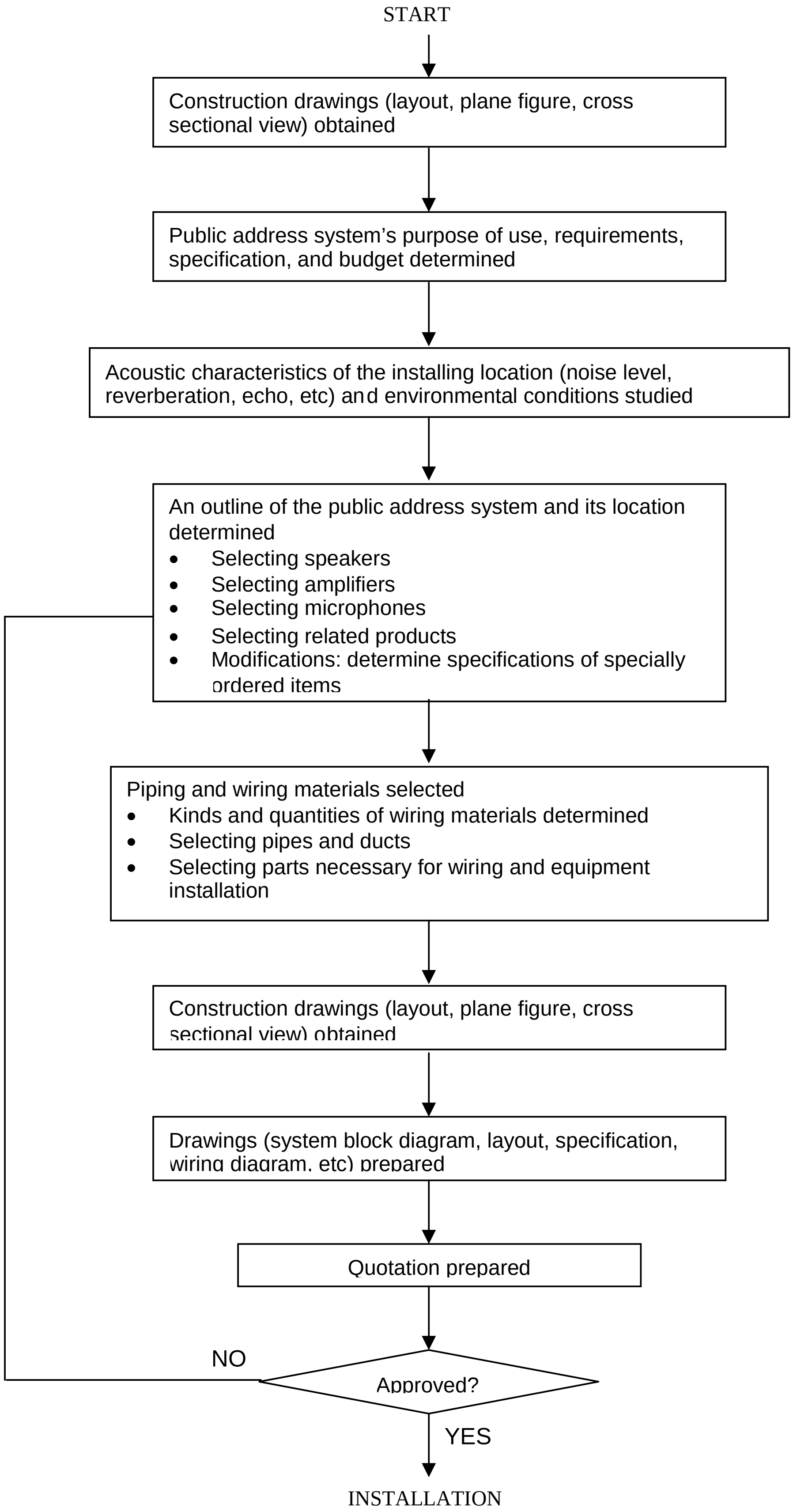
Public Address System

1.0 System Design Procedure

Public address systems of various scales are used in all fields of today's world for various purposes at various locations. A system engineer designs a system suitable to a specific application. In all cases, he starts it with preparing a system plan for the customer, involving the purpose of use, budget, and specifications.

Toward achieving an appropriate system design within the budget of the system plan, it is important to clarify the main purpose of acoustic devices to be used and to decide whether to select or not to select incidental functions (such as additional functions which may be of help if provided). It is also necessary in selecting system components to carefully study not only their performance but the ease of operation and the use of PA system as well as reliability (i.e., capability of performing the intended motion whenever required). A general system design procedure is shown in the flow chart given.



Flow Chart for System Design

2.0 Acoustic Design Basics

The first problem raised in designing a public address system concerns the noise and acoustic characteristics of the place where the system will be installed. Noise can be generally classified into two kinds, that is, noise inside the building, and noise outside. Noise inside the building includes, for example, the noises produced by the elevators and air conditioners, talking people, machines at work, and the goods carried on the floor. Outside noise may be such that produced by traffic, construction work, waves of the sea, or running water in a river. It generally varies much depending on the kind of its source, its distribution, the topography, and the buildings in the neighborhood. It can also vary greatly from time to time. The acoustic characteristics can pose a problem particularly when a public address system is installed indoors. The main factors involved are reverberation and echo.

A room that has walls of a heavy and hard material with small acoustic absorptive (for example, concrete, slate, or plywood walls) generally has a long reverberation time. Specifically, slate covered factories in the shape of a dome, parking areas in buildings, and gymnasiums have a long reverberation time. Reverberation lowers sound clarity, and is detrimental to acoustics at low frequencies, particularly in rooms which are not acoustically well designed. Echo is a reflection of the original sound heard later. Reflected sounds reaching the ear within 1/20 second (50 mS) from the direct sound reinforce the original sound so that they sound like a signal sound with reverberation. If reflected sounds reach the ear later than that, the reflected sounds are heard as an echo because they sound separate from the direct sound. The echo so seriously affects sound clarity that it makes a music performance impossible. It is the most harmful of all acoustic ill effects.

Outdoor echoes, such as caused by winds, mountains buildings, and topographical features, also pose a problem. When selecting speaker locations, therefore, high places where the speakers can take best advantage of fair winds, and places less likely to be troubled by echoes are chosen. Another way of coping with this problem is to locate small-powered speakers at many points.

2.1 Noise and Speaker Sound Pressure

If noise level is higher than the level of the sound coming out of the speaker, the speaker sound cannot be heard. No matter how close the speaker may be its sound cannot be heard if noise level is too high. The required difference between speaker sound and noise levels varies depending on the kind and degree of noise, but at least a sound pressure difference of 6 to 10 dB (2 to 3 times) is necessary for making announcements, or at least about 3 dB (about 1.5 times) for background music or other music programs.

For your reference, noise levels at various locations are shown in me table below.

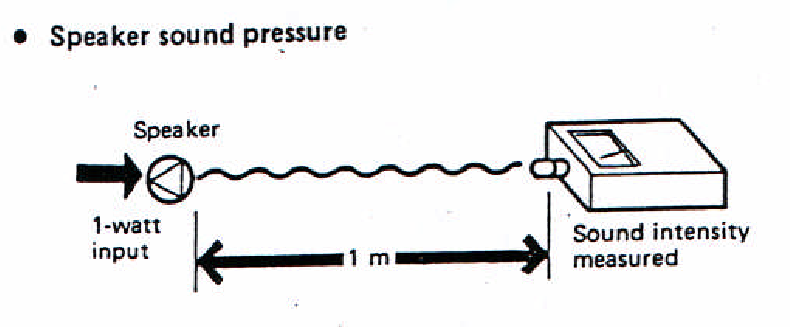
Noise Levels

Near jet aircraft engine	120 dB
Under railway girder	100 dB
Road intersection	80 dB
Noisy office	60 dB
Suburban housing area	40 dB
Tree leaves rustling in breeze	20 dB
Minimum audible sound	0 dB

Note: Generally, noise level is high at low frequencies, and low at high frequencies. Noise level is measured with a noise meter, and measured noise levels in WRMS are used.

2.2. Speaker Output Sound Pressure and Sound Attenuation

Output sound pressure Speaker specifications include output sound pressure, which represents the sound volume that can be produced by the speaker, measured by applying a 1-watt input to the speaker and measuring the sound one meter away from it.



Output sound pressure is expressed in decibels (dB), which is equal to phone used to express noise used to express the same in noise calculations Output sound pressure also represents the speaker capacity (or efficiency) of converting electrical signals into sound, which varies from 85 dB to 110 dB with the kinds of speakers.

Difference in output sound pressure with kinds of speakers

Speaker	Output sound pressure
Ceiling / wall mount speaker	85 to 93 dB
Column gymnasium speaker	90 to 106 dB
Horn speaker	95 to 110 dB

What will be the output sound pressure level if a higher input of 2 watts and more is applied to the speaker? The output sound pressure increases as shown in the table below.

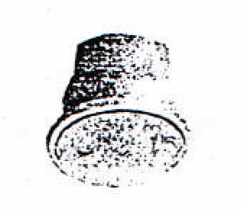
Speaker Input versus Increased Sound pressure

Speaker input	Increased sound pressure	Speaker input	Increased sound pressure
1W	0dB	16W	12dB
2W	3dB	20W	13dB
3W	5dB	25W	14dB
4W	6dB	30W	14.8dB
5W	7dB	32W	15dB
6W	8dB	40W	16dB
7W	8.5dB	50W	17dB
8W	9dB	60W	17.8dB
9W	9.5dB	70W	18.5dB
10W	10dB	80W	19dB
13W	11dB	90W	19.5dB
15W	11.8dB	100W	20dB

Note: A double input gives an increase of 3 dB

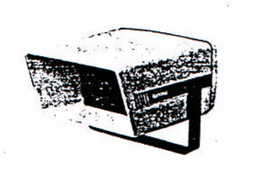
watts is applied to the speaker = (Output sound pressure in dB in the speaker specifications) + (Increased sound pressure in dB).

Example 1: A 3-watt input is applied to WS-4600GN



The output sound pressure of the WS-4600GN is 92 dB (1 m, 1W). If a 3-watt input is applied, the sound pressure in creases by 5 dB. Thus, 92 dB + 5 dB = 97 dB (1 m).

