Constant Voltage Distribution Center

By Jack Sondermeyer

We are celebrating our twenty-fifth anniversary of the microprocessor. The past twenty five years have brought us a great amount of change. Everywhere we look the world is being controlled by microprocessors. The audio industry started to take notice of this technology only a decade ago, and then ony as the "brains" in remote controls for large audio systems.

The audio industry was invaded by specialized microprocessors we fondly call DSPs (digital signal processors). These devices opened up a new world for the audio industry and have been the key to pushing an otherwise slow to change industry forward. Computer control of DSP-based equipment was the next step in the development of this emerging technology. In 1993, MediaMatrix was introduced, which further enhanced the integration of DSP and computer control into a single operation.

Merging audio and computer technologies has been a personal mission for this writer for the last twelve years, but it has not been easy! The computer industry doesn't understand the nuances of professional audio. The audio industry is reluctant to embrace the advantages and economies that the computer industry provides; the audio industry is very slow to change. The computer technology that we are discussing in this article is over ten years old. However, many in our industry are talking about it as if it is a revolutionary new technology that will take the world by storm, when the fact is it did a long time ago.

At the 101st AES show (November, 1996) it was announced that Peavey Electronics, QSC Audio Products, Inc., and Rane Corp. became licensees of CobraNet. What is CobraNet?

CobraNet will replace analog cable and audio distribution with digital, using standard Ethernet. Why Ethernet? Ethernet is a cost-effective, widely used and well-supported networking standard.

This poses some interesting questions: Are you, as a contractor, ready to support this technology? The computer industry has ten, plus years of experience with this technology. How will the audio industry stack up to the expectations that the computer industry has laid before it? Is the existence of the audio industry in jeopardy?

Before you answer, let me state this: Recently, a test was provided at one of our advanced audio training semi ears. The test was given to gauge the level of understanding of networking on the parts of the leading audio consultants, designers, and engineers. Only 10% of the tests were completed, 5% had answered several questions, and the other 85% were blank. For a manufacturer of totally digital audio systems this is alarming. The audio industry is ill-prepared for the digital age that is now upon us.

The audio industry, as a whole, needs to gain a new set of skills to compete: PC architecture and technology, networking, and programming, in addition to the skills that are currently required. This magazine is committed to the sound and communications industry and will provide the information necessary to increase the skills required to become and remain competitive.

Constant voltage distribution systems have been a source of confusion for many people for a long, long time. It seems that the more technical the person, the more complicated he perceives a constant voltage distribution system. Once learned, constant voltage systems are really not very complicated at all, but rather just "simple solutions to a very complex problem." Most good solutions are just that...simple. Constant voltage systems rely on the simplicity and easy usage of line matching transformers. Before we proceed with this; however, let's create a little scenario...

STORY TIME

Imagine a rather simple distributed "sound system" installation. The requirements are to install 10 speakers in the ceilings of a small office building for background music and paging. Although nothing is formalized, there must be provisions for some of the speakers to "play softer" than others in parts of the office building. An enterprising technician might just take on this "simple" project and set about to figure the arrangement he could use to connect 10 speakers. Without a specific knowledge of constant voltage distribution system techniques, he first takes ten 8 ohm speakers and mentally connects them all in parallel..... "hmmmmm: 8 divided by 10 or 0.8 ohm load...what kind of an amplifier will I need to drive that low an impedance?" Next, he connects them mentally in series...'"hmm: 8 times 10 or 80 ohms load...what kind of an amplifier will drive that impedance effectively? How about some series/parallel combination...we'll try 'series-ing' them in pairs and then connecting the combinations up in parallel...hmmmm: 16 divided by 5 or 3.2 ohms load...a 4 ohm amp...great. Next question...just how much power will this system need...well, I'll worry about that later. Now, how will I address the requirement for changing levels at the various loudspeakers...(long time thinking)...use different impedance speakers? Gosh...the math gets complicated...now what...PUNT!!!!'

THE 70 VOLT SYSTEM

Enter the 70 volt distribution system...a knowledgeable installer has in hand a 70 volt, 10 watt line matching transformer (Component Specialties - Model No. T-7010...$3.89 each...see Figure 1 for transformer diagram). This particular unit has six primary wires available and three secondary wires. The secondaries are common - 4 ohms and 8 ohms. The primary wires are common - 10 watts, 5 watts, 2.5 watts, 1.25 watts, & 0.625 watts. This transformer will be used as follows: One will be installed at each individual speaker location with the correct secondary wire connected to an 8 or 4 ohm speaker; the primary will be connected across a 70 volt distribution line (pair); and the particular wires used will be ones that will deliver the desired power to the speaker. The system power amp must have a 70 volt output, and its power rating must be equal to or greater than the "sum" of all the individual power levels desired to be delivered to each speaker by each of the line matching transformers connected to the power amp.

