HYBRID LAMP

Evgeny Karpov

The article analyzes a hybrid amplifying device based on a vacuum vacuum tube and gives recommendations for its use.

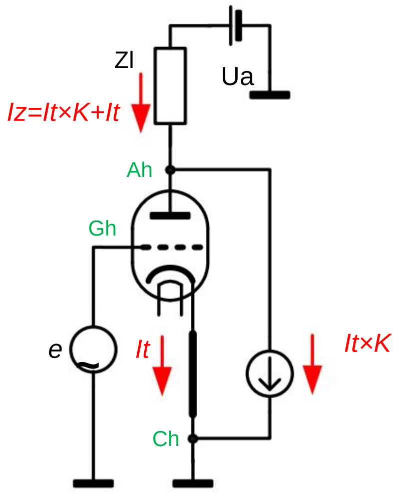
background

I want to tell dear readers right away that the idea itself is not mine (unfortunately), but was scooped from an accidentally seen hybrid amplifier circuit shown on some audio forum. As usual on Russian-language forums, local "gurus" quickly put the upstart in his place - and there is no cleanliness of the lamp rows, and it will work crookedly, and in general - complete stupidity. In general, they trampled on a man, like a flock of sheep frightened by a new gate.

It is possible that the technical implementation was not ideal, but the idea, the idea itself, seemed to me very interesting and promising. Unfortunately, at the time I viewed this topic, there was no information about the primary sources and a clear description of the principle of operation. And judging by the author's sluggish attempts to fight off the local "gurus", he himself did not really understand how it works. After some time, I safely forgot what the topic was called, and what kind of forum it was. But the idea haunted me, and searches on the World Wide Web (albeit without fanaticism) for primary sources and analysis of the work did not give any results. In general, I decided to do the analysis myself.

Finger analysis

The idea itself and, in fact, the circuit used for the analysis are shown in Figure 1. Parallel to the lamp (let's call it - the lamp model) the current source is switched on, controlled by the current of the lamp itself, with a scaling factor K.



Picture 1

For analysis and understanding, it is convenient to consider the circuit as a three-terminal network with electrodes Ah, Ch, Gh, which will correspond to the anode, cathode, and grid of a new equivalent hybrid lamp. Thus, the current flowing into the anode of our hybrid will be the sum of the currents of our model lamp and the current of the current source, and the voltage between the anode and cathode of the hybrid will be determined only by the characteristics of the model lamp. If we now translate all fiction into a formal channel and relate the parameters of the hybrid with the parameters of the lamp of the model, then, omitting all intermediate calculations, we obtain the following relations:

ÿ =×(+1)

ÿ = ——— +1

ÿ =

Where: S, R, µ are the transconductance, internal resistance and amplification of the lamp of the model, and ÿ, ÿ, ÿ are, respectively, the parameters of the hybrid. - scale factor of the current source.

Simply put, the hybrid lamp exactly replicates the shape of the anode characteristics of the anode current scaled model lamp, since the multiplication operation is linear. To illustrate the above, Figure 2 shows the anode characteristics of the lamp of the model and the hybrid based on it.