Example 2: A 15-watt input is applied to WT-715N

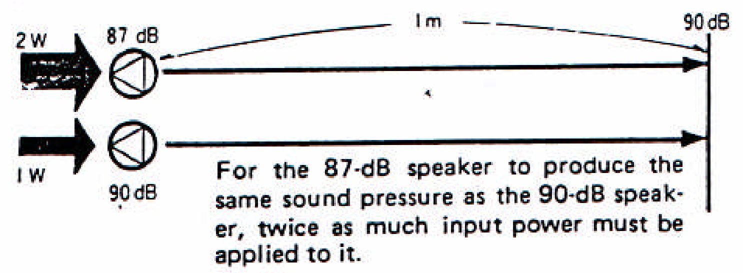


The WT-715N is a horn type speaker called the CLEARHORN, which features a high output sound pressure of 101 dB (1 m, 1 W). If a 15-watt input is applied to it, 101 dB+ 11.8 dB = 112.8dB (1 m).

As is clear from the two examples above, the higher the output sound pressure, the higher sound can the speaker produce more efficiently.

In terms of amplifiers, the same sound pressure can be obtained from a smaller powered amplifier if the speaker has a high output sound pressure. Assume that we now have a 87-dB speaker and a 90-dB speaker here, for example;

Output Sound Pressure and Required Input Power



To produce a sound pressure of 90 dB from the 87 dB speaker, its output sound pressure must be increased by 3 dB. This means that a 2-watt input must be applied to the 87-dB speaker.

Thus, if speakers that have a difference of 3 dB in sound pressure are used, an amplifier with twice the output of the other must be used. If the difference is 6 dB, an amplifier with four times the output power must be used. If the difference is 9 dB, an amplifier eight times as powerful is required.

What will be the total output sound pressure in dB if two or more speakers, each with an output sound pressure of X dB, are installed in the same place in the same direction?

If a 1-watt input is applied to two 90-dB speakers, their total output sound pressure increases by 3 dB to 93 dB, which is the same as when a 2-watt input is applied to one of them.

If a 1-watt input is applied to three 90-dB speakers, the result will be same as when a 3-watt input is applied to one of them. That is, the total output pressure increases by 5 dB to 95 dB.

• Increased Sound Pressure Where Two or More Speakers of the Same Capacity Are Installed in the Same Place

Number of speakers	Increased sound pressure
1	0 dB
2	+ 3 dB
3	+ 5 dB
4	+ 6 dB

Incidentally, the rated output sound pressure of a speaker applies where a certain specified sound source, not a speech or music, is used. In the past, the required sound pressure was often calculated from the rated output sound pressure. This, however, does not have a peak factor (allowance for speeches or music) so that .sound becomes distorted at peak level

Therefore, we calculate the required sound pressure by adding the peak factor for the peak of the program source to the required sound pressure difference, which is the difference between noise level and the average sound pressure of the program source.

Sound clarity increases as the required sound pressure difference increases. A. difference of about 6 to 10 dB between noise and the average sound pressure of the program source is normally sufficient.

The peak factor (the difference between the average sound pressure and peak sound pressure of a program source) varies from one program source to another, but it is 10 dB for speeches and background music, or 20 dB for music.

This can be summarized as follows:

Required sound pressure = Noise level + Required sound pressure difference + Peak factor

<u>Speeches and Background Music</u>

Required sound pressure

= Noise level + (6 to 10 dB) + 10 dB
= Noise level + (16 to 20 dB)

<u>Music</u>

Required sound pressure

= Noise level + (6 to 10 dB) + 20 dB
= Noise level + (26 to 30 dB)

The table below shows the required sound pressures at various locations

Noise effect	Noise level (dB)	Description	Required sound pressure	
Conversation inaudible	120	- Near aircraft engine	If noise level is 100 dB or more, a sound pressure of more than 120 dB (maximum audible sound level) may be necessary (varying depending on noise frequency) so that announcements will be hardly audible.	
	110	- Siren, automobile horn		
	100	- Under railway girder, inside electric train		
	90	- Machine shop	100 dB or more	
Conversation hardly audible	80	- Road intersection, printing shop		
Must speak aloud	70	- Department store, noisy office	70 to 90 dB	Where music is the primary sound source, 80 to 100 dB
Normal conversation possible	60	- Restaurant, hotel lobby, office, urban housing area		
	50	-…………..	70 dB or more (Noise can be nearly ignored)	
	40	- Suburban housing area, hospital, hotel		
	30	- Broadcasting studio		
	20	- Tree leaves rustling in breeze		
	10	- Whisper		
	0	- Minimum audible sound		

2.3 Sound Attenuation

Speaker output sound decreases in volume as the distance from the speaker increases. Sound volume (sound pressure) decreases in inverse proportion to the square of distance.

The table below shows sound attenuation outdoors (wherein air density difference, temperature difference, wind direction, reflection from obstacles, refraction, etc. are ignored).

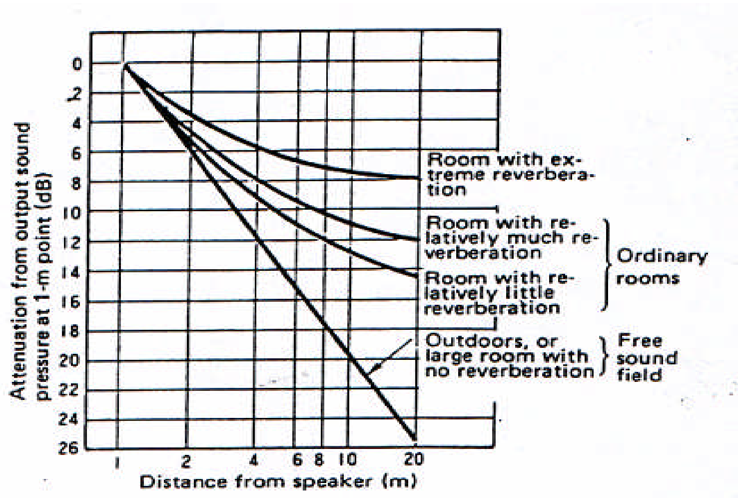
• Distance from Speaker and Sound Attenuation in Free Space

Distance	Attenuation	Distance	Attenuation
1 m	0 dB	28 m	29 dB
2 m	6 dB	30 m	29.5 dB
3 m	9.5 dB	32 m	30 dB
4 m	12 dB	36 m	31 dB
5 m	14 dB	40 m	32 dB
6 m	15.5 dB	45 m	33 dB
7 m	17 dB	50 m	34 dB
8 m	18 dB	56 m	35 dB
9 m	19 dB	60 m	35.5 dB
10 m	20 dB	64 m	36 dB
11 m	21 dB	70 m	37 dB
13 m	22 dB	80 m	38 dB
14 m	23 dB	90 m	39 dB
15 m	23.5 dB	100 m	40 dB
18 m	25 dB	150 m	43.5 dB
20 m	26 dB	200 m	46 dB
22 m	27 dB	300 m	49.5 dB
25 m	28 dB	400 m	52 dB

Sound attenuation indoors is less than that in free space, varying depending on the acoustic characteristics of the room. Generally, public address systems are designed with sound attenuation in free space as reference, using the above as peak factor.

Sound attenuation also varies with frequency. That is, a high-frequency sound attenuates more than a low-frequency sound.

• Sound Pressure Attenuation Indoors Versus Distance



The sound pressure at a point a certain distance away from the speaker is calculated as follows:

[Output sound pressure (dB) where an input of a certain wattage is applied] — (Attenuation by distance (dB)].

Suppose that the rearmost seats in an auditorium are 25 meters away from the speakers. The speaker output sound pressure required to reach them at 80 dB level is, by compensating for attenuation of the original sound pressure:

80dB+28dB = 108 dB.

Example 1:

What wattage of input must be applied to the speakers of a PA system in an office?

Step 1

Suppose that the noise level indoors is 60 dB. If the required sound pressure difference is 6 dB, the required sound pressure will be, by adding a peak factor of 10 dB:

Required sound pressure = Noise level + Peak factor + Required sound pressure difference

= 60dB + 10dB + 6dB

= 76dB.

Step 2

A sound pressure of 76 dB is required at the listening points, which are 1.7 meters away from the speakers.

This means an attenuation of about 5 dB.

Speaker sound pressure by distance = Required sound pressure + Attenuation

= 76 + 5

= 81dB.

Step 3

To achieve a uniform sound pressure, the speakers are so arranged that their directional angles cross at the listening points on condition that their service area is 90° each.

Speaker to speaker distance = 2 x (2.7 m — 1 m) = 3.4 = 3 m

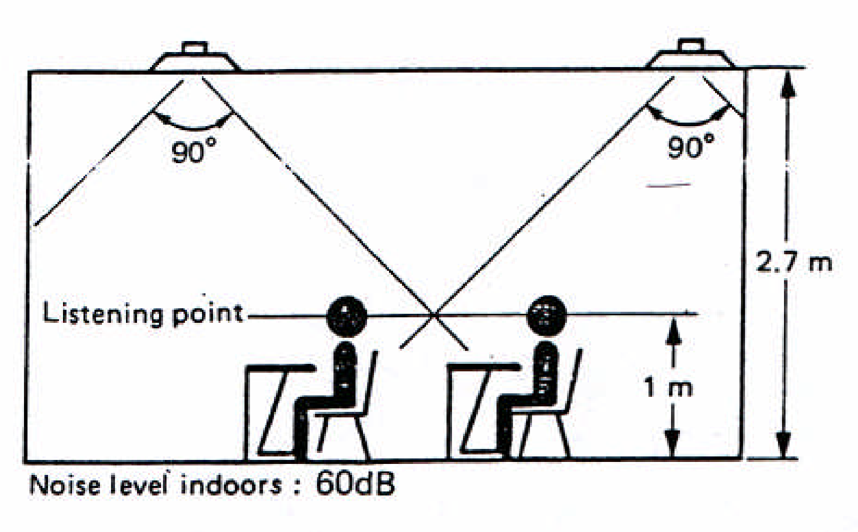
Thus, the speakers are installed on the ceiling 3 meters apart.

Step 4

Selecting a speaker:

The WS-4150N was selected as a ceiling speaker. This speaker has an output sound pressure of 92 dB (1 m, 1 W) so that enough sound volume can be obtained even if an input of about 0.1 watt is applied to it.

Actually, the total input wattage is the input wattage per speaker multiplied by the number of speakers



Example 2:

What wattage of input must be applied to the speakers of a sound reinforcement system in, for example, a gymnasium or auditorium?

Step 1

Suppose that the noise level at the audience seats is 60 dB. If the required sound pressure difference is 6 dB, the required sound pressure will be, by adding a peak factor of 20 dB:

Required sound pressure = Noise level + Peak factor + Required sound pressure Difference

= 60dB + 20dB + 6dB

= 86dB.

Step 2

Even the rearmost row of seats must have a sound pressure of 86 dB. Because it is 14 meters away from the speakers, the original sound pressure will be attenuated by 23 dB.

Speaker sound pressure = Required sound pressure + Attenuation by distance

= 86dB + 23dB

= 109dB.

