

Code of practice for

The design, planning, installation, testing and maintenance of sound systems

ICS 33.160.30

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Committees responsible for this British Standard

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- Association of British Theatre Technicians
- Audio Engineering Society
- British Broadcasting Corporation
- British Educational Suppliers' Association
- British Federation of Audio
- British Radio and Electronic Equipment Manufacturers' Association
- British Telecommunications plc
- Federation of the Electronics Industry
- Independant Television Association (ITVA)
- Institute of Sound and Communication Engineers
- Institution of Electrical Engineers
- International Association of Broadcasting Manufacturers
- Professional Lighting and Sound Association
- Royal Institute of British Architects
- Royal National Institute for Deaf People
- Society of Cable Television Engineers

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- British Entertainments and Discotheque Association
- District Surveyors' Association
- Health and Safety Executive
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Foreword

This British Standard has been prepared by Technical Subcommittee EPL/100/3 in conjunction with Panel EPL/110/3/2.

This code of practice is a revision of BS 6259:1982 and has been developed in an expanded form at the express wish of industry, as the original code of practice was mainly applicable to small installations. The standard recommends good accepted practice for the accomplishment of the defined tasks and their sequence as followed by competent practitioners. This standard supersedes BS 6259:1982, which is withdrawn.

Annex A is reproduced from RIBA Publications Plan of work for project team operation [10], which is abbreviated and adapted from RIBA Publications RIBA Handbook [11].

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of conformity are not misleading.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 116, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1.0 Introduction

1.0.1 How to use this code of practice

This standard is divided into sections intended for:

- a) purchasers of sound systems (see particularly sections 1 and 3);
- b) designers of sound systems (see sections 4, 5, 6 and 9);
- c) installers of sound systems (see sections 6 and 7);
- d) users of sound systems (see sections 7 and 8).

1.0.2 General

Sound and communications systems are becoming increasingly integrated into building design, either forming part of the emergency warning/fire alarm and evacuation system of a building, complex or open-air site, general announcement (paging) system, or as a special design feature enabling music or live entertainment to be played or relayed. An even greater need for early consideration and appropriate integration of the sound system occurs in public buildings housing auditoria, lecture theatres, and conference facilities where high quality sound reinforcement systems are required. The system chosen should complement the natural acoustics of such halls.

In buildings with hostile acoustic environments, such as noisy and/or reverberant leisure centres, ice rinks, and swimming pools, special care needs to be taken in order to ensure that adequate speech intelligibility is achieved.

Where large crowds gather noise levels can be high, so the system should be capable of comfortably overcoming the anticipated noise level and providing a clear and distortion-free signal. Similar considerations also apply to noisy industrial process areas and plant rooms.

In addition to the more usual speech and music signals, sound systems may be used to transmit warning tones or signals, or information tones or signals (for example to indicate factory processes, swimming pool sessions). Sound systems are frequently required to interface with or form an integral part of other systems such as fire alarm and emergency evacuation control systems, or systems for the hard of hearing, audiovisual (AV) systems, video and film projection systems, language interpretation systems, and broadcast and relay systems.

In order to achieve an appropriate sound quality and intelligibility, a sound system should meet certain performance criteria, which are dependent upon the type and application of the system concerned. The basic characteristics to be considered include:

- a) sound level;
- b) overall frequency response;
- c) signal-to-noise ratio;
- d) freedom from distortion and echoes;
- e) reliability;
- f) freedom from interference both to and from other systems operating within the vicinity.

Humidity and other climatic conditions, such as wind strength and direction, influence how a system performs on individual occasions, especially at open-air sites.

Systems used for fire alarm and emergency announcement purposes should be appropriately fire protected and monitored, and incorporate secondary power supply back-up and switch-over facilities (see BS 5839-1 and BS 5839-4 and BS 7443). There may also be the need for emergency override and priority for emergency messages, and it may be necessary to divide the system coverage into zones.

All relevant aspects of local acoustic and environmental conditions should be taken into account at the system planning and design stage.

1.0.3 Sound systems

1.0.3.1 Types of sound system

Sound systems can be divided into three different types, each designed to fulfil a particular purpose.

- a) Sound reinforcement system. A sound system intended to reinforce sound from orators, actors and musicians, so that their voices can be heard in areas and at distances beyond the range of an unassisted human voice or solo musical instrument.

NOTE 1 In these systems the microphones are exposed to the sound produced by the loudspeakers.

- b) Sound distribution system. A sound system designed to distribute audio signals from a source in one or more locations to a number of other locations through a multiplicity of loudspeakers.

NOTE 2 In these systems the microphones, if used, are not normally exposed to the sound produced by the loudspeakers.

- c) Sound reproduction system. A sound system designed for the reproduction, usually through a small number of loudspeakers, in one (or in a small number of) location(s) of sound signals generated or reproduced in another location.

NOTE 3 In these systems the microphones (if any) are not exposed to the sound produced by the loudspeakers.

A complete sound system may consist of a number of different types of subsystem, which may be interconnected or entirely separate.

1.0.3.2 Sound reinforcement system

This type of system enables the sounds of speech, singing or music produced by a lecturer, actor, singer or musical instruments, to be heard satisfactorily by listeners in the same acoustic area but at a distance (which may be considerable) from the sound source, for example, in an auditorium, lecture theatre, concert hall, arena or other closed or open areas. There is a limitation on the sound level (see note) in the area due to the microphones being exposed to the sounds produced by their associated loudspeakers. Above a certain sound level, depending on the acoustic properties of the area, acoustic feed-back occurs, which is heard as a “howl” or “ring” from the loudspeakers.

NOTE Strictly speaking, it is the amount of amplification, not the sound level produced by the system, that determines whether acoustic feedback occurs. However, for a constant input to the system, for example a person speaking in a normal voice at a fixed distance from a microphone, the sound level produced by the system is proportional to the amount of amplification (see 1.0.3.5.2).

Sound reinforcement systems used for the reproduction of live popular music in large auditoria or open air sites employ amplifiers of high output power and the loudspeaker systems have extended low frequency response. The dispersion of middle and high frequencies is closely controlled by special types of horn loudspeakers. Very careful microphone techniques are required in order to obtain the high sound pressure levels required without acoustic feedback. Sophisticated audio processing equipment may also be required in order to obtain these very high sound pressure levels.

1.0.3.3 Sound distribution system

A distribution system enables the sounds of speech, music, tone etc., occurring at one or more places to be reproduced, usually at the same time, in another place or places, for example messages or announcements spoken into a microphone by an unseen announcer. Announcements or background music may also be recorded in analogue or digital formats. These signals may be reproduced, amplified and distributed to a considerable number of loudspeakers to cover a large area.

1.0.3.4 Sound reproduction system

Such systems are mainly for the realistic reproduction of music (and speech) usually from recordings, disc, tape (cassette) or film. Large full range loudspeakers are usually employed, with high quality power amplifiers. Noise reduction and other sound processing equipment may be necessary to optimize the fidelity of reproduction.

1.0.3.5 Acoustic considerations

1.0.3.5.1 General

This introduction does not give detailed considerations of acoustic factors as they apply to sound systems generally, but a few basic factors which affect sound system installations are as follows:

- a) longer than acceptable reverberation times;
- b) the background noise level at the proposed site;
- c) the distances between the sound source and the nearest and furthest listeners;
- d) sound insulation or reduction of overspill;
- e) acoustic absorption;
- f) echoes due to wall and other surface reflections.

1.0.3.5.2 Reverberation

Reverberation is the prolongation of sound within a space. When excessive it can lead to a loss of intelligibility of speech. For music, the effect of reverberation is generally less; it can be beneficial or not, depending on circumstances. In lay terms, the reverberation time of a space is the time taken for a sound to decay to inaudibility.

In large spaces, such as some stone-built churches and cathedrals, reverberation can be the most difficult feature. A reverberation time of much more than 1 s becomes difficult to deal with and a solution is the use of a large number of loudspeakers, each producing a low sound level.

An already constructed area obviously cannot be rebuilt. Therefore, from experience, a careful choice of loudspeaker types, the number required, the position of each unit, the overall frequency response and the most suitable type of microphone, is essential.

1.0.3.5.3 Background noise level

For any sound system, other than a background music system, to be satisfactory, it is essential that the sound level of the wanted sound exceeds that of any unwanted sound by a sufficient margin. It is often necessary to operate various types of loudspeaker at different sound levels, depending on the amount of sound absorbing materials that may be on the ceilings, walls or floors, which in some locations can create a quite “acoustically dead” area.

1.0.3.5.4 *Distant listeners*

In sound reinforcement systems, if the loudspeakers are closer to the listener than the original sound source, the sound may appear to come from the loudspeaker not the source. Where additional loudspeakers are used in a reinforcement or reproduction system, a similar problem can occur. Where some listeners are a considerable way from the sound source but are in the same space, it may be necessary to employ delayed techniques to preserve the impression that the sound is coming from the direction of the original source rather than from the loudspeakers.

1.0.3.5.5 *Sound insulation and reduction of overspill*

As well as providing satisfactory sound coverage of the target area, a sound system should not cause a nuisance to adjoining areas. This depends on the sound level produced by the system, the sound insulation provided by the building in which the system is used (if any) and the usage of the adjoining areas.

For sound generated in buildings of heavy construction, the existing sound insulation is often adequate. For buildings of lightweight construction, or with substantial apertures in the enclosing walls or roof, it may be necessary to improve the sound insulation.

At open-air sites, overspill of sound into unwanted areas is normally reduced by the use of directional loudspeakers, appropriately orientated.

1.0.3.5.6 *Acoustic absorption*

The acoustic characteristics of a space depend on the amount of acoustic absorption present. This may change due to redecoration, movement of furniture or fittings, the number of occupants and, for large spaces, atmospheric conditions.

1.0.3.5.7 *Echoes*

An echo is a repetition after a perceptible delay of a sound due to the original sound being reflected and returned. Such a reflected sound has also to be loud enough for it to be recognized as an echo.

Echoes are generally detrimental to speech intelligibility and the perception of other sounds. Echoes may occur in large enclosed spaces, and where there are trees, buildings or high ground near an open-air site. Due to the distances involved, such echoes can arrive with a sufficient delay after the original sound to be not only destructive of intelligibility, but also to interfere seriously with an announcer's ability to speak.

1.0.4 Consultants

For large installations, or where there are special problems, the purchaser may wish to employ the services of a specialist consultant. Most consultants can offer a range of services, from an initial report or feasibility study, to full specification and contract supervision. If the sound system is part of a major project, such as the design of a new building, the main project consultant, for example the architect, may employ a specialist sound system consultant (see 3.2.4).

1.0.5 Site inspection

Whenever installation or modification of a sound system is being considered, a site inspection should be carried out. For a simple system, a brief visit may be all that is required, but where the system is complex or the space has particular complications, a detailed site survey with tests and measurements may be necessary. Where the space has not yet been built, inspection of the plans or the work in progress may be all that is possible. From the beginning, site visits should consider acoustic, aesthetic, structural and technical requirements.

1.0.6 Limitations of sound reinforcement

In a sound reinforcement system, the person(s) speaking, the microphone(s) and the loudspeaker(s) are all in the same space. Severe acoustic feedback, resulting in unacceptable performance of the system, occurs if the sound level from the loudspeakers at the microphone position is not much less than the sound level at the microphone from the person speaking.

NOTE Acoustic feedback causes a "ringing" effect on speech, or even a continuous howl or whistle.

1.0.7 Audio-frequency induction-loop systems and infra-red systems

Systems for the hard of hearing may either be based on an Audio-Frequency Induction-Loop System (AFILS) (see BS 7594), which enables any hearing aid with a "telecoil" usually identified by the aid having an additional switch position marked "T", or via an infra-red transmission system (IR) (see BS 6418). The latter system requires a special receiver but may have the ability to transmit up to 12 separate channels simultaneously, making it very suitable for multi-lingual systems, for example, "museum tour" systems. Another application is "audio description" for blind persons.

