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# DEVELOPMENT OF A 150 W LINEAR LABORATORY POWER SUPPLY UNIT

*The laboratory power supply is an indispensable device for the manufacture, testing, adjustment and repair of electronic equipment. The object of research is the process of selecting and justifying the device circuit on a modern element base, developing a printed circuit board, manufacturing and testing the created device layout in practice. The toroidal transformer of the required power was also calculated. The test was carried out in the voltage and current stabilization mode, and the data obtained indicate the possibility of further improvement of the device's circuitry. To build a laboratory power supply, it is desirable to use a linear circuit, because of the small pulsations that are critical when powering electronic equipment. A switching power supply can be used as an additional source when working with high-power circuits. A universal option is a bipolar power supply built according to a linear circuit with an output voltage of 0...±30 V and a current of 0...5 A. This solution will allow the device to be used for operation with most radio electronic devices, including those sensitive to RF noise, whose power consumption does not exceed 150 W. Thanks to the use of a bipolar circuit, it is also possible to work with high-quality audio frequency amplifiers that require bipolar power supply, operational amplifiers and some digital equipment. The galvanic isolation of the channels will make it possible to adjust the output parameters independently for each arm, which may be necessary when repairing digital equipment. Equipping the laboratory power supply with a current stabilization unit will make it possible to use the power supply as a battery charger and help in finding short circuits in circuits. Short-circuit protection will save the power supply in the event of an emergency and, in some cases, save the connected load.*

*Keywords: linear power supply, current stabilization, voltage stabilization, toroidal transformer, bipolar power supply.*

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# РОЗРОБКА ЛІНІЙНОГО ЛАБОРАТОРНОГО БЛОКУ ЖИВЛЕННЯ ПОТУЖНІСТЮ 150 ВТ

*Лабораторний блок живлення є незамінним приладом при виготовленні, тестуванні, настройці та ремонті радіоелектронної апаратури. Об'єктом дослідження роботи є процес вибору та обґрунтування схеми пристрою на сучасній елементній базі, розробка друкованої плати, виготовлення та перевірка створеного макета пристрою на практиці. Також було проведено розрахунок тороїдального трансформатора необхідної потужності. Перевірка проводилася у режимі стабілізації напруги та струму, отримані дані свідчать про можливість подальшого покращення схеми пристрою. Для побудови лабораторного блоку живлення бажано використовувати лінійну схему, через малі пульсації, які критичні при живленні радіоелектронного обладнання. Імпульсний блок живлення може використовуватися як додаткове джерело необхідне при роботі з високопотужними схемами. Універсальним варіантом є двополярний блок живлення побудований за лінійною схемою з вихідною напругою 0…±30 В та струмом 0…5 А. Таке рішення дозволить використовувати прилад для роботи з більшістю радіоелектронних пристроїв, у тому числі і чутливих до ВЧ шумів, потужність споживання яких не перевищує 150 Вт. Завдяки використанню двополярної схеми можливо також працювати з високоякісними підсилювачами звукової частоти, які потребують двополярного живлення, операційними підсилювачами та деякою цифровою технікою. Гальванічна розв'язка каналів дасть можливість регулювати вихідні параметри незалежно для кожного плеча, що може знадобитися при ремонті цифрової техніки. Оснащення лабораторного блока живлення вузлом стабілізації струму дасть можливість використовувати блок живлення в якості зарядного пристрою для акумуляторів та допоможе при пошуку короткого замикання у схемах. Наявність захисту від короткого замикання збереже блок живлення при виникненні нештатної ситуації та, в деяких випадках, врятує підключене навантаження.*

*Ключові слова: лінійний блок живлення, стабілізація стурму, стабілізація напруги, тороїдальний трансформатор, двополярного живлення.*

### Statement of the problem

Transformer power supplies were replaced by switching power supplies, which made it possible to obtain more power with smaller device dimensions. Modern power supplies use digital and microprocessor technologies, which allows them to have a wide range of parameters, high accuracy and efficiency, and protection systems that ensure the reliability of the power supplies and the reliability of the devices they power. The advantages of switching power supplies include high efficiency (70-90%). This is due to low power losses on power elements operating in the key mode; small size and weight; high output power. Disadvantages of switching power supplies: high circuit complexity, which makes it difficult to repair and maintain the power supply; presence of high-frequency interference and noise that can enter the network and the load; high output voltage ripple factor. This is due to the occurrence of short-term high-frequency pulses during the operation of key transistors, which are poorly suppressed by filters. Linear power supplies have a number of advantages: output voltage accuracy, absence of high-frequency pulsations compared to switching power supplies; high reliability; relative ease of repair; relatively simple structure. Disadvantages of linear power supplies: large dimensions and weight due to the use of a low-frequency transformer; low efficiency. Typically, the efficiency of linear power supplies is no more than 50%. This is due to the fact that the stabilizer transistors always operate in the active mode; high heating of power elements [1]. So, based on the above advantages and disadvantages, we can conclude that linear power supplies are advisable to use as laboratory power supplies (LPS), where there is no need for too much power, it is possible to neglect the large dimensions of the device and low efficiency in exchange for greater reliability, ease of repair and high accuracy of the output voltage with the absence of high-frequency pulsations.

