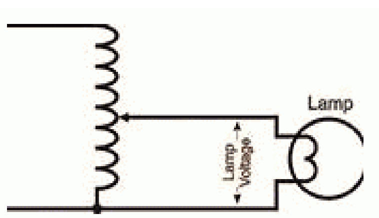
Transformers

A transformer is a nearly lossless way to convert a high voltage low current condition (high impedance) to or from a low voltage high current condition (low impedance). Watts in equals Watts out. Good transformers are roughly 98 percent efficient! Big ones like this can handle thousands of Watts. A little one like the 3619 or 3636 can only handle power levels used by the squawker in a loudspeaker. They are still 98 percent efficient at transforming power.



A Variac is an adjustable autotransformer. It will adjust the voltage applied to a load to any level required without loss of power. The 3636 or 3619 transformer uses fixed taps to points on the winding rather than a movable wiper. As the voltage applied to the load goes up by moving the tap or the wiper up the winding the current flowing in the load goes up as well. Ohms law will show that the current changes in exactly proportion to the voltage.

Attenuation units, the dB

If you change just ONE thing, the voltage, current changes as well. If you change voltage by 2, current changes by 2 as well. This is Ohms law again. I = E / R. If E doubles so does I. Power however is E X I, so power goes up by 4 times! If one change causes changes in THREE different things at once. That is, Voltage, Current and power. Voltage and Current by a factor of 2 and power by a factor of 4. How can we describe this single change as one thing? Answer: The dB!

Voltage dB = 20 X Log10 (voltage change)

Current dB = 20 X Log10 (current change)

Power dB = 10 X Log10 (power change)

6.02 dB = 20 Log10(2 volts change) = 20 Log10(2 Amps change) = 10 Log10(4 watts change)

Voltage, current, power and turns ratios

What about the source of the power? It has a fixed voltage. In the case of the Variac, it's the 120V AC power line that can deliver any current you need from it. With the 3619, it's source is your power amplifier. If Watts is E X I then simple algebra says that I = Watts / current (I = W / E).

The voltage change through a transformer is proportional to the ratio of number of turns the source is connected across to the number of turns the load is connected across. That is, the voltage ratio is equal to the turns ratio. If we pick the 3619 autoformer to study, it has taps 5,4,3,2,1 X and 0. The full winding is between 5 and 0 and is connected to the source. The other taps are 4,3,2,1 and X. They represent 3, 6, 9, 12 and 15 dB respectively. If we decide to connect a 16 Ohm load (the K55 driver) between the 6 dB tap (3) and 0 we select 6 dB attenuation. The dB formula says that 6 dB is 20 X log10(2). So the voltage applied to the load is ½ that applied across taps 0 and 5, the source.

