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PRINCESS

Evgeny Karpov

Part 1

High power single ended amplifier.

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Wrong bees - bring the wrong honey.

Winnie the Pooh

In general, this amplifier is completely wrong from an audiophile point of view. Purists from tube technology will be horrified by the number of semiconductor elements, and fans of solid state devices in general will be surprised by the presence of vacuum tubes. However, despite the motley mixture of components, this scheme cannot be classified as a hybrid one. The signal is amplified precisely by the lamps, and a small modification of the circuit (more on this later) makes it possible to exclude all semiconductor components from the path, and the length of the sound path is no longer than in a classic tube amplifier. The impetus for the design of this amplifier was a rather unusual desire to replace a push-pull solid-state amplifier in the low-frequency section of a multiband sound system with a tube and, of course, a single-ended one. Desire - desire, and the task is not easy. Of course, the main problem is getting the necessary output power. Measurements of the real power supplied to the low-frequency link in the current system, on different types of sound material, gave a value of at least 30 watts. It was also desirable to provide a sufficiently low output impedance and, of course, good frequency characteristics in the low frequency region. But to make such a highly specialized amplifier, in general, did not make sense, and I decided to get the coveted 30 watts in a broadband mode.

As an output lamp, I decided to use 6C33C. There were several reasons for this. Firstly, an amplifier with such a tube was already used in the system, but I did not want to multiply the types of output tubes, and, secondly, the tube sounds good if you create the necessary conditions for it.

Getting the right output power and good frequency response with a blow to the forehead, for example, by turning on two lamps in parallel, is quite difficult. Parallel switching of lamps does not bode well: the contradiction between the necessary magnetizing inductance and the parasitic parameters of the output transformer is only exacerbated. After much thought and doubt, I decided to abandon the classic version of a single-cycle output stage altogether (primarily because it is already simply boring, and secondly, because it was not possible to obtain the desired parameters with one lamp). As a result, the output tube was turned on as a cathode follower with current OS. In fact, this circuit is similar to the MOSFET follower circuit in detail. considered in [1] and has the same properties. But I still want to remind readers that the reverse the connection introduced into the circuit is not quite ordinary. The feedback signal does not explicitly interact with the input signal of the stage, but affects the transfer characteristic of the lamp itself.

The efficiency of using the lamp in such a cascade is noticeably higher than in the classical one. This made it possible to obtain the desired output power using only one lamp. And since the output cascade is a cathode follower, it is clear that it has a low output impedance and good frequency properties, and, due to the design features, an excellent transient response. But the most important thing is something else - such an output stage has a higher linearity, as in comparison with the classical transformer cascade, and in comparison with the cathode follower. It is convenient to compare this amplifier with Cinderella, this is quite legitimate, since the output is one lamp and in a similar mode. Objectively, the nature of the introduced distortions is very similar, but "Princesses" have a slightly shorter harmonic "tail" and noticeably lower harmonic levels. Listening to this amplifier, there is no doubt that it is single-ended, but it sounds cleaner and more dynamic, both due to a significant power reserve and high response speed.

I will deviate a little from the established tradition, and the amplifier circuit will be considered first, and in the second part of the article - its objective characteristics and test results are given, issues of implementation and adjustment.

