

TOA Electronics Amplifier Guide

Guide

Amplifier



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Welcome to the TOA Amplifier Guide!

TOA has been providing complete sound systems since 1934. After our first U.S. sales office was established in 1974, our TA-900 Series mixer/amplifiers quickly gained recognition for their unmatched combination of flexibility, reliability, and performance. Since that time, TOA has steadily expanded and improved our line of amplifiers, mixer/amplifiers, and associated electronics. The TOA 900 Series, now in its 3rd generation of product design, is renowned for its flexible modular architecture, elegant simplicity of operation, and bulletproof reliability. The new BG-M Series builds further on our tradition by offering the flexibility of a module port in a package that is remarkably affordable without sacrificing either performance or reliability. With six distinct series of amplifiers and mixer/amplifiers to choose from, plus a range of mixers, signal processors, and now network audio, TOA offers the most comprehensive line of audio electronics for systems contractors.

The TOA Amplifier Guide is a sound system design tool aimed at helping system designers, sales staff, installers and end users select the right amplifiers and accessories for their applications. It includes a review of the basic concepts of audio amplification, such as signal flow, levels, and impedance, plus useful references such as thermal dissipation, power consumption and line loss charts, as well as tips for troubleshooting (including impedance measurement). Further information on speaker system design and speaker selection and placement may be found in the *TOA Speaker Guide*, available for download at www.toaelectronics.com.

Disclaimer: *This design guide does not cover all of the general concepts underlying sound system design and installation, which would require several hundred pages. This guide is not meant to replace the participation of an experienced consultant or engineer.*

References: For more in-depth coverage of sound system design principles, we recommend the following two excellent books:

Sound System Engineering, Second Edition, Don & Carolyn Davis, 1975, 1987 by Howard Sams & Co. ISBN: 0-672-21857-7

Handbook for Sound Engineers: Third Edition, Glen Ballou, Editor, 2001, Butterworth & Heinemann. ISBN: 0-240-80454-6

Acknowledgements

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David Menasco
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Chapter 1: Selecting An Amplifier

Amplifiers are the heart of any sound system. In addition to providing the audio power for a system, amplifiers may also incorporate the input mixing and control functions vital to a system's operation (such an amp is called a *mixer/amplifier*). Selecting the right amplifier or mixer/amplifier for a job means choosing a set of features and characteristics suited to meet the customer's needs. The main characteristics of an amplifier or mixer/amplifier include: The number and type of input channels, the number of busses (signal paths) and output channels, and the amount of output power per channel. Dimensions, weight and other basic parameters may also be important, depending on the installation. Features needed for a job may include: Auto-muting (e.g. voice-over-music), remote volume control, transformer-isolated inputs/outputs, phantom power, bass/treble controls, multi-level muting, rack mounting, equalization, or any of a number of other special purpose features.

When selecting an amplifier, there are three key questions to consider:

1. What sound sources will be used?
2. What speakers will it be driving?
3. How does the client or end user need the system to operate?

Answers to these questions will dictate what characteristics and features are needed. Below is a more detailed look at each question.

Sound Sources

One of the first questions you will need to answer, at least in general, is what sound sources will be used in the system. Will the system be used with microphones? A CD player? A telephone exchange? Due to standardization, many sources can be treated similarly — for example, CD and DVD players, VCRs and computer sound cards all provide unbalanced line level outputs, usually with a similar output level, and thus may be treated the same in the design phase. But it is still important to know how many such sources you will have, and what other sources may also be used.

Speaker Requirements

Two more key questions when selecting an amplifier is how much power is needed, and what kind of load (impedance) the speakers will present — and here, the answers will depend on the type of speakers used. It is usually preferable to select the speakers, or at least the general type of speakers, before selecting the amplifier. Please refer to the ***TOA Speaker Guide*** for information on selection and placement of speakers. Once the type of speakers has been determined, it will be possible to choose an amplifier with adequate power and an appropriate output impedance. See Chapter 3 "Amplifier/Speaker Matching" for discussions of impedance, power levels, and 70.7V/25V line operation.

System Function

The paramount rule of sound system design is almost too obvious, and yet it is all too often overlooked: it is important to let the system design be guided by the needs of the client or end user, and the function they need the system to fill. For example, if they need the mic to automatically mute the music, you will need a mixer/amplifier that includes this feature. Often, the user won't be very

specific until after the system is installed and they try to make it work. The designer's job includes asking enough questions in the beginning to make sure the design will meet the client's needs. As a start, imagine yourself in the place of your client, using the system, and asking questions such as "where will this go?" and "how will this work?" Experience helps a lot in this process, but installers and designers of all levels of experience can save time and headaches by asking some basic questions at the outset.



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Chapter 2: Amplifier Basics

Important Concepts: Signal Flow, Level and Impedance

When designing and installing sound systems, mastery of some key concepts helps a great deal. A basic understanding of signal flow, levels, and impedance can increase your efficiency on the job, and dramatically reduce the number of costly call-backs.

Signal Flow: The Audio Chain

Signal Flow refers to the path of the sound from the source (page announcement, CD player, satellite receiver, etc.) to the listener. This path can be very simple, using just a single source, a power amplifier, and one or more speakers, or it can be complex, having multiple sources, multiple paths, and multiple destinations, with extra processing stages. A typical paging system signal path will begin with two or three sources — for example, background music, paging audio from the phone system, and a microphone (see fig. 1). These will be fed into a mixer, which combines the sources into one single line. The mixer output may be fed into an equalizer, compressor or other processor, or directly to an amplifier. The amplifier increases the power of the signal and feeds it to the speakers. In most smaller systems, the mixer and amplifier sections are integrated in one unit, which may include a built-in or optional processing stage, such as an equalizing module for premium speakers.

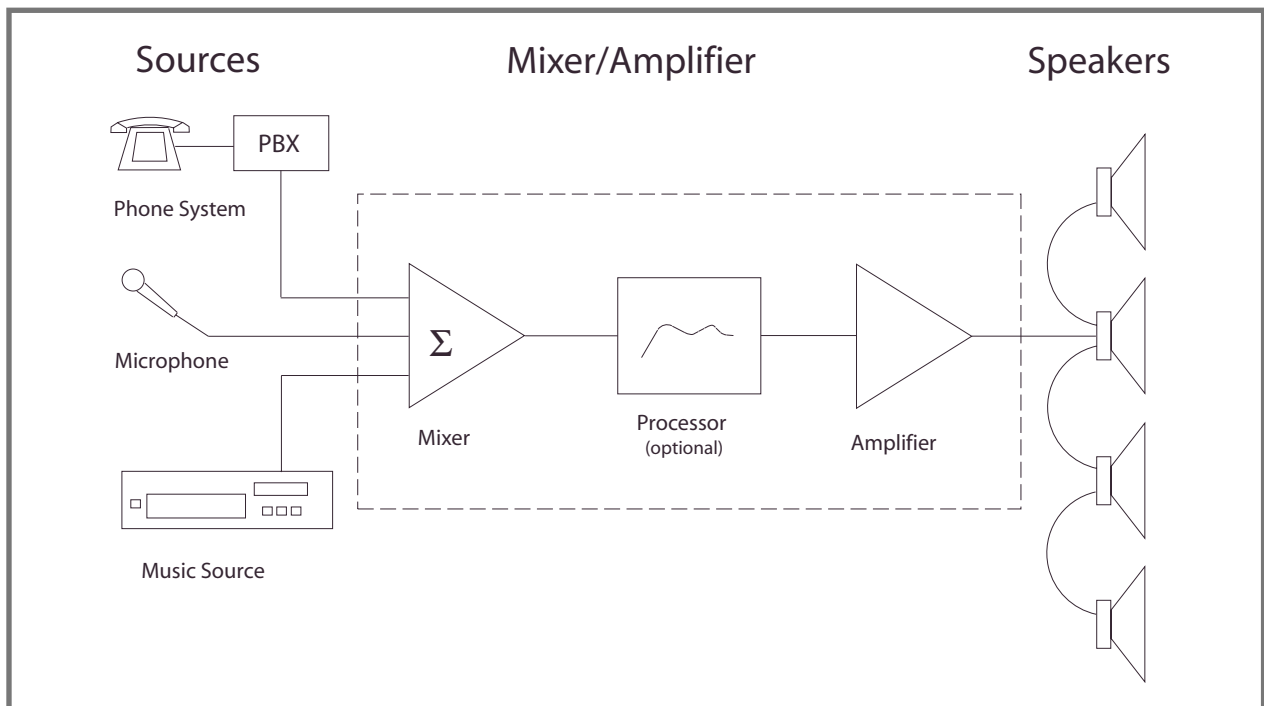


Figure 1: Basic System for Paging and Background Music

More complex systems include all these same stages — sources, mixing, processing, amplification, and speakers — but may add additional signal paths (called busses) so that some sources or listening areas can be treated differently. A common addition to the typical paging system is the Music On Hold (MOH) output bus. This bus is fed from the music input, and not affected by speaker processing modules or by mute functions used for the overhead paging (see fig. 2). TOA 900 Series amplifiers can provide an MOH output using the T-12S module, which provides for both the music input and the MOH output. This module also works with the 900 Series mute bus to allow for muting of the music during paging announcements to the main output, while the separate MOH output is not muted and receives no page announcement. TOA BG and BG-M Series amplifiers include MOH outputs as standard features.