The only decision to be made in such a system is how much power is to be delivered at each speaker location. Once this is determined, then the "tap" associated with that power level is selected, and you simply add up all the individual "powers" to determine the power amp requirement. Superficially, that's all there is to it, but in practice most installers "pad" the power requirement and use a larger power amp than necessary, because they know that the transformer loading is greater than expected. Additionally, there are power losses associated with the line matching transformers, so the delivered speaker power will be less than expected. Nevertheless, no complicated impedance calculations or series/parallel speakers...just simple addition. Neat, huh?...Now for some details...

THE SECRET OF SUCCESS

As I mentioned earlier, the whole constant voltage distribution system relies on relatively "small and inexpensive" line matching transformers, and as such is the 'secret' of the system. The concept of a transformer for many of us goes back to usage as a kid with the "electric trains" or some other low voltage application where the transformer was designed to plug into the wall socket and convert the AC mains (line) to some lower value of AC. In audio applications, transformers are used to convert impedances from one value to another. This is where they really "excel" and is the real "magic" that makes these distribution systems work. Let's review some theory:

Transformers only work on AC voltages...they are short circuits to DC. They raise or lower AC voltages in direct relation to the turns ratio, and they convert impedances up or down in direct relation to the "turns ratio" squared.

Now, back to the matching transformer diagram: It has secondary wires of common, 4 ohms and 8 ohms. The primary wires include common, 10 watts (500 ohms), 5 watts (1 k ohms), 2.5 watts (2k ohms), 1.25 watts (4k ohms), & 0.625 watts (8k ohms). What this is saying: If you put an 8 ohm load (speaker) on the 8 ohm secondary tap (or 4 ohm load on the 4 ohm tap), this transformer, by its design, will convert the load upward to a new indicate value (assume 500 ohms), dependent upon which primary tap you select together with the common tap. Now, it just so happens that if you place a 500 ohm load on a constant 70 V RMS line, you will deliver exactly 10 W RMS to that 500 ohm load, and in this case you will "transform" that 10 W RMS into the 8 or 4 ohm loudspeaker load.

Having the power rating indicated, you really don't have to get involved in the fact that the "reflected" load is 500 ohms if you don't want to, and most installers who don't understand don't need to. This is what makes using the matching transformer so easy. All the information is right there. If you hook up this tap to a constant voltage line you will get this many watts into your speaker. Now add up all your watts to come up with a minimum amp requirement...case closed. Practically speaking, the transfer of power between primary and secondary is always accomplished at a typical 33% loss. Matching transformer spec sheets show this as an INSERTION LOSS expressed in dB. Notice I said "minimum." Let's talk about the power amp first...

THE POWER AMPLIFIER

The design of a constant voltage capability in a power amplifier is not a trivial exercise, although what is created is simply 25/70/100 output V RMS. Such an amplifier will produce a constant voltage "cleanly" (usually less than 1 % total harmonic distortion) as a maximum output rating, just before clipping. Generally, this voltage level is created using (of all things) a specially designed OUTPUT TRANSFORMER. In the old days of Stubs' type power amps, large, bulky output transformers were a way of life, needed to convert the relatively high tube plate impedances down to 4, 8, & 16 ohm levels, and the constant voltage tap(s) was just another winding on that transformer. In contemporary amplifiers, direct coupled, solid state designs have virtually eliminated the need for the output transformer, since they can drive the typical speaker load directly. For a 70 volt output, for example, the power amp design usually includes an output transformer (or AUTO-FORMER), since it often cannot produce 70 V RMS directly and therefore it must be "transformed." We call these systems "constant voltage" systems, when they really are audio signals with a maximum of either 25, 70, or 100 V RMS when the power amplifier is at full rated output. To understand this voltage concept better, let's review a power amplifier rating system that most folks are familiar with.

Assume we have a power amplifier that is rated at 400 W RMS into 4 ohms. Such is the rating for one channel of Peavey's CS-800(TM) power-amplifier (the actual rating is 400 W RMS per channel, with both channels operating).