AFILS and IR systems may also be used to transmit speech or background music to personnel working in very noisy conditions where hearing protectors are required. Special protectors incorporating a receiver and in-built miniature loudspeaker/earphone are available, to maintain “wireless” communication. In certain circumstances, radio transmission may be used, if the conditions for granting a licence are satisfied.

1.1 Scope

This British Standard gives recommendations for the design, planning, installation, testing and maintenance of sound systems intended for communicating speech, music and/or other signals. Unless otherwise stated, the recommendations in this standard apply to monaural systems and may need to be varied for stereophonic systems (see 2.6).

NOTE Additional requirements and recommendations for systems to be used for the reproduction of emergency warning signals are included in various other standards, for example, in BS 7443 and BS 5839-1 and BS 5839-4.

This standard is not applicable to:

- a) simultaneous interpretation systems (see ISO 2603);
- b) some of the aspects associated with recording studios, and applies only to some types of broadcasting studio;
- c) home entertainment systems;
- d) some aspects of systems intended only to modify the perceived acoustic characteristics of the space.

1.2 References

1.2.1 Normative references

This British Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate points in the text and the cited publications are listed on page 115. For dated references, only the edition cited applies; any subsequent amendments to, or revisions of the publications apply to this British Standard only when incorporated in the reference by updating or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

1.2.2 Informative references

This British Standard refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on page inside back cover, but reference should be made to the latest editions.

1.3 Definitions

For the purposes of this standard, the following definitions apply.

1.3.1

sound system

a system including amplifiers, loudspeakers and sources of speech, music or tone signals, which is intended to present the signals to persons outside the household environment

1.3.2

sound reinforcement system

a sound system intended to reinforce sound signals from actors, musicians, etc

NOTE In these systems the microphones are exposed to the sound produced by the loudspeakers.

1.3.3

sound distribution system

a sound system intended to distribute signals from one or more locations to a number of other locations through a multiplicity of loudspeakers

NOTE In these systems, the microphones are not normally exposed to the sound produced by the loudspeakers.

1.3.4

sound reproduction system

a sound system intended for the reproduction in one (or a small number of) location(s) of sound signals generated in another location, usually through a small number of loudspeakers

NOTE In these systems, the microphones are not exposed to the sound produced by the loudspeakers.

1.3.5

acoustic feedback

the energizing of a microphone by the acoustic output of a loudspeaker of the same sound reinforcement system

NOTE As the effect increases so does the distortion, which may become intolerable, and eventually the system may oscillate continuously at some frequency, usually audible, at which the microphone to loudspeaker gain exceeds the loss in the feedback path. The system is then said to howl-round.

1.3.6

channel

a signal path between input and output of a system

1.3.7

matching

the correct coupling of a source to a load, for example a microphone to an amplifier, or an amplifier to a loudspeaker system

NOTE Correct matching enables units to work together satisfactorily. It does not normally imply maximum power transfer between units.

1.3.8**user control**

a device usually operated manually, for varying some characteristic that may require adjustment or selecting a particular programmable configuration during the normal functioning of the equipment

1.3.9**pre-set control**

a device for varying some characteristic of the equipment, the use of which is not required during the normal functioning of the equipment. Such controls are used only for setting up the equipment and are usually arranged to be inaccessible to unauthorized persons

NOTE "User pre-sets" should be adjusted (if necessary) only by the user and then in accordance with the manufacturer's instructions. "Factory pre-sets", however, should be adjusted only by the manufacturer or authorized service agents

1.3.10**screened wiring**

wiring in which the insulated conductor or conductors are enclosed within a continuous electrically conducting screen

1.3.11**equalizer**

equipment used in a sound system to adjust the overall frequency response, i.e. that of the total signal path including the room or space

NOTE The performance of a sound system can often be most effectively improved by the provision of appropriate equalization. The setting of an equalizer should be regarded as, at least, semi-permanent, and should not be altered to change the "tone" of the system, or to compensate for deficiencies in input signals.

1.3.12**graphic equalizer**

a bank of band filters, each of whose loss or gain can be varied by means of a continuously variable control (usually a vertical sliding control)

1.3.13**parametric equalizer**

a set of one or more filters in which the centre frequency, response shape and, sometimes, the symmetry of each filter can be adjusted in addition to its loss or gain. Adjustable band limiting filters may also be provided

1.3.14**sound power level (L_w)**

ten times the logarithm to base ten of the ratio of the sound power under consideration (W) to a reference sound power (W_{ref}). The sound power level L_w expressed in decibels, is calculated as follows:

$$L_w = 10 \lg \frac{W}{W_{\text{ref}}}$$

NOTE The standard reference sound power (W_{ref}) is 10^{-12} W (1 pW)

1.3.15**sound pressure level (L_p)**

twenty times the logarithm to base ten of the ratio of the sound pressure under consideration (p) to the reference sound pressure (p_0)

the sound pressure level L_p , expressed in decibels, is calculated as follows:

$$L_p = 20 \lg \frac{p}{p_0}$$

NOTE 1 The standard reference sound pressure (p_0) is $20 \mu\text{Pa}$ in air.

NOTE 2 Unless otherwise specified, the sound pressures are understood to be expressed in root-mean-square values.

1.3.16**mixer**

a specialized preamplifier with facilities, to allow input signals from several sources to be controlled or combined or both

1.3.17**echo**

a sound heard as a repetition of a first hearing, due to the reflection of sound waves

NOTE Repetition of a sound may also occur without involving reflection in two other ways:

- if sound travels to a distant listener by more than one route and the path length differences result in arrival time differences of more than approximately 30 ms;
- if delayed signals are intentionally generated electronically.

1.3.18**long path delay**

the time interval between the generation of a sound and its perception at a distant point, due to the finite velocity of propagation of sound waves (approximately 340 m s^{-1} in air at 20°C)

1.3.19**line voltage**

a voltage of 0.775 V r.m.s. (corresponding to a power of 1 mW in 600Ω). When this voltage is used as a reference level in decibels (0 dB), it is written as 0 dB (0.775 V) or 0 dBu;

NOTE 1 Although the reference level is derived from a system having a characteristic impedance of 600Ω , such systems are rarely used now. See 9.16.3 and BS EN 61938.

NOTE 2 Some systems or equipment use other values of line voltage, not in conformity with BS EN 61938. The specification of such a system or equipment should include a statement of the relevant line voltage, or its level in dBu. Use or specification of equipment with other line voltages is not recommended.

1.3.20**voltage line principle**

a principle for designing and specifying amplifiers and loudspeakers, with the following objects:

- to simplify the connection and matching of several loudspeakers to one amplifier;
- to minimize power losses in cables;

- c) to facilitate interchangeability;
- d) to provide a simple means of adjusting the sound level produced by an individual loudspeaker in a system, without incurring power losses and affecting the rest of the system.

1.3.21 control point

a place where controls for the operation of the system are located

NOTE A control point may have controls for operating the system only under special conditions, for example a police or fire control point. There may be more than one control point.

1.3.22 closed circuit television (CCTV)

a television service, either monochrome or colour, provided over a restricted distribution system

1.3.23 reverberation time

of an enclosure, for a sound of a given frequency or frequency band. The time that would be required for the sound pressure level in the enclosure to decrease by a given amount, after the source has been stopped. The recommended amount is 60 dB

1.3.24 intelligibility

a measure of the proportion of the content of a speech message that can be correctly understood

NOTE Satisfactory intelligibility requires adequate audibility and adequate clarity

1.3.25 clarity

the property of a sound which allows its information-bearing components to be distinguished by the listener

NOTE Clarity is related to the freedom of the sound from distortion of all kinds.

1.3.26 client

the person, group or organization that commissions the design and installation of the sound system

NOTE The client is usually, but not always, the purchaser of the system.

1.3.27 user

the person, group or organization who supervises the operation of the equipment in use

NOTE The needs of the user will be an important factor in the design of a sound system. There may be more than one user and the user may not be the client or owner of the system, when a room is hired with a sound system.

1.3.28 operator

the person who controls the sound system manually when it is in use

1.3.29 system designer

the person responsible to the client for the design and specification of the sound system

1.3.30 installer

the person, group or organization responsible for the installation of the sound system as specified by the System Designer

1.3.31 contractor

the person or company that enters into a contract with the purchaser to supply a sound system

NOTE The contractor may also undertake the system design and/or the installation. In major building projects the sound system maybe the subject of a sub-contract between the main building contractor and the specialist supplier.

1.3.32 foldback

provision to a performer, by headphone or loudspeaker, of a signal selected to assist coordination with other performers or signals

1.3.33 confidence signal

the response, audible to an announcer, which confirms that his speech is being delivered by the system

1.3.34 functional surveillance

continuous automatic monitoring that audio equipment is functioning correctly

Section 2. Application

2.1 General

Table 1 gives a summary of typical building types and sound installation requirements. In many buildings such as hotels, conference centres, and theatres, more than one type of system may be required, such as stage music, speech reinforcement, systems for the main auditorium, public paging/announcement for the front-of-house, circulation and ancillary areas, and staff or technical paging/announcements behind the scene.

Self-contained systems may need to be linked or interfaced with other systems or subsystems for emergency announcements, evacuation, or fire alarm purposes.

2.2 Categorization of systems by sound quality

2.2.1 General

The three basic system types (see 1.3.1 to 1.3.4) covered by this standard are divided into three categories based on the subjective quality of reproduction.

- a) Category C (clarity).
- b) Category N (naturalness).
- c) Category A (accuracy).

2.2.2 Category C

Category C systems aim mainly at the reproduction of speech of good intelligibility (see 5.21.1), but not necessarily a high degree of naturalness. Music, if reproduced at all, would be of an acceptable quality but not necessarily of artistic merit. Where acoustic conditions are bad, for example because noise levels are high or reverberation is excessive, this system should provide the best results that can be achieved.

2.2.3 Category N

Category N systems are most commonly used. The aim is to produce intelligible and natural sounding speech and/or music of a quality that the average listener considers pleasant. It is desirable that the listening conditions are either already fairly good acoustically, or can be made so by suitable acoustic treatment.

2.2.4 Category A

Category A systems aim at the highest possible quality of reproduction. This category is appropriate when the audience is expected to be critically interested in the programme for its own sake and not merely as a background. It is essential that the listening conditions are acoustically very good, and that the input to this system is of adequately high quality, as any defects may sound more objectionable. Signal quality from an amplitude modulated broadcast receiver, for example, may cause the reproduction from this system to be less satisfactory than that obtained from a category N system using similar inputs.

2.3 Types of building and location

2.3.1 Hospitals

The main programme distribution is to bedside sockets for headphones, pillow-phones etc. for patients use. A choice of programmes is desirable and individual volume controls are essential. A paging system is often required and this may also carry programmes from the main distribution, particularly in areas such as waiting rooms, nurses' rest rooms, etc.

2.3.2 Airports, railway stations, passenger termini

The ambient noise levels may be high and cover a wide range of frequencies. The reverberation time in many cases may be excessive. The area to be covered is usually so large that a number of spaced loudspeakers have to be used.

2.3.3 Hotels, clubs, restaurants

Sound distribution systems for background music and announcements will usually be required. A sound reproduction system may be required if a performance in one room is to be reproduced in other rooms. Local sound reinforcement systems may be required. The sound system may need to interface with other sound systems and fire alarm and evacuation systems. See also 2.3.8 and 2.3.9.

2.3.4 Factories, offices, canteens and department stores

An example of an extensive sound system for a large department store is shown in Figure 1. Recorded material and broadcasts are generally of secondary interest to the listeners who are engaged in other activities, but their attention may need to be drawn to announcements and artificial signals by the use of increased sound levels. If audible information signals are likely to cause disturbing interruptions on the main system, it may be preferable for those used for process control to be separately zoned or have a separate system of their own. High noise levels or excessive reverberation or both may be found and require special consideration. For example, an audio-frequency induction-loop system (AFILS) may be used in a noisy factory, the operators having “ear-defender” headsets fitted with AFILS receivers which can receive background music, paging, etc.