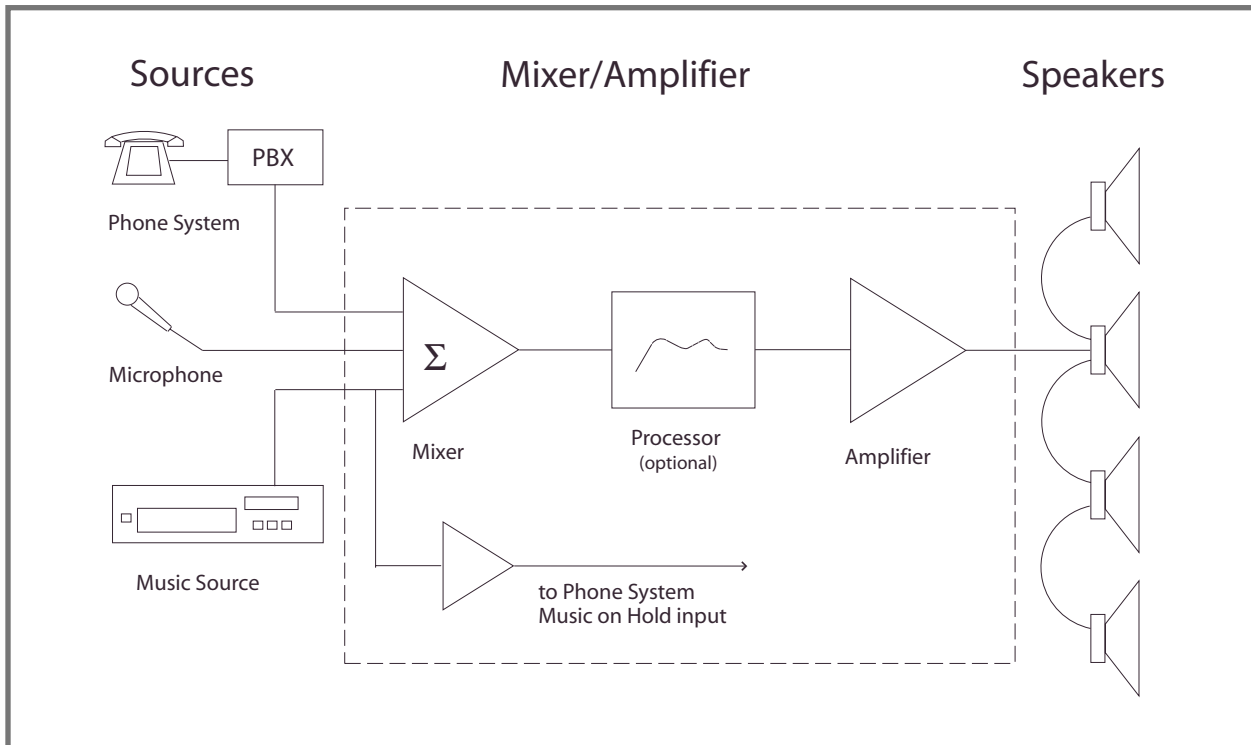


Figure 2: Basic System Plus Music-On-Hold Output

Zone paging and multimedia systems can use additional signal paths to route sounds to different areas (see figs. 3 and 4). Figure 3 shows a typical 3-zone paging system for central mic and/or telephone paging with background music. Simple contact closures, provided by the phone system or contractor, are used to activate the zones in any desired combination, simultaneously muting the background music in each activated zone. TOA BG-M Series amplifiers offer an especially economical solution for this type of zone paging system. The background music may be from sources local to each zone or distributed from the head-end via the MOH output.

In multimedia applications, multiple signal paths can be used to route speech and music or movie sound to different speakers, allowing precise matching of speaker type for the intended application. Figure 4 shows a multimedia system for a lecture hall, training room, or multi-media-ready meeting room. This system provides for stereo playback of music sources and stereo sound for video, using a pair of speakers which may be located flanking a fixed or retractable screen, alongside distributed mono speech. The resulting system can provide powerful and moving reproduction of music and movie soundtracks and clear, intelligible speech. An optional subwoofer for the music feed further enhances the impact.