In this case, one channel of the CS-800 can produce 40 V RMS, or we may call the output a "40 volt line." Some common levels are as follows:

- 200 W RMS/4 ohms=28 V RMS
- 100 W RMS/4 ohms=20 V RMS
- 100 W RMS/8 ohms=28 V RMS
- 50 W RMS/8 ohms=20 V RMS

Notice certain combinations of power & load will give the same voltage. Continuing, if you were to connect a transformer to one channel of a CS-800, that would convert 40 V RMS up to 70.7 V RMS; then, the CS-800 could successfully 'drive' a 70 V RMS line up to a 400 W RMS power level. Such a transformer exists and is available through the Peavey Accessory Program. The unit is called an AUTOMATCH, and it is actually an auto-former, which is a transformer that does not have a separate primary and secondary, but rather just one winding with various 'taps' available. (It has the same common terminal for both input and output.) It has been designed to "create" 70 volt lines from various standard level power amplifiers including the CS-800 and other popular models. The AUTOMATCH will accept voltage levels of 20, 28, 40, & 56 V RMS and transform these to both 70.7 & 100 V RMS at up to 400 W RMS levels. This unit is priced very reasonably and provides an effective means to drive 70 volt lines with standard, direct coupled type power amplifiers. The unit can also be used to convert speaker (load) impedances either up or down (8 ohm to 4 ohm, etc.) to effectively match amplifier ratings. (Figure 2 is the power, impedance, and voltage chart on the AUTOMATCH. You should notice that the chart indicates all the output voltage levels we just reviewed.)

THE SYSTEM ITSELF

Now, let's use our "creation" of a 70 volt amplifier with the CS-800 and the AUTOMATCH. Suppose we take only one 70 volt line matching transformer, connect the secondary 8 ohm tap to a single 8 ohm speaker, and connect the 10 watt primary tap together with the common tap of this single "system" across the 70 volt line. How much power will the CS-800 deliver to the speaker? If you answered 10 watts, you're right...read on. Notice the power amplifier can deliver a maximum of 400 W RMS, but with just one 10 watt/70 volt load connected (500 ohms), it will only deliver 10 W RMS. It can, however, drive a total of 40 such loads (40x10 = 400).

This is what makes constant voltage (70 volt) distribution systems so flexible and explains why previous discussions have always said, "Add up the individual powers of the 70 volt system; this is the MINIMUM power amplifier requirement." YOU CAN ALWAYS USE OVER-RATED POWER AMPLIFIERS ON ANY 70 VOLT SYSTEM. Although economically impractical, a 1000 watt 70 volt power amplifier could be used on a 50 watt system with no problems, and the system performance would be exactly the same as if a 50 watt amplifier were used instead. As a practical matter, however, most experienced sound installers will rarely use a 50 watt power amp on a 50 watt system. Let's review why.

TROUBLE IN PARADISE

Contrary to prevailing impressions, the "simple" line matching transformer is one of the most 'complex' electronic components. It is completely understood by fewer engineers than almost any other part of the system. However, there are several basic characteristics that need to be discussed that will assist you in the system design and power amp selection.

First, it must be realized that associated with the transfer of current and voltage between the primary and secondary windings there are losses. These losses are typically due to resistance in the windings of both the primary and secondary, where the current itself causes internal heating. For example, a 10-watt unit with a 1.5 dB "insertion loss" would deliver only 7 watts to the speaker with 10 watts of input power at the primary. If 7 watts is not enough, you must select a higher powered transformer.

Here the speaker will simply operate at 1.5 dB lower SPL than expected, and the 70 volt system will still only be "loaded" with a 10 watt system. To make matters more confusing, some manufacturers actually adjust the transformer windings internally to compensate for insertion loss by reflecting a lower than normal impedance at the primary winding, so the power amp will deliver the extra power necessary to overcome the insertion losses. In this case, a "compensated" 10-watt unit with 1.5 dB less would require 14 watts of power at the primary to deliver 10 watts to the speaker.

With this transformer, then, the speaker will operate at the expected SPL but the 70 volt system will actually be "loaded" with a 14 watt loads. Thus, one must ascertain: (1) the true amount of insertion losses as opposed to the manufacturer's claimed losses, and (2) whether the windings are compensated or uncompensated. Obviously, compensated matching transformer units have higher power amp requirements than uncompensated ones.

Secondly, the majority of small line transformers use "reactive" at both the lower & higher frequencies. This means the impedance that the unit presents to the 70 volt line will drop, open dramatically, as the system program material moves away from either side of the 1000 Hz reference frequency "conveniently" used by most manufacturers in the specifications and ratings. The real problem is dealing with the lower, not the higher, frequencies. Suppose the impedance of transformer drops from 500 ohms to 250 ohms at some low frequency value. Then the input power requirements have doubled! Hence, it is imperative that we know AND ACTUALLY CONTROL the low (and high) frequency operating limits of the system, and at those limits know what the actual transformer loading is on the 70 volt distribution line. The "inductive" and "capacitive" reactances of matching transformers do significantly effect the frequency response of the loudspeaker. This is particularly noticeable in the bass frequency range. If a typical music distribution system is found to be lacking in lows, the only alternative is to "buy more iron" by purchasing a larger (more expensive) transformer and/or to use a smaller wattage rating tap. Great caution should be exercised with equalization on systems with poor, low frequency response. For these and many other reasons it is a good idea to evaluate the line transformers before installation. By far the best way is to actually connect the unit to a 70 volt power amp and then measure the various critical parameters.

