Laboratory Power Supply Unit – Variant of Implementation

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A laboratory power supply is required for testing tube-based circuits. It should include sources of both heater and plate voltages. The latter should be adjustable. To implement such a laboratory unit, I chose the schematic of an adjustable high-voltage stabilizer proposed by E.Karpov [1], with modifications [2]. The result is a laboratory power supply unit, shown in Fig.1 – a kind of functional analogue of the well-known Soviet UIP-2, but several times smaller and lighter.

The unit provides AC heater voltages in two channels: 6,3 V and 5+1,3 V (the load current of each channel is approximately 2,5 A, determined by the used TN-36 transformer, the channels can be switched on both in parallel and in series), as well as a DC plate voltage, smoothly adjustable from several volts to 450 V. The load current of this channel is limited by about 140 mA. Below I will describe some of the features of its implementation – perhaps it will be useful for someone.

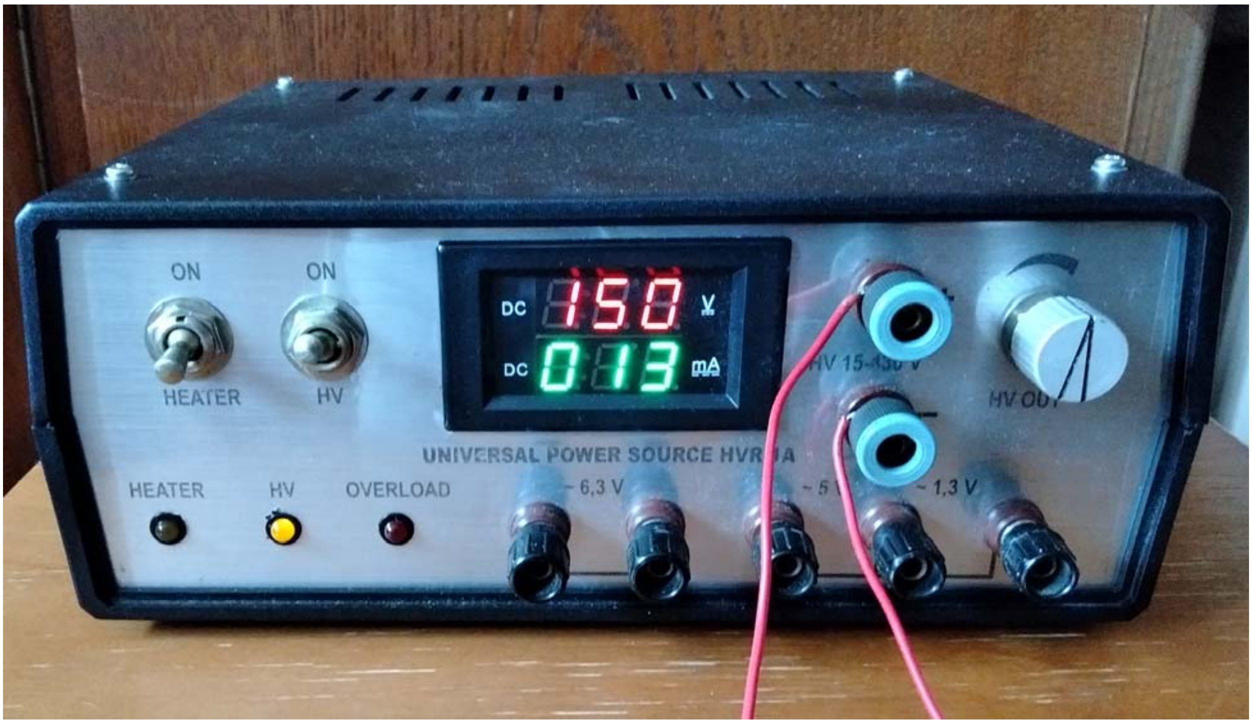


Fig. 1 – The exterior of the laboratory power supply.

To power the high-voltage stabilizer, it was necessary to wind a power transformer (I didn’t manage to find a ready-made one, but a suitable core with an empty frame was found). The transformer is wound on a SHL20X40 core and has 4 windings: the primary one has 1115 turns of winding wire with a diameter of 0,41 mm, and three secondary ones: 1920 turns, 95 turns and 78 turns of wire with a diameter of 0.355 mm, to obtain high voltage, low voltage for the stabilizer control circuit (15 V), and joint power supply to the cooler fan and electronic voltammeter, respectively. Note that the joint power supply of the stabilizer control circuit, the fan and the voltammeter from the same source is undesirable due to the possible penetration of interference from the motor and the electronic voltammeter to the output of the high-voltage stabilizer – hence two separate low-voltage windings are necessary.

The stabilizer circuit diagram basically corresponds to the one given in [2], some minor differences are mainly due to the components available at my disposal. Here and further, the numbering of the parts corresponds to the schematic [2]. So, the parallel connected R4-R8 (240 K, 2 W) are replaced by a set of 6 resistors – 5 pieces 8,2 k + one 7,5 k connected in series. R15 is combined of two 2 W resistors 51 k each – because it dissipates quite a lot of power at high output voltages U_{out}. R16 = 470 Ohms. VD2 is of type D814G. With the selection of R19, R21, I had to tinker a little to fit the range of U_{out}, their values differ from those indicated in the diagram (in my case, 216 and 510 Ohms, respectively). Two electrolytic capacitors have been added to the +15 V power supply circuit – 470 uF x 25 V and 1000 uF x 16 V at the input and output of DA1, respectively. It was reported that without these capacitors, the stabilizer circuit may lose its stability.

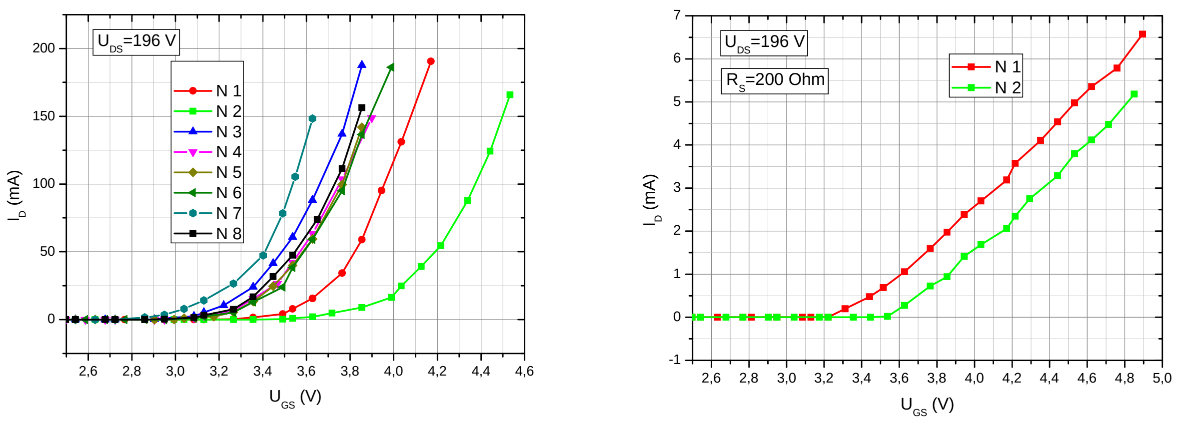
After assembly, the circuit worked without any problems, however, there are several considerations for improving it.

Firstly, it is desirable to combine a capacitor C8 of two ones connected in series, shunting them with equalizing resistors, in the same way as it is done at the input of the stabilizer. This will keep them alive if the VT2 regulating transistor breaks down. In such a situation, the full input voltage will be applied to the C8. And in my case, this is almost 540 V, which a 450 V rated capacitor may not survive (some capacitors do not tolerate voltage overload well). Since the printed circuit board was already manufactured according to the schematic described in [2], I had to limit myself only to replacing VD4 with a suppressor 1.5KE440A – to clear my conscience.

Secondly, E.Karpov strongly recommends that several regulating transistors should be connected in parallel in place of a single VT2. Let's look at the reasons for this in some more detail.

In the event of an abnormal situation (short circuit in the load) or even simply if the connected layout contains large capacitances in its power supply circuits, large power will quickly be released on the regulating transistor even in current limiting mode. 540 volts at a current of 150 mA will already give 80 Watts. It would seem that this does not exceed the rated power dissipation of IRFBG30 transistors (120 W, almost the limit for TO220 case). However, if we open the datasheet [3] and look at the Fig. 8, where the safe operation area (SOA) is shown, we will see that at a drain-source voltage of U_{DS} = 500 V and a current of 200 mA, the transistor channel will heat up to the maximum permissible 150°C in a few tens of milliseconds, and this if the case temperature is kept equal to 25°C. This is due to the inertia of the heat transfer processes from the channel to the case. This inertia is illustrated to some extent by Fig. 11 in [3], from which it can be seen that the nominal value of the channel-case thermal resistance is set in about 0.1 s. At previous points in time, it is significantly higher. If we consider that during the operation of the device, the temperature of the regulating transistor case will most likely be clearly higher than 25°C, then it becomes clear that the probability of failure and thermal breakdown as a result of dynamic overload, even at a current limit of 140-150 mA, is very high.

In order not to go beyond the limits of the SOA in case of an emergency, it is advisable to use several transistors in parallel (of course, each with its own resistors in the gate and source circuits). The resistance in the source circuit (R14) increases in proportion to the number of transistors connected in parallel. In my case, the radiator pad (a processor cooler with a copper core) allows to place 3 transistors without problems, which corresponds to the value of the resistance in the source circuit of 150-160 Ohms. These resistances should be matched as close as possible to avoid an imbalance of the limiting currents. By the way, if possible, it is not superfluous (although not mandatory) to select transistors based on the drain-gate characteristic – a dependence of the drain current on the gate–source voltage $I_D(U_{GS})$ – these dependencies have a fairly large spread. The presence of resistors in the source circuit, of course, reduces this spread, decreasing the difference in drain currents at equal U_{GS}, but does not completely eliminate it. As an illustration, Fig. 2 shows the drain-gate characteristics $I_D(U_{GS})$ for 8 samples of transistors without a resistor in the source circuit (a) and with a 200 Ohm resistor (b), measured at a U_{DS} of about 200 V.



a) b)

Fig. 2 Drain-gate characteristics $I_D(U_{GS})$ for transistors IRFBF30 without (a) and with 200 Ohm resistor in the source circuit (b).

The IRFBG30 MOSFETs can be replaced by other transistors of this series, for example, IRFBF30 with a maximum value of U_{DS} = 900 V, as well as by transistors of other types. The selection criteria are that the rated U_{DS} is much higher than the maximum input voltage, taking into account the amplitude of the ripples, the high value of rated power dissipation, the SOA is not worse than that of the IRFBx30, the dynamics of heat transfer from the structure to the case should be as good as possible.

When placing VT2 transistors on the heatsink, do not forget about the heat-conducting paste (preferably silver-based). Its layer should be as thin as possible, the task is to fill the air gaps in the irregularities between the transistor case and the heatsink. Forced air cooling is highly desirable, since it is necessary to effectively dissipate up to 80 Watts of power. The VT1 control transistor is mounted on the board and equipped with a small heatsink with dimensions approximately 50x30x10 mm – it is quite enough, since the power dissipated by VT1 is relatively low (approximately up to 3 Watts).

The entire unit was placed in the Kradex Z17W housing. Fig. 3 shows the "inside" of the unit with the top cover removed.

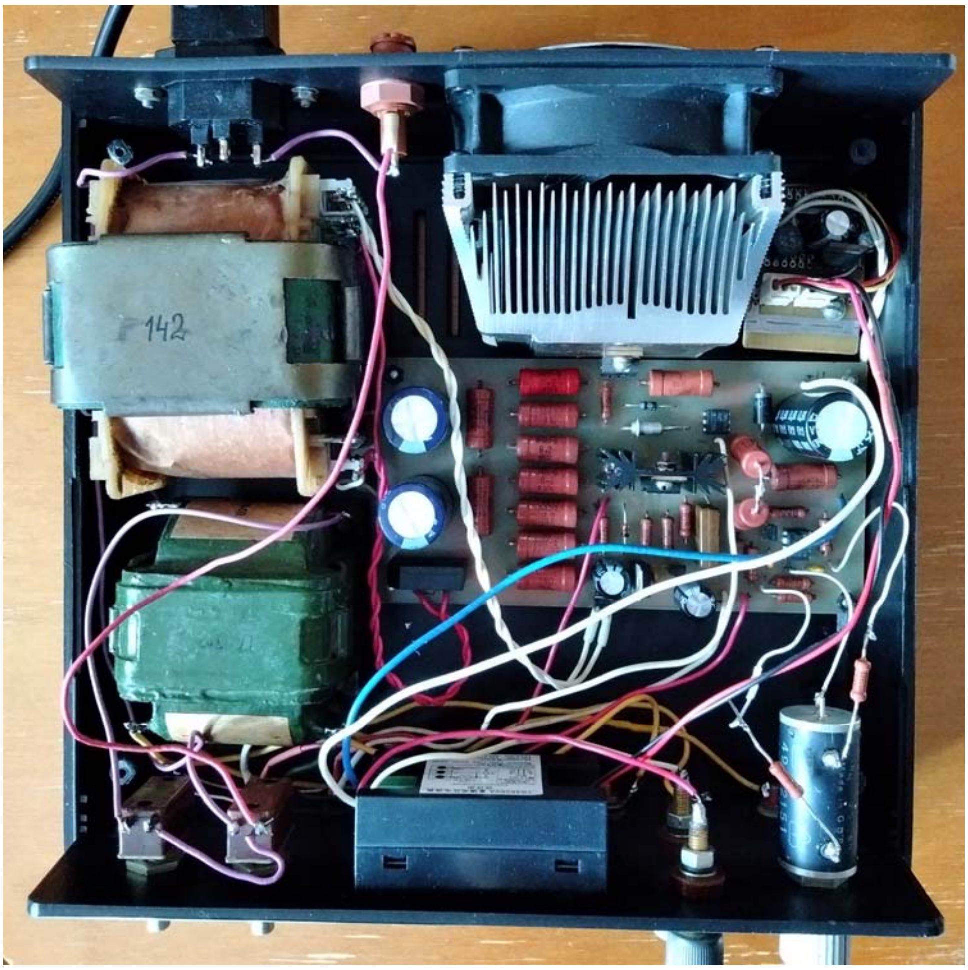


Fig. 3 – View of the laboratory power supply unit with the top cover removed.

As a voltammeter, the YB4835VA unit available on Aliexpress is used, its measuring limits are 0-600 V, 0-999 mA. The readings of his voltmeter match up to 1 V with the readings of the control device. The milliammeter readings in this unit are underestimated by about 2 mA.

It turned out to be quite difficult to measure some parameters of the stabilizer with the available means. So, with an active load of 10 k and an output voltage of 200 V, the ripple range at the input was 5,3 V, but at the output the ripple value (amplitude about 10 mV) turned out to be comparable to the noise level (for noise, the value of 12 mV RMS was measured, the device is quite noisy). Thus, the ripple suppression coefficient is approximately 250-300. Indirectly, the stabilization coefficient can be approximately judged by this value. The stabilizer's response to a pulsed active load change (a jump from 15 k to 120 k and back) is aperiodic in nature, the voltage varies by about 7-8 mV. This corresponds to a DC output resistance of about 0.6–0.7 Ohms.

And finally a warning. The device has life–threatening voltages (over 500 V at the input of the stabilizer and up to 450 V at the output). At the same time, it is capable of producing a current of more than 100 mA. A current of 100 mA is known to be fatal to humans. In particular, the heatsink of the regulating transistor, which occupies a significant part of the housing, has a potential of over 500 V relative to the ground. Therefore, when working with the device, you should be extremely attentive and careful. Carelessness is deadly here. Remember this!

LITERATURE

1. E.Karpov. The adjustable high voltage regulator.
2. E.Karpov. The adjustable high voltage regulator. Adding to the article.
3. IRFBG30 Power MOSFET. Vishay Siliconix Datasheet.