 20 cm
4	... Foreign bodies > 1 mm	... Splash water	---
5	... Dust deposit	... Water jet	... 2.0 J = strike of 500 g from a height of 40 cm
6	... Dust entrance	... Flooding	---
7	---	... On immersion	... 6.0 J = strike of 1.5 kg from a height of 40 cm
8	---	... On submersion	---
9	---	---	height of 40 cm

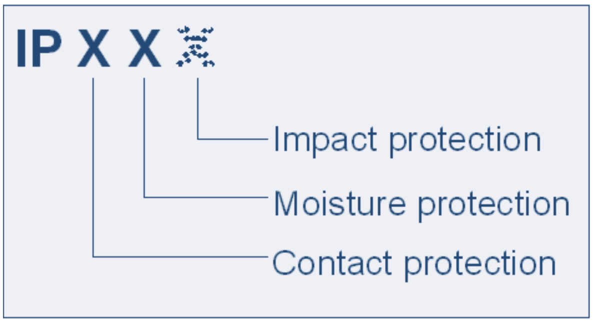


Fig.: IP ratings

2.1.4 Terms/definitions

Alarm group
Summary of several alarm areas (detection areas) of the fire alarm system for a joint VAS announcement (e.g. a floor of a building with an area of more than 400 m² which would exceed the monitoring area of a detection area)

Attention signal
Also known as a preliminary noise or instruction signal. Tone or ringing-style short signal before an announcement. The way the sound is made up means that it clearly stands out from the ambient noise without using a huge amount of energy, and it advertises that a spoken announcement is going to be made.

Fire operation/fire announcement
Highest priority level announcement via the VAS when there is an event to give information to people who are in the building (alerting / evacuation). The fire announcement suspends all other VAS applications such as normal voice announcements or background music.

Fire operation is used for alarms, information for the issuing of instructions to employees and visitors and/or for guiding people away from the hazard zone when there is a fire.

The following also applies:
- An announcement must be preceded by an attention signal.
- A fire announcement must be preceded by the uniform emergency signal as per DIN33404-3.

DIN alarm
The DIN alarm according to the requirements of DIN 33404 part 3 is a standardised hazard signal (sound signal) for work places. The DIN alarm alerts the people in the alarm area to a hazard situation such as fire, gas, explosion etc.

Self-interference
The measurable output voltage of a microphone can cause an amount of noise on the microphone membrane - this is the alternative interference sound level. This level can be measured using various procedures and, as a rule, should be below 30 dB for VAS (CCIR measurement procedure).

Incorrect operation safety
The public address system must be able to be operated with the minimum amount of effort when there is an event. At the same time, unintentional operations (accidental activations) e.g. due to concealed installed operating elements, key switches/keyboard locks or password entries must be avoided.
This also includes the definite responsibility of the system operator and the stipulated process in the case of an event.

Group call
Announcements via a specified group of loudspeaker circuits (loudspeaker group). In the case of the group call, attention must be paid to the spatial assignment of the alarm areas and the corresponding escape routes.

Audibility
Property of a tone/tone signal which makes it possible to distinguish different tones. The relative volume and frequency of the data signal in relation to the ambient noise are considered as part of this (see also STI).

Loudspeaker group
Combination of one or more loudspeaker power circuits for which there is a specific operation and display system for messages and faults. As a rule, oud speaker groups can only span one floor and mit sound to a maximum area of 1.600 m² and, in doing so, must not cut across a fire section

Loudspeaker electric circuit
Transmission route, which contains one or more loudspeakers. Each loudspeaker electric circuit must be monitored. If there is a short circuit, it must be possible to disconnect a loudspeaker circuit from the corresponding amplifier without there being any reaction.

Line monitoring
Monitoring of the connecting lines between devices/within the system for faults (short circuit, wire breakage).
In practice, loudspeaker lines are also monitored for earth faults.

Manual operation
The playback of the VAS signals (speech, music etc.) is manually controlled by the operating personnel. The same also applies for the activation of the fire announcement.

Proximity effect:
The nearer a microphone is to the sound source (e.g. speaker), the higher the disruptive influence of low frequencies.
The measurement of this effect usually takes place at a distance of 1 m. A suitable speaking distance needs to be selected in practice.

Even in the case of microphones which are installed directly next to the sound source (e.g. headsets), a minimum distance of 5-10 cm is usually required.

Non-fire operation
Operating mode of the VAS in which information or entertainment contributions can be transmitted. Is used in systems which are not exclusively used for voice alarms when there is a fire.

Nominal power

Loudspeaker:
Describes the electrical capacity with which a loudspeaker can be permanently operated without disruption. The stipulation of the nominal power takes place via a signal as per DIN 45324 (pink noise).

Amplifier:
Describes the maximum electrical power that can be supplied at a stipulated load impedance, signal as per DIN 45324 (pink noise).

Automatic playground system
Time-controlled signal distribution for the allocation of signals e.g. for indoor/outdoor areas. An example of when this is used is the bell for break time in school buildings. An acoustic signal for the start of the break is only given indoors. However, the end of break is signaled both inside and outside the school building.

This procedure means that additional, unnecessary noise is not emitted in the surroundings/is reduced to a minimum.

Pilot tone monitoring
Functional test for amplifier modules carried out using a permanently emitted tone (outside of the human hearing range) of e.g. 20-22 kHz. If this pilot tone can no longer be measured on the amplifier output (acoustic test), then it is probable that the amplifier can no longer function properly due to a defect.

The evaluation of the pilot tone can lead to automatic switching to a backup amplifier.

Emergency priority
Announcements and signals with the highest priority (e.g. fire announcements) must reach all assigned alarm areas/listeners. Particular attention must be paid to areas in which individual loudspeakers may be switched off or may be switched to a quieter level. In this case, a technical solution must be found for the emergency priority which bypasses the loudspeaker being switched off and ensures that the signal is received at the required volume (emergency priority relay, 3-wire technology).

Phantom voltage
"Phantom voltage" is used to supply power to capacitor microphones via the signal line.

Phantom voltage is not needed in the case of dynamic microphones. In this case, it does not matter if the phantom voltage is switched on or off.

In practice, this is mostly a DC voltage of 48 V ± 4 V which is provided via the microphone connection of the power amplifier or the VAS components to which the microphone is connected. The positive pole of the DC voltage is applied via a defined isolation resistance on the two symmetrical tone frequency wires. The cable shielding of the signal line carries the negative pole. Microphones supplied with phantom voltage can only be operated on symmetrical amplifier inputs. The phantom voltage must be switched off in the case of asymmetric amplifier inputs.

No phantom voltage is provided in the VARIODYN® D1 system. The terminals used are equipped with an electret microphone, which does not need phantom voltage.

Priority
The order or precedence of the acoustic signals must be stipulated for VAS. A differentiation is made between low priority signals (e.g. background music) and high priority signals (fire announcement). A high priority signal is given preferential treatment in the system and must be able to be enforced ahead of any signals of lower priority that may be present. In public address system technology, the following order of precedence must be complied with for the priorities:

- Fire announcement via the fire microphone.
- Stored fire signal that is manually triggered.
- Stored fire signal that is automatically triggered.
- Non-fire operation.

Collective call
Group call that comprises all loudspeaker lines. Usually predefined as a group in modern systems. This is therefore significant in classic systems, because the individual circuit relay could remain in the idle position when using a particular relay (collective call relay) and this reduced the control current.

Noise groups
The combination of loudspeakers (e.g. sound columns, arrays) in order to achieve the overlapping of sound waves with a particular effect and a combined sound radiation is referred to as a sound group.

Speech alarm
Spoken announcement when there is an alarm. The announcement can be recorded beforehand and played back when there is an event or can be read off from a previously stipulated written text (live announcement).

Comprehensibility of speech
A measurement of the comprehensibility of speech is required for fire announcements in VAS. The quality of the measurement is greatly dependent on the level of basic noise and so the measurement must be carried out in the conditions which can be expected.

The STI measurement (Speech Transmission Index) specifies the comprehensibility. The reverberation, interference noises, room reflections and the directivity of the sound source are recorded in a total of 98 individual measurements. The level of comprehensibility is stated in the range of 0 to 1. An STI value of more than 0.50 is required for VAS.

The RASTI measurement (Rapid Speech Transmission Index) is a simplified original form of the STI measurement. Only the signal share in the octave bands 500 Hz and 2 kHz is assessed. However, the STI measurement should preferably be used for the assessment of speech comprehensibility.

The syllable comprehensibility (in %) can be determined with special artificial words and static methods. The recording of syllable comprehensibility involves a great amount of work. The value for VAS should be above 75 %.

The percentage consonant loss "ALCONS" (Articulation Loss of Consonants) considers the comprehensibility of syllables in simplified form. In VAS, the ALCONS value should be less than 15 % (ideally less than 10 %).

Signal distribution
In the case of signal distribution in VAS, the input signal is divided between several loudspeakers (or alarm groups).

For the signal distribution, the input signal is amplified, fed to several power amplifiers and distributed to several loudspeakers of an amplifier. Actuators or the matrix procedure can be used for flexible signal distribution.

Side circuit
One or more loudspeaker lines which lead from the amplifier control panel to the start of the respective public address area. There are particular installation regulations for side circuits in safety-relevant systems.

Spur
Line within a loudspeaker circuit, which connects the first (or next) loudspeaker of a circuit with other loudspeakers.

Feedback, acoustic
Feedback of the output signal of an amplifying system on the input of the system (acoustic feedback). Depending on the difference in the intensity and phasing between the input and output signal, there may be a reduction (negative feedback)/increase (positive feedback) of the amplification.

Voice alarm control panel (VACP)
Control panel used for alerting people affected by fire hazards and giving them information.

Comprehensibility of speech
Assessment of the proportion of the spoken information which the listener will be able to understand. Various assessment criteria are used to determine the comprehensibility (see STI, RASTI, CTI, Alcons).

Environmental protection
In practice, sound generation and diffusion cannot be limited to a particular area. This means that noise also spreads to areas which are not actually affected by the particular sound signal.

People perceive these unintentional announcements as avoidable noise. The correct design of a VAS system should also pay attention to environmental compatibility through the noise impact on people (and animals).

Cross-talking
Cross-talking occurs due to the spatial proximity of two systems during installation or also due to commonly used transmission routes.

The information from one system is unintentionally transferred to a second system.

Preliminary noise
See attention signal

Scope
Area inside and/or outside of a building in which the VAS system meets the specifications of the corresponding standards and requirements. A scope may include several alarm groups (detection areas).

100-V technology
Transmission and adjustment technology used in public address systems between power amplifiers and loudspeakers.

2.2 Areas of application of VASs

In terms of the standard, a voice alarm system (VAS) must consist of components which comply with the DIN EN 54 series of standards. It must be ensured that these components interact together in a manner appropriate to the function. Devices for use in demanding ambient conditions, such as cold stores, galvanising plants or corrosive atmospheres, must be suitable for this particular application or must be adapted using suitable protective measures.

Voice alarm systems (VAS)
A voice alarm system must be used for alarms everywhere where it can be expected that there may be hazards to people. Voice alarms are particularly effective for buildings and in rooms in which people are not trained on how to act or are visitors, or where optical signal devices cannot always be clearly recognised. During an event there is an especially high level of risk for people who are dependent on external help when an event such as the evacuation of a building occurs. These include both the elderly and infirm, and also workers using noise protection equipment.

The voice alarm system is mainly used in combination with a fire alarm control panel for emitting alarms. In practice, the VAS is also used for tasks outside of this area of application.

Typical examples of this include spoken messages such as advertising or calling people in airports, announcements in stations or playing background music.

Different requirements are placed on the VAS depending on this combined use as an alarm and as a general public address system. For example, external loudspeakers which can generate a high sound pressure are required for voice alarms. However, at the same time a high quality music signal must be able to be transmitted in other areas and ideally the volume should also be able to be controlled for individual areas.

The requirements for the areas of safety, comfort and flexibility demand a high level of specialist skill for the planning and implementation of a system, as well as very good knowledge of individual product components.

Safety-relevant functions

- Constantly ready for operation (> 99 %), failure safety.
- Monitored line paths.
- Mains and emergency power supply.
- Automatic control from the fire alarm system via a permitted interface.
- Option of manual triggering.
- Priority for fire operation (fire announcements).
- High speech comprehensibility and minimum noise level +10 dB over the ambient volume.

Voice alarm control panel (VACP)

Voice alarm control panels must comply with the tandard DIN EN 54-16. Only internal system announcements and information may be processed.

Internal system announcements and information should be understood to mean those which are produced in connection with a fire warning or another function of the voice alarm system. Voice Alarm system should be EN54-16 certified.

Announcements and information from other systems, which are transmitted via the transmission paths of the voice alarm system must not impair the function of the voice alarm system.

2.2.1 General system requirements

In addition to the standard-compliant design, a stipulation of the minimum requirements and functions between the operator of the system and the responsible authorities is needed for the construction and operation of a VAS system. Voice alarm systems must be operated according to the requirements of DIN VDE 0833-1.

Basic stipulations
- Definition of the safety level (I, II, III).
- Scope of public address system.
- Alarm areas, detection areas, fire sections.
- Site of the voice alarm control panel (VACP), configuration levels and accessibility.
- Need for fire microphones and number of terminals, as well as their usability.
- Alarm organisation and stipulation of the announcement texts.

The voice alarm control panel (VACP) must be installed in a dry, conditionally accessible room. Any available display and operating elements and labels must be sufficiently illuminated and must be recognisable. The audibility of the acoustic announcements of the VAS must not be restricted by ambient and background noise.

The installation location of the VACP must be selected so that it can be assumed that there is the lowest possible risk of fire in this location. The installation location (e.g. room) must be monitored by a fire alarm system.

If the VACP is distributed across several housing units/modules which are not installed in a housing (e.g. upright cabinet), the connection lines must be designed to be redundant and must also be installed so that they are separate in terms of fire protection.

The display and operating unit of the VACP must be located at the start of the monitoring area, preferably directly next to the fire alarm control panel (FACP). It must be ensured that if the alarm goes off, the fire service officers have unrestricted access to the VAS display and operating unit, as well as to the fire microphones (e.g. using a building key kept in the fire service key store (FSKS) of the FACP).

The system must be able to start emitting the alarm 10 seconds after the connection of the power supply. Instruction signals and announcements must be able to be transmitted simultaneously to one or more areas. At least one suitable instruction signal must be emitted in alternation with one or more spoken announcement(s).

The operating personnel must always be informed of the correct functioning of the emergency system or important parts using a monitoring display. The monitoring system must display the failure of an amplifier, loudspeaker power circuit and all components needed for an alarm to be sounded.

The failure of an amplifier or a loudspeaker power circuit must not lead to the failure of the entire alarm area. If the evacuation procedure so requires, the system must be divided into emergency loudspeaker areas. Acoustic crosstalk in the emergency loudspeaker areas must be avoided or must meet the required speech comprehensibility.

2.2.2 Failure safety

Safety level I:
If there is an error in a transmission path (interrupt, short circuit or error with the same effect) the worst that may happen is that the public address system fails within one fire section/alarm area in a floor.

It is recommended that this safety level is used for buildings of less than 2.000 m^2 and with less than 200 people.

Safety level II:
If there is an error in an amplifier or in a transmission path (interrupt, short circuit or an error with the same effect), the public address system in the alarm area must be remain secure. The sound level must not be reduced by more than -3 dB (A) and the speech comprehensibility (STI) must not be less than 0.5 (CIS > 0.65). When groups of loudspeakers are formed (see also A/B public address system) e.g. one loudspeaker group may fail if the abovementioned criteria are complied with.

It is recommended that this safety level is used for buildings of more than 2.000 m^2 and more than 200 people.

Safety level III:
The requirement for this safety level, is that all the requirements of safety level 2 are met. In addition a further VAS system with fire announcement (microphone) in redundant operation must also be provided. This also applies for the planning of the transmission paths.

It is recommended that this safety level should be used for buildings with the highest level of failure safety (example: nuclear power stations).

2.2.3 Requirements for the activation

Automatic activation
The activation of the VAS via the control system of a fire alarm control panel (FACP) must usually take place via an approved and appropriate interface (see section "System coupling"). Monitored transmission paths are needed for the direct activation of a VAS via a FACP. The same also applies for fault messages of the VAS to the FACP. Transmission paths for activation and for fault messages between the VAS and the fire alarm control panel must be monitored from the fire alarm control panel. Messages and information, such as the triggering of control systems of the FACP and the FAS must be able to be transmitted individually for each alarm area (detection area).

Manual activation
In addition to automatic activation via a FACP, the voice alarm control panel (VACP) must be able to be activated via a manual triggering unit and must also be manually independent of the FACP control system.

Monitored transmission paths
The transmission paths between loudspeakers and VACP, as well as between the VACP and the fire microphones, must be available as per the standardised requirements and must be monitored for their functionality. If display and operating elements are transmitted by the VACP, the required transmission paths must also be monitored. If the required function may be disrupted in transmission paths that are not used exclusively for hazard warning systems, then a second transmission option must be provided.

Disruptions such as wire breakage, short circuits or errors with the same effect in a section of a transmission path between individual voice alarm control panels and the transmission paths to the particular or the subordinate voice alarm control panels or display and operating elements must not impair the function of the system (single error elimination).

Disruptions such as wire breakage, short circuit or errors with the same effect in a section of a transmission path must not lead to the failure of more than one alarm area (detection area).

2.2.4 VAS power supply

The power supply for the correct operation of a VAS must be guaranteed for at least the following listed operating period:

Bypass time
- 4 hours, if there is a mains backup system available and the failure of the power supply is recognised at any time
- 30 hours, if the fault can be recognised at any time (e.g. transfer of the fault message to a constantly occupied, commissioned position)

Alarm time
In addition, consideration must be given to the maximum energy requirement for the activation of optical and acoustic signal devices and an alarm time of 30 minutes after the expiry of the bypass time.

During this time, it must be possible to sound an alarm on the system even during emergency power operation. The duration of the alarm time must correspond to double the evacuation time, but must be a minimum of 30 minutes.

Requirements for the power supply of hazard warning systems
As per VDE 0833 part 1 to 2:

Two independent energy sources are needed for the power supply of an HWS. One of these must be in the position to operate the HWS at the correct performance without restriction (mains and emergency power supply).

One energy source must be a general supply network or equivalent network which is operated without interruption. The other (emergency power) source is an internal system unit (accumulator) or a specially secured backup network.

If the mains supply is interrupted, an interruptfree emergency power supply must be made available automatically which will ensure the unrestricted operation of the system.

The energy supply of an HWS must not be used to supply other systems or system parts. Equipment used for the transmission of messages may be supplied at the same time.

Other energy supplies may also be used for the supply of equipment which is connected via secondary lines (unmonitored lines) (such as registration, devices, status displays).

The power supply must be designed so that mains voltage changes in the region of 230 V ± 10 % do not affect the correct functioning of the HWS in the case of exclusive supply via the mains.

There must be a particular electric circuit with its own fuse protection (and labelling e.g. FAS) for the energy supply from the electrical network.

In front of this fuse protection, there may only be one more fuse protection up to the delivery point of the electrical network on the low-voltage side (point of the energy supply into the building in which the HWS is situated). It must be impossible for the electric circuit to the warning system to be interrupted if other equipment is switched off. If an error current protective circuit is provided, the HWS must be operated via an internal error current circuit breaker.

Mains supply line
Only suitable cable must be used for the mains supply line. If necessary it must be ensured that the function of the mains supply line is maintained depending on the installation and the requirements.

The mains supply lines for the VAS (and fire alarm system) must be star-shaped leading from a common point of the building distribution board.

2.2.4.1 Emergency power supply

In principle, the same requirements apply for the dimensioning of the emergency power supply in the alarm systems as for the Voice Alarm Systems (VAS).

For this reason, EN 60849 must be observed and the UPS must satisfy the product standard EN54-4 (A2).

A regulated charging device must be provided for the charging and receipt of charge of the accumulators.

It must be dimensioned so that it can charge an accumulator at its final discharging voltage up to 80 % of its nominal capacity within a maximum of 24 h. It must be ensured that the loading is possible even with network voltage changes in the region of 230 V ± 10 %, load, temperature and frequency changes. During a temporary peak load, the recharging must be restricted or suspended.

The required capacity of the battery, with the exception of the energy requirement of the Voice Alarm System in ready to report state (quiescent current), is dependent on …

- The period between the recognition of a power supply malfunction.
- The availability of the maintenance and service personnel as well as the provision of
- The increased power requirement for alarms and the duration of alarms.
- The presence of a mains backup system.

Consideration of the capacity loss due to ageing
When using voltage-restricted chargers with 2.3 V / cell at 20°C battery temperature and continuous charging, a battery service life of four to five years will be achieved, while increased temperatures will reduce the service life. The service life may be doubled under favourable conditions. It will be possible to recharge the battery approx. 240 times in the case of partial discharge or corresponding high current discharge. The end of the duration of usability is defined as per EN 50272, if 60 % of the nominal capacity is reached. This also corresponds to the manufacturer's specifications. At least 80% of the rated capacity is required for the battery dimensioning in voice alarm systems.

Testing the battery capacity
The nominal capacity k20 is the resulting value in ampere hours for 20 hours of even, continuous discharge up to a final discharging voltage of 1.75 V/cell at a temperature of +22°C. Before a capacity test is carried out, recharging will always be needed if the battery was not connected with the charger (and was being charged). It is recommended that the battery capacity should be tested as per EN 50272.

Charger for maintenance-free lead accumulators
The charger must be dimensioned so that it can charge an accumulator at its final discharging voltage up to 80 % of its capacity in a maximum of 24 hours. For reasons of safety, we recommend that it should be charged to 90 %. The charging takes place with constant voltage of 2.3 V / cell ± 30 mV at 20°C. If the temperature is different to this, a correction will be needed as per table a). If these values are not complied with, it must be assumed that the battery capacity will be lower. Also, the duration that the battery is useable for will decrease.

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2.2.5 100-V technology

100-V technology is primarily used in public address system technology in voice alarm systems (ELA) or PA (Public address) systems. Using this technology, it is possible to carry out connection of the individual loudspeakers with a very low cable cross-section and still to transfer the required power.
The output signal of the amplifier is transformed to 100 V for the loudspeaker using a transformer.

An indicator is the uniform high voltage on the amplifier output when there is full conduction, irrespective of the amplifier or loudspeaker power. The power consumption of a connected loudspeaker is determined by its nominal impedance (via the transformer).

Advantages of 100-V technology

- Optimally suitable for announcements and acoustic alarms.
- High number of loudspeakers can be achieved.
- Easy extension/increase in the number of loudspeakers (parallel switching).
- Low cable diameter of the loudspeaker supply line.
- Low line losses due to high voltage.
- Large cable lengths/distances are possible.
- Individual volume regulation possible for each loudspeaker.

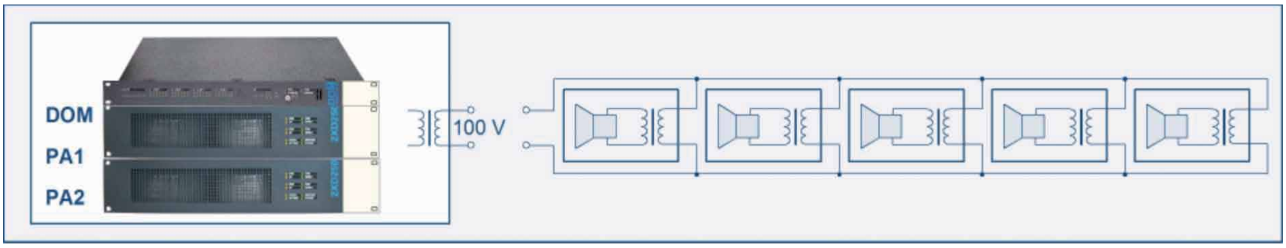


Fig.: 100-V technology (schematic view)

End of line module (EOL Part No. 583496)

End of line module for terminating the loudspeaker lines of the voice alarm system VARIODYN® D1 for standardcompliant monitoring of the system if more than 20 loudspeakers are connected per line.

The module is connected at the end of the line, after the last loudspeaker.

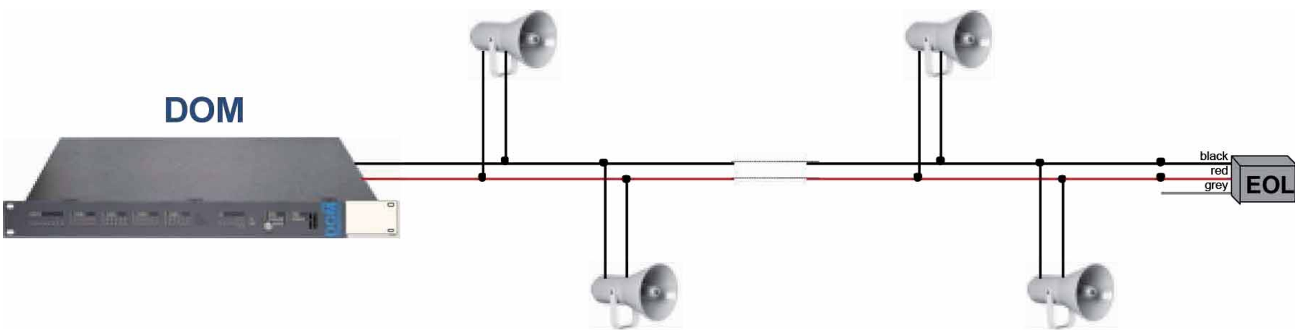


Fig. : Wiring incl. EOL-Module and more than 20 loudspeaker

2.2.6 Fire resistance class

Fire resistance class (as per DIN 4102).