KEEPING OUT OF TROUBLE

IF YOU AVOID USING LOW COST AND COMPENSATED TYPE MATCHING TRANSFORMERS AND YOU ALWAYS USE EQUIPMENT THAT HAS 50 HZ AS THE LOW FREQUENCY LIMIT, THEN THE MINIMUM POWER AMPLIFIER RATING IS 150% OF THE SUM OF POWERS, OR...FOR A GIVEN AMP, THE MAXIMUM SIZE SYSTEM IS 67% OF THE RATED POWER, AND...YOU CAN EXPECT SPEAKER SPL LEVELS -1.7 DB BELOW EXPECTED (67%) POWER.

In our little office design we talked about previously, the target power level for each of the 10 speakers was 10 watts, then the minimum power amplifier requirement would be 100 watts. However, a prudent installer might use a 200 watt amp instead, which would allow for the system loading, and will also allow for some future system expansion. If the budget was tight, he might just use a 150 watt amp (using the target 150% value), or he might rewire each transformer to 5 watts and use a 75 watt power amp accepting 3 dB less system level. This is what makes the design of a 70 volt system so neat. The combinations are limitless. And notice with the 70 watt system, you don't necessarily have to wire transformers the same or deliver the same power levels to all speakers.

Again, in our little office, the entry area could have 3 speakers at 5 W RMS; 6 separate offices - 1 speaker each office at 2.5 W RMS each; and a break area - 2 speakers at 10 W RMS each. Calculating the total load: (3 x 5) + (6 x 2.5) +(2x10)-15+15+20=50WRMS (USE 75 W AMP) Notice, this exercise was just choosing taps, and yet the installer had great flexibility in setting levels throughout the office complex to meet the sound level needs of all involved. To install such a system without using these constant voltage techniques would be just about next to impossible.

BACKGROUND & HISTORY

At this point you might be asking, "Why 70 volts; who choses this level?" The original intention was to have 100 volts peak on the line, and since the peak to RMS conversion for a sine wave is 0.707, a 100 volt peak line was 70.7 volts RMS. The technically correct value is 70.7 volt RMS, but 70 volts is the common term. Various other voltages have been tried including 25 V, 35 V, 50 V, 70 V, 100 V, 140 V, and 200 V, but the 25 V, 70 V, or 100

V systems have become the most widespread. By the late 40's, several standards had evolved to regulate 70 V specifications for amplifiers and transformers, and in the 1950's we found the usage of 70 V systems very well established in the western hemisphere (100 V elsewhere). There's another reason why the 70 volt system passed the test of time above all the other voltage systems. The answer is simply one of "shock hazard." Years ago, Underwriters Laboratory determined through extensive research that 70 V RMS was the highest AC voltage it would approve on the exposed output terminals of an amplifier. The only restrictions that U. L. places on 70 volt outputs that the user could possibly be "exposed to" is to provide an ADEQUATE VERBAL WARNING. Armed with these WARNINGS, the constant 70 volt distribution system is still very much alive and kicking, even after almost 50 years of usage. Peavey has completed designs on its new Architectural Acoustics products, all of which have constant voltage output capability. These units use the screw type barrier strips for all the output connections, including the 70 volt line. U. L. will put its "blessing" on any such "exposed" strips provided the manufacturer provides adequate notifications of voltage output and prints a disclaimer stating that THE INSTALLATION MUST MEET ALL APPLICABLE CODES.

A LOWER VOLTAGE SYSTEM

Although the 70 volt system is the most popular and the most widely used in the U.S.A., there are many STATE CODES which consider 70 V RMS a potential problem. For example, some states require 70 volt cables to be double insulated, and/or single insulated cables must be placed in conduits. Still, others impose severe application limitations on 70 volt systems. Some states won't permit 70 V system usage in schools, churches, and public places. In cases such as these, installers will choose a lower voltage system...a 25 volt system, which most codes allow. Like the 70 volt system, the 25 volt system also has a key ingredient, the line matching transformer. In this case, the matching transformer must be a unique 25 volt version.

