A modified Audio Innovations L-2 line amplifier

by Peter van Willenswaard

The design of the Audio Innovations L-2 may be over 10 years old, it is still a nice preamp, but its sound quality can be vastly improved.

The proposed modification takes place not in the amplifying circuitry itself, but in the power supply. If you have ever seen the schematic diagram of the L-2, you'll have noticed that its power supply is unusual. I have redrawn part of it in figure 1. TP1 (right hand top corner) is the point where the HT diode bridge is connected, delivering some 350 V of raw DC into C2. This is smoothed further by R8 and C3. The resulting low-ripple HT then feeds the circuit around half an 5687 and an OA2 (or 150C2), through resistors R7, R6 and R5. R6 (390R) is normally strapped on the European Continent, but may be needed in the UK because of the somewhat higher mains voltage. By the way, the voltage across C4 is used to 'lift' the heater supply of the 5687 to about 150 V, near the valve's cathode voltage, to prevent breakdown of the heater-cathode insulation.

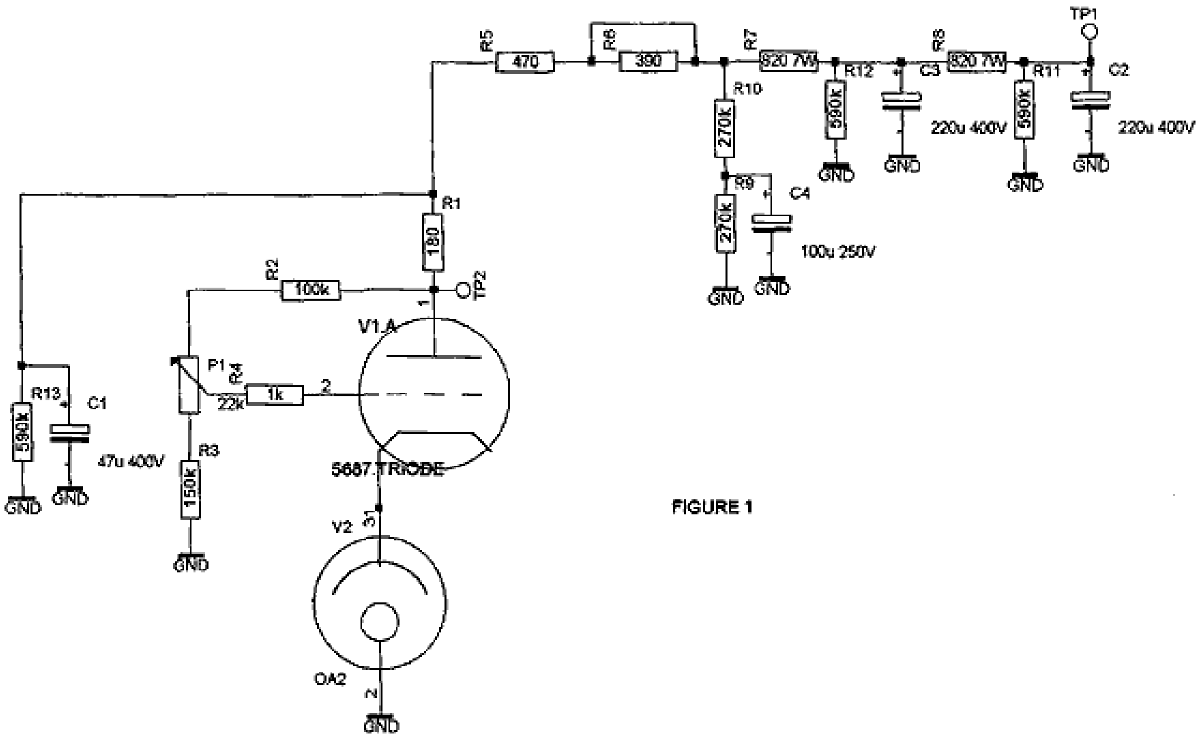

FIGURE 1

The circuit comprising V1a and V2 is called a shunt regulator. It feeds the amplifying stage (not shown) from TP2 at the anode of the 5687. It is called a shunt regulator as it is electrically in parallel with the amplifying stage, viewed from the HT unstabilized HT supply. The L-2 has two such shunt regulators, one for each channel but only the left channel is shown here (the right channel uses the other half of the 5687 double triode and a second OA2 and connects via another 470 ohm resistor to R6).