### Analysis of recent research and publications

Linear power supplies have come a long way in evolution, but due to a number of advantages, even taking into account the higher efficiency of switching power supplies, they are still being developed and improved. Thus, in [2], a linear power supply was analyzed and a new design was proposed. The implementation of the design using integrated circuits is given in [3], and information on a highly stable linear power supply is provided. For some industrial applications, it is necessary to maintain high current values, so a type of linear AC or DC power supply based on linear theory is investigated in [4]. Another task is to increase the voltage for linear sources, it is described in [5], and calculation formulas for selecting capacitors are presented. Finally, [6] describes and develops a real model of a linear source with the ability to regulate voltage up to 38 V and current up to 5 amps, the design is based on transistors.

**Formulation of the goals of the article:** the laboratory power supply is built according to the scheme of a linear power supply. It is necessary to apply a bipolar power supply circuit using a toroidal transformer with a single secondary winding with a midpoint. Output voltage is 30 V, maximum current is 5 A. Voltage and current stabilization, short circuit protection.

### Presentation of the main research material

Taking into account the specifics of the use of laboratory power supplies, the main requirements for them are high reliability, ease of repair, and stability of the output voltage. The use of a switching power supply circuit is impractical due to the complexity of its structure and repair in case of failure and the presence of high-frequency output pulsations that can affect some noise-sensitive equipment. Therefore, the device will be built according to the scheme of a linear power supply.

The voltage stabilizer must meet the following requirements: constant bipolar output voltage of 0...30 V; output voltage ripple ≤ 1%; output current 0...5 A; output voltage regulation and current limitation.

Based on the requirements for the stabilizer, it is advisable to use a stabilizer built on an integrated voltage regulator chip. Such a solution allows simplifying the structure of the stabilizer compared to circuits that use transistor-based voltage stabilizer circuits. The LM338 chip, which can provide voltage regulation in the range of 1.2 - 32 V and current up to 5 A, but this chip does not have its analog for negative voltage. Using Lowdrop chips has a lower voltage drop, but they are also available only for positive voltage. Therefore, it is advisable to use the LM317T chip for the positive arm stabilizer and the LM337T for the negative arm. These integrated stabilizers allow you to get an output voltage of 1.25 to 37 V (-1.2 to -37 V) and a current of up to 1.5 A [7, 8].

To provide an output current of up to 5 A, an additional bipolar transistor can be used to pass current through itself and unload the chip. For the positive arm stabilizer, a P-N-P transistor is used, and for the negative arm, an N-P-N transistor is used. The transistors must have sufficient power to provide the required output current, such as TIP36C and TIP35C.

The minimum output regulation voltage of the integrated regulator chips is 1.25 V for LM317 and -1.25 V for LM337. To obtain a range of output voltage control from 0 V, you can connect the voltage control unit instead of the case to a separate voltage source of -1.25 V for the positive and 1.25 V for the negative arm [7, 8].

Current stabilization in the circuit can be achieved by using an additional integrated stabilizer chip connected in series after the voltage stabilizer. The disadvantage of this method is an additional voltage drop on the current stabilization chip and its heating. A better option is to use an operational amplifier chip as a negative feedback [9].

Considering the power of the circuit, special attention should be paid to the choice of the mains transformer. Since the circuit is bipolar, the following types of transformers can be used: a transformer with one secondary winding with a midpoint output for AC voltage with an effective value of 24 V (± 34 V after rectification, provided a capacitive filter is used) between the outermost output and the midpoint and a current of 5 A; a transformer with two secondary windings with parameters of 24 V and 5 A each; two separate transformers with one similar secondary winding, separately for each channel. The circuit will use a variant with one transformer and a midpoint secondary winding. To power the operational amplifiers and display elements, you can use the free windings of the transformer (if available), or use a separate power supply for a voltage of 5 V or more. Two low-power transformers for 9 V will be used as additional power sources in the laboratory power supply.

It is advisable to use a single-phase bridge (Gretz) rectification circuit. It allows obtaining the same voltage waveform as the two-half-period midpoint circuit, but has a higher transformer utilization factor, half the reverse voltage across the diodes, and smaller dimensions. The disadvantages include a voltage drop across the diodes that is twice as large as in the midpoint circuit [9]. If necessary, this disadvantage can be overcome by using Schottky diodes in the rectifier, which have a lower voltage drop compared to conventional rectifier diodes.