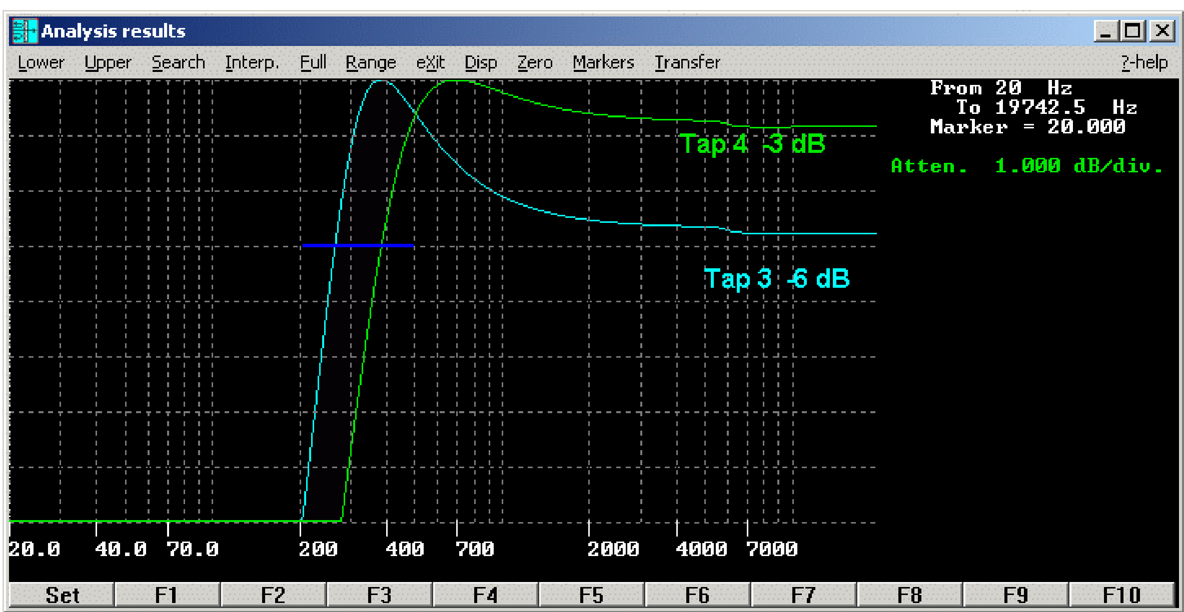
Lets assume we have 16V applied to the 16 Ohm load. Ohms law says I=E / R so I = 16 V / 16 Ohms = 1 Amp of current. Power is I X E = 1 X 16 = 16 Watts. If it's a Klipsch K55 driver you best be wearing ear plugs! Anyhow, if the transformer is wasting nothing the source must also be delivering 16 Watts to the transformer. The voltage applied must be 32 Volts to get 16 Volts out of the 6 dB tap. To get 16 Watts from a 32 Volt source we will draw ½ amp. W = 32 X .50 = 16.

Notice what has happened: By Ohms law R = E / I = 32V / .50 amps = 64 Ohms. Our load on tap 3 is 16 Ohms but the source "sees" 64 Ohms. So we say the voltage and current ratio of a transformer is equal to it's turns ratio and the impedance ratio is the SQUARE of the turns ratio!

If you moved the 16 Ohm load down to the 9 dB setting (2), which is a turns and voltage ratio of .355, the impedance ratio is .355 X .355 or .126. Impedance is stepped up, so we use the inverse, or 7.94. The source will see 127 Ohms! Your amp and the network filters won't like that even slightly!

Impedance change effects on filters

The plots above show what happens to the response of the squawker filter in the Klipsch AA network, a single 13 uF capacitor, if the transformer tap is move from the 3 dB tap to the 6 dB tap. The impedance seen by the one element filter changes from 32 Ohms to 64 Ohms. The crossover moves from 450 Hz down to about 250 Hz. The plots below is what happens to the AK-3 network of the Khorn with the same tap change. It also get rough. This is why you can’t move the tap settings on any of the Klipsch networks.

