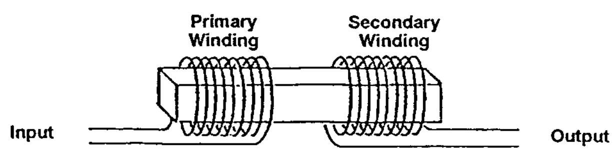
For Your Information
"Understanding Line Matching Transformers"

No doubt you have heard the old saying, "Nothing is constant except for change" Truer words have never been spoken when it comes to the people involved in the commercial sound business. Nowadays individuals and companies who have experience in related industries, such as security, telco, fire and life safety, etc., are finding themselves, either by choice or due to less than ideal economic circumstances, faced with designing and/or installing a commercial type sound system that includes a distributed speaker system. To "old-timers" in the sound business, buzz-words such as "constant voltage", "matching transformer", and "70 volt line are very familiar, and designing such systems is almost second nature. But to newcomers these things can be baffling.

To gain a reasonable understanding of line matching transformers and their usage, it's necessary to know some basics about transformers in general.

TRANSFORMER BASICS (VERY BASIC)

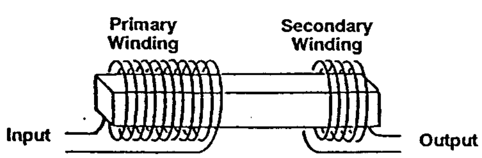
Long ago, someone discovered that when you cause an electrical current to flow through a piece of wire you also generate a magnetic field around the wire. Later on, it was discovered that if you wrap that piece of wire around a piece of iron and then apply the current, the piece of iron becomes magnetized for as long as current is flowing in the wire Of course, the next logical step was to wrap two lengths of wire around the piece of iron and apply current to one of them. What happened? Nothing of any consequence. That is, as long as you use direct current. But if alternating current is applied something amazing happens. The voltage and current that you apply to the first wire, or winding, will appear in the second wire, or winding. This is because the alternating magnetic field generated in the iron, or core, by the electrical current flowing in the first winding induces an identical (more or less) electrical current in the second winding.



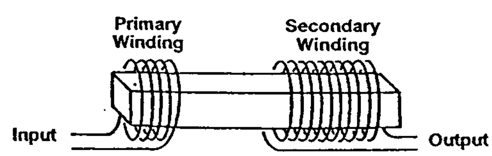
INPUT $\cong$ OUTPUT

So far, what we have discussed assumes that the primary and secondary windings will be identical. What if they're not? Then the relationship between the input and output will be directly proportional to the relationship of the number of turns, or windings, on the primary and secondary.

In other words, if the secondary has 50% less turns than the primary, then the voltage output from the secondary will be 50 less than the voltage input on the primary depending on whether there are more turns on the primary or secondary, the transformer could be referred to as either a "step-up" or "step-down" transformer.



STEP-DOWN



STEP-UP

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Not only is there a relationship between "turns ratio" and the input/output "voltage ratio", but impedance comes into play as well If the secondary of a transformer is connected to a fixed impedance, then that impedance will be "reflected" back to the primary as either a higher value, a lower value, or an equa value, depending on whether the primary has more turns, less turns, or the same number of turns as the secondary This impedance relationship is very important to understanding line-matching transformers.

The next thing to consider is power, which is measured in watts. The basic rule here is "what comes out has to go in". In other words, if a transformer delivers 10 watts to the load connected to it's secondary, that 10 watts to the load connected to it's secondary, that 10 watts has to come from somewhere. It has to come from the primary.

So then, in summary, the important things to know about a transformer are voltage (measured in volts), impedance (measured in ohms) and power (measured in watts). And since these things are interrelated, if you know two of them, you can mathematically determine the third. The following three formulas, (which are part of what is known as Ohm's Law) apply in all cases:

$$\text{Voltage (volts)} = \sqrt{\text{Power (watts)} \times \text{Impedance (ohms)}}$$

$$\text{Power (watts)} = \frac{\text{Voltage (volts)}^2}{\text{Impedance (ohms)}}$$

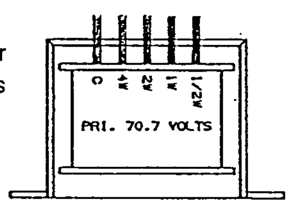
$$\text{Impedance (ohms)} = \frac{\text{Voltage (volts)}^2}{\text{Power (watts)}}$$

Everything we've covered so far has intentionally been very simplified and basic Innumerable volumes have been written over the years on the subiect of transformer design and performance by people much smarter than you or I. But our aim here is not to become a "professor of transformers", merely to understand line matching transformers and their proper usage. So then..

