Loudspeaker Installation Methods and Connection Techniques

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and
Connection Techniques

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LOUDSPEAKER INSTALLATION METHODS
AND
CONNECTION TECHNIQUES

GENERAL

Efficient power transfer between the amplifier and associated loudspeakers is one of the prime considerations in any sound system design. The two power transfer methods used are direct connection of the amplifier output to the loudspeaker voice coils and connection through loudspeaker matching transformers. Both methods have their advantages and disadvantages.

Direct connection is the most efficient and cost effective method for systems that have only one or two loudspeakers or loudspeaker systems such as sound columns and have the amplifier located relatively close to the loudspeakers. In these systems, direct connection between the amplifier's 4 or 8 ohm outputs and the loudspeaker voice coils eliminates both the power losses inherent in all transformers and their costs.

Direct connection also offers improved performance since matching transformers also introduce at least a small amount of distortion into the system and affect the system's overall frequency response. This is especially true when the amplifier has a direct 4 or 8 ohm output that passes its output transformer. In these systems, direct connection eliminates the losses and signal degradation of two transformers.

Direct connection, however, is most efficient only when the distance between the amplifier and associated loudspeakers is relatively short. Otherwise, the amount of power lost in the speaker lines quickly offsets the improved efficiency gained through eliminating the loudspeaker matching transformers. Chart #1 shows the amount of power loss experienced in 8 ohm loudspeaker systems as a function of distance and wire size. As you can see, the loss can be quite significant.

Impedance matching also becomes a problem on direct connected systems if more than one or two loudspeakers are involved. Direct connected systems are also difficult to expand since adding one or two speakers requires an entirely new set of impedance calculations and quite often also necessitates a new wiring scheme.

For these reasons, direct connection is normally used only on systems where wire runs are short and only one or two loudspeakers are involved, or in professional systems where the improved overall performance offered by direct connection justifies the added cost of the heavy gauge wire needed to keep line losses to a reasonable amount.

It follows that the matching transformer method is normally used whenever more than one or two loudspeakers are being connected to a single amplifier or when the distance between the amplifier and the loudspeaker is great.

Further information on both methods follows.

IMPEDANCE MATCHING WITHOUT TRANSFORMERS

For the most efficient transfer of power, the total loudspeaker impedance must match the output impedance of the amplifier.

Matching Single Loudspeaker
Single loudspeakers should be matched as shown in Figure 1.

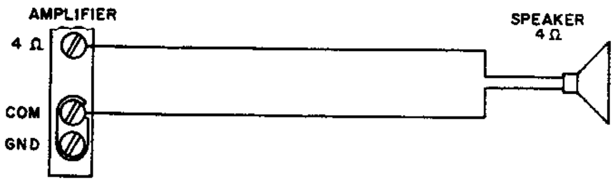


Figure 1

When there is more than one loudspeaker in a sound system, calculation of the total loudspeaker impedance is based upon several formulas:

Matching Loudspeakers Connected in Series

For series connection of loudspeakers, add the individual loudspeaker impedances together to obtain the Z_T total matching impedance: (See Figure 2)

1. $Z_T = Z_1 + Z_2 \ldots + Z_n$
2. $Z_T = 4 + 4$
3. $Z_T = 8$

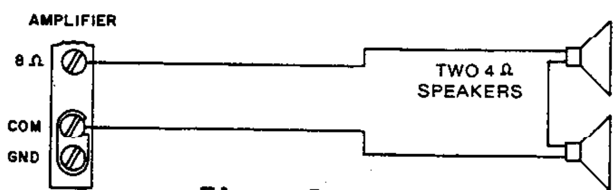


Figure 2

Matching Two Loudspeakers Connected in Parallel

For parallel loudspeakers connection, use the following formula to obtain Z_T, the total matching impedance: (See Figure 3)

1. $Z_T = \dfrac{1}{\frac{1}{Z_1} + \frac{1}{Z_2} + \ldots + \frac{1}{Z_n}}$
2. $Z_T = \dfrac{1}{\frac{1}{8} + \frac{1}{8}}$
3. $Z_T = \dfrac{1}{\frac{2}{8}} = \dfrac{1}{\frac{1}{4}}$
4. $Z_T = 4$

Impedance Matching Without Transformers (continued)