2.3.5 Indoor sports stadia, swimming baths and exhibition halls

The ambient noise levels are likely to be high and variable and the reverberation time is often excessive.

NOTE Adverse environmental conditions should be taken into account, for example in swimming baths the high humidity and presence of corrosive substances.

Table 1 — Basic recommendations for sound system applications

Building type	Live reinforcement	Paging and general announcement	Emergency announcement	CCTV	Tone signals excluding fire alarms (see 5.18)	Radio/TV	Back-ground music	High quality recorded programme	Assisted hearing	Interface	Notes
Airports	—	*	*	*	—	—	*	—	*	FA/E	Multiple inputs and zones required. Noise levels vary
Auditoria General	SM XS	Rehearsal only	*	*	—	—	—	*	*	FA/E E/S A/V	Paging only during rehearsals. Relay to other areas
Canteens	(SM)	*	*	R (see note)	R	*	*	R (see note)	R (see note)	FA/E	May be used for live entertainment; use a separate system (see also auditoria)
Clubs	SM XS	As auditoria Theatres	*	R	—	R	*	*	*	FA/E A/V E/S	Zone areas (see theatre)
Concert halls (see theatres)	SM XS	Rehearsal only, see theatres	*	—	—	R	—	*	*	FA/E E/S A/V	Relay to other areas. Zone peripheral areas
Council chambers	S	—	*	R	—	—	—	—	—	FA/E A/V	Relay to other areas. Zone separately
Other areas of congregation	—	—	*	—	—	—	—	—	—		May act as overflow area. Zone accordingly (see offices)
Court buildings	—	R	*	—	—	—	—	—	—	FA/E	Announcement to public area
Court rooms	S	—	* R	—	—	—	—	R	—	FA/E A/V	High quality recording and playback usually required
Conference rooms/centres	S (XS) (M) (SI)	(See note)	* *	R	R R	R R	Areas of circulation only	*	* R	FA/E ES A/V SI	Paging generally restricted to areas outside conference rooms. Zone systems

Key:

() = Possibly necessary

* = Usually or often necessary

R = May be necessary/should consider

XS = External system (brought in). May operate and need to interface with permanent systems for example a “rock” band PA system or broadcast system

SI = Simultaneous Interpretation Systems

M = Music

S = Speech

FA = Fire Alarm System

E = Emergency Evacuation System

A/V = Audio Visual

Table 1 — Basic recommendations for sound system applications

Building type	Live reinforcement	Paging and general announcement	Emergency announcement	CCTV	Tone signals excluding fire alarms (see 5.18)	Radio/TV	Back-ground music	High quality recorded programme	Assisted hearing	Interface	Notes
Department stores	—	R	*	R	—	—	R	—	—	FA/E	Zone different floors/areas. (Microphone ports for spot announcements)
Discos	S (XS) SM	*	*	*	—	*	Only in areas isolated from dance floors	*	—	FA/E A/V M/S	Sound level noise limiters. FA/E overrides. Zone areas
Factories	—	*	*	—	*	R	R	—	In noisy areas for communication	FA/E	Zone system
Halls/assembly rooms	SM XS	(See note)	*	R	—	R	R	*	*	FA/E A/V MS E/S	Treat as theatre/conference centre
Hospitals	—	(See note)	*	R	R	*	R	—	—	FA/E	Treat patients areas and public and staff areas separately
Hotels	*SM (see note)	*	*	R	—	*	*	R	(See note)	FA/E A/V (XS)	Incorporate many types of system. See other building types
Lecture theatres	*S (M) (SI)	(See note)	*	*	—	R	—	*	*	FA/E (SI) A/V	Not usual to page but external areas should be covered. SI facilities sometimes needed
Offices	—	*	*	R	R	R	R	—	—	FA/E	Zone as required

Key:

() = Possibly necessary

* = Usually or often necessary

R = May be necessary/should consider

XS = External system (brought in). May operate and need to interface with permanent systems for example a “rock” band PA system or broadcast system

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Table 1 — Basic recommendations for sound system applications

Building type	Live reinforcement	Paging and general announcement	Emergency announcement	CCTV	Tone signals excluding fire alarms (see 5.18)	Radio/TV	Back-ground music	High quality recorded programme	Assisted hearing	Interface	Notes
Passenger Termini	—	*	*	*	—	R	R	—	*	FA/E	Poor acoustics and high noise levels. Zone areas. Local microphone and control facilities
Places of worship	*S(M)	R	R	—	—	—	—	R	*	FA/E	May have poor acoustics; some require high quality music
Railway stations	—	*	*	R	—	—	*	—	*	FA/E	Poor acoustics and high noise. Zone platforms
Restaurants	*(M)	R	R	—	—	R	*	—	—	FA/E	May need to zone different area. Some have live entertainment
Pubs (see clubs)	R SM	R	R	—	—	R	*	R	—	FA/E M/S A/V	Zone bars and performance area
Schools/Educational establishments	*SM	*	*	*	*	*	—	*	R (see note)	FA/E M/S A/V	May have separate auditorium system and sometimes requires special assisted hearing systems
Shopping precincts	—	*	*	*	—	—	*	—	R	FA/E	May have poor acoustics. Zone areas. Cater for local systems
Sports stadia indoor	SM (R)	*	*	*	R	R	*	*	R	FA/E (E/S)	May have poor acoustics and high crowd noise levels
Key: () = Possibly necessary * = Usually or often necessary R = May be necessary/should consider XS = External system (brought in). May operate and need to interface with permanent systems for example a “rock” band PA system or broadcast system SI = Simultaneous Interpretation Systems M = Music S = Speech FA = Fire Alarm System E = Emergency Evacuation System A/V = Audio Visual											

Table 1 — Basic recommendations for sound system applications

Building type	Live reinforcement	Paging and general announcement	Emergency announcement	CCTV	Tone signals excluding fire alarms (see 5.18)	Radio/TV	Back-ground music	High quality recorded programme	Assisted hearing	Interface	Notes
Sports stadia outdoor	SM (R)	*	*	*	R	R	*	*	R	FA/E E/S	Zone areas separately. May have poor acoustics and high crowd noise levels
Swimming pools	—	*	*	R	*	R	*	R	—	FA/E	Poor area should be separately zoned. May have poor acoustics and high noise level
Leisure centres	R	*	*	R	*	R	*	R	R	FA/E	Careful zoning of different areas required
Theatres comprising											
a) Auditorium	SM (XS)	R (see note)	*	—	—	*	—	*	*	A/V E/S FA/E	Paging only under rehearsal conditions
b) Other public area	R (See note) SM	*	*	*	*	*	*	*	—	FA/E	Possible connection to other systems and local inputs. Foyer entertainment
c) Back stage		(See note)	*	*		R				FA/E	Specialist show relay and technical intercoms
d) Performance area	—			*	—		—	—	—	Other theatre systems	
Key: () = Possibly necessary * = Usually or often necessary R = May be necessary/should consider XS = External system (brought in). May operate and need to interface with permanent systems for example a “rock” band PA system or broadcast system SI = Simultaneous Interpretation Systems M = Music S = Speech FA = Fire Alarm System E = Emergency Evacuation System A/V = Audio Visual											

Table 1 — Basic recommendations for sound system applications

Building type	Live reinforcement	Paging and general announcement	Emergency announcement	CCTV	Tone signals excluding fire alarms (see 5.18)	Radio/TV	Back-ground music	High quality recorded programme	Assisted hearing	Interface	Notes
Exhibition halls	R S	*	*	*		R	*	R	*	FA/E	Acoustic characteristics may change between empty and occupied. Local microphone inputs and zoning
Ice rinks	R	*	*	*	*	R	*	*	R	FA/E Music systems	May have poor acoustics. Zone rink separately
Plant rooms, engine rooms and machinery spaces	—	*	*		R	—	—		R	FA/E	May have poor acoustics and high noise levels. (Consider use of visual indicators to alert staff). Failure alarms from individual items of equipment may be introduced into the general emergency alarm system
Museums, Art galleries	(See note) R	*	*	R	—	R	—	*	*	FA/E	In some cases a portable system may be appropriate. Separate systems required for some exhibits. IR of other tour systems may be used
Key: () = Possibly necessary * = Usually or often necessary R = May be necessary/should consider XS = External system (brought in). May operate and need to interface with permanent systems for example a “rock” band PA system or broadcast system SI = Simultaneous Interpretation Systems M = Music S = Speech FA = Fire Alarm System E = Emergency Evacuation System A/V = Audio Visual											

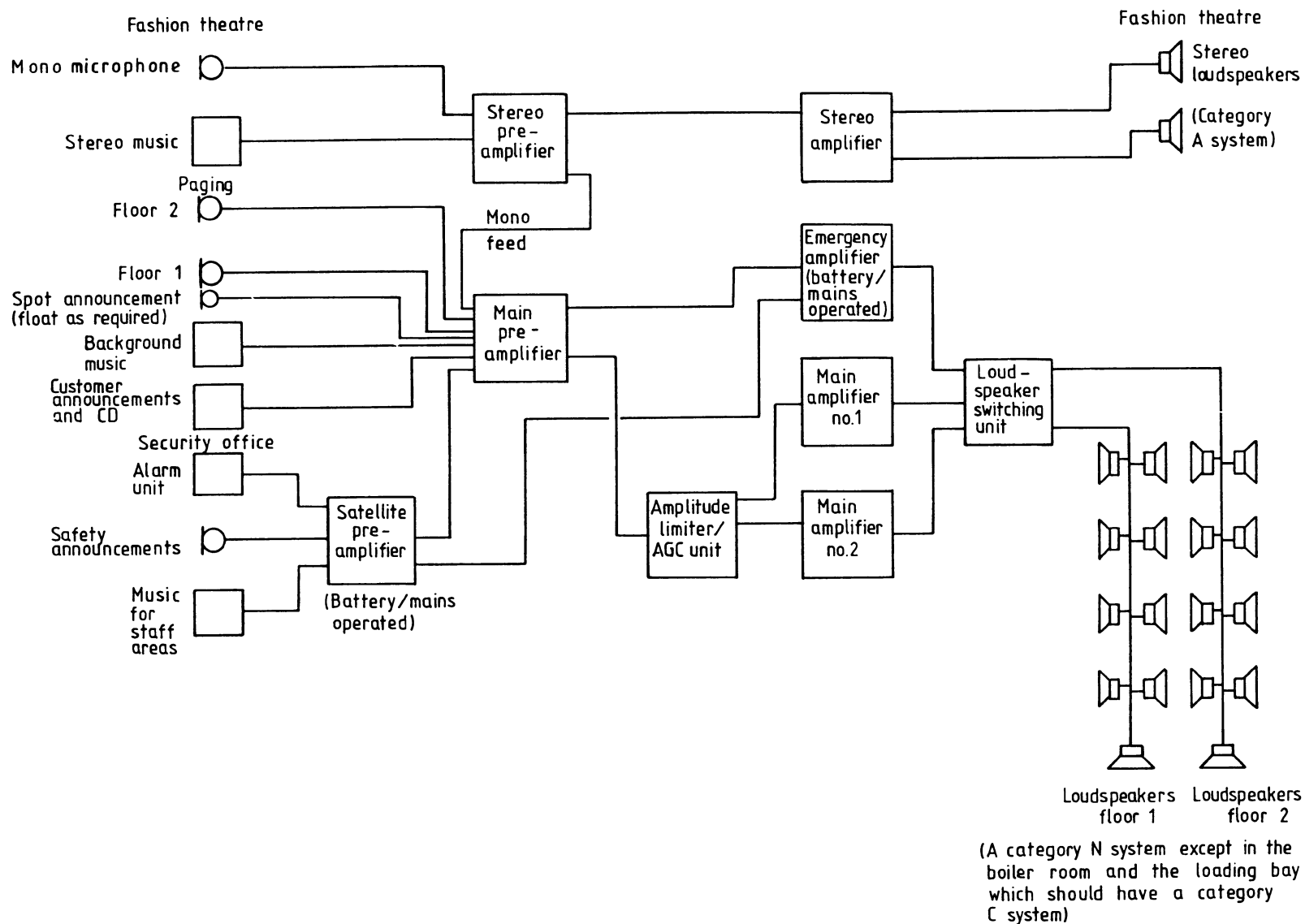


Figure 1 — Block diagram of an extensive sound system for a large store

2.3.6 Outdoor sports stadia and showgrounds

The area to be covered is usually large and generally requires use of a number of spaced loudspeakers. Careful positioning of the loudspeakers when widely spaced is essential to prevent the generation of sound echoes and long path delay effects. Prevailing wind direction and air temperature gradient may also affect the optimum aiming of directional loudspeakers, in both the vertical and horizontal planes. See also BS 7827.