The fire resistance class, often also referred to as the fire protection class, is used to determine for how long a component should retain its function if there is a fire.

F0 ➔ Less than 30 minutes
F30 ➔ At least 30 minutes (fire-resistant)
F60 ➔ At least 60 minutes (highly fireresistant)
F90 ➔ At least 90 minutes (fireproof)
F120 ➔ At least 120 minutes (highly fireproof)
F180 ➔ At least 180 minutes (highest level of fireproofing)

Code letters of the fire protection classes

F Walls, ceilings, building supports and beams, stairs
F Fire-protective glazing. Protection against heat radiation on the side facing away from the fire.
T Doors and covers
G Fire-protective glazing or window element without radiation protection on the side facing away from the fire.
L Ventilation channels and lines
E Electrical installation channels or installtion lines which retain their functionl Elektroinstallationskanäle ohne Funktionserhalt
K Cut-off devices in ventilation lines
R Tube sealing, tube feedthroughs
S Bulkhead, fireproof cable bulkhead
W Non-load-bearing external walls

For example, partition walls in flats must usually comply with fire resistance class F90 (doors in these walls comply with T30).

Fire walls must have a minimum fire protection class of F90 and must also withstand mechanical impact tests.

Maintaining function

Maintaining function applies for the line paths (incl. fastening material, distributors etc.) which must retain their function for a stipulated time when there is a fire. The function of the cables must not be impaired due to a short circuit or an interrupt.

This requirement places a high demand on the design of the line paths and on the materials used for cable insulation and fastening. Line paths which are designed to retain function are marked by an orange casing and a printed text repeated at intervals. When the installation paths are selected, it must be ensured that no bursting or falling objects can damage the line network if there is a fire. In critical areas, different wiring should be selected or suitable measures (e.g. laying in an armoured steel tube) should be used to protect the line.

In practice, it is often required in Europe that the line paths maintain their function for 30 minutes (E30), 60 minutes (E60) or 90 minutes (E90).

If high reliability requirements apply, a loudspeaker loop can also be used as an alternate configuration. Along with relatively high reliability, the loop wiring offers the advantage that normal, standard cable can still be used.

2.2.7 Classification of public address systems

In practice, the VAS is subject to different requirements for use and for the area of application, as well as for the related functions. Primary use.

Following the multitude of tasks and possible options for public address systems, these can also be classified according to very different features.

Typical classifications:
- Alarm and announcement address systems (e.g. for places of assembly).
- Speech transmissions (e.g. department stores)
- Background music systems (e.g. gastronomy).

The following table gives examples of the values for the frequency range of the individual signal types. The frequency range of the loudspeakers used must be suitable for noise production in this transmission range.

Signal type	Transmission range [Hz]
Alarm/announcement	400 - 4000
Background music	100 - 15000
Voice	200 - 10000
High-quality music reproduction	50 - 20000

Spatial assignment of the sound source

The use of several sound sources (loudspeakers) means that in practice the listener cannot always classify the location of the sound source. In addition, the fact that the loudspeakers are often covered in their installation location makes optical assignment harder.

In most public address systems, the spatial assignment of the sound source is not that important. An exception to this rule is transmission of e.g. high quality concert music with a number of instruments.

In this case, the type of transmission requires the acoustic assignment of the individual instruments (see stereophony, quadraphony).

In VAS, the spatial assignment of the sound source can also be used for guided escape route control.

Intelligent, temporal signal distribution can be used to provide orientation via the listener's hearing system.

The sound source (loudspeaker) must be designed for alarms according to the standard so that a sound level of at least 10 dB above the ambient noise level reaches the listener.

Environment	Sound level (dB)
Residential area, at night	< 30
Individual offices	50
Open-plan offices	55-60
Railway platform *)	70 -< 110
Warehouses with fork-lift trucks	70-75
Production halls with machines or very loud traffic noise	> 80
Rock concert, disco	100 - 130

*) because of the big diffrence a very fast automatic volume leveling system is necessary.

2.3 Public address system

Scope of public address system

- Full protection.
- Alarms issued to all areas of the building.
- Partial protection.
- Selected areas of the building are issued with alarms, at least all detection areas of the fire alarm system (FAS).

Exceptions from the public address system

- Areas that are not accessible to people.
- Cable channels and chutes that are not accessible to people.
- Shelters that are not used for other purposes. Areas defined in the fire protection plan in which there are no people, or where there are only rarely people.

Fire operation / fire signal

Fire operation is used for alarms, information for the issuing of instructions to employees and visitors and/or for guiding people away from the hazard zone when there is a fire.

- As a rule, an announcement must be preceded by an attention signal (preliminary noise).
- A fire announcement must be preceded by the uniform emergency signal.
- The emergency signal preceding the fire announcement must always exceed the interference sound level by 10 dB (A).

Order of priority

The following order of priority must be adhered to:

- Fire announcement via the fire microphone.
- Stored fire signal that is manually triggered.
- Stored fire signal that is automatically triggered.
- Non-fire operation.

Implementation

In the case of the implementation, in principle there is the option of distributing the VAS and other public address tasks to two separate systems or of constructing a standard-compliant VAS, which also meets the additional requirements (music, voice etc.).

1. Two separate systems.

A "pure" VAS for alarms and a separate system as a background music system with general use for speech advertisement incl. consideration/ compliance with the guidelines such as switch off, muting when there is an alarm etc.

This solution is the easiest to put into practice in terms of planning, implementation and compliance with standards. However, the extensive doubling of modules (= 2 systems) means that the economic expense for the products and installation costs are very high.

2. One single VAS which also operates the "subsidiary tasks", such as music and speech announcements, and meets the requirements of the standard. This system is the one used most commonly in practice and from the planning stage it must be designed for safety level 2.

Audio channels

If the construction regulations legally require selective alarming according to the existing evacuation plan, several independent audio channels which work simultaneously must be provided.

Positioning of the sound sources

Good knowledge of technical acoustics and extensive experience in the practical implementation of this kind of calculation model are needed for the detailed calculation of public address systems and the components needed for the particular purpose of application.

A helpful solution to support the incredibly time consuming calculation is given by simplified approximation formulae, which can be used to achieve good results in the planning of VAS.

A further, very widely used solution is to use PC supported calculation and planning of VAS. Dependent on the respective application, there are a number of special software tools available for this purpose. These also calculate an approximation value and the "best possible" solution. It is not always possible to carry out a precise calculation due to the difference between the individual objects (rooms), the room acoustics and the requirement for the public address system type.

In order to compensate for this inaccuracy in the simplified calculation, a "small addition" to the performance calculation and number of sound sources should always be considered during the dimensioning of the VAS. This also applies for the calculation of the comprehensibility of speech and all applicable parameters such as reverberation time etc. Ideally, the worst case scenario should be taken into consideration even during the planning stage.

Horn loudspeakers (high sound pressure, high IP rating) are often used in VAS for alarms outside of buildings.

Inside buildings, the wall/ceiling attachment or ceiling installation of loudspeakers is often used. Buildings with lots of individual rooms, such as offices, classrooms, lounges and guest rooms, or also staircases and corridors are suitable for alarms via ceiling loudspeakers.

The opportunity to individually arrange the loudspeakers and the independent selection of the type of loudspeaker can be used to achieve a very effective public address system with a high level of speech comprehensibility. In addition, individual volume regulation is easily possible for the separate rooms or even alarm areas.

In buildings with very large/very high rooms, such as exhibition halls, sports halls, stations or airports, funnel/horn loudspeakers are also preferable for internal public address systems or high-performance loudspeaker groups (arrays).

Ceiling installation

When loudspeakers are installed on ceilings or suspended ceilings, or when dome loudspeakers are installed in the immediate proximity of the ceiling, the ceiling height must not be more than 6 m. This value is dependent on the sound properties of the room and may reduce in the case of heavily insulated rooms (carpets, upholstered furniture etc.) because the loudspeakers radiate sound from the ceiling (incl. reflection of the ceiling) directly towards the floor and cause reflections between the ceiling and floor.

In the case of long corridors, it is sensible if the fire alarm system is oriented towards the regulations for the arrangement of manual control points. These must be no more than 40 m apart. On the basis of this, a corridor that is 40 m long and 3 m wide could be defined as a separate public address area.

In the case of the public address system, it must be ensured that sound-reflecting surfaces do not beam directly onto each other so that the unwanted reverberation effect is avoided.

In the worst case scenario, an additional installation of targeted wall loudspeakers must be included in the plan.

2.3.1 Types of public address system

Differentiations are made between different types of public address when designing a public address system. Essentially, three basic forms of public address can be identified:

- Central public address.
- Semi-central public address.
- Distributed public address.

In practice, the abovementioned types of public address are rarely used without alteration.

Mostly a mixture of the different types of public address is used which is adapted to the requirements of the object where the address is to be made.

The frequency range that is to be transmitted must be considered in the public address system. High frequencies have a stronger directivity than lower frequencies.

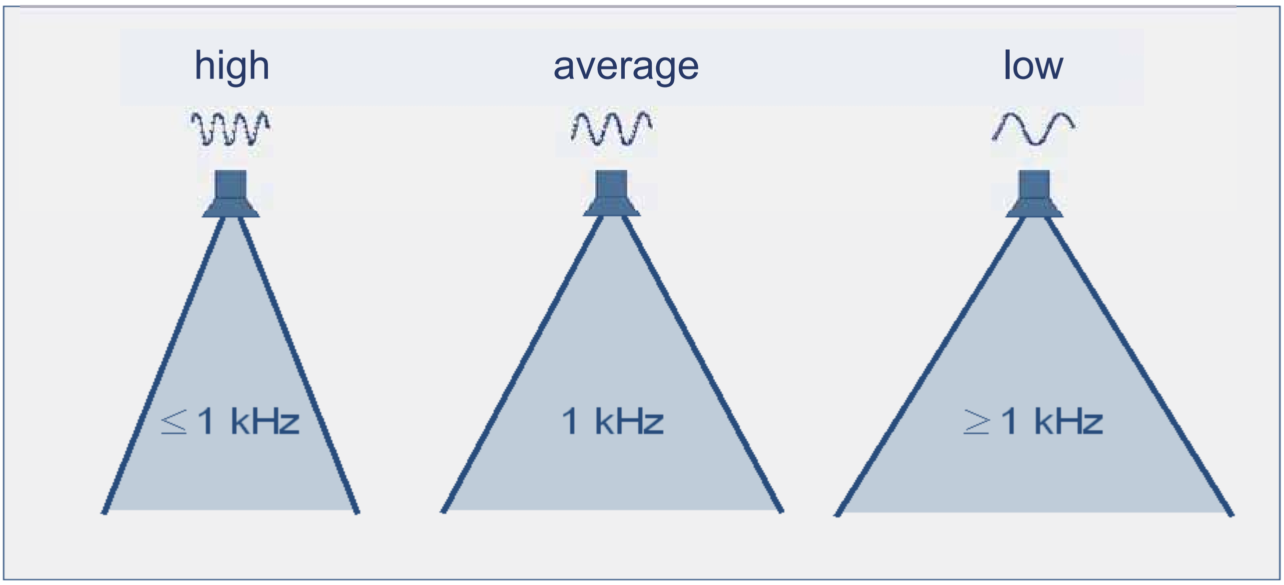
2.3.2 Public address system criteria

In principle, it must be assumed that the spatial and therefore the acoustic relationships in the place where a VAS system is used are objectdependent and therefore are always different.

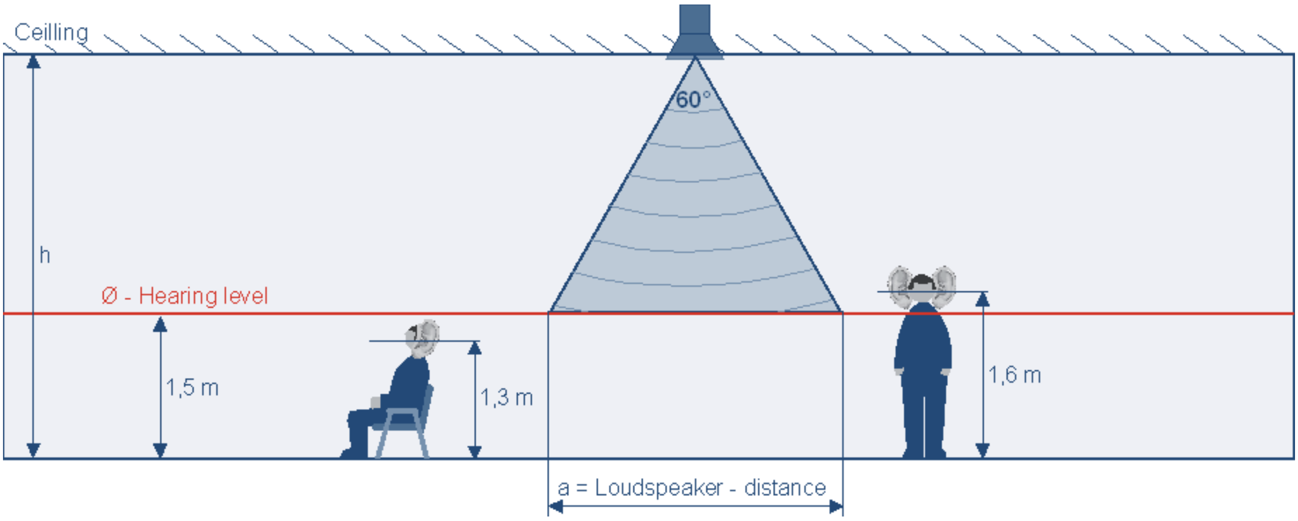
This also applies for the selection and configuration of the individual VAS components. The criteria listed below for the VAS can be used to check and extensively describe the requirements for the public address system.

- Transmission characteristics of the microphones and loudspeakers.
- Number of loudspeakers and types used at the same time.
- The distance between the speaker and the terminal.
- Distance between the terminal and loudspeaker.
- Installation location and directivity of the
- loudspeaker.
- Distance between the loudspeaker and listener.
- Room shape, room size and furnishings in the individual alarm areas.
- Constantly present ambient noises and temporarily occurring or expected disruptions (ventilation units, machines, affect of external noise e.g. due to open windows/doors).

Frequency-dependent sound diffusion (schematic diagram)

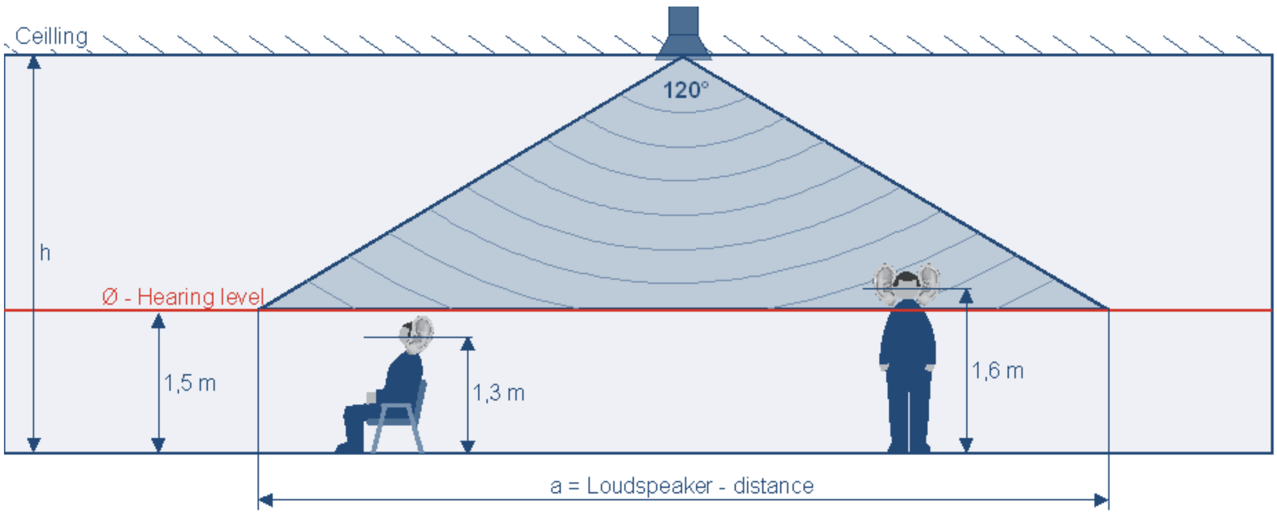


Minimum supply area of a loudspeaker for optimum speech comprehensibility



Ceiling height	3 m	3.5 m	4 m	4.5 m	5 m	5.5 m	6 m
Loudspeaker distance a	1.8 m	2.2 m	3 m	3.6 m	4.2 m	4.8 m	5.4 m
Supply area	3 m^2	5 m^2	9 m^2	13 m^2	18 m^2	23 m^2	29 m^2

Maximum possible supply area a x a of a loudspeaker for music and speech



Ceiling height	3 m	3.5 m	4 m	4.5 m	5 m	5.5 m	6 m
Loudspeaker distance a	5.5 m	7 m	9 m	10.5 m	12 m	14 m	16 m
Supply area	30 m^2	49 m^2	81 m^2	110 m^2	144 m^2	196 m^2	256 m^2

2.3.3 Central public address
Central public address is used to mean the supply of an area or a room from one single point. One or more loudspeakers are centrally arranged at a point in the room. Loudspeakers with directivity are mostly used in order to achieve optimum supply in the case of central public address. If several loudspeakers are used centrally, these should always be arranged on top of each other (not next to each other) due to the fact that the reflected beam is usually at a horizontal angle.

- The spatial properties permit public address from a central location. There are no strongly reflecting walls/objects on the opposite side.
- When several loudspeakers are used, they should be arranged so that no interference is created.
- The speech comprehensibility decreases when the distances are greater.

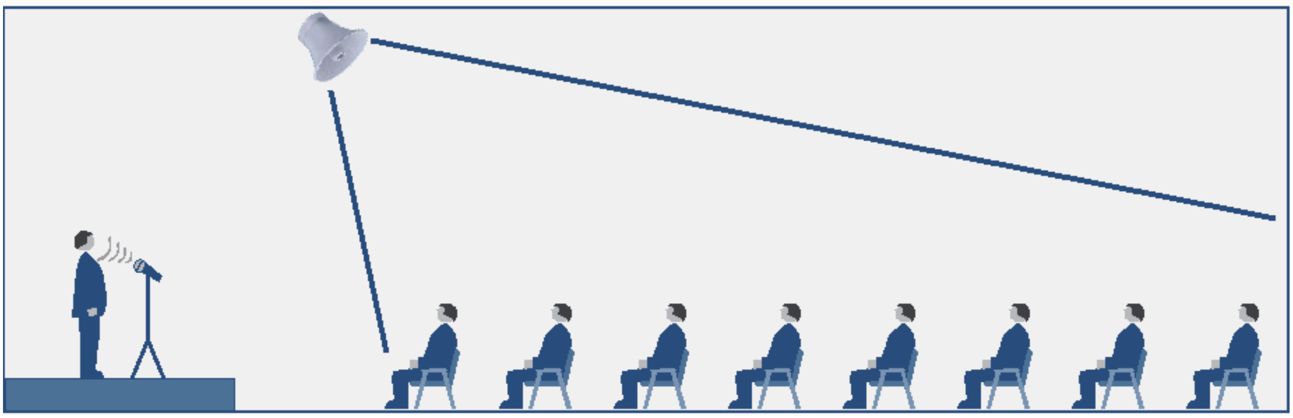
Example application:
Presentations in corresponding rooms (training rooms, auditoriums etc.).

2.3.3.1 Semi-central public address
In the case of semi-central public address, several undirected loudspeakers are distributed in different places around the area to be addressed. In this case, the individual loudspeakers are assembled in spatial proximity to the listener (e.g. ceiling installation).

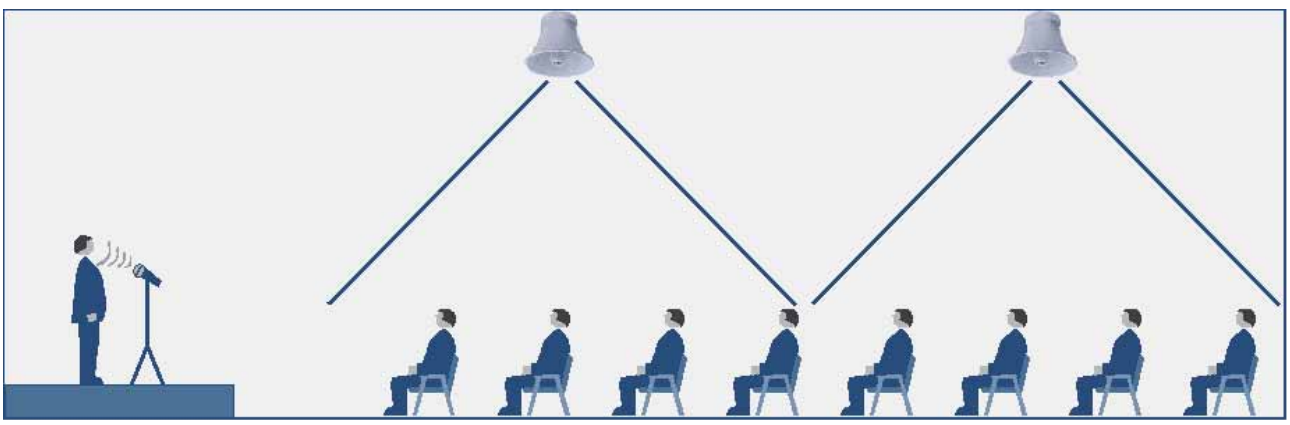
- Improvement of the speech comprehensibility for the rear of the listening room.
- The distance of the loudspeakers should not be selected to be too large (max. 15 m) in order to avoid "echo effect" due to different running times.
- Each loudspeaker must reach the suitable sound level in its public address field.
- It may be necessary to have local volume regulation.

[1] With this type of public address, it is must be ensured that instructions can be announced from the speaker's position in event of an alarm.

Central public address



Semi-central public address [1]



2.3.3.2 Distributed public address

- The most complex, but also the best solution for voice alarm systems.
- Non-directed public address due to distribution of the loudspeakers.
- An even arrangement principle facilitates consistent public address quality.
- It is possible to individually adjust the volume, frequency and the sound pressure.
- High loudspeaker density – well suited for A/B operation.

2.3.4 The A/B public address system

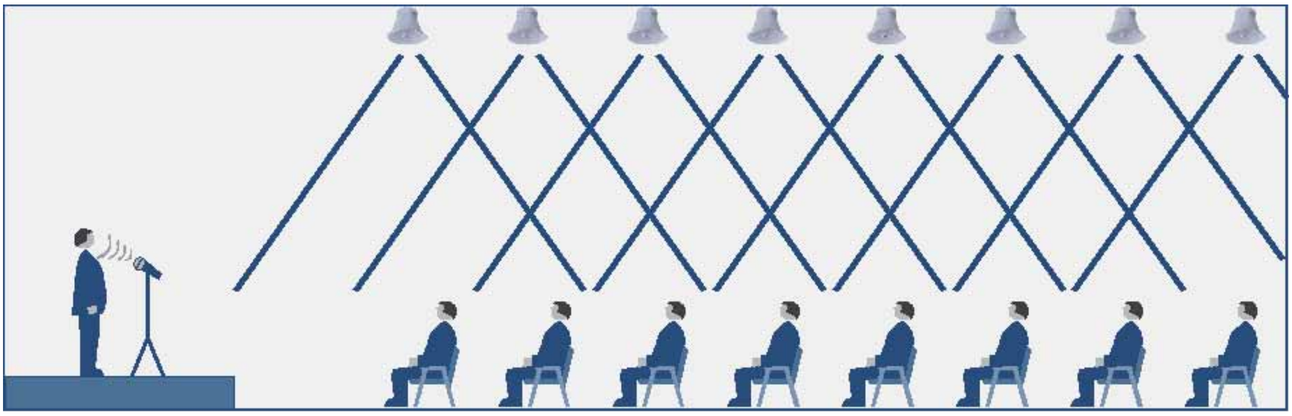
If standardised A/B public address is required when planning a VAS system, then the following criteria must be complied with:

- At least 2 loudspeakers (with integrated transformers) must be provided for each alarm area (or room).
- Specific line network for A/B operation of the loudspeakers (A line, B line).
- Control of the power amplifiers separated according to A/B incl. backup amplifier.
- If separate volume regulation is required, 2 volume controllers must be used in each case which must be equipped with emergency call relays (for alarm announcements of the highest priority).

