Speaker Impedance Matching in Sound Systems

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Every engineer can benefit from a fundamental review of the techniques of matching speakers to a sound reinforcement system.

EFFICIENT transfer of power from the amplifier to the loudspeakers is of prime consideration in connecting a sound system. To deliver its maximum rated power output, the amplifier's output impedance must match the combined impedance of the loudspeaker load. The method of connection used to obtain efficient transfer of power will vary depending upon the size of the loudspeaker load to be connected to the amplifier. The load will be determined by the number of loudspeakers in the sound system and the voice-coil impedance of the various speakers.

Loudspeakers, as used in today's sound systems, usually have a voice-coil impedance of 4, 8, or 16 ohms. In order to simplify loudspeaker transmission, line connection, impedance calculation and a flexible method of controlling power delivered to loudspeakers, most amplifiers are equipped with a multi-screw terminal strip on the rear panel.

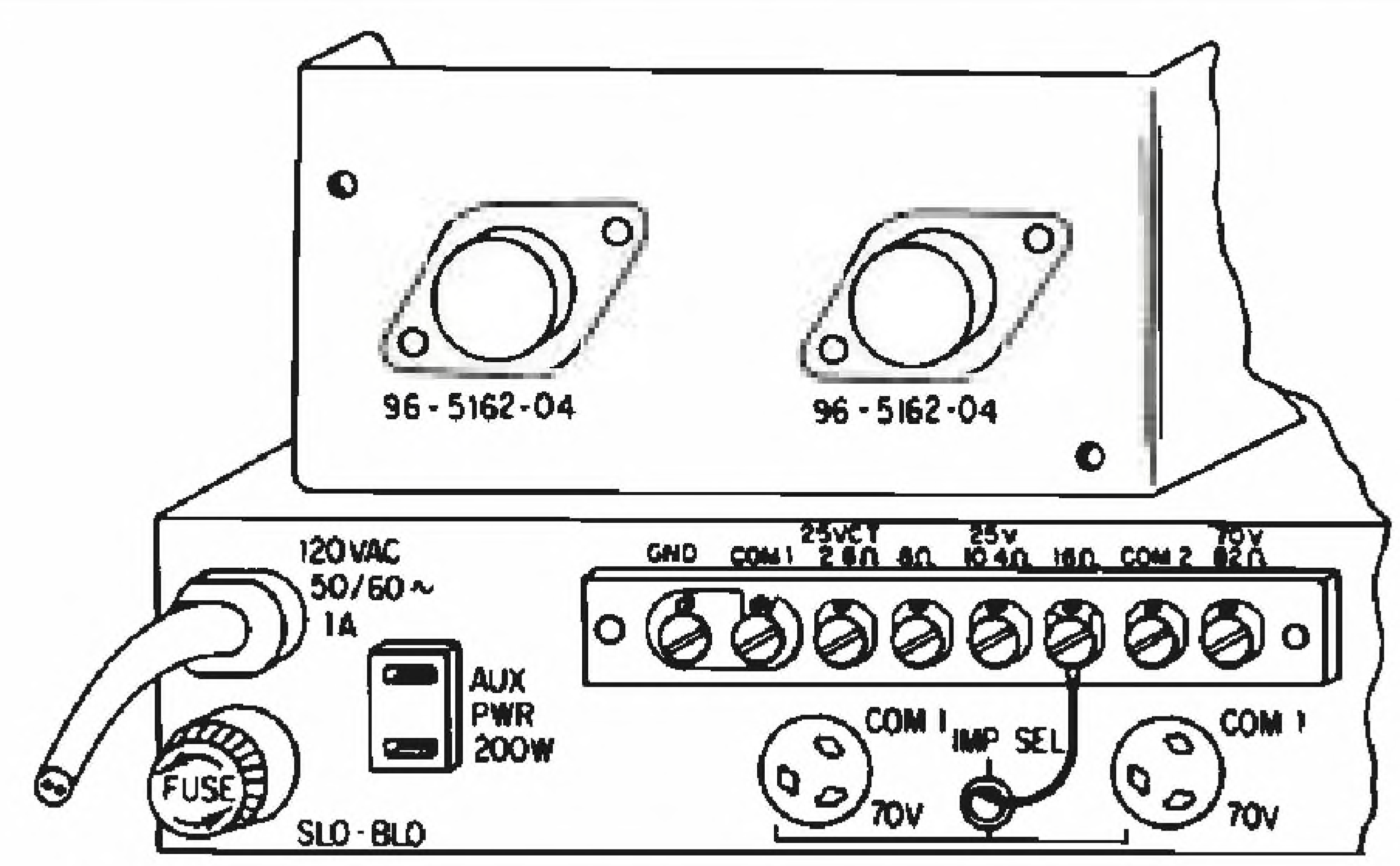

Fig. 1. With minor variations, these are the speaker connections you can expect to find on the back of an amplifier.