All the "rules of the road" are the same as before. You simply replace 70 with 25 in all the calculations. (Component Specialities offer many - Model No. T-2510...$3.89 each...see Figure 3 for transformer diagram.) Like the 7010, it also has six primary wires and three secondary wires. Again, the secondaries are common, 4 ohms & 8 ohms; the primary wires are common, 10 watts (62.5 ohms), 5 watts (125 ohms), 2.5 watts (250 ohms),1.25 watts (500 ohms), & 0.625 watts (1 k ohms). This transformer is used exactly as the 70 volt count counterpart, the secondary wired to each speaker. The primary will be connected across a 25 volt distribution line (pair), and the particular wires used will be ones that will deliver the desired power to the speaker. The system power amp must have a 25 volt output and its power rating must be equal to or greater than the sum of all the individual power levels desired to be delivered to each speaker by each of the distribution transformers (exactly the same as before) and here, too, you still should pad the power amplifier requirement by 150%.

Again, like the 70 volt version, the 25 volt transformer is saying, "If you put a 4 ohm load (speaker) on the 4 ohm secondary tap (or 8 ohm load on the 8 ohm tap), this transformer, by its design, will convert the load upward to a new indicated value (assume 62.5 ohms), dependent upon which primary tap you select together with the common tap." Now, it just so happens that if you place a 62.5 ohm load on a constant 25 VAC line, you will deliver exactly 10 W RMS to that 62.5 ohm load and in this case you will "transform" that 10 W RMS into the 8 or 4 ohm loadspeaker load.

As mentioned, the 25 volt system must employ a power amp that delivers 25 V RMS at full power output. Although not as common as 70 volts, the 25 volt output capability is still "around and kicking," and all the new Peavey distribution type products will offer both 25 & 70 volt outputs. Although the 25 volt system was intended to be exactly 25 V RMS, it will work quite well on 28 V RMS, which just happens to be the voltage level that 200 W/4 ohm and 100 W/8 ohm direct coupled prover amplifiers supply. This "overage" in voltage usually doesn't cause any performance problems and thus most distribution products will "call" 28 V RMS a 25 volt line. This voltage level is also available on Peavey's AUTOMATCH transformer, so it can be used where necessary to convert any power amp to 25 V RMS.

Often installers are asked to upgrade existing systems in churches and schools. The most common mistakes made are by those who proceed to add to or change an existing system without knowledge of what type of system really exists: 25 volts, 70 volts, or "0 volts".

MIX & MATCH

I make reference to a system called "0 volts." It is simply a system where vast numbers of 8 ohm or so speakers are PARALLELED on forever, creating almost a "zero" load value, which some unfortunate power amp has to drive. Such systems are (regrettably) very common. Where problems occur is when a 0 volt "add-on" system is connected to an existing 70 volt system. I have seen 70 volt parts added to an already overloaded 70 volt system, and even worse, watched folks "hang" 70 volt parts on a 25 volt system and wonder why the system just doesn't sound right. I make the following suggestions to those who would attempt to mix 25 & 70 volt pans in the same system: Unless you really have your constant voltage fundamentals mastered, don't attempt this. Wire 25 & 70 volt pans separately, and then use separate amplifiers/systems.

BRIDGE MODE OPERATION

There is another technique that allows direct coupled stereo amplifiers to drive 70 volt lines directly without using a conversion output transformer. This technique is called BRIDGE MODE. When a two-channel amplifier is operated in BRIDGE MODE, it is converted to a single channel amp with a power rating and a load rating TWICE that of the single channel ratings. For example, the CS-800 bridge rating is 800 W RMS into 8 ohms (the single channel rating was 400 W RMS into 4 ohms). The bridge mode operation is accomplished by placing the mode switch in the bridge position and connecting the "load" between the red binding posts of each channel, and using channel "A" as the input channel (all functions of channel "B" input are defeated). What actually happens from the technical standpoint is that "B" channel is supplied an input signal which is equal in level, but is 180 degrees out-of-phase from that of the channel "A" input signal. Thus, the load, which is connected between the channels, must be twice the single channel rating, and it "sees" the sum of output voltages of both channels. This technique then allows the CS-800 to produce an output voltage of 80 V RMS at full rated output. This bridged amp is now used to drive 70 volt systems directly without a transformer, resulting in a very simple and cost effective approach; however, there are SOME LIMITATIONS THAT ARE USUALLY NEVER TAKEN INTO ACCOUNT...