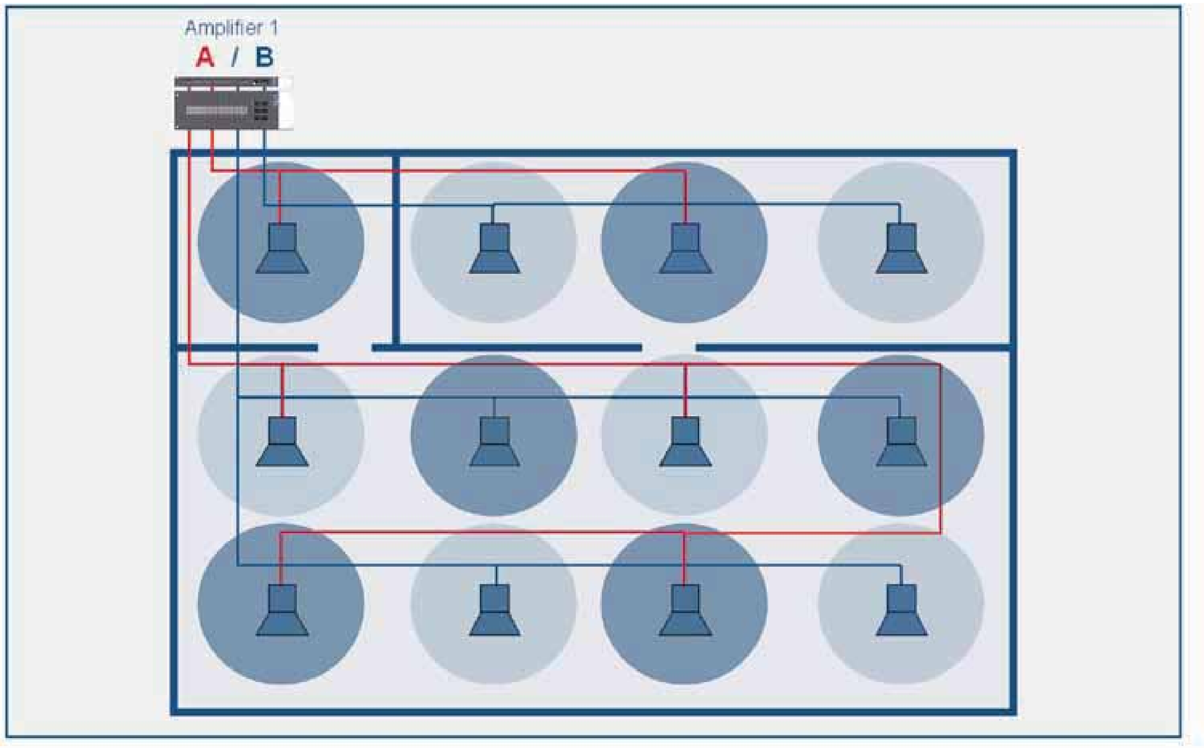
Example of public address with double loudspeakers according to the A/B principle
Same requirement as for A/B principle for single loudspeakers.

Exception: Suitable double loudspeakers (2 in one housing incl. integrated transformers).

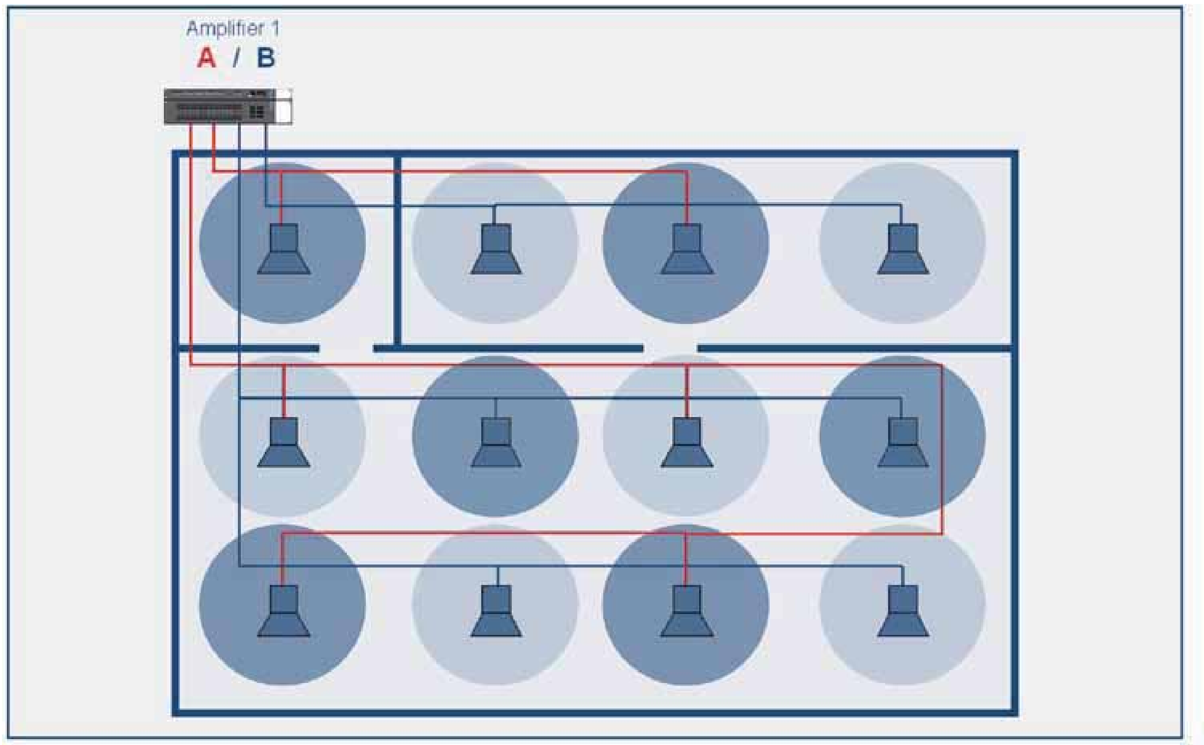
Distributed public address



A/B principle for loudspeakers (with integrated transformers) with a single Power amplifier



A/B principle for loudspeakers (with integrated transformers) with two separate Power amplifiers

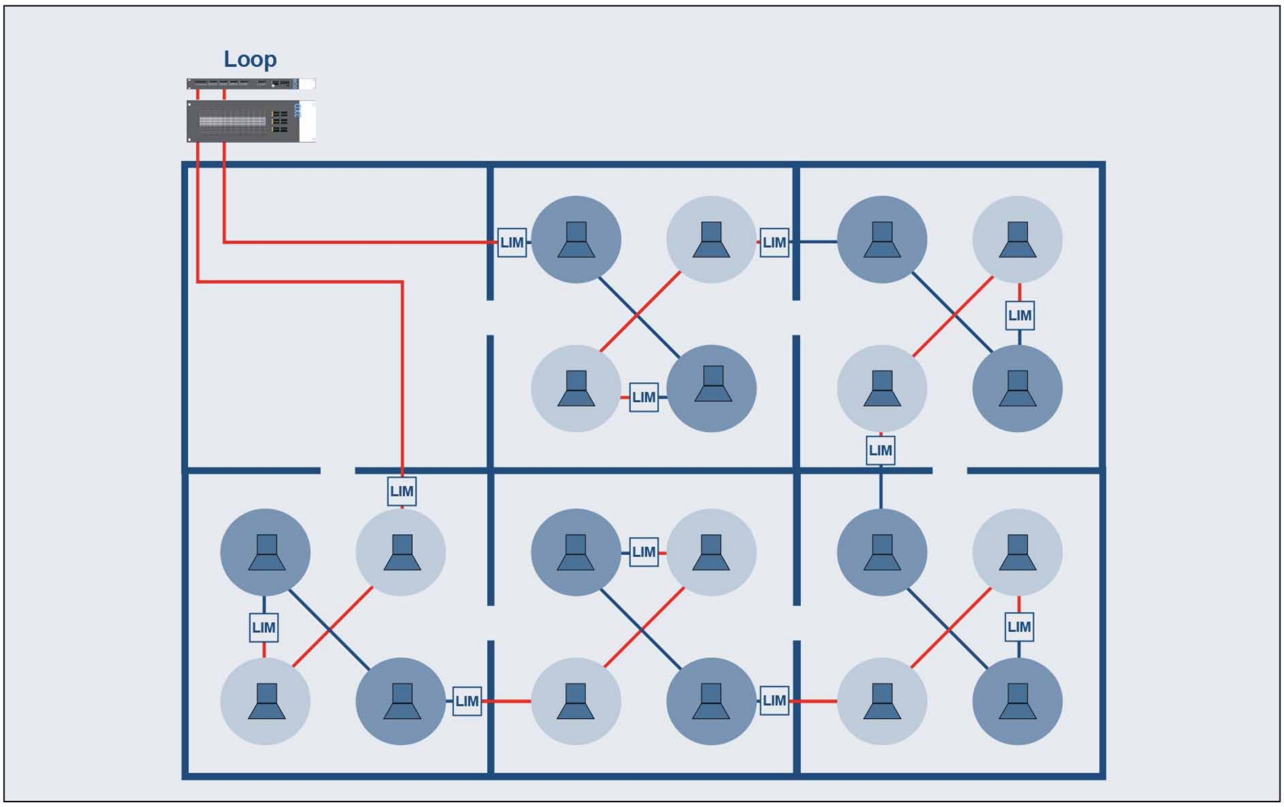


Loop Isolation Module (LIM)

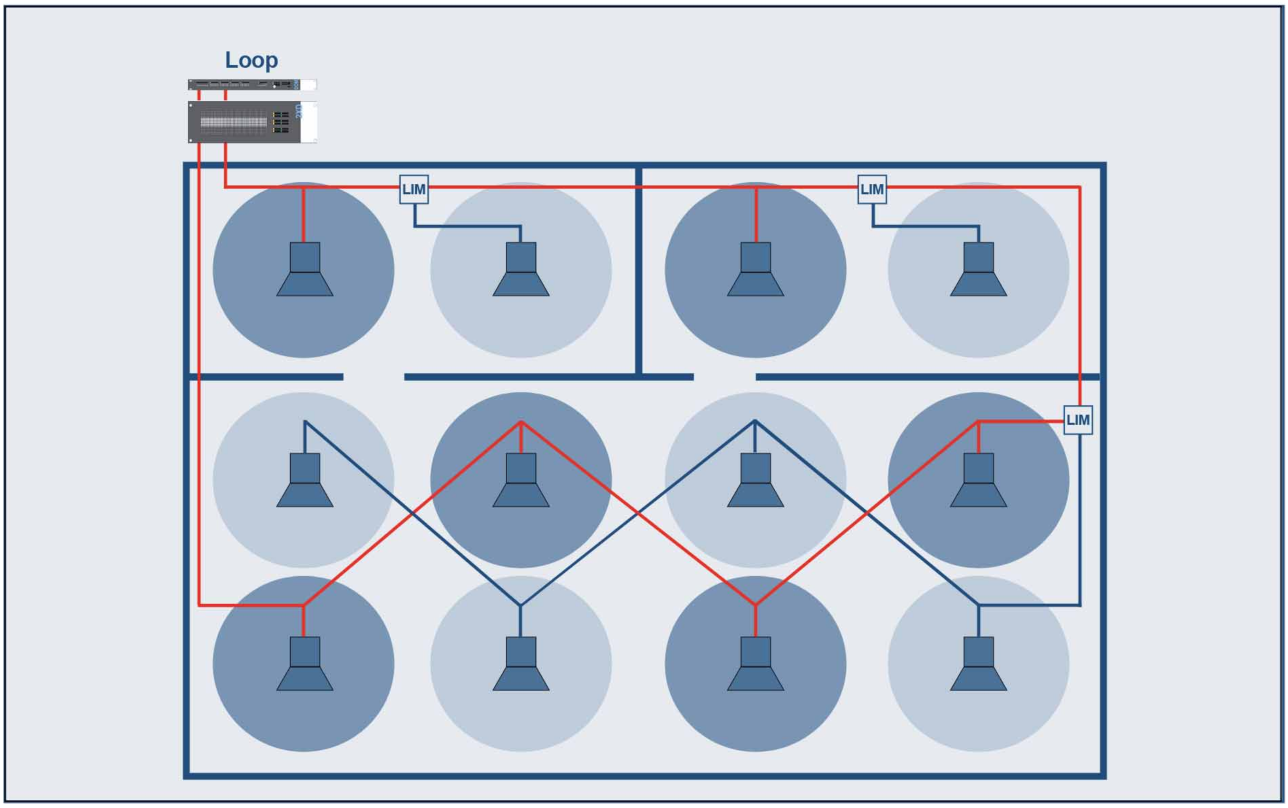
The Loop-Isolations-Module (LIM) can isolate faulty segments of a loop. Loop-Isolations-Moduls monitor the status of all segments for short break and isolate the affected segment of the loop. The other segments still remain operational.

In special cases the loop can replace fire resistant cable. This can be discussed with persons in charge and authorities. Using the loop instead of fire resistant cable will reduce in most cases the costs significantly.

loudspeaker loop cabling for loudspeaker (with integrated transformers)



loudspeaker loop cabling for loudspeaker (with integrated transformers) using the T-spur of the LIM



2.3.5 Sound and voice announcements

Voice announcements are introduced with an attention signal, the "preliminary noise".

Hazard/evacuation announcements
This is a fire alarm. Please leave the building immediately via the nearest escape route. The fire service has been notified.

Attention, attention!
This is an emergency. Please leave the building via the nearest available exit.

Reassurance message
Warning! An incident has been reported in the building. Please remain calm and await further instructions.

The current alarm has been cancelled. We apologise for any inconvenience.

Test announcements
This is a test announcement.

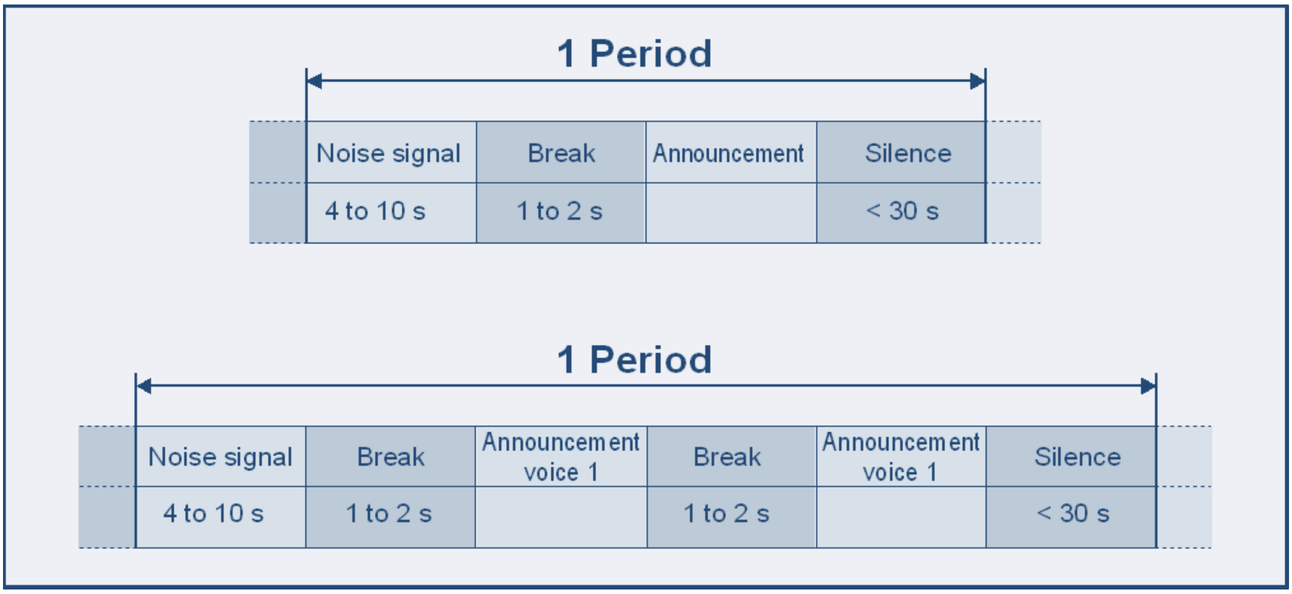
Requirements for fire announcements
Fire announcements must be short, clear and understandable.

If it can be assumed that people who speak different languages are in the alarm area then the fire announcement must be multilingual.

The fire announcement must correspond to the required values for speech comprehensibility (STI, CIS, Alcons).

The ambient volume in the place that the fire microphone is installed must be less than 50 dB. The content of the fire announcement must be specified for an automatic announcement (tape or another sound source). This also applies for "live fire announcements" that are read out or spoken. In this case it must also be ensured that the text for the announcement is stored in a known location and that the people affected (speakers) are informed and have received training.

Example:
Temporal sequence for a fire announcement.



2.3.6 Measurement of speech comprehensibility

Fig.: Example: Measuring device for the sound level

A measurement of the comprehensibility of speech is required for fire announcements in VAS. The quality of the measurement is greatly dependent on the level of basic noise and so the measurement must be carried out in the conditions which can be expected.

The STI measurement records the reverberation, interference noises, room reflections and the directivity of the sound source in a total of 98 individual measurements.

The level of comprehensibility is stated in the range of 0 to 1.

The quality of the speech comprehensibility in a room is dependent on the reverberation time and the volume of interference noises. The reverberation time must be low to ensure a good level of speech comprehensibility.

A sound emitter is installed at the speaker position which emits a sound signal which is technically similar to speech. At the listening station there is a second device as a receiver which calculates the STI value following an analysis of the received signals.

STI ➔ Speech Transmission Index (level of comprehensibility)
Alcons ➔ Articulation Loss of Consonants (percentage consonant loss)
CIS ➔ Common Intelligibility Index

- The level of comprehensibility (STI) must be greater than or equal to CIS 0.7 on the general comprehensibility scale (CIS) or have an STI greater than or equal to 0.5. A CIS value of 0.7 corresponds to an STI value of 0.5.
- If a defined group of people are familiar with the announcements due to regular testing, the value for the level of comprehensibility can be reduced to 0.65 on CIS. This applies e.g. in production buildings, open-plan offices etc.).

	Incomprehensible	Poor	Sufficient	Good	Excellent
STI	0 – 0.3	0.3 – 0.5	0.5 – 0.6	0.60 – 0.75	0.75 – 1.0
Alcons	100 – 33 %	33 – 15 %	15 – 7 %	7 – 3 %	3 – 0 %

2.4 The VARIODYN® D1

2.4.1 VARIODYN® D1

Thanks to its modular construction and the various system components, the VARIODYN® system can easily be adapted to the objectspecific requirements. Up to 250 digital output modules can be linked together via the Ethernet connection (LAN).

System limits

- 250 digital output modules.
- 500 double-end amplifiers
- 1000 DAL BUS participant terminals (DCS)
- or universal-interface-modules (UIM).
- 6000 loudspeaker circuits.

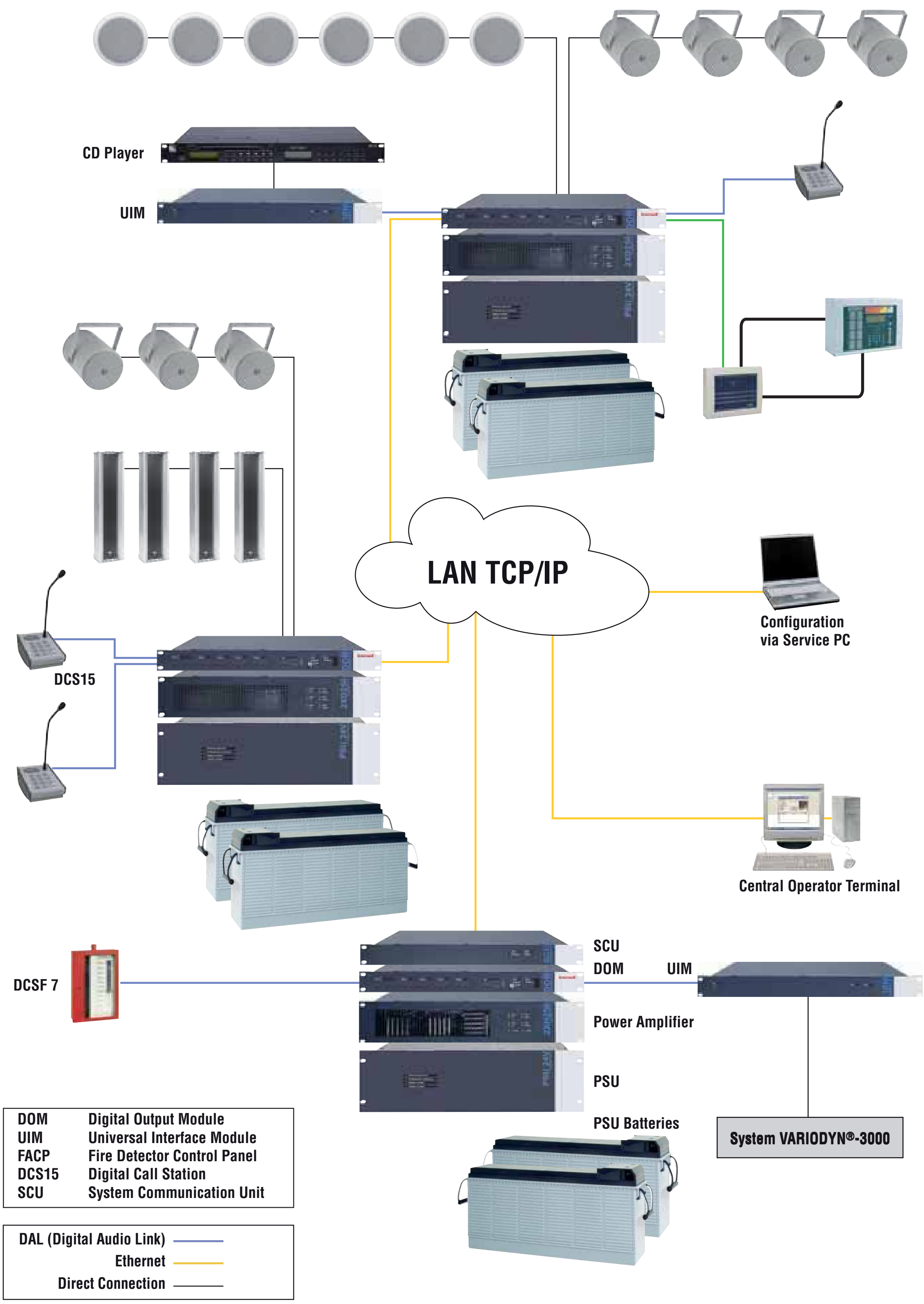


Fig.: VARIODYN® D1 (diagram)

2.4.2 Digital output module (DOM)

The DOM is the central control element of the VARIODYN® D1 system.

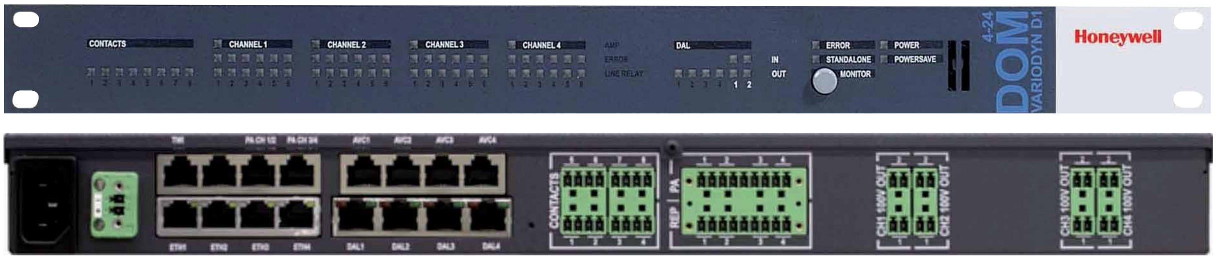


Fig.: Digital output module DOM4-24

Components such as the terminals, the doubleend amplifiers and also the loudspeakers are connected to a DOM. A DOM provides the interfaces to all input/output modules, and manages and monitors the loudspeaker circuits.

Up to 250 DOM can be connected via the Ethernet connection and therefore small to large voice alarm systems can be achieved.

Design

The DOM is designed as a 19" installation device with a height of 1 HU. On the reverse, there is a European IEC plug for mains connection and a fuse.

A mains cable (stripped end) is included in the delivery. The DOM may only be connected using three-wire mains supply earthing equipment.

The DOM4-8 and DOM4-24 modules are equipped with four independent audio outputs in order to control four amplifier channels. Each audio output can operate two switched loudspeaker circuits (i.e. a total of 8 circuits) in the case of the DOM4-8, or six switched loudspeaker circuits (i.e. a total of 24 circuits) in the case of the DOM4-24.

Displays

There are coloured LED on the front of the DOM to display the status of the digital output module, the connected components and loudspeaker circuits.