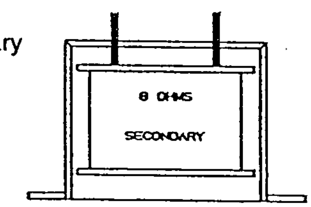
Why are line matching transformers so confusing?

One reason might be that the typical line matching transformer is labeled with different units of measure on the primary and secondary.

For example, one popular 70 volt transformer has it's primary labeled like this:



The secondary looks like this:



The primary and secondary can be converted into the same unit of measure by using the formulas mentioned earlier. We know the voltage and wattage of the primary. (The label tells us that much). so then, to compute the impedance of the one watt tap, for example, simply plug the numbers into the formula like this:

$$\text{Impedance} = \frac{70.7 \text{ volts}^2}{1 \text{ watt}} = \frac{4998.5}{1} = 5000 \text{ ohms}$$

(Notice that we rounded off the answer to the nearest manageable number). Therefore, (if we are using the one watt tap) the primary impedance is 5000 ohms, and the secondary is 8 ohms.

The 8 ohm secondary can be converted to a voltage by using the formula:

$$\text{Voltage} = \sqrt{\text{Wattage} \times \text{Impedance}}$$

We know the impedance because the label tells us that. The wattage will be whatever the primary tap says. (Remember the rule: What comes out has to go in). Inserting the num4'ers into the formula gives us:

$$\text{Voltage} = \sqrt{1 \text{ watt} \times 8 \text{ ohms}} = \sqrt{8} = 2.83 \text{ volts}$$

Therefore, the transformer has a primary voltage of 70.7 volts and a secondary voltage of 2.83 volts. Used in this manner, the line matching transformer is really a voltage step-down transformer.

The next logical question is why are transformers labeled with wattages on the primary and impedance (ohms) on the secondary?

Because, in many ways, this makes them easier to use. The impedance indicated on the secondary tells You what the impedance of the loudspeaker voice coil should be. Typical values are 4 ohms, 8 ohms, and 16 ohms, with 8 ohms being the most common. The wattage values shown on the primary tell you how much power will be drawn from the amplifier by that tap on the transformer. Having this information allows you to quickly determine how many speakers can be connected to an amplifier, and also what taps on the transformers can be safely used

For example: Suppose you have a 20 watt amplifier and you want to connect fifteen speakers to it. If you were to use the four watt tap on each transformer, then the total load on the amplifier would be: 15 speakers times 4 watts each, or 60 watts. This would be three times the power that you have available from your 20 watt amplifier. Obviously, this would be a severe overload. However, if you use the one watt tap, then the total load would be: 15 speakers times 1 watt each, or 15 watts. This would be a comfortable load for a 20 watt amplifier.

But what if you needed two of the speakers in this system to be louder than the rest? This can be accomplished by adjusting the wattage taps. For example, if two speakers are tapped at four watts each, and the remaining thirteen speakers are tapped at one-half watt each, then the total load on the amplifier is still only 14.5 watts.

It is generally not a good idea to load the amplifier up to it's maximum capacity. Most experienced sound contractors design in at least a 25% "headroom factor" In other words, if the speaker system requires 75 watts, use an amplifier with at least a 100 watt rating. So you can see why it's convenient to have the wattage ratings shown on the line matching transformer.