2.3.7 Racecourses

Racecourses differ in the following ways from other sporting venues:

a) the ambient noise level is characterized by a wide range of values. During periods between races the ambient noise level is steady and quite low, but during the race the shouting causes the background noise level to rise by up to 40 dB. The sound system may, therefore, use ambient noise sensing with advantage (see section 5 and BS 7827);

b) there is a need for race commentary.

If there are CCTV displays in indoor and/or public areas, the sound associated with the programmes for these displays, the general racecourse announcements and commentary, and emergency messages all usually need to be reproduced in these audience areas but without mutual conflict.

2.3.8 Theatres and opera houses

2.3.8.1 Most theatres and opera houses require the following facilities:

a) a main sound reinforcement/reproduction system for amplifying the performance and replaying effects and music. This system may be concealed or a prominent feature. The system should be capable of reproducing loud sounds without distortion;

b) a system for replaying sound effects at various locations on stage and in the auditorium. Loudspeakers may be moved between a large number of outlet points according to the specific needs. This system usually also feeds the main sound reinforcement system;

c) a system for relaying the performance backstage to dressing rooms, workshops, etc., usually called the “show relay system”. In some theatres, performers and technicians rely on the “show relay” for their cues. It is essential that the system is extremely reliable. Automatic gain control should be considered and outputs may be required for other systems, before and/or after automatic gain control. It is essential that a fault on one of these systems or the interconnections does not disable the whole system. Loudspeakers may have level controls, but where performance cues are taken from “show relay”, the level control should reduce but not mute the signal;

d) a system to relay the performance to latecomers (using CCTV and the signal from item c));

e) systems for the hard of hearing and visually impaired;

f) an announcement system, usually zoned to stage, front of house and backstage. There may be a number of paging points each requiring access to different zones, for example stage manager (all zones), house manager (front of house), stage door (backstage only). The stage manager should have the highest priority. In buildings with more than one auditorium, each auditorium can be prioritized or (preferably) all stage managers have equal access, with clear indication when the system is in use. This system may be interlinked with the fire alarm system;

g) a sound control room housing the operational controls for items a) and b). Some of the equipment for these systems may be located near the loudspeakers, in the stage and auditorium areas. If the sound control room is to be the main monitoring position, any window should be removable or retractable, and the opening should be at least 2.5 m × 1.5 m. The operator should have line of sight view of the main reinforcement loudspeakers from the normal control position;

h) an auditorium control position. This may be an area where the seats can be removed, or where a facility panel is provided, with a trestle to go over the seats. Ideally, the monitoring position should be on the centre line, in the main body of the auditorium, at least 1.5 m from any overhang or wall.

2.3.8.2 An equipment room is usually required for items c) to f) of **2.3.8.1**. This room may also house some of the equipment for items a) and b) of **2.3.8.1**.

2.3.8.3 Powerful amplifiers are often used for items a) and b) of **2.3.8.1**. These amplifiers should be located where cooling and forced ventilation do not cause noise problems.

2.3.8.4 Theatre sound systems should be provided with a separate mains supply from stage machinery and lighting. A technical or clean earth should also be provided. General service mains and earths should be provided in areas served with “clean” mains and earths, to ensure that any general equipment (such as vacuum cleaners or power tools) does not corrupt the system. See also **5.17.5**.

2.3.8.5 Systems a) and b) of **2.3.8.1** should be Category A. Systems c) to e) of **2.3.8.1** should be Category N. Other systems should be Category C.

2.3.8.6 Most theatres use multichannel output for reproduction but most of the equipment is arranged to be stereo capable. If films are shown in the theatre, a surround sound system may be required.

2.3.8.7 The following may be required for some theatres.

- a) Provision for visiting artists with large sound systems. A suitable power supply on the same phase as the installed sound system and loudspeaker positions are the basic requirements. Numerous tie lines and cable routes may also be required. Visiting artists may also bring their own sound sources and use the theatre sound reproduction system. In this case, the system should be able to accept a variety of sources (see **9.11** to **9.14**).
- b) System outlets for broadcast and other external facilities. Audio lines should be isolated and provision may be made to supply clean power on the same phase as the installed sound system and earths to mobile technical vehicles.
- c) Theatres that are used for conferences or meetings need some or all of the facilities of **2.3.10**. Many of these facilities can be provided by the systems detailed above.

2.3.9 Concert halls

2.3.9.1 Most concert halls require the following facilities:

- a) a system for relaying the performance backstage to the dressing rooms, offices, etc., usually called the “show relay” system;
- b) a system to relay the performance to latecomers (using CCTV and the signal from item a);
- c) systems for the hard of hearing and visually impaired;
- d) an announcement system, usually zoned to stage, auditorium and backstage;

NOTE 1 There may be a number of paging points, each requiring access to different zones. If more than one auditorium shares common facilities in a building, the auditoria may be prioritized or have equal access with clear indication when the system is in use. This system may be interlinked with the fire alarm system.

The following may also be required:

- e) a main sound reinforcement system for amplifying elements of the performance;

NOTE 2 Depending on the use of the hall, this may be a simple system used mainly for spoken announcements, or a large system used regularly for pop concerts.

- f) a sound control room housing the operational controls for item e);
- g) an auditorium control position.

NOTE 3 This may be an area where the seats can be removed, or where a facility panel is provided, with a trestle to go over the seats. The monitoring position should be on the centre line of the auditorium in the main body of the hall, at least 1.5 m from any overhang or wall.

2.3.9.2 The facilities described in **2.3.8.7** are also applicable to concert halls.

2.3.10 Conference centres

These venues are used not only for conferences but also for lectures, product launches, company seminars, small scale music events, sales promotions, etc. A good quality flexible sound system is desirable to take account of the normal range of activities which might be presented. When simultaneous interpretation facilities are to be included, these are generally provided by a hard-wired system to each seat or an infra-red system with delegates using personal receivers. As these requirements are usually occasional, managements often provide only cable containment (and sometimes cabling) to minimize costs and then rely on hire companies to provide the required facilities.

2.3.11 Discotheques

Discotheques utilize high level sound systems for the reproduction of dance music and high level speech. Normally, high efficiency horn-loaded loud speaker systems are used in large discotheque premises, usually in conjunction with time delayed peripheral area systems using small direct radiators. Smaller premises normally utilize direct radiator systems. The operating duty cycle can be arduous, in that continuously high sound levels are typically required for a duty cycle of 6 h per day, 5 days or 6 days per week. Systems, particularly loudspeakers, should be designed with this requirement in mind and attention paid to keeping the electronic equipment sufficiently cool. Attention is drawn to the need for systems to be designed to conform to the Noise at Work Regulations 1989 [1] (in respect of employees present). Licensing authorities may also require systems to contain shut down devices, to allow fire alarm announcements to override in the event of an emergency. Modern systems frequently include digital sound processing equipment, to allow the system performance to be changed to suit different types of programme material. Compact disc players, video disc and video tape machines are increasingly used as signal sources. Advanced voice signal processors are also often necessary to optimize vocal dynamics, particularly where maximum sound levels become critical in relation to permissible operating levels within the Noise at Work Regulations.

2.3.12 Places of worship

2.3.12.1 Places of worship may require the following facilities:

- a) a sound reinforcement system for services;

NOTE 1 Large reverberant churches (see Figure 2) present problems, usually requiring extremely careful investigation and system design;

- b) a number of microphone positions;

NOTE 2 If a radiomicrophone is provided, careful consideration is essential to avoid the risk of acoustic feedback.

- c) sound reinforcement for the performance of music as part of services, which may vary from a choir to a rock band, although in the latter case a separate system may be essential;

- d) sound reproduction for the playback of a favourite song at weddings or funerals, usually on compact disc;

- e) systems for the hearing impaired;

- f) a sound distribution system for announcements may be needed where the building has a large number of visitors.

2.3.12.2 The sound system should be category N. Where a separate system is provided for item c) of **2.3.12.1** this should be category A.

2.3.12.3 In historic buildings there may not be convenient cable routes available. Particular care should be taken to ensure that the installation is in keeping with the character of the building.

2.4 Induction loop systems

2.4.1 Audio-frequency induction-loop systems (AFILS)

The provision of an AFILS for use with hearing aids fitted with a T switch position should always be considered. The design, installation, operation and maintenance of AFILS is covered in BS 7594.

2.4.2 Carrier-frequency induction-loop systems (CFILS)

Where a loop system is used for simultaneous interpretation systems and when more than one channel (i.e. language) is required, a carrier frequency system (CFILS) is used. At venues, where both an AFILS and a CFILS are installed, generally, the floor language is fed to the AFILS. Hearing impaired persons requiring anything other than floor language make use of the CFILS multi-channel receiver and the associated ear-piece or headphone. For comfort, this might entail users removing their hearing aids. Alternatively, and providing the low frequency magnetic noise level is sufficiently low (and no AFILS is in operation), the CFILS receiver can be provided with a magnetic coupling device for use with hearing aids switched to the T position. This arrangement enables the user to select the required language channel and adjust the reproduction level to take account of the hearing impairment.

2.5 Infra-red systems

Systems using infra-red transmissions may be used for simultaneous interpretation, information and communication with the hard-of-hearing (see BS 6418).

NOTE BS 6418 will shortly be superseded by:

BS EN 61603 *Transmission of audio and/or video and related signals using infra-red radiation*

BS EN 61603-1:1997 *General*

BS EN 61603-2:1997 *Transmission systems for audio wideband and related signals*

They have the advantage of eliminating inconvenient direct cable connection, but the disadvantage that special receiving equipment has to be issued to, used by and recovered from users.

2.6 Stereophonic systems

A stereophonic system should be used where the most pleasing reproduction of music (category A) is desired, for example from a disc or tape recording. These systems need to be laid out by experts, but some general information on them is given in later sections. Difficulties can arise when the geometry of the space is such that two groups of loudspeakers cannot provide satisfactory stereophony.

NOTE It may not be satisfactory to derive a mono signal by paralleling or mixing the stereo channels. A special “mono deriving amplifier” may be required.

2.7 CCTV systems

CCTV systems may be provided in addition to, or in conjunction with, sound system installations. However, the CCTV sound signal may differ from that of the sound system; this may occur, for example, with action replays or off-air inserts. In this case, careful design is necessary to prevent conflict between the differing sound fields.

The loudspeakers (if any) of the CCTV display units are not generally adequate except for very small areas, and a separate sound reproduction system is necessary.

Provision for overriding CCTV sound for priority/emergency announcements may be needed (see BS 7443). It is necessary to make specific provision for generating and distributing the sound signal association with the CCTV.