Враховуючи відносно невисоку потужність блока живлення доцільним є використання ємнісного фільтра у вигляді конденсатора, ввімкненого на виході діодного мосту паралельно до навантаження. Використання індуктивного або Г-подібного фільтра у лінійному блоці живлення є недоцільним через наявність активного опору дроселя та більшу вартість [9]. Taking into account the relatively low power of the power supply, it is advisable to use a capacitive filter in the form of a capacitor connected at the output of the diode bridge in parallel with the load. The use of an inductive or low-pass filter in a linear power supply is impractical due to the presence of an active choke resistance and higher cost [9].

Taking into account the previously selected transformer with a midpoint, it is advisable to implement the rectifier circuit with a filter using a single diode bridge. A two-bridge circuit can be used when using a transformer with two independent secondary windings. When using a single diode bridge, it should be borne in mind that the reverse voltage across each diode will be equal to the voltage between the two extreme terminals of the transformer secondary winding, which for the selected transformer will be 48 V. This should be taken into account when selecting the bridge diodes [10]. The complete block diagram of the laboratory power supply is shown in Figure 1.

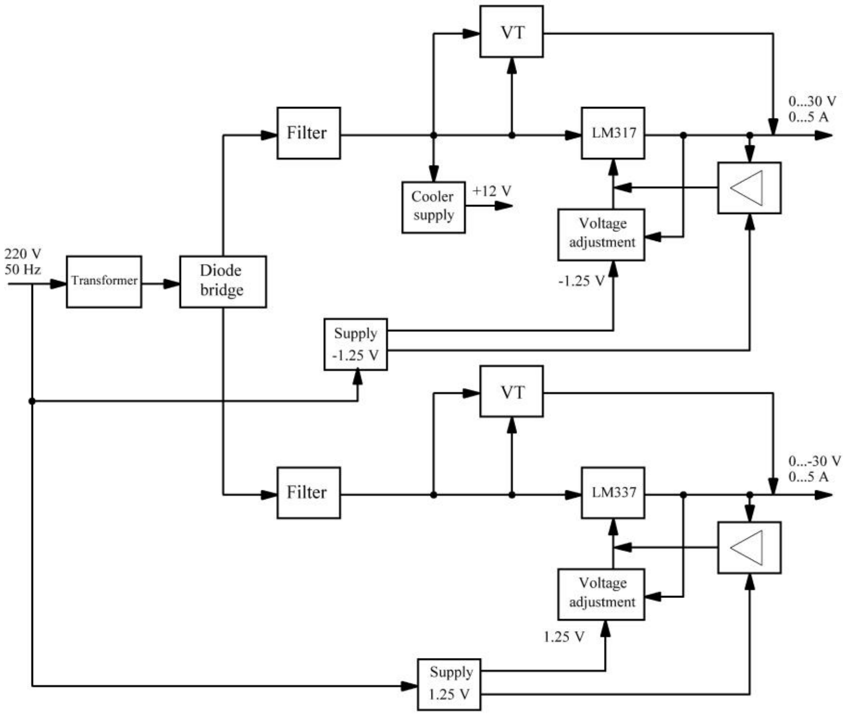



**Fig. 1 Complete block diagram of the laboratory power supply**

The main difficulty in developing a circuit diagram is the search for a voltage stabilizer circuit with a current stabilizer. Analyzing various circuit solutions in [10, 11], a circuit was found and modified for the available element base to satisfy the structural diagram developed above, it is shown in Figure 2. This circuit includes an integrated voltage stabilizer DA2 on the LM317 chip and a current stabilizer DA4 on the LM301a operational amplifier chip, which should also provide current protection for the power supply. The voltage stabilizer circuit is amplified by the MJ2955 transistor VT1 (to be replaced by another), made in a TO-3 package with a maximum power dissipation of 150 W.

When the circuit is lightly loaded, the current will flow through the DA2 stabilizer; when the circuit load increases, a voltage drop of about 0.6-0.8 V will occur across the resistor R3, which will open the transistor VT1, after which the current will flow through it. Analyzing the materials on this circuit, we can conclude that this transistor can be replaced by two TIP36C transistors in a TO-247 package with a maximum power dissipation of 125 W [12], placed on a radiator with forced cooling by a fan. This solution will increase the stability of the circuit when the power supply operates with a current of up to 5 A.

The output voltage in the circuit is controlled by the resistive divider R10 - R11 by changing the position of the variable resistor R11. To ensure smoothness, the control resistors must have a linear change in resistance.

The resistive divider R7 - R8 sets the reference voltage at the inverting input of the operational amplifier DA4. Current control in the circuit is provided by rotating the knob of resistor R7. Resistor R9 acts as a shunt. When the voltage on the inverting input is greater than on the non-inverting input by a difference not exceeding the reference voltage, the output of the operational amplifier (pin 6) will have a voltage equal to the supply voltage, i.e. equal to the voltage at the output of the power supply. The diode VD6 and the LED HL1 are connected with the cathode to the output of the op amp. This means that a positive voltage will not be applied to the DA2 tuning pin. When the voltage on the inverting input exceeds the voltage on the non-inverting input by a difference equal to the reference voltage, a negative voltage of -5...-16 V (depending on the voltage value on the fourth pin of DA4) will appear at the output of the op amp, which will cover the DA2 chip through diode VD6 and LED HL1, reducing the output voltage and, consequently, the current. The HL1 LED will light up. Pins 1 and 8 of the operational amplifier are frequency correction pins [10]. When the protection is triggered, they will turn off the voltage at the output of the op amp through diode VD7 to a level safe for HL1.