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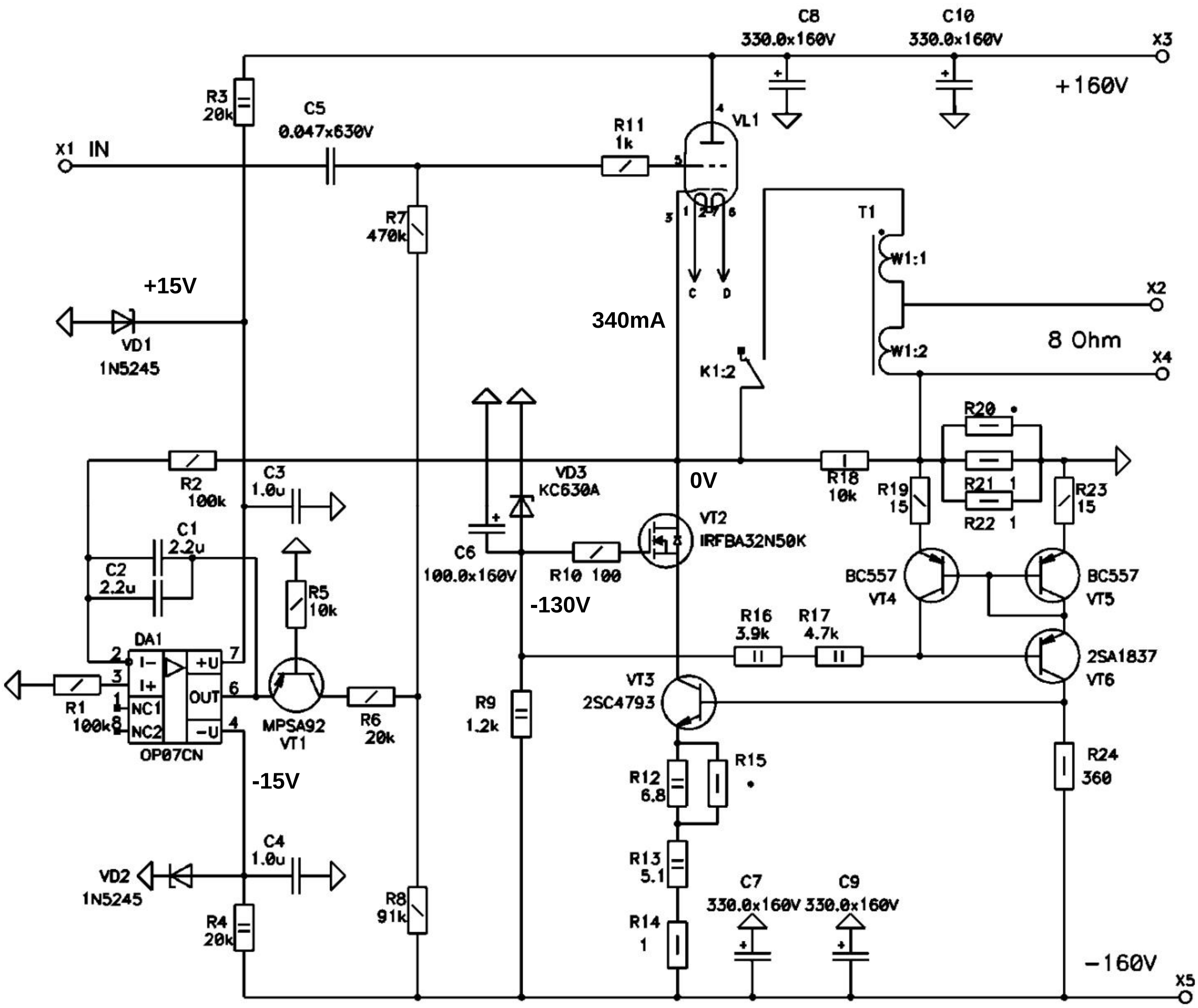
Amplifier circuit

The whole circuit can be divided into three rather independent nodes - the output stage, the driver, and the power supply systems. Each node is self-sufficient and can work autonomously. This was done deliberately, as it greatly facilitates the configuration of a rather complex circuit. The amplifier channels are independent - each has its own set of power sources that receive voltage from individual transformer windings. Only the power transformers themselves and the filament voltage stabilizer are common. Although this approach significantly complicates the design, but provides good channel-to-channel decoupling and solves all problems with the ground. Structurally, one channel of the amplifier is one printed circuit board, which carries all the components on board, except for the output transformer and power transformers. This allows optimal placement components of the amplifier itself, locate the power supplies in the right places, and minimize the length of the connections.

Output stage

The output stage circuit is shown in Figure 1.



Picture 1

As mentioned above, the output stage is a cathode follower on a VL1 lamp with a controlled current source in the cathode. The repeater transfer coefficient is about 0.75, the output impedance is ~14 ÿ, the power band (excluding the output transformer) is ~800kHz.