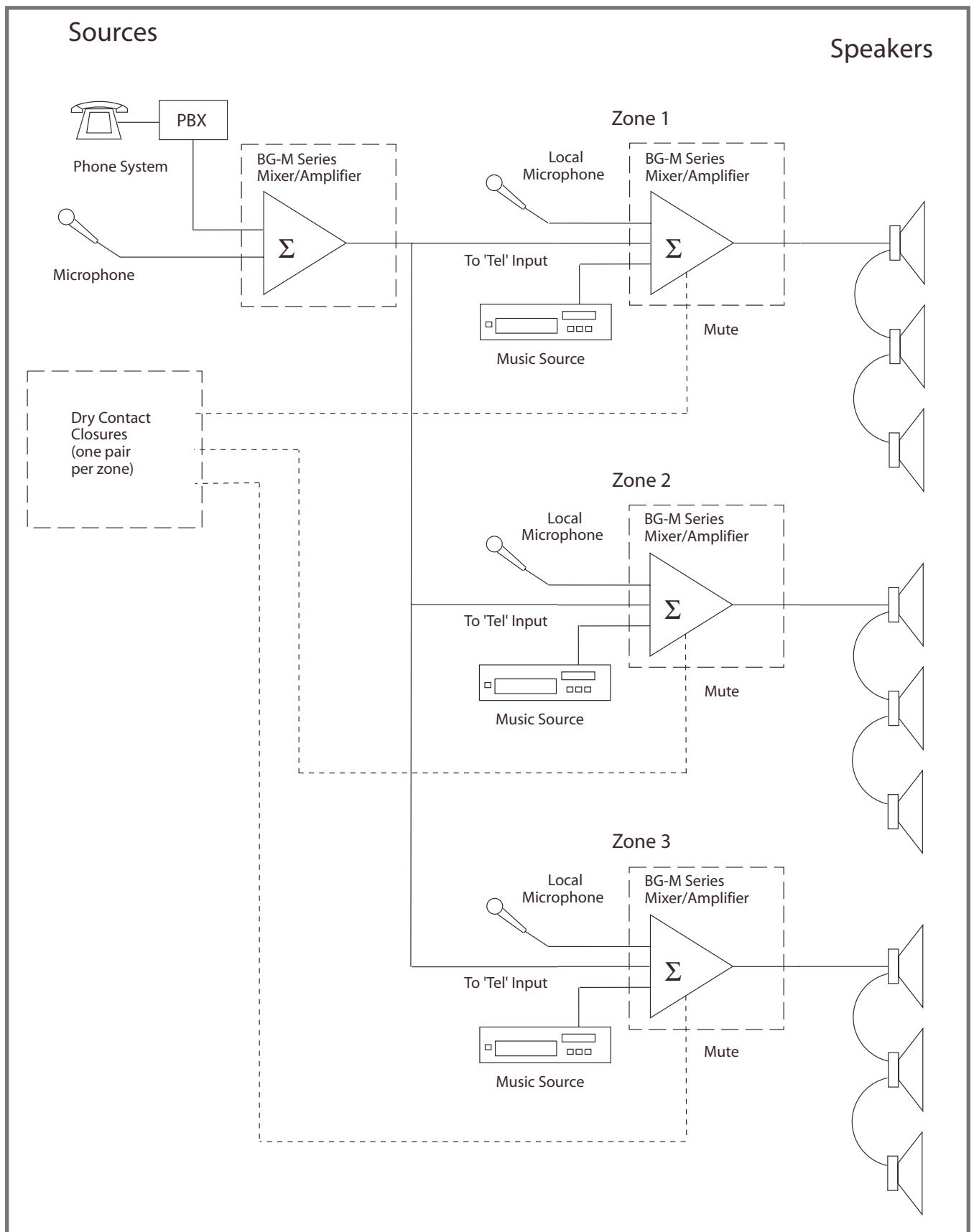


Figure 3: Three-Zone Paging System

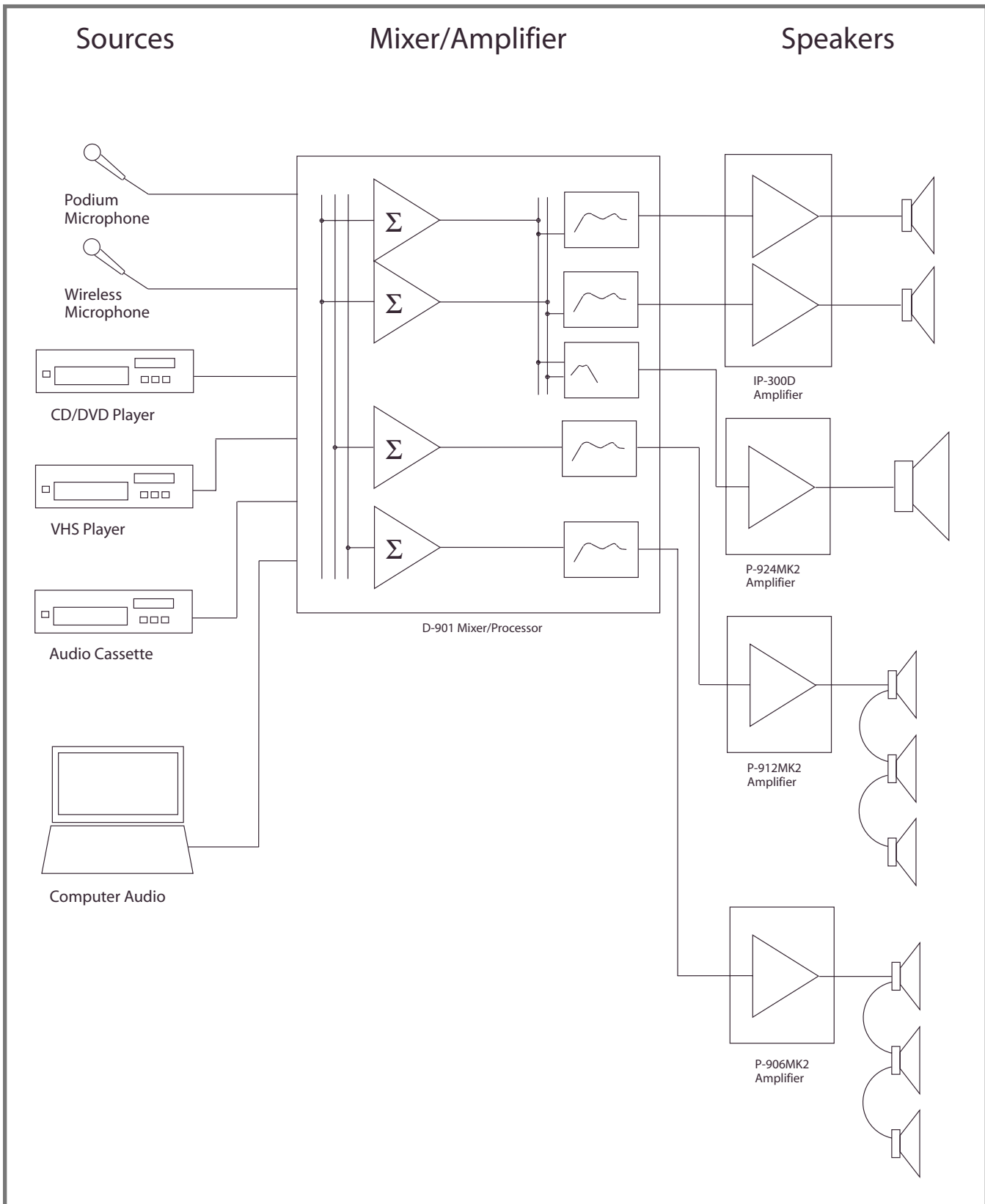


Figure 4: Multimedia System

Audio Levels: Voltage, Gain and the Decibel

A basic characteristic of any audio signal is its amplitude, measured electrically in terms of voltage or acoustically in terms of sound pressure. When assessing the loudness of a signal, the amplitude or pressure is converted to a decibel value. The decibel scale gives a relative number referenced to a certain voltage or pressure. For example, 0 dBV is a popular standard reference for audio levels, and represents one volt. Note that *amplitude* is expressed as a voltage, while *level* (or loudness) is expressed using a dB scale.

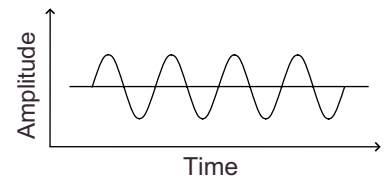
When working with audio electronics, levels are commonly divided into three ranges: mic level, line level, and speaker level. Mic level is the smallest signal. Microphones and other passive transducers (devices that convert energy from one form, such as sound, to another, such as electricity) produce signals ranging from a few microvolts to a few millivolts. A typical nominal operating level for a microphone output would be -55 dBV. Line level is hundreds of times greater in voltage terms — typically ranging from several millivolts up to around 1 volt, with a nominal level of 0 dBV. Speaker level is the strongest, ranging from a fraction of a volt (during quiet periods) to several dozen volts depending on the output rating of the amplifier. Of course, sound is very dynamic in nature, so whatever the nominal operating level of your signal is, if you read it with a meter during operation, you are likely to see large fluctuations from moment to moment within that range.

An important function of amplifiers is providing the “gain” needed to raise signals from mic or line level up to speaker level. Gain is another word for amplification, and simply means an increase of the voltage or power. The opposite of gain is attenuation. Both gain and attenuation are commonly measured in decibels.

The dBV scale is not the only one used for audio levels. Another popular reference scale is the dBu, where 0 dBu represents 0.775 volts. The historical predecessor to these two scales is the original dBm scale, where 0 dBm represents one milliwatt, or 0.001 watts. Other scales you might encounter include dBW (referenced to one watt) and dB μ V (referenced to one microvolt). These scales are seen mostly in the radio broadcast industry. Care should be taken not to confuse one scale with another, especially the common dBV and dBu scales. To make things especially aggravating, the term for dBu was previously dBv — with a lower-case “v”; so if you encounter dBv on an old spec sheet, it means dBu, not dBV.

What is RMS Power?

An audio signal is defined by its amplitude (loudness) and frequency (pitch). When the sound is represented as a waveform, the amplitude is the vertical dimension, while the frequency is the number of up and down cycles of the wave per second, with seconds running from left to right.



Amplifier power ratings are based on the amplitude of the waveform. Since the peak levels of a complex waveform (one containing many frequencies) may occur rarely or frequently, an averaged value is used, based on the “root mean square” or RMS method. In this method, the amplitude is squared (so that all values are positive), then the resulting values are averaged, and the square root of this average is the RMS value. For simple sine wave test signals, the RMS voltage will be 0.707 times the peak voltage. After calculating RMS voltage, the RMS power is calculated by squaring the voltage and dividing by the load resistance.

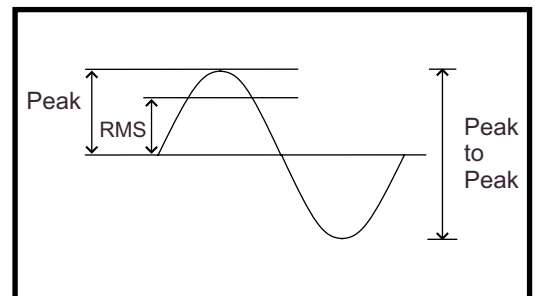


Figure 5 shows a simplified block diagram and a level diagram, indicating gain stages inside a mixer-amplifier, from mic and line level inputs to 70.7 volt speaker level output. The signal is amplified in stages, with attenuators (volume controls) between each stage to reduce the overall gain when needed. The mic pre-amp provides 32 to 52 dB of gain, bringing the mic level signal up to a level that can be matched with other line level sources. The summing amplifier provides additional gain, bringing all sources up to 0 dBV. The power amplifier serves to boost the power up to a level that can drive a speaker. It also provides a low output impedance for efficient power transfer. Lastly, the output transformer matches the amplifier to the 70.7 volt line and increases drive voltage to a maximum rated output of +37 dBV.