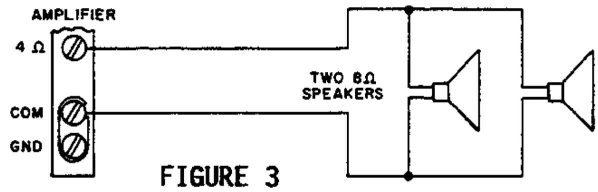


FIGURE 3

The following formula can also be used when the impedance of all the speakers is the same:

1. $Z_T = \frac{Z_1}{N}$

2. $Z_T = \frac{8}{2}$

3. $Z_T = 4$

Matching Loudspeakers Connected in Series/Parallel

For Series/Parallel connections, combine the two formulas as the loudspeaker connections indicate. For example, in Figure 4, apply the series formula for A and B, then for C and D. Take the results of this and apply the parallel formula to obtain Z_T the final matching impedance;

1. $Z_T = \frac{1}{\frac{1}{X} + \frac{1}{Y} + \ldots \frac{1}{Z_N}}$

Where: X = A + B (X = 8+8=16)
Y = C + D (Y = 8+8=16

2. $Z_T = \frac{1}{\frac{1}{16} + \frac{1}{16}}$

3. $Z_T = \frac{1}{\frac{2}{16}}$

4. $Z_T = 8$

The formula $Z_T = \frac{XY}{X + Y}$ can also be used when there are only 2 impedances.

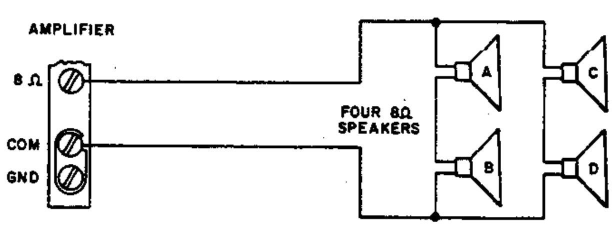


FIGURE 4

POWER DISTRIBUTION WITHOUT TRANSFORMERS

In a series system of loudspeakers with like voice coil impedances, equal power distribution will occur. However, if one loudspeaker has 4 ohms impedance and another 8 ohms, the power consumed by the 8 ohm loudspeaker will be twice that of the 4 ohm loudspeaker.

In parallel systems of loudspeakers with like voice coil impedances, equal power consumption will result. When loudspeakers of different impedances are connected in parallel, the smaller impedance loudspeaker will receive the greater power. If one loudspeaker is 8 ohms and one is 16 ohms, the 8 ohm loudspeaker will consume twice as much power as the 16 ohm loudspeaker.

LOUDSPEAKER/AMPLIFIER MISMATCHING

Mismatching upward (i.e., connecting an 8-ohm loudspeaker to the 4-ohm output of an amplifier) will affect the power delivered to the loudspeaker. Power loss will be about proportional to the upward impedance mismatch (i.e., 50 percent when connecting an 8-ohm loudspeaker to a 4-ohm amplifier tap). Mismatching cannot ordinarily damage a well-designed amplifier.

As a general rule, no serious frequency response deficiency will be noted if upward mismatches up to about five-to-one ratio are used. The effect will be less noticeable the higher the amplifier quality.

Downward mismatching (i.e., connecting a 4-ohm loudspeaker to an 8-ohm amplfier tap) should always be avoided. It overloads the amplifier and may seriously affect both its performance and life expectancy.

In direct connected systems, care also must be taken to not overpower the system. Connecting a 100 watt amplifier to a loudspeaker rated at 20 watts will most likely destroy the speaker if someone accidently turns the amplifier up to full power.

LINE/POWER LOSSES IN DIRECT CONNECTED SYSTEMS

In direct connected 4 and 8 ohm systems the size and length of the loudspeaker lines is a major consideration as these factors determine the amount of power lost in the lines. Chart #1 shows this in graphic fashion.

Often overlooked is the fact that the resistance of the line adds to the loudspeaker impedance to change the actual total connected impedance. For example, in an 8 ohm system having 2 ohms of line resistance (20% line loss), the actual load impedance connected to the amplifier is 10 ohms. This mismatch further reduces the amount of power delivered to the loudspeaker as explained under Loudspeaker/Amplifier Mismatching.

For these reasons, the use of as large a wire size as possible is always recommended. Runs from 50 to 100 feet should be #18 gauge or larger for best operation, and runs of 100 feet or more should be at least #16 gauge or larger.

IMPEDANCE MATCHING WITH TRANSFORMERS

The use of loudspeaker matching transformers which permits the signal to be transmitted at a high voltage and then reduced (stepped down) at the loudspeaker, greatly reduces the amount of power lost in the transmission line. It enables relatively large amounts of power to be transmitted efficiently over comparatively small size wire. Charts #2 and #3 graphically illustrate this for the 25V and 70V distribution systems used in most of today's commercial sound installations.