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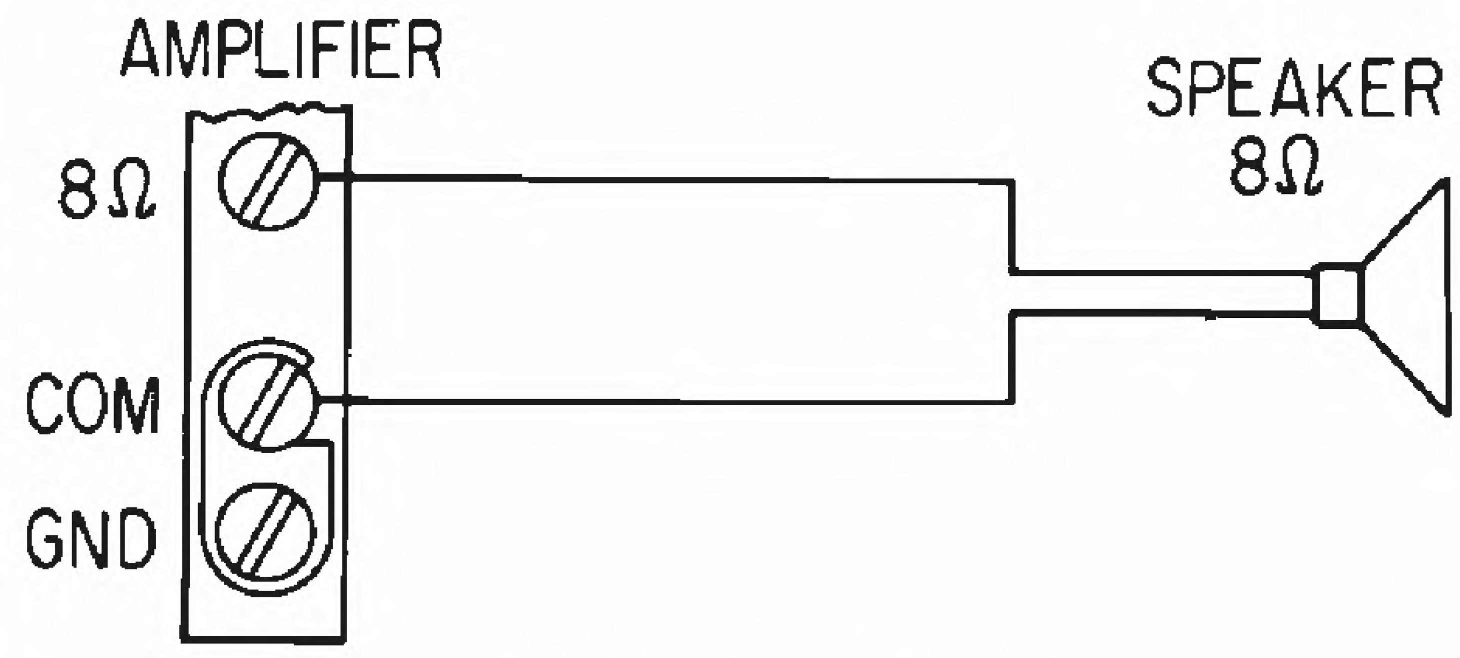

Fig. 2. A single speaker connects directly to the amplifier tap matching its impedance rating.