How does a shunt regulator work? The anode of the 5687 is connected to a voltage divider R2-P1-R3 and the 5687 grid connected to P1 compares the divided voltage to that of the cathode. An OA3 stabilizing valve offers a fixed voltage of 150 V to the cathode, and as R3 is 150k and R2 is 100k, the anode voltage must be 100 V higher than the grid/cathode voltage of 150 V if the valve is to function normally. Hence, there must be 250 V at the valve's anode. The grid forces the valve to draw enough current from the HT to create the necessary voltage drop across resistors R5 thru R8.

Shunt power supply regulation is an interesting thing. Many amplifiers have no power supply regulation at all, but if they do it's usually a series regulator: a valve or a FET or a transistor is connected in series between the HT and the amplifying stage(s). This means that the series regulator only delivers current if the amplifying stage ask for it; should the amp stage momentarily draw no current, then the series regulator falls dry as well. A shunt regulator on the other hand ALWAYS maintains a current flow. Therefore, the shunt regulator can be considered as running in Class A while a series regulator is fundamentally a Class B device. And we all know that Class A sounds better than class B. So why isn't everyone using Shunts? Because it produces more heat, needs higher HT voltages on the outset and hence a bigger mains transformer. It's just more expensive.

The shunt circuitry as implemented in the L-2 is quite effective for DC regulation, but has rather poor performance at AC. This is due to the presence of C1 which limits the active external anode resistance to a mere 180 ohm (R1). Thus, for AC the valve's amplification is about 1x, meaning the feedback through R2-P1-R3 can't do very much.

The original circuit for this shunt was found in a book published in 1934. Valves and electronic components in general were scarce and expensive, so designers were forced to be clever and obtain maximum results with a minimum of parts. Our man in 1934 decided to connect R2 not to the lower but to the upper side of R1. See figure 2 (where I also connected C1 to a point higher up in the HT supply, but I'll discuss that later). Now this seems a minuscule change, but it appears to be the choice of a genius: it totally changes the operation of the circuit! Let me try to explain.

