

# Distributed Speaker Systems 101

By Rick Kamlet

In a typical paging, background music or noise-masking system, several loudspeakers are placed across a single amplifier in parallel. They must often be powered at different levels, and the calculations involved in determining the actual load impedance at the amplifier's output can be quite tedious.

A solution for this problem comes in the form of the 70-volt distribution system, which makes calculations simple and straightforward. In this method of distribution, amplifiers are designed so their full power output is 70 volts RMS, which is a fairly high voltage. Many loudspeakers are placed across this "70 Volt" speaker line, using distribution transformers at each speaker to convert this high voltage back down to the proper level for the speaker.

## HOW IT ALL WORKS

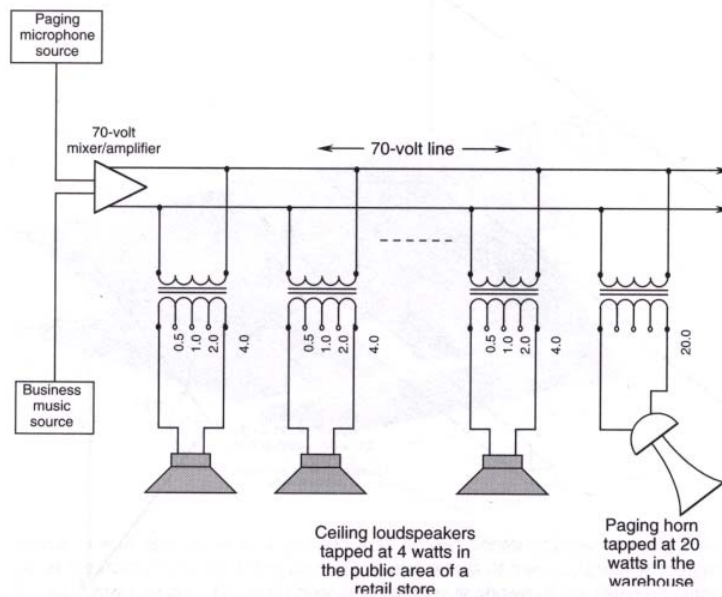


FIGURE1. Basic 70 Volt Distributed Speaker System

**Transformer Load Impedance.** The load impedance of each transformer determines how much power it draws from the 70 Volt line at those times when the amp hits its maximum output of 70 volts. The load impedance that corresponds to several common power ratings is shown in the chart below:

Impedance	5000 $\Omega$	1000 $\Omega$	500 $\Omega$
Power Draw @ 70V	1 W	5 W	10 W
Impedance	167 $\Omega$	83 $\Omega$	50 $\Omega$
Power Draw @ 70V	30 W	60 W	100 W

The computational formula is voltage squared divided by impedance:  
 **$Power = Voltage^2 / Impedance$** .

When the speaker line reaches its top voltage of 70 Volts, the formula is:  
 **$Power = 5000 / Impedance$**  (because 70 squared equals 5000).

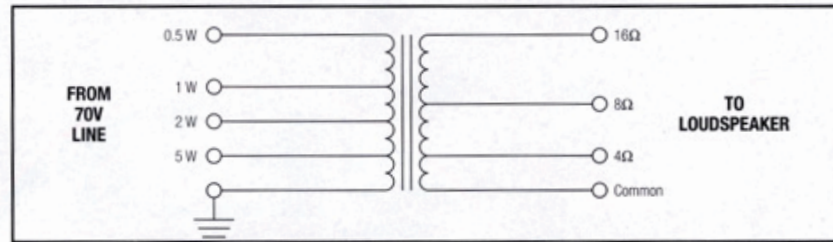


FIGURE 2. Typical 5 Watt, 70 Volt Distribution Transformer with Power Selection Taps on the Primary Coil.

**Stepping Down the Voltage.** Let's assume that we want to drive a particular loudspeaker at 5 watts. The connection is made and the impedance of the loudspeaker as seen from the primary side is calculated. The 8-ohm loudspeaker is transformed across to the primary as a 1,000-ohm load to the amplifier. What is the voltage that gets to the speaker when the speaker line hits it maximum voltage of 70 Volts?

Ignoring for a moment the insertion loss of the transformer, we can do the calculations at either the primary or the secondary of the transformer. The formula is voltage squared divided by impedance:

$$\text{Primary Power} = \text{Secondary Power}$$

$$(70)^2 / 1000 = (6.3)^2 / 8$$

The 70-volt primary has, in process, been transformed down to 6.3 volts RMS at the speaker's voice coil. Note that  $(6.3)^2 / 8$  equals 5 Watts, the same amount of power that is being drawn from the 70 Volt distributed speaker line.

