Understanding and Working with Distributed Sound Systems

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The technique of constant-voltage (CV) loudspeaker distribution has been a standard audio practice since the earliest days of sound contracting.

Developed specifically for distributed paging and public address systems, and adopted by the EIA, the CV method relies upon standardizing the RMS voltage level of distribution lines. The common CV voltage standards are 70-volt and 25-volt. (Technically, it's 70.7-volt, selected because of electrical, insurance and/or building code regulations limiting the maximum voltage in unprotected speaker lines.)

CV systems permit flexible connection of loudspeakers across the distribution line, much like connecting a light bulb across a power line. Transformers are utilized at each loudspeaker to regulate the proportion of the total amplifier power that the speaker "sees," which determines the maximum sound pressure level in the corresponding zone. This results in a very reliable system, as long as the net power demanded by each branch does not exceed the rated power of the driving amplifier. Even if one or more speakers become disconnected or fail, the power applied to the others remains the same.

Constant-voltage distribution greatly simplifies the calculations involved in designing a background music or paging system. Within the amplifier's power limit, speakers can be freely added to (or subtracted from) the system without the relatively tedious recalculation of total load impedance. Moreover, the CV method allows a single amplifier to drive many speakers without resorting to series/parallel connection techniques. All connections are made in parallel with the line.

CV systems require that the output voltage be constant over a relatively wide range of load impedances, to a practical minimum limited by the output capability of the amplifier. Early direct-coupled tube amplifiers rarely met this requirement (or had output voltages that were far too high), and so tube amplifiers for CV systems once employed integral output transformers. Virtually all modem professional transistor amplifiers deliver an output voltage that is essentially independent of load, however, making contemporary CV systems much easier to implement.

Read more about the full line of Electro-Voice® commercial sound products.

One relic of the tube days, though, is the relatively common misconception that you must use an output transformer on any amplifier that drives a CV line. In fact, given the state of modem power amplifier technology, a transformer is not necessarily required. In this article, we will explore a number of alternative methods for driving constant-voltage distribution systems.

Amplifier Bridging

Read more about the Electro-Voice CPS-2T amplifier.

One of the primary reasons that output transformers are often employed is to boost an amplifier's output voltage to the CV line's standard operating level. To see why this would be necessary, let's consider what kind of amplifier we would need to develop 70 volts directly.

A derivative of Ohm's Law states that power equals voltage times current:

$$\mathbf{P = E * I}$$

Substituting **E/R** for current (again in accordance with Ohm's Law), we get:

$$\mathbf{P = E^2 / R}$$

To get the 8-ohm rating of a power amplifier capable of 70 volts RMS output:

$$\mathbf{P = (70\ volts)^2 / 8\ ohms = about\ 600\ watts}$$

This is more power than most CV systems would require. Furthermore, an amp rated at 600 watts per channel would be expensive for a smaller distributed system installation.

The common solution has been, of course, to use dual-winding step-up transformers at the outputs of an amplifier with a more modest rating. Such transformers carry their own limitations, however. Especially with the advent of foreground music systems, the power requirements for CV systems have risen somewhat. But output transformers capable of significant power handling are large, expensive and heavy. They may also exhibit limited low-frequency response and might impose substantial insertion losses.

How, then, does one deliver 70 volts to the CV line? One way is to use bridging. Because a bridged power amplifier drives the load push-pull, the voltage across the load is effectively double that of each channel's individual output. If we need to develop a total of 70 volts across the line, we can use an amplifier which delivers half of that, or 35 volts, for each channel.

Using the previous equation:

$$P = E^2 / R = (35 \text{ volts})^2 / 8 \text{ ohms} = \text{about } 150 \text{ watts}$$

Professional amplifiers of this power class are today quite common and relatively inexpensive.

Note: Amplifier bridging should only be done when the amplifier is specifically designed for this purpose.

The manufacturer's instructions should be followed when using this technique. You must take the amplifier's bridged, 8-ohm power rating as the reference maximum power figure for loading calculations. Remember that the minimum load impedance for a bridged power amplifier is twice that of each individual channel. The bridging power figure will be specified accordingly, and may also be de-rated to reflect performance limitations of the amp's power supply circuitry. For this reason, a 200 watt per channel amplifier (or thereabouts) may actually be required, even though the 150-watt amplifier could develop sufficient voltage.