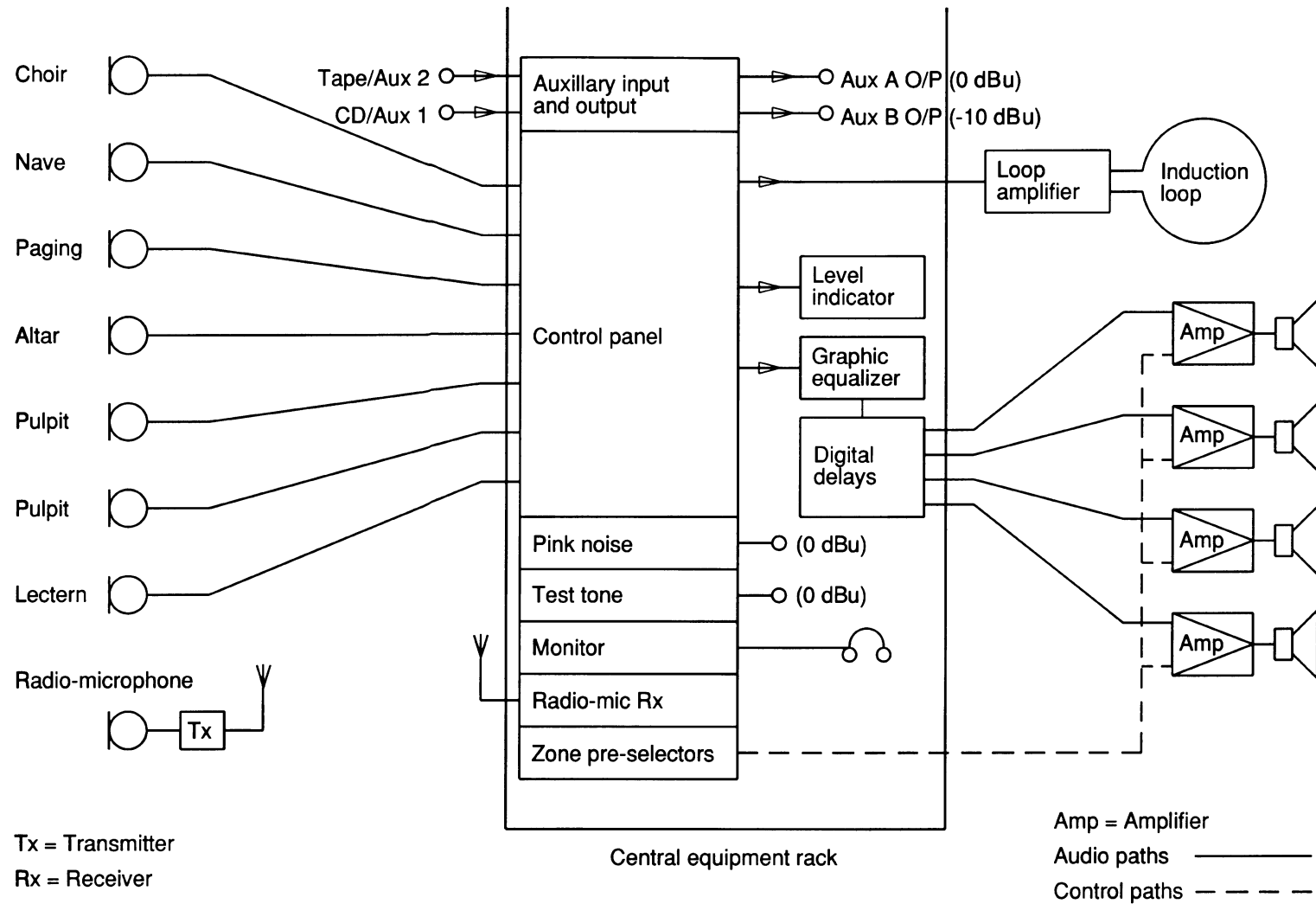


Figure 2 — Block diagram of a sound system for a large church

Section 3. Guidance for prospective purchasers

3.1 General

This standard details the optimum design and installation procedures for sound systems. Prospective purchasers should stipulate that the system is to be designed and installed in accordance with this code. Operation and maintenance procedures should also follow its recommendations. The responsibility for ensuring that the system, when installed, meets its specification, lies with the System Designer.

NOTE This implies that the System Designer should take a full part in commissioning the system (see section 7).

The standard also forms the basis on which a consultant may be requested to provide independent assurance of the performance of an installation.

It is not expected that the purchaser should be able to brief the System Designer at the technical level. It is, however, essential that the purchaser describes all the functional requirements of the system as clearly and definitely as possible. There should be specific agreement on these functional requirements between the purchaser and the System Designer, and the purchaser should make no assumption that the system will do anything that is not included in the agreement.

3.2 Acquiring or modifying a sound system

3.2.1 Possible procedures

There are several possible procedures for acquiring or modifying a sound system and the choice of procedure depends on the area to be covered, the funds available and any special complications which may be involved.

Possible procedures are:

- a) design and installation by the purchaser;
- b) design by the purchaser with contractor installation and project managed by the purchaser;
- c) design and installation by a contractor;
- d) design by a consultant with installation by a contractor and project management by the purchaser;
- e) design and project management by a consultant with installation by a contractor.

3.2.2 Modification of an existing sound system

Modifications to an existing system may not require the application of all the procedures in sections 3 and 5; this has to be determined by the System Designer.

3.2.3 Seeking technical advice

Observance of this standard will greatly increase the probability that satisfactory results will be obtained. However, its provisions cannot be properly applied without adequate technical knowledge and experience, and each design presents individual problems. Unless a purchaser is certain of having adequate technical knowledge, advice should be sought during the early planning stages. Such advice should cover:

- a) the suitability of a sound system for a particular venue;
- b) factors that may adversely affect the performance;
- c) factors that may add to the cost of installation;
- d) the need for, and scope of, a site assessment (see 4.6).
- e) interface and liaison with other specialists and systems, for example architect and project manager for fire alarm systems, power requirements.

3.2.4 Sources of technical advice

Technical advice should be sought only from:

- a) bona fide system designers (see also 3.2.5);
- b) sound system equipment manufacturers;
- c) appropriate professional organizations, for example:
 - 1) Institute of Sound and Communications Engineers;
 - 2) Association of Noise Consultants;
 - 3) Audio Engineering Society;
 - 4) Institute of Acoustics;
 - 5) Professional Lighting and Sound Association.

3.2.5 The nature of the advice

The advice required depends on the particular requirements of each installation, but is generally covered by the following categories:

- a) advice provided through an architect or specialist managing a large project;
- b) advice direct to the purchaser on specific issues, for example feasibility study or problems with existing systems, from a consultant employed specifically for that purpose.
- c) advice supplied direct to the purchaser covering all aspects of the design;
- d) advice supplied to a technically competent person on a specific issue beyond the scope of that person;
- e) advice following disagreement between the purchaser and supplier of an existing contract.

3.2.6 Independent professional (consultancy) advice

Independent professional advice from a specialist consultant is advisable when installations are to be undertaken in extra large buildings, prestigious buildings and for installations with special difficulties. However, a consultant can only give good advice if the purchaser supplies good information.

When using the services of a consultant, the consultant's responsibilities and terms of engagement should be clearly defined. Consultants may work on a fixed fee, time or percentage basis. In either case, there may be extra costs for travel, disbursements, test equipment, etc.. After an initial meeting, a clear letter of agreement should be issued, stating the duties and fee basis for the agreement. It is necessary for the purchaser to satisfy himself that the consultant understands the objective of the purchaser and has experience in the relevant field.

The advice of an independent consultant may also be required in the event of an otherwise unresolvable dispute between the purchaser and supplier or manufacturer. Such advice can often provide a more economical resolution than recourse to litigation.

3.3 Choosing the system supplier

3.3.1 Approaching a contractor

Particularly for small and uncomplicated sound systems, a contractor can be asked to supply and install suitable equipment. Names of contractors who specialize in this work may be obtained from business directories and trade associations. The purchaser may wish to inspect similar installations by the contractor or arrange for a demonstration. Responsibility for equipment selection usually rests with the contractor, providing the purchaser clearly states the intended application and any special requirements. It is necessary that the purchaser is satisfied that the contractor's solution meets his needs before accepting any offer.

3.3.2 Approaching a manufacturer of sound systems or associated equipment

A manufacturer of sound systems or associated equipment can be asked to recommend competent system designers and/or installers. In some cases the manufacturer may also offer its own site survey of the proposed installation and systems design services. In this case, the responsibility for choosing appropriate equipment (microphones, amplifier, etc.) and commissioning the system normally rests with the selected manufacturer. The contractor is responsible to the manufacturer for the correct installation of the system and commissioning (where this is also undertaken).

For some systems, a manufacturer may be called in to provide detailed technical advice on areas of uncertainty or particular difficulty. On these occasions the contractual obligations of the installation contractor and the manufacturer to the prospective purchaser should be clearly documented, preferably under a single contract.

NOTE British Standards do not purport to include all the necessary provisions of a contract.

3.3.3 Approaching a specialist consultant

For large or complex systems, it can be appropriate to engage a specialist consultant, who will be responsible for the initial survey, design and commissioning of the system, specification of equipment and recommending which installation contractors should be invited to tender. In this case, the main contract may be between the purchaser and the contractor, with the consultant acting as the purchaser's agent. In a new building, the consultant would also liaise with architects, main and subsidiary construction contractors on matters affecting the system. Names of consultants who specialize in this work may be obtained from business directories and trade associations.

3.4 Contractual provisions

3.4.1 Observance of the code and agreement on deviations

The word "should" used in a standard is sufficient to require a contractor to provide a good reason why any variation to the stated requirement is proposed. It is recommended that contracts include a "specific variation" clause under which parties document any agreed variations.

3.4.2 Contents of contract

The contract which determines the conditions under which any work is carried out should include the following:

- a) the parties to the contract;
- b) the work to be undertaken;

- c) the standard of the workmanship etc.;
- d) performance tests;
- e) prices and payment terms;
- f) conditions for variations and extensions;
- g) timetable;
- h) ownership, insurance, etc., while the work is in progress;
- i) resolution of disputes including arbitration;
- j) warranty, spares and maintenance;
- k) other terms as appropriate.

NOTE British Standards do not purport to include all the necessary provisions of a contract.

3.4.3 Model contracts

Model contracts are available from various bodies, such as the Royal Institute of British Architects (RIBA) and the Institution of Electrical Engineers (IEE), and many contractors and consultants have their own standard contracts. The purchaser may wish to amend these contracts to ensure that the terms are suitable.

3.5 Functions and limitations of a sound system

3.5.1 Function

The basic function of a sound system is described in section 1.

3.5.2 Limitations

3.5.2.1 Overspill

In a single space (for example, a room, or outside in the open air) served by loudspeakers, it is not practicable to increase the sound level without limit because of the danger that the amplified sound will “spill over” into areas where it is not wanted, perhaps causing annoyance. This inability to confine the sound to particular locations may be because the loudspeakers are insufficiently directional or it may be fundamental to the nature of sound propagation itself, i.e. the ability of sound to travel round corners by diffraction.

NOTE Recommendations for reducing overspill are given in 5.5.

3.5.2.2 Acoustic characteristics of the listening area

If the listening area is an enclosed space having few absorbent surfaces, the unwanted sounds arising from the reflecting surfaces may be so numerous, intense and delayed that they mask the wanted sound. Speech may be rendered unintelligible; the character of music may be altered to an unacceptable extent. Examples of such spaces include underground railway stations, some indoor swimming pools, some ice rinks.

3.5.2.3 Acoustic feedback

If the sound level radiated by the loudspeakers is increased by raising the amplification of the system, microphones in the same space may receive such a high level of sound that the resultant re-amplification leads to distortion of the frequency response of the system. This distortion imparts a characteristic coloration, most readily detectable with speech or impulsive sounds such as a handclap. At higher levels of amplification, the sound system may generate self-sustaining oscillations i.e., it may howl-round.

3.5.2.4 Ambient noise

The greater the ambient noise level, the greater the level of wanted (amplified) sound has to be in order for it to be effective. If the level of ambient noise is very high, the limitations on the level of amplified sound may make it difficult to design an effective system. For example, in an underground train, on a railway station platform or in an aircraft, the level of the amplified sound level may need to be so high that it becomes uncomfortable or even painful. Automatic control of the sound level in response to changes in ambient noise can be provided. In these systems, microphones are strategically placed to monitor the noise environment, so that any change in noise level results in a corresponding change in wanted sound level.