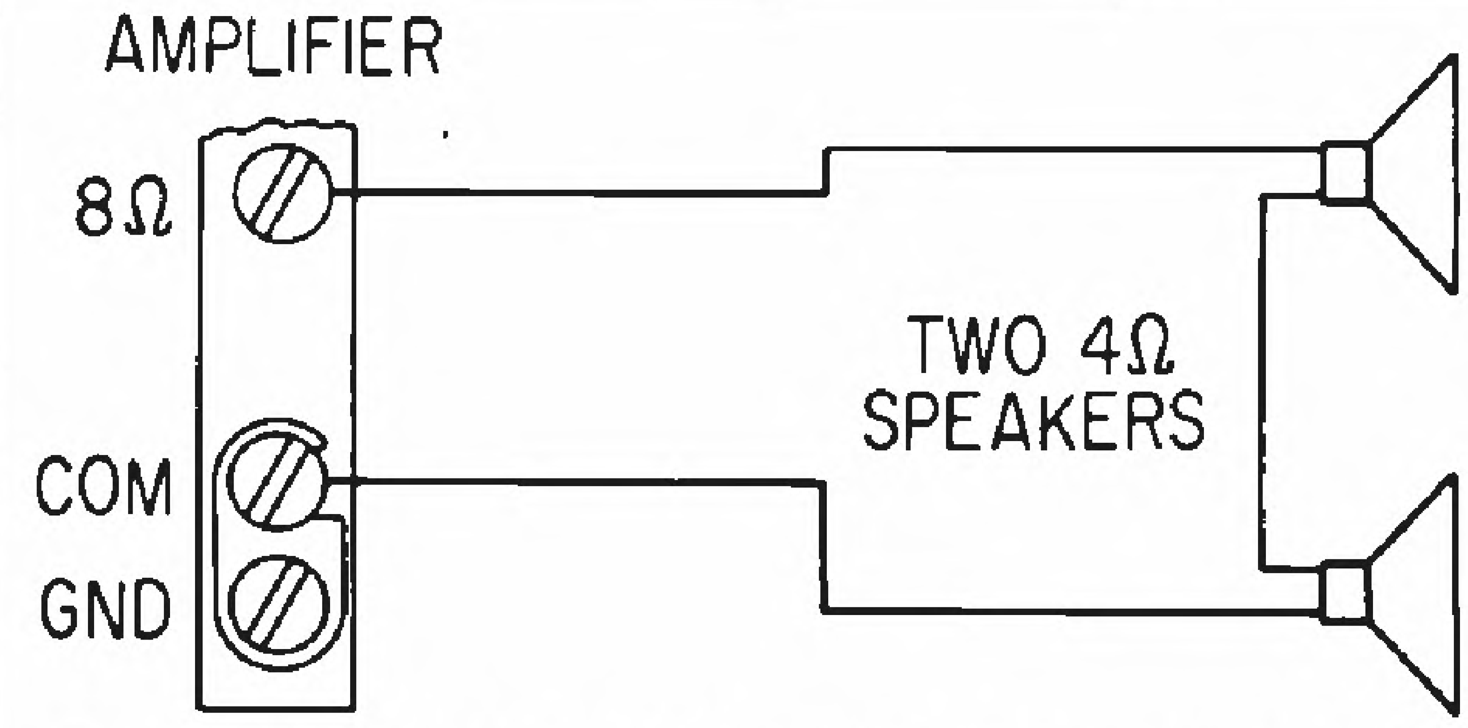

Fig. 3. Series connection of two loudspeakers. This should be generally avoided; an open connection anywhere kills the entire line.

The output terminal strip, as provided by most amplifier manufacturers, have 4, 8, 16 ohms, as well as 25-volt and 70-volt output taps. A typical output terminal strip on the rear panel of an amplifier is shown in FIGURE 1.

The various methods used for loudspeakers connection are commonly referred to as impedance matching. The three methods in use are *direct voice-coil connection, constant impedance* and *constant voltage*.

In the *direct voice-coil connection method,* the amplifier output is connected directly to the loudspeaker voice coil and no matching transformer is required. The direct voice-coil connection method is employed for simple systems requiring only a few loudspeakers and short runs of wire (not over 200 feet in length).

For installation of a single loudspeaker, a single 8-ohm speaker is properly matched to an amplifier when the transmission line is terminated at the 8-ohm output of the amplifier as shown in FIGURE 2. Similarly, if the loudspeaker has a 16-ohm voice coil, its connection is made to the 16-ohm tap.

When loud-speakers are connected in series (see FIGURE 3) the total impedance is equal to the sum of their individual voice-coil impedance. When two 8-ohm speakers are connected in series, their total load impedance is 16-ohms; connections are made to the 16-ohm tap on the amplifier and to the common or ground terminal. In the same manner, when two 4-ohm speakers are connected in series, the total impedance is 8 ohms, and connections are made to the 8-ohm amplifier output tap.

Wherever possible, the series arrangement should be avoided, because a broken wire, anywhere in the circuit, will cause the entire circuit to become inoperative. When loudspeakers are wired in parallel, as shown in FIGURE 4, the total load impedance is found by dividing the impedance of any one loudspeaker by the total number of speakers in the system. For example, two 8-ohm speakers would be wired to the 4-ohm output tap. Two 16-ohm speakers, wired in parallel, would be connected to the 8-ohm tap on the amplifiers.