TROUBLE IN RIVER CITY

First, most bridged amps have an 8 ohm minimum load rating, thus the 70 volt system impedance must be limited to 8 ohms. It can be shown mathematically that a 600 watt 70 volt system load is about 8 ohms. Therefore, to keep from overloading the amplifier, we must limit the size of this 70 volt system to 600 watts (NOTE: YOU CAN'T LOAD THIS 800 WATT AMP WITH A 800 WATT "IDEAL" SYSTEM), but from our 67% rules for system limits we better limit it to only 400 watts. Now the strange part...this 400 watt system will be driven to 533 W RTMS (all 70 volt parts will be "overpowered" to 133%) as you will see in the chart below. Fortunately, all this works out well; however, the typical matching transformers have a 33% power loss. Notice all these "crazy" 70 volt limits occurred because a bridged CS-800 was an 80 volt line and not a 70 volt line. Following is a chart listing some standard bridged power amp ratings and the resulting performance:

-POWER LEVEL/LOAD-APPROX V LINE- % PWR IN 70 V SYSTEM-APPROX SPL

• 400 WATTS/8 OHMS 56 V RMS LINE UNDER-POWERED TO 67%... -2 dB SPL

• 600 WATTS/8 OHMS 70 V RMS LINE REFERENCE PWR @ 100 %... 0 dB SPL

• 800 WATTS/8 OHMS 80 V RMS LINE OVER-POWERED TO 133%... +1 dB SPL

• 1000 WATTS/8 OHMS 90 V RMS LINE OVER-POWERED TO 167%... +2 dB SPL

• 1200 WATTS/8 OHMS...100 V RMS LINE... OVER-POWERED TO 200%...+3 dB SPL

Notice that only a 600 WATT/8 OHM power amp actually delivers 70 V RMS. In all cases. The 8 ohm bridged power amps can drive up to a 400 W RMS size 70 volt system, but will "power" each part as indicated above. Generally, the 600 and 800 W RMS/ 8 OHM amplifiers driving 70 volt systems will perform well (Peavey CS-800s find extremely wide usages here). But a 400 W RMS/8 OHM amp can result in a very under-powered system. In this case, I would suggest selecting the next highest power level tap on the matching transformer (if available) and limit system size to 200 W RMS. Amplifiers that produce more than 80 V RMS should never be connected to normally wired 70 volt components, since they will be over-voltaged and could possibly be damaged and/or could cause severe distortion due to the possibility of transformer "saturation" at the higher voltages. In this case, a viable alternative is to select the next lowest power tap on the matching transformer. WARNING...THE TRANSFORMER MUST BE RATED FOR THE DESIRED POWER (it must be a 10 W unit but use 5 W tap for 10 W RMS). This wiring "trick" changes a 70 volt system to 100 volts, so 1200 WATT/8 OHM amps could "drive" up to a 1200 watt, 100 volt system (assuming an ideal one). However, for loading we should limit the system size to 800 watts.

THE 100 VOLT SYSTEM

100 volt distribution systems find wide usage in many countries outside the western hemisphere. They are however, very rarely used in the U.S.A. and Canada, and most local audio distributors have never heard of a 100 volt distribution transformer. Again, this 100 V system is treated just like the two systems we have already covered, except 25 V or 70 V becomes 100 V. Peavey does sell many products in world markets and we address the 100 volt applications with the 100 V RMS tap on the AUTOMATCH (just in case you were wondering why). Both the CS-1000 & CS-1200 bridged are good 100 volt distribution amps. You may be asking, "Why 100 volt systems?" The answer lies in another real advantage of distribution systems themselves. This advantage is that the typical voltage distribution system generally has less losses in long cable runs than those encountered in a typical "direct coupled" system, and/or you can generally use smaller wire sizes in a distributed system. Just ask your local power company about their distribution system. Have you ever wondered why power companies use such high voltage levels on their long "runs" from the generating plants to where the consumers are? The answer is simply avoiding LOSSES. A utility/power company sells power, electrical power. Electrical power is a product of the voltage level times the current delivered. For a given power, THE HIGHER THE VOLTAGE, THE LESS CURRENT IS REQUIRED, & current is what causes losses. LOWER CURRENT MEANS LOWER CABLE LOSS.

The typical power company will use 200,000 V RMS or even higher on their distribution lines. This allows them to have less losses in the cables and also use a relatively "small" wire. Both these reasons are dollars. The power companies apply this logic through the whole system. On that power pole in front of your home is 10,000 V RMS or more. That voltage is applied to a distribution transformer which steps it down to the 120 V RMS, which then feeds that plug or light which we all take for granted.

The analogy between this system and constant voltage audio distribution systems should be apparent and should answer the question "why" 100 volts, and "why" the typical audio distribution system has less losses in long cable runs than those encountered in a typical "direct coupled" system. It should be obvious that delivering 70 V RMS over a long cable run to a line matching transformer which presents a bad of 500 ohms (10 W), can be accomplished using a relatively small wire as compared to delivering 9 V RMS the same distance to an 8 ohm speaker "direct coupled" (10 W). The significant difference between the two systems is simply "loading." For example, assuming a 100 ft. run, the 70 V RMS cable can be a #27 AWG pair with losses of 0.21 W. The 9 V RMS cable should be a #10 AWG pair, but 100 ft. of #10 AWG is too expensive, so we use #16 AWG and base 1 W. You may be wondering how I came up with the wire sizes and the losses. There are many good publications that cover this topic in great detail. Most deal with the wire size required for certain length runs which must carry so much current. This information is important for any system, including 120 VAC electrical wiring & regular power amp speaker loading. Choosing the right size wire for the job is also very important in any distribution system.