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The repeater is powered by bipolar voltage. With a separate, very low frequency loop OOS (DA1, VT1) zero potential is maintained at the output of the repeater. For optimal matching with the load, an autotransformer is used, which is directly connected to the output of the repeater. The use of an autotransformer had two main goals: to maximize magnetization inductance and reduce the leakage inductance. The value of the magnetization inductance relative to the output resistance of the follower is chosen to be very large - 3 Henry. *(If we draw an analogy with a classical power triode amplifier with a typical internal resistance of about 1 kÿ, then the magnetization inductance of its output transformer would have to be about 220 Henry)* This made it possible to significantly reduce the influence of nonlinearities

transformer at low frequencies. The low output impedance of the follower imposes very stringent requirements on the amount of leakage inductance of the autotransformer, on the one hand, but on the other hand, the requirements on its own capacitance are significantly weakened. This made it possible to apply deep sectioning in the auto transformer and obtain the leakage inductance (reduced to the entire winding) about 70 microhenries. As a result, it was possible to obtain a blockage of the frequency response of the order 1dB at 100kHz. The frequency range of the output stage from below (the cutoff frequency is about 15 Hz) is deliberately limited due to the choice of a small value of feed capacitances at the input of the output stage and drivers.

The reduced load resistance to the output of the cascade is 100 Ohm, which is much more than the output resistance of the repeater. Therefore, the output stage is insensitive to changes in the resistance of the load itself and works well even with acoustics with large impedance jumps.

The controlled current source is, in fact, a two stage transconductance differential amplifier with a low transconductance (approximately 1.44) and a wide bandwidth (cutoff frequency of about 2 MHz). The output impedance of the amplifier is tens of megohms. The load current is converted into an input signal for the amplifier on the current sensor (R20 - R22) and with a given scale is broadcast to its output. In the absence of signal current, the amplifier can be considered as conventional current source, the output current of which sets the mode of operation of the output lamp. Globally, the operating mode of the OS amplifier is set by the current determined by the resistors R16, R17. Basically, the amount the quiescent current can be adjusted by changing their magnitude, but adjusting the quiescent current in this way also leads to a change in the slope of the amplifier. To reduce this effect, the quiescent current is set under the value of the resistor (R15) in the VT3 emitter circuit. The current transfer scale is set by changing the value of the current sensor (R20).

Transistors VT3 and VT6 must be installed on the same cooler with an area of at least 400 cm2 , transistor VT2 must be installed on a cooler with an area of at least 1200 cm2 . The antiparasitic resistor R10 is installed next to the transistor, directly on the heatsink. It is desirable that the cases of transistors VT4, VT5 have thermal contact with each other.

Driver

A schematic diagram of the driver stage and preamplifier is shown in Figure 2. The driver itself is made on a VL3 lamp based on a dynamically powered stage. Such the cascade was described in detail earlier [2], so I will not repeat myself and focus on small differences between the circuits. The driver is powered by an increased anode voltage, and a lamp with a higher μ is used. The output source follower was slightly simplified, the current source was replaced by a resistor. Since it works almost at idle, this is not reflected in the sound in any way. Driver capable of providing up to 80 volts (rms) output at a harmonic level of about 0.7%. AT The distortion spectrum contains mainly the second harmonic. The gain of the driver stage is not enough to get full power at the output at an acceptable signal level at the input. Therefore, I had to introduce another amplification stage on the lamp VL1. This is an ordinary resistive cascade and has no special features. A cathode follower on a VL2 lamp is connected between the preliminary stage and the driver.