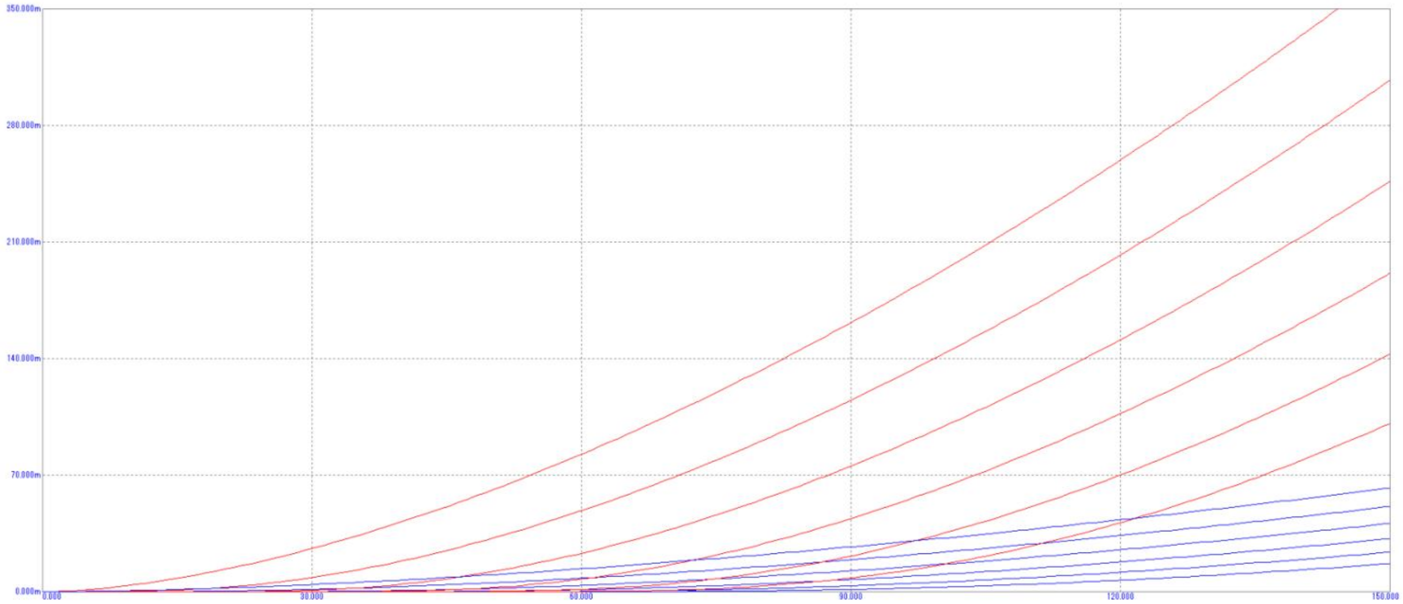


Figure 2

The red lines correspond to the anode current of the hybrid lamp, and the blue lines correspond to the lamps of the model.

The resulting hybrid can operate in almost all modes used in linear tube amplifiers. There is some ambiguity in the operation of the lamp with grid currents, for some reason my equations are not solved. But since low-power lamps are very rarely used in such modes in linear circuits, the issue was shelved due to its irrelevance.

What can we get from this?

Let's take our favorite triode with its unique sound signature and use it as a model in a hybrid lamp. Theoretically, we get its analogue with unlimited power dissipation at the anode and now we use it in the output stage. In general, we get a complete audiophile nirvana.

But this is theoretically, practically - a number of problems arise. The first and most difficult issue is the controlled current source and its errors. In principle, using a modern element base, it is possible to implement a current source that approaches the ideal in terms of parameters. The second issue is the selection of a candidate lamp model. The fact is that it is interesting to use a hybrid lamp in the output stage, and it is clear that the lamp will operate with a large swing of the variable component at the anode. Not all low-power lamps are favorable to this, it is necessary to select lamps with a large opening of the anode characteristics. This somewhat limits the possible choice of applicants.

But even with restrictions on the choice of lamp type of the model, the list of lamps suitable for use in the output stage is expanding significantly. There is also a side effect - a rather large gain of the output stage on a hybrid lamp, which greatly facilitates the construction of the driver and allows you to reduce the length of the path to a minimum. In the limit, with a large source output level, this can be only one output stage.

Since we brought this hybrid device to an equivalent lamp, therefore, all standard methods used for calculating lamp cascades are suitable for calculations. And having the anode characteristics of the lamp of the model, it is possible to obtain the characteristics of the hybrid without much difficulty, simply by multiplying all the current values by the coefficient K + 1.

A very pleasant property of a hybrid lamp is its reduced output resistance.
which greatly simplifies the implementation of the output transformer.

Practical implementation

To verify the correctness of the theoretical conclusions, I assembled a layout of the output stage on a hybrid lamp (Figure 3). I was also very interested in the question related to the possible expansion of the spectrum of distortions upwards. Since the current source will be solid state, such a danger existed. For experiments, I chose a 6N6P lamp. Without further ado, I decided to implement
the current source according to the classical circuit with an op-amp, but given the significant range of the variable component, the circuit was slightly modernized to the “cascode” version. And quite deliberately, not a super-duper audiophile op amp was chosen, but the good old NE5534 with moderate speed and good linearity.

The diagram does not show auxiliary elements - such as power filtering and protection, but
their presence is expected.

