Analogue of ultralinear modes in the output stage

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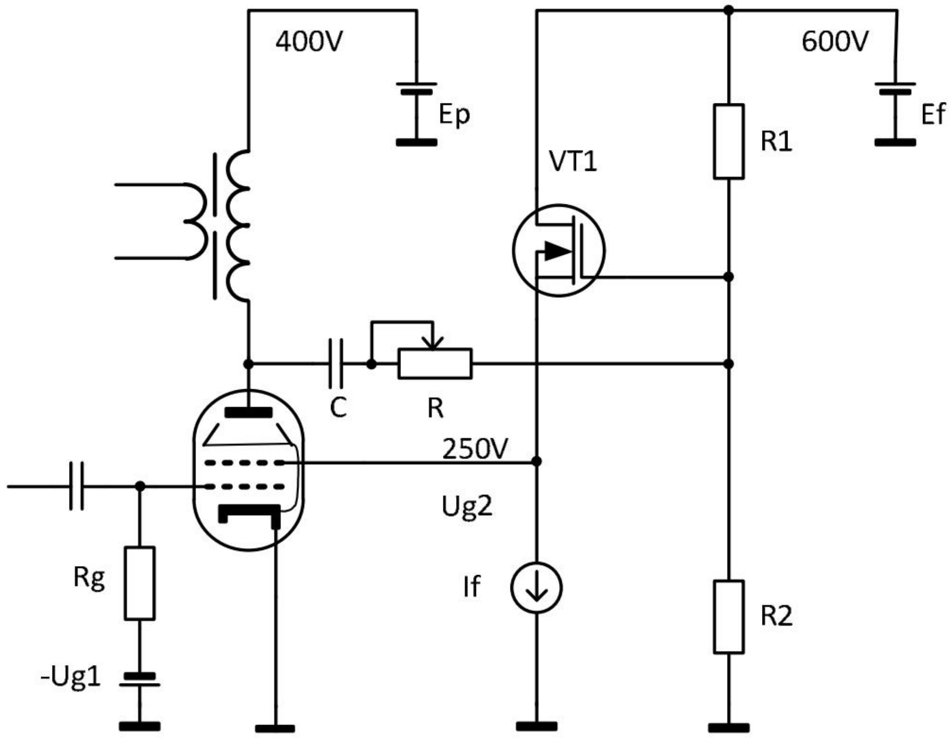
I have already considered the possibility of implementing an ultralinear mode in the absence of an output transformer in the application to low-power five-electrode lamps [1]. In general, no one does not prohibit the implementation of an ultralinear mode in a similar way for a powerful lamp of the output stage in the presence of an output transformer.

Figure 1 shows a diagram of such a cascade. In fact, this is a real output stage, the circuit of which has been simplified for ease of presentation.



Picture 1

The basis of the circuit is a classic single-cycle cascade on a powerful beam tetrode (6P3S). The source follower provides the setting of the second grid mode for direct current (divider by resistors R1, R2) and transfers to it part of the variable component of the anode voltage. The level of the variable component on the second grid is determined by the divisor formed by the variable resistor R and divider R1, R2.

Despite the complication of the circuit, in comparison with the classical implementation using a tap from the transformer winding, this solution has a number of advantages.
Firstly, it is possible to provide a static mode of operation of the second grid without exceeding the permissible parameters and increase the anode voltage of the lamp. This has a positive effect on the efficiency of the cascade and its linearity.
Secondly, significantly smaller phase shifts of the OS circuit in a wide frequency range reduce the probability of self-excitation of the cascade. Thirdly, it became possible to smoothly adjust the OS depth to the second grid. In fact, right "on the go" you can transfer the cascade from the pentode mode to the triode.

I want to remind readers that the ultra-linear mode was patented by D. Hafler, HI Keroes in 1955 [2].

The classical scheme is considered as a cascade with a distributed load, and the OS depth is defined as the load distribution coefficient p.

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Where: *Zs, Za* - reduced resistance in the circuit of the screen grid and lamp anode,
Ws, Wa - number of turns of the screen grid and the total number of turns of the primary winding, *Us, Ua* - variable component of the voltage on the screen grid and at the anode of the lamp.

It can be seen from the formula that it is possible to operate not with the reduced resistances, but directly alternating voltages on the electrodes of the lamp, which actually allows us to speak about the similarity of the operating modes. In what follows, we will operate with the relation ÿÿ/ÿÿ, what's in ta which scheme is more consistent with physical processes.
In the same patent, the optimal value of p = 0.185 was determined (which corresponds ÿÿ/ÿÿ ÿ 0.43). to And it was also shown there that the value of "p" can vary widely depending on task and lamp type. Unfortunately, the calculation of the optimal value of "p" analytically - in general problematic, and experimental determination is very laborious. This leads to the fact that the average value of "p" for different lamps is used, and as a result, the potential lamps are not fully utilized.
The diagram above allows you to set the optimal value ÿÿ/ÿÿ for a specific mode and particular type of lamp.

The main purpose of writing this article is not so much a description of the output stage, but what type (although, he is quite interesting in itself), how much the presentation is very curious and a previously undescribed phenomenon that surfaced during its detailed study.

Change of attitude ÿÿ/ÿÿ near the optimal value leads to significant changes in the spectrum of distortion products, although the integral value of the harmonic coefficient the nickname of the cascade changes little.