It is not the intention of this paper to cover cable sizing. We will leave such for another time and another paper. I will make just one point about cable "sizing." Most folks just think that 70 volt systems automatically can use very small wire sizes. Somehow converting that 40 volt amp (CS400) up to 70 volts "magically" cuts way down on those cable losses. Always remember that wire size is directly related to the level of current it has to carry. In the above example we raised the voltage by seven-fourths...so we lowered the current by four sevenths. That means we can use four sevenths of the wire size originally required without the conversion to 70 volts. That's about two (or three) wire sizes smaller...that's all. Example: We are driving an 8 ohm loudspeaker array with that CS-800 and about 100 ft. of cable. It is determined that such a run should use #10 AWG cable. Now, using the 70 volt conversion transformers (Peavey Automatches) at both ends (one at the amp to convert up and one at the speaker to convert down) will allow us to use #12 AWG cable...big deal. You will find that the cost of the two Automatch transformers and the #12 wire is more expensive than using the #10 cable in the first place. And, yes, you must use #12 with that 70 volt system, not that #18 that you hoped to use. Right here in Lauderdale County we have a certain football stadium that uses a 130 watt Packaged P.A. with our Automatch transformer to drive a 70 volt loudspeaker array about 1000 ft away in the scoreboard. They use a #27 telephone wire...that's about 60 watts down the drain.

ADJUSTING LEVELS

Most background music systems require a convenient means for adjusting the volume level at each speaker or at small groups of speakers. This feature is usually provided through the use of a "local" line control. Selecting the correct line control can be as important as the choice of the line matching transformer in the typical distribution system. The term "attenuator" includes potentiometers (called "pots"), pads, and auto-transformers. All three find usage as level setting devices in typical sound systems, but each performs a slightly different function.

THE POT

Power pots (or Rheostats) have often been used to control the volume level of a single speaker. A typical pot used with an 8 ohm speaker is 50 ohms/5 watts. As a general rule, pot values should be at least 5 times (but no more than 10 times) that of the speaker impedance (or line impedance) value, and have a power rating of at least 20% of the expected speaker power level. If the resistance value is too high, the result will be loss of "range," where no sound will be heard until the pot is turned almost completely up, at which time full volume will be produced. If the value is too low, excessive power will be drawn from the power amplifier and "dissipated" in the pot itself, and it could be destroyed by "heating." Figure 4 shows the wiring arrangement for the typical pot application. Notice that when the pot is full CW, the speaker is connected directly to the source and the pot itself is additional "loading" on the source - the total load being 8 ohms in parallel with 50 ohms (approx. 6.9 ohms). When the pot is full CCW, the speaker is removed from the source, but the pot itself is still providing loading on the source (pot value 50 ohms). At the mid-range setting the pot powers the signal level and provides a loading of about 31 ohms (25 + 25 "in parallel with" 8,25 + 6=31).

The additional loading must always be considered when using this approach, and the bad variation can cause problems in applications where the source must have a constant load value, such as between the 8 ohm secondary taps of a line matching transformer, and an 8 ohm speaker. In this case the line matching transformer characteristics change significantly when the 8 ohm taps are terminated with 50 ohms, and thus A POT SHOULD NOT BE USED HERE. However, a pot can be successfully used in the primary (70 volt) side. A 5000 ohm, 2 watt pot finds wide range usage in single transformer applications, and a 2000 ohm, 3 watt pot can be used for controlling up to 5 units. Generally, pots should be avoided when controlling more than 5 transformers, since the value required will cause excessive pot dissipation (heating). In this case, the 5000 ohm pot dissipates about 1 W RMS of power.

All such loading must be added to the total power calculation to determine the power amp requirement, but unlike the matching transformer case, the pot loading values do not have to be "padded" upward due to bad changes at low frequencies.

THE L-PAD

L-pads avoid many of the problems associated with pots as these controls contain dual offsetting resistance elements and are designed to provide a constant impedance to the source. Figure 5 is the wiring arrangement for an 8 ohm, 10 watt L-pad. Note that this unit uses an 8 ohm, 10 watt resistance element connected between the source and the speaker, and a separate 40 ohm, 5 watt resistance element connected across the speaker. At the full CW setting the 8 ohm element becomes a low resistance value and the 40 ohm element is actually "open," the wiper not making contact. At this seeing, then, the only load on the source is the speaker itself, the L-pad basically being "out of the circuit." This is the first real advantage of L-pads...THEY DO NOT PROVIDE ANY ADDITIONAL SYSTEM LOADING. Hence, when used they don't increase the power amplifier requirements.