Step 3

As shown, a speaker sound pressure of 109 dB is necessary. Because two speakers are used here, the required sound pressure per speaker is 109 dB minus 3 dB, that is, 106 dB.

Step 4

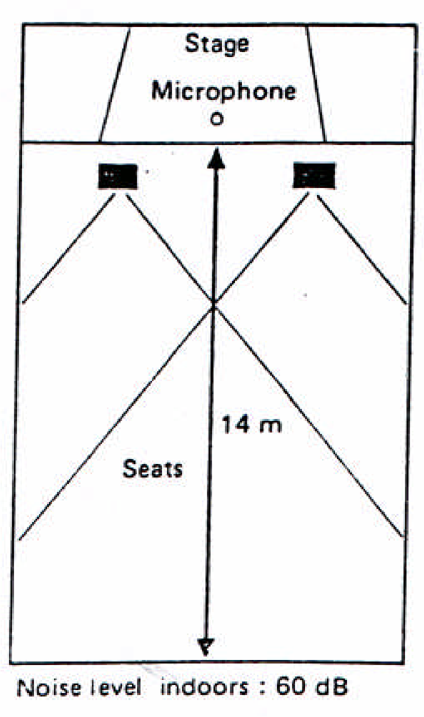
Next is the selection of a speaker model. Here, the WS-3200N was selected. The WS-3200N has excellent directivity and provides satisfactory performance for music as well. The output sound pressure of the WS-3200N is 95dB.

Increased sound pressure = Speaker sound pressure - Output sound pressure

= 106dB - 95dB

= 11dB.

This can be obtained by applying a 13-watt input. The selection of the WS-3200N is correct because its rated input is 15 watts.



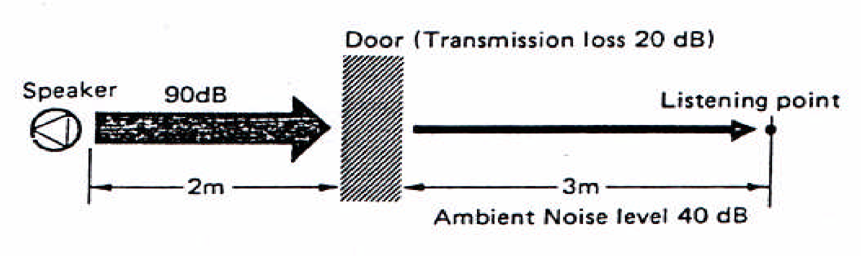
2.4 Sound Insulation and Transmission

Sound insulation and transmission have two meanings. One is to shutting out the sounds or announcements that originate in the next room, and the other is to transmit sounds or announcements through a door, for example.

These are calculated as follows:

Transmitted sound pressure (dB)
= Incident sound pressure (dB) – Transmission loss (dB)

Example 1:



Sound pressure (dB) at the listening point

= 90dB - (Loss at 2 m: 6 dB) - (Transmission loss: 20 dB) - (Loss at 3 m: 9.5 dB)

= 54.5 dB.

Under this condition, the sound from the speaker is louder than the noise level at the listening point, and can be heard through the door.

Transmission Losses

Glass window (3mm thick)	Approx. 10 dB
Wooden door (9mm thick)	Approx. 25 dB
Concrete block (100mm thick)	Approx. 45 dB
Concrete (100mm thick)	Approx. 50 dB

2.5 Frequency Characteristics (Effect of a graphic equalizer)

The human ear is sensitive to sounds of 2,000 Hz to 6,000 Hz. In other words, one of the conditions for good audibility is to produce aloud sounds of 2,000Hz to 6,000Hz.

Each building or room has its own reverberation time frequency characteristic, which means the reverberation time characteristic of that building or room against sounds from low to high.

Generally, gymnasiums and auditoriums have such a structure and interior materials that bass sound can hardly be absorbed. That is, bass sound lingers on and thus is emphasized.

Suppose an acoustic system having a very flat characteristic is used in a gymnasium.

The actual sound in a gymnasium having a reverberation time frequency characteristic such as shown in Fig. 1 will be as shown in Fig. 2. If bass sound is emphasized, the sounds within the range of 2,000 Hz to 6,000 Hz that are necessary for, clarity fall, resulting in less clear sounds.

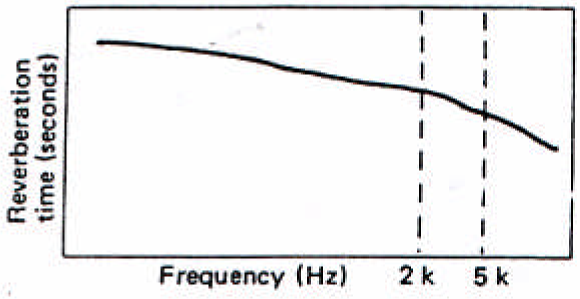


Fig. 1. Reverberation Time Frequency Characteristic

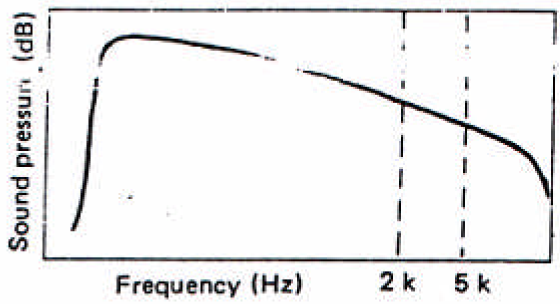


Fig. 2. Transmitting Frequency Characteristic

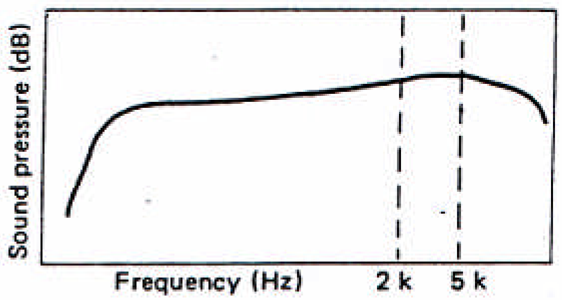


Fig. 3. Transmitting Frequency Characteristic after Correction

A graphic equalizer for sound field correction electrically corrects this phenomenon.

The graphic equalizer can vary sound level at every certain frequency. If the power response is as shown in Fig. 2, the graphic equalizer suppresses the sounds of up to 1,000 Hz, and slightly raises treble sounds of 2,000 Hz and upward.

Clarity can be raised as described above.

3.0 Speaker Selection

Speaker selection and arrangement is so important that the performance of an acoustic system depends mostly on it. Such troubles as poor clarity and lack of volume are often caused by the wrong selection or arrangement of speakers.

3.1 Kinds of Speakers

Speakers can be roughly classified into indoor and outdoor types, which can be further broken down by place of use and purpose of use as shown in the table below.

Kind of speaker		Use		
		Public address	Background music	Music
Indoor	Ceiling mount	●	●	
	Wall mount	●	●	
	Column	●		●
	Horn	●		
	CLEARHORN	●		●
Outdoor	Column (Weatherproof)	●	●	●
	Horn	●	(●)	
	CLEARHORN	●	●	●

The required reproducing frequency bandwidths of specters by use are explained.

a) Public address
b) Generally, a frequency band of about 200 to 6,000 Hz can achieve the purpose. In the worst case, the required frequency band is from about 250 to 4,000 Hz, which corresponds to the voice frequency band of man.
c) Background music
d) Background music, including music in a light sense of the word, requires a frequency band of about 100 to 8,000 Hz.
e) Music

In a hall primarily designed for amplifying music, a frequency band of about 40 to 5,000 Hz is necessary.

Therefore, conditions for music reproduction are stricter than in the other cases, and special care must be taken in selecting speakers for it.

3.2 Speaker Arrangement

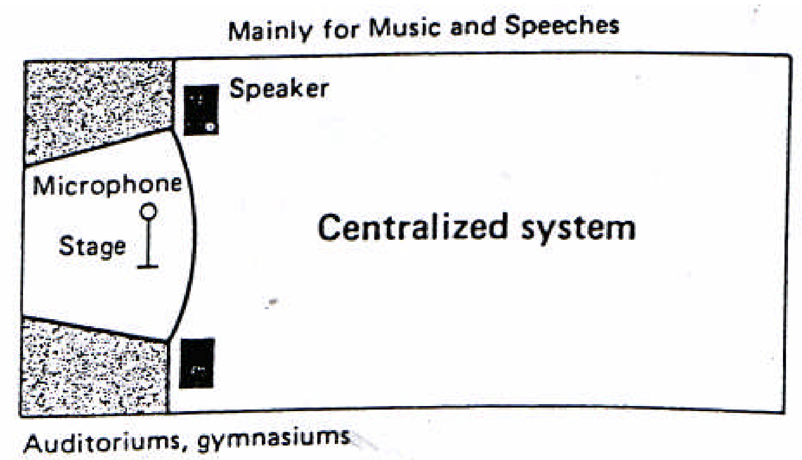
Speaker arrangement varies with the electrical input to be applied and speaker efficiency as mentioned before. Where speakers are used indoors, the purpose of use, acoustic characteristics (reverberation, echo, and sound insulation), and speaker directivity must also be taken into account. Where speakers are used outdoors, weather resistance to winds and rains must be additionally considered.

Generally, there are three types of speaker arrangement normally applied in sound system design:-

3.2.1 Centralized system

This system places speakers in a centralized position to operate in a single direction; and has the advantages of providing a directional sense and low installation cost. The former is particularly effective for lectures, speeches, and concerts where the visual direction must meet the sound direction.

It also has disadvantages: Difficulty of providing a uniform level; poor clarity caused by reverberation and echo; and large output power required where noise level is high. In factories where much noise is produced, the dispersed system mentioned next is suitable.



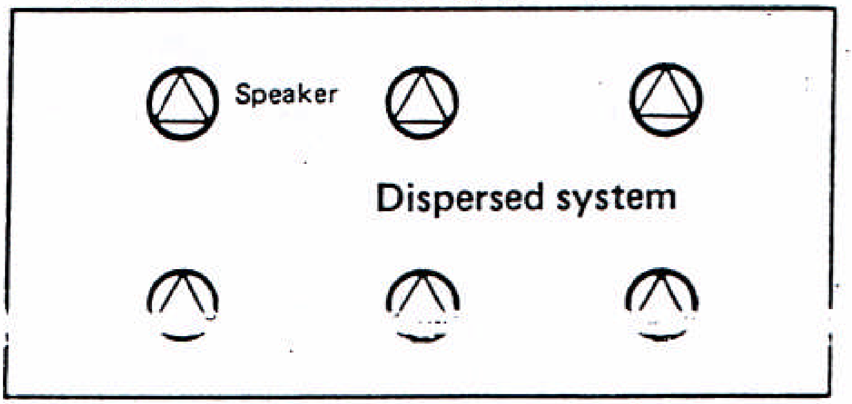
3.2.2 Dispersed system

This system uses speakers in a dispersed arrangement. It is suitable to background music because it provides uniformity of sound level. If a small electric input is applied to one of the speakers to narrow the audible range, sound reflection decreases so that clarity can be increased where reverberation time is long.