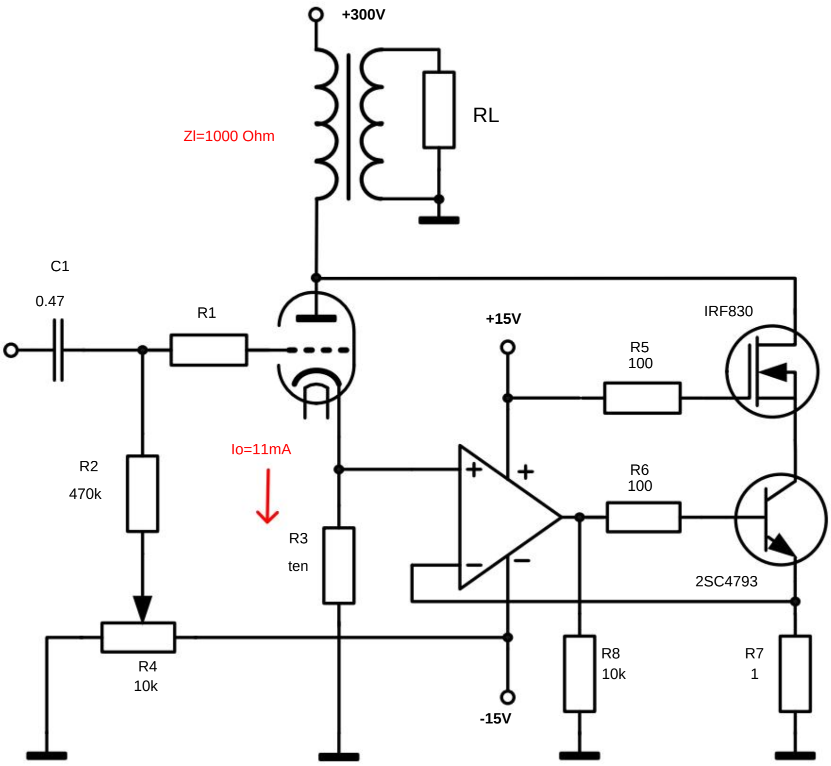


Figure 3

The lamp uses a fixed bias, the lamp current sensor is resistor R3, the current scale is given by the ratio of resistors R3 and R7. Since the resistance R3 is two orders of magnitude less than the resistance of the anode load, the resulting local OS can be neglected.

The objectively measured gain of the stage (without taking into account the transformation factor) is 12, the output impedance is 320 ÿ.

This agrees satisfactorily with the previously measured lamp parameters. The choice of the reduced load resistance depends on the tasks. I initially focused on an output power of about 3 watts, but it turned out that the stage can deliver more power, so the chosen value is some kind of compromise between output power and distortion level. The band of the cascade is 99% determined by the parameters of the output transformer, without taking it into account - the band from below is limited by the separating capacitance C1, and from above it reaches 200 kilohertz without a significant deterioration in the distortion spectrum.

Graphs of dependences of the level of harmonics and total distortion on power are shown in Figures 4 and 5, respectively.