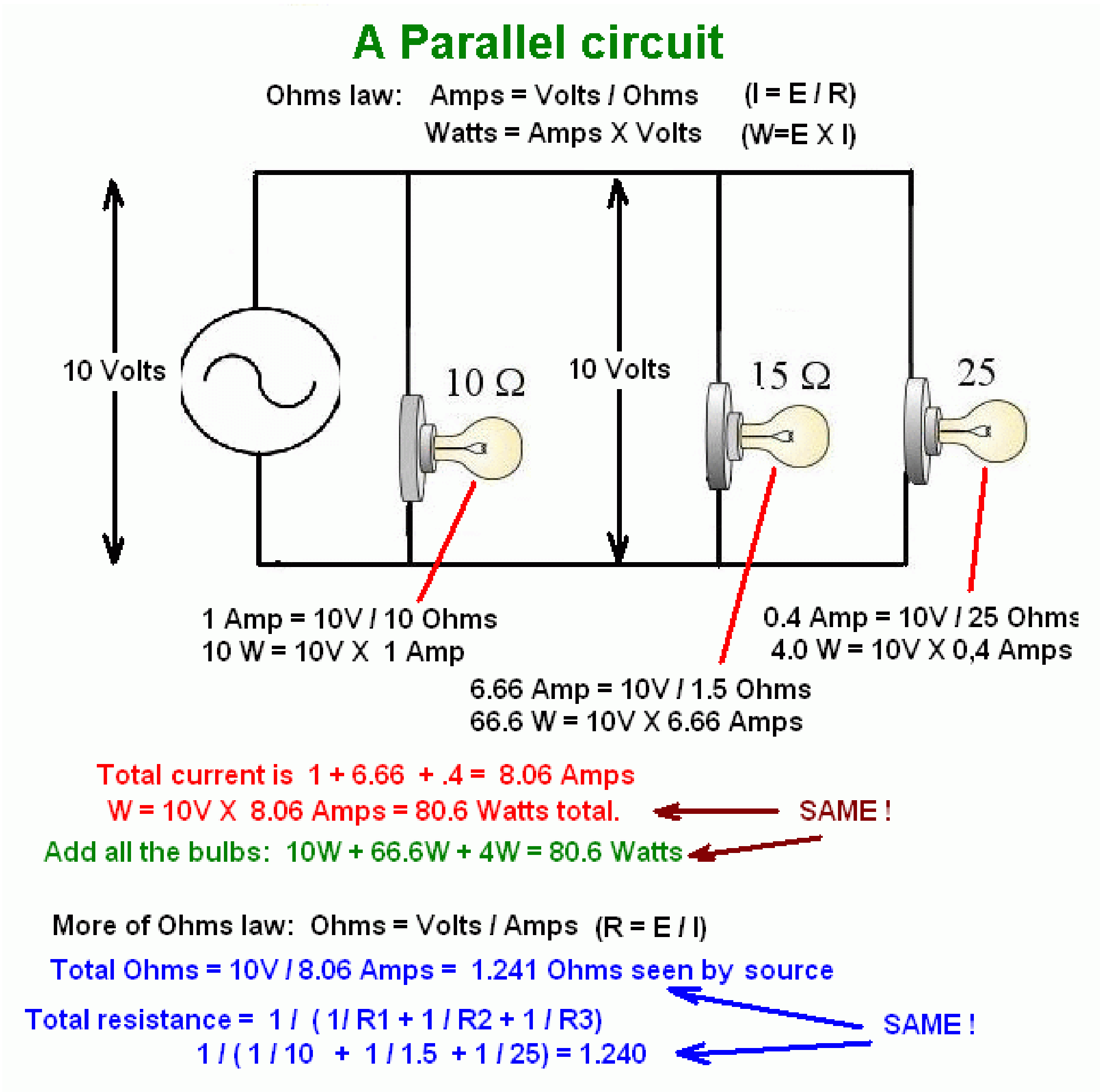


If something could be done to stabilize the impedance seen by the filter when a transformer tap was moved, the level to the squawker driver could be adjusted without disturbing the filter. Enter the swamping resistor!