It is generally not advisable to use any combination of loudspeakers that have a combined impedance of less than 4 ohms, because operation with less than 4-ohms impedance will result in extensive power loss.

In some cases, it may be impossible to find a satisfactory match for a group of loudspeakers in parallel for connection to the available output impedance taps. In this event, it may be necessary to use a series/parallel connection shown in FIGURE 5.

To find the total impedance for a series/parallel connection, combine the two formulas, series and parallel. Compute the impedance separately for each group of speakers, then consider each group as a single loudspeaker and compute the total impedance as a parallel combination. FIGURE 5 shows four 8-ohm speakers connected as a series/parallel arrangement. Speakers A and B present a series impedance of 16 ohms. Similarly, speakers C and D another 16 ohms. Paralleling the two groups (A+B and C+D) results in an impedance of 8 ohms. When connected to the 8-ohm output a perfect match results.

A second method of impedance matching is the *constant-impedance method.* This requires the use of a matching transformer. The constant-impedance method of connection was adopted years ago for installations where the direct voice-coil method was impractical, because of long transmission lines, or the use of many loudspeakers in a system. The constant-impedance method provides a convenient means for connecting loudspeakers, so that various speakers within a system can be operated at different power levels. This is especially useful in large industrial and commercial systems, that have high noise as well as quiet areas.

In the constant-impedance method of connection, a high-impedance line, usually 250 or 500 ohms, is used. The high-impedance line from the amplifier is connected to the individual loudspeaker voice coil through a line-matching transformer with a secondary winding that is properly matched to the loudspeaker voice coil. The primary windings of these line-matching transformers are connected by the installer to the proper primary impedance tap to control the amount of power that a particular loudspeaker will draw. Most line-matching transformers have four impedance taps.

The constant-impedance connection method has worked well in the past, but it has a number of serious disadvantages. Among these are the complex and complicated computations that are required in a large sound system, using many loudspeakers. Another difficulty is that in the large, high-power systems, high voltages, frequently in excess of 200 volts, are developed across the transmission lines.

This problem is a very serious one, due to the dangerous shock and fire hazards these voltages present. Another problem and inconvenience encountered when using the constant-impedance connection method is that when a system requires moving or enlarging, it is necessary to readjust every transformer in the system. In a great many cases, it may even be necessary to replace the transformers in order to

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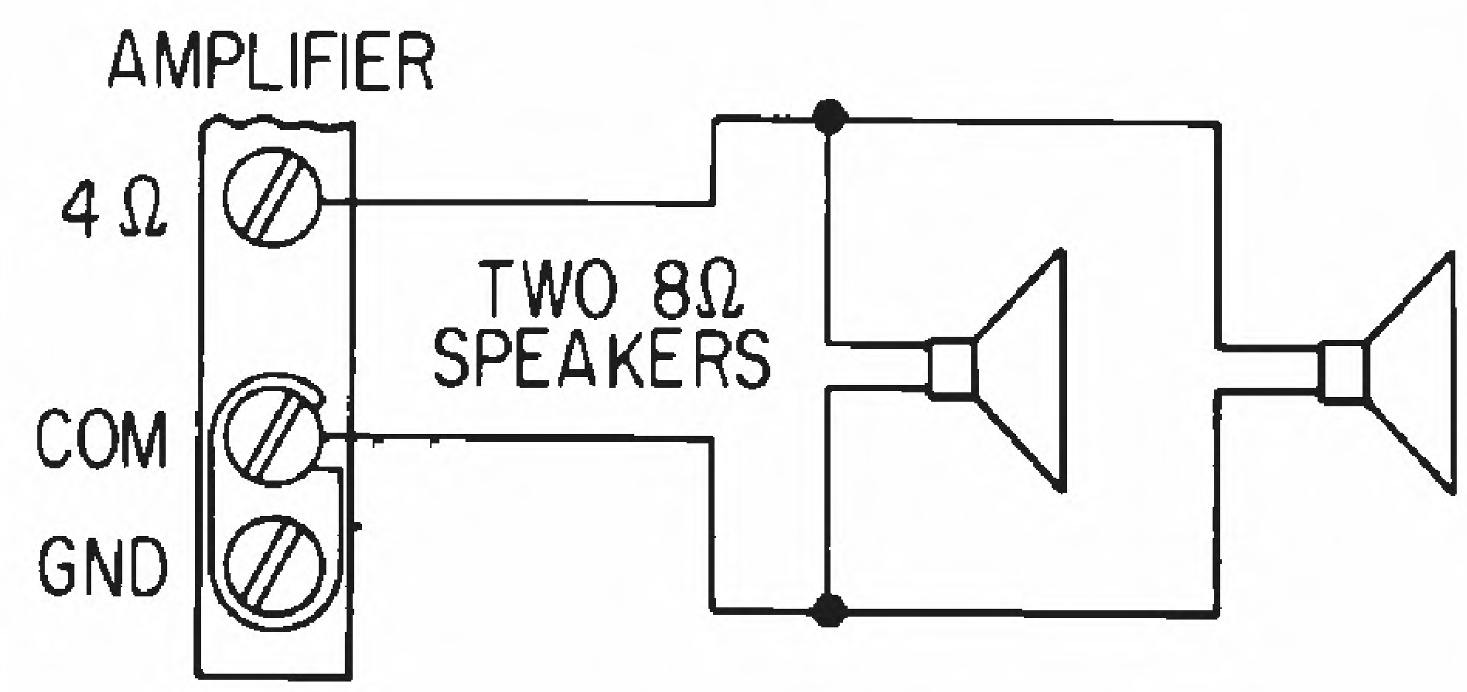