- Green POWER LED
- Yellow POWER LED
- Orange STAND-ALONE LED
- Yellow POWERSAVE LED
- Eight green CONTACT LEDs
- Four green/yellow amplifier indicators AMP
- LINE RELAY indicators
  DOM4-8: 8 green LEDs
  DOM4-24: 24 green LEDs
- Loudspeaker zone fault
  DOM4-8: 8 yellow LEDs
  DOM4-24: 24 yellow LEDs
- Four green/yellow DAL status LEDs
- Four green DAL channel LEDs

Monitor button

The monitor button can be used to listen in to the audio outputs and inputs on the DOM. Pressing the button repeatedly will run through the individual listening points. Listening will be automatically terminated after a time which can be set, or it can be stopped manually.

Inputs/outputs

- Four digital audio links (DAL BUS).
- Four Ethernet connections 100 Mbit/s with switch function.
- Four automatic level control (ALC) inputs.
- Two combined NF/control outputs for power amplifiers.
- Four power amplifier inputs.
- Four power amplifier backup inputs.
- Loudspeaker circuits
  DOM4-8: 4 channels, each with 2 circuit relays.
  DOM4-24: 4 channels, each with 6 circuit relays.
  Eight potential-free control contacts.
- One I2C bus.
- One power supply.

Automatic volume regulation inputs (AVRI)

The installed automatic volume regulation function can be used to adjust the volume continually in real time and individually for each audio channel according to the ambient volume.

There are 4 sensor microphone inputs with a nominal level of -50 dB available for this purpose. Up to 2 sensor microphones can be connected per channel.

Digital audio links (DAL)

A universal-interface-module (UIM) or a terminal (DCS) can be connected to each of the four digital audio links (DAL). The modules are controlled via the DAL BUS and are supplied with 24 V. The maximum distance with a shielded CAT5 cable is 300 m. Alternatively, it is possible to have a fibreglass connection of up to 2 km.

Ethernet (LAN)

The DOM has an installed 4 port Ethernet switch which is designed for fast Ethernet (100 base T2 as per IEEE 802.3).

The communication with the other system components (DOM, SCU) takes place via the Ethernet connection. According to the standard, the maximum distance is 90 m with a CAT5 cable (plus 2 x 10 m patch cable). Greater ranges can be achieved with standard Ethernet media converters.

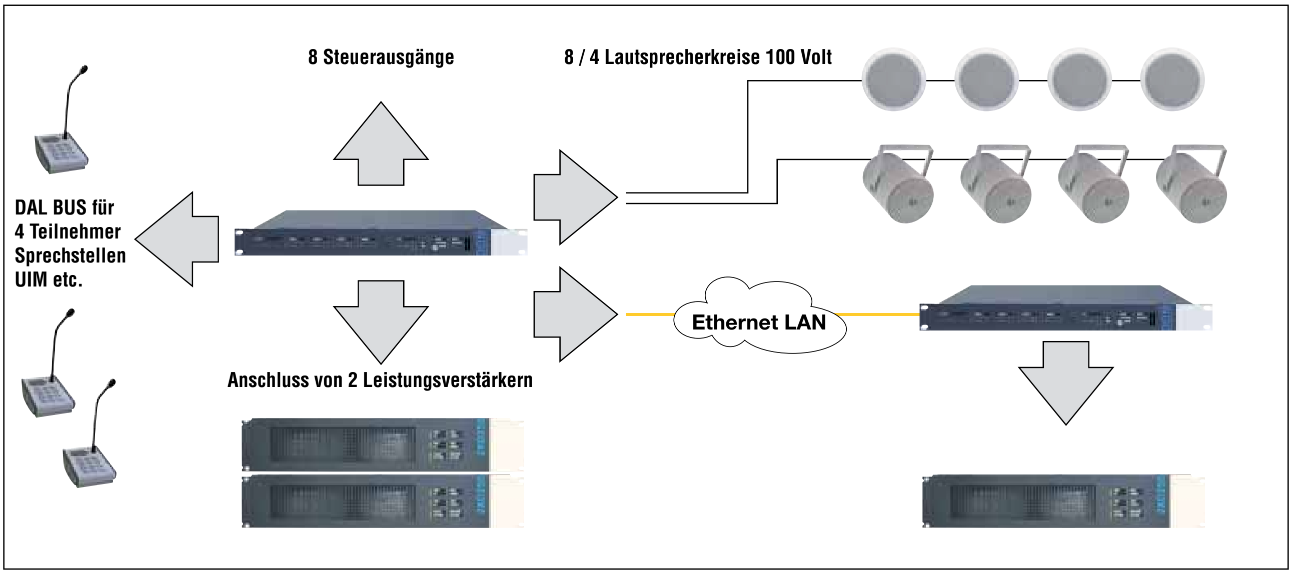
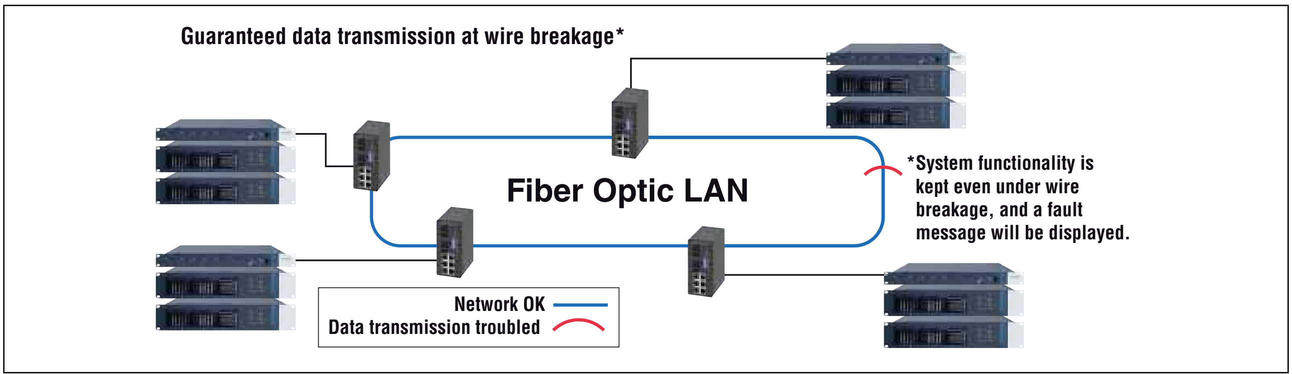


Fig.: Digital output module (DOM) - schematic diagram



VARIODYN D1 system networking

Up to 250 DOMs can be networked via Ethernet to build larger systems. This allows for systems with up to 6000 loudspeaker circuits.

In order to ensure the greatest possible security here, the Ethernet networking can also take place over a fibre-optic Ethernet ring with intelligent switches.

The fibre-optic switch is used to build an Ethernet with a ring topology. Due to the ring structure, the network is fully redundant, meaning that if one fibre-optic line breaks, communication remains possible via the other side of the ring. In addition, each switch has two operating voltage inputs (24 V DC) and a relay for forwarding a fault message.Suitable for multimode fibres 50/125 µm and 62,5/125 µm.

Fibre-optic switch multimode	➔	583392
Fibre-optic switch single mode	➔	583393

2.4.3 Microphones/terminals

The term "terminal" is used for the microphone in voice systems (VAS).

Fig.: Example: Digital terminal DCS15 with button module DKM18

Fig.: Example: Fire service terminal DCSF12

Fire microphone

The microphone must meet the requirements of DIN EN 54-16 (FAS voice alarm control panels). The terminal of a VAS must be assembled / installed in a room with a suitable climate (table / console installation). The fire brigade call station unit DCSF12 or DCSF1 is installed in the cabinet with the associated dummy plate (4 HU) Part No. 583709.

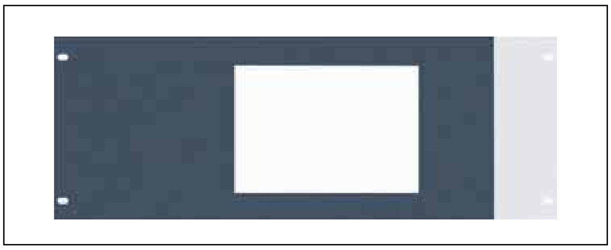


Fig.: Dummy plate for installation of a fire brigade call station

In critical areas (e.g. due to moisture, cold, mechanical load), suitable measures must be used to protect the terminal or a different installation place must be chosen.

Depending on the requirements, the terminal and the corresponding operating elements can be protected against accidental operation using a suitable cover.
Appropriate transparent protective covers are available for this purpose.

The place of installation of the terminal and its funtion must be known to people authorised by the system operator and they must be freely accessible to them, but protected against unauthorised access.
The terminal must be positioned at a suitable distance from disruptive electromagnetic fields, energy cables and other sources of electrical interference so that negative interference is avoided. This also applies for the connection line (minimum distance to the 100 V line or energy cables is 50 cm).

It must be ensured that the ambient noise level in the place of installation does not disrupt the voice announcement. This also applies for ambient noise that can only occur intermittently. If a fire microphone is available for the fire service, then this terminal must be located directly next to the fire alarm control point/at the main access for the fire service.
The microphone forms the first step of the signal recording after the speaker's voice and its typical characteristics are largely responsible for the signal quality. When microphones are used in VASs, the focus is on the following characteristics and features when selecting the microphone:

- Suitability for voice alarms (frequency range)
- Good directivity.
- Triggering of pre-programmed alarm calls via alarm buttons.
- Function buttons for e.g. voice announcement with preliminary signal (integrated alarm generator).
- Announcements in freely selectable and preselected zones/areas via the keyboard as individual, group or collective calls.

With the installation kit (Part No. 584960), it is possible to install a fire brigade call station DCSF1 or DCSF12 directly into an FDIOS.

Speaking distance

As a rule, there should always be a speaking distance of approx. 15 cm from each microphone. If there is not enough distance, the comprehensibility of speech will suffer. One of the causes of this is the proximity effect.

Example: Terminal DCS15

- The digital terminal DCS15 provides 12 functions buttons and 12 LED for the optical display..
- A specific audio input and output is integrated to allow the connection of an external audio source such as CD players, recording devices etc.
- The function of the microphone and the connection to the digital output module (DOM) are permanently monitored and the status is displayed via an LED operating display.
- An integrated loudspeaker is available for listening to saved messages and for the intercom operation.
- The digital terminal DCS15 is also available in a fire service version with a remote handheld microphone.

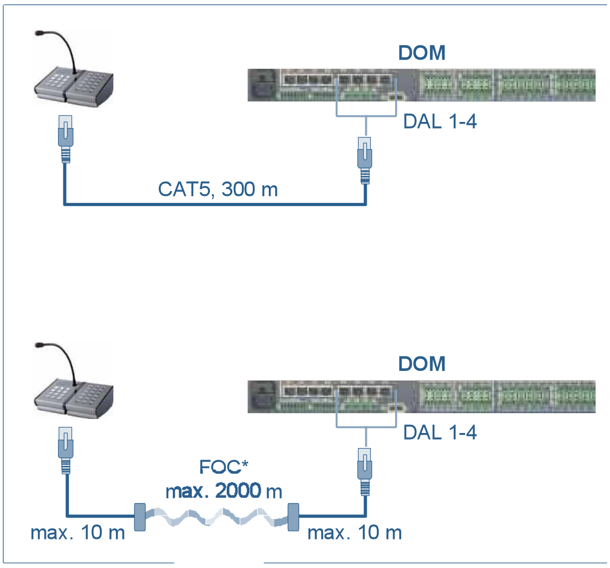


Fig.: Connection of the terminal

Connection of the microphone

The terminals are connected to the digital output module (DOM) VARIODYN® D1 via the DAL BUS with a CAT5 cable (shielded). The module is controlled via the DAL BUS (digital audio link) and is fed with a voltage of 24 V.

The maximum distance is 300 m. If the distances are greater than this, fibre optic cables with a length of up to 2.000 m are used.

Fig.: Fibre optic converter (accessory)

Keypad expansion DKM 18

The keypad expansion module DKM18 has 18 configurable keys and serves as an expansion for a call station (e.g. DCS15).

In total, it is possible to connect 6 DKM18s, allowing the use of up to 120 keys per call station.

Fig.: Example: Digital terminal DCS15 with button module DKM18

2.4.4 Power amplifier

The main task of the power amplifier is to amplify the data signal to the electrical energy required by the loudspeakers without reducing the quality.

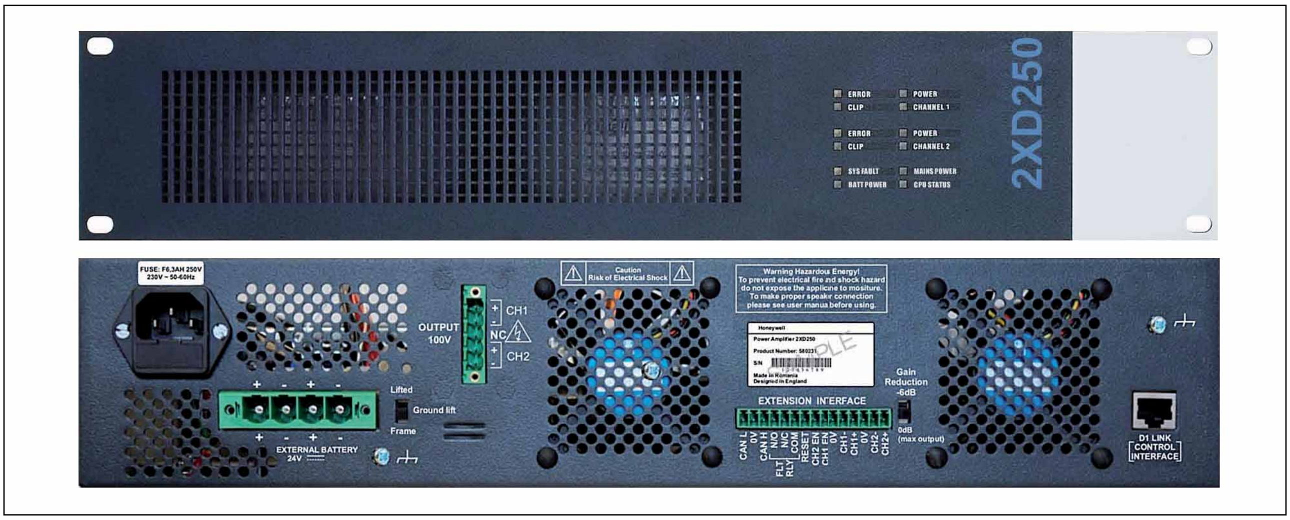


Fig.: XD double final amplifier, class D

Design

The VARIODYN® D1 power amplifiers have two independent amplifier channels (double-end amplifiers) with 100 V toroidal core output transmitters. The dimensions correspond to those of a 19" installation device of 2 HU. The VARIODYN® power amplifiers are available with the following output powers:

- 2 x 250 watt/100 volt
- 2 x 400 watt/100 volt
- 2 x 500 watt/100 volt

Displays (per channel)

POWER LED

Operating display/amplifier switched on.

ERROR LED

Display of the activated protective circuit by e.g. triggering a fuse or activating the output relay to isolate the loudspeaker line.

SIGNAL LED

Display for the output signal.

CLIP LED

Display that the amplifier channel is being operated only 0.5 dB under full load (limitation area).

Ventilation

Temperature-controlled forced ventilation ensures that the temperature is low and remains even. It must be ensured that there is sufficient ventilation (incoming and outgoing air) in the case of cabinet installation.

Dimensioning/output power

An amplifier with a suitable nominal (output) power must be selected for the supply of the connected loudspeakers. The selection of the amplifier must ensure that the required sound level is reached with the corresponding loudspeakers.

In principle, it is sensible to select an amplifier with a higher power because as a rule this means that a better sound result can be achieved (low distortions when loaded) and that the loudspeakers are suitable for a short-term overload.

When there are generous amplifier dimensions there are still expansion reserves available if the VAS needs to be extended at a later date e.g. due to an additional use/distribution of the alarm areas.

Connection

The double-end amplifiers are connected to the digital output module (DOM). Two double-end amplifiers with the same or different output powers can be operated on a DOM.

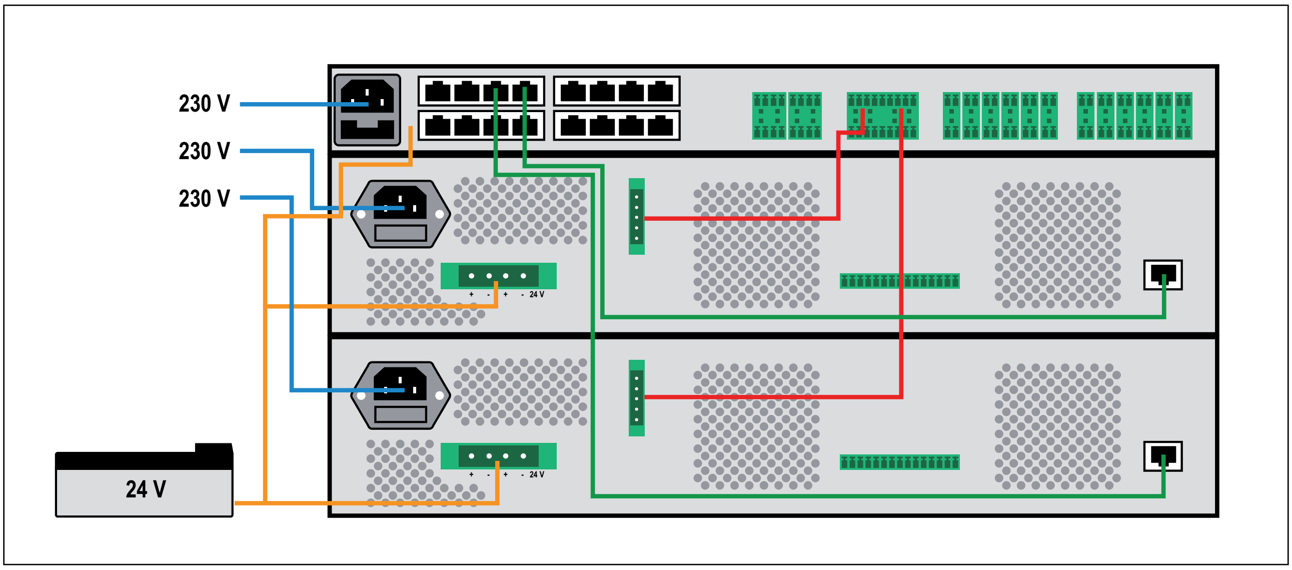


Fig.: Two final amplifiers with a DOM 4-24

Connections per amplifier

- One combined NF/control line.
- One two-channel 100 V output.
- One power supply.
- One connection for 24-volt emergency power. The amplifiers 2XD250 and 2XD400 also have their full rated power when operated with 24 volts.

The final level may only be operated using specific three-wire mains supply earthing equipment. The operating voltage of the amplifier is 230 V/50 Hz AC. There are prefabricated cables available to connect the amplifier with the corresponding inputs/outputs of the digital output module (DOM).

NF/control input

The two NF inputs and the control input are connected to the connections (PA) of the DOM using the cable AVD-G11-A471.

100 V outputs

The 100 V output voltages of the amplifier can be connected to the "100 V IN" input of the DOM via the 583491 cable.
One cable for 2 double amplifiers.

Loudspeakers

The loudspeaker is connected to the terminal strips of the digital output module (DOM) or via the 583452.21.

Mechanism

In the case of upright cabinet installation, two double-end amplifiers and a ventilation field with an installation height of 6 HU are allocated for one "unit" with a DOM.

There may be a maximum of 2 double-end amplifiers installed directly next to each other. Due to the high weight, the lower double-end amplifier is connected to a suitable support bracket (upright cabinet accessories).

Backup operation

In backup operation, a separate amplifier must be provided which compensates for the failure of an active amplifier without interrupts.

In VASs with several amplifiers, the backup amplifier must be of suitable dimensions so that it can even "replace" the defective amplifier with the highest output power.

The backup amplifier can be installed in the same upright cabinet as the active amplifiers. It is even possible to install another upright cabinet in the case of larger systems with several DOMs and amplifiers.

One DOM 4-8 with a backup amplifier can supply 2 other DOMs (fully equipped). One DOM 4-8 with two can supply 4 other DOMs.
One DOM 4-24 with a backup amplifier can supply 6 other (fully equipped) DOMs. One DOM 4-24 with two backup amplifiers can supply a maximum of 12 other DOMs.

Intelligent switching

In the VARIODYN® D1 system, the amplifier which is defective is identified and notification is given of a fault. The defective amplifier is then replaced with the backup amplifier if this is actually needed.

Failure of several amplifiers

If two or more amplifiers fail then the backup amplifier carries out the function of the one which has an announcement of the highest priority. The system recognises the priority of the announcement (e.g. fire announcement) and the required control of the backup amplifier is automatically carried out.

The dynamic backup switching exceeds the requirements of the applicable standards.

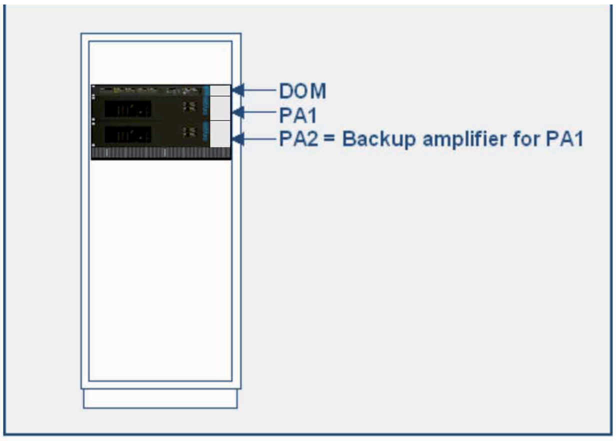


Fig.: Backup amplifier in the same cabinet

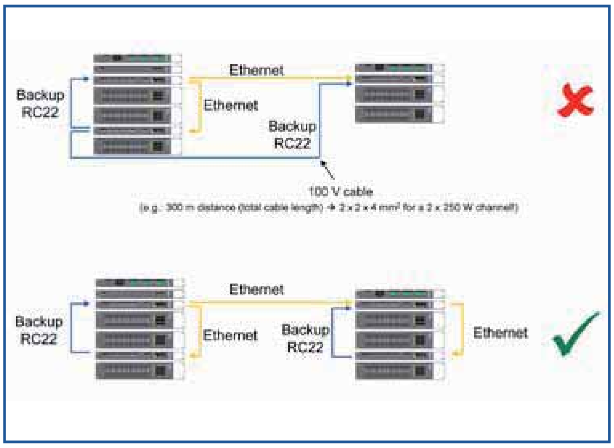


Fig.: Backup amplifier in different cabinets

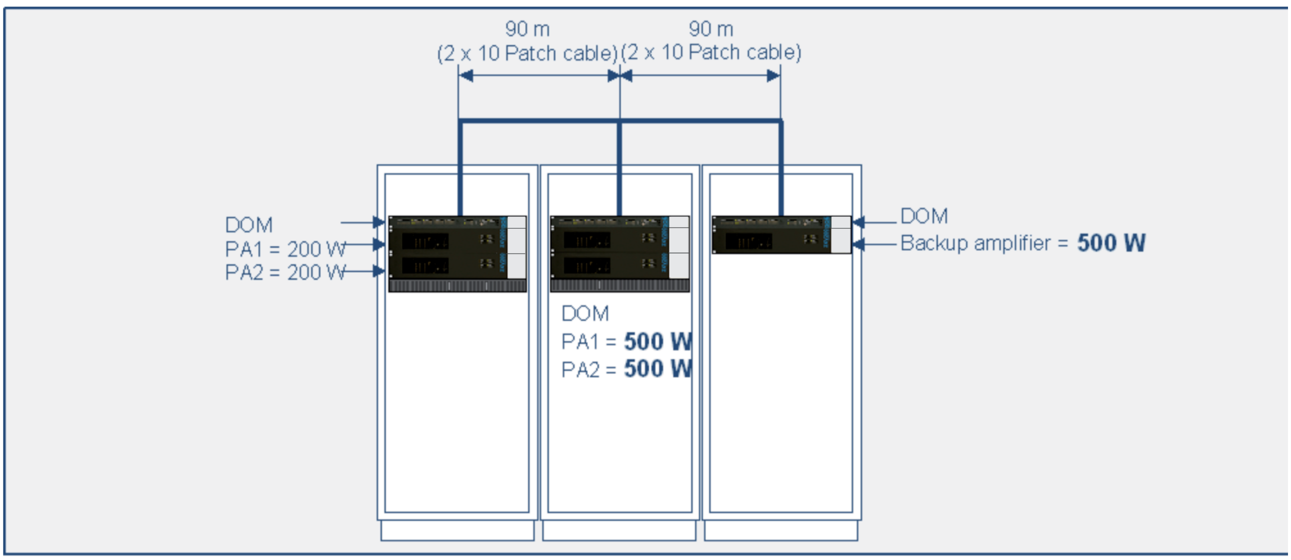


Fig.: Remote backup amplifier in a system with several different amplifiers

2.4.5 Universal-interface-module (UIM)

The universal-interface-module (UIM) is used as an interface of the VARIODYN® D1 for the connection of 2 analogue audio inputs, 2 analogue audio outputs and 48 control contacts.