3.6 Maintenance and replacement funding

After a sound system has been installed, commissioned and paid for, it is still necessary to spend money on it from time to time, to keep it in good condition. Furthermore, it will inevitably, after some years of satisfactory service, need to be replaced, usually by a system with more facilities and/or more advanced technology. If the system cannot be properly maintained, for lack of funds, the need to repair or replace it will arrive that much sooner.

It is therefore prudent to make specific financial provision for funding both in-service maintenance and repair, and for the eventual replacement of the system. A projected life of approximately 10 years is realistic in the present situation of product lifetimes and advances in technology. Ideally, the “sound system fund” should be ring-fenced so that it cannot be appropriated for any other purpose.

Section 4. Planning and contract management of the system

4.1 General

This section covers the period from the initial enquiry by the client briefing to final acceptance of the completed installation. Depending on the size of the system and the amount of design work necessary, the stages outlined below may be fulfilled by a simple exchange of letters or may involve months of specialist effort.

4.2 Initial enquiry

At the initial enquiry, the purchaser should state the general sound system contractual requirements (see 3.2.3). The consultant or contractor should outline their suitability for the project and declare any special interests. Outline solutions, timescale, terms of engagement and fees may also be discussed. A preliminary site visit may be arranged. Any special conditions should be identified as soon as possible.

4.3 Outline proposal

The consultant or contractor should provide a general outline proposal, giving details of the major items of equipment that might be involved and levels of performance that should be attained. Alternative proposals may be offered at this stage. Budget costings should be provided, and a detailed site survey may be undertaken. Details of engagement of contractors, supervision, performance tests, services and other requirements should be agreed at this stage. Any issues identified but not resolved at this stage should be clearly stated.

4.4 Written records

Throughout the design, installation and commissioning of a sound system, a written record should be kept of all discussions and agreements. Where a consultant is employed, he should keep records and copy them to the purchaser and contractor. The purchaser and contractor may wish to keep their own records of any agreements. Where an agreement is reached verbally, it should also be agreed who is to confirm that agreement in writing.

4.5 Planning

4.5.1 General

The planning function involves the solution of any immediate problems disclosed by the initial enquiry or the site assessment, and scheduling and monitoring progress of the project in all its phases. This should include the following steps:

- a) collection of data for cost estimation and quotation or tendering;

- b) design;

- c) liaison and coordination with building contractors and other service providers;

- d) installation, including scheduling delivery of equipment to site;

- e) commissioning;

- f) information for the managerial staff of the owners of the system;

- g) training for system operators.

An example plan of work for projects involving budgets in excess of £30 000, is given in annex A.

NOTE A typical project checklist is given in annex B.

This activity also comprises the technical functions that are not directly related to the design of the sound system.

4.5.2 Progressing the project

Regular progress meetings should be arranged to ensure that all parties are aware of the whole project progress. The meetings should be minuted and minutes circulated to all participants in the contract, whether present at the meeting or not. The purpose of holding these meetings is to ensure that problems are identified as soon as possible and any remedial action taken. It is essential that all contributors should give accurate information to these meetings. When problems arise, the emphasis should be on finding solutions, not on apportioning blame.

Stages should be identified in each of the participants' activities that can be inspected or verified in order to verify the project's progress. When a project involves innovation, special care is needed in project management to ensure that all the design objectives will be met.

4.5.3 Power supply

An adequately rated mains power supply, substantially free from electrical interference, should be provided in accordance with the System Designer's requirements. This supply should not be shared with other equipment, especially motor-driven or thyristor-controlled equipment. Where battery back-up is provided, arrangements should be made for charging and suitable accommodation (see BS EN 60896, BS 6312 and BS 6313).

4.5.4 Accommodation

The location of all equipment, microphones, loudspeakers and their means of mounting should be agreed between the parties concerned, so that adequate provision for their means of installation is ensured (see 6.3). Security and storage of portable equipment should also be considered. Any special requirements for equipment rooms and control points should be identified.

4.5.5 Cabling plan and schedule

A cabling plan should be agreed in collaboration with those responsible for other services, to enable the necessary ducts, chases, sleeves, etc. to be specified before building operations commence. Segregation from other services may be essential and should be considered at an early stage.

4.5.6 External lines

Wayleaves should be obtained for any lines that run outside the client's property. If external lines cross, or are in close proximity to, electric power or telecommunication lines, safety of the installation should be cleared with the appropriate authority.

Leased telephone circuits (leased lines) used to interconnect remote systems have to be terminated by the appropriate authority. The system equipment to be connected to this point has to be approved for connection and has to bear the recognized approval label as specified in Telecommunications (Marking and Labelling) Order 1982 SI 1982/491 [2].

4.5.7 Approval of the proposed installation

Early approval of the proposed installation should be obtained from the client or the authorized consultant and sought from any public or other authority which may be concerned.

4.5.8 Time schedule

4.5.8.1 Commissioning date

It is essential that the latest date by which the commissioning is to be completed is firmly established, since:

- a) the system may be required to be operating for an event immediately following commissioning;
- b) the achievement of the commissioning date may involve extra costs, such as 24 h working during installation.

4.5.8.2 Ordering equipment

As the equipment may have to be specially manufactured, it should be ordered at an early date to ensure its availability at the appropriate time for installation.

4.5.8.3 Wiring

It is often necessary to install wiring into ducts, conduits and chases at an early stage of building construction. The ducts should be cleared and dried out before wiring is begun. Care should be taken to protect cable tails from damage and moisture ingress. Surface wiring should be installed immediately prior to the final decoration.

4.5.8.4 Installation of equipment

Equipment should be installed at a late stage in the project to minimize risk of damage and loss, and in any event not until the building work and preferably the decoration work in the immediate vicinity have been completed. It is essential to protect the equipment from dust and moisture until all construction and decoration work is finally completed. Protection to IP 54 (BS EN 60529) is recommended.

4.5.9 Prefabricated and custom made equipment

Some equipment assembly or prefabrication may be undertaken off-site. Where this is the case, or for custom made equipment, regular inspections should be made to ensure that satisfactory progress is being made and that the equipment can be installed in its final location.

4.6 Site survey and client briefing

4.6.1 Site survey

The satisfactory completion of the design and installation of a sound system is frequently a demanding task, whose critical aspects vary from case to case. To achieve a good result, it is essential that the preparations for design and installation are very thorough. It is therefore necessary to examine the site at the earliest reasonable time, to collect data and investigate any potential problems.

A detailed site survey should be carried out at an early stage, in order that the sound pressure levels required from the system may be more accurately assessed. The need for group or automatic noise sensing controls may also be established.

Areas with long reverberation times should be noted. The measurement and assessment of room acoustic data requires specialist equipment and consultancy should be sought accordingly.

The site survey should take account of the following.

- a) The use(s) of the premises

The proposer should visit the site, preferably accompanied by the client. If the system is intended to be used for a particular event, for example, theatre, football, factory paging, then the visits should be made so that the facility or operation can be observed under typical conditions.

b) The location and dimensions of the required coverage area(s)

A survey should be made of all areas under consideration and their usages. It is important to look at all the areas. For example, when confronted with a series of rooms, it should not be assumed that they are all the same, even if it is so implied.

c) Whether the system configuration is permanent or subject to change.

d) Noise levels and reverberation

Where applicable, measurements should be made of operational noise levels, ambient noise levels and reverberation times.

e) Access and working conditions

The question of access and working conditions should be discussed with the client. Any disruption to the day-to-day operation should be clearly defined.

It is imperative that notes are taken (a dictation machine is very useful) and details are not committed only to memory. Where possible, photographs should be taken which incorporate scaling factors. Particular attention should be paid to heights, access and cable routes, and fixing methods. Any special environmental aspects of the site should be noted, together with any possible noise annoyance to neighbours. The coverage required should be considered, and an estimate made of the number and type of loudspeakers to be used, including for outdoor situations the possible positions for exposed loudspeakers. If there is a designated equipment room/rack space proposed, this should be checked to ensure that there is sufficient power and space for the equipment, and adequate ventilation. Cable access should also be considered to and from the equipment location.

f) Audio-frequency induction-loop system (AFILS)

If an induction loop is to form part of the installation, a background magnetic noise survey should also be carried out (see BS 7594). The site survey should include an assessment of potential cable routes, equipment locations, and fixing methods. Any areas requiring special fixings or access should be noted.

g) Location of equipment

Discussions should be held with the client in order to establish microphone positions, control points and system input priorities. Wherever possible, early discussions should be held with the architect in order to establish suitable loudspeaker and equipment locations.

4.6.2 Briefing the client

The following actions should be taken when briefing a client:

a) The proposer's status, for example contractor, consultant, installer, distributor etc., should be declared to the client. Confusion can arise where a company claims to offer consultancy and contracting services simultaneously.

b) The proposer should declare to the client on what financial basis the work would be carried out. Some contractors carry out the design "free of charge" (see note), whilst consultants would make a charge. The client should be left in no doubt as to the basis of the operation.

NOTE "Free of charge" means that no separate charge is made for design, the cost being absorbed in the charges for equipment and/or installation.

c) The proposer should declare to the client what services are offered, for example, design, design and build, supply only, or supply and install.

d) The proposer should declare any vested interests. This is especially applicable when:

1) the "consultant" is really a contractor and expects, if the design is adopted, to carry out the installation;

2) a contractor is also an agent and hence the client might expect any design to employ preferred products.

e) The proposer should discuss with the client the basis of the client's perceived needs and the client's expectation. It should be noted that the client's perceived needs may be different from the actual needs.

f) The proposer should discuss with the client the basis for their ongoing cooperation and define precisely the proposed contractual relationship.

g) The proposer and client should discuss the project in hand, in broad terms and arrive at a predesign budget estimation. This estimation is required to avoid wasting either the client's or the proposer's time. It is not intended to be binding but to provide approximate figures.

h) The proposer should request the client to supply copies of any relevant drawings.

i) The proposer should provide references and accreditation to the client. This may include a brochure and information on similar projects, with photographs and client lists.

j) The proposer should provide a succinctly written proposal. It is recommended that the proposer includes the following text in the proposal:

This proposal covers the following aspects of the system:

- 1) design;
- 2) supply of equipment;
- 3) installation;
- 4) commissioning, etc.

After completion of the client briefing, it should be possible to complete a design check list, a model for which is given in annex C.

4.7 Contract management

4.7.1 General

The contract between the purchaser and the other parties involved should specify every aspect of the project, not only the required performance of the system. On all but the simplest contracts, supervision is necessary to ensure that the contract is executed with satisfaction. Most sound system installations require the coordination of a number of suppliers, services and resources. If there is a significant time between the placement of the contract and its completion, there may be variations and alterations to the contract. Regular checks should be made to ensure that all parts of the contract are proceeding to a satisfactory completion.

4.7.2 Types of contract

There are a number of ways that a contract may be placed depending on the complexity of the design, the knowledge and experience of the purchaser and whether the sound system is part of a larger scheme of works.

4.7.2.1 *Competitive tender*

When a consultant prepares a detailed design, he usually arranges for competitive tenders by suitable contractors, on the basis of the design and agreed contract terms. Tenderers may be required to adhere exactly to the specification, or invited to suggest alternative solutions where appropriate. In either case, it is important that each tenderer is given the opportunity to compete on an equal basis. If the purchaser does not wish to be bound by the lowest tender, this should be made clear when inviting the tenders. The consultant should confirm the purchaser's acceptance of the design and contract terms before the specification is issued and again before the contract is issued. Alterations to the design, timetable and contract terms after the placement of the contract should be avoided, as these are likely to increase the costs.

NOTE In certain cases, the purchaser may decide to proceed on the basis of an incomplete specification, because the cost of waiting time while the specification is finalized exceeds the cost of any likely late changes (see 4.7.2.4).