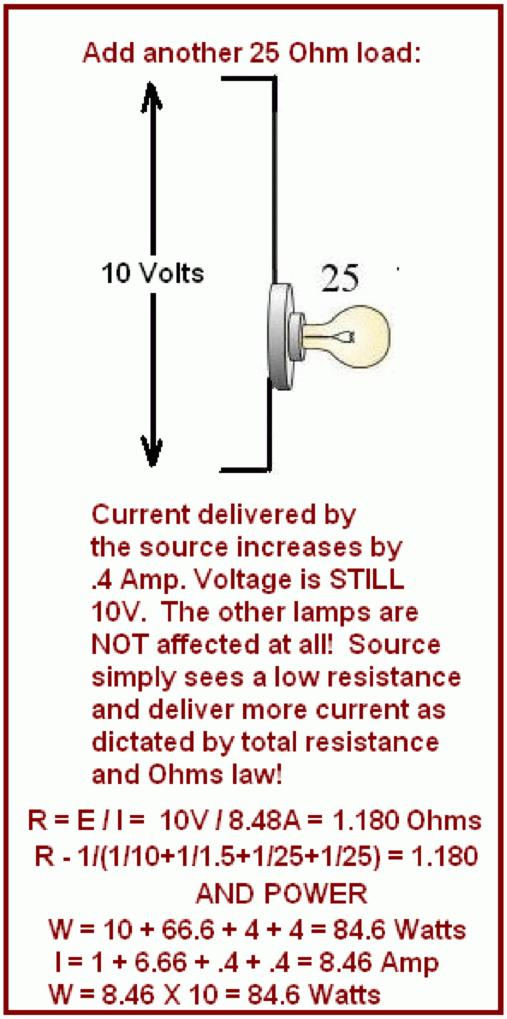
Rather than design the squawker filter to work into the 32 Ohm load reflected through the autoformer when set to the 3 dB tap. Lets design it for the 8 Ohm level most amplifiers want to have as a load.

Recall that resistors in parallel total up as 1 / (1/R1 + 1/ R2). What value of resistor could we connect in parallel with the 32 Ohms looking into the autoformer to bring the total down to 8 Ohms? The value turns out to be about 10 Ohms. 1 / (1/32 + 1/10) = 7.6 Ohms. We can connect it right across the 0 and 5 taps of the transformer. Now, if we move the transformer tap all the way down to the 15 dB setting, where the turns ratio becomes 5.62, the impedance ratio becomes 31.6, or the square of the turns ratio. The 16 Ohm load now looks like 506 Ohms (31.6 X 16) looking into the transformer. Using the parallel resistance formula again the filter sees 1 / (1/10 + 1/ 506) = 9.8 Ohms. Any 8 Ohm system would be happy with that load! The impedance seen by the filter can't go higher than 10 Ohms even with no load at all!

The 10 Ohm resistor swamps out the inductance of the driver in the same way as the resistive part of the drivers impedance. In addition, a speaker driver is a linear electric motor which generates "back-emf" as it moves. This voltage sees the 10 Ohm resistor on the other side of the transformer as a much LOWER impedance because the transformer now is stepping the impedance down rather than up in the exact same way. This improves the damping factor to the driver. A resistive L-Pad attenuator can not do this! The 10 Ohm resistor forms a parallel circuit which does not add attenuation to the driver. It simply draws extra current from your amp. The extra power it draws is not going to raise your electric bill even slightly! Your amp will see the 8 ohms it was designed to see, not 32 Ohms like it sees with the stock Klipsch crossover networks. The swamping resistor is a win-win situation and has no down side.



A parallel circuit has all loads connected directly to the power source. Each draws the amount of current from the source as dictated by Ohms law. The example above uses three light bulbs as loads. Using both the laws governing current with a given voltage (I = E / R) and power (Watts = E X I), the example shows that no matter if you total the currents drawn by each bulb and compute the power by Ohms law you get the same answer as if you added the power drawn by each bulb. You will also get the same total resistance of the combined load if you computed it using Ohms law from the total current or if you computed the total by adding the “conductance” (Mohs or G = 1/R) of each bulb.



It's easy to show that adding the 10 Ohm swamping resistor in parallel with the transformer simply draws more current from the source just as adding another bulb to the circuit in the example.

The additional lamp simply draws more power from the source and has no effect whatever on the other loads.

The 10 Ohm swamping resistor does not waste power in any way that will reduce the efficiency of the loudspeaker. It simply takes up the mount of power NOT used by the midrange making the midrange efficiency equal to that of the woofer by presenting a constant load to the amp over the entire audio range. The actual reduction in efficiency is intentionally done by the transformer.