As you can see from these Charts, in a 70V system, 5 Watts can be transmitted over 5,000 feet of 20 gauge wire with only a 10% power loss. The distance drops to slightly over 600 feet in a 25V system. Chart #1 shows that in a direct connected 8 ohm system, the distance drops to under 50 feet for the same amount of power loss.

In complex installations having large numbers of loudspeakers, and/or different types of loudspeakers, the use of matching transformers also simplifies power distribution and level adjustment. The amount of power each transformer draws from the distribution line and passes on to its loudspeaker depends on the transformer's impedance. In this respect, matching transformers are like light bulbs, as a transformer presenting a 10 Watt impedance to the line will draw 10 Watts from the line, just as a 60 Watt light bulb draws 60 Watts from a 120V AC power line.

The overall design of these systems also permits loudspeakers to be added to, or removed from, systems without significantly affecting the sound level at any of the other loudspeakers. Thus, several loudspeakers can be added to the system without having to adjust the level of all the other loudspeakers. The only precaution that must be observed is to make sure the proper matching transformers are used and that the amplifier is not overloaded by the installation of too many additional speakers.

25 VOLT AND 70 VOLT "CONSTANT VOLTAGE DISTRIBUTION SYSTEMS"

General Information

Today's 25V and 70V "Constant Voltage Distributions" were developed years ago and standardized upon by the industry to answer the needs of large multi-speaker installations and to simplify the calculations involved.

The "Constant Voltage" nomenclature comes from the fact the amplifiers used in these systems must be able to deliver a "Constant Voltage" to the distribution line regardless of the number of loudspeakers connected to the line and the amount of power being used. Specifically, the requirement is that their output voltage must vary no more than 3 dB from No Load to Full Load conditions. Since the human ear finds it difficult to distinquish level changes of less than 3 dB, this permits the addition or deletion of loudspeakers to the system without any noticeable change in level.

It should be noted here that most of today's amplifiers operate well under the 3 dB requirement. This, however, wasn't true years ago when these standards were adopted by the industry.

25 Volt and 70 Volt "Constant Voltage Distribution Systems" (continued)

The "Constant Voltage" terminology does not mean that the amplifiers deliver a constant 25V or 70V signal to the distribution line. The amplifiers do this only when they are being driven to their full rated power output by a constant sine wave signal. In actual use, their output voltage is usually much less than 25V or 70V and varies along with the audio signal. Remember speech and music are very complex signals whose intensity varies greatly.

At the time these systems were established, 70V (it is actually 70.7V) was chosen as one standard since with 3dB regulation the output voltage never exceeded 100 V even under No Load conditions and therefore, met electrical codes for Class 2 open wiring. This allowed these systems to be installed without the use of conduit. This is still true today in most areas, however, there are some areas that no longer permit this and insist that 70V system loudspeaker lines be installed in conduit. In these areas, 25V systems are now widely used for open wire installations.

The 25V line system was originally included primarily for use in institutional (school) intercom and communications systems where the lower impedance reduced the possibilities of cross talk between the intercom and program channels. The 25V system also was close enough in impedance and voltage to the "500 ohm" systems previously used by many manufacturers that the new 25V line equipment could be used to expand older 500 ohm systems.

It should be noted that many countries overseas have standardized on other line voltages. 100 V "Constant Voltage Distribution" systems are popular in Europe. Some high power work has also been done with 140V line systems.

LINE MATCHING TRANSFORMERS

Most 25V and 70V line matching transformers provide a number of different power taps and are marked to show the wattage of each tap.

The following chart provides a ready cross-reference for those instances in which the impedance is shown but the wattage is not.

Power in Watts	Impedance in ohms	
	25 Volt Line	70 Volt Line
0.5	1250	10000
1	625	5000
2.5	250	2000
5	125	1000
10	62.5	500
25	25	200
50	12.5	100
100	6.25	50

The impedance of other wattage taps can be calculated using the formula:

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

If the impedance is known, the wattage can be calculated using the formula:

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

Where: Z = Impedance in ohms

E^2 = 625 in 25V line systems ($25^2 = 625$)

5000 in 70V line systems ($70.7^2 = 5000$)

P = Power in Watts

The line matching transformers and associated loudspeakers are connected in parallel across the amplifier's output as shown below:

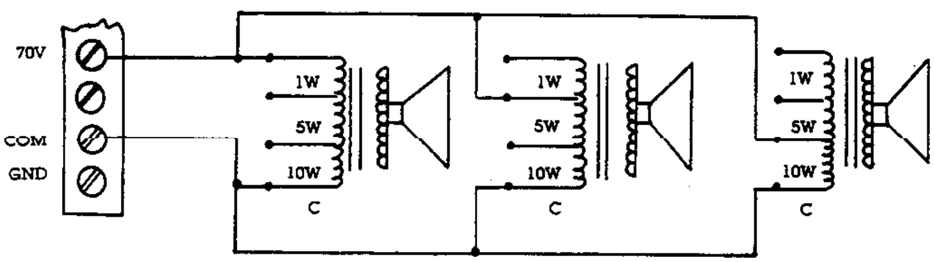


FIGURE 5

LINE MATCHING TRANSFORMERS (continued)

Please notice that different wattage taps can be used on the same distribution line. The only precautions that have to be observed in this installation are:

- To observe loudspeaker phasing when more than one loudspeaker is used in the same area.
- To make sure the proper line voltage matching transformers are being used. Accidentally connecting 25V line transformers to a 70V line will overload the amplifier very quickly. Conversely, connecting 70V line matching transformers to an amplifier's 25V line output will result in an inadequate amount of power being drawn from the line and reduced sound levels.
- To make sure the total of the wattage taps used does not exceed the output rating of the amplifier. This would overload the amplifier and either degrade the sound quality or shorten the life expectancy of the amplifier, or both.

In practice, it is wise to choose an amplifier having somewhat more output than is actually required to allow for future system expansion. Placing a load less than its rated output on an amplifier produces no ill effects.

If the load is not known, as is often the case when replacing existing amplifiers, it is advisable to verify the load before installing a new amplifier. The best way to do this is with an impedance meter, as it eliminates the need to check each loudspeaker transformer connection.

LINE MATCHING TRANSFORMER CHARACTERISTICS

Loudspeaker matching transformers are not 100% efficient and thus, introduce a certain amount of power loss into the system. They also affect the system's overall frequency response and do introduce at least a small amount of distortion.

Transformer power loss is usually stated in terms of dB insertion loss, with losses of 1 or 1½ dB being common. A table translating dB insertion loss into efficiency and power loss follows.

Insertion Loss	Efficiency	Power Loss
.5 dB	87.5 %	12½%
1 dB	79 %	21 %
1.5 dB	70 %	30 %
2 dB	63 %	37 %
3 dB	50 %	50 %

The efficiency of transformers also falls off at high and low frequencies, thus affecting the overall frequency response. The electrical characteristics causing the frequency response loss also tend to introduce distortion into the system.

This is particularly true of the lower or bass frequency where the actual transformer impedance tends to fall off rapidly. The result is that at these lower frequencies, the line presents a much lower impedance to the amplifier and in severe cases, may actually overload it. This phenomenon usually shows up as a "muddy" or unclear sound.

This characteristic can, in severe cases, actually cause amplifier failure. For this reason, many manufacturers, including Bogen, include a low cut filter on-off switch in their amplifiers. The roll off protects the amplifiers from damage when they are used with speaker systems where this problem is present. Its use provides an added margin of safety and does not degrade the sound quality as the low frequencies in question are not being reproduced. In fact, in some cases, its use actually improves the sound as the "muddy" sound is eliminated.

This characteristic is also the reason that many manufacturers recommend that their amplifiers not be loaded beyond 80% of their rated output power. This provides an added margin of safety.

BALANCED AND UNBALANCED LINE OPERATION

Loudspeaker lines can be run as either unbalanced or balanced lines. Unbalanced means that one side of the line is connected to Ground. Balanced means that neither side of the line is connected to Ground, thus, both sides of the line "float" at the same potential above Ground.

Most Bogen amplifiers have provisions for both balanced and unbalanced 25V and 70V output lines. This, however, is not true of many amplifiers manufactured by others. Many of them allow only for balanced 25V line operation or do not provide for balanced line operation.

Figure 6 shows a typical unbalanced 25V line installation. Two conductor (actually one twisted pair) cable is normally used in such installations. One side of the line connects to the 25V terminal on the amplifier, the other to common and then to Ground through the Grounding strap.