Fig.: Universal-interface-module (UIM)

Connections
- Two analogue audio inputs.
- Two analogue audio outputs.
- 48 control contacts.
- Digital audio link (DAL).

Displays
- One green POWER LED.
- One yellow ERROR LED.
- 4 green SIGNAL LED for modulation.

Audio inputs
The audio inputs are suitable e.g. for the connection of an external audio source (CD/MP3 player etc.). The two analogue potential-free audio inputs are designed symmetrically on the XLR sockets and asymmetrically on the CINCH sockets. The stereo signal is mixed into a mono signal on the CINCH sockets. It is not possible to use the XLR sockets and the corresponding CINCH sockets at the same time.

Connector pin assignment XLR socket:
Pin 2: Tone wire a
Pin 3: Tone wire b
Pin 1: Shielding

Audio outputs
The two analogue potential-free audio outputs are designed symmetrically on the XLR sockets and asymmetrically on the CINCH sockets. The same audio signal is available twice on the CINCH sockets.

Connector pin assignment XLR socket:
Pin 2: Tone wire a
Pin 3: Tone wire b
Pin 1: Shielding

Control contacts
The 48 control contacts can be used either as inputs or outputs.
Four GND terminals act as reference potential. Input signals are assessed via a comparator. An input signal in the area between 8.5 V and 36 V is used as logical 0, an input signal < 7.5 V is assessed as logical 1.

The control contacts can be used for controlling VAS components or also for connecting to other systems such as a fire alarm control panel.

If the wires to the control contacts are longer than 3 m, the surge protector module 583332 must be used in systems that comply with EN 54-16.

POWER LED
The POWER LED goes green when the operating voltage is applied.

ERROR LED
The ERROR LED goes yellow when there is a communication problem on the DAL bus or nonconfiguration. Please check the transmission route.

SIGNAL LED
The presence of audio signals on the two audio inputs and the two audio outputs is always displayed with an LED.

DAL

The universal-interface-module (UIM) is connected to one of the four inputs of the digital output module (DOM) via the DAL BUS with a CAT5 cable (shielded). The module is controlled via the DAL BUS (digital audio link) and is fed with a voltage of 24 V.

The maximum distance is 300 m. If the distances are greater than this, fibre optic cables with a length of up to 2.000 m are used.

A special fibre optic converter (accessory) is required for this application due to the 24 V voltage supply via the DAL BUS.

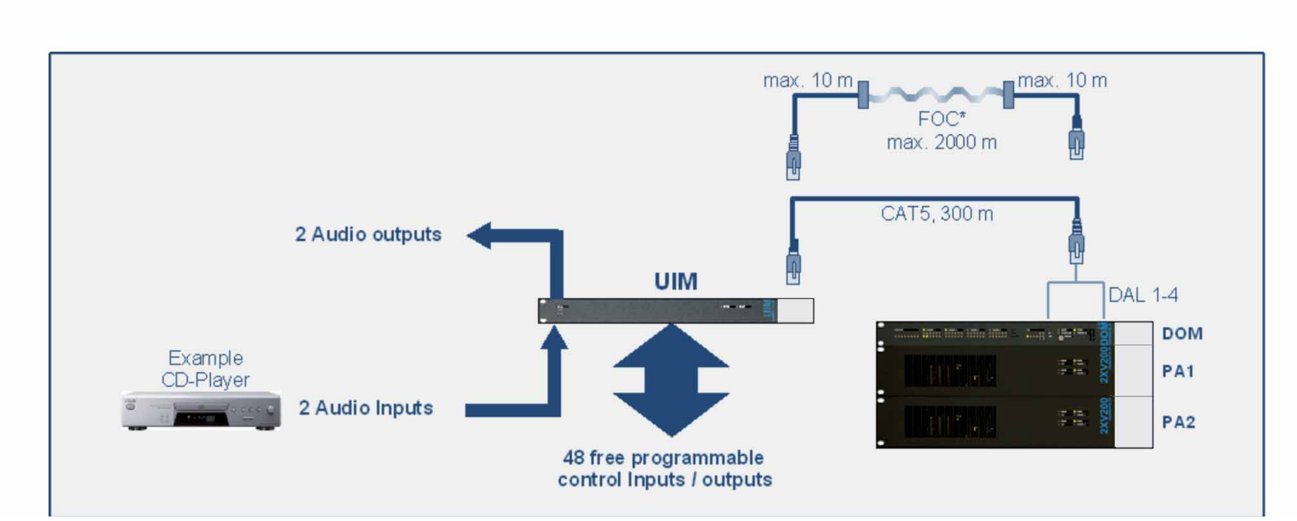


Fig.: UIM connection options (schematic diagram)

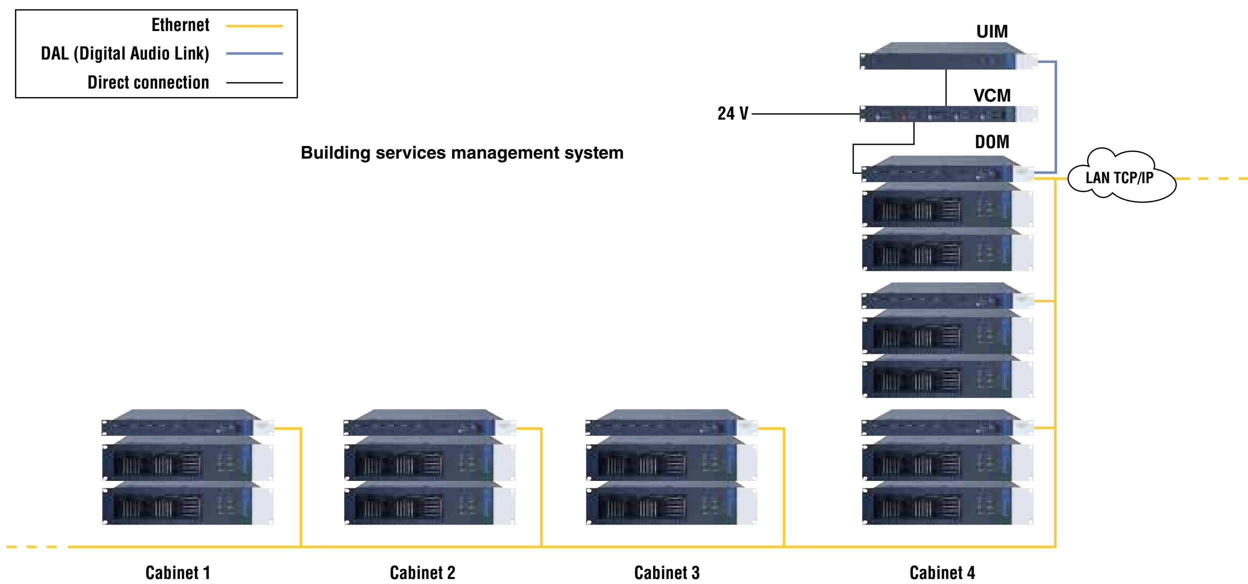
2.4.6 View Controle Module (VCM)

Fig.: View Control Module (VCM)

As part of the EN54-16 certification, the system VARIODYN D1 was expanded with the VCM (View Control Module). This allows for the standard-compliant display of collective messages and permits the entry of conditions using 5 keys. At least one VCM module is required for EN 54-16 systems. In a single upright cabinet solution, up to 3 DOMs can be managed from one VCM.

In the event that multiple upright cabinets are positioned directly next to each other in one room and together form one system, one VCM module per room is sufficient. Remote cabinets each require their own VCM. The VCM is connected directly to a UIM and 24 V DC.

The up to 3 DOMs in the cabinet containing the VCM are also connected to three separate inputs of the VCM. All other DOMs are integrated via Ethernet. Programming of the VCM is simple and convenient using a macro in the programming software “Designer”.



2.4.7 System communication unit (SCU)

The communication unit (SCU) is used as a digital audio memory for the VARIODYN® D1 system.

Fig.: Communication unit (SCU)

Use
The system communication unit (SCU) is connected to the VARIODYN® D1 system and permanently monitored via the Ethernet network.

The SCU offers the memory space for the audio signals (voice, tone, music) which are required in the system.
Further stored audio items such as announcements, signals or advertising texts are saved on the installed hard drive. The memory capacity of the hard drive also amounts to roughly an additional 150 hours.

As per IEC EN 60849, the storage of availability-critical announcements for e.g. alarms and evacuations takes place on the non-volatile flash memory, not on the hard drive, due to the increased operational security. The memory capacity of the non-volatile flash memory is approx. 120 minutes.

The option of absorbing and transmitting several audio data streams (announcements) at the same time means that the SCU is suitable for use in VAS in which different announcements (e.g. voice and music) need to be transmitted to various alarm areas at the same time.

The SCU can also be used for recording and taping remote announcements. These are also stored on the hard disk and are secured with information on the date, time and trigger. DOM announcements can be automatically buffered and automatically played out within a time limitation when the required target is released.

Connections
- 1 Ethernet connection 100 Mbit/s.
- 1 230 V AC mains connection.
- 1 emergency power connection 24 V DC

Displays
- POWER LED, HARDDISK LED.
- ERROR LED, STANDALONE LED.

Fig.: Connection options

2.4.8 Mains switching unit (MSU)

The mains switching unit (MSU) is used to safeguard the power supply of all VARIODYN® D1 components, which are installed in an upright cabinet.

Fig.: Mains switching unit (MSU)

In addition, the device has a plug for the connection of a laptop for local/network-wide maintenance purposes.

Connections and displays

- 3 overcurrent switches with lamp (one per phase).
- 3 connections for auxiliary switching contacts for each overcurrent switch (idle, work, root).
- 230 V IEC power socket, switched with L1.
- RJ45 socket for Ethernet connection.

Input

The network phases used must be connected to block 1. Earthing equipment PE and neutral lines N must always be wired. A maximum cable cross section of 4 mm² (flexible) to 6 mm² (rigid) is possible.

Output

Up to 4 consumers are connected to blocks 2, 3 and 4 according to requirements. These blocks can be single switched with the fuses arranged on the front.

Fuse

Each of the up to three phases can be loaded with a maximum of 18 A. The overcurrent switch (per phase) triggers automatically when there is an overcurrent, but can also be used for manual switching of the power supply. The application of the supply voltage and the fuse being switched on will cause the respective indicator light to go green.

Contacts

In addition, the switching status of the fuses can be remotely determined with the contacts made in block 5. A max. cable cross section of 2.5 mm² may be used. When switched off, contact 1 is connected with contact 2; when switched on, contact 1 is connected with contact 3.

An external consumer with max 10 A can be connected to the front IEC power socket. This IEC power socket is supplied with phase L1 and switched with fuse F1.

Ethernet

The RJ45 sockets on the front and back are connected with a CAT5 cable 1:1. The mains switching unit (MSU) is conected to the VARIODYN® D1 system and monitored via the Ethernet network.

2.5 Loudspeakers

Loudspeakers for use in VAS must meet the requirements of DIN EN 54-24.

Fig.: Loudspeakers

EN54-24 describes the loudspeakers for a VAS application. Just like EN54-16, it specifies requirements for the functionality, product properties and quality. Certification processes similar to EN56-16 are also described.

This means that using loudspeakers certified according to EN54-24 ensures that important product properties from the data sheet, such as frequency response (range and uniformity) or sound pressure, are actually achieved.

The use of EN-54-24-certified loudspeakers therefore ensures high quality public address systems not only for VAS projects.

Complete emitters combine all loudspeakers in a housing. This means that a good coverage of the frequency range and a high transmission quality (e.g. music transmission) can be achieved.

Individual segments of a line array will only contain the housing of the loudspeakers of a particular frequency range, and as a result e.g. combinations with different directivities can be achieved.

Funnel loudspeakers for pure voice transmission have a very high level of efficiency, an average transmission bandwidth with relatively larger linear distortions and, frequently, a very high harmonic distortion.

Horn systems for the transmission of music combine a very high level of efficiency with good sound characteristics and a relatively large bandwidth.

Ceiling loudspeakers are used in the cavities of suspended ceilings. It is possible to achieve very good music and speech quality depending on the type of loudspeaker.

Dome loudspeakers are often used for public address systems if there are no attached ceilings for the installation of loudspeakers.

Installation of the loudspeakers

In practice, ceiling and wall loudspeakers are mostly used in buildings with lots of individual rooms and low ceiling heights such as office blocks and classrooms. The reverberation time which can be expected plays a secondary role due to the furnishings of the rooms (furniture, carpet etc.). The distance of the loudspeakers is based on the ceiling height as well as the required sound level and the comprehensibility.

If several loudspeakers of the same or even different types are installed at a point in the room or in immediate proximity to each other, then the individual loudspeakers must be arranged vertically.

Funnel or horn loudspeakers are often used in outdoor areas and larger halls. These types of loudspeaker usually provide a high IP rating and a robust mechanical design.

The directivity of the loudspeakers means that particular attention must be paid to the arrangement of the individual sound sources, as well as to the supply of the entire public address area.

Volume controller

Separate (decentralised) volume controllers are required for the individual regulation of the volume of a loudspeaker, irrespective of other connected loudspeakers.

If an event occurs, the fire announcement must be able to be transmitted at the required volume. If an event occurs, the VAS must offer the technical options of bypassing the decentralised volume setting.

It is possible to use e.g. volume controllers with emergency call relays for this purpose.

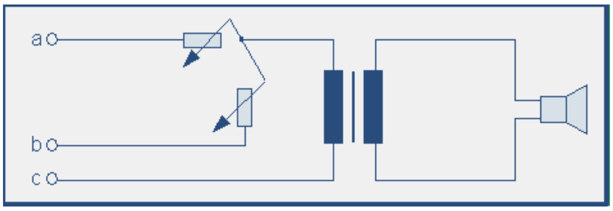


Fig.: Volume controller (schematic view)

2.6 Cabinet systems

VAS components in the 19" design are suitable for installation into an upright cabinet.

Fig.: VARIODYN® cabinet system (24 and 40 HU) with pivot frame

Conventional cabinet systems offer good access from the front and back or have a pivot frame which can be used to swivel the installed electronics system out of the cabinet. Optional components can be assembled e.g. on C profile rails.

Ventilation grating and also active fans can be used depending on the temperature which can be expected inside the upright cabinet as a result of the installation of VAS components.

1 HU = height unit (44.45 mm or 1¾ inches)

VARIODYN® cabinet system
When developing the VARIODYN® cabinet system, attention was paid to the technically required high weight of the installation components, to modules such as final amplifiers and to a UPS. The relatively low unladen weight reduces the transport costs and simplifies assembly work.

The VARIODYN® cabinet systems are available in different heights and designs. Detailed descriptions of our upright cabinet system can be found in our current catalogue "Voice Alarm Systems".

Devices with optical displays
As a rule, attention should be paid to the visibility of the optical displays during the installation of the 19" devices. It is recommended that devices with optical displays should not be installed above a height of 1.600 mm (+ 200 mm) over where the operator stands.

Weight of the installation devices
The high weight of the final amplifier (UPS) means that this must be fastened/secured separately with special installation brackets. In principle, an additional installation bracket must be provided for the combination of a DOM and two final amplifiers.

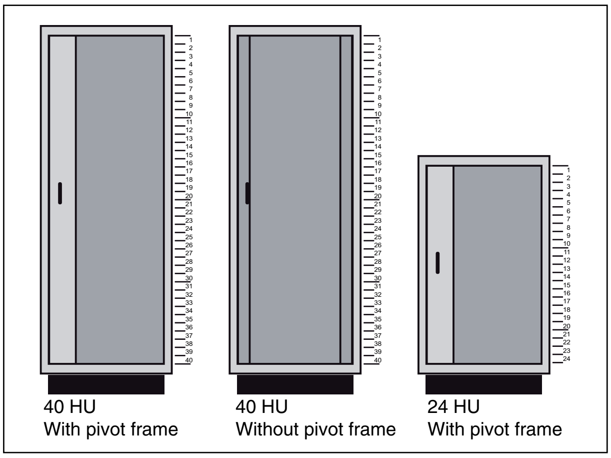


Fig.: Upright cabinet size comparison

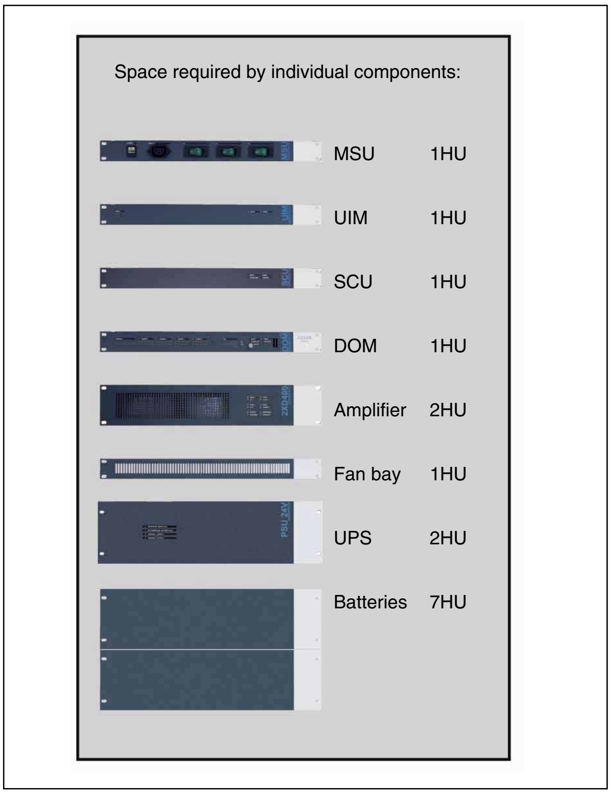


Fig.: System components with HU specifications

Overview of the Individual System Components for Rack Mounting

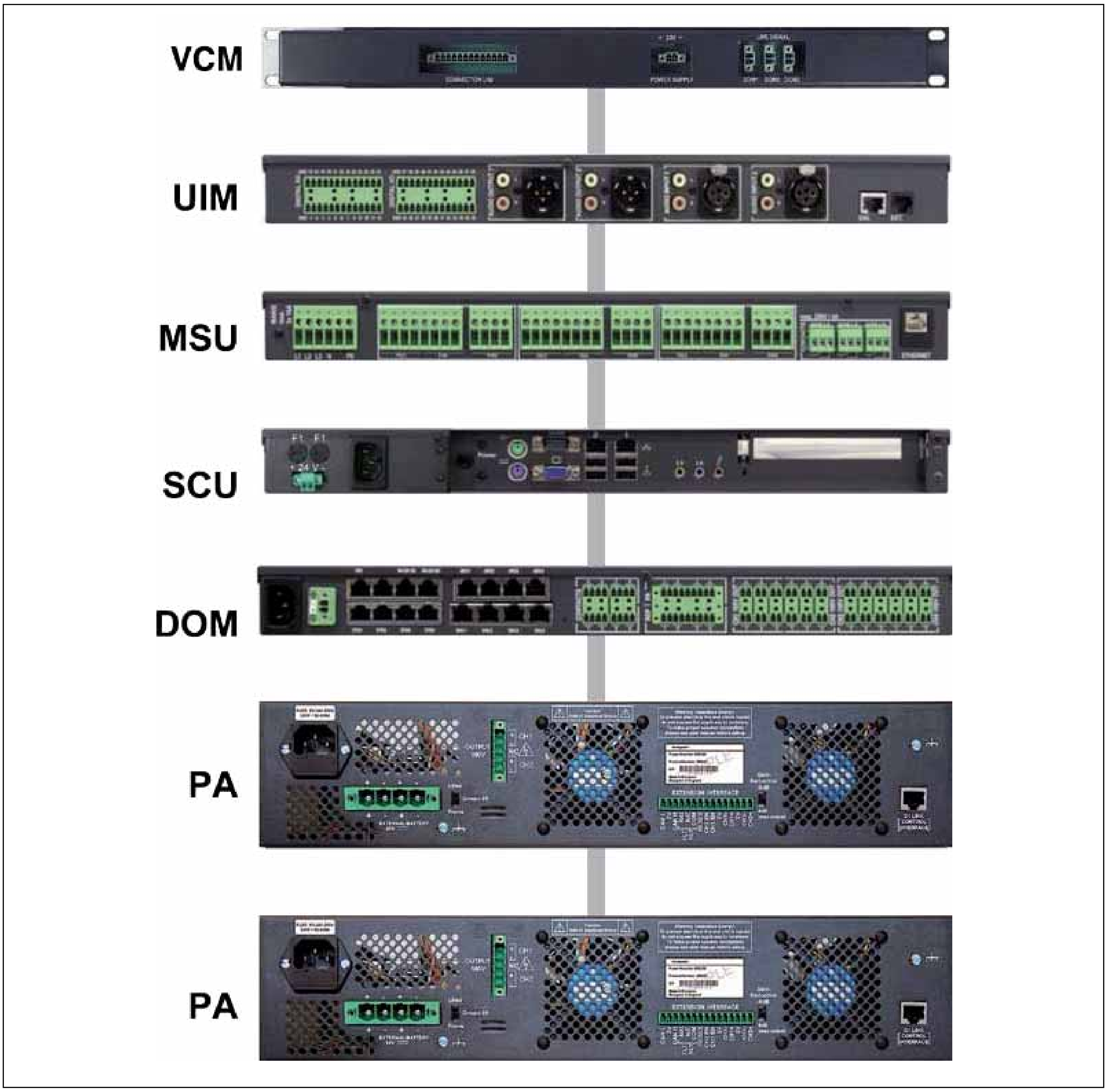


Fig. 6: VARIODYN® system components (example)

Abbreviation	Description	Part No.
VCM	View-Control-Module	583351
UIM	Universal-Interface-Module	583331.21
MSU	Main-Switching-Unit	583371.21
SCU	System-Communication-Unit	583381.22
DOM	Digital-Output-Module	583361.22, 583362.22
PA	Power Amplifier	580221.41, 580222.41, 580231, 580232

Floor type cabinet / Rack-mounting (Part No. 5849xx)

Conventional cabinet systems offer good access from the front and back or have a pivot frame which can be used to swivel the installed electronics out of the cabinet. Optional components can be mounted on C profile rails, for example. Depending on the temperature that can be expected inside the cabinet due to the installation of voice alarm system components, ventilation grating and active fans can also be used.

VARIODYN® cabinet system

When developing the VARIODYN® cabinet system, the technically required heavy weight of the individual installation components, such as final amplifiers and UPS, was taken into account. Despite the high stability, the cabinet system has a low deadweight, which simplifies transport and assembly work.

The VARIODYN® cabinet systems are available in different heights and designs.

1 HU = 1 height unit = 44.45 mm or 1¾ inches

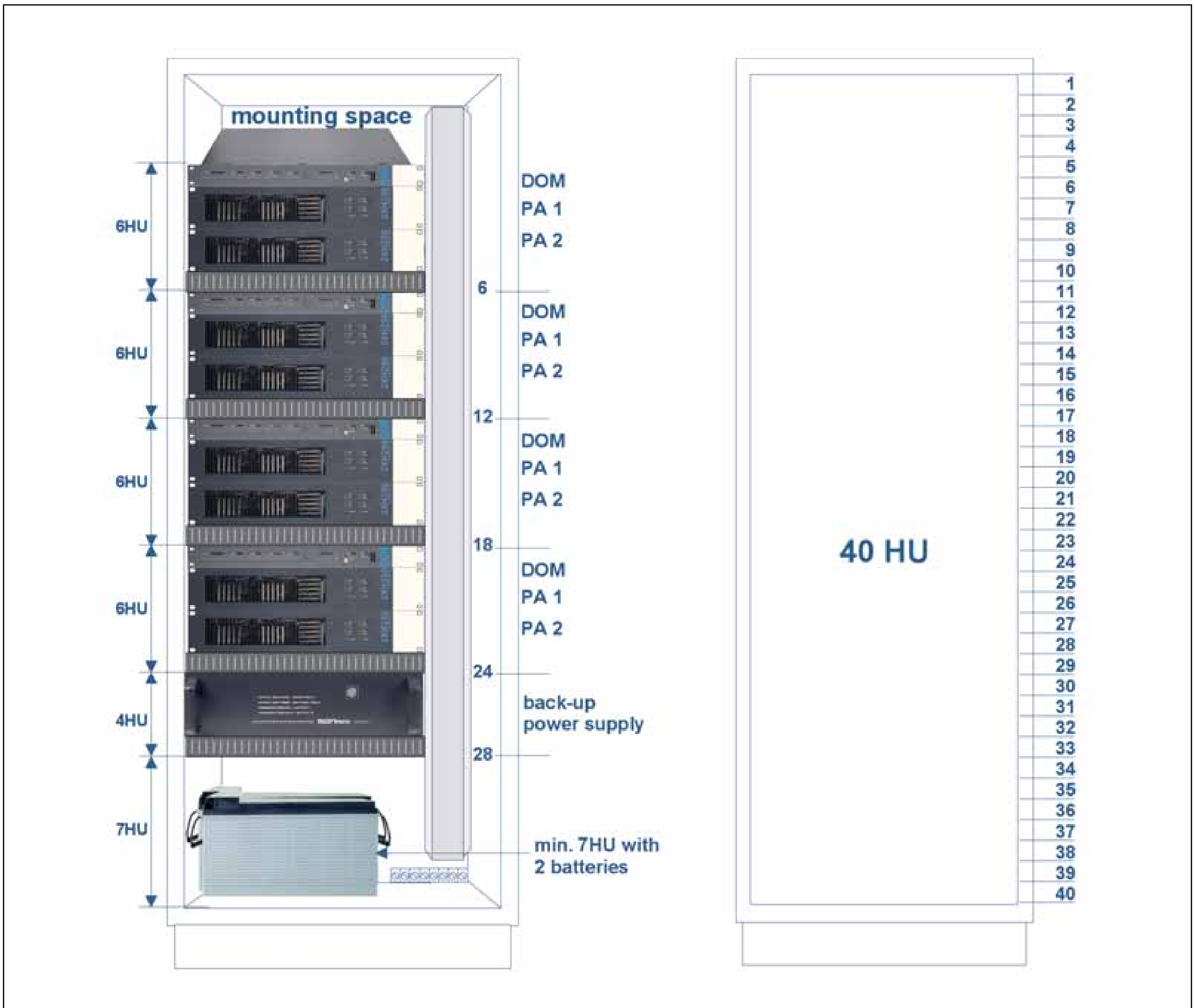


Fig. 7: System components with HU specifications (Example)

Please note the weight and installation depth of the power amplifiers!
All devices are installed with M6 screws from installation set 1

Max. 2 back-up power supply and max. 4 batteries per floor type cabinet.