Single-Channel Direct Drive

As we have seen, the 70-volt line standard discourages direct drive from a single amplifier channel, if for no other reason than economy. But the same is not necessarily true of the 25-volt standard. As above, we can use the form of Ohm's Law that solves for power to ascertain what kind of amplifier we would need to develop 25 volts RMS across a CV line:

$$P = E^2 / R = (25 \text{ volts})^2 / 8 \text{ ohms} = \text{about } 75 \text{ watts}$$

Certainly, a 75-watt-per-channel professional power amplifier is well within the range of many CV system budgets. Given the state of contemporary amplifier technology, there is no reason why an amp of this power class could not drive two 25-volt branches directly.

The use of a 75-watt-per-channel amplifier can also bring added benefits in certain installations. For instance, there is often a need to drive one or two full-range high-quality loudspeakers—say, for foreground music—in addition to a CV paging line. (One could imagine such a situation in a small airport terminal that included a restaurant or bar, for example.) In such situations, combining music and paging on a single branch may impose a compromise in sound quality that will frustrate the client. The solution here is to use one channel of a high-quality 75-watt amplifier to drive the CV line, and the other to drive the foreground music system.

Use of Autotransformers

Realistically speaking, many installations will present demands, which cannot be satisfied by the techniques that we've discussed thus far. One such case would be the moderate-sized 70-volt music-and-paging system shown in Figure 4 (next page). The system comprises two separate branches, each of which requires approximately 100 watts from the power amplifier.

This application clearly does not demand anywhere near the power capability of two bridged 150-watt amplifiers (one per 70-volt branch). Must we in this instance go back to using dual-winding step-up transformers in order to match a lower-powered amplifier to the CV lines? Not necessarily.

Consider that the DC isolation afforded by a dual-winding transformer could easily be waived if we employ a professional solid-state amplifier, which incorporates protection against output offsets (as most do nowadays). This opens up the possibility of using an autotransformer to boost the output voltage of the amplifier.

Autotransformers offer a significant advantage over dual-winding transformers in that they impose far less insertion loss, chiefly because of tighter magnetic coupling and lower coil resistance. This translates into far more efficient power transfer.

Remember that insertion loss must be factored into all CV design calculations. Power transfer is the name of the game here. An insertion loss of only I dB corresponds to a power loss of over 20%, and an insertion loss of 3 dB cuts the available amplifier power in half!

Such losses directly affect the number of speakers that can be connected to a CV line. The Electro-Voice® Model AT100 is a wide-range autotransformer designed specifically for use in high-quality distributed systems. The AT100 features multiple taps at specified impedance ratios, which were chosen for maximum utility in CV system implementations. Rated at 100 watts long-term average power capacity, the AT100 can operate with very low distortion at peak levels far exceeding 100 watts, and may be used in CV applications either in step-up (amplifier output matching) or step-down (loudspeaker matching) mode.

Read more about the AT100 and 15000 Series transformers.

Applying the AT100 to an installation, for example, we could connect each output of a power amplifier with a 4-ohm power rating of 100 watts to the brown and black terminals of an AT100. The 70-volt lines would then be connected across the respective yellow and black terminals (common carries through). Operating the power amplifier at the equivalent of a 4-ohm load utilizes all of its available power, for further cost efficiency. The extremely low insertion loss of the AT100 allows virtually all of that power to be transferred to the line, maximizing the capabilities of the system.

Conclusion

We have presented an overview of some methods that are available to the sound contractor for driving constant-voltage distribution lines. As we have seen, amplifier output transformers are not the only solution there are alternatives.

The basic principles discussed here may easily be extended to solve a wide range of practical installation problems. With creativity, and knowledge of the underlying theory of CV systems, you can achieve substantial cost savings while achieving the attendant benefits of higher sound quality and reliability.

Caution: Not all amplifiers are stable when operated in "bridge" mode. Refer to the unit's specs, or contact the manufacturer directly for guidance. Some amps do not operate correctly into a transformer or autotransformer, particularly at low frequencies. If you have any questions about the proper use and application of transformers and autotransformers with a specific amp or system, the manufacturer of the product should be able to provide appropriate technical support.