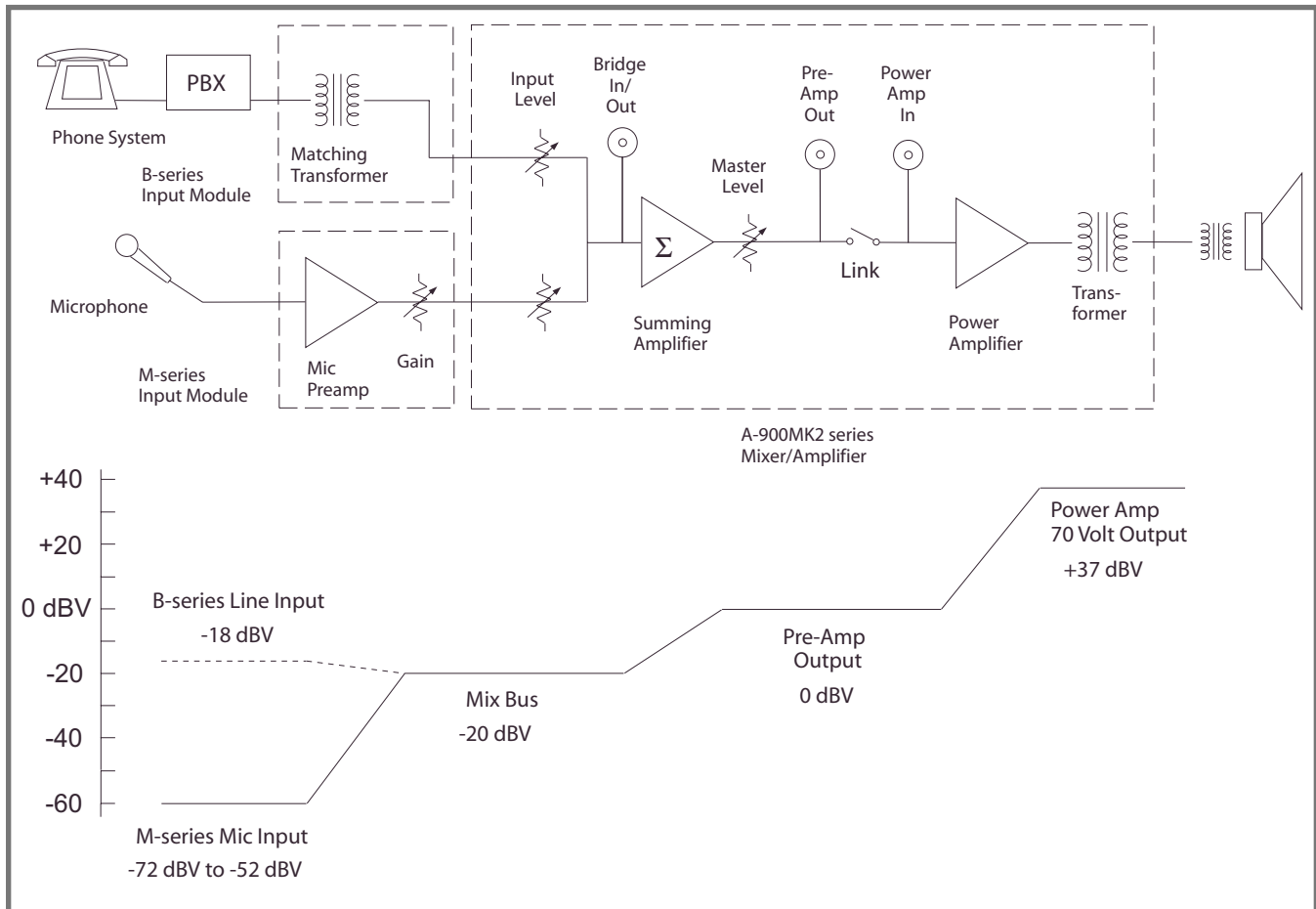


Figure 5: Block Diagram and Level Diagram of Mixer/Amplifier

Impedance

Impedance refers to the way a device reacts to the application of electric current. The device will exhibit varying amounts of resistance and either capacitance or inductance. For our purposes, the resistance is most important. In keeping with common practice, when we say “impedance” we will mean resistance.

Impedance, in this sense, refers to how much resistance the device presents to the free flow of electricity through it. At a given drive voltage, the lower the impedance of the receiving device, the higher will be the current flow through it. This is important to know when working with amplifiers, because if the load impedance presented by the speakers is too low, it may draw so much current that the amplifier will overwork itself and deliver distorted sound, overheat — perhaps even burn out.

Impedance is measured in ohms, named for Georg Ohm, who first described the set of electrical relationships now known as Ohm’s Law (see fig. 6). Every device will have both an input impedance (also called the *load* impedance) and an output impedance (also called the *source* impedance). The input impedance of an amplifier could range from 600 ohms to 10,000 ohms, or even higher (see side bar). A typical speaker impedance may range from 4 to 16 ohms.

Impedance “Matching”

A common point of confusion is the concept of “impedance matching.” Transmission line theory states that the load impedance and source impedance should be equal, to avoid reflections in the line. But this requirement holds only when the line is longer than the shortest wavelength of the signal. For audio frequencies, the line would need to be over 9 miles long for transmission line theory to apply. When using solid-state equipment and typical cable runs of several hundred feet or less, the best performance is obtained when the load impedance is about 5 to 20 times greater than the source impedance. So, for example, a 10,000 ohm input is a good “match” for a 600 ohm output.

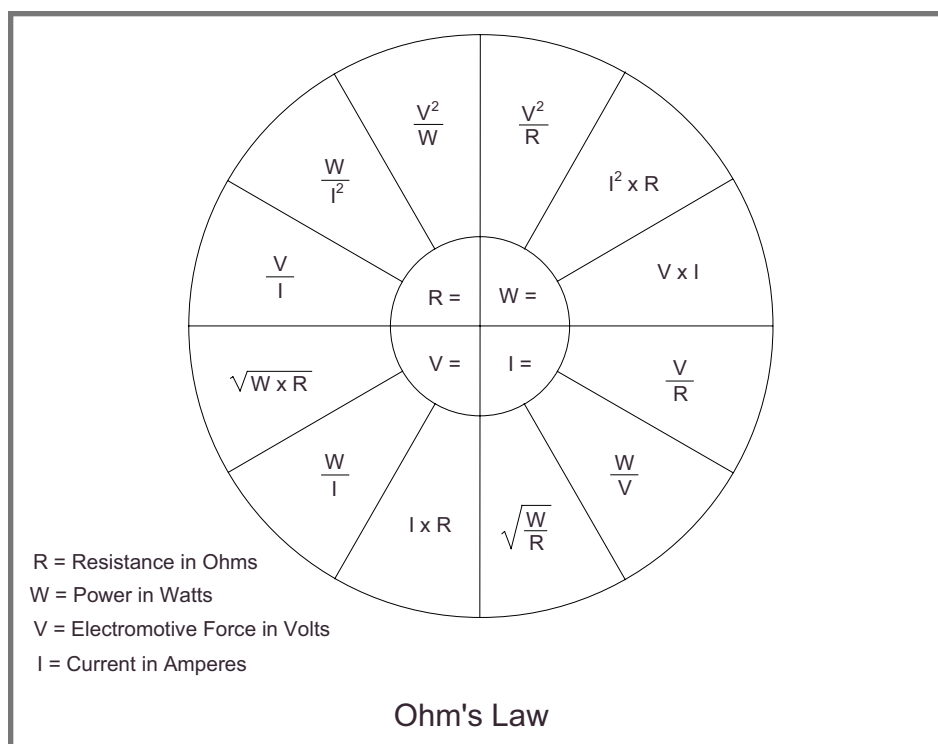


Figure 6

Chapter 3: Amplifier/Speaker Matching

Interfacing between the amplifier and speakers is commonly done in one of two ways. Small systems with one or two speakers will typically use a direct connection between the speakers and the amp. This is sometimes called *low impedance* operation, because the load impedance ranges from 4 to 16 ohms nominal. Systems with more than 2 speakers usually use transformers at the amp and at each speaker to simplify impedance matching and reduce line loss. These systems are commonly called distributed line systems, *70.7 volt* (or *25 volt*) systems, or *constant voltage systems*. In both cases, speakers should be wired in parallel (plus to plus and minus to minus).

Low Impedance Systems

When matching amplifiers with speakers, there are a couple of important rules to remember. First, low impedance amplifier outputs are described in terms of the recommended load impedance, i.e. "4 ohm output" or "8 ohm output" (the actual source impedance of a power amplifier output is seldom specified but is typically less than one ohm). Second: With rare exceptions, when using more than one speaker, the speakers should be wired in parallel.