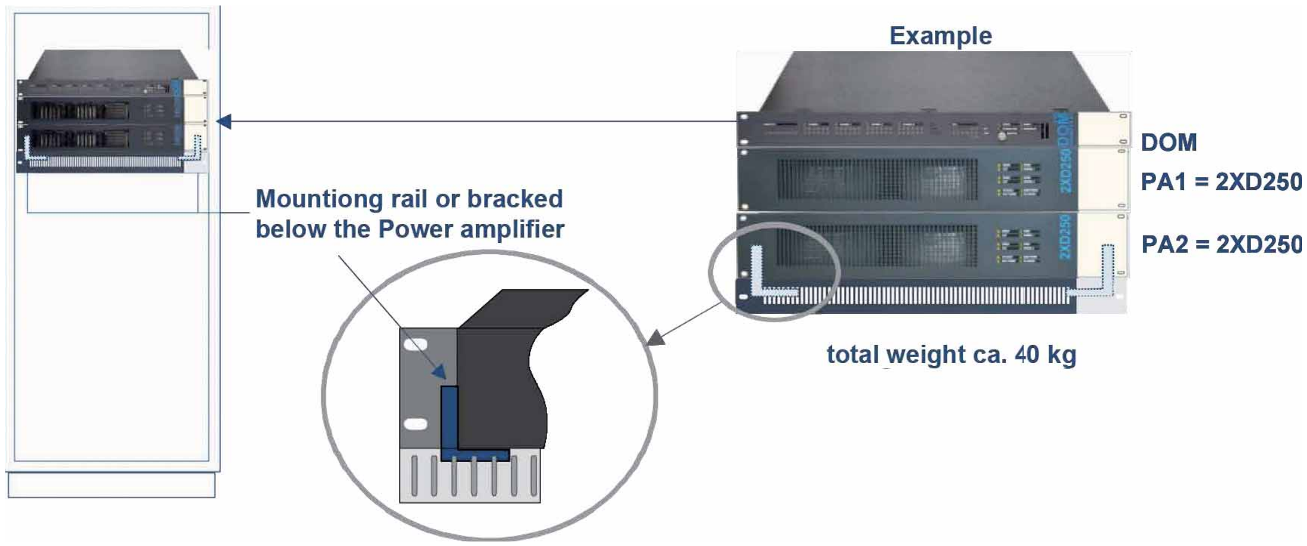


Fig. : Example installation of devices with retaining brackets (Example)

Device	Weight	Device	Weight
Amplifier 2XH250 (2 x 250 W)	approx. 13 Kg	Digital Output Module 4-8	approx. 5.7 Kg
Amplifier 2XH500 (2 x 500 W)	approx. 14 Kg	Digital Output Module 4-24	approx. 6.5 Kg
Amplifier 2XD250 (2 x 250 W)	approx. 16.5 Kg	Universal Interface Module (UIM)	approx. 3.6 Kg
Amplifier 2XD400 (2 x 400 W)	approx. 19 Kg	Main Switching Unit (MSU)	approx. 4.2 Kg
View Controle Module (VCM)	approx. 2 kg	System Communication Unit (SCU)	approx. 3 Kg

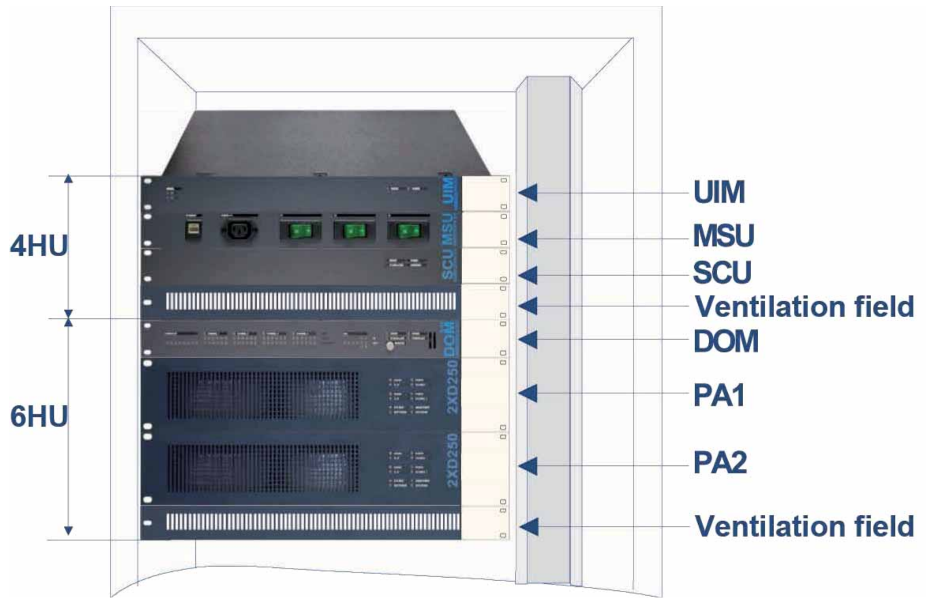


Fig. : Sample arrangement of the devices

As a rule, in a cabinet, the heavy devices should be installed on the bottom and the lighter components should be installed towards the top. Two power amplifiers installed on top of each other must be additionally fastened with suitable installation brackets.
If components are included in addition to the MSU (SCU, UIM), they should also be installed with a ventilation field below them and fastened with installation brackets.

Power Supply
In general, all devices of a VARIODYN® D1 system are supplied with power via the mains supply. This can be connected directly or via an MSU.

Fig. : Amplifier with 230 V AC direct connection (example)

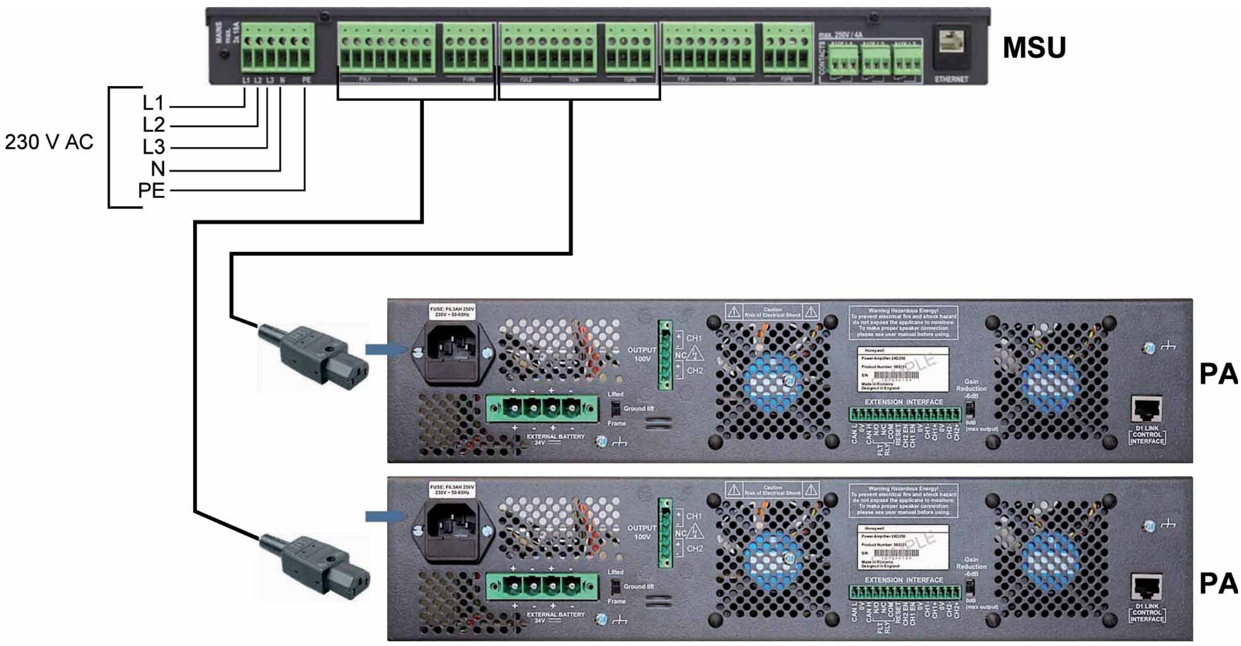


Fig. : Two amplifiers with 230 V AC cabling via the MSU (example)

Back-up power supply
The emergency power supply (Part No. 581720) is used in accordance with VDE 0833-4 and EN 60849, TRVB 158 S for the independent supply of power to the VARIODYN® D1 system. In the event of a mains power failure (230 V AC), the connected batteries will supply the system with power without any interruption.

Mounting
The emergency power supply as well as the batteries are installed in the cabinet according to Fig. 12.

Initial start up
New batteries must be recharged for at least 24 hours before the system is started up. If the batteries were manufactured more than nine months ago (see print on them), they will have to be recharged for at least 48 hours.

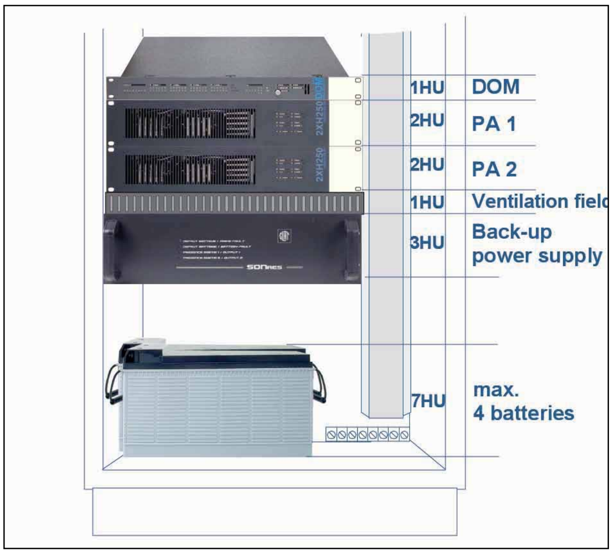


Fig. 12: Example – Rack mountinge

- Only use approved battery types for the system's emergency power supply.
- Only ever connect batteries of the same type to the emergency power supply (manufacturer, manufacturing date, capacity, charge).
- Also note the information from the manufacturer on the total discharging of batteries.
- Connect the batteries in series.
- Battery connection cable (inherently safe)
  - Length: Max. 1.5 m
  - Wire cross-section: ≥ 25 mm2
- Max. 4 batteries per floor type cabinet.

Specification

Nominal voltage	:	230 V AC
Output voltage	:	24 V DC
Output current (idle)	:	max. 12 A
Output current (alarm)	:	max. 100 A
Weight	:	10 kg
Dimension	:	483 x 133 x 395 mm (3 HE)
Specification	:	EN 54-4:1997/A2:2006
CE certificate	:	0333-CPD-075243

For rack mounting, the batteries 12 V / 105 Ah (Part No. 581730) or 12 V / 150 Ah (Part No. 581731) must be used.

PE connection

Connect the PE and FE connection (function earth) of the housing with the same PE rail of the (sub-) distribution box from which the system is supplied with the operating voltage (required cable cross section ≥ 4 mm²).

Electrically conductive parts of the housing of the upright cabinet must be connected with a PE cable (required cable cross sectio n ≥ 1.5 mm², flexible).

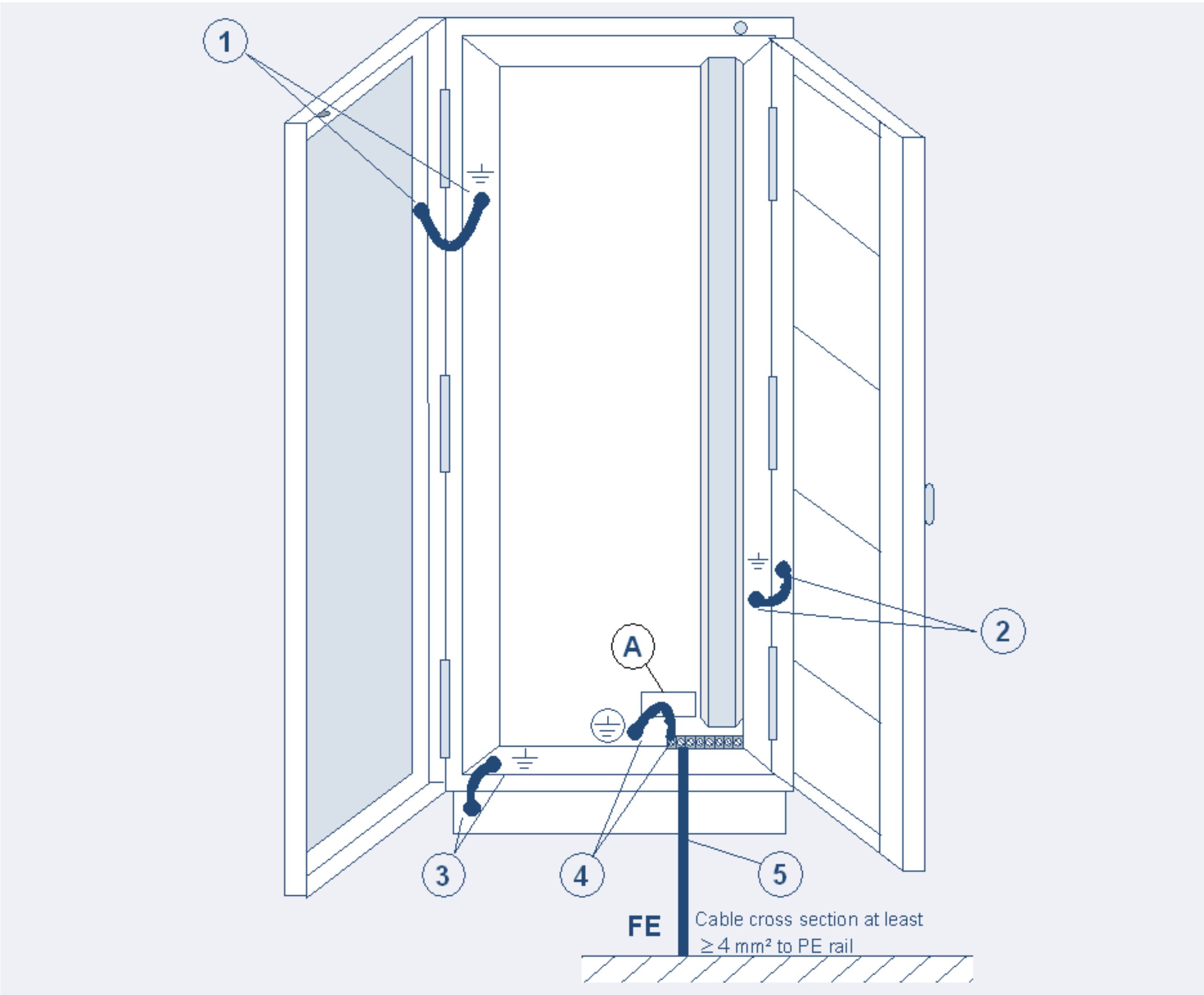


Fig. : PE connection

PE connections				Cable cross section
er	Cabinet door	⇔	Side wall	1.5 mm²
&	Pivot frame	⇔	Side wall	
●	Side wall	⇔	Cabinet base	
❍	Terminal strip	⇔	Mounting plate	2.5 mm²
■	Terminal strip	⇔	Central grounding point/potential equalisation	≥ 4 mm²
Ⓐ	Position of label – reference to leak current			

2.6.1 Installation information

Ambient conditions
The ambient conditions for assembly locations and surfaces must comply with Class 3k5 according to IEC 721-3-3:1994.

Assembly location and assembly surface
The 19" installations and cabinets with fire alarm control panels may be installed only in dry, clean, conditionally accessible and adequately lit rooms. If several fire alarm control panels are to be assembled in an enclosed 19" cabinet, then e.g. the maximum bearing strength (kg/m^2) of the floor may have to be considered (e.g. pile floors).
To prevent the 19" cabinet becoming top heavy when the pivot frame is open, it must be fixed to a suitable wall.

The fire alarm system/VAS must not be installed in facilities with may cause damage to the system. Parts of the fire alarm system may be fed through these facilities if the requirements of the DIN VDE 0800 series are fulfilled.

Assembly material
Suitable fixing materials (screws, threaded bolts) must be used to assemble the VAS components in the 19" cabinet with no mechanical stress. The VAS may be operated only when it has been properly secured on the surface with sufficient bearing power.

Installation height of the operating modules and optical displays
In the case of cabinet installation, operating modules and optical displays must be installed between 800 mm and 1.800 mm above the place where the operator stands.

Disturbance variables
Avoid electrical and mechanical disturbance variables. This applies especially to the installation of components and installation cables in the direct vicinity of fluorescent lamps or energy cables and mounting on vibrating, unstable surfaces such as thin partition walls.

Cabinet ventilation
The ambient conditions for the assembly / operation of the system must comply with Class 3k5 according to IEC 721-3-3:1994. If these climatic conditions cannot be fulfilled, appropriate countermeasures must be taken.
If you believe that the ambient temperature is unsuitable for the installed devices, you must take appropriate measures to air-condition the 19" cabinet.

In the case of temperature-critical applications, up to two fan modules 584932 can be used.

Door contact
The 19" cabinet can be fitted with an electrical door contact that monitors when the door is opened. This door contact may be used e.g. in fire alarm control panels to switch off the master box (MB) of one or more control panels.

Cable entry and installation
Only use the cable entries provided from the factory. Use separate cable entries and cable fittings for the power supply and signal lines. All connected voltage and signal lines must be secured with suitable fixing material, such as plastic cable fasteners, so that they cannot move around.

It is important that the power supply line cannot touch the signal lines (SELV) when moved.
Work may only be carried out on the system when it is voltage-free (network and emergency power supply).

The devices installed in the 19" cabinet must be protected against inadmissible moisture. To ensure this, all installation cables must be equipped with suitable cable sleeves before they are fed into the 19" cabinet.

Openings and cable entries
Unused cable entries must be closed with suitable material. Open installation spaces in the pivot frame must be closed with filler plates.

Fibre optic converter
Special fibre optic converters are required to connect the digital call station DCS or the UIM interface module to a DOM 4-xx via fibre optic cables (see “Accessories”).

The fibre optic cable connection increases the possible distance (cable path) between the DOM and a DAL bus device to max. 2000 m.

Accessibility
The 19" cabinet must be accessible at all times for operation and maintenance work.

Ground
Even when switchgear is installed carefully and properly planned in advance this cannot completely prevent undesired short circuits during operation of the system. The appropriate safety measures must be taken to reliably prevent personal injury and damage to property in such cases.

Openings and cable entries
Unused cable entries must be closed with suitable material. Open installation spaces in the pivot frame must be closed with filler plates.

Danger – Electric shock!
Assembly and installation work may only be performed when the system is de-energised (voltage free).

ESD / EMC preventive measures
Before handling electronic modules, always take suitable precautions to prevent static electricity.

Protective and functional earth
For the device to function properly, the network side protective earthing (PE) connection must be connected to the correct terminal. The functional earth (FE) must also be connected to the PE rail.

Commissioning
A complete function test must be performed on the system upon completion of the commissioning as well as after every change to the customer data programming.

2.7 Planning phases

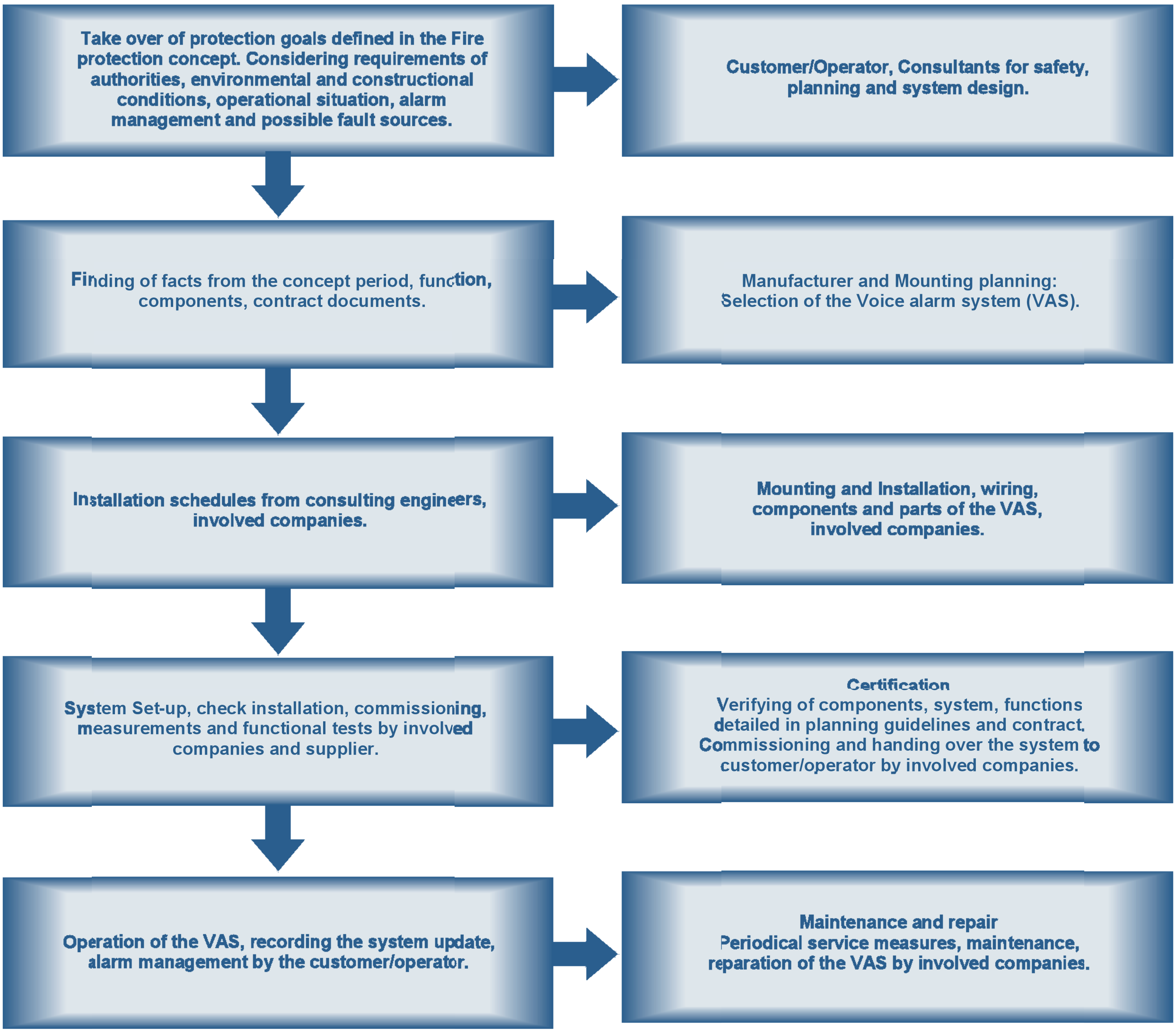


Fig.: Planning phases as per DIN 0833-4

2.8 Servicing

Operation and maintenance of hazard warning systems (HWS)
The operator of the HWS must have received training on operation, or must commission a person who has received training to carry out operation.

The operator or the person he/she commissions must take responsibility for ensuring that inspections are carried out when there are signs of constant readiness for operation being impaired, irregularities in the function and in the case of influences on the monitoring tasks of the HWS caused by alterations (e.g. of the room use or room design).

All necessary maintenance and alteration work to the HWS must be carried out immediately by the operator or the trained person who he/she commissions.