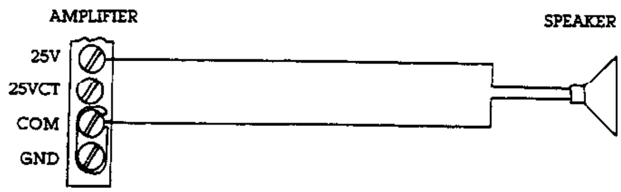


FIGURE 6

In many installations it makes little difference whether the lines are run either balanced or unbalanced. In other installations however, the loudspeaker lines may be run in close proximity to other lines such as telephone lines, RF cable or AC power lines for a considerable distance. In these installations, the signals in one set of lines may be picked up by the other lines and actually introduce hum, noise or cross-talk into the other system.

Balanced line connections reduce this interaction between systems and are recommended for any installation where the loudspeaker lines may be run in close proximity with other lines for a long distance. In balanced line operation, a current developed in one side of the line is offset by an equal and opposite current in the other side of the line.

A balanced 25V line installation is shown below. Notice that in this instance, the common terminal is not connected to Ground.

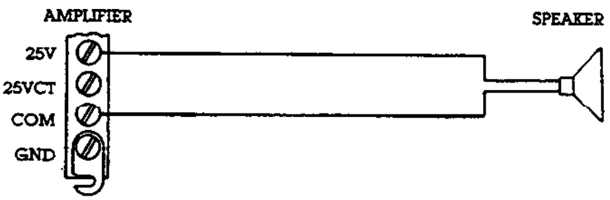


FIGURE 7

In other installations, the lines may be run in close proximity to the input lines of systems or equipment. This occurs, for example, in school intercom and program distribution systems. In these cases, the speaker lines should be balanced to Ground. This is accomplished by connecting the center tap of the 25V output circuit to Ground as shown below in Figure 8. The speaker lines in this system should also be shielded and the shield connected to Ground. This further reduces the interaction between systems.

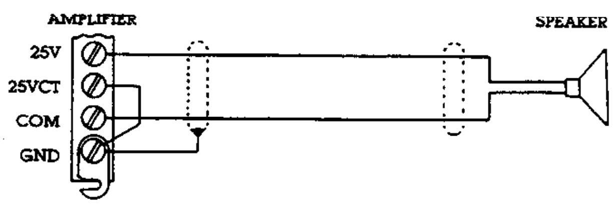


FIGURE 8

In any installation, care should be taken to keep as much separation as possible between an amplifier's speaker lines and its input lines. Failure to do so results in interaction between the amplifier input and output circuits, and may produce an oscillation in the amplifier. These oscillations usually occur at a very high, and often inaudible frequency, making them difficult, if not impossible, to detect without sophisticated test equipment. Sometimes, though, their presence shows up as a "fuzzy" or distorted sound. Other tell-tale signs of high frequency oscillation are amplifiers that run unusually hot, even without an input signal, and blow fuses for no apparent reason. In all cases, high frequency oscillations shorten the life expectancy of the amplifier and in severe cases, may actually destroy it.

It is also important in any installation that the amplifier be properly connected to a good earth Ground. Failure to observe this precaution can also result in oscillations, or in hums, buzzes and other assorted problems.

PHASING OF LOUDSPEAKERS

When more than one loudspeaker is used in an area, it is important to phase the loudspeakers correctly in order to reduce cancellations. Loudspeakers out of phase will lose up to one-half of their normal volume and will not sound nearly as well.

Loudspeakers are in phase when their respective diaphragms move outward and inward at the same time.

Phasing is accomplished by checking the polarity of the speaker terminals with respect to the movement of the speaker diaphragm, and connecting the speakers so as to produce the diaphragm movement or phasing desired. With loudspeakers of the same make and model, the respective diaphragms should move in the same direction when the terminals are connected in the same manner, but it is safer to check the polarity as described below.

Where different speakers are used, carry out the following procedure to determine the diaphragm movement with respect to the speaker terminals for speakers connected in parallel:

1. Connect one lead from a 1.5 volt dry cell to one voice coil terminal of the speaker.

2. Momentarily touch the other lead from the dry cell to the other speaker terminal.

3. Observe direction of cone or diaphragm movement (either inward or outward) when the circuit is closed.

4. Note this direction of the movement on a slip of paper.

5. Mark the terminal connected to the positive pole of the dry cell if the movement is outward, mark the terminal connected to the negative pole if the movement is inward.

6. Repeat steps 1 through 5 for other speaker or speakers to be checked.

7. Connect the marked and unmarked terminals according to the manner of electrical arrangement shown in Figure 9 if the speakers are facing in the same direction.