Parallel wiring always results in a lower load impedance than the individual rating of each speaker. For example, two 8 ohm speakers in parallel results in a 4 ohm load. Two 16 ohm speakers in parallel results in an 8 ohm load. The general-purpose equation for calculating the load of multiple speakers in parallel is shown in Figure 7. But as the above two examples illustrate, you will find that ***when all the speakers have the same impedance, the total load will be equal to the rated impedance divided by the number of speakers.***

A commercial-grade speaker without any transformer may have a rated nominal impedance anywhere from 4 ohms to 16 ohms. The most common ratings are 4 ohms, 8 ohms or 16 ohms. The most common recommended load ratings for low impedance amplifier outputs are 4 ohms and 8 ohms. This means that in most cases, you will be limited to one or two speakers per amp channel when connecting low impedance speakers in parallel.

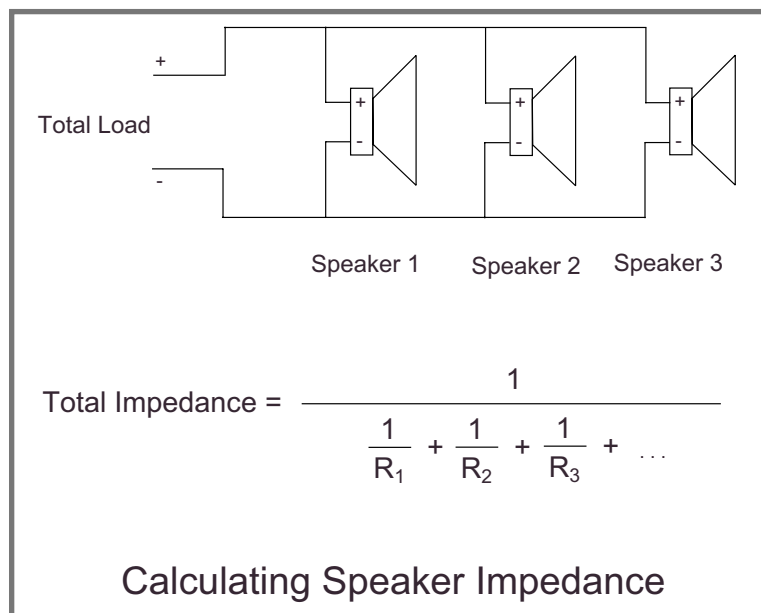


Figure 7

High Impedance (70.7 Volt / 25 Volt) Distributed Line Systems

In order to overcome the limitations of low impedance speaker systems, most medium-scale installed sound systems in the United States use either 70.7 volt or 25 volt distributed line systems, also known as *high impedance* or *constant voltage systems*. Often, they will be called simply “70 volt” or “25 volt” systems.

These systems work by including transformers at the input to each speaker and directly after the amplifier output (see fig. 8). The transformers are used to convert the impedance of each speaker to a higher value, and to convert the amplifier output impedance to a correspondingly high value. In a 70 volt line system, speaker impedances (with transformers) may range from below 20 ohms to as high as 10,000 ohms or more. But you won’t need to calculate the load impedance in ohms, because of how the high impedance approach works.

High impedance (70.7 volt and 25 volt line) systems have three major advantages over low-impedance systems:

- 1) System impedance-matching is made much easier — it is simply a matter of adding up speaker power taps and selecting an amplifier rated for at least that much power plus an allowance for headroom.
- 2) Line loss is greatly reduced, especially over long cable runs, resulting in better performance and reduced cost compared to long low impedance lines.
- 3) The amplifier output is electrically isolated from the speaker line by the output transformer, protecting the output stage against a grounded line and thus eliminating a potential source of system failure.

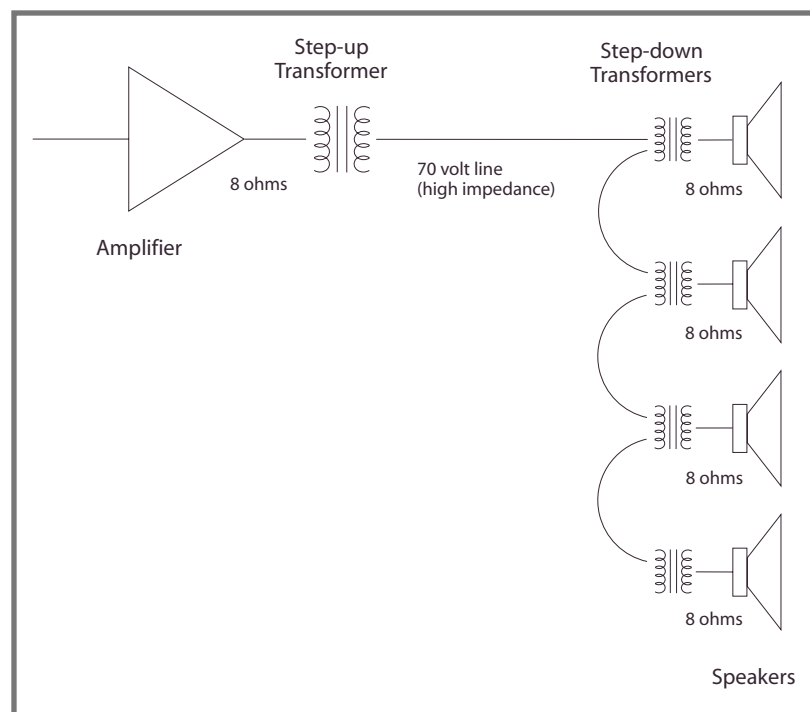


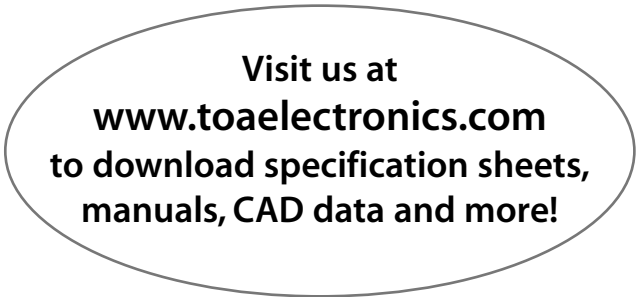
Figure 8: High Impedance Distributed System

How To Design A High Impedance Distributed System

In designing a high impedance speaker system, there is no need to calculate the total impedance from the speaker impedance values, the way you would for a low impedance system. This is because in high impedance systems (i.e. 70.7 volt and 25 volt line systems), the load impedance rating is expressed in terms of the amount of power that would be delivered to it at the rated line voltage. The rating is given in Watts, which can simply be added to the other speakers to get the total power drawn by the load. Just add a little extra for headroom (see example below), and you know how much power is needed. You don't even have to know Ohm's Law.

Here's the process in more detail: You should begin by choosing the type of speakers, how many, and how much power each one will need in order to reach the desired volume in the listening area. Help with this can be found in the *TOA Speaker Guide*. Once you know the type(s) of speaker(s) and how much power each one will need, determine what is the lowest available transformer tap that will supply at least that much power to the speaker. *For example, the SC-615T has 70.7 volt transformer taps at 15, 7.5 and 3.8 watts. To reach your desired level (maximum average level plus headroom for short-term peaks), you decide you'll need at least 5 watts at the speaker. In this case, choose the 7.5 watt power tap.*

When you have selected the proper power tap for each speaker, simply add them up and multiply the total times 1.25. Your amplifier should have at least this much power into the selected line voltage. *For example, the job requires twelve SC-615T horns, each tapped at 7.5 watts, to cover the listening area. Twelve times 7.5 watts = 90 watts, and 90 watts times 1.25 = 112.5 watts. Your amplifier should have at least this much power.*



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manuals, CAD data and more!**

Chapter 4: Wiring

The “audio chain” analogy is an especially good one when talking about wiring. Like a chain, a sound system is only as good as its weakest link. The kinds of cables used and how they are connected can often be the difference between a great system and a useless one. Most experienced audio professionals can tell stories about contractors who have saved a few pennies on installation and wiring costs, only to spend costly hours back on site correcting noise or other problems later.

The kind of wire to use will vary depending on the kind of signal it will be carrying, as well as the environment it will be used in. For most commercial installations, wiring will be “jacketed,” meaning that the insulated conductors will be bundled together, often in twisted pairs, inside an overall jacket for extra protection.