If many speakers of the system interfere with one another, it can lower sound quality. The important point for the dispersed system is to correctly select a number of speakers and the operating range of each speaker.

The dispersed system costs more to install than the centralized system.

Mainly for Public Address, Paging, Background Music



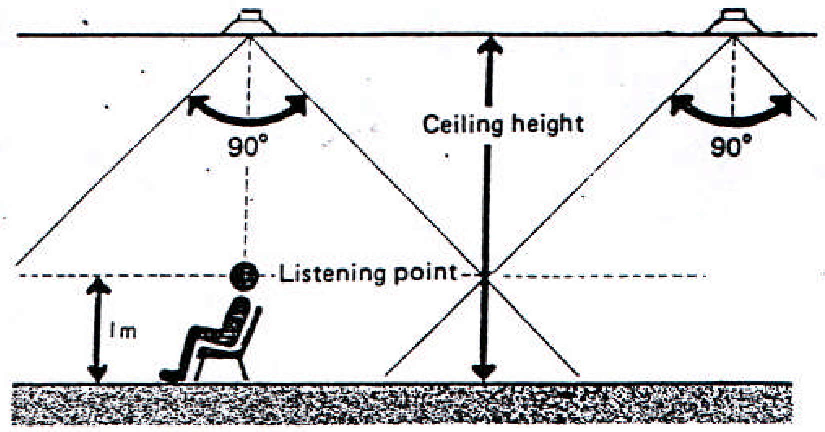
Offices, Stores, Coffee houses

3.3 Composite system

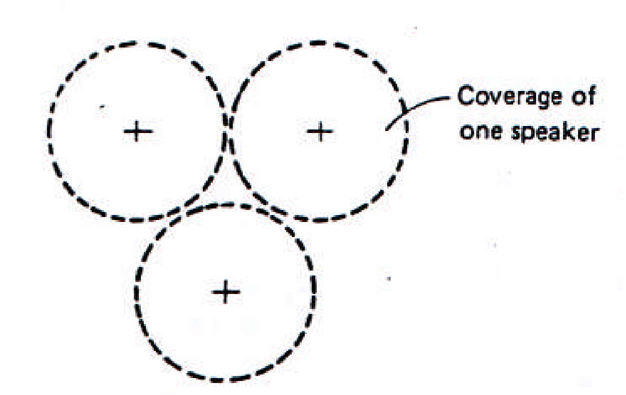
This is a combination of the centralized system and the dispersed system. It uses centralized speakers to achieve the intended sound pressure and small powered auxiliary speakers in a dispersed arrangement at points where sound pressure is short of the required level. The composite speaker system is frequently seen in auditoriums and gymnasiums.

3.3.1 Speaker Arrangement Indoors

a) Restaurants, Offices, Stores because the ceiling is generally low, install many ceiling mount speakers of about 1 W to 3W. Determine a number of speakers suitable to the room size.



Install speakers zigzag to achieve a uniform sound.



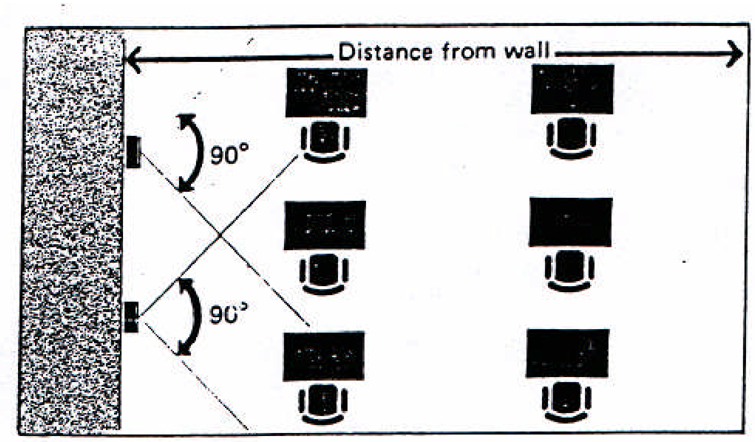
• Ceiling height and the coverage of each speaker

The following table applies where noise level is 60 dB, the peak factor 10 dB, and the required sound pressure difference 6 dB.

Ceiling height	Speaker spacing	Coverage of one speaker	Input per speaker
2.5 m	3 m	Approx. 9 m^2	1 W
3.0 m	4 m	Approx. 16 m^2	1 W
3.5 m	5 m	Approx. 25 m^2	1 W
4.0 m	6 m	Approx. 36 m^2	3 W
5.0 m	8 m	Approx. 64 m^2	3 W

b) Classrooms and Offices

Select 1-to 6-watt wall mount speakers suitable to the room size.



• Distance from wall and the coverage of each speaker

The following table applies where noise level is 60 dB, the peak factor 10 dB, and the required sound pressure difference 6 dB.

Distance from wall	Speaker spacing	Coverage of one speaker	Input per speaker
Up to 4 m	4 m	Approx. 16 m^2	1 W
Up to 7 m	7 m	Approx. 50 m^2	3 W
Up to 9 m	8 to 16 m	Approx. 100 m^2	5 W

Do not install the wall mount speaker facing each other. If wall mount speakers are installed facing with each other the sound clarity will be degraded.

As bi-directional wall mount speaker (1750N) emits sound in both directions, it is suitable for wide space or narrow, long areas such as lobbies, waiting rooms or passage ways of hotels, theaters, movie theaters, hospitals, railway stations, airports, etc.

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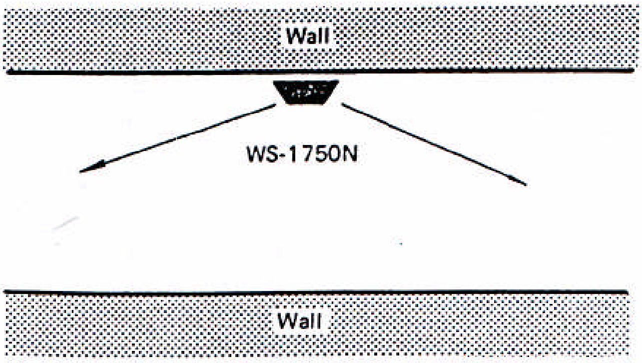
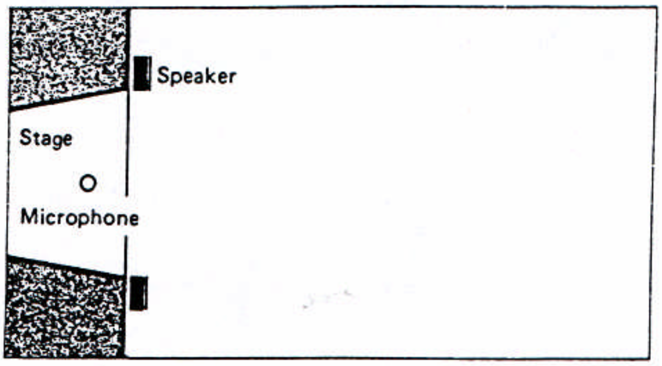


c) Meeting Rooms, Conference Rooms, Gymnasiums

Select 15-W or 30-W 2-way column speakers suitable to the room size



Install the speakers about 4 meters to the front side on the stage, from where the microphone is located. Select a number of speakers and their model from Table (A) where the speakers are intended for music; or from Table (B) where they are mainly for speeches.

There must be a difference of 20dB or more between the peak sound pressure and noise.

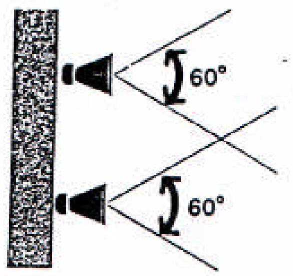
2-way column speaker	Quantity	A	B
		Distance from speaker for obtaining a sound pressure of 90 dB (at maximum output) at audience seats.	Distance from speaker for obtaining a sound pressure of 85 dB (at maximum output) at audience seats.
WS-3200N (15W)	2	Approx. 10m	Approx. 18m
	4	Approx. 14m	Approx. 25m
WS-3250N (30W)	2	Approx. 18m	Approx. 32m
	4	Approx. 25m	Approx. 45m

d). Noisy Rooms

Noise level about 90 dB

If noise level is 90 dB, a sound volume of 96 to 100 dB is necessary.

Use horn speakers which are efficient.



In noisy rooms, install horn speakers on the ceiling or wall.

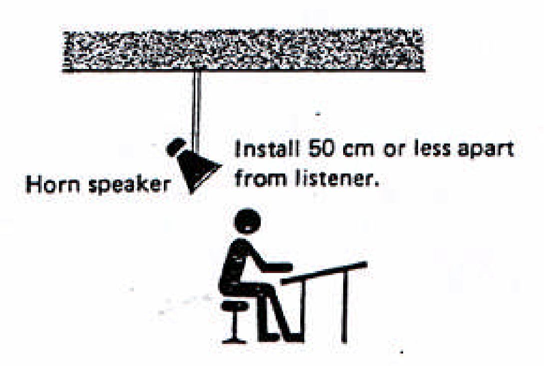
Horn speaker	Distance for obtaining 100 dB at peak output	Speaker spacing
5 W	Approx. 3 m	Approx. 3 m
10 W	Approx. 4.5 m	Approx. 4 m
15 W	Approx. 7 m	Approx. 6 m
30 W	Approx. 11 m	Approx. 10 m

Horn speaker	Distance for obtaining 96 dB at peak output	Speaker spacing
5 W	Approx. 5 m	Approx. 4 m
10 W	Approx. 7 m	Approx. 6 m
15 W	Approx. 11 m	Approx. 10 m
30 W	Approx. 17 m	Approx. 15 m

Noise level about 100 dB

If noise level exceeds 100 dB, the speaker sound cannot be distinguished from the noise even if the volume is raised above the level.

If noise level is about 100 dB, install a horn speaker of about 5 to 10 watts near each listener.