In simple sound systems, it may be easier to check phasing by listening to a low audio frequency while alternating the speaker leads. The human ear can usually detect when the low frequency sound is at the higher volume, indicating that the speakers are properly phased.

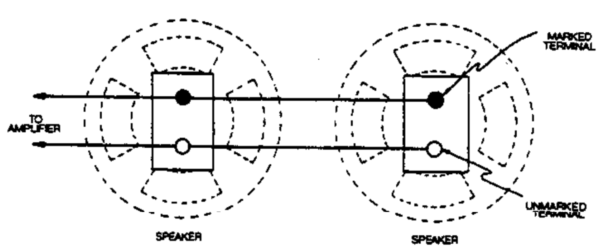
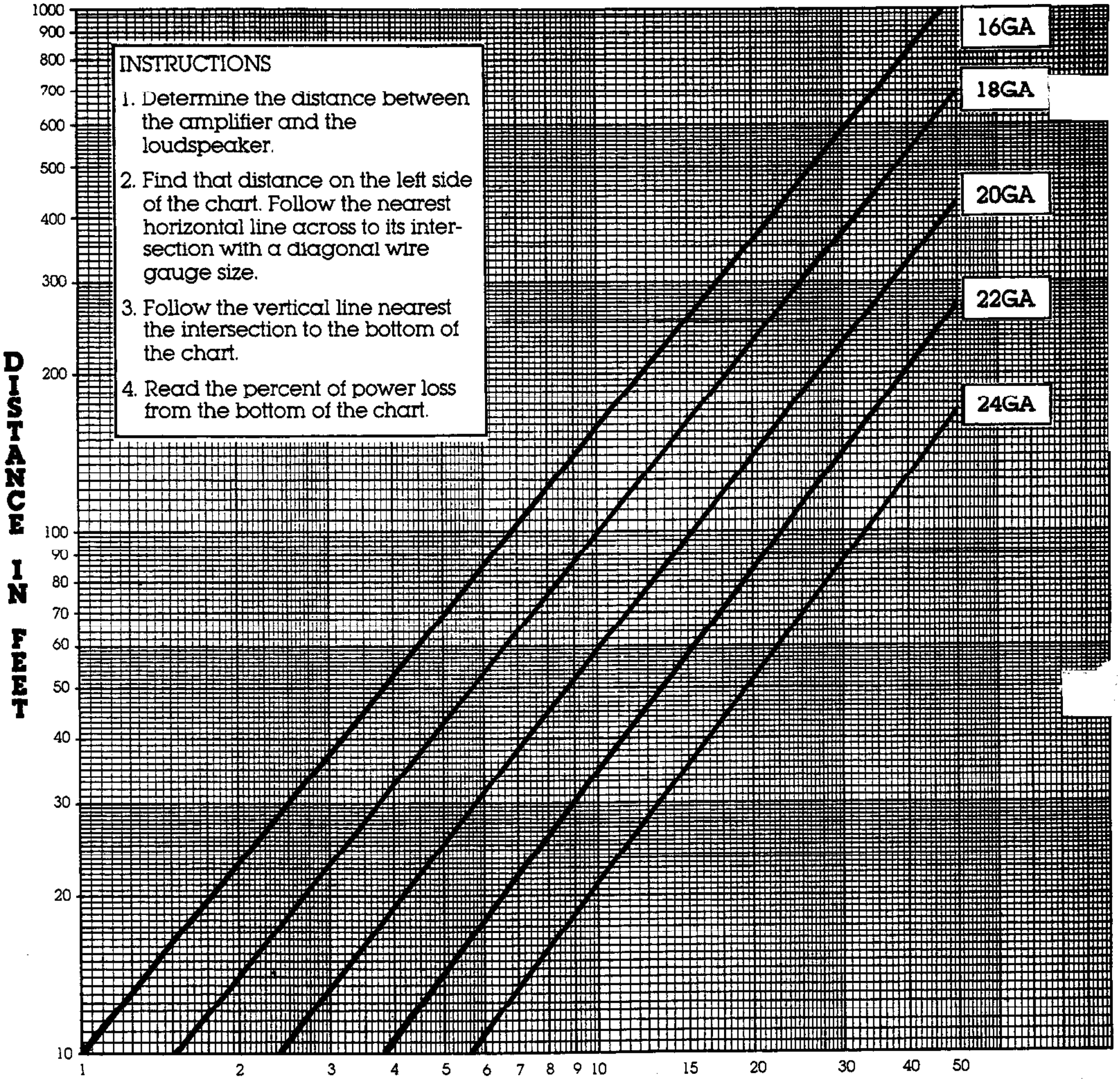