Low level and Line Level Wiring: Twisting, Shielding, Balancing and Isolating

One of the challenges in sound engineering is to avoid the introduction of unwanted electrical noise and interference into the system. Unwanted noises enter the system in one (or both) of two ways:

Induced noises can come into the system from sources that are not directly connected, much as radio waves can be picked up at a distance. In fact, radio waves are one of the main sources of induced noise (this type of noise is called *radio frequency interference*, or *RFI*). Induced noises may also be the result of inductance or capacitance between cable conductors and other conductors nearby (often called *electro-magnetic interference* or *EMI*, and *electro-static interference*). Common sources of induced noise include electric motors, radio transmitters, some types of lighting equipment, digital circuits, all kinds of power supplies. Indeed, in microphone applications, if you use the wrong cable, then just about any circuit where AC current is flowing could be a source of induced noise. The good news is most induced noises are easy to control by choosing the right type of cable and input/output circuit.

Ground loops come from ground reference mis-matches, which are a function of the power source(s) used for the sound system. If a mixer/amplifier is plugged into one AC outlet, and the input signal comes from a source that is plugged into a different outlet elsewhere in the building, the ground wires at the two outlets might have slightly different voltage potentials with respect to ground (and more importantly, with respect to each other). If the signal ground is tied to the AC mains ground, as is commonly the case in *unbalanced* audio circuits, then connecting the audio cables from the source to the mixer/amplifier will complete a circuit through which will flow a voltage equal to the potential difference between the two AC mains grounding points. This circuit is called a ground loop. The main symptom of a ground loop will be a 60 Hz hum in the sound system, often with harmonics above this at multiples of 60 Hz. There are three ways to alleviate ground loops, or avoid them altogether:

- 1) Use the same AC outlet for all equipment in the system. This may be impractical, if distances are great, or even inappropriate if the current draw exceeds the rating of the AC circuit.
- 2) Use transformer isolation between sound system components (see page 16).
- 3) Use a “floating” balanced line for the audio signal, so that neither leg of the signal is tied to ground (see page 16). Often, methods 2 and 3 are combined with the use of transformer-balanced inputs and outputs.

The two most popular methods to reduce the pickup of induced noises through sound system wiring are the use of *twisted pair* wiring, and the use of *shielded* cable.

Twisted Pair Wiring

Twisted pair wiring is just what it sounds like: two insulated conductors are twisted around each other over the length of the cable run. The twisting has the effect of rejecting certain types of induced noise, since each half-turn of the wire exposes it to the noise source with the opposite polarity of the preceding half-turn. The effect also works in reverse: twisted pairs generate less noise than pairs run in “flat,” untwisted wire. This fact helps to reduce the effect of “crosstalk” between pairs when multiple lines carrying similar signals are bundled together. Twisted pairs have been used by telephone companies for the better part of a century to carry voice communications, and are now the standard type of cable for Ethernet networking and other data transmission protocols (for example, CAT 5 wiring is simply a set of twisted pairs).

In sound systems, twisted pairs are often used for speaker wiring, especially over longer distance runs. For other sound system applications, twisted pair wiring is seldom used, except in conjunction with shielding and balancing (see *Balanced and Unbalanced Lines*, below). So, while CAT 5 may be the cat’s meow in data networking, you don’t want to use it for your microphone wiring, or you risk serious noise problems.

Shielded and Unshielded Cable

Shielded cables are the most common, and a more effective, line of defense against noise pickup in audio applications. They protect the signal path from noise pickup by surrounding one or more of the cable’s conductors with another conductor (the *shield*) that is tied to ground at one or both ends of the line. Shielded cables should always be used for microphone wiring. They should also be used for all unbalanced line level wiring, such as the outputs of CD players, tape decks, or many other common music sources. Standard stereo RCA patch cords are a common example of shielded wiring for unbalanced sources.

Balanced and Unbalanced Lines

The most effective defense against the pickup of induced noise through the wiring is to use a “balanced” circuit for the connection between equipment. This method involves not only using the right cable, but also having a certain type of input and output circuit. In sound systems, balanced circuits, or *balanced lines*, are typically run using three conductors — a twisted pair of inner conductors surrounded by a shield conductor. Running a balanced line requires the use of balancing output and input circuits, which work by splitting the signal into two paths, then inverting the polarity of one path, so that each conductor carries a signal that is the exact electrical opposite of the signal on the other conductor. While the signal is carried by the two conductors in opposite polarity, the noises that accumulate on the line will have the same polarity on both conductors. When the polarity of the reversed “low side” conductor is reversed again at the receiving end, any noise picked up by the line will be cancelled out. The combination of this balancing action with the use of shielded cable, and the twisted inner pair makes this arrangement the best for protecting audio signals from noise pickup.

Balanced circuits also protect the system against noise from ground loops. This is because the signal carried on the balanced pair represents a complete, “floating” or independent circuit, and is not connected to ground as a reference.

Transformer Isolation

Another way of protecting against ground loops is to use a transformer at one or both ends of the line. The transformer works by converting the signal from electric energy into magnetic energy, then back to electric energy. Since it is not a direct electrical connection, the transformer does not complete the circuit that would create the ground loop. But it still passes the audio signal unchanged. Low-cost transformers should be avoided, since they can add distortion and limit frequency response. But good quality transformers have a transparent audio quality and can give a high degree of assurance that ground loops will not occur. In balanced applications, where the floating circuit already protects against ground loops, the transformer adds protection against equipment failure that could occur if one side of the audio pair were shorted to ground. Here again, because it is not a direct connection, the transformer does not complete the circuit, and the output stage is protected. This is an important benefit in high powered speaker applications.

Speaker Level Wiring

Noise pickup is not usually a problem for speaker cables, because the voltages used to drive speakers are much greater than the voltage levels of induced noises. The main concerns for speaker wiring are adequate durability for the installation environment, adequate spacing from mic- and line-level wiring to avoid feed-back loops (do not put speaker and mic lines in same conduit), and adequate wire size to minimize line loss.

Minimizing Line Loss

Line loss occurs in speaker wiring in two ways, both related to the resistance of the wire. First, the wire will dissipate some of the power as heat. This power is wasted. Second, the wire will increase the total line resistance, causing the line to draw less power from the amp. This power is not wasted, but is just unused. Either way, it is best to keep line losses down to a minimum — preferably less than 1 dB.

One of the great benefits of 70.7 volt distributed line systems is that they are not affected by losses due to speaker line resistance to the same degree that low impedance or 25 volt line systems are. In most typical installations, if 18 gauge speaker wire is used, line loss will be less than 1 dB. If the total speaker load on the line is greater than 120 watts, or if the cable runs exceed 200 feet, consider using heavier gauge wire, as indicated in Appendix A, Table 1. Line losses are greater in 25 volt line systems. Appendix A, Table 2 shows the wire size to use for a given load and distance on a 25 volt line. An 8 ohm load will be very susceptible to line losses when the cable length exceeds about 100 feet.

Troubleshooting Guide

Load Troubleshooting

Shorted speaker lines and mis-matched loads are among the most common causes of sound system failure. Being attentive to the condition, configuration and installation of the speakers and wiring are the first line of defense against these common problems. But alas, the best laid plans do sometimes go awry, and when this happens, the installer/troubleshooter's best friend is a speaker line impedance meter such as the TOA ZM-104. Mastering this relatively simple measuring device can save hours of valuable field service time per job when tracking down existing problems, and most importantly, can help avoid call-backs by identifying mis-matched loads before the system is ever turned on.

When installing a system, it is prudent to check each branch line with the meter before bringing them together at the amplifier's output terminals. A final test of the impedance of the full load should be made before connecting it to the amplifier. If the system is already in place and load problems are suspected, the process is reversed: First, check the load at the amp. If the impedance is below the amplifier's rated impedance (or the effective power tap total is above the amplifier's rated power output), then check each branch line to see which one (or more) has a lower impedance than it should. Keep tracing this path, following the lowest impedance (or the impedance farthest below its expected value), until you find the culprit. This may be either an improperly tapped speaker/ transformer, a speaker without a transformer, a shorted line, or even a shorted speaker voice coil or transformer.