HWSs must be regularly serviced by an electrician. If there are faults, the HWS must be immediately inspected and corrected by an electrician.

Inspections
Must be carried out at least four times per year at roughly.

Repairs
Must be carried out immediately if it is confirmed during an inspection that there unauthorised deviations from the nominal conditions of the HWS..

Maintenance work
Must be carried out according to manufacturer instructions, but at least once per year. These may include e.g.:
Maintenance of system parts, replacing construction elements with limited service life (e.g. light bulbs), alignment, resetting and adjusting components and devices. The specifically required annual maintenance work may be linked in with the quarterly inspections.

In addition, voice alarm systems should be inspected every five years to ensure that they still satisfy the requirements of the relevant standards.

Regular tests
In principle, the statutory specifications, standards and local requirements apply for the maintenance of the VAS.

However, these may be additionally restricted by the manufacturer's specifications. This may be the case if e.g. the manufacturer stipulates that the maintenance intervals or replacement cycles of the devices must be shorter than required by law.

- Regular tests must be carried out to ensure that there is not and will not be any restriction on free radiation from the loudspeakers or on their function.
- Regular tests must be carried out to check whether rooms excluded from the public address system in the planning documents now need to be included in the public address system.
- Regular tests must be carried out to ensure that when the VAS or even one of the individual system parts of the VAS is switched off or malfunctions there is a suitable backup measure available (e.g. guards with megaphones etc.).
- Loudspeaker testing must be carried out at least once per year using suitable audio tests. If there is any doubt, a measurement must be carried out to prove the speech comprehensibility.

IMPORTANT
- In accordance with EN 60849, a maintenance contract must be concluded.
- Faults must (should) be documented in an ope rating.

Honeywell

2.9 System couplings

2.9.1 Fire alarm systems couplings with dry contacts

A standardised interface must be used for the system coupling of e.g. fire alarm systems.

The fire alarm system 8000 / IQ8Control provides this interface via the BSL interface module.

The voice alarm system is activated by a suitable control system (e.g. monitored relay) of the fire alarm control panel. The terminal strip of the interface between the two systems must be appropriately labelled and must be accessible to authorised specialist companies for servicing and maintenance work (measurements) without them having to interfere with the system.

Electrical isolation is needed on the side of the VAS.

2.9.2 Serial data interface to Fire alarm systems

If you are using the ID3000 or the ESSER fire panel you don't need the Multi Protocol Gateway at all to communicate with D1. Will be only neccessary with the US version FN 3030. At both systems (ID3000 and Esser) D1 is directly connected to their serial interface (at Esser via SEI). What you only need is a serial cable and our TWI-Adapter (Order no. 583386.21), as directly on the DOM, the serial interface is only available through this.

To the function:

- connection between D1 and fire panel is supervised
- D1 is "hearing" on the VOPs. That means if a VOP is activated in the ID3000, D1 recognizes this and can start an announcement with any audio source to any destination in D1 (as configured). If more VOPs are programmed each can e.g. announce a different zone.
- D1 can send all status information outputs (e.g. failures), which are normally possible over contacts, also virtually to VIPs, to activate something in the ID3000.
- Time synchronization between both (from D1 to fire or from fire to D1)

The big advantage is that you get much more control about the escape route control for the people in the case of an disaster, this is especially for bigger buildings like Airport important.

Input

It must be possible to transmit the following signals/ messages:

- Alarm, alarm area.
- Collective alarm.
- System fault (if there is an alarm).

Further permitted transmissions:

- Alarm area preliminary alarm (only for the transmission of preliminary warning texts).
- Resetting the alarm.

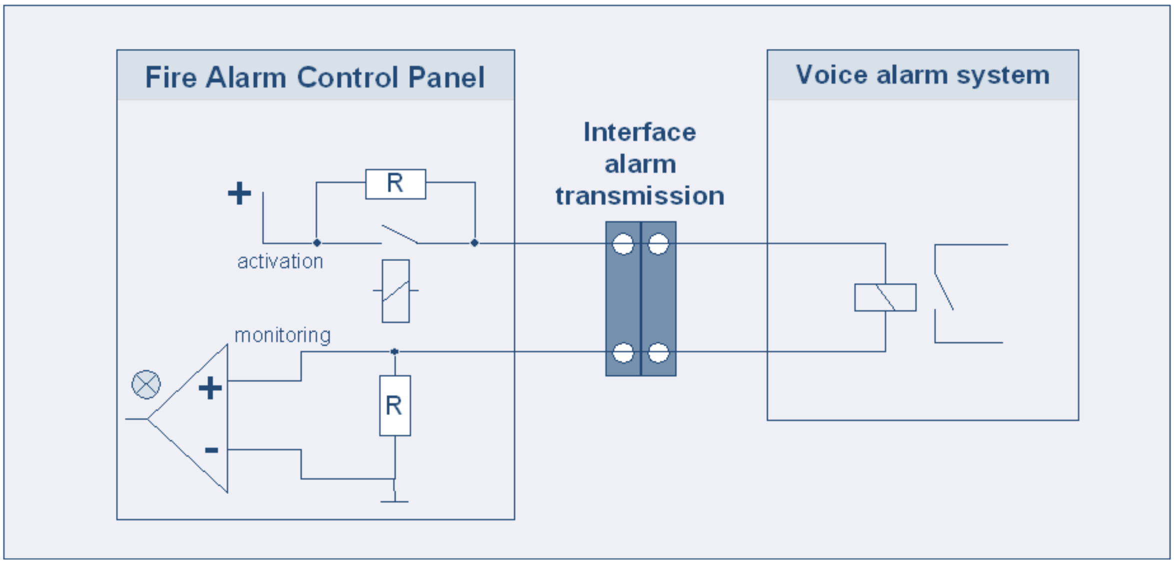


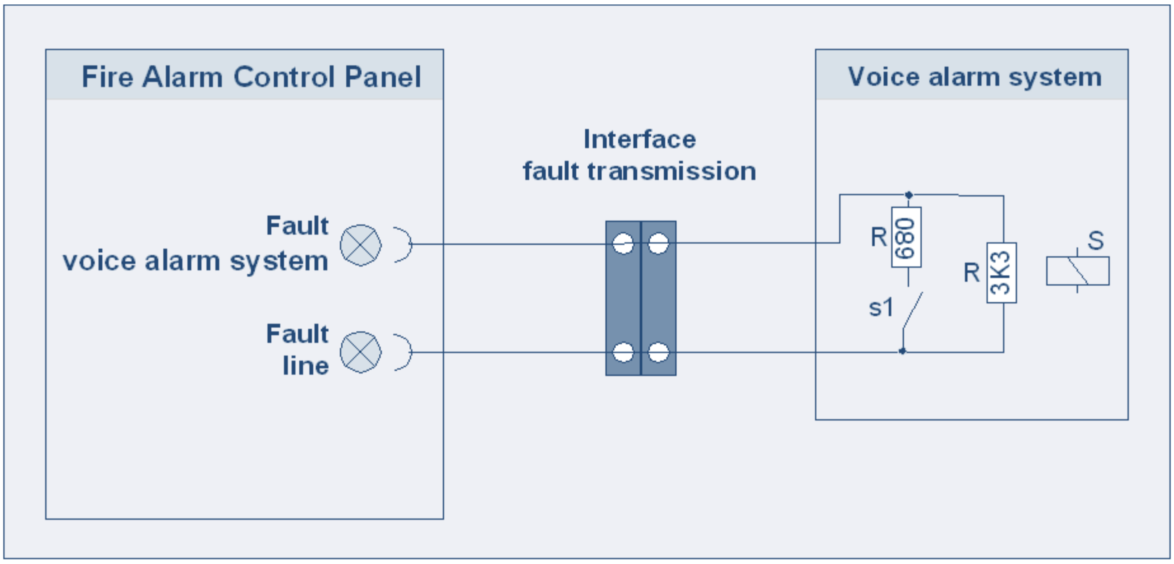
Fig.: Wiring and monitoring of the alarm transmission (example)

Output

It must be possible to transmit the following signals/messages:

- Fault VAS (collective signal).
- Each deviation (error) from the target status of the VAS.

Alternatively, transmission via a suitable data interface (as per VdS 2463 and 2465) is also permitted.



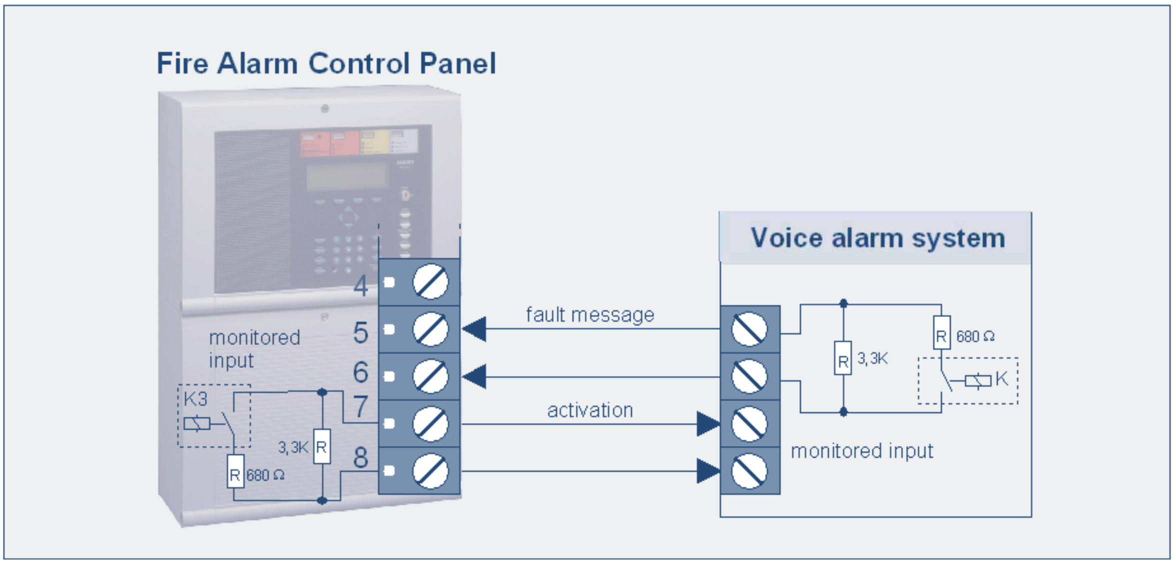


Fig.: Wiring – Voice alarm system fault (example)

2.10 Configuration software DESIGNER D1

The construction of the system with different components is graphically displayed in the configuration software >DESIGNER D1<.

This clear graphical representation means that it is possible to configure the VAS quickly and easily.

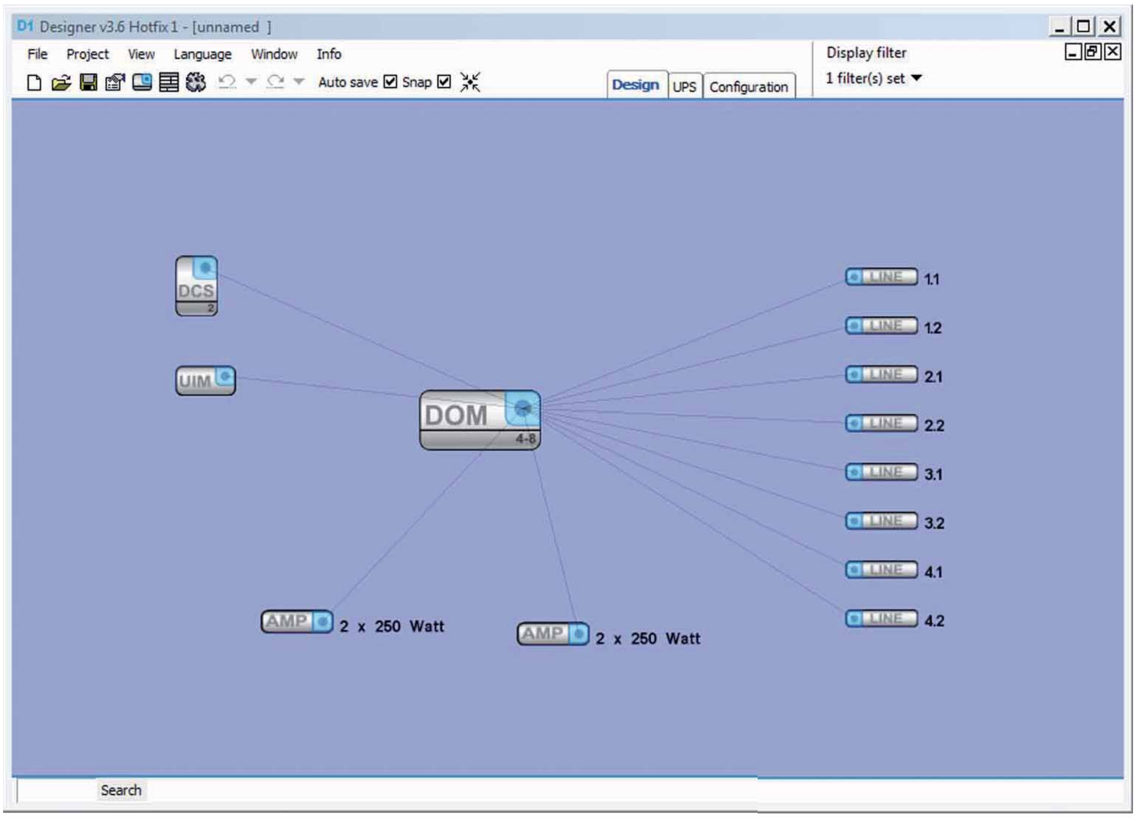


Fig. Graphical user interface >DESIGNER D1< (example 1)

The screenshot above shows a DOM4-8 with 8 loudspeaker circuits (LINE) and two 300 W final amplifiers.

A terminal and a universal interface module (UIM) are connected to the DOM. The diagram below shows the VAS components which correspond to this screenshot.

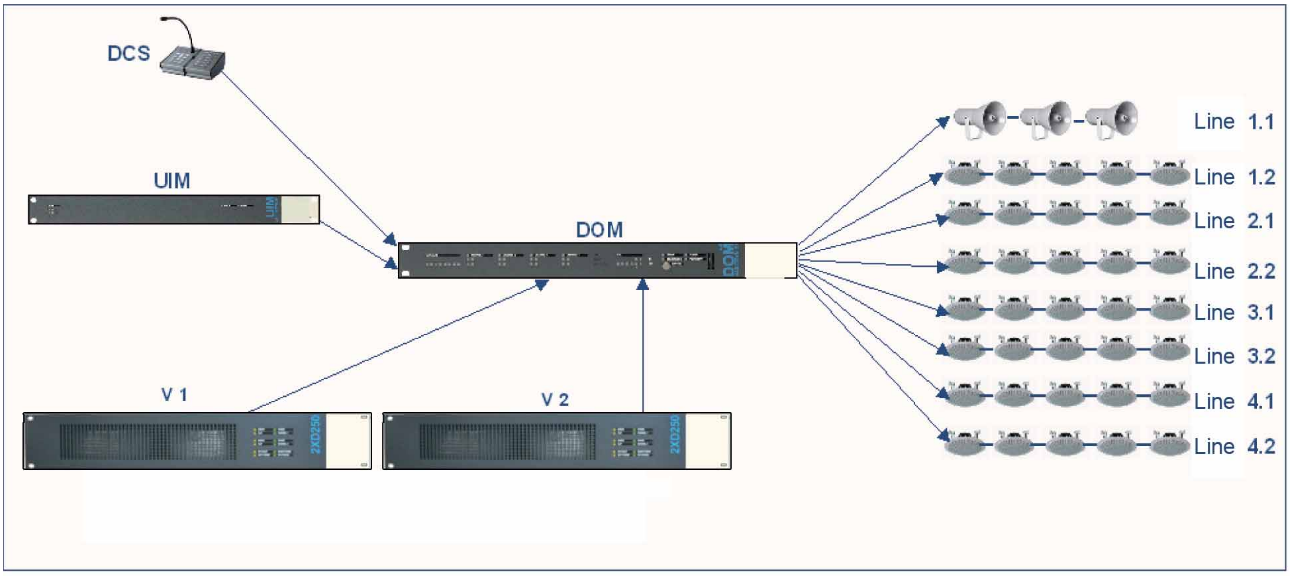


Fig.: Actual hardware construction for example 1

In the following screenshot, different calls are applied for the terminals (DCS) which are assigned to the different call buttons of the terminal.

In this example, 3 calls (e.g. fire announcement, evacuation announcement and test announcement) are applied for the terminal. The individual calls can be selected and parameterised separately using the right-hand mouse button (side click menu).

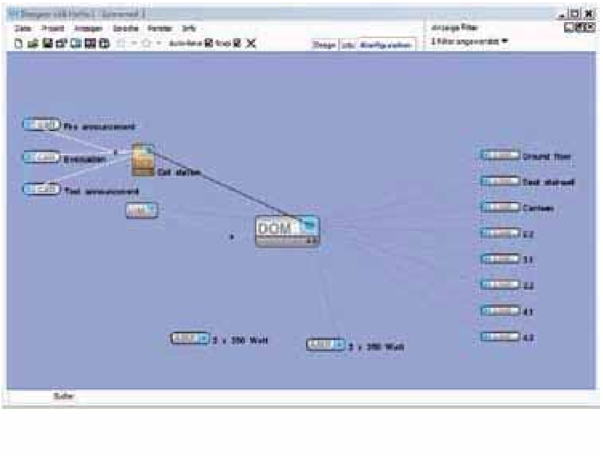


Fig. Graphical user interface >DESIGNER D1< (example 1)

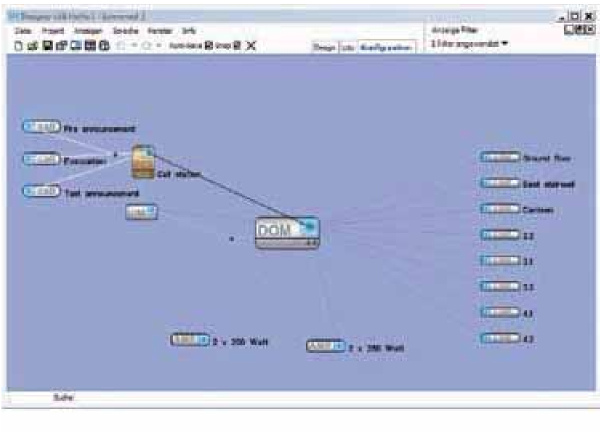


Fig.: Graphical user interface for UPS dimensioning

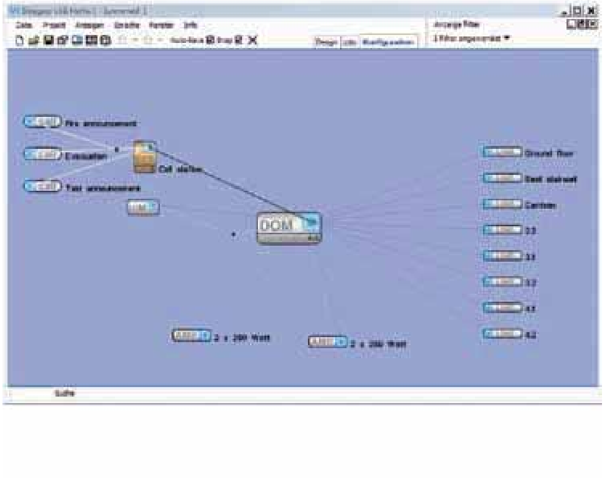


Fig.: Graphical user interface for serial connection

2.11 Tables and calculations

2.11.1 Cable dimensions

All specifications for the cable cross section area are given in millimetres [mm], related to a maximum voltage loss of 10 %.

A maximum of 500 W can be switched via the relay contact of a digital output module (DOM).

Z	100 V		Distance/interval [m]								
Ohm	Watt	AMP	5	10	20	30	40	50	100	150	200
1600	6	0.06	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
840	12	0.12	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
420	24	0.24	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
335	30	0.30	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
250	40	0.40	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5
200	50	0.50	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.75
125	80	0.80	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.75
100	100	1.00	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.75
80	125	1.25	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.75	0.75
65	150	1.54	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.75	1.0
50	200	2.00	0.3	0.3	0.3	0.3	0.3	0.5	0.75	1.0	1.5
40	250	2.50	0.3	0.3	0.3	0.3	0.5	0.75	1.0	1.5	2.0
32	300	3.13	0.3	0.3	0.3	0.5	0.5	0.75	1.5	2.5	2.5
25	400	4.00	0.3	0.3	0.3	0.5	0.75	1.0	1.5	2.0	2.5

Z	100 V		Distance/interval [m]								
Ohm	Watt	AMP	250	300	400	500	600	700	800	900	1000
1600	6	0.06	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
840	12	0.12	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.5
420	24	0.24	0.3	0.3	0.5	0.5	0.5	0.75	1.0	1.0	1.5
335	30	0.30	0.3	0.3	0.5	0.75	0.75	1.0	1.0	1.5	1.5
250	40	0.40	0.5	0.5	0.75	0.75	1.0	1.5	1.5	2.5	2.5
200	50	0.50	0.75	0.75	0.75	1.0	1.5	2.5	2.5	2.5	2.5
125	80	0.80	0.75	1.0	1.5	2.5	2.5	2.5	2.5	4.0	4.0
100	100	1.00	1.0	1.5	1.5	2.5	2.5	2.5	4.0	4.0	4.0
80	125	1.25	1.0	1.5	2.0	2.5	4.0	4.0	4.0	4.0	6.0
65	150	1.54	1.5	1.5	2.5	2.5	4.0	4.0	4.0	6.0	6.0
50	200	2.00	2.0	2.5	4.0	4.0	6.0	6.0	6.0		
40	250	2.50	2.5	4.0	4.0	6.0	6.0	6.0			
32	300	3.13	2.5	4.0	4.0	6.0					
25	400	4.00	4.0	6.0	6.0	6.0					

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2.11.2 Calculation of the required battery capacity

In order to allow for interrupt-free emergency power supply to the VAS via accumulators, the required battery capacity must be determined.

For this purpose, the emergency power must be measured for the actual construction of the VAS in the ready-for-operation state.

Example:
Emergency power bypassing time = 30 hours Measured quiescent current = 0.3 A

$Capacity_{Quiescent} = I_{Quiescent}$ 0.3 A x 30 h = 9 Ah

The battery capacity required in an emergency (case of alarm) must be added to this calculated capacity value for "normal" operation in the ideal state of the SAA. This battery capacity must be designed so that in the emergency power bypassing time required in the example given here, the necessary alarm current is available for 30 minutes (0.5 hours). The alarm current is considerably higher than the quiescent current value, depending on the scope of the activation and the system construction. This example assumes that there is a measured alarm current of 20 A.

$Capacity_{Alarm} = I_{Alarm}$ 20 A x 0.5 h = 10 Ah

The required battery capacity for this example is 19 Ah.

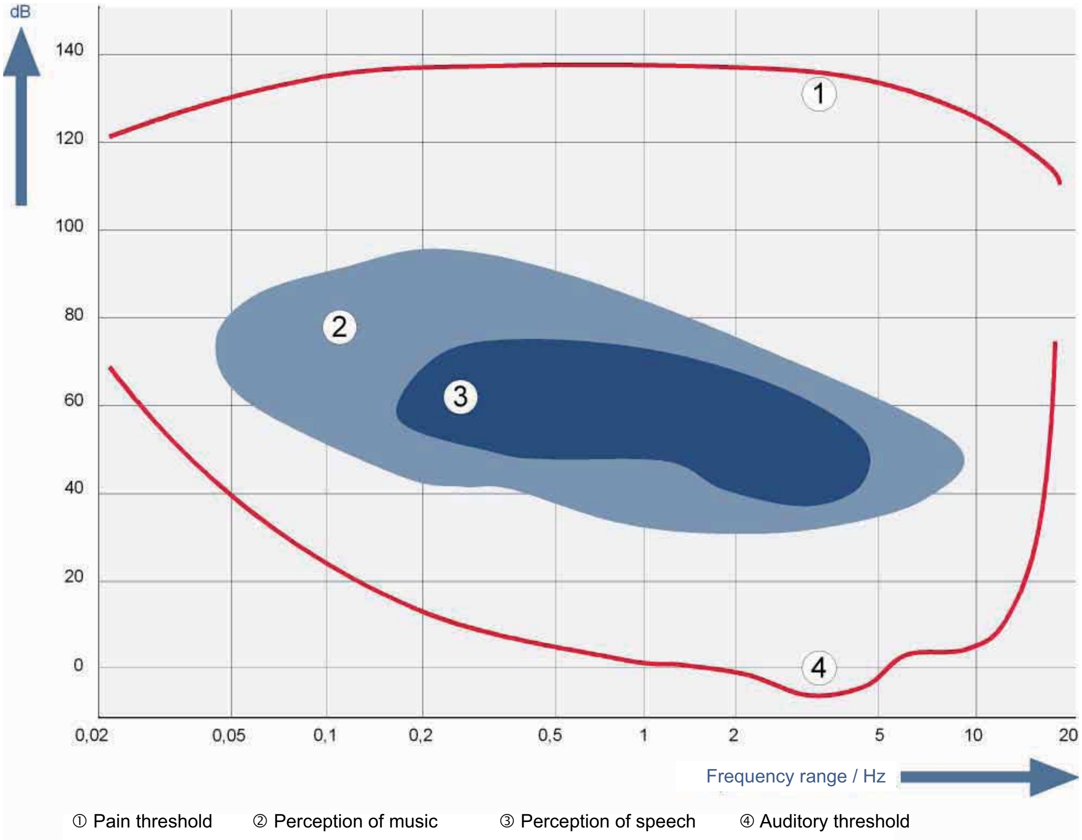
Standardised requirements e.g. charging time of the accumulators, must also be considered for the final stipulation of the battery capacity (see chapter "Emergency power supply").