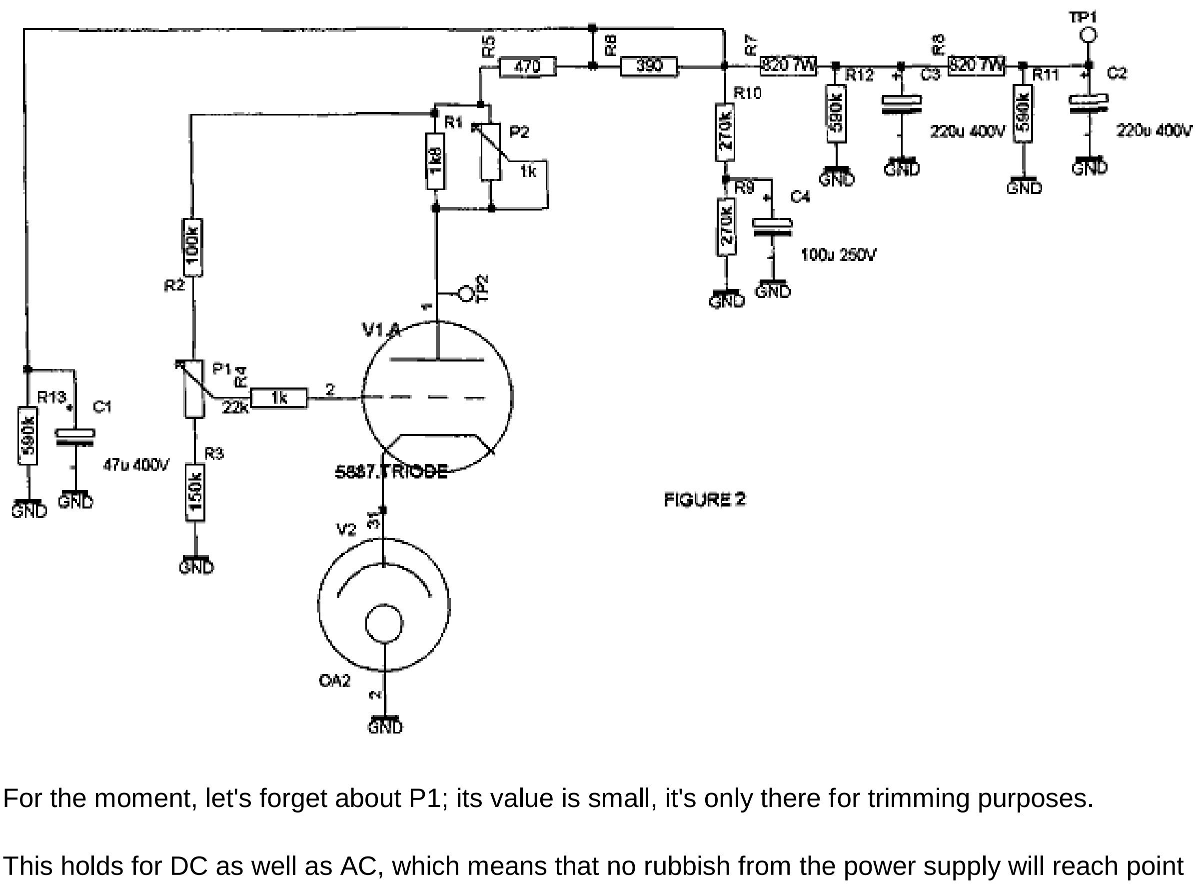

FIGURE 2

For the moment, let's forget about P1; its value is small, it's only there for trimming purposes.

This holds for DC as well as AC, which means that no rubbish from the power supply will reach point TP2 from where the amplifying stage is fed. What's more is that this is accomplished without feedback: this circuit works by compensation. Isn't this pure elegance? And it sounds wonderful.

Why this circuit never ended up as intended in the L-2 remains unclear. Maybe the 1934 text book wasn't fully understood in those early days of valve revival around 1990.

Anyway, if you happen to have an L-2 and know what you're doing, change the L-2's shunt according to figure 2 and you'll be amazed. Be aware, however, that this is not a beginner's project!

The value of R1 must be fine-tuned for optimum results, which is why it has risen in value to 1k8 and has a 1k potmeter P2 in parallel now. Although the dissipation will not exceed 0.5 W, it is a good idea to buy a 1 W potmeter. Avoid the Cermets; Conductive Plastic would be a better choice, or maybe you can find a good-sounding wirewound one. The tuning requires the injection of a test signal at the top of R1/P2 (where it is connected to R2-R5). Take a large 400 V filmcap, say 10 uF, and solder it to the end of a piece of coax cable. Solder a 470 ohm resistor in series with the cap, to protect the signal generator. Connect the loose end of this resistor to the top of R1, ground the cable screen to mass somewhere in the amp and connect the other end of the cable to the generator. Set the generator to 1 V 100 Hz sinewave. Switch on the L-2 and let it settle for a few minutes. Connect an oscilloscope to lower end of R1 (TP2 in fig. 2). Put P1 in its mid position. Now adjust P2 for minimum signal at TP2. Ideally, you'd get total cancellation but you won't. The reason for that is some mysterious behavior of the OA2. It took me a while to track it down, but stabilizer valves like the OA2 are not purely resistive but somewhat reactive, like an L or a C. This means that the OA2 creates some phase shift between voltage and current in the shunt regulator, preventing total cancellation. Stabilizer valves have minimum phase shift near their maximum current, and fortunately the OA2s in the L-2 are set to operate at a healthy 25 mA. In my experience the best minimum you'll get will be about -40 dB. Repeat the measurement at 1 kHz.

Another strange phenomenon is that the circuit does NOT sound at its best at maximum cancellation. The final value of R1//P2 should be chosen 5% higher than what was found when tuning to minimum signal. So switch off the L-2 and let the reservoir caps bleed to below 10 V (check this with a voltmeter; 250 V can be quite nasty and even lethal if you're unlucky). Disconnect the test-signal cable from R1. Connect an ohmmeter across R1//P2, note the value and readjust P2 so that it reads a 5% higher value. You could take out P2 at this point, measure it solo and replace it with a fixed resistor of that value if you like. The adjustment will be fine as long as you don't swap valves. Or if your mains voltage rises or falls considerably, because the shunt as implemented in the L-2 is unfortunately sensitive to that. So if you listen mainly in the evenings, perform the adjustment in the evening as well. If you move to another house, repeat it there. P1 allows minor corrections once you've determined the optimum value for R1//P2.

If you do not have an oscilloscope and a generator, replace R1//P2 in figure 2 with a fixed resistor of 470 ohms. You may not be exactly at the optimum then, but you'll be close.

I have moved C1's connection to R6 not only to facilitate the injection of a test signal, but also to have it further away from the audio. It is an electrolytic, after all. You may even try to leave it unconnected altogether, I don't think hum will be a problem.

As a final remark, use the L-2 with the rear switch in its max gain position if your power amp gain and speaker sensitivity allow. The L-2 sounds best this way.