To accurately set the maximum current value of the power supply, resistor R7 can be replaced with one trimmer and one variable resistor of a larger value than R7 connected in parallel. Next, the circuit will use a 500 kΩ variable resistor and a 470 kΩ trimmer. The next step is to develop an additional negative voltage source to power the bias voltage operational amplifier to control the output voltage from 0 V.

As mentioned above, additional low-power transformers are used to power the periphery. To the output of the secondary windings, it is advisable to install a diode bridge with a filter on the capacitor and a voltage regulator chip LM7905, which at its output will give a constant negative voltage of -5 V, which can be applied to the fourth pin of the operational amplifier DA4.

Given a diode drop of 0.7 V, when using a diode bridge circuit, the diode drop will be $0{,}7 \cdot 2 = 1{,}4$ V. The integrated stabilizer chip creates a maximum voltage drop of 1.1 V. Consequently, the minimum voltage at the input of the diode bridge should be $1{,}4 + 1{,}1 + 5 = 7{,}5$ V, which is less than the transformer secondary voltage (9 V).

Since the power supply circuit of the operational amplifier does not require high power, the diode bridge VD1...VD4 can be built on low-power diodes 1N4007. The capacitor C1 acts as a filter. The capacitance of 1000 μF will provide high efficiency of the circuit. Capacitor C4 is used with a capacity of 0.1 μF for additional filtering of the stabilized voltage [11].

To obtain an offset voltage of -1.25 V to control a voltage from 0 V using a resistive divider, it is calculated using formula (1):

$$U_{out} = U_{in} \cdot \frac{R_2}{R_1 + R_2} \quad (1)$$

Using a resistor R5 with a nominal value of 200 ohms, the required resistance of R6 is 67 ohms. For convenience, we will use a 100 ohm trimmer to more accurately select the required voltage.

To cool the voltage regulator transistors, it was decided to use forced cooling in the form of a cooler. The standard supply voltage for coolers is 12 V. This value can be easily obtained by using the LM7812 integrated stabilizer chip (DA1). By connecting the cooler power supply in parallel to the input of the positive voltage regulator, there is no need to use a separate supply voltage source [9]. The final circuit of the voltage regulator for the positive arm of the power supply is shown in Figure 2.

In addition to the above changes, additional filtering capacitors C2, C3, C5, C12, C13, resistors R1, R2 for balancing transistors, diode VD5 to protect the DA2 stabilizer chip from a sharp voltage drop that can occur when the capacitors are discharged in the event of a sudden input voltage loss, and diode VD8 to protect the circuit from incorrect load switching.

The voltage regulator of the negative arm will have an identical structure with some changes. Since the stabilizer circuit will operate on a negative voltage, it is necessary to use the LM337 stabilizer chip, which is analogous to the LM317 chip for working with negative voltage [7; 8].