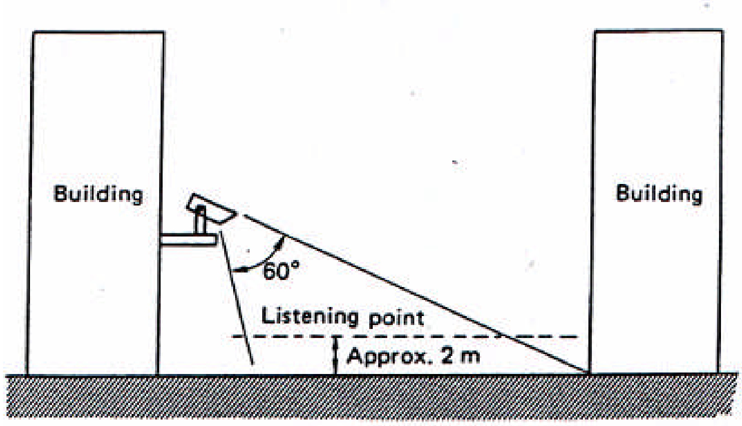


e) Speaker Arrangement Outdoors

i) Factory premises

Install horn speakers or CLEARHORN speakers of 7 or 15 watts on the premises at the necessary position in a dispersed way.

If speaker sound (sound within a vertical dispersion range of 60°) directly hits the building opposite the speaker, its reflected sound adversely affects clarity. Install the speakers so that the upper limit of the vertical dispersion range will be at the ground level of the opposite building.

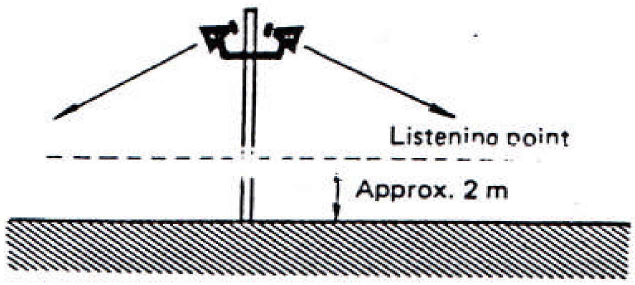


Speaker	Distance for obtaining 76 dB at peak output
WT-707N (7W)	Approx. 32 m
WT-715N (15W)	Approx. 64 m
WT-202AN (10W)	Approx. 80 m
WT-200AN (15W)	Approx. 100 m

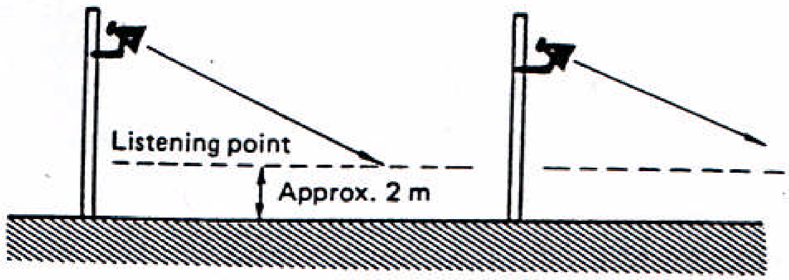
ii) Streets and shopping centers

- Install horn speakers or CLEARHORN speakers of 7 or 15 watts in a dispersed way.
- Speakers may be installed by either method A or B, but method B is recommended because it provides better sound uniformity and clarity than method A.

A (Where pole-to-pole distance is too large)



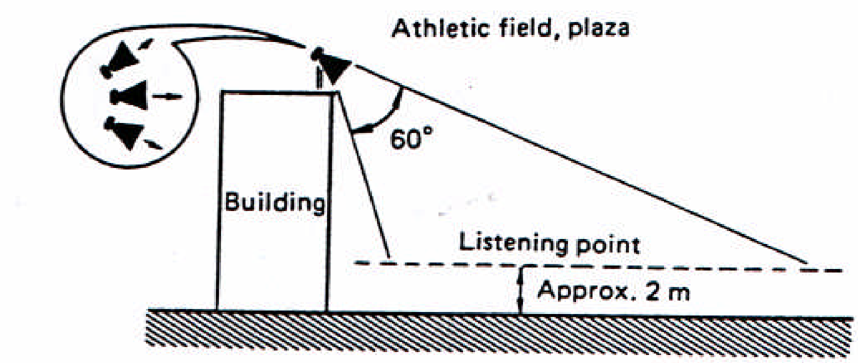
B (Where pole-to-pole distance is small)

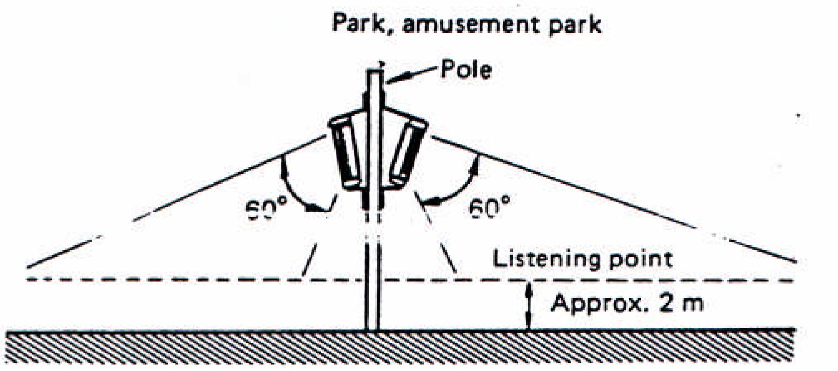


Speaker	Distance for obtaining 76 dB at peak output
WT-707N (7W)	Approx. 32 m
WT-715N (15W)	Approx. 64 m
WT-202AN (10W)	Approx. 80 m
WT-200AN (15W)	Approx. 100 m

iii) Athletic fields, parks, etc.

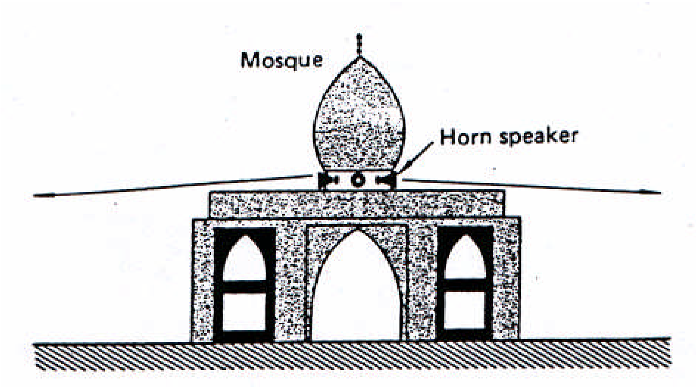
- Install horn speakers or weatherproof column speakers of 20 or 30 watts in a centralized arrangement.
- Install the speakers on building roof or on top of a pole, or other elevated location.



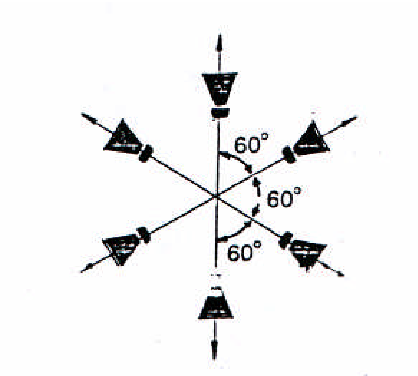


Speaker	Distance for obtaining 76 dB at peak output
WS-928N (20W)	Approx. 40 m
WS-929N (30W)	Approx. 45 m
WT-200AN (15W)	Approx. 100 m
WT-516N (15W)	Approx. 150 m
WT-531N (30W)	Approx. 200 m
WT-551HN (50W)	Approx. 350 m

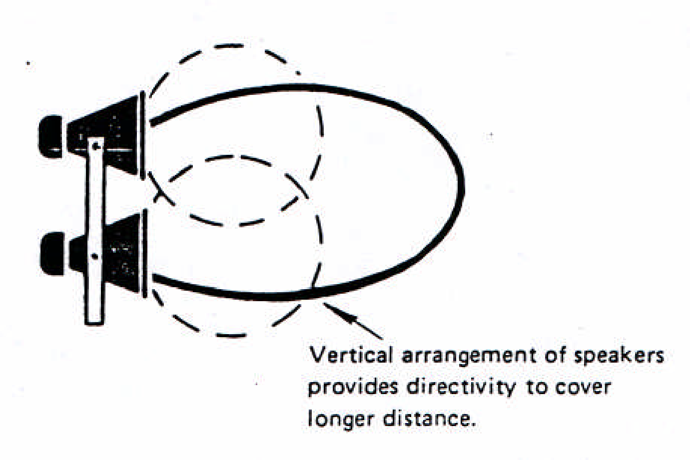
f) Mosques, etc.



- Install horn speakers of 30 to 50 watts at as high a place as possible. Install them in a circular arrangement to emit sound in all directions.



- If sound pressure is not enough with a single speaker, combine plural speakers vertically to provide directivity.



- Where speaker sound must reach far and wide, speaker output power

must be somewhat greater than normal because the effects of winds, topography, temperature difference, and noise variations cannot be ignored.

Speaker	Quantity	Distance for obtaining 76 dB at peak output
WT-531N (30W)	1	Approx. 200 m
	2	Approx. 300 m
	3	Approx. 400 m
	4	Approx. 600 m
WT-551HN (50W)	1	Approx. 350 m
	2	Approx. 500 m
	3	Approx: 700 m
	4	Approx. 1,000 m

4.0 Amplifier selection

After determining speaker arrangement and the required input to each speaker, the total required input (wattage) can be calculated, and an amplifier that has an output power corresponding to it can be selected. Select an amplifier on the basis of, not the maximum output, but the rated output wattage. If additional speakers are planned to be installed in the future, take this into account in selecting an amplifier wattage.

The number of input and output terminals, input and output impedances and levels must also be studied. Performance wise, frequency response, signal-to-noise ratio, and distortion factor also need to be examined. If the speakers are used exclusively for music, the specifications must also be more strict than in other applications.

4.1 Amplifier Wattage Selection from Speakers

Too small an amplifier output cannot produce enough sound volume, whereas too great an amplifier output can damage the speakers due to the excessive input applied to the speakers. This problem is particularly true of low-impedance speakers.

a) High-impedance speakers

A system involving multiple speakers normally uses high-impedance speakers connected parallel. As you know, the combined impedance of speakers connected parallel is smaller than the impedance of the individual speakers. It is necessary for an amplifier to meet the following condition in order to drive speakers properly.

$$\text{Amplifier output impedance} \leqq \text{Combined impedance of speakers}$$

Therefore, an excessively large number of speakers cannot be connected to an amplifier. To allow simple designing of such a system, the output voltage of the amplifier is regulated at constant level. This is called a 100-V line or 70-V line. A large-output amplifier may be described as one which can supply a large current at a constant voltage.

Because the amplifier output voltage is constant, the input power applied to the speakers can be automatically determined from the input impedance of each speaker.

As many speakers as desired can be connected to an amplifier if their total input is within the limits of the rated output of the amplifier.