FIGURE 9

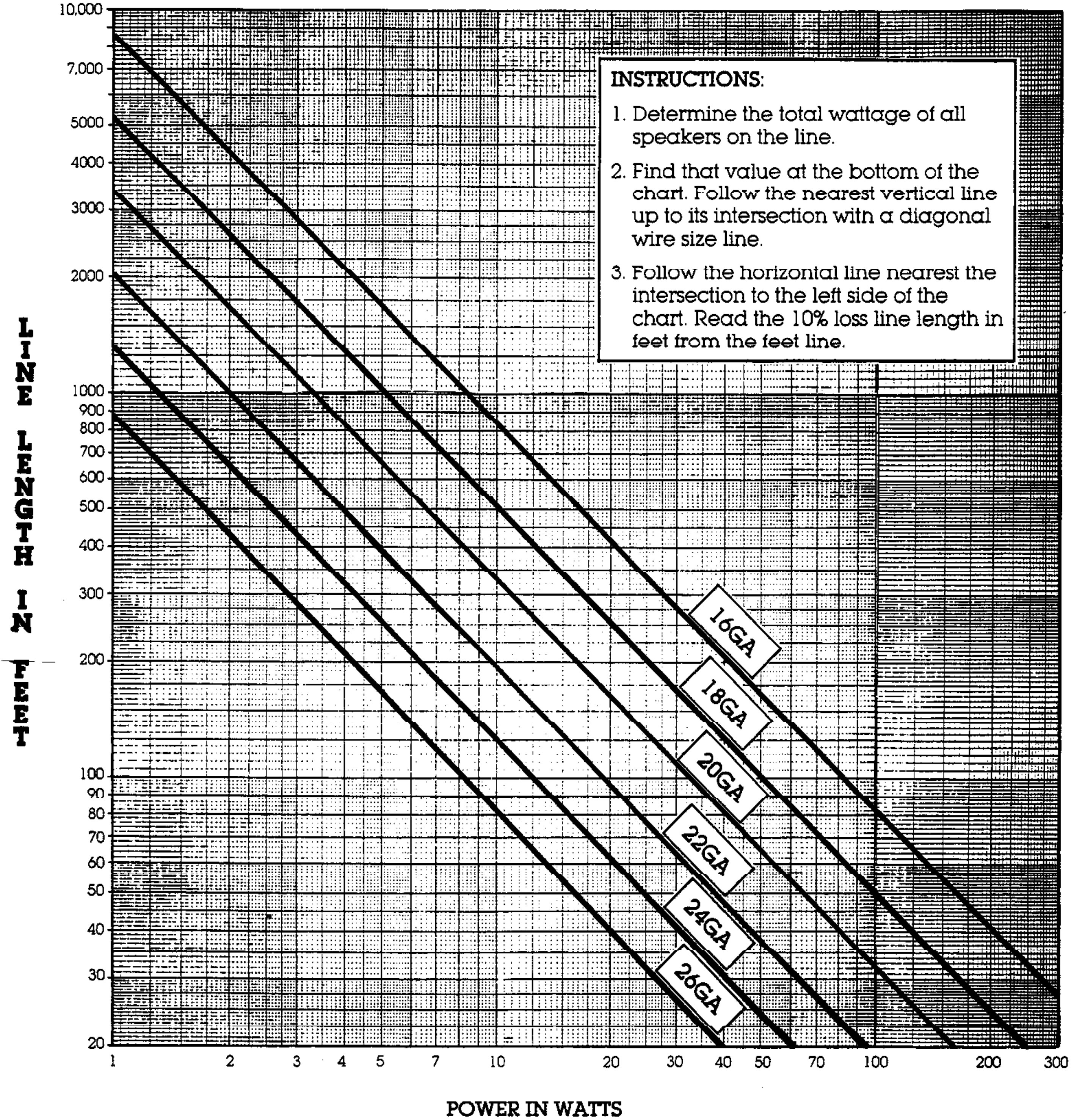


PERCENT OF POWER LOSS
8 OHM LINE

NOTE:

1. On 4 OHM speaker systems the power loss is double that shown for 8 OHM systems; on 16 OHM systems it's one half.
2. That if the correct size wire is not readily available running 2 pair of the same size cable in parallel cuts the power loss in half.