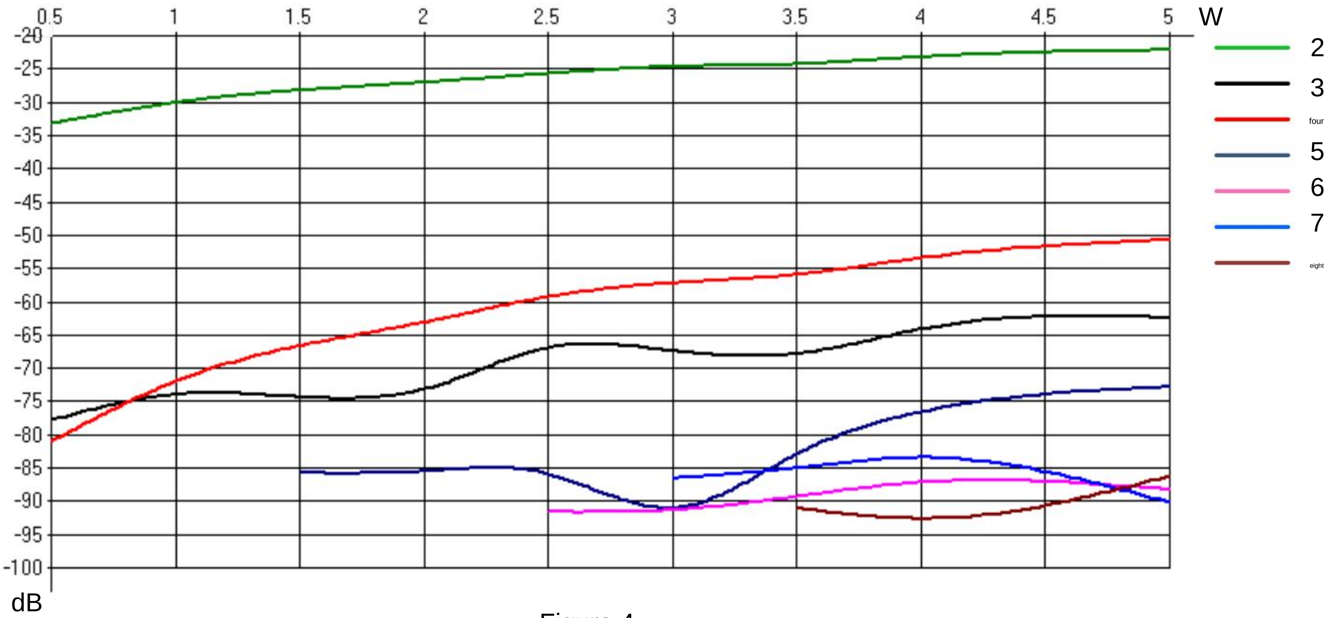


Figure 4

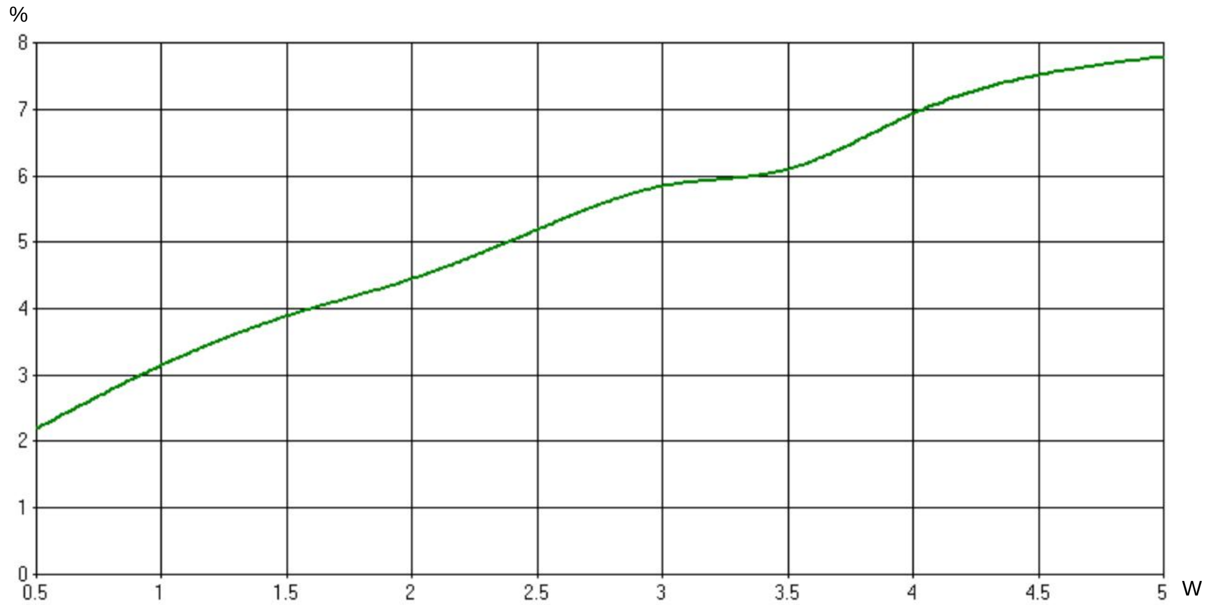


Figure 5

The distribution of harmonic components is quite curious: what is pleasing is that the solid state source practically did not give higher harmonics. If we compare it with the distortion spectrum when the lamp is turned on classically, we get an approximately similar picture. But here the question arises of what to take for the initial data for comparison. I took the resulting spectrum with the same amplitude of the variable component at the anode with a recalculated reduced load.

Taking the scaled power criterion as a basis for comparison, we get a completely different picture. I thought that it would be more correct to rely on the range of the variable component. If a
to directly compare the magnitudes of the harmonics, then the even harmonics with classical inclusion turn out to be slightly less, and the odd harmonics more, the difference is within a few decibels. And if the growth of even harmonics can theoretically be substantiated, then the mechanism for reducing odd harmonics is not entirely clear to me. This issue requires further research. And anyway, hell

The validity of such a comparison raises some doubts.

In general, if you look at the spectrum of distortion, then the cascade directly asks for a symmetrical push-pull circuit. So in my plans I have a point for the implementation of such a fully functional
push-pull amplifier.

If we return to single-ended circuits, then relatively recently I had the opportunity to fairly thoroughly examine a single-ended amplifier based on 6P44S with all the audiophile tricks and bells and whistles. It had very similar distortion characteristics at comparable power, and I have a feeling that the sound character will be similar. In general, both will

lie beautifully.

Conclusion

To sum up, the issue has not been studied to the end, so that everyone has the opportunity to continue research. Well, the question of the optimal construction of a controlled source is
It also opens up great opportunities for creativity and experimentation.

I want to touch a little on the design and calculation of a cascade on a hybrid lamp. In
First, once again recall the need for careful selection of the type for the lamp model. Secondly, the design process itself should be divided into two parts. First, determine the optimal modes for the lamp of the model at large voltage swings at the anode, the next step is to select the scaling factor and obtain new characteristics, and then make the final calculation of the cascade using traditional methods.