25 VOLT, 70.7 VOLT AMPLIFIER OUTPUTS

Most commercial type amplifiers have three outputs: 8 ohm, 25 volt line, and 70 7 volt line The same principles that we've already discussed in regard to line matching transformers also applY to amplifier-outputs Therefore, the 8 ohm output will deliver a specific voltage to the speaker connected to it, which can be determined using the formula:

$$\text{Voltage} = \sqrt{\text{Wattage} \times \text{Impedance}}$$

For example, to find the voltage delivered to an 8 ohm load by a 100 watt amplifier, simply insert the numbers like this:

$$\text{Voltage} = \sqrt{100 \text{ watts} \times 8 \text{ ohms}} = \sqrt{800} = 28.3 \text{ volts}$$

Likewise, the output impedance of the 25 volt and 70 7 volt lines can be calculated by using the formula:

$$\text{Impedance} = \frac{\text{Voltage}^2}{\text{Wattage}}$$

So then, using our 100 watt amplifier as an example, the impedance of the 25 volt line output is:

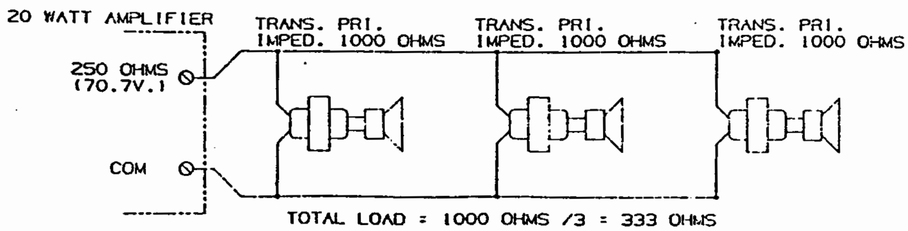
$$\text{Impedance} = \frac{25 \text{ volts}^2}{100 \text{ watts}} = \frac{625}{100} = 6.25 \text{ ohms}$$

And the impedance of the 70 7 volt line output is:

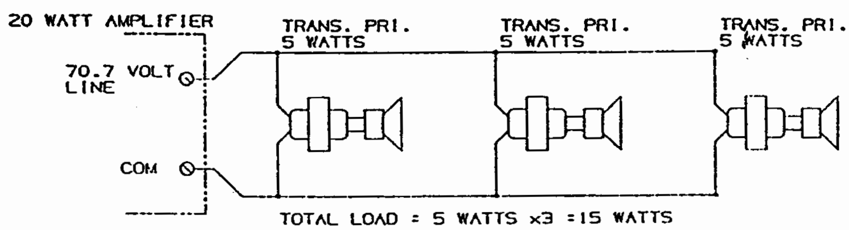
$$\text{Impedance} = \frac{70.7 \text{ volts}^2}{100 \text{ watts}} = \frac{4998.5}{100} = 50 \text{ ohms}$$

Therefore, the three outputs of our example amplifier could be accurately labeled "28.3 volt line", "25 volt line", and "70.7 volt line". Or it could be labeled "8 ohms", "6.25 ohms-, and "50 ohms". It is, in fact, fairly common to see the 25 volt and 70 7 volt line outputs on an amplifier labeled with their respective impedances.

By examining the relationships between voltage, impedance, and power, it becomes easier to understand how a distributed speaker system using linematching transformers works. It can be summed up like this... The amplifier output is matched to a specific impedance. Each line matching transformer has a specific impedance which is much higher than the amplifier output impedance. When connected to the amplifier, each transformer consumes a small amount of power, relative to the total available from the amplifier. Acceptable amplifier loading can be determined by computing the total load impedance and then making sure that it is not less than the amplifier output impedance.



Or an easier way is to add up the wattage taps on all the line matching transformers and then make sure that total does not exceed the rating of the amplifier (including a comfortable "headroom" as we discussed earlier)



One final topic to consider: What's the difference between a "25 volt" and "70.7" volt system?

In many ways, there are no differences. They both work exactly the same way. All the rules that we've discussed so far apply to both systems The only real difference is the impedances and voltages involved. In practical terms, that means that 70.7 volt systems will have much less "line loss" than 25 volt systems because of the higher impedances involved. For example, a thousand feet of 22 gauge wire (which has a resistance of about 33 ohms) installed between the amplifier and the line matching transformers will have a minimal effect on a 10 watt, 70.7 volt load, which is 500 ohms. However, that same length of wire would have a drastic effect on a 10 watt, 25 volt load, which is only 62.5 ohms.

One disadvantage to 70.7 volt systems is that many building codes consider them to be "high voltage" and, therefore, require the lines to be run in conduit.

On the other hand, 25 volt lines are usually regarded as "low voltage" and, therefore, immune to conduit requirements. However, because of the lower impedances involved, line losses can become critical in larger systems.

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