If the focus is on obtaining the maximum linearity or obtaining the desired spectrum distortion, this phenomenon gives the designer a fairly powerful tool that allows fine-tune the circuit. To some extent, this phenomenon can also explain the striking difference in sound when replacing output tubes in push-pull amplifiers with ultra-linear switching, although the tubes have a similar pair meters.
The experiment was carried out as follows: the output stage was excited by a driver with low inherent distortions, a constant power was maintained at the output of the cascade *(Ua=const, P=8W),* the cascade supply voltages have been stabilized, the load is active. The integrated harmonic coefficient of the output voltage and the levels of harmonic components relative to the fundamental. The measurement results are shown in Table 1, and in graphical form in Figure 2. In order not to obscure the results, the measurement results in the table are given with a fairly large step. Intermediate values for linear interpolation are in good agreement with real measurements.

Table 1

p	Us/Ua (%)	THD (%)	Harmonics (dB)						
			2	3	four	5	6	7	eight
0.08	29	3.9	-28.1	-49.8	-70.8	-64.6	-72.5	-75.6	-84.0
0.12	34	3.9	-28.1	-56.0	-65.2	-66.2	-73.5	-77.9	0
0.16	40	3.9	-28.2	-73.5	-66.4	-66.6	-75.6	0	0
0.21	46	4.0	-28.0	-62.1	-68.2	-63.9	-71.1	0	-79.0
0.26	51	4.2	-27.5	-56.2	-65.8	-64.3	-95.9	-79.5	-72.9

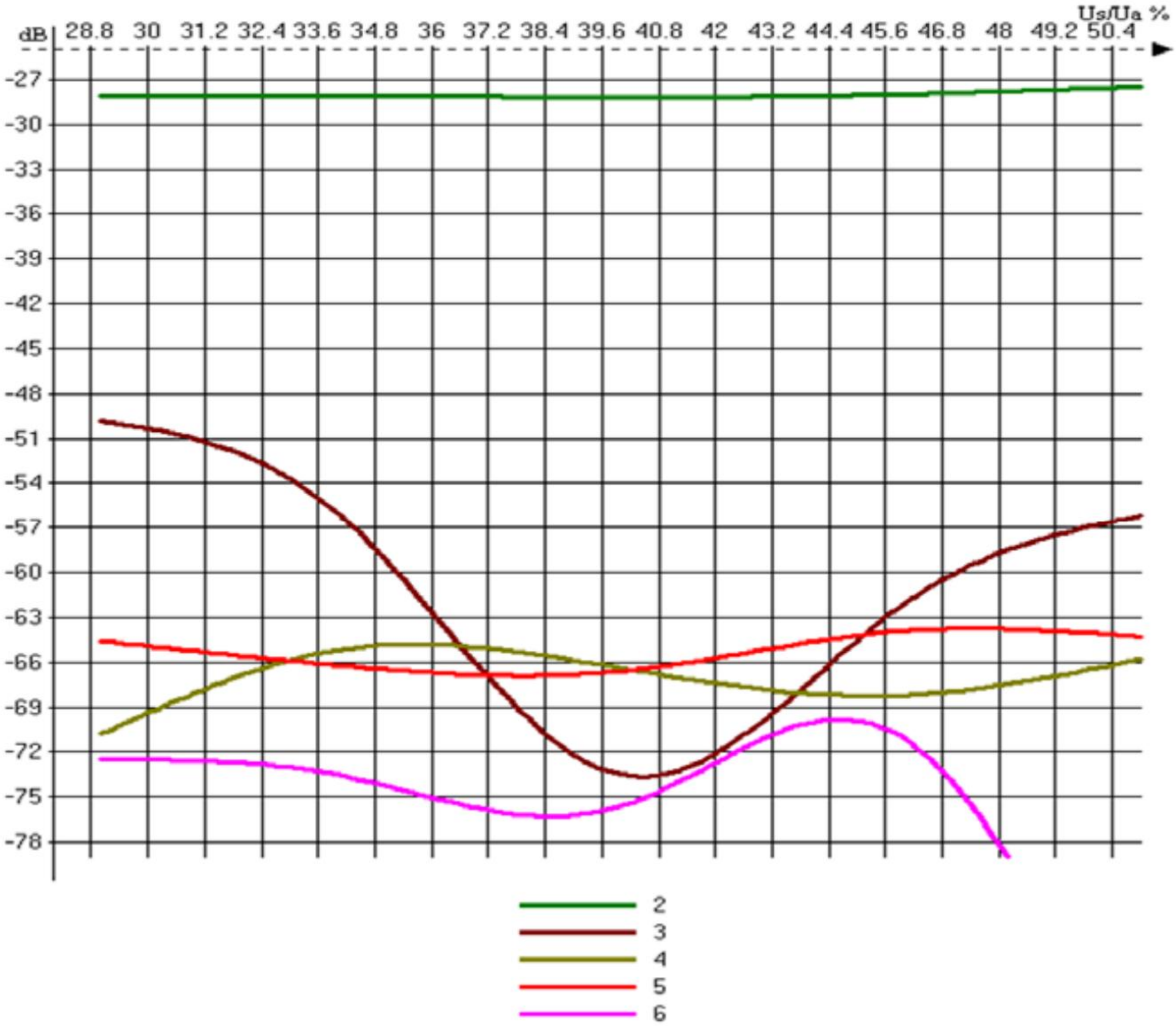

Figure 2

For other types of lamps, of course, the graphs are slightly different, but the general trend of changing the levels of harmonic components is preserved.

Literature

1. E. V. Karpov, Ultralinear mode of a pentode in preliminary amplification stages, Inter no edition, 2010.
2. D. Hafler, HI Keroes, ULTRA LINEAR AMPLIFIERS, US patent, 1955