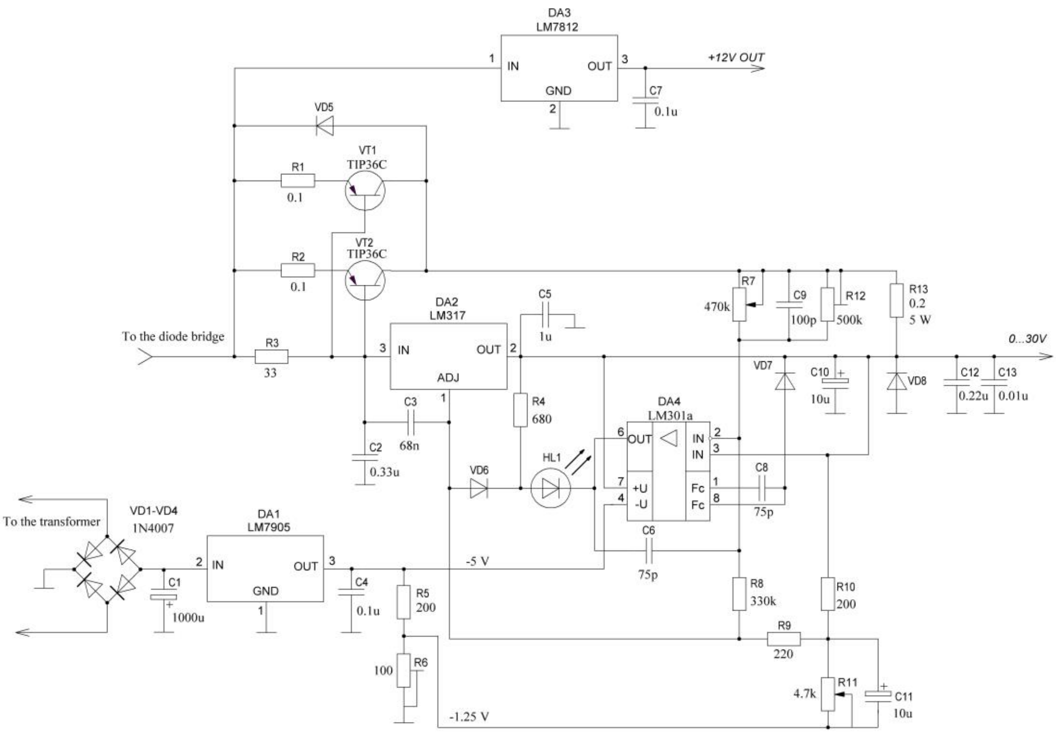



**Fig. 2 Diagram of the voltage stabilizer of the positive arm**

The current amplification transistors TIP36C P-N-P structure must be replaced by their analogs N-P-N structure, ie transistors TIP35C. Capacitors C1, C10, C11 and diodes VD5, VD8 should be switched on with opposite polarity, instead of the DA1 chip LM7905, its analog for positive voltage LM7805 will be used, the voltage from the diode bridge VD1...VD4 will be removed from the opposite arm. In addition, the negative arm circuit does not have a cooler power supply, since one cooler can be used to cool four transistors. The main difference from the positive arm circuit is the current stabilizer DA4. The LM301a can operate normally only when there is a positive voltage at its inputs. To work with a negative voltage, the op amp must be replaced with an LM358n. In the negative-arm circuit, the voltage from the output of DA1 will be positive and will be 5 V. It will be fed to the 8th input of the operational amplifier DA4, and the voltage from the output of the power supply must be fed to the 4th input. In addition, the LED HL1 and diode VD6 must be connected with the anode to pin 1 of the operational amplifier. This is due to the fact that now the voltage regulator chip DA2 will be closed by a positive voltage. The voltage regulator circuit of the negative arm is shown in Figure 3.

The development involves equipping the power supply with a short-circuit protection circuit. The protection circuit is a current stabilization unit on the operational amplifier. Since the stabilizer operates on the principle of current limitation, in case of a short circuit at the output, the output current will not exceed the value set by resistors R13, R16 (Figure 3). The advantage of a power supply with this type of protection over circuits that disconnect the load in the event of a short circuit is that it can be used to find short circuits in circuits for heating a faulty cell and for charging batteries of various types [10]. The complete electrical schematic diagram is shown in Figure 3.