**Adding the Watts.** Loudspeakers are connected across the distributed speaker line and tapped as needed, and all the designer has to do is count watts — the sum of all the taps. When the total wattage drawn by the line equals the power output rating of the amplifier, then the maximum number of speakers has been attached to the amplifier's output. In practice, it is best to keep the total sum of the taps below 80% of the power amplifier rating.

The simplicity of this method means that the user never needs to calculate load impedance in parallel combinations.

## INSERTION LOSS

In reality, not all the power that goes into the transformer's primary gets transformed to its output. There is some insertion loss. These days, transformers in distributed systems should probably exhibit no greater than 1 dB of insertion loss.

## 70 VOLTS VS 100 VOLTS

The standard in North America is 70 volts for a distributed system. Most other areas of the world use 100 volts, in which case figuring out the total load on the amp is still simply a matter of adding up the sums of the speaker taps, using the 100-volt rating of the tap instead of a 70-volt rating. Any impedance calculations, if necessary, are done by dividing the tap rating into 10,000 (100 volts squared) instead of into 5,000 (70.7 volts squared).

Today, there are speakers which use the same taps for both 70- and 100-volt systems. For example, a tap with 500 ohm impedance is a 10-watt tap when used on a 70-volt system and a 20-watt tap on a 100-volt system. The manufacturer must ensure that the transformer is capable of handling the higher voltage (which almost all are) and that the transformer is capable of transforming the full power at 100 volts without saturating (which many 70-volt transformers are not capable of doing).

## OTHER REASONS FOR DISTRIBUTED SYSTEMS

In addition to making calculations simpler, there are some other technical reasons for using distributed systems.

**Paralleling Impedances.** If you were using 8-ohm speakers, you would not be able to parallel very many speakers before loading the amplifier with too low of an impedance. Series-parallel configurations are often not the right way to go. In distributed systems, the impedance of each speaker is transformed upward to allow the connection of many speakers in parallel.

**Wire Gauge.** When running into the higher impedance of the transformer, you can typically use smaller gauge cable. The amount of voltage (and therefore total power) eaten up in the cable is a function of cable impedance divided by the load impedance. If the load is 8 ohms, then the cable impedance better be pretty small, which requires large gauge cable. On the other hand, if the total load on the amp is, perhaps, 100 ohms (where the sum of taps is 50 watts), then the cable impedance can be higher without eating up very much voltage. The smaller gauge cable can save the installer and customer a substantial amount of money. It would get very costly if you had to wire every speaker with 12-gauge cable or larger!

**Tap Selection.** In many applications, speakers need to be set at different volumes, either because of different ceiling heights, different densities of speakers or because the customer wants some areas to be quieter than others. The multiple taps on most speaker transformers allow the installer to select how loud the speaker will be simply by attaching to a different power tap.

## WHY IS IT CALLED "CONSTANT VOLTAGE?"

You may have heard a distributed speaker system referred to as a "70-volt constant voltage system." Does this mean that there is a constant AC or DC voltage of 70 volts always going through the speaker line? No, it doesn't.

I've heard that the term goes back to early days of audio. Audio engineers of that time were concerned with how the voltage arriving at the receiving device varied from the voltage sent out by the sending device, and how the voltage transfer would vary in conjunction with changes in the impedance of the receiving device. In distributed speaker systems, where the impedance of the receiving device (in this case, the transformer) is very high relative to the impedance of the sending device (in this case, the power amplifier), then the receiving device receives the same voltage regardless of the impedance of the receiving device (within reason). For example, if the amplifier is putting out a sine wave of 70 volts RMS, then the full 70 volts goes across the primary of the transformer whether you've connected to a 5-watt tap (which is 1,000 ohms) or to a 50-watt tap (which is 100 ohms). So there is "constant voltage" transfer regardless of the impedance.

Does this mean that multiple low-impedance speakers (8 ohms) driven by an amplifier is not a "constant voltage" system? Driving a low-impedance speaker system (16 ohms, 8 ohms, 4 ohms) with a power amplifier is also a "constant voltage" system until you have too low of an impedance for the amplifier to drive. For example, a 10-volt sine wave from the amplifier driving a 16-ohm speaker will continue to be a 10-volt sine wave if you connect an 8-ohm speaker instead. The 8-ohm speaker will simply draw more current from the 10-volt signal, resulting in more power draw. The voltage stays the same but the current draw varies, which results in different power taps.

In my opinion, the term "constant voltage system" is not very useful or meaningful in describing 70-volt distributed speaker systems, but it has somehow stuck with us through the years.

## CONCLUSIONS

Understanding the concepts in designing a distributed system is the first step in successfully completing the project. Using these simple math examples can help you install large-scale systems in theme parks, stadiums and more. Don't be confused by the term "constant voltage system" -- it is a hold-over from an earlier time and won't help you understand the distributed systems of today. As with everything, experience is the best teacher. Try multiple configurations and listen to what sounds best.

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