At the full CCW setting, the 8 ohm element becomes an 8 ohm load to the source and the 40 ohm element becomes a low resistance value effectively shorting the speaker. At the mid-range setting, the 8 ohm element is 4 ohms (in series with the speaker), and the 40 ohm element is 20 ohms (in parallel with the speaker). 20 ohms across an 8 ohm speaker yields approximately 5 ohms. Hence, the source loading is about 9 ohms (5 + 4). This, then, is the second advantage of L-pads...THEY PROVIDE A RELATIVELY CONSTANT IMPEDANCE TO THE SOURCE, and hence the device of choice between the 8 ohm secondary taps of the line transformer and the 8 ohm speaker.

As expected, L-pads also have some major disadvantages. First, they are much more expensive than single element pots, although current prices are becoming more competitive. Second, you must match the impedance of the pads to the loudspeaker impedance, and they also have a MAXIMUM POWER RATING THAT CAN NEVER BE EXCEEDED. This makes using them for multiple speakers almost impossible. Third, the L-pad has a very poor maximum attenuation value (generally less than 30 dB), and as such doesn't turn the speaker "off" completely, the resulting "leakage" being annoying. A pad called the T-pad addresses this L-pad disadvantage by using three offsetting resistance elements, the 3rd element being in series with the speakers. This type pad has a greater maximum attenuation value than the L-pad, but T-pads are extremely expensive and are not readily available. The pot approach generally can attenuate signal levels more than 50 dB.

And last, the constant impedance to the source characteristic is often not a desirable feature in applications that really don't require this. The constant impedance "thing" means a constant system loading. There are many versions of L-pads available for usage at 70 volt line levels. In the old days of tube type power amplifiers, you learned to NEVER MISMATCH A TUBE POWER AMPLIFIER. That large "output transformer" was not very forgiving of higher than normal impedance loads, and that "open circuit" was a disaster. Such conditions usually destroyed the output transformer itself due to the extreme high levels of 'inductive energy' that had no place to go at full power (clipping) operating levels, and would simply "arc" over internally causing the primary winding to short. Hence, born out of necessity, the L-pad came about to maintain a CONSTANT 70 VOLT SYSTEM IMPEDANCE which was required for good amp reliability. Unfortunately, many folk still think that "YOU GOT TO GO WITH THE PAD."

AMPLIFIERS HAVE CHANGED

Contemporary power amplifiers no longer suffer from such problems, and are very "happy" to drive higher than normal loads or even open circuits, and under these conditions run far cooler than when fully loaded. Thus, the 5000 ohm pot is the economical contemporary choke. Although it has the disadvantage of adding system loading, it is usually not the case, since generally not all the pots are at the maximum setting. Hence, system loading is actually less, and the amplifier likes it. Most experienced installers simply ignore the pot loading on a system. NOTICE YOU CAN GET IN TROUBLE IF ALL POTS ARE TURNED UP TO THE MAXIMUM! A very popular item used in many installations is a speaker that has the line matching transformer already mounted to the unit itself and has the 8 ohm output taps already connected to the speaker. Here, the installer simply connects the desired power taps. In this case, a 5000 ohm pot wired into the primary circuit works out real well. Using an 8 ohm L-pad in the secondary circuit here would be difficult.

The third type of attenuator is the auto-transformer. This type operates in a manner similar to an ordinary line matching transformer, with each step or change in volume being accomplished by switching to a lower or higher ratio primary tap with a rotary switch. The type is generally very expensive and is not used very often in contemporary applications.

THE END...NO, JUST THE BEGINNING

As you can see, constant voltage distribution systems are not as complicated as many would make them out to be. With a few simple rules, and just plain common sense, you can avoid the pitfalls that are lurking out there. I would suggest, however, before you set yourself up as that expert installer and tackle that really big distributed system, that you try a small one like our little office scenario. Like any other electronic endeavor, adequate test equipment is a necessity. There are several really great portable impedance measurement devices available from your local electronic distributor that can check the actual impedance of a distribution line and/or the distribution transformer, and will tell you what the actual loading is at any point in the system. Such measurements cannot be accomplished with a simple ohmmeter.

I have found the following publications to be very helpful on this subject:
AUDIO CYCLOPEDIA by Committee / Howard Sams publisher

SOUND SYSTEMS ENGINEERING by Don Davis / Howard Sams publisher

Also, if all else fails, my phone works. Seriously, we at Peavey Electronics stand ready to answer any questions that you might have on this subject...

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