Rated amplifier output $\geq$ Total speaker input

Rated amplifier load impedance $\leq$ Combined speaker input impedance

Speaker input (100-V line)

$$P = \frac{100^2}{Z}$$

Speaker input (70-V line)

$$P = \frac{70^2}{Z}$$

P : Speaker input (W)

Z : Speaker impedance (ohms)

Example 1: WS-4000BN

The input impedance is 3.3 k ohms or 10 k ohms. If it is 3.3 k ohms where a 100- V line is used,

$$P = \frac{100^2}{3.3 \times 10^3} = 3 \text{ (W)}$$

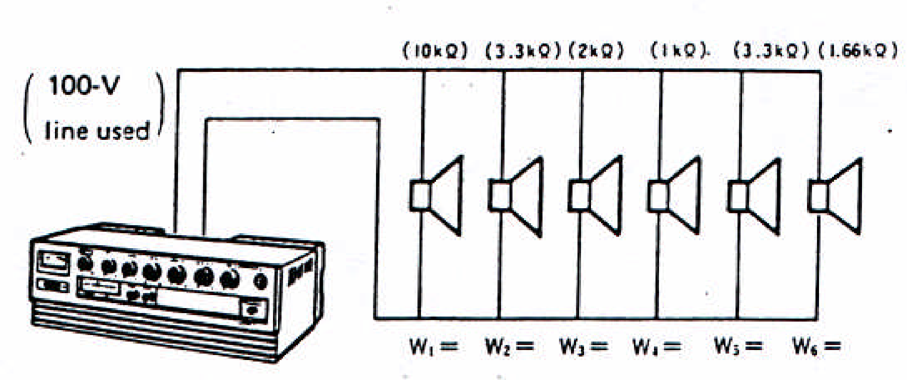
If it is 10 k ohms where a 100-V line is used,

$$P = \frac{100^2}{10 \times 10^3} = 1 \text{ (W)}$$

If the amplifier with an output power of 30 watts is used, up to ten speakers can be connected to it if the input impedance is 3.3 k ohms; or up to 30 speakers can be connected to it if the input impedance is 10 k ohms. Since the output sound pressure of the WS-4000BN is 92 dB, sound pressures of 97 dB and 92 dB can be produced respectively. (Sound pressure increase by 3-watt input is 5 dB).Maximum numbers of speakers to be connected to typical models are shown in the table below

Example 2:

What amplifier output wattage is necessary for the speakers connected as shown below?



Calculate W1 to W6 for each speaker, and select an amplifier that has an output greater than the calculated total.

$$W_1 + W_2 + W_3 + W_4 + W_5 + W_6$$

$$= \frac{100^2}{10 \times 10^3} + \frac{100^2}{3.3 \times 10^3} + \frac{100^2}{2 \times 10^3} + \frac{100^2}{1 \times 10^3} + \frac{100^2}{3.3 \times 10^3} + \frac{100^2}{1.66 \times 10^3}$$

$$= 28 \text{ (W)}$$

Speaker impedance	Input to each speaker	Connectable number of speakers		
		30W (WA-AP105N)	60W (WA-740N, WA-745N)	120W (WA-750N, WA-755N WA-25N)
330Ω	30W [15W]	1 [2]	2 [4]	4 [8]
400Ω	25W [12.5W]	1 [2]	2 [4]	4 [9]
500Ω	20W [10W]	1 [3]	3 [6]	6 [12]
670Ω	15W [7.5W]	2 [4]	4 [8]	8 [16]
1kΩ	10W [5W]	3 [6]	6 [12]	12 [24]
1.66kΩ	6W [3W]	5 [10]	10 [20]	20 [40]
2kΩ	5W [2.5W]	6 [12]	12 [24]	24 [48]
3.3kΩ	3W [1.25W]	5 [10]	20 [40]	40 [80]
4kΩ	2.5W [1.25W]	12 [24]	24 [43]	48 [96]
5kΩ	2W [1W]	15 [30]	30 [60]	60 [120]
10kΩ	1W [0.5W]	30 [60]	60 [120]	120 [240]

Note: Numbers given in [ ] indicate those for the 70-V line.

The above condition is satisfied by an amplifier with a rated output of 30 watts. The WA-320N or WA-730N, for example, may be selected. Remember not to select an amplifier output by simply totaling the rated inputs of the speakers to be used. This method, however, can end with the same result in some cases.

4.2 Low-impedance speakers

If low-impedance speakers are used, the amplifier delivers its full output power. Even in this case, the following conditions must be met. Rated amplifier load impedance (ohms)

Example 1:

If the volume is raised in a connection as shown below, the 30-watt output of the amplifier is fully applied to the speaker and damages the 15-watt speaker.

Example 2:

In a connection as shown below, only a 15-watt input is applied to the speaker because the speaker impedance is double the amplifier impedance of 4 ohms.

5.0 Microphone selection

In selecting a microphone, directivity, frequency response, impedance, balanced or unbalanced type, etc .must be studied depending on the purpose of use and the location.

The wrong use can cause poor tonal quality, lack of volume, or howling. It is important, therefore, to fully explain the correct method of using the microphone to the user.

First, select a place of use, and a type of microphone suitable to the purpose of use. It is necessary for this purpose to be fully familiar with the basic characteristics of the microphone.

5.1 Types of microphone (Based on method of signal generation)

5.1.1 Condenser microphone*

A microphone utilizing a capacitor (condenser) as a pickup element. Electronics are usually contained in the microphone body and a polarizing voltage is necessary; so external or battery power is required, and output levels are usually higher than other types of microphones. Condenser microphones are commonly used for high quality audio applications.

5.1.2 Electrets condenser microphone*

A variation of a standard condenser microphone where the element is permanently charged so no external polarizing voltage is necessary. However, due to the electret's very high impedance, an electronic impedance converter is usually built in and does require a small amount of voltage from a battery or external supply.

Electrets condenser microphones have similar characteristics to condenser microphones. Their small size and light weight make them particularly suitable for studio use (tie-clasp livelier microphones etc.) and for speech microphones in which clear tones are required.

5.1.3 Dynamic microphone*

A type of microphone which converts acoustical to electrical energy by means of a permanent magnet and a moving coil. Dynamic microphones do not require external power.

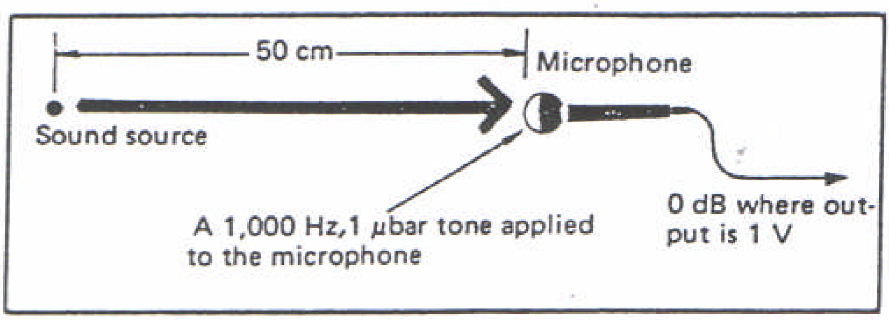
As dynamic microphones are rugged in construction, they provide stable performance and are easily handled. They generate minimum noise when used in windy conditions, and as such they are used in speech and vocal applications.

[* Partially from the CAMEO/Dictionary of Creative Audio Terms]

5.2 Microphone Sensitivity

If a 1,000 Hz tone of 1 µbar (microbar) is applied to a microphone at a distance of 50 cm, and if it produces an output of 1 V, this microphone has a sensitivity of 0 dB. That is, microphone sensitivity represents the capacity of quantitative conversion from sound into electricity. Incidentally, a tone of 1 µbar is equivalent to a speaker output sound pressure of 74 dB, which is the level of an ordinary human voice heard at a close distance.

A -50dB microphone has higher sensitivity than a -70dB microphone by 20 dB. If a 50dB amplifier is used, its output will be 0 dB.



5.3 Microphone Frequency Response

Generally, the range of frequencies audible to the human ear is about 20 to 18,000 Hz.

A microphone is considered having good characteristics if it has a wide frequency band. But a microphone having the required frequency range, through it may be somewhat narrow, can well serve the purpose depending on what it is used for. In paging applications, for example, a microphone that can cover the human voice frequency range of about 150 to 6,000 Hz is satisfactory for the purpose.

A microphone with the unnecessary portion of the bass range cut off can rather permit amplification of clear sound with less "confinement" of sound.

It is important, therefore, to select the correct microphone for the purpose.

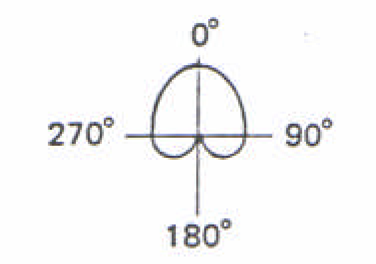
5.4 Microphone Directivity

Directivity means the sensitivity difference of a microphone in the direction of the sound source, and can be generally classified into two kinds as follows:

5.4.1 Unidirectional (cardioid)*

A microphone with a heart-shaped pickup pattern that is sensitive to sound in the forward direction(0^o) and rejects sound from the rear of the mic (180°). At the sides (90° and 270°) the cardioid is about half as sensitive as the front.

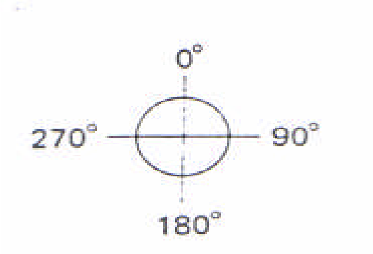
This type of microphone is suited to use in cases in which only a selected sound is required. Since it is resistant to howling when used in public address systems, it is commonly used for a wide variety of purpose.



5.4.2 Omni directional*

A microphone that is equally sensitive to sounds in all directions. This type of microphone is suited to use in cases in which the selected sound, as well as reflected sound, and other sounds in the area, are required to give an impression of the surrounding sound environment.

[* Partially from the CAMEO/Dictionary of Creative Audio Terms]

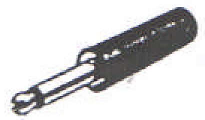


5.5 Output Impedance

The output impedance of a microphone means the impedance of its terminal which is connected to an amplifier. It is necessary to match the input impedance of the amplifier with the output impedance of the microphone. Actually, however, a microphone may be connected to an amplifier having impedance higher than the microphone output impedance.

Microphones come in two output impedances, high and low. An impedance of 10 k ohms or more is called high impedance; and an impedance of 600 ohms or less is called low impedance. There are also dual impedance type microphones, which can be easily converted from one impedance to the other or not verse with a switch or by changing the plug and internal connections.