Power Tap (Watts)	Impedance (Ohms)	
	25 V	70 V
0.25	2500	20000
0.5	1250	10000
1	625	5000
2	313	2500
3	208	1667
4	156	1250
5	125	1000
8	78	625
10	63	500
12	52	417
15	42	333
20	31	250
30	21	167
60	10	83
75	8	67
100	6	50
120	5	42
150	4	33
180	3.5	28
200	3.1	25
220	2.8	23
300	2.1	17
400	1.6	13

Table 1: Power Tap to Impedance Conversion

TOA Amplifier Overview

700 Series

A-706

A-712

A-724



60/120/240 WATT 9-CHANNEL MIXER/AMPLIFIERS

- Flexible mixer/amplifiers for sound reinforcement, paging and background/foreground music distribution
- Six switchable Mic/Line inputs, balanced, with mic trim and switchable 24 VDC phantom power
- Two auxiliary inputs, unbalanced, with dual-RCA jacks
- 900 series module slot accepts 900 series plug-in modules for custom system configurations
- 25 V, 70.7 V and 4 ohm speaker outputs
- Transformer isolation for telephone paging (Input #1)
- User configurable auto-mute function with sensitivity adjustment
- Five-segment LED power meter
- Remote master volume (via 10k ohm pot) and remote turn-on
- Insert jacks for connecting external signal processor
- Protection circuitry prevents potential damage from overloads, short-circuit and overheating
- Five year warranty

BG-M Series

BG-1015

BG-1030

BG-1060

BG-1120



15/30/60/120 WATT 5-CHANNEL MIXER/AMPLIFIERS

- Compact, flexible mixer/amplifiers for paging, background/foreground music distribution and music/messaging-on-hold
- 900 series module slot with Page/BGM switch accepts most 900 series plug-in modules for custom system configurations
- 25 V, 70.7 V and 4 / 8 ohm speaker outputs
- Microphone page input, balanced, with 24 VDC phantom power
- Telephone page input, balanced, transformer-isolated with switchable 600/10k ohm input impedance
- Program input, balanced, with screw terminal connector
- Auxiliary input, unbalanced, with dual-RCA jacks for convenient connection of stereo sources
- Music-on-hold (MOH) outputs, 600 ohm balanced 0 dBV, and 8 ohm / 1 watt
- Selectable muting modes for versatile priority paging configurations
- Insert jacks for connecting external signal processor
- Protection circuitry prevents potential damage from overloads, short-circuit and overheating
- Five year warranty

BG Series

BG-115

BG-130



15/30 WATT 3-CHANNEL MIXER/AMPLIFIERS

- Compact mixer/amplifiers for paging, background/foreground music distribution and music/messaging-on-hold
- 25 V, 70.7 V and 4 / 8 ohm speaker outputs
- Microphone/telephone paging input (switchable), balanced, transformer-isolated, with switchable 600/10k ohm input impedance
- Program (PGM) input, balanced, screw-terminal connector
- Auxiliary (AUX) input, stereo-summing dual-RCA jacks
- Music-on-hold (MOH) output adjustable from line-level to 1 W at 8 ohms
- Auto-mute function allows voice-activated paging override of AUX/PGM without interrupting the MOH output
- Protection circuitry prevents potential damage from overloads, short-circuit and over-heating
- Five year warranty

900 Series



**A-903MK2
A-906MK2
A-912MK2**

30/60/120 WATT 8-CHANNEL MIXER/AMPLIFIERS

- Modular design allows fast and easy custom configurations for unmatched flexibility
- Eight module slots accept any combination of TOA plug-in modules
- 25 V, 70.7 V and 4 / 8 ohm speaker outputs
- Dual mute bus permits multiple levels of paging priority using optional mute-type modules
- Remote master volume terminals for control with an external 10k ohm linear-taper potentiometer
- Low cut switch to limit low frequency response
- Auxiliary output for connecting an external mixer or recording device
- Insert jacks for connecting external signal processing
- Bridging input/output for input expansion or system combining
- Protection circuitry prevents potential damage from overload, short-circuit and over-heating
- Five year warranty



A-901A

10 WATT 3-CHANNEL MIXER/AMPLIFIER

- Modular design allows fast and easy custom configurations for unmatched flexibility
- Two module slots accept TOA plug-in modules
- Program input for unbalanced line-level source
- 25 V, 70.7 V and 4 / 8 ohm speaker outputs
- Muting function for priority paging over background music
- Bass and treble controls for program input
- Optional rack-mount kit, model MB-920 (2 RU)
- Five year warranty



**P-906MK2
P-912MK2
P-924MK2**

60/120/240 WATT POWER AMPLIFIERS

- Modular single-channel power amplifiers
- Input module slot accepts most TOA plug-in modules for custom system configurations
- 25 V, 70.7 V and 4 / 8 ohm speaker outputs
- Direct input for connecting an external mixer or other source
- Selectable input sensitivity to accommodate high or low input levels
- Low cut switch to limit low frequency response
- Protection circuitry prevents potential damage from overload, short-circuit, or over-heating
- Five year warranty



M-900MK2

8-CHANNEL MODULAR MIXER

- Modular design allows fast and easy custom configurations for unmatched flexibility
- Eight module slots accept any combination of TOA plug-in modules
- Balanced, transformer-isolated output with selectable impedance, screw terminal connector and protective cover plate
- Dual mute bus permits multiple levels of paging priority using optional mute-type modules
- Remote master volume terminals for control with an external 10k ohm linear-taper potentiometer
- Auxiliary output for connecting an external mixer or recording device
- Bridging input/output for input expansion or system combining
- Protection circuitry prevents potential damage from overload, short-circuit or over-heating
- Five year warranty



W-906A
W-912A

60/120 WATT 6-CHANNEL IN-WALL MIXER/
AMPLIFIERS

- Modular design allows fast and easy custom configurations for unmatched flexibility
- Six module slots accept TOA plug-in modules, expandable to eight slots with optional kit, model WE-2
- 25 V, 70.7 V and 4 / 8 ohm speaker outputs
- Flush or surface-mount with optional back boxes — BX-9F (flush-mount) and BX-9S (surface-mount)
- One-octave nine band equalizer
- High and low pass filters
- Compressor prevents overload and distortion
- Muting function for input priority override
- Bridging input/output for input expansion or system combining
- Protection circuitry prevents potential damage from overload, short-circuit and over-heating
- Five year warranty

500 Series

A-503A
A-506A
A-512A



30/60/120 WATT 6-CHANNEL MIXER/AMPLIFIERS

- Integrated mixer/amplifiers for sound reinforcement, paging and background/foreground music distribution
- 25 V, 70.7 V and 4 ohm transformer-isolated speaker outputs with screw terminal connector and protective cover plate
- Two low impedance microphone inputs, balanced, transformer-isolated with XLR-F connectors (expandable to 4)
- Three auxiliary line inputs, unbalanced with RCA connectors
- Hi-z mic/phono input (switchable), unbalanced with RCA/screw terminal connectors
- External mute terminals for switch closure override of inputs 3-5 with adjustable mute depth
- Insert jacks for connecting external signal processor
- Booster and tape outputs for connecting external equipment
- +24 VDC input for connection to external power source
- Protection circuitry prevents potential damage from overload, short-circuit and overheating
- Five year warranty

CA Series



CA-115
CA-130
CA-160

15/30/60 WATT MOBILE MIXER/AMPLIFIERS

- Mobile mixer/amplifiers for remote applications
- 12 VDC powered
- Supports 4 or 8 ohm speaker loads
- Two microphone inputs and one auxiliary input
- Handheld microphone included — unidirectional, dynamic-type with talk switch, 6' cord and mounting hardware
- Mounting hardware included — mounts under dashboard or into standard DIN-size console cutout
- Five year warranty

IP Series

IP-300D
IP-450D
IP-600D



300/450/600 WATT DUAL CHANNEL POWER AMPLIFIERS

- Stereo, bridged, and parallel output modes
- Electronically balanced screw-terminal and XLR input connectors
- Optional input transformer available — model IT-101
- Precision stepped attenuators, recessable to prevent accidental setting changes (security covers included)
- Variable-speed fan for quiet, efficient cooling
- Advanced protection circuitry monitors voltage, current and thermal levels to prevent potential damage from overloads, short circuit, DC offset or over-heating
- In-rush current limiter prevents AC breaker overload during system turn-on of multiple amplifiers
- Optional transformers for 25 volt / 70.7 volt applications: model MT-300M (200 W), MT-450M (300 W), MT-600M (400 W)
- Five year warranty