4.7.2.2 *Design and build*

When a contractor offers to design and build a system for an inclusive price, the purchaser should be sure that the system design is likely to meet his requirements before agreeing to any contract. This may be done by agreeing subjective or objective tests. If the purchaser has chosen the contractor on the basis of a previous installation, comparison with this system may be used as the performance test. In addition to agreeing the performance tests, the contract should establish exactly what is and is not included in the design/build package.

4.7.2.3 *Contract placed directly by the purchaser*

When a purchaser has sufficient technical knowledge to design his own system and experience of contract placement and negotiation, he may decide to engage the contractor directly. This need not preclude the use of consultants by the contractor for specific matters or elements of design.

4.7.2.4 *Design freeze*

There may be elements of the design that cannot be determined at the initial design stage, for example the acoustic properties of a new building may not be known with sufficient accuracy. Each such element should be identified and a suitable course of action agreed. This may be by designing for the worst case, or a separate contract, or agreed prime costs.

At some stage in the design, both parties should agree that the design is finalized and any variations may have cost implications. The design freeze should usually be as close as possible to the installation date, subject to allowing sufficient time for any custom manufacture or long order items. Where the contractor is required to undertake the detailed design of some components, the design freeze should be after placement of the contract.

Section 5. Recommended design principles and procedures

5.1 Design principles

When designing a sound system, the most important factor to consider is the intelligibility (which depends on both audibility and clarity, see 5.21) of the required speech signals, the audibility of any warning tones, and the desired quality of reproduction of any music signals. Sound systems are classified in this respect in 2.2. This clause is primarily concerned with the factors and methods for obtaining good speech intelligibility, and if this can be achieved, then the audibility of warning signals is almost automatically assured. The quality of reproduction of music signals depends on additional factors.

The three primary factors to be considered are:

- a) loudness;
- b) frequency range;
- c) echoes and reverberation.

A sound system consists essentially of the following four basic components, as shown in Figure 1.

- 1) microphone, or signal input;
- 2) pre-amplifier (control unit);
- 3) power amplifier;
- 4) loudspeaker.

Additionally, loudspeaker zoning or group switching may be required. In order to obtain the maximum performance from a system, to maintain an adequate signal-to-noise ratio and provide an appropriate frequency response, a number of other additional elements may be added, such as compressors or limiters, equalizers and volume controls. (See also annex D).

5.2 Loudness

5.2.1 General

Good siting of loudspeakers is very important for uniform sound coverage. A position above audience listening height helps to establish a clear line-of-sight path to every listener and also helps to equalize the distances between loudspeakers and listeners.

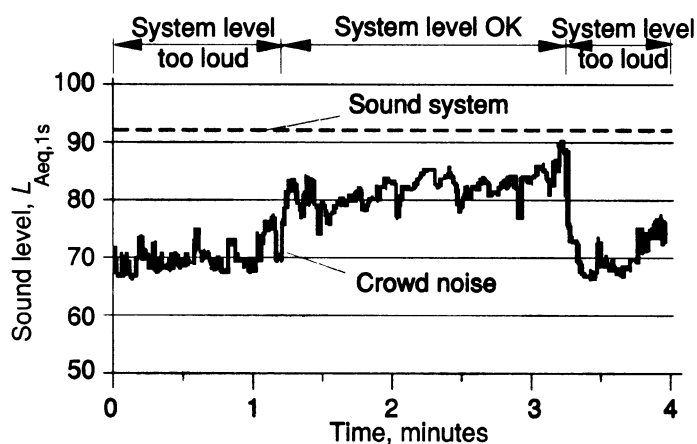
The relationship between the power supplied to the loudspeaker and the sound level achieved depends on the distance from the loudspeaker and the acoustics of the room. Near to the loudspeaker, the sound pressure is proportional to the voltage input to the loudspeaker; as the distance between listener and loudspeaker increases, so the sound reflected from the room boundaries becomes more important. The presence of an audience can radically change the reverberant properties of the room and thereby reduce sound levels away from the immediate vicinity of the loudspeakers. When commissioning the system it is important to bear in mind that the addition of furnishings and the presence of an audience reduces perceived sound levels.

An important point to be borne in mind is that the relationship between amplifier output power and perceived loudness is logarithmic. A doubling of power produces an increase in perceived loudness of 3 dB, which is just perceptible. An increase of 10 times in amplifier power is required to produce an apparent doubling of loudness.

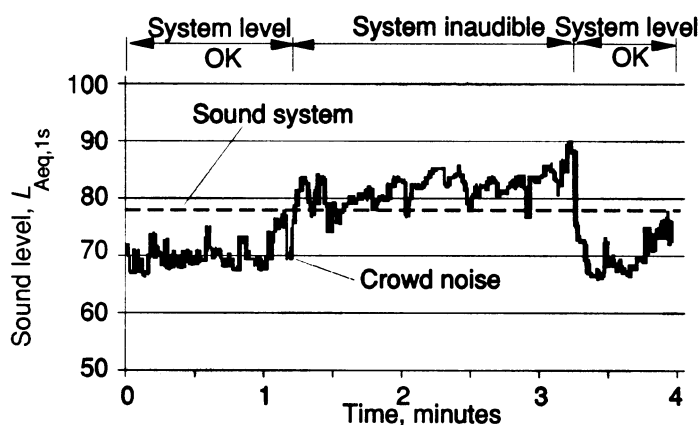
5.2.2 Ambient noise level sensing

In many locations, for example sports stadia, railway stations and airports, the background noise level is not constant. It may fluctuate over long or short periods, or both. The technique of ambient noise level sensing may be applied to systems whose sound output is required to be controlled automatically, depending on the nature and level of the background noise. A sound system having a fixed output level may be too loud when the noise is least, or inaudible when the noise is greatest. See Figure 3 for examples.

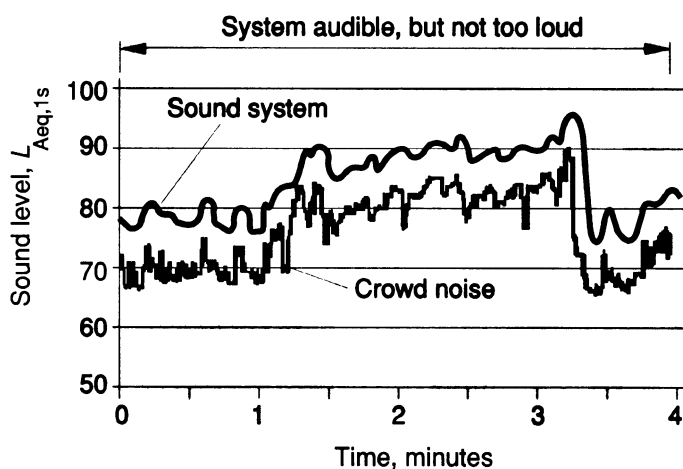
Equipment which provides such automatic control is commercially available, and is particularly useful where the output of the sound system needs to be kept to a satisfactory minimum in order to prevent overspill which causes nuisance to nearby residents. Some ambient noise level sensing equipment is able to disregard the sound originating from the sound system itself, thereby preventing feedback effects which could cause the system sound level to fluctuate unpredictably. Such "intelligent" systems can also differentiate between background music and background noise.



a) Sound system output level fixed above the maximum noise, resulting in excessive loudness during quieter periods



b) Sound system output level fixed below the maximum noise, resulting in inaudibility during noisier periods



c) Using ambient noise sensing, sound system output level varies with crowd noise

Figure 3 — Examples of sound system output levels

5.2.3 Speech

A prerequisite of any sound system is that it is loud enough to be heard clearly. Research has shown that under normal quiet listening conditions, optimum speech intelligibility is achieved at sound levels of 65 dBA to 75 dBA with the range of 70 dBA to 75 dBA preferred. This level should therefore be designed for wherever possible. However, in conditions of higher background noise, the overall level of the sound system has to be increased to compensate for the effect of the background noise masking out the speech.

Ideally, the system should be designed to achieve a minimum speech-to-background noise or signal-to-noise ratio of 10 dB. The maximum signal level should not normally exceed 90 dBA to 95 dBA, except under exceptional conditions or in areas where hearing protection is worn.

In extremely quiet areas, where paging signals for example are not to be intrusive, levels towards the lower end of the 65 dBA to 75 dBA range should be used but the final setting should always be made subjectively.

The target sound levels given above refer to the long-term average level of the speech signal. However, the level of speech fluctuates considerably, with the short-term peaks being some 10 dB to 12 dB higher than the mean (see note). When planning a sound system, adequate provision should be made to cater for this significant peak-to-mean ratio.

NOTE In fact, peaks up to 20 dB or more above the mean can occur, but it is not normally necessary to make full allowance for this.

For sound distribution systems where the microphone user cannot hear the sound from the loudspeakers, it is helpful to provide a visual indication of the sound level being produced, using, for example, one to three light emitting diode (LED) indicators.

An allowance for at least a 10 dB headroom margin should be made, if the power amplifier is not to “clip” (be overdriven) to an unacceptable extent. Clipping can result in excessive distortion and hence loss of intelligibility, and possible damage to loudspeakers if sustained signal clipping occurs.

In terms of the required amplifier power output, a 10 dB margin is very significant, being equivalent to a multiplication factor of 10. However, techniques such as compression and limiting of speech input signals are available which enable smaller power margins to be employed.

5.2.4 Background music

The sound level required for background music depends on:

- a) the type of venue, for example shopping arcade, restaurant, shop;
- b) the background noise level;
- c) listeners' preferences.

It is impossible to generalize as every case will be different, but levels of approximately 60 dBA to 65 dBA are typical in busy retail environments. The level should be such that it does not interfere with conversation.

Managements of public houses and similar venues frequently expect “background” music systems to be capable of levels which would normally be associated with foreground music. Care should be taken at the specification and design stages that there is clear agreement as to the maximum sound level capability of the background music system; this will help to avoid potential misunderstandings arising later.

5.2.5 Foreground music

In contrast to background music, the sound levels required for foreground music are determined largely by the type of music, rather than the listening venue. The aim of a foreground music system is to create an emotional experience via the music; this is often closely linked with the level at which the music is produced. It is difficult to generalize, but surveys of common practice (and thereby listeners' expectations) suggest that the sound levels shown in Table 2 are expected.

Table 2 — Expected sound levels

Type of music	Average L_{eq} dB	Peak dB
Classical orchestral music	Programme dependent	105 to 110
Middle of the road (MOR) orchestral music	94 to 99	123 to 127
Rock/pop	103 to 110	132 to 140

These levels are typical of those measured at the front barrier near to the stage; levels in the body of the hall can be some 4 dB lower. In some extreme cases (for example “rap” music) peak levels in excess of 140 dB can occur.

0.1 5.2.6 Cinemas (see 5.19)

Cinema sound systems are usually set up to proprietary industry-standard levels associated with a particular system, for example the Dolby Cinema system. Peak levels may reach the values given in 5.19.3 per loudspeaker during reproduction of film sound tracks.