25 VOLT LINE LOSS CHART

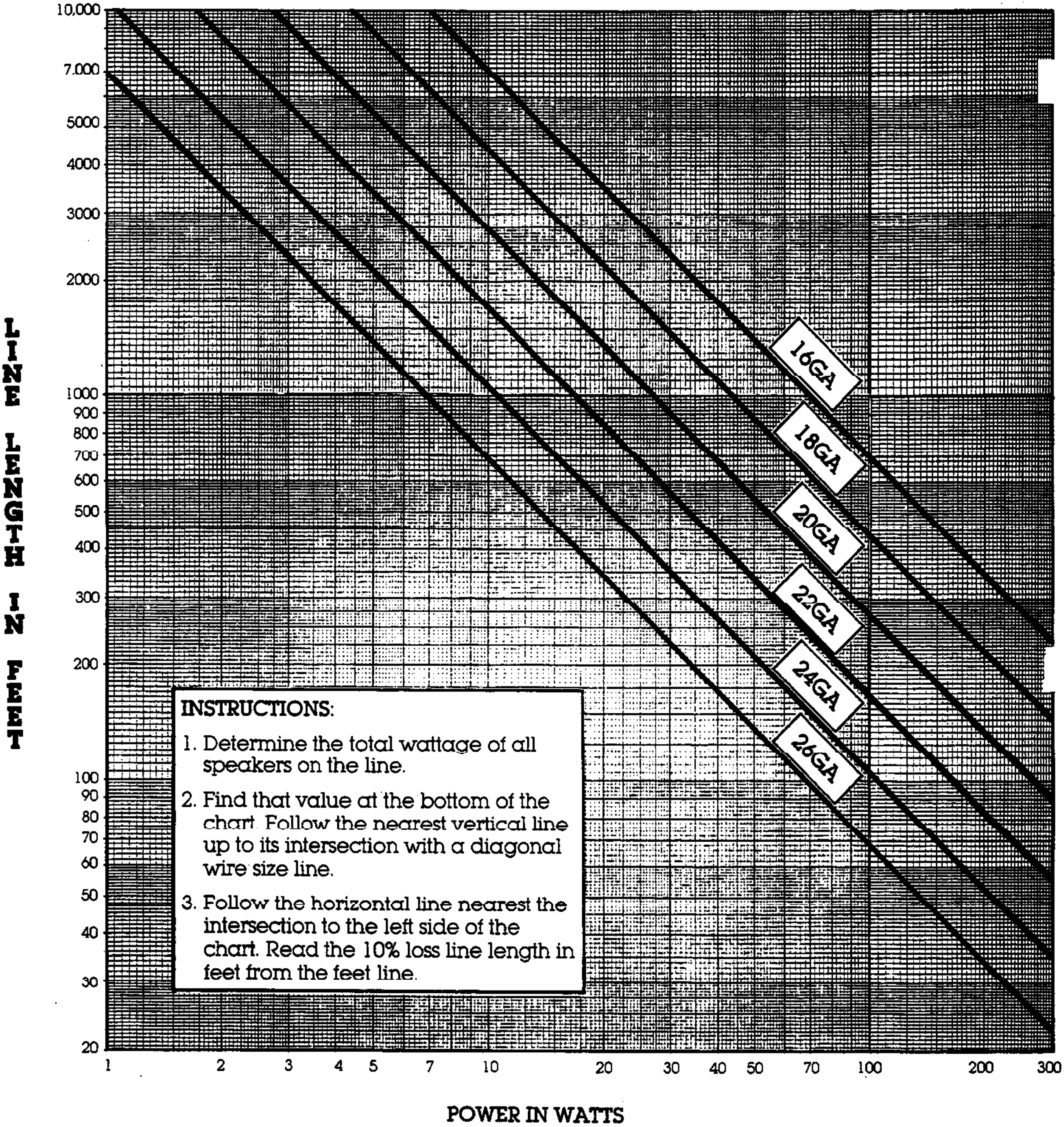


NOTE:

1. This chart is based on a line loss of 10 percent. Line lengths for a 5% loss can be obtained by multiplying the 10 percent length by 0.5. The line lengths double for a 20% loss.

2. That the power loss in self-amplified speaker systems approximates the loss in 25V line systems because of the DC voltage drop in the 24V DC power cable associated with self-amplified speakers.

70 VOLT LINE LOSS CHART



NOTE:

1. This chart is based on a line loss of 10 percent. Line lengths for a 5% loss can be obtained by multiplying the 10 percent length by 0.5. The line lengths double for a 20% loss.

2. That a 70V line can be run 8 times further than a 25V line for the same loss.