- **High impedance**

Cable extension distance	10 m or less
To extend cable	Use microphone mixer (WR-420N)
Sensitivity (Output level)	Relatively high: About −60 dB
Output impedance	20 k ohms to 50 k ohms
Connector	TS phone plug 

- **Low impedance**

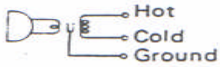
Cable extension distance		70 to 80 m (balanced type), or 20 m (un-balanced type)
To extend cable		Use microphone mixer (WR-420N)
Sensitivity (Output level)		Relatively low: About −75 dB
Output impedance		200 ohms to 600 ohms
Connectors	Un-balanced type	TS phone plug 
	Balanced type	TRS phone plug 
		XL-type connector 

5.6 Balanced Type, Unbalanced Type

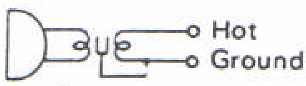
The noise induced in the microphone cable is amplified together with the voice signals by the amplifier.

Therefore, all microphones use a shielded cable to prevent externally induced hum and noise. The type which uses a two-conductor shielded cable is called the balanced type; and that which uses a single-conductor shielded cable is called the unbalanced type.

- Balanced type

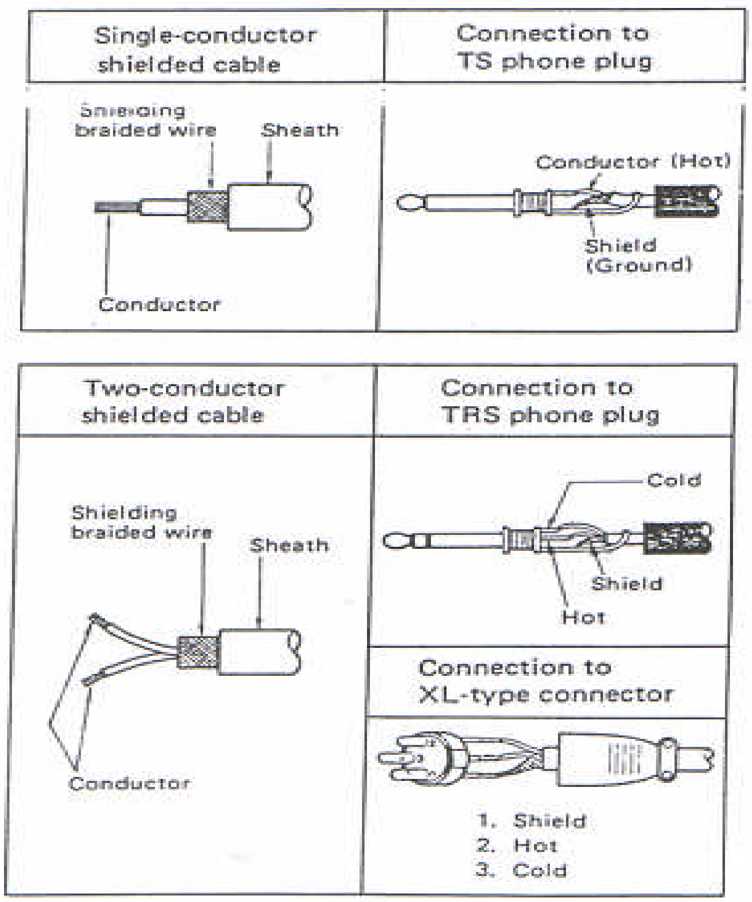
Impedance	Low impedance
Plug	TRS phone plug, XL-type connector
Output circuit	

- Unbalanced type

Impedance	High impedance, low impedance
Plug	TS phone plug
Output circuit	

The balanced type is recommended where the microphone is used far away from the amplifier because it is less susceptible to externally induced noise and provides constant tonal quality. In this case, however, the amplifier must have a balanced type input terminal. Some unbalanced type microphones use a two-conductor shielded cable. These microphones can be converted to the balanced type if its TS phone plug is changed to a TRS phone plug or a XL-type connector.

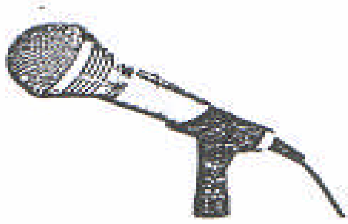
- Shielded cable and plug connection



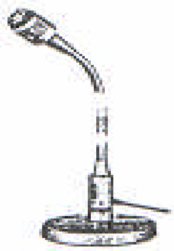
5.7 Microphone Selection

Select a suitable microphone by referring to the foregoing explanation. Here are typical examples of microphone selection.

Paging and Public Address



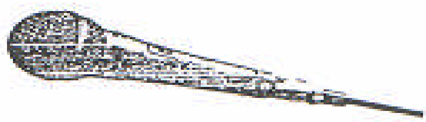
Unidirectional dynamic microphone
WM-305X



Unidirectional dynamic microphone
WM-359N

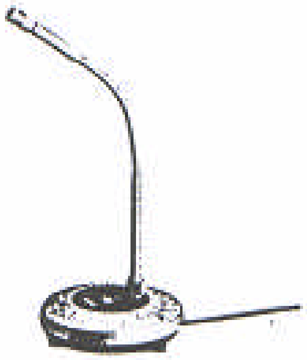
Vocals

Unidirectional dynamic microphone
WM-331N



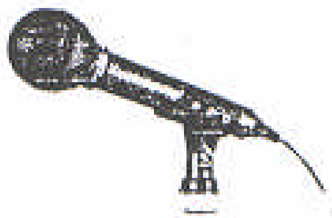
Unidirectional dynamic microphone
WM-333N

Meetings and Speeches



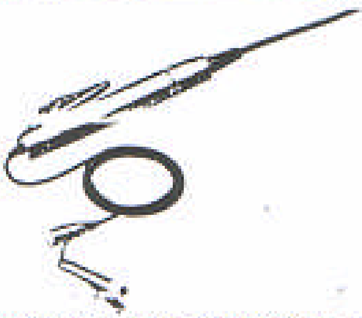
Unidirectional electret condenser microphone
WM-681N

Outdoor



Unidirectional dynamic microphone
(with drip-proof filter)
WM-381BN

Interviews



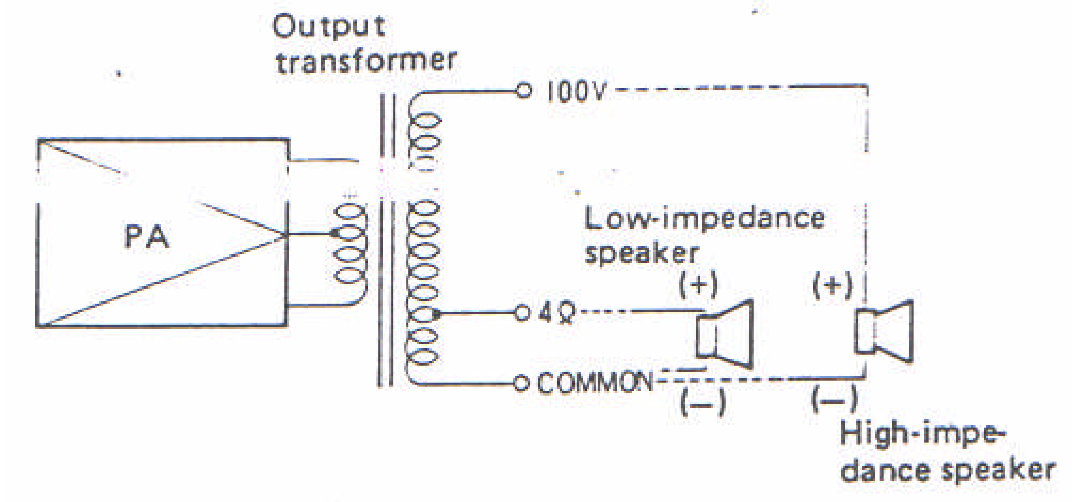
Omnidirectional electret condenser microphone
(with tie-clip holder)
WM-611N

6.0 Connecting Speakers

6.1 Basic Connection

The output stage of the HI-POWER AMP (and other amps as well) contains an output transformer. This transformer is wired as follows.

Connect speakers so that the COMMON terminals are connected to (-), and the 4-ohm terminal of the low-impedance speaker, or the 100-V or 70-V terminal of the high-impedance speaker, is connected to (+) (low- and high-impedance terminals cannot be used simultaneously, 100-V and 70-V lines cannot be used simultaneously). As the rated load impedance of the 70-V line is half that of the 100-V line, twice the quantity of speakers can be connected when the 70-V line is used (the speaker input, however, will be half that for the 100-V line). For these reasons, the 70-V line is used in cases such as BGM broadcasting in which a large number of speakers with relatively small input rating are used.

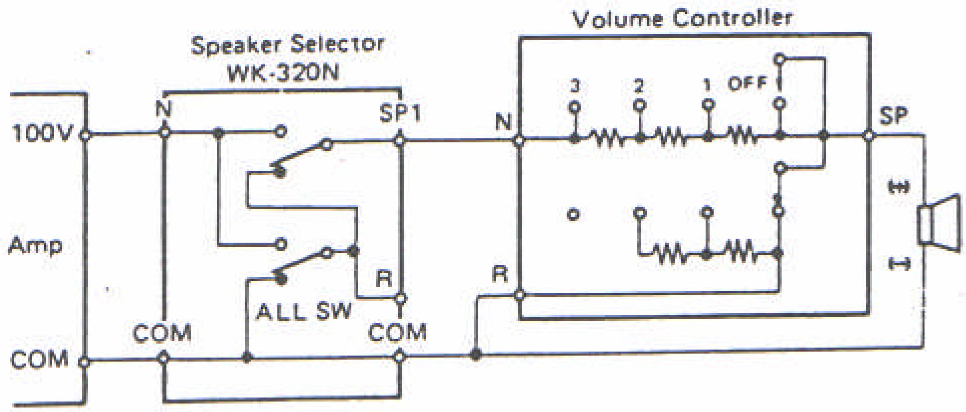


6.2 Using Volume Controller

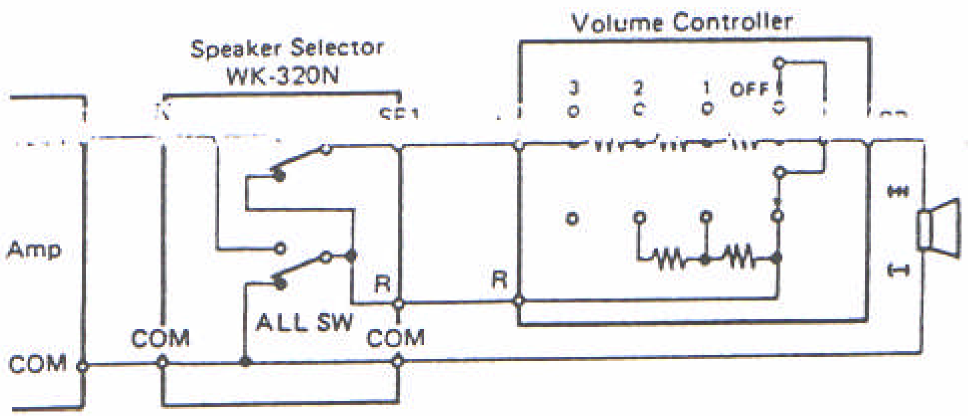
Volume controller may be used only with high-impedance speakers. The wiring for the volume controller is of either the 2- or 3-wire system. Volume control for each speaker is possible with both the 2- and 3-wire systems. However, when it is OFF, emergency announcement is impossible in case the 2-wire system is used; but possible in the 3-wire system.