Fig. 4. The preferred parallel connection method.

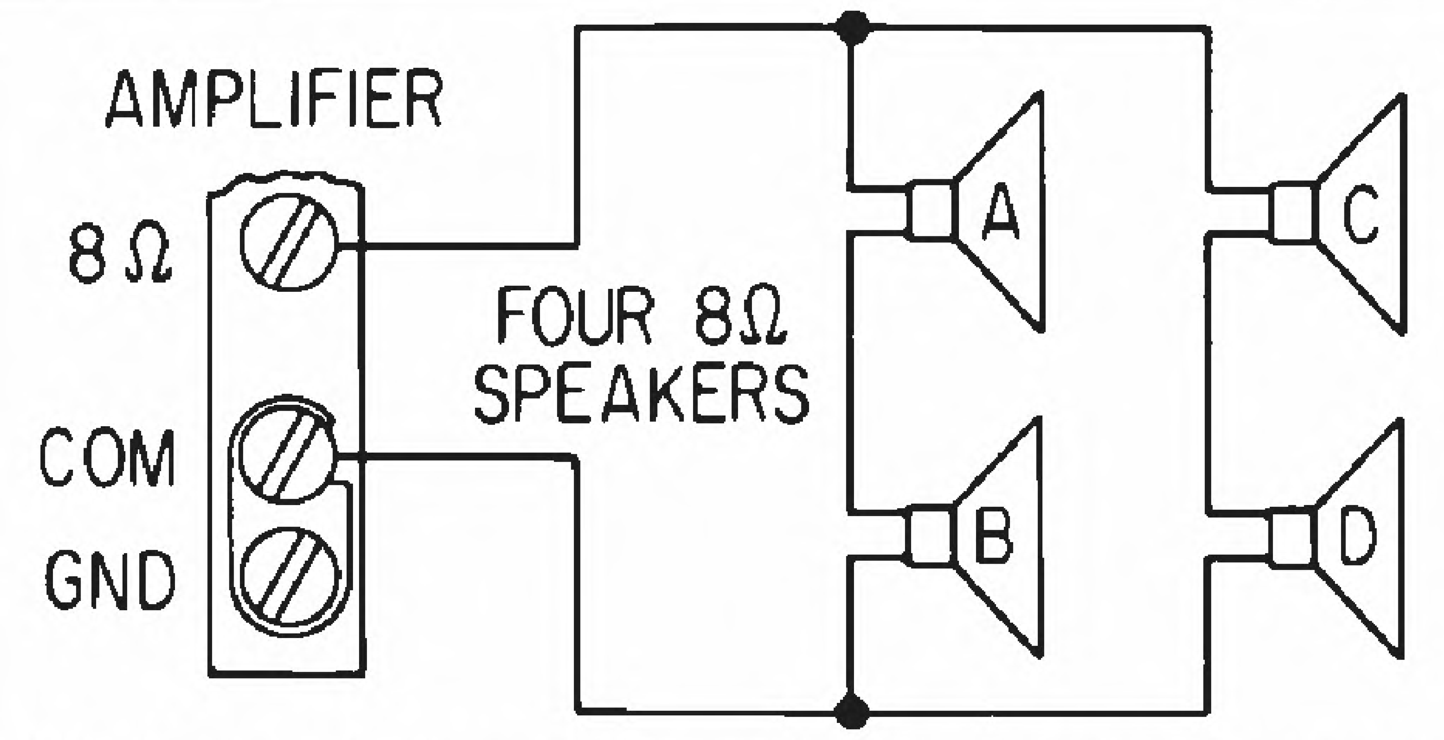

Fig. 5. A series/parallel combination may be necessary in order to insure that the amplifier doesn't feed less than a 4-Ω load.

provide the correct impedance tap. It is for these and other reasons that the constant-impedance method of connection is rarely used in sound-system installations today.