TOA Amplifier Comparison Chart

Model	Description	Power	Total Inputs	Input Types	Output Channels	Main Output Type
A-706	Mixer/Amplifier	60 W	9	1 Module Port, 6 Bal. Mic/Line (Rem. Term. Blk), 2 Unbal.	1	4 Ω , 25 V, 70.7 V, Record (Unbal. Line)
A-712	Mixer/Amplifier	120 W	"	"	"	"
A-724	Mixer/Amplifier	240 W	"	"	"	"
A-503A	Mixer/Amplifier	30 W	6	2 Bal. Mic (expandable to 4), 1 Unbal. Mic/Phono, 1 Unbal. Mic/Line, 2 Unbal.	1	4 Ω , 25 V, 70.7 V, Record (Unbal. Line)
A-506A	Mixer/Amplifier	60 W	"	"	"	"
A-512A	Mixer/Amplifier	120 W	"	"	"	"
A-901A	Mixer/Amplifier	10 W	3	2 Module Ports, 1 Unbal. Line (single RCA)	1	4 / 8 Ω , 25 V, 70.7 V, Aux (Unbal. Line)
A-903MK2	Mixer/Amplifier	30 W	8	8 Module Ports	1	4 / 8 Ω , 25 V, 70.7 V, Aux (Unbal. Line)
A-906MK2	Mixer/Amplifier	60 W	"	"	"	"
A-912MK2	Mixer/Amplifier	120 W	"	"	"	"
BG-1015	Mixer/Amplifier	15 W + 1 W	5	1 Module Port, 1 Bal. Mic, 1 Transformer-Bal. Line, 1 Active-Bal. Line, 1 Unbal. (Dual RCA)	1 Main, 1 MOH	4 Ω , 25 V, 70.7 V
BG-1030	Mixer/Amplifier	30 W + 1 W	"	"	"	"
BG-1060	Mixer/Amplifier	60 W + 1 W	"	"	"	"
BG-1120	Mixer/Amplifier	120 W + 1 W	"	"	"	"
BG-115	Mixer/Amplifier	15 W	3	1 Transformer-Bal. Mic/Line, 1 Active-Bal. Line, 1 Unbal. (Dual RCA)	1 Main, 1 MOH	4 Ω , 25 V, 70.7 V
BG-130	Mixer/Amplifier	30 W	"	"	"	"
CA-115	Mobile Mixer/ Amplifier	15 W	3	2 Lo-Z Unbal. Mic, 1 Bal. Line	1	4 / 8 Ω
CA-130	Mobile Mixer/ Amplifier	30 W	"	"	"	"
CA-160	Mobile Mixer/ Amplifier	60 W	"	"	"	"
IP-300D	Power Amplifier	300 W/Ch. @ 4 Ω 200 W/Ch. @ 8 Ω 600 W Mono @ 8 Ω	2	1 Bal. Line per channel (Screw terminals, Female XLR, Male XLR)	2	4 / 8 Ω , optional 25/70.7 V using MT-300M
IP-450D	Power Amplifier	450 W/Ch. @ 4 Ω 300 W/Ch. @ 8 Ω 900 W Mono @ 8 Ω	"	"	"	4 / 8 Ω , optional 25/70.7 V using MT-450M
IP-600D	Power Amplifier	600 W/Ch. @ 4 Ω 400 W/Ch. @ 8 Ω 1200 W Mono @ 8 Ω	"	1 Bal. Line per channel (Female XLR, Male XLR, Screw terminals)	"	4 / 8 Ω , optional 25/70.7 V using MT-600M
P-906MK2	Power Amplifier	60 W	1	1 Module Port	1	4 / 8 Ω , 25 V, 70.7 V
P-912MK2	Power Amplifier	120 W	"	"	"	"
P-924MK2	Power Amplifier	240 W at 4 or 8 Ω , 220 W at 25 or 70.7 V	"	"	"	"
W-906A	In-Wall Mixer/ Amplifier	60 W	6/8	6 Module Ports, Expandable to 8 Ports w/ WE-2	1	4 / 8 Ω , 25 V, 70.7 V
W-912A	In-Wall Mixer/ Amplifier	120 W	"	"	"	"

TOA Amplifier Comparison Chart

Model	MOH Output	Auto-Mute	Phantom Power*	Insert Jacks	Additional Features	Color	Rack Space	Rack-Mount Kit
A-706	Optional, using T-12S	User Configurable	Yes	Yes	Selectable mute assign., 5-seg. LED meter, remote master vol. & turn on	Black	2U	MB-25B
A-712	"	"	"	"	"	"	"	"
A-724	"	"	"	"	"	"	"	"
A-503A	—	—	Inputs 1 & 2 Only	Yes	RIAA phono pre-amp input, closure-controlled muting	Black	2U	MB-21B2
A-506A	—	—	"	"	"	"	"	"
A-512A	—	—	"	"	"	"	"	"
A-901A	Optional, using T-12S	Optional, using muting module	Yes	Yes	Closure-controlled muting (auto-mute optional), transformer isolated output	Silver	2U	MB-920
A-903MK2	"	"	"	"	Remote master vol., bridge in/out jack**, 2 mute busses, low cut filter	Black	"	MB-25B
A-906MK2	"	"	"	"	"	"	"	"
A-912MK2	"	"	"	"	"	"	"	"
BG-1015	Yes	User Configurable	Yes	Yes	Closure-controlled inputs for zone applications, user-configurable muting and buss assignments	Black	2U	MB-1000
BG-1030	"	"	"	"	"	"	"	"
BG-1060	"	"	"	"	"	"	"	"
BG-1120	"	"	"	"	"	"	"	"
BG-115	Yes	User Configurable	—	—	Selectable 600 / 10k ohm transformer-isolated paging input	Black	2U	MB-25B-BK (1) MB-25B-J (2)
BG-130	"	"	—	—	"	"	"	"
CA-115	—	—	—	—	12 Volt DC operation for automotive applications, includes handheld PTT mic	Black	(DIN Chassis)	(Mounting brackets incl.)
CA-130	—	—	—	—	"	"	"	"
CA-160	—	—	—	—	"	"	"	"
IP-300D	—	—	—	—	Stereo, bridge and parallel output modes; variable-speed fan; precision stepped attenuators	Black	2U	Built-in
IP-450D	—	—	—	—	"	"	"	"
IP-600D	—	—	—	—	"	"	"	"
P-906MK2	Optional, using T-12S	—	Yes	—	Low-cut filter, high-gain mode, extensive protection circuitry	Black	2U	MB-25B
P-912MK2	"	—	"	—	"	"	"	"
P-924MK2	"	—	"	—	"	"	(3U)	MB-35B
W-906A	Optional, using T-12S	Optional, using muting modules	Yes	—	Wall-mount, 10-band equalizer and compressor, bridge in/out connection**	Silver	—	(Backbox: BX-9S or BX-9F)
W-912A	"	"	"	—	"	"	—	"

* Mic inputs only

** For expansion and room combining

Appendix A: Wire Size Charts

Table 1 Speaker Cable Lengths (ft) and Gauges (AWG) for 70.7 V Line with 1 dB Power Loss

70.7 V	Wire Gauge (AWG)	10	12	14	16	18	20	22
Load Power (W)	Load Impedance (Ω)	Maximum Cable Distance (ft)						
10	490	*	*	*	7,200	4,600	2,800	1,800
15	327	*	*	7,600	4,800	3,000	1,920	1,200
20	245	*	9,200	5,600	3,600	2,200	1,400	900
30	163	10,000	6,200	3,800	2,400	1,500	960	600
40	122	7,400	4,600	2,800	1,800	1,100	700	450
60	81	5,000	3,200	1,900	1,200	730	480	**
100	49	2,900	1,820	1,120	720	230	**	**
200	24.5	1,450	910	560	360	110	**	**
400	12.2	730	460	280	180	**	**	**

Table 2 Speaker Cable Lengths (ft) and Gauges (AWG) for 25 V Line with 1 dB Power Loss

25 V	Wire Gauge (AWG)	10	12	14	16	18	20	22
Load Power (W)	Load Impedance (Ω)	Maximum Cable Distance (ft)						
10	61	3,700	2,300	1,400	900	575	350	225
15	41	2,500	1,550	950	600	375	240	150
20	31	1,850	1,150	700	450	275	175	113
30	20	1,250	775	475	300	188	120	**
40	15	925	575	350	225	138	**	**
60	10	625	400	238	150	**	**	**
100	6	363	228	140	90	**	**	**
200	3	181	114	70	**	**	**	**

* Greater than 10,000 feet

** Not recommended, may exceed safe current capacity of wire

Appendix B: Power Consumption and Thermal Dissipation

Model	Power Consumption at Rated Output (Watts)	Power Consumption at 50% duty cycle (Watts)	Heat Dissipation (BTU / Hr.)
A-503A	60	30	102
A-506A	100	50	171
A-512A	180	90	307
A-706	68	34	116
A-712	110	55	188
A-724	215	108	367
A-901A	30	15	51
A-903MK2	60	30	102
A-906MK2	100	50	171
A-912MK2	180	90	307
BG-115	50	25	85
BG-130	90	45	154
BG-1015	50	25	85
BG-1030	80	40	136
BG-1060	160	80	273
BG-1120	260	130	444
IP-300D	1040	520	1774
IP-450D	1650	825	2815
IP-600D	2080	1040	3548
M-900MK2	18	9	31
P-906MK2	100	50	171
P-912MK2	180	90	307
P-924MK2	360	180	614
W-906A	100	50	171
W-912A	180	90	307



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