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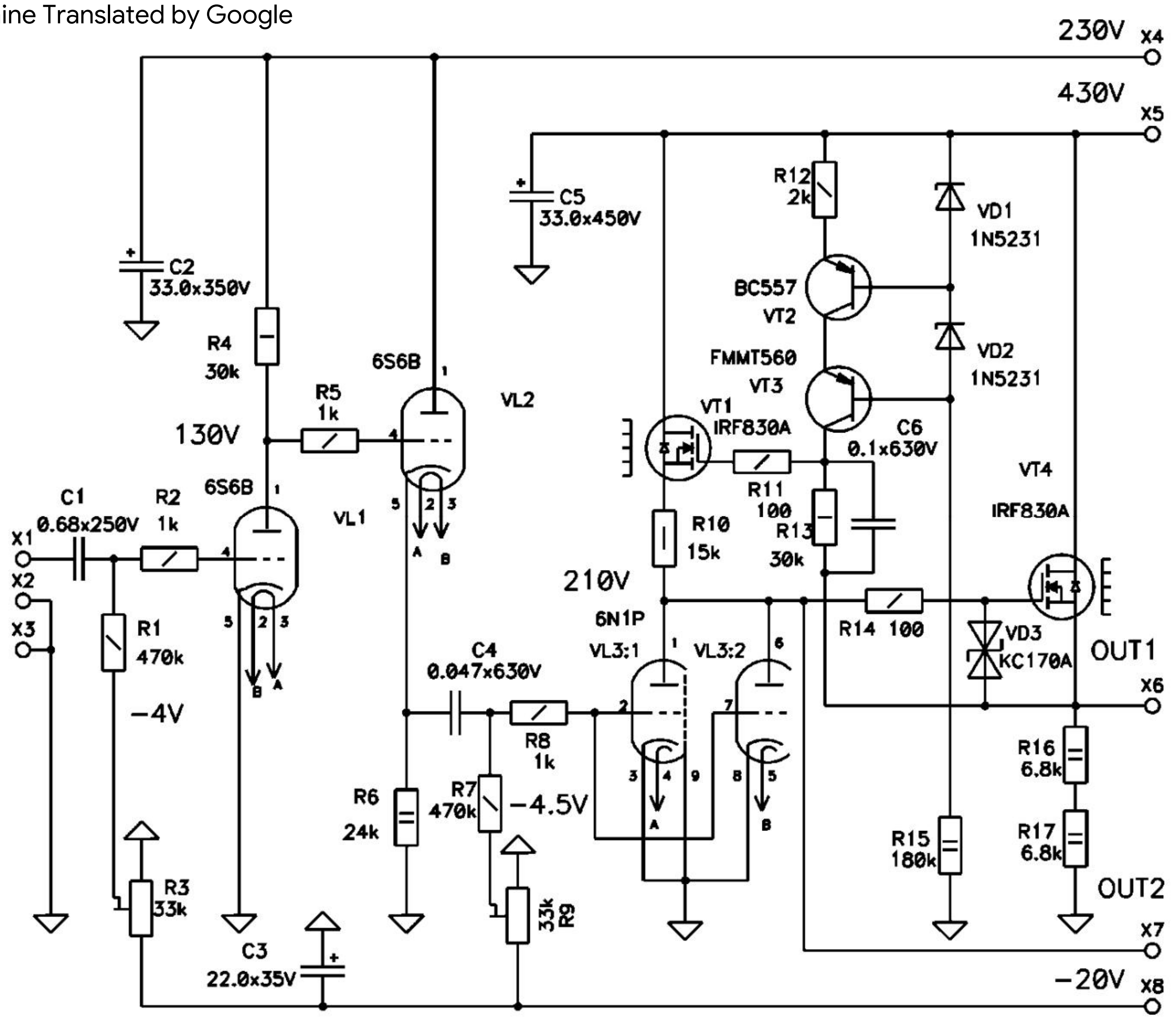

Figure 2

The presence of a cathode follower (some consider it a great sonic sin) in this case and objectively and subjectively improves the parameters of the amplifier. The operation of the first stage, practically at idle, noticeably increases its linearity. And decoupling its output from the fairly significant dynamic input capacitance of the driver itself provides excellent frequency and transient response.

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Let us now return to the question of which point to connect the output stage to. I'll tell you right now, I listened both options and settled on connecting to the “OUT1” output. There are also objective differences. Connecting the output stage to the “OUT2” output has very little effect on the linearity of the driver. Wherein the fourth harmonic slightly decreases and a small fifth appears, the levels of the second and third harmonics practically do not change. The recorded changes are very small - at the level of 1÷1.5 dB, with the level of the harmonics themselves -70÷-80 dB. Such inclusion is much more strongly reflected in the frequency response of the amplifier, it worsens by a factor of one and a half. So it's up to you to choose what is more important: getting high quality sound or the absence of solid-state devices in the audio path.

Transistors VT1, VT4 are installed on small radiators capable of dissipating 2÷3 watts. Transistor VT3 is supplied with a small polygon.

Supply system

Almost all amplifiers are sensitive to supply voltage instability, and especially lamp circuits without a common feedback loop, and even more so - single-ended ones. If with supply voltage ripples it is possible successfully fight by choosing the appropriate filter parameters, then only a stabilizer can save the network from instability. Moreover, this also solves the issue of pulsations. And in general, not so scary slow, significant changes, how much short-term instability. If connected to the network

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registrar and record the mains voltage values, say, for half an hour, then you will see that the voltage continuously "breathes" for several volts according to a random law. Although these changes are minor, they lead to small fluctuations in the parameters of the amplifier; in fact, the amplifier is continuously in the transient mode of setting its parameters. This has a very negative effect on the final the result is sound. To avoid this, all amplifier supply voltages are stabilized.

The amplifier uses two transformers, one feeds the filament circuits of the lamps and the driver. The second transformer feeds the output stages. Anode supply voltage to the output stages arrives with a delay, after warming up the output lamps, the anode voltage is supplied to the driver stages by steps simultaneously with the filament voltage.

To stabilize the filament voltage, a group stabilizer with a linear regulator located on the primary side of the transformer is used. The controller circuit is shown in Figure 3, and the principle of its operation is described in detail in [3].

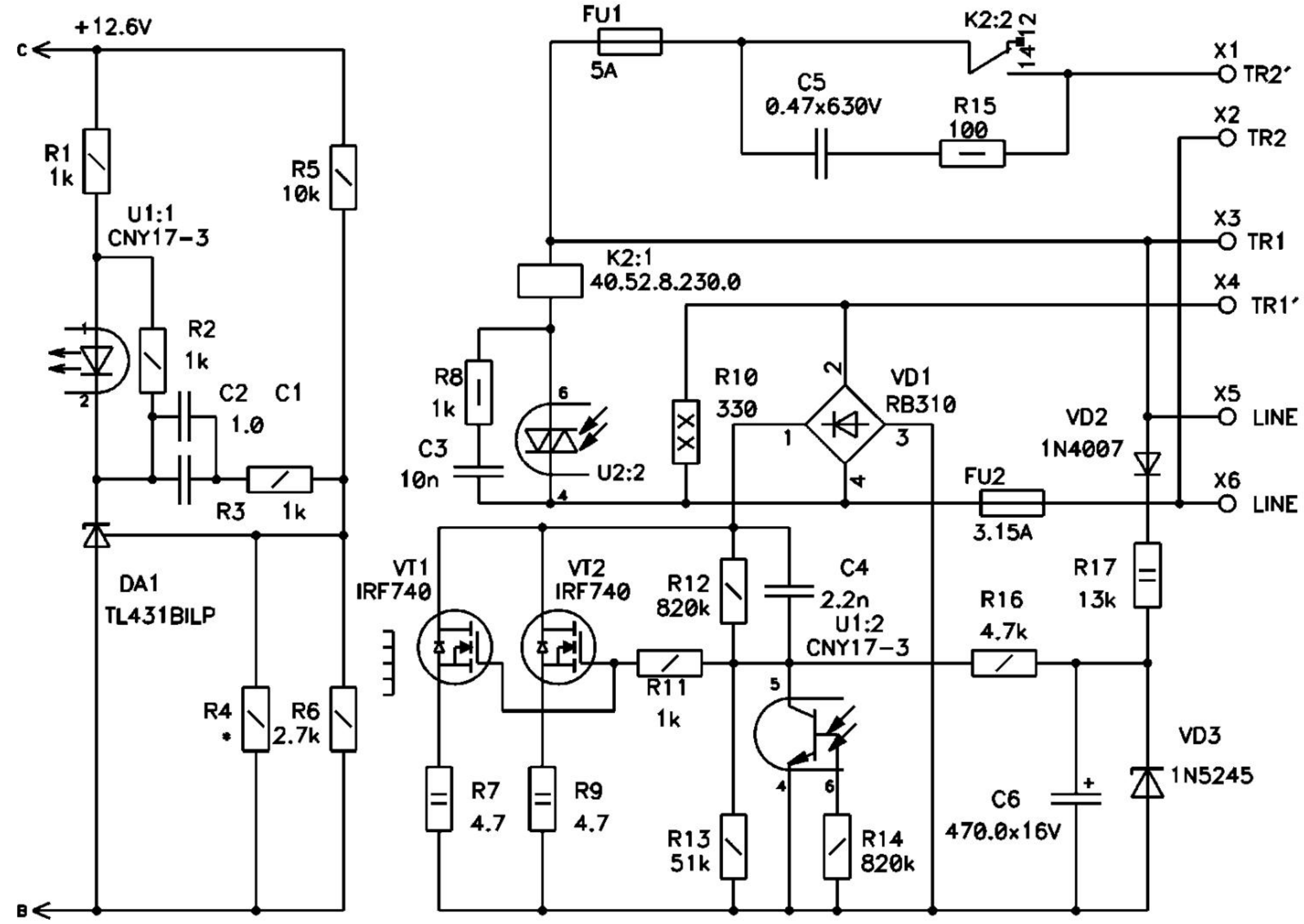

Figure 3

Along the way, preliminary stabilization of the anode voltages of the driver stages is also carried out. The system stabilizes the filament voltage of the output lamp of one of the channels. The voltages at the other outputs of the stabilizer are rigidly connected with the stabilized one, and since the currents of their consumption currents are stable, they also do not depend on the mains voltage. Regulating transistors VT1, VT2 are installed on a cooler with an area of about 1000 cm2 , re the resistors R7, R9, R11 are located directly on the radiator. If the amplifier is manufactured as a monoblock, then one of the regulating transistors can be excluded and reduce the area of the cooler.

The group stabilizer rectifier assembly (for one channel) is shown in Figure 4. Incandescence lamps are powered by direct voltage from rectifiers with a midpoint. The zero point of the rectifier is raised above the ground by 9 ÷ 10 volts and is grounded through capacitances C3, C6.

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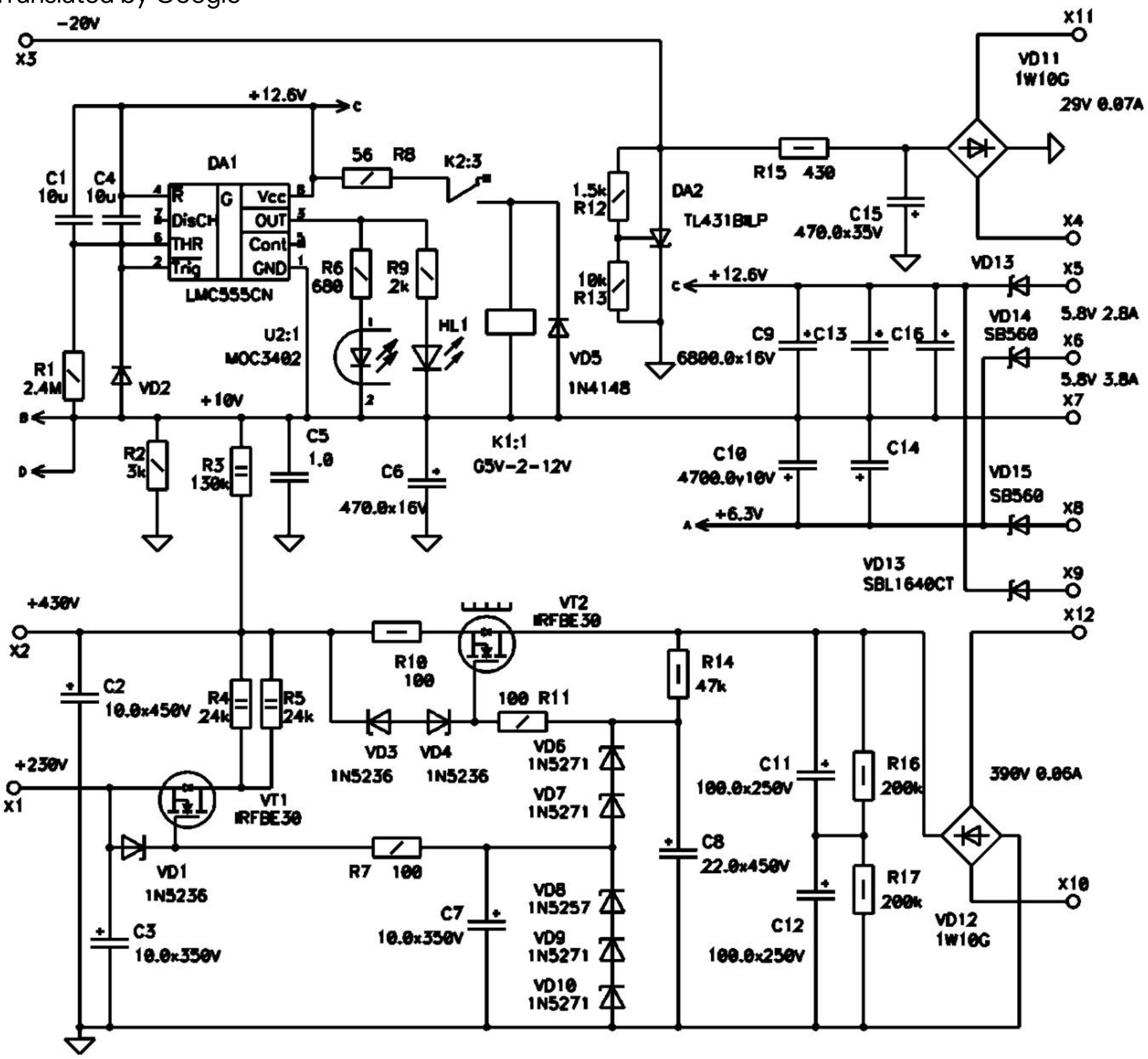

Figure 4

The power supply turn-on delay circuit (DA1) and the turn-on relay are also powered from the filament voltage output (K1:1). I used a not quite usual solution, the delay circuit does not control the relay directly, but an opto-isolator, which in turn turns on the relay, which is powered directly from the mains voltage. The load switching relay is controlled by the contacts of the power relay. This is done so that when the mains voltage is turned off, both relays immediately turn off.

The bias voltage is additionally stabilized by a parallel regulator on the micro scheme DA2.

The anode voltages of the driver and preliminary stages are additionally stabilized and filtered by a simple parametric stabilizer based on transistors VT1, VT2. The main purpose of using these stabilizers is not so much stabilization as good filtering of anode voltages. The use of stabilizers, rather than active filters, allows us to solve another problem - to limit voltage on the circuit elements when turned on to cold lamps. The VD13 diode must be installed on the radiator, and the VT2 transistor is also installed on the radiator (based on a power dissipation of 3 watts).

The power stabilizers of the output stage (Figure 5) are implemented in a conventional serial structure and have no special features. Both stabilizers are equipped with a protection system (R14, VD4, VD5 and R9, VT1), which limits the current to 0.7 amperes. On the one hand, it protects the output cascade from damage (short-term), and on the other hand, the stabilizer itself. Holidays are not shown on the chart. capacitance, as they are located directly at the load.

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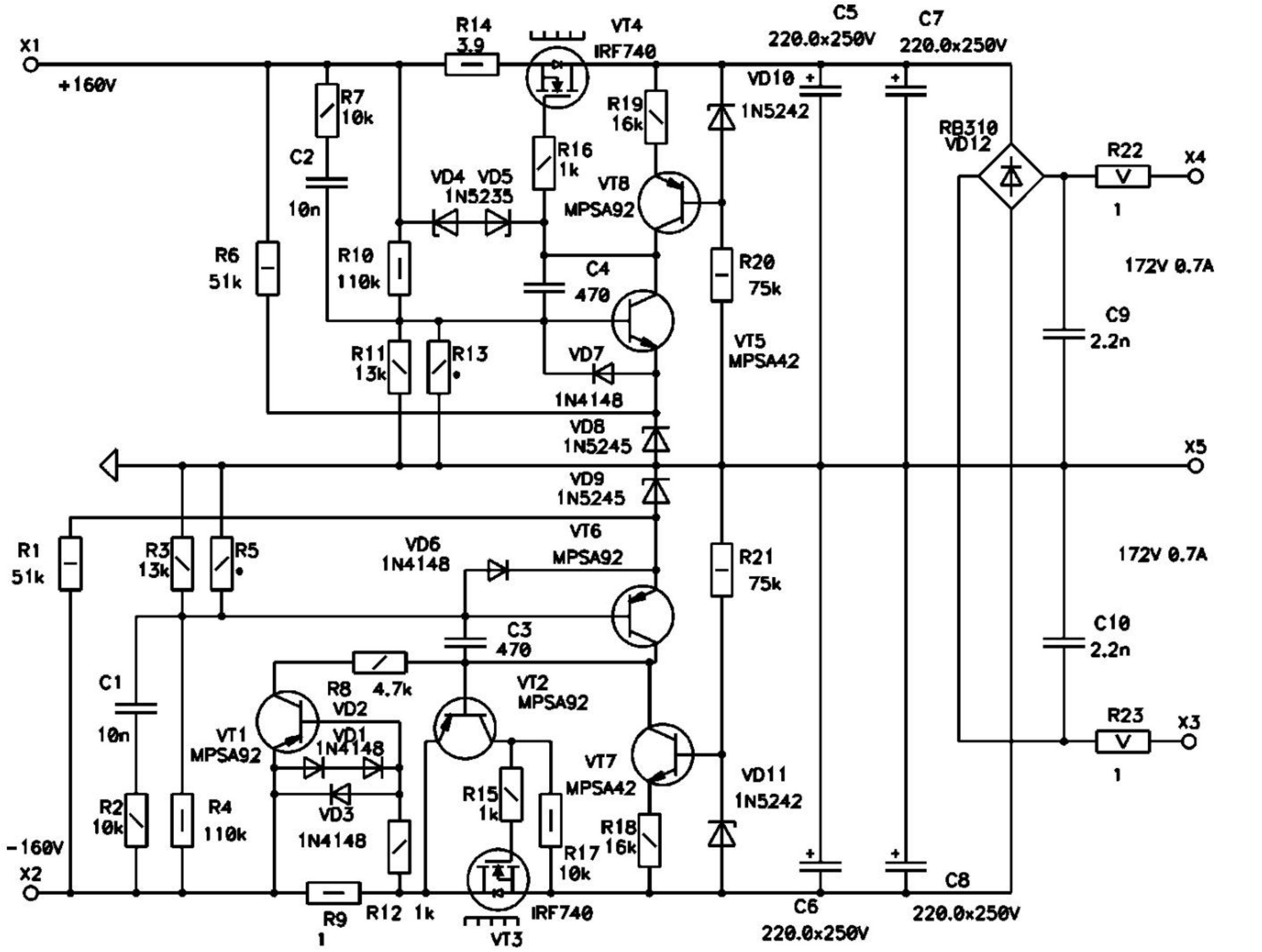

Figure 5

If the stabilizer is located far from the output stage, then directly at its output it is necessary to install capacitances, at least 47 microfarads each. The ripple level at the output of the stabilizers does not exceed ten millivolts. Pass transistors VT3, VT4 are installed on one cooler with an area of at least 1500 cm2

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resistors R15, R16 are also installed there. Pay attention to the resistors R22 and R23, they are not should be wire. But when the stabilizer is started, a large dynamic dissipates on them.
power. They are best made up of three to four two-watt resistors. All these

efforts have made the amplifier completely insensitive to changes and surges in the network. voltage and also very quiet. What
a fully assembled board of one amplifier channel looks like is shown in Figure 6.

Component Replacement

In conclusion of the consideration of the circuit diagram, we briefly touch on the issue of replacing components. In general, 98% of the components used are not problematic. Of course, it is necessary to pay attention to the quality of the components installed in the signal chain and the quality of the electrolytic bones (but you should not make a fetish out of this). Help in all
In real circuits, you can change components quite arbitrarily. Of course, they should not be worse in terms of
parameters. Some care must be taken
when replacing zener diodes. Most zener diodes in the circuit

Figure 6

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works at low currents, and this must be taken into account when replacing. The relay switching the output transformer (K1:1) must be of the signal type. Three components can cause certain difficulties - 6S6B lamps, the FFMT560 transistor and the IRFBA32N50K transistor.

The use of 6S6B lamps is caused solely by the desire to save space. You can also try use 6N16B or 6N1P.

With the FFMT560 transistor, the issue is complex. You can try to use ZTX758. When looking for a replacement, one should be guided by the following requirements - collector voltage -450÷-500V, cutoff frequency - 40÷50MHz, gain - at least 50 and small output capacitance - up to 20pF.

The use of the IRFBA32N50K transistor is caused by the design features of its case. With a relatively small crystal size and, accordingly, a small output capacitance, the transistor has large power dissipation. If you can not find such a transistor, an excellent solution would be parallel connection of several less powerful transistors such as IRF830. Currents through transistors it will be necessary to align by including 8 ÷ 10 Ohm resistors in their sources.

Literature

1. E.V. Karpov, Hybrid World, Next-Tube, 2003 2.
E.V. Karpov, Driver Cascade, Next-Tube, 2007 3. E.V.
Karpov, Stabilized tube amplifier power supply, Next-Tube, 2006

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