The user should be advised to note that the 2-and 3-wire volume controls are exactly the same. As is obvious from the circuit diagram above, ALL terminal is normally connected to COMMON. However, when the all-speaker switch is ON, it is connected to the 100-V output of the output transformer. Since accurate attenuation is not obtained if the volume controller is not suited to the impedance of the connected speaker, a volume controller having the same wattage rating (or a wattage rating within the specified range) as the speaker must be selected. A number of speakers can be connected and controlled together by a volume controller within the specified rating.

- 2-wire system



- 3-wire system



- **Volume Controller Selection Table**

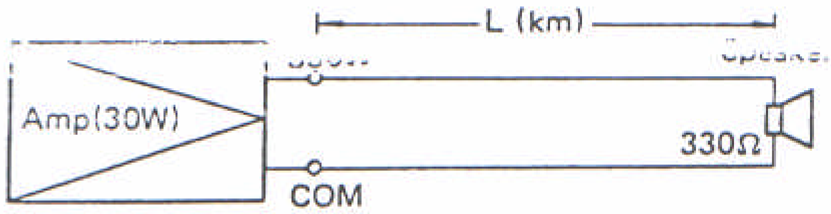
Model	Suitable rating
WZ-550N/1	1W
WZ-550N/2	2W
WZ-550N/3-5	3 to 5W
WZ-550N/6-30	6 to 30W

a) Speaker Wiring

As wiring between the amp and speakers must be designed with consideration for transmission losses, line loop resistance must be no more than 10% of the combined impedance of the speakers or the rated load impedance of the amp.

For Example:

If the rated load impedance of the amp is 330 ohms and wiring is 1.0 mm in diameter, what is the maximum length of the wiring?



The line resistance of annealed copper wire (single strand) is 22.9n/km (at 20°C). The maximum length of wiring is calculated with the following equation:

Loop resistance < = 10% of the rated load impedance

2 x 22.9L < = 330 x 0.1
L < = 0.72

The maximum length of wiring, therefore, is approximately 700m.Maximum allowable distance between an amplifier and a speaker is shown below.

• Maximum allowable distance between an amplifier and speakers

Rated load impedance of amp \ Wire diameter		1.0mm	1.2mm	1.6mm	2.0mm	2.6mm
Low impedance	4Ω	10m	13m	23m	40m	60m
High impedance	670Ω	1,400m	2,200m	3,800m	6,000m	10,000m
	330Ω	700m	1,100m	1,500m	3,000m	5,000m
	170Ω	350m	550m	1,000m	1,500m	2,600m
	85Ω	180m	280m	500m	770m	1,300m
	42Ω	90m	140m	250m	380m	650m

Note: This table indicates cable lengths for anneald copper wire (single strand) on a condition that loop resistance is approximately 10 percent of the load impedance of the amplifier.

6.3 Radio Antennas

6.3.1 AM Radio Antennas

AM radio antennas are always required. In strong broadcast areas, a 2- to 5-m vinyl-covered wire should be attached to the wall or ceiling in a horizontal attitude and as high as possible. Coaxial cable should be used between the antenna and a radio tuner.

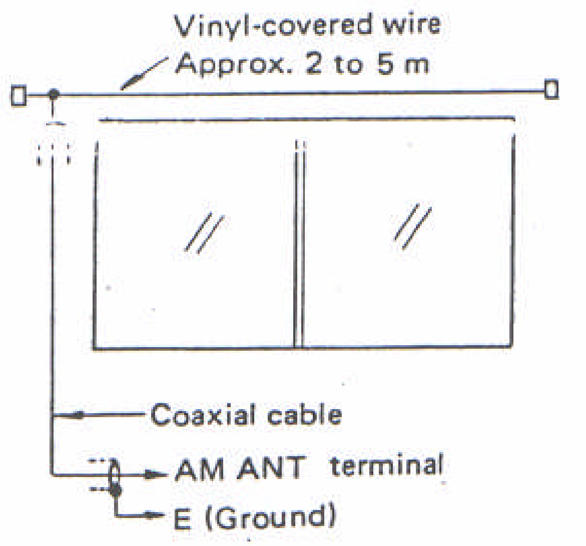
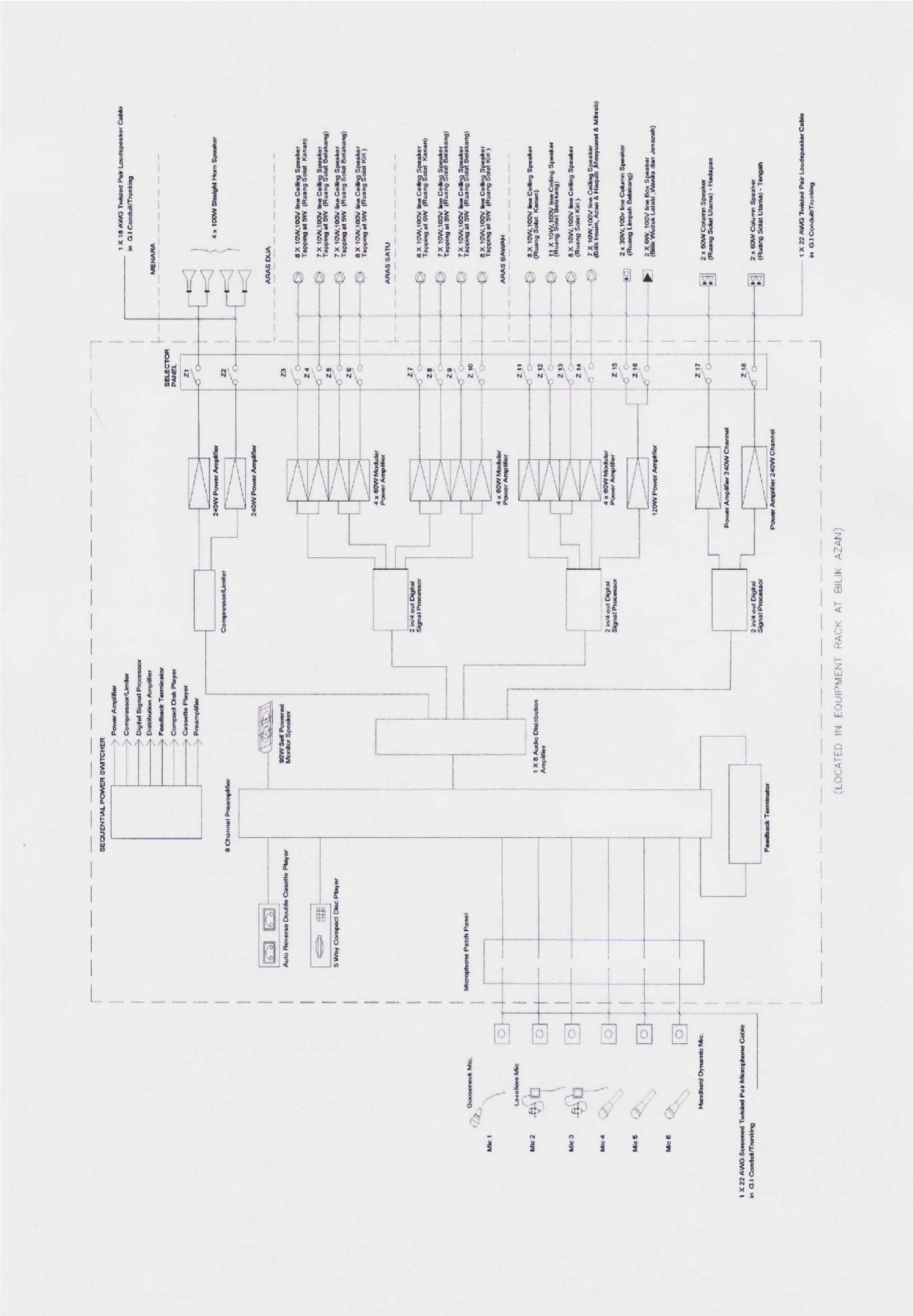


Table 1: Guideline for Audio Visual Requirement and Criteria

NO	ROOM TYPE	PROPOSED SIZE (mm)	CRITERIA / GUIDE
1.0	**General System**		
1.1	P.A. Equipment Room	2000 x 2500	
1.2	Security Control Room	3000 x 4000	Can be combine within the Command Control Centre
1.3	Riser Room	1200 x 900	For MATV / AV / Security / Sound Systems Door kerb:100mm – 150mm
1.4	Floor Opening	200(w) x 1200(l)	Will be covered by approved 2 hrs fire barrier Door to follow UBBL 75mm kerb around the floor opening; 50mm kerb across the door
2.0	**Auditorium**		Shall be acoustically treated and sound insulated Sound insulation required if metal roofing used
2.1	AV Control Room	4000(l) x 3500(w) 2000 x 900(h)	Fully carpeted, air conditioned Full height partitioned (brickwall or sound insulated partition) Sliding glass window: tinted, 800mm from floor level
2.2	SIS Cubicle / Room	1500 x 2000 1000 x 900(h)	Size is for one cubicle Sound insulation shall follow ISO Std: i.e. full height partitioned (brickwall or sound insulated partition) Fully carpeted, air conditioned Glass window: tinted, 800mm from floor level
2.3	Back Projection Room	6000(d)	For fixed screen system, behind the stage / screen
2.4	Stage Cross beams and roof supports		Required to support the I-beams across the stage area: for all the lighting barrels and curtain railings Approximate load: 4000 kg
2.5	Catwalk Ceiling Catwalk		For maintenance of stage equipments Recessed catwalk within the acoustic ceiling for maintenance
3.0	**Meeting / Operation / Seminar / Board Rooms (Single volume rooms)**		
3.1	AV Control Room	2500 x 3000 1200 x 900(h)	Fully carpeted, air conditioned Fully height portioned (brickwall or sound insulated partition) Sliding glass window: tinted, 800mm from floor level Sliding board built-ins required

NOTE: All sizes given may differ according to the sizes of the project.

Appendix 1: Schematic Diagram of PA Systems



Appendix 2: Schematic Diagram of SMATV System