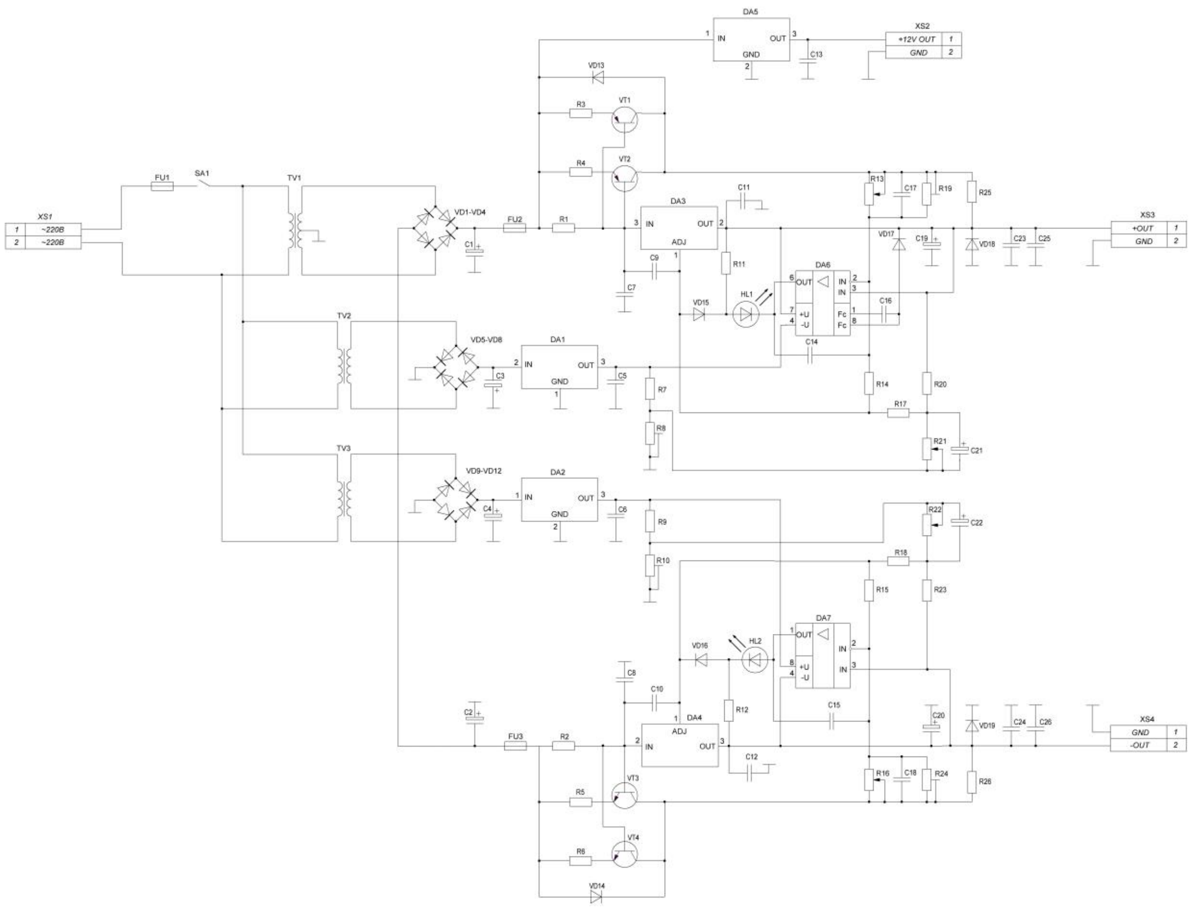



**Fig. 3 Proposed scheme of the device**

Now let's calculate a mains toroidal transformer with the following parameters: mains voltage 220 V / 50 Hz; secondary winding voltage = 48 V with output from the midpoint; load current = 5 A. We determine the power of the secondary winding by formula (2) and the overall power of the transformer by (3). All further calculations were performed according to the methods given in [12; 13].

$$P_{out} = U_l \cdot I_l = 48 \cdot 5 = 240 \text{ (W)}. \quad (2)$$

$$P_o = \frac{P}{\eta} = \frac{240}{0{,}94} = 255{,}3 \text{ (W)}, \quad (3)$$

where $\eta$ – the efficiency of the magnetic circuit for a transformer of this power is taken to be 0.94.

We select a magnetic circuit OL 65/110-30, the overall power of which is 318 W. Determine the actual steel cross-section at the location of the coil by formula (4), the calculated steel cross-section of the magnetic circuit by (5), and the actual cross-sectional area of the core window by (6):

$$S_{ssc} = \frac{D-d}{2} \cdot h = \frac{11-6{,}5}{2} = 6{,}75 \text{ (cm}^2\text{)}, \quad (4)$$

$$S_{ssm} = \frac{\sqrt{P_0}}{1.2} \cdot h = \frac{\sqrt{255{,}3}}{1.2} = 13{,}3 \text{ (cm}^2\text{)}, \quad (5)$$

$$S_{cw} = \frac{d^2 \cdot \pi}{4} = \frac{6{,}5^2 \cdot 3{,}14}{4} = 33{,}2 \text{ (cm}^2\text{)}, \quad (6)$$

where D, d, h –appropriate dimensions of the transformer magnetic circuit.

Determine the value of the rated current of the primary winding using formula (7):

$$I_1 = \frac{P_{out}}{U_1 \cdot \eta \cdot \cos\varphi} = \frac{240}{220 \cdot 0{,}94 \cdot 0{,}94} = 1{,}23 \text{ (A)}. \quad (7)$$

where $\cos\varphi$ is taken equal to 0.94 for a transformer of a given capacity.

We determine the wire cross-section for the primary and secondary windings using formula (8):

$$S_{w1} = \frac{I_1}{J} = \frac{1{,}23}{3{,}5} = 0{,}35 \text{ (mm)}, \tag{8}$$

$$S_{w2} = \frac{I_2}{J} = \frac{5}{3{,}5} = 1{,}43 \text{ (mm)}. \tag{9}$$

where J – is the current density for a given transformer capacity, taken to be 3.5.

Determine the wire diameter for the two windings without taking into account the insulation thickness using formulas (10) and (11):

$$d_{w1} = 1{,}13 \cdot \sqrt{S_{w1}} = 1{,}13 \cdot \sqrt{0{,}35} = 0{,}67 \text{ (mm)} \tag{10}$$

$$d_{w2} = 1{,}13 \cdot \sqrt{S_{w2}} = 1{,}13 \cdot \sqrt{1{,}43} = 1{,}35 \text{ (mm)} \tag{11}$$

Determine the number of turns of wire in the primary and secondary windings of the transformer using formulas (12) and (13):

$$w_1 = 45 \cdot \frac{U_1 \cdot \left(1 - \frac{U'}{100}\right)}{B_{\max} \cdot S_{ssc}} = 145 \cdot \frac{220 \cdot \left(1 - \frac{3{,}5}{100}\right)}{1{,}65 \cdot 6{,}75} = 858 \tag{12}$$

$$w_2 = 45 \cdot \frac{U_2 \cdot \left(1 - \frac{U'}{100}\right)}{B_{\max} \cdot S_{ssc}} = 45 \cdot \frac{48 \cdot \left(1 - \frac{3{,}5}{100}\right)}{1{,}65 \cdot 6{,}75} = 188 \tag{13}$$

where $U'$ - the voltage drop across the winding, expressed as a percentage of the nominal value, is taken to be 3.5 for a given transformer capacity; $B_{\max}$ – the maximum value of magnetic induction for a given power, is taken to be 1.65. The midpoint should be obtained halfway through the secondary winding, i.e. after 94 turns. Let's determine the number of turns of the secondary winding per 1 V of voltage using formula (14):