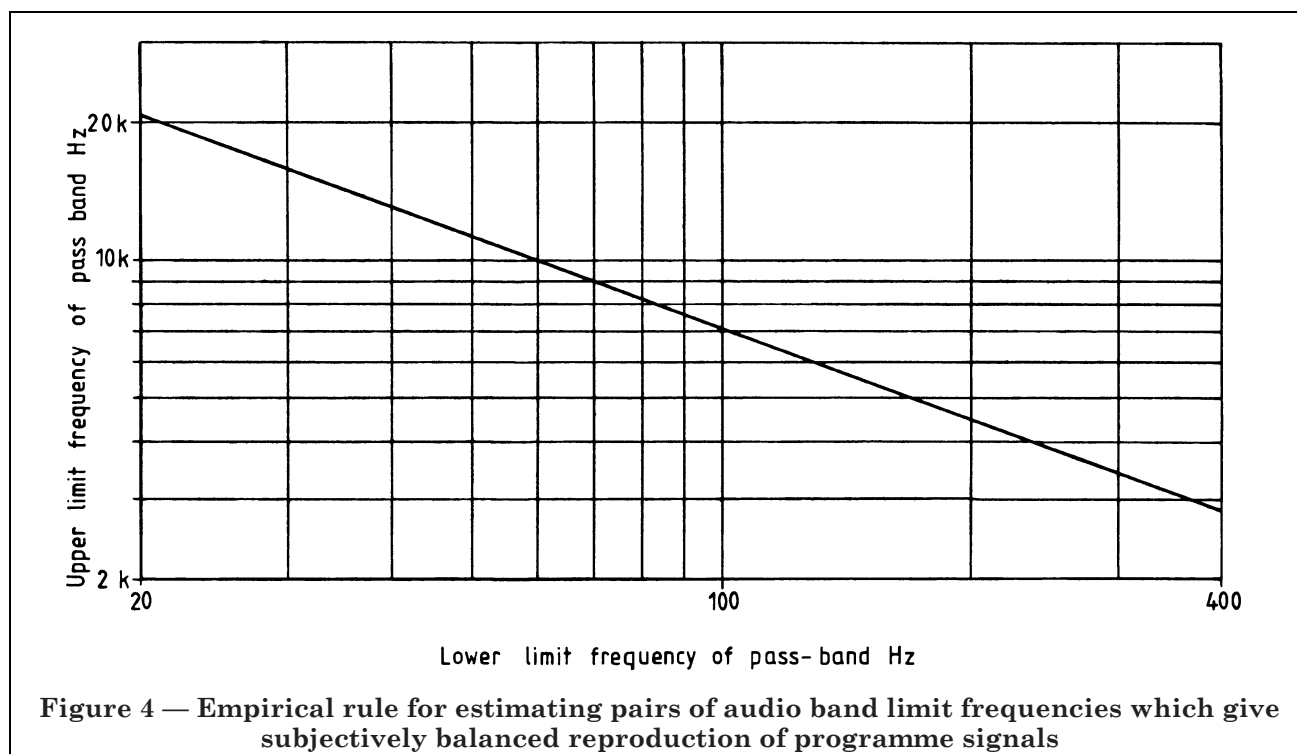


Figure 4 — Empirical rule for estimating pairs of audio band limit frequencies which give subjectively balanced reproduction of programme signals

5.2.7 Exposure to high sound levels

A major concern in the performance of popular music is that of potential hearing damage arising from high sound levels. The rock/pop levels listed in Table 2 (see 5.2.5) are considered potentially injurious to hearing. Employers have statutory duties via the Noise at Work Regulations [1] to protect employees from damaging sound levels, but it is a general legal principle that members of the general public are entitled to subject themselves to hazardous conditions in the pursuit of leisure if they so wish. Nevertheless, Section 3 of the Health and Safety at Work Act [3] places a general duty on employers to have regard for the safety of members of the public affected by their commercial activities. Where average sound levels are in excess of 96 dBA, warnings should be given to the public that hearing damage could result.

In cases of doubt, advice should be sought from the Health and Safety Executive, which has a great deal of experience in this area. The *Guide to Health, Safety and Welfare at Pop Concerts and other similar events* [4] is recommended reading. It recommends that event continuous sound level (Event L_{eq}) in audience areas should not exceed 107 dBA.

5.3 Frequency response limits

When selecting equipment for a sound system, due consideration should be given to the frequency response characteristics of the equipment and the nature of the task it is required to perform.

The minimum frequency range which a sound system should reproduce for intelligible speech is 400 Hz to 4 kHz. However, the quality of such a limited range is extremely poor. For reasonable quality reproduction a sound system should be capable of reproducing the range 150 Hz to 6 kHz. For high quality sound reinforcement, the range should extend to 8 kHz or 10 kHz. For high quality reproduction of music, a range extending from at least 100 Hz to 10 kHz is required (see Figure 4).

For speech reinforcement applications an extension at the high-frequency end of the band may be necessary to combat atmospheric attenuation if the value derived from Figure 4 is 5 kHz or more. In highly reverberant areas, it is often desirable to limit the low frequency response of the system in order to reduce the sound masking effect of the low frequency reverberation and hence improve the potential intelligibility of the reproduced speech. Although the basic tone controls found on sound equipment can be useful, their flexibility of control is limited. The use of a multi-band filter or graphic equalizer to adjust the overall frequency response of a sound system is an extremely useful and powerful aid to system performance.

5.4 Echoes and reverberation

Secondary sources of sound, for example reflections from room surfaces, or the output from supplementary or repeater loudspeakers, which arrive at a listening position within a period of up to 35 ms after the original sound, integrate or merge with the original, direct sound (person speaking or loudspeaker) and combine to produce one overall louder sound and intelligibility is usually enhanced. Secondary sounds arriving after 50 ms do not fully integrate and depending on their level relative to the initial sound may be heard as echoes which have the effect of reducing the overall intelligibility of the speech signal.

Sound systems should be designed to ensure that the generation of long-delayed secondary sound signals, caused either by structural reflections or by secondary loudspeakers, does not occur or is well controlled.

Any acoustic treatment necessary to increase sound insulation, reduce reverberation or improve monitoring positions should be clearly specified.

5.5 Outdoor systems

Loudspeakers should be placed no more than 12 m to 15 m apart when facing in the same direction or 25 m apart when directed to cover an area. The loudspeakers should be angled downwards to cover the appropriate area and to limit the overspill to adjacent areas. A row of loudspeakers, even though individually spaced at 12 m to 15 m apart, can still give rise to an appreciable echo effect at certain positions, due to the difference in distance between the nearest and subsequent loudspeakers whose output is still audible.

Local authorities are empowered to impose limits on sound levels and should therefore be consulted.

5.6 Distance and sound pressure level (SPL) considerations; the inverse square law

In general, the SPL decreases with distance from the loudspeaker, reducing by 6 dB every time that the distance is doubled. For example, the SPL at 2 m from a loudspeaker is 6 dB less than at 1 m, whilst at 4 m the SPL is 6 dB less than at 2 m, and 12 dB less than at 1 m. It can be seen therefore that the SPL initially decreases rapidly with distance but as the absolute distance increases, the relative change becomes less. For example, the SPL 100 m away from a loudspeaker is only 6 dB less than at 50 m, yet it is 40 dB less than at 1 m. Furthermore, the SPL at 52 m is not measurably different from that at 50 m.

Each 3 dB increase in SPL output required from a loudspeaker needs a doubling of the audio frequency power delivered to the loudspeaker.

An example calculation applying these principles is as follows.

If the sensitivity of a particular loudspeaker is 90 dB for an input of 1 W when measured at 1 m distance (the standard rating conditions), what is the SPL at 8 m, and how much additional power will be required to achieve an SPL of 85 dB?

At 8 m from the loudspeaker, the SPL has decreased by:

$$20 \lg 8 = 18 \text{ dB};$$

so that the final value is $90 - 18 = 72 \text{ dB SPL}$.

To achieve 85 dB requires a power increase equivalent to:

$$85 - 72 = 13 \text{ dB}$$

13 dB relative to 1 W is 20 W.

The above approach is sufficiently accurate for both outdoor and indoor calculations for planning purposes. In indoor situations, the contribution from the reflected or reverberant sound components should be considered as this affects not only the perceived loudness (this is increased) but also the intelligibility if the reverberant component is too strong with respect to the direct sound. For large reverberant areas, expert advice from either the manufacturers and suppliers, or from a specialist sound consultant should be sought.

5.7 Loudspeaker layout and coverage

Loudspeakers should be selected and located to provide as uniform a coverage of an area as practicable. The inverse square law (see 5.6) and coverage angle data should be used initially to predict the coverage and plan an installation. For paging systems, the maximum variation of sound pressure level in the coverage area should be less than 10 dB at 2 kHz. In areas of high noise or reverberation, a smaller variation will be required if intelligibility is not to be downgraded. In sound reinforcement systems, the variation should be within 6 dB and preferably within 4 dB at 2 kHz and 4 kHz.

The coverage angles of each loudspeaker should be taken fully into account when designing the layout. The coverage angles are defined as the angles at which the output from the loudspeaker is 6 dB less than that produced on the main axis of the loudspeaker. Usually, the total included angle is quoted. This angle changes significantly with frequency, usually decreasing as the frequency increases. When designing sound systems, the coverage angle measured in the octave band centred on 4 kHz should be used.

When laying out and positioning loudspeakers, consideration should be given to the difference in sound pressure level (SPL) which is produced at a position on the main axis of the loudspeaker, and that produced at the same distance at an off-axis position — at half the coverage angle for example where, by definition, the SPL is 6 dB lower than on the main axis. A 6 dB difference is quite noticeable, and is sufficient to affect significantly the potential intelligibility of the system in a noisy environment by decreasing the apparent signal-to-noise ratio calculated for the on-axis case. In such circumstances, loudspeakers should be positioned so that their coverage areas either meet or preferably overlap, resulting in a higher overall SPL; theoretically, when two separate but equal sound sources combine, a 3 dB increase in SPL can be expected.

Loudspeaker coverage of a space can essentially be achieved in one of the two following ways:

- a) by use of a centralized loudspeaker system cluster;
- b) by use of a grid of ceiling-mounted loudspeakers usually operated at a low sound level.

Many sound systems make use of both types of distribution. There is often no clear-cut reason for using one type, and so other considerations such as architectural constraints, accessibility, and installation costs are often the deciding factors.

Centralized loudspeaker systems typically comprise column, Constant directivity (CD) horn, or full-range loudspeaker cabinets. The units may either be mounted on either side of the stage or rostrum, or alternatively they may be mounted centrally over it in the form of a cluster. Use is made of the loudspeaker's directional properties to direct sound into the audience and away from reflecting wall surfaces thus reducing the degree of reverberation generated by the system and aiding intelligibility and gain without risk of acoustic feedback.

They should provide an even coverage of a space by employing different parts of the cluster to cover different areas, for example the front and rear of the room. Delayed repeater loudspeakers may also be required, either to fill in areas which cannot be reached from the central cluster, for example under balconies, or to compensate for the effect of the inverse square law, causing too large a variation in direct SPL.

Low-level distributed sound systems are an alternative to the centralized cluster, consisting of a relatively high density of small loudspeakers spaced to provide a good overlap between adjacent units. This method can provide extremely uniform coverage of a space and normally provides better coverage than column or similar loudspeakers, in spaces which are wide or have low ceilings.

5.8 Loudspeaker signal distribution

5.8.1 Methods of distribution

Distribution of signals from amplifiers to loudspeakers can be carried out in one of the following two ways:

- a) at low impedance, typically 2 Ω to 8 Ω ;
- b) by voltage line distribution.

5.8.2 Low impedance distribution

Low impedance distribution generally offers an extended low frequency response but cable lengths have to be short and/or conductor diameters large to minimize resistive losses. Satisfactory connection of several loudspeakers to one amplifier can also be difficult, due to the need for complex series-parallel arrangements to produce the wanted division of power and the correct source and load impedances. Loudspeaker switching in such a system may be very difficult indeed, and reliability is compromised by series connection.

5.8.3 Voltage line distribution

According to this principle (see 1.3.20), all amplifiers are designed, regardless of their rated output powers, to have the same rated output voltage, traditionally 100 V in the UK, but lower voltages are now used as well. This voltage is called the "loudspeaker line voltage", and the higher it is, the lower the power loss is in a cable of fixed conductor length, diameter and material, for a given amount of useful power carried.

Amplifiers are designed to operate satisfactorily into any load impedance equal to or greater than an impedance Z_A (in ohms), given by:

$$Z_A = V^2/P_o$$

where

V is the line voltage in volts; and

P_o is the rated output power of the amplifier in watts.

Similarly, all loudspeakers are designed to present at their terminals an impedance Z_L , related to the designed loudspeaker line voltage V and the rated power P_R of the loudspeaker by the equation:

$$P_R = V^2/Z_L$$