In order to correct these disadvantages of the constant-impedance connection method, a new system of impedance matching has been developed. This new system, known as the *constant voltage method*, has virtually superseded the constant-impedance method.

The constant-voltage system was developed by the **Committee on Sound Systems** of the **Radio Electronic Television Manufacturers Association.** In developing the constant-voltage system, the committee complied with the recommendations of Underwriters Laboratories, with regards to line voltage selection for the rated output of the amplifier. The constant-voltage system, as recommended by the committee, was accepted and adopted by the trade.

An amplifier designed for the constant-voltage system will deliver a maximum voltage when operating at its full-rated power output. Most amplifiers provide 70-volt (actually 70.7 volts)and25-volt taps at the multi-screw output terminal strip (see Figure 1). It should be understood that in the constant-voltage system the 70 volts or 25 volts nomenclatures represent the highest voltage the amplifier will develop and that these voltages will appear only when the amplifier is operating at its full-rated power.The voltage will accordingly be less when the amplifier is operating at levels below the output as rated by the manufacturer. Standardizing on the output voltage simplifies the computation of transformer taps required for varying sound levels of the loudspeakers. The line-matching transformers for use in constant-voltage systems are available for operation with the two standard line voltages, 70 and 25 volts. The size of the transformer will depend on the power it is designed to handle.

The transformers, as a general rule, have taps for matching loudspeakers with 4, 8, or 16-ohm voice coils. Constant-voltage transformers have taps marked in watts. This makes it convenient for the technician and installer to select the required transformer wattage from the multi-wattage tap to provide the sound level for each loudspeaker. Care should be taken to insure that the total power consumed by all loudspeakers in the system is equal to or less than the power rating of the amplifier.

Large sound systems, with long transmission line runs, usually are wired to 70-volt lines. This reduces power loss caused by long transmission lines. Systems requiring shorter transmission line runs or systems such as school or hospital (using home run transmission lines) are usually installed with 25-volt lines. It should be noted that there has been a general trend for greater use of the 25-volt line, as many local building codes are requiring that 70-volt transmission lines be run in conduit or armored BX-type cables.

If constant-voltage transformers with taps marked in watts are not available, transformers designed for use in the constant-impedance system with taps marked in impedance can be used. To determine the wattage delivered by a transformer marked in impedance, the formula to use is $Z=E^2/P$. In this formula, Z equals the desired impedance tap, E the voltage, and P the power (in watts). For the 70-volt system, the formula is *Z=5000/desired power,* in watts. For the 25-volt system, the formula is *Z=625/desired power,* in watts.

Besides the obvious advantage of eliminating detailed mathematical calculations, another very important advantage of the constant-voltage system is that when the system is expanded, requiring additional power, higher powered amplifiers may be substituted. No changes or rewiring of the speakers already installed are required. Another advantage is that after a system has been installed, and it is found that a loudspeaker is too loud or not loud enough, it is a simple matter to change the transformer tap on the loudspeaker so that it will handle more or less power as required.

This is just as simple as changing a light bulb in a lamp. If it is too bright, you change the bulb to one of less wattage. If it is not bright enough, you change the bulb for one of greater wattage. In the constant-voltage system, it is also possible to switch loudspeakers in and out of the circuit, at will, with no noticeable increase or decrease in volume of the remaining speakers. This is not true in the constant-impedance system, as any change in the number of loud speakers affects the impedance match of the system.

It must be remembered that manufacturers of amplifiers devote a lot of time and spend much money to provide amplifiers with a rated power output at a fixed amount of distortion and frequency response. If the loudspeakers are not connected properly, the amplifier will not perform efficiently and the specifications as listed by the manufacturer will not hold true. The time required to insure that the loudspeaker system is properly connected will reward the installer with a system that will provide better quality sound and a more reliable system, with fewer service problems. It will also result in a more flexible system that can be easily expanded or relocated. Most important it will help assure a more professional installation and a more satisfied customer.

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