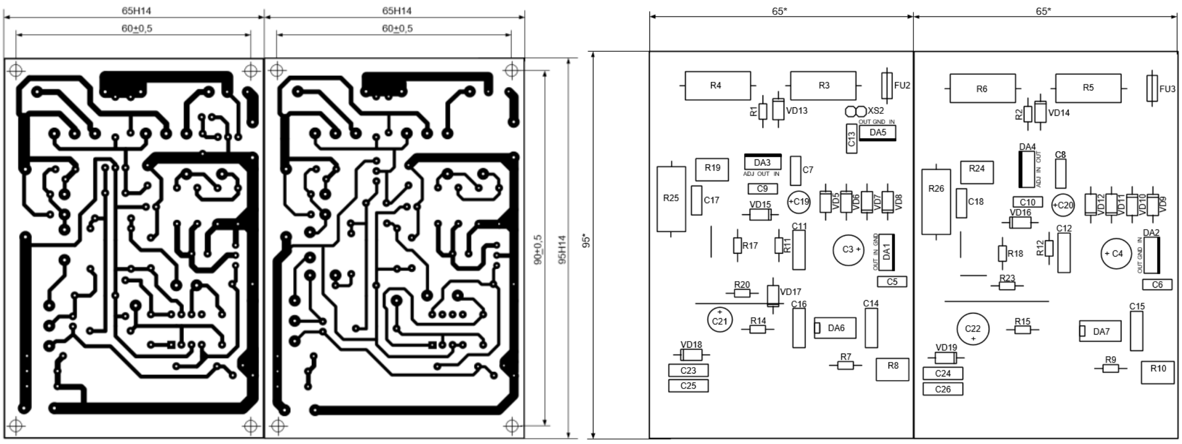
$$w_0 = \frac{w_2}{U_2} = \frac{188}{48} = 3{,}92 \tag{14}$$

Let's determine the maximum power that a magnetic circuit is capable of delivering using formula (15):

$$P_{out} = \frac{B_{\max} \cdot J \cdot K_w \cdot K_s \cdot S_{ssc} \cdot S_{sw}}{0{,}901} = \frac{1{,}65 \cdot 3{,}5 \cdot 0{,}27 \cdot 0{,}88 \cdot 6{,}75 \cdot 33{,}2}{0{,}901} = 341 \text{(W)} \tag{15}$$

where $K_w$ – window filling factor, taken equal to 0.27 for a given capacity; $K_s$ – is the coefficient of filling of the magnetic circuit with steel, taken equal to 0.88 for a given thickness of the magnetic circuit steel.

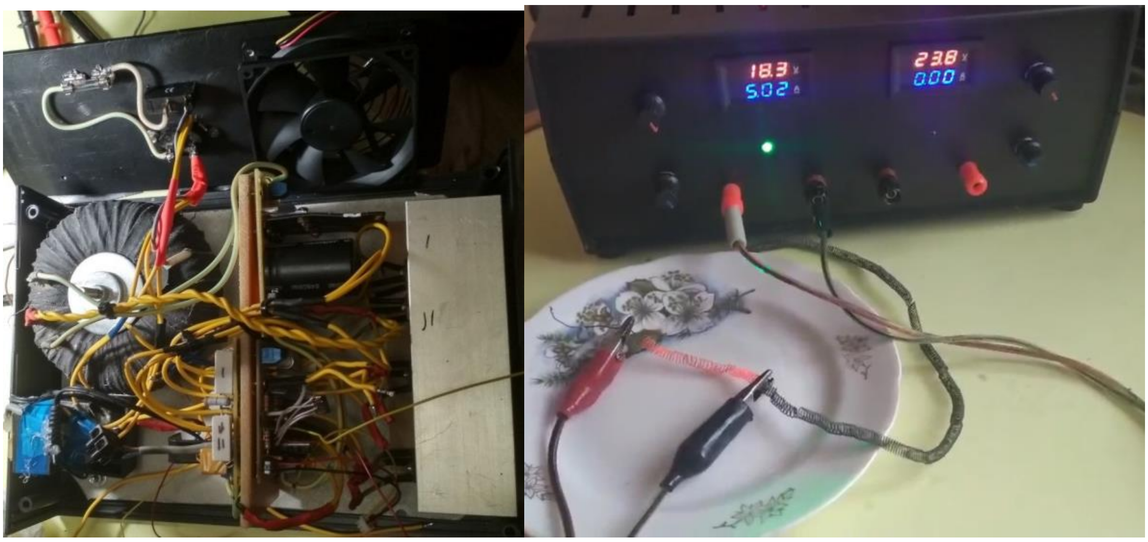
To assemble the model of the device, a printed circuit board and assembly drawings were developed, the result is shown in Figure 4 (a, b).




**a)** **b)**

**Fig. 4 Circuit board a), assembly drawing b)**

The assembled device is shown in Figure 5, with an inside view (a) and a view of the front panel with voltammeters and voltage and current control knobs (b) and with a load connected. The voltage regulator in the laboratory power supply is designed to regulate the output voltage and maintain its set point when the input voltage or load resistance changes.



**a)** **b)**

**Fig. 5 View of the model from the inside (a), view of the control panel with the load connected (b)**

The tests were performed separately for each channel, the output voltage was set to 15 V for the positive channel and -15 V for the negative channel. An ammeter is connected to the load in series, and a DC voltmeter is connected in parallel to eliminate the error of the output indicators. The purpose of the load characteristic is to show the dependence of the output voltage on changes in load resistance. The ideal load characteristic looks like a straight line, but in real voltage regulators, with an increase in current at the load, there will always be a drawdown, the value of which is influenced by many factors. The load characteristic is built on the basis of eleven readings taken at different load impedances. The data obtained during the study are shown in Table 1.

Table 1

**Results of the study of the voltage stabilizer**

| $I_l$, A | 0 | 0,5 | 1 | 1,5 | 2 | 2,5 | 3 | 3,5 | 4 | 4,5 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| + $U_{out}$, B | 15 | 15 | 15 | 15 | 15 | 14,9 | 14,9 | 14,9 | 14,9 | 14,9 | 14,9 |
| - $U_{out}$, B | 15 | 14,7 | 14,2 | 13,9 | 13,4 | 13,2 | 13,1 | 12,9 | 12,7 | 12,5 | 12,4 |

The results show that the positive channel drop when the load resistance changes is ≈ 100 mV. This value is quite satisfactory. The negative channel drop at the maximum current is ≈ 2.5 V. This value is quite significant. Taking into account the constructive and functional identity of the voltage regulator circuit in both channels, this may be due to the loss of capacitance of the capacitor of the input filter of the negative arm, or to the lack of elements in the negative voltage stabilization circuit (LM337, TIP35C power transistors). You can compensate for this by adjusting the output voltage with the variable resistor knob after connecting the load or its equivalent.

The purpose of a current limiting stabilizer is to set a current limit at the output of the power supply, beyond which the output voltage will decrease in accordance with Ohm's law and the current will remain constant. To check the operation of the current stabilizer, set the output voltage of the power supply to ± 25 V, connect a load or its equivalent, and set the current limit to ≈ 1 A using the current control resistor knob. The data on the dependence of the load current on the decrease in load resistance with the corresponding output voltage for both channels are shown in Table 2.

Table 2

**Results of the study of the current stabilizer**

| $R_l$, Om | 20 | 18 | 16 | 14 | 12 | 10 | 8 | 6 | 4 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| + $U_{out}$, V | 20,8 | 18,6 | 16,1 | 14,1 | 11,7 | 9,6 | 7,8 | 5,9 | 4 | 1,7 | 1,6 |
| + $I_l$, A | 1,02 | 1,02 | 1,02 | 1,02 | 1,02 | 1,02 | 1,02 | 1,02 | 1,02 | 1,17 | 2,25 |
| - $U_{out}$, V | 21,7 | 19,2 | 16,8 | 14,7 | 12,3 | 10,1 | 8,3 | 6,3 | 4,3 | 1,6 | 1,2 |
| - $I_l$, A | 1,04 | 1,04 | 1,05 | 1,05 | 1,06 | 1,06 | 1,06 | 1,07 | 1,08 | 1,09 | 1,87 |

From the data obtained, it is clear that the current stabilizers of both channels operate stably at a load resistance of >2 Ohms. With a further decrease in resistance, the current begins to increase disproportionately and, at a short circuit at the output, reaches ≈ 6...7 A, slightly depending on the position of the variable current limiting resistor knob. This may be due to the use of LM317 (LM337) as regulating elements amplified by bipolar transistors. You can get better control over the output current at all load resistance values in stabilizer circuits where the regulating elements are bipolar transistors. This should be taken into account when using the power supply to find short circuits in low-power circuits, in which case an additional load of 2 ohms or more should be applied in series with the circuit under test.

## Conclusions

In this work, a linear laboratory power supply was developed, with current and voltage stabilization and short-circuit protection, the voltage is adjustable within 0-30 V, the maximum current is 5 A, a radiator and a fan are used for cooling. The toroidal transformer, which can be considered the main element of the device, was calculated. Printed circuit boards and a model of the device were developed. Experimental studies have shown the efficiency of the design, but there is a possibility of improving the scheme. The development is considered successful and is proposed for use.

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