

ELECTRONIC MODULE FOR OSCILLOGRAPHY OF THE CHARACTERISTICS OF ELECTRONIC SEMICONDUCTOR COMPONENTS AND SENSORS

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Abstract

When designing electronic circuits, it is extremely important to know the actual characteristics of electronic components (diodes, transistors, zener diodes, Hall sensors, magnetotransistors, etc.). This is due to the fact that there are tolerances in the parameters of electronic semiconductor components. These tolerances are reflected in the catalog data of the components as an interval of values, and not as a specific value for a specific component. When designing electronic circuits and developing prototype electronic blocks, it is good to conduct tests on each component to show its individual characteristics. There are devices on the market that allow for oscillography of the characteristics of electronic components. In many cases, however, they are very expensive or are inaccessible to a wider range of designers and developers of electronic circuits.

This report proposes and describes a real electronic module that allows oscillography of the characteristics of most electronic semiconductor components and some types of sensors using a standard two-channel oscilloscope. A block diagram, a schematic electrical diagram, diagrams reflecting the principle of operation, sample measurements, and a photo of the developed module are presented.

Keywords: Semiconductor electronics components, Research of semiconductor elements, Chartwrite device, automation measurement system, DAQ – system, galvanomagnetic sensors, discrete sensors.

Абстракт

При проектирането на електронни схеми е от изключително значение да се познават действителните характеристики на електронните компоненти (диодни, транзистори, стабилитрони, сензори на Хол, магнитотранзистори и др.). Това се налага от факта, че съществуват толеранси в параметрите на електронните полупроводникови компоненти. Тези толеранси се отразяват в каталожните данни на компонентите като интервал от стойности, а не като конкретна стойност за конкретен компонент. При проектирането на електронни схеми и при изработването на прототипни електронни блокове е добре да се проведат тестове на всеки компоненти, които да покажат индивидуалните му характеристики. На пазара съществуват устройства, които дават възможност за осцилографиране на характеристиките на електронни компоненти. В много случаи, обаче, те са на много висока цена или са недостъпни за по-широк кръг проектантите и разработчиците на електронни схеми.

В настоящия доклад е предложено и описан реален електронен модул, позволяващ осцилографиране на характеристиките на повечето електронни полупроводникови компоненти и някои видове сензори чрез стандартен двуканален осцилоскоп. Представени са блокова схема, принципна електрическа схема, диаграми, отразяващи принципа на работа, примерни измервания и снимка на разработения модул.

INTRODUCTION

The development of electronic technology is mostly determined by the development and improvement of methods and means for obtaining measurement information [2, 3, 14, 16, 18].

There are various types of automated measurement devices and methods, one of which is the characteristic graph [4, 5, 12, 13, 15, 17]. They allow for recording the characteristics of various types of electronic

components, thereby facilitating their research [1, 8, 9].

And automated testing of electronic semiconductor components would lead to improved accuracy of their characteristics and parameters. Capturing static characteristics in laboratory conditions is a laborious process, associated with increased attention from the operator, requirements for ambient temperature, stability of power supplies and, finally, the time for which the meas-

urement is carried out [6, 7]. The purpose of this work is to present an alternative electronic module, enabling the display (oscillography) of the static characteristics of electronic semiconductor components and sensors (without a built-in signal pre-processing circuit) using a standard two-channel electronic oscilloscope.

WORKING PRINCIPLE. BLOCK DIAGRAM

Capturing the characteristics of electronic semiconductor components using classical schemes and methods [3, 17] is a laborious process, the accuracy of which depends on various factors such as ambient temperature, accuracy of measuring instruments and signal sources, accuracy of setting by the operator, etc. As a disadvantage of classical methods, the need for many measuring instruments can be noted. They must be of the same type and accuracy class. Signal sources are required, and finally is the time for performing the tests. To improve the accuracy of the test, it is necessary to capture more points of the characteristic, which extends the measurement time. This leads to an increase in the temperature of the sample tested and a change in its parameters. All this is avoided when using more modern methods for capturing static conversion characteristics [4, 11, 12].

A block diagram of the developed module, allowing oscillography of the static characteristics of semiconductor electronic components and some types of sensors, is presented in Fig. 1. The main block in the circuit is a sawtooth voltage generator (SVG) that produces negative or positive pulses depending on the type of the element under study (diode, NPN or PNP transistor, N-MOSFET or P-MOSFET, Hall element, magnetotransistor or magnetoresistive bridge, etc.) with an amplitude $U_{GEN}=10V$. This voltage is amplified by a current amplifier so as not to load the generator. The amplified sawtooth signal is fed to the power electrode of the element under study and

simultaneously fed to the horizontal scan channel (X) of the oscilloscope. To control the vertical scan, the signal received from the amplifier output is converted into voltage by the current-voltage converter (CVC) and fed to input Y of the electronic oscilloscope. The converter is equipped with a current limiter that limits the supply current ($I_s \leq 40mA$). This protects the amplifier and the measured component from damage.