Only approved accumulators from the manufacturer of the VAS/fire alarm system may be used.

Independent power supply (UPS)
The UPS must be designed so that the required current (or power) for the operation of the VAS in the emergency power bypass time is guaranteed to be supplied.

Temperature in °C	Daily capacity loss in %
18	0.0108
19	0.0120
20	0.0130
21	0.0139
22	0.0148
23	0.0156
24	0.0166
25	0.0177
26	0.0189
27	0.0204
28	0.0220
29	0.0239
30	0.0261
31	0.0286
32	0.0314
33	0.0345
34	0.0381
35	0.0421
36	0.0466
37	0.0517
38	0.0575
39	0.0639
40	0.0713
41	0.0797
42	0.0891
43	0.0999
44	0.1122
45	0.1261
46	0.1421
47	0.1602
48	0.1808
49	0.2043
50	0.2309

2.11.3 Graph of human hearing capability



2.11.4 Power and level ratios

The table shows that a doubling of the sound pressure "p" also means a concurrent increase of the sound pressure level "L" by +6 dB

Level [dB]	Energy ratio	Sound pressure
0	1	1
1	1.25	1.12
2	1.6	1.25
3	2	1.4
4	2.5	1.6
5	3.15	1.8
6	4	2
12	15.8	4
20	100	10
30	1,000	32
40	10,000	100
50	100,000	316
60	1,000,000	1,000
80	100,000,000	10,000
100	10,000,000,000	100,000
120	1,000,000,000,000	1,000,000

+ 6 dB (from 0 to 6)

+ 6 dB (from 6 to 12)

2.11.5 Sound production and propagation

Distance to sound source	Sound pressure	Note
1 m	0 dB	Reference point for value (e.g. 90 dB at 1 m distance)
2 m	-6 dB	Corresponds to half the original sound pressure
4 m	-12 dB	Corresponds to one-fourth of the original sound pressure
8 m	-18 dB	
16m	-24 dB	
32 m	-30 dB	Corresponds to 1/32nd of the original sound pressure

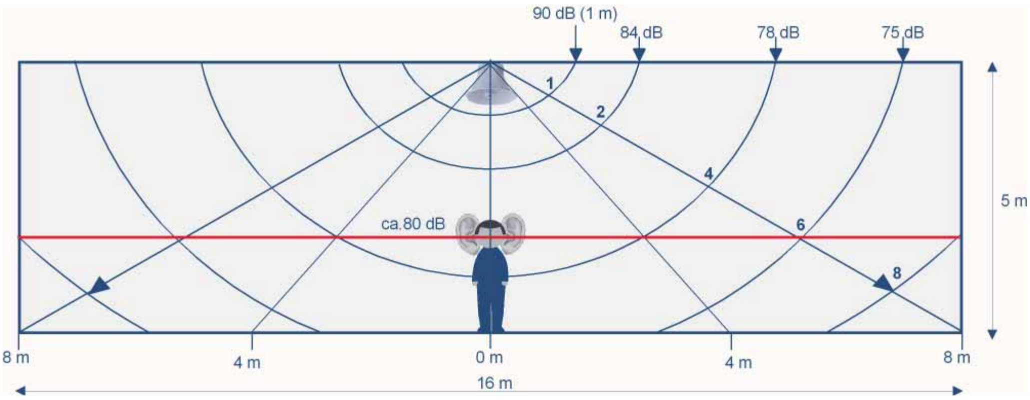


Fig.: Decrease in sound pressure level based on distance

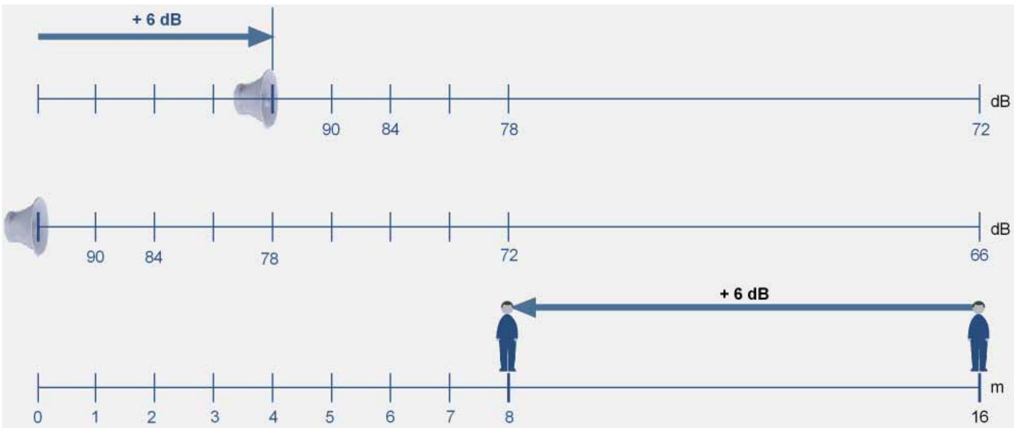
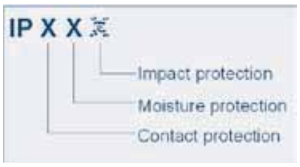


Fig.: Increase in the sound pressure level by changing the position

2.11.6 IP Ratings

IP	1st position Contact and foreign body protection	1st position Moisture protection	3rd position Impact protection against impact energy up to ...
0	---	---	---
1	... Foreign bodies > 50 mm	... Dripping water falling vertically	... 0.225 J = strike of 150 g from a height of 15 cm
2	... Foreign bodies > 12 mm	... Dripping water falling at a slant	... 0.375 J = strike of 250 g from a height of 15 cm
3	... Foreign bodies > 2.5 mm	... Spray	... 0.5 J = strike of 250 g from a height of 20 cm
4	... Foreign bodies > 1 mm	... Splash water	---
5	... Dust deposit	... Water jet	... 2.0 J = strike of 500 g from a height of 40 cm
6	... Dust entrance	... Flooding	---
7	---	... On immersion	... 6.0 J = strike of 1.5 kg from a height of 40 cm
8	---	... On submersion	---
9	---	---	height of 40 cm



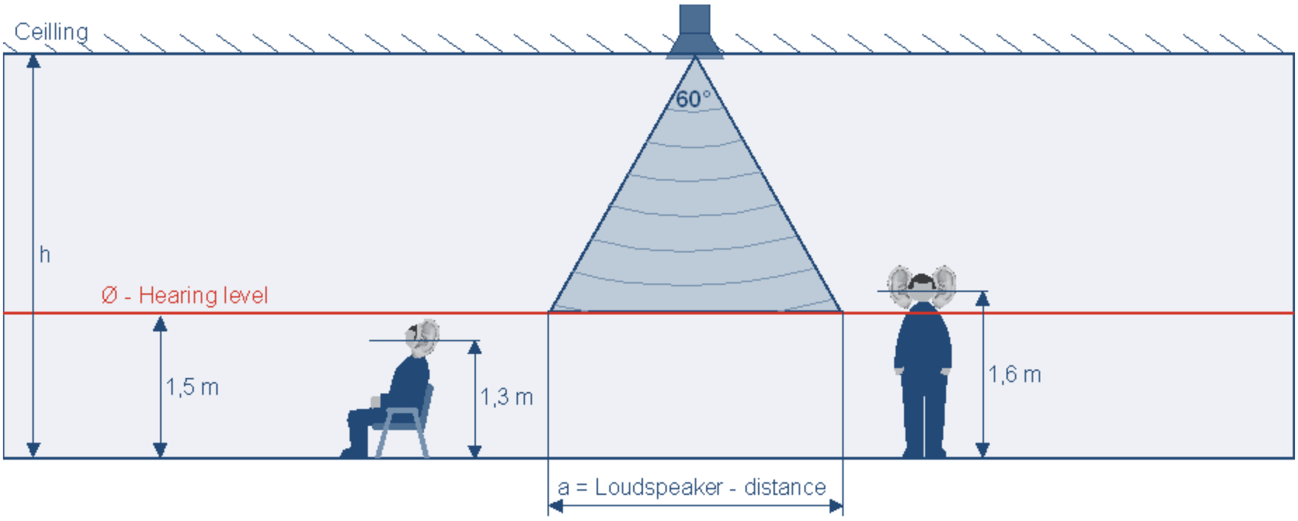
2.11.7 Table of examples of the values for the frequency range of the individual signal types

Signal type	Transmission range [Hz]
Alarm/announcement	400 - 4000
Background music	100 - 15000
Voice	200 - 10000
High-quality music reproduction	50 - 20000

Environment	Sound level (dB)
Residential area, at night	< 30
Individual offices	50
Open-plan offices	55-60
Railway platform *)	70 -< 110
Warehouses with fork-lift trucks	70-75
Production halls with machines or very loud traffic noise	> 80
Rock concert, disco	100 - 130

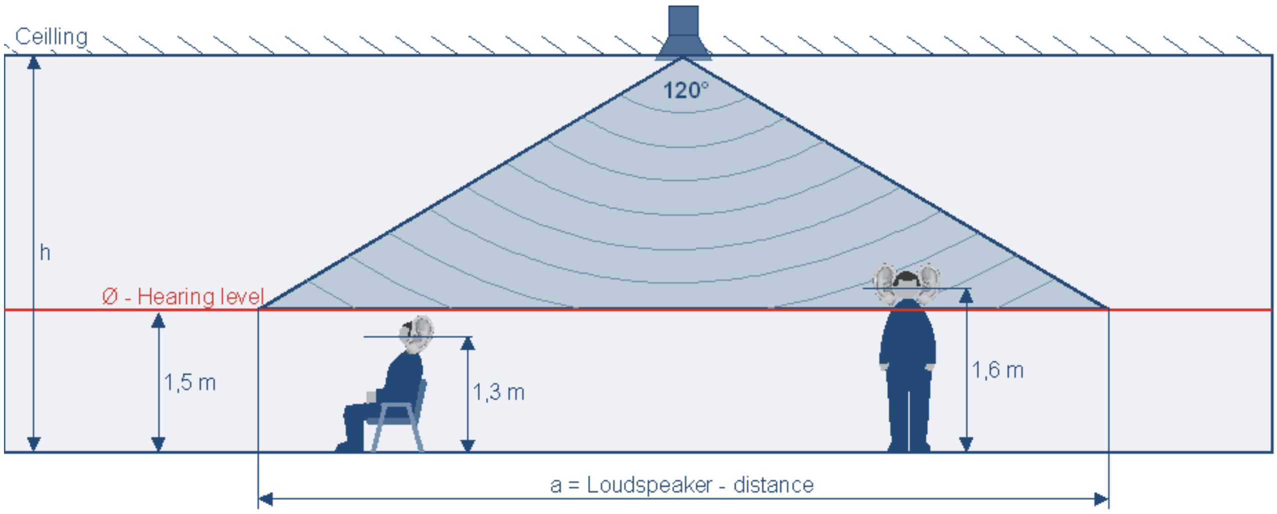
*) because of the big diffrence a very fast automatic volume leveling system is necessary.

2.11.8 Minimum supply area of a loudspeaker for optimum speech comprehensibility



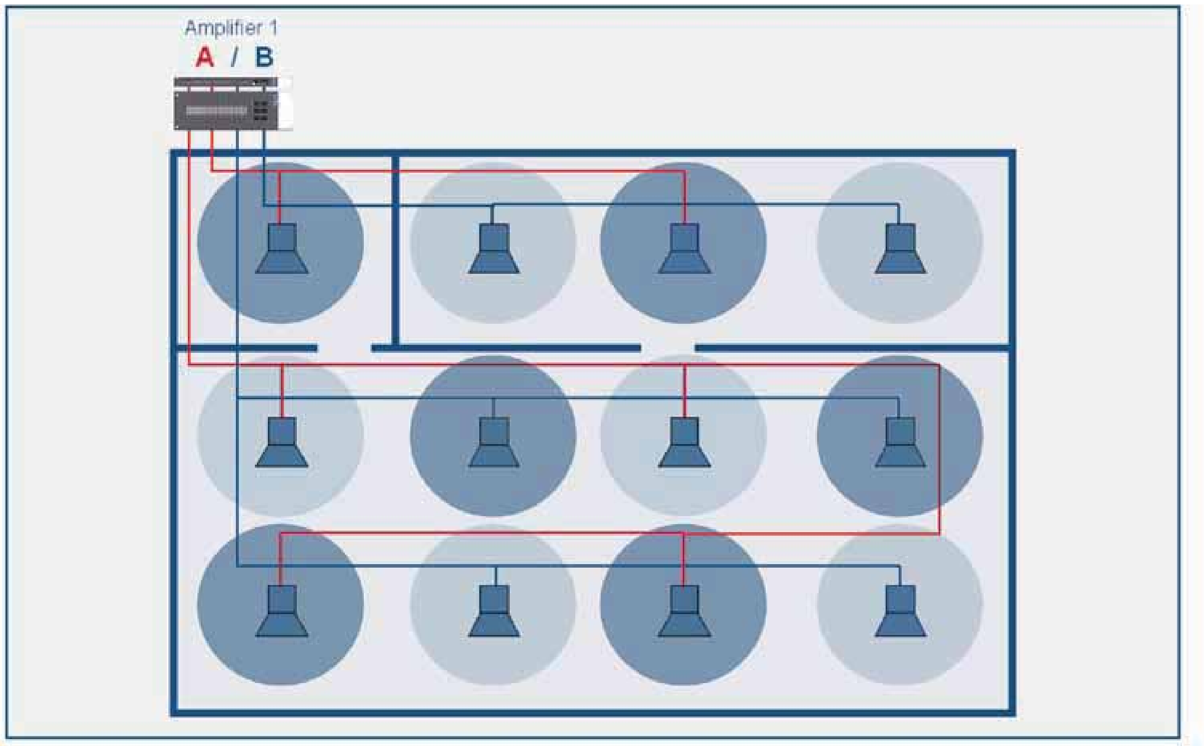
Ceiling height	3 m	3.5 m	4 m	4.5 m	5 m	5.5 m	6 m
Loudspeaker distance a	1.8 m	2.2 m	3 m	3.6 m	4.2 m	4.8 m	5.4 m
Supply area	3 m²	5 m²	9 m²	13 m²	18 m²	23 m²	29 m²

2.11.9 Maximum possible supply area a x a of a loudspeaker for music and speech

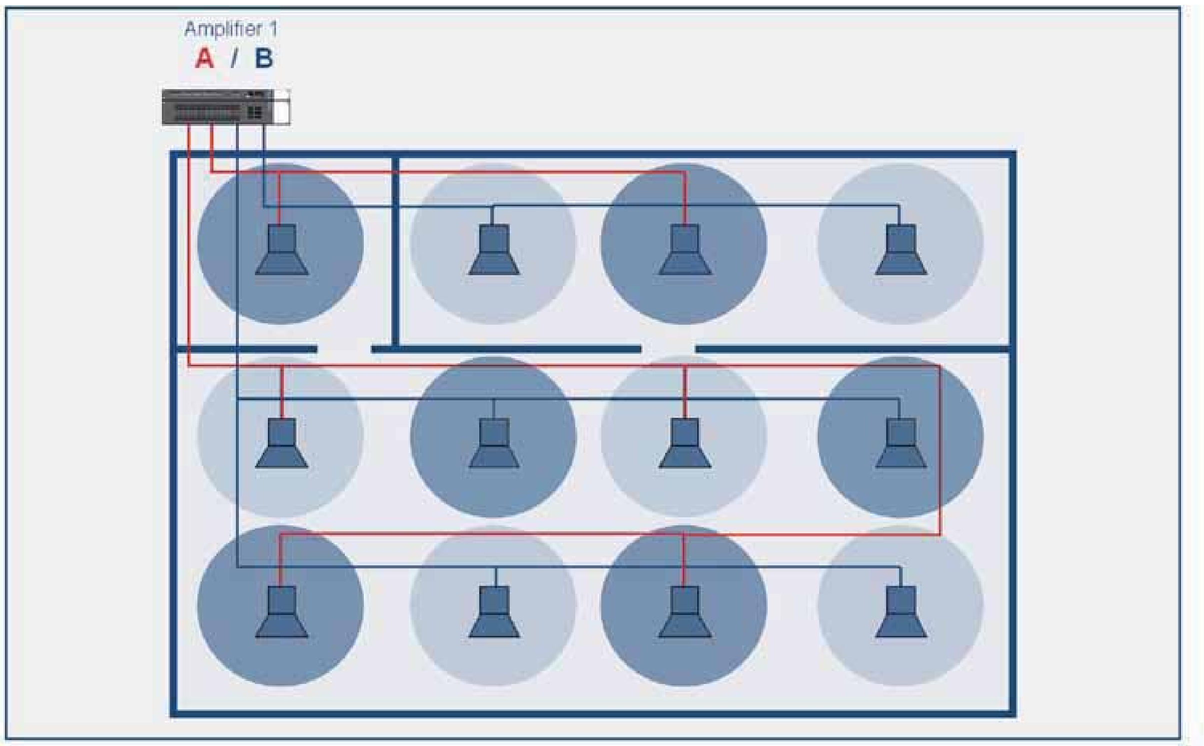


Ceiling height	3 m	3.5 m	4 m	4.5 m	5 m	5.5 m	6 m
Loudspeaker distance a	5.5 m	7 m	9 m	10.5 m	12 m	14 m	16 m
Supply area	30 m²	49 m²	81 m²	110 m²	144 m²	196 m²	256 m²

2.11.10.1 A/B principle for loudspeakers (with integrated transformers) with a single Power amplifier

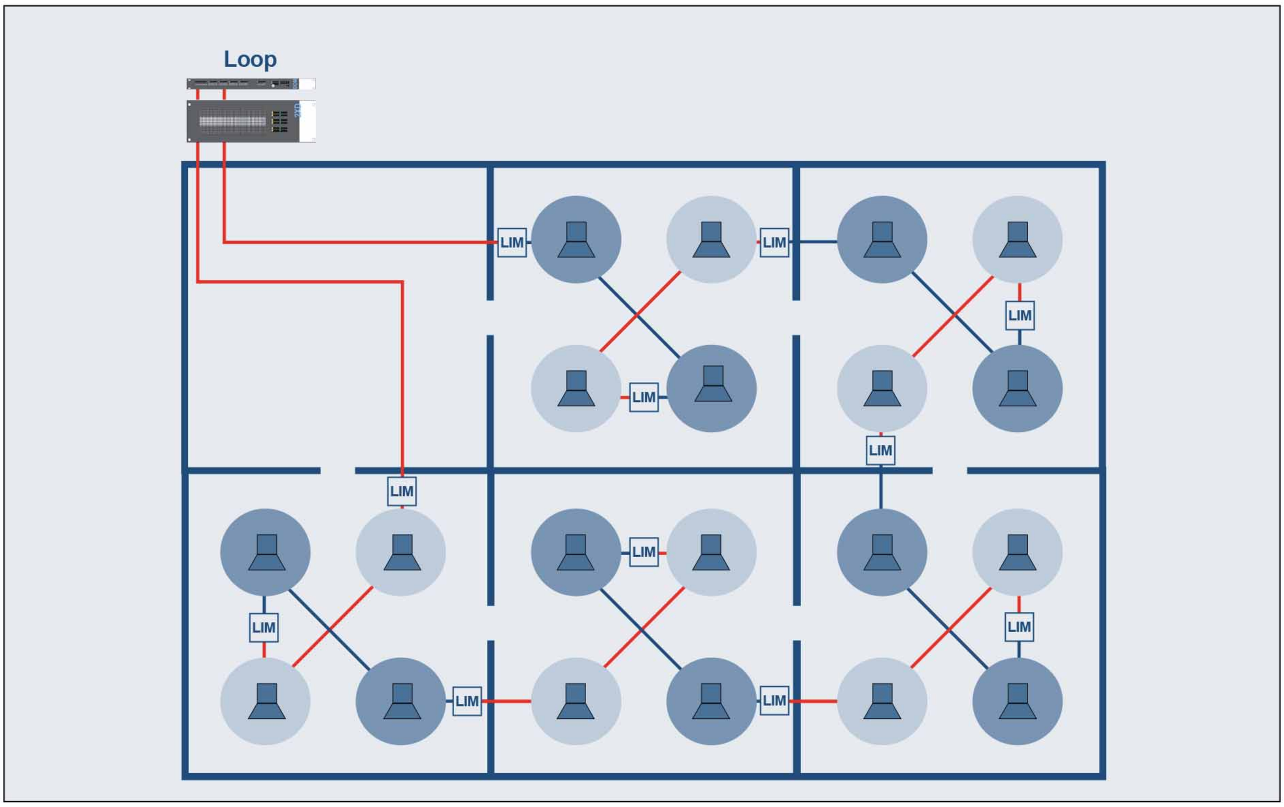


2.11.10.2 A/B principle for loudspeakers (with integrated transformers) with two separate Power amplifiers

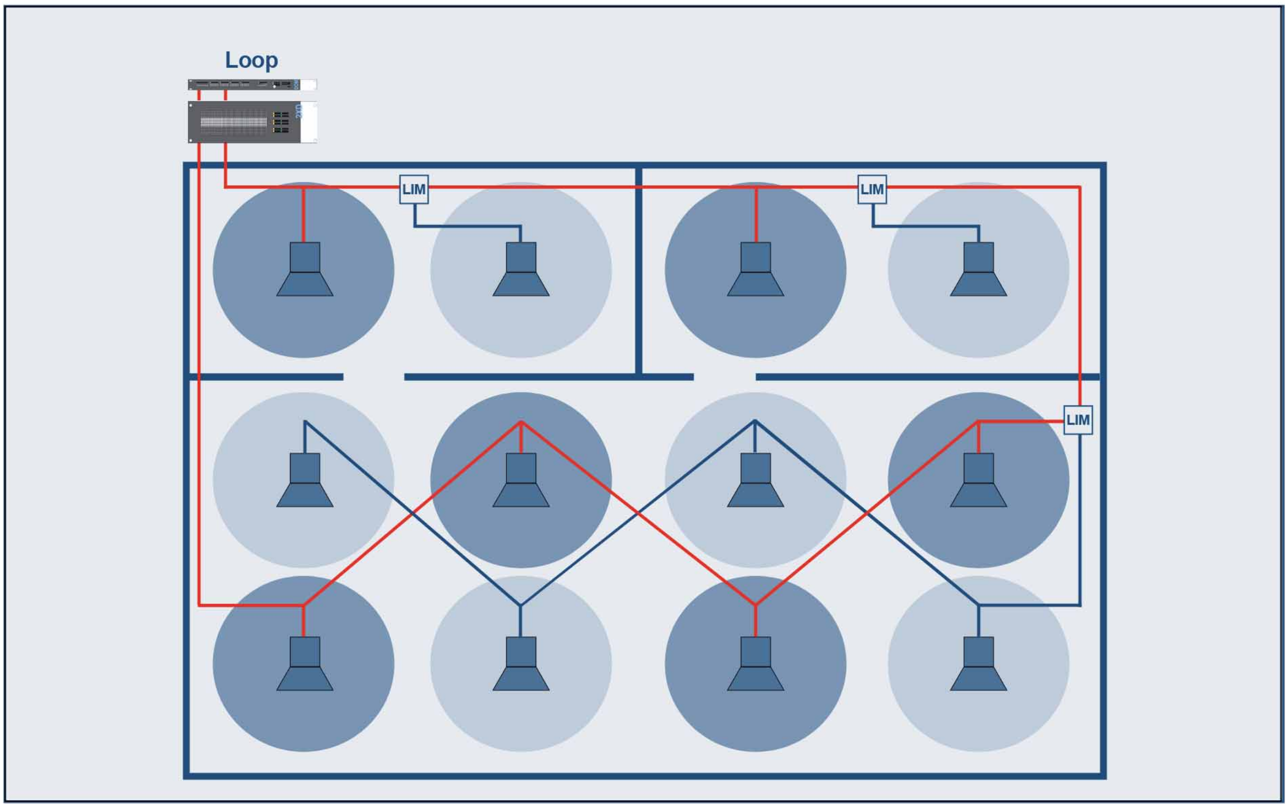


2.11.11 Loop Isolation Module (LIM)

2.11.11.1 loudspeaker loop cabling for loudspeaker (with integrated transformers)



2.11.11.2 loudspeaker loop cabling for loudspeaker (with integrated transformers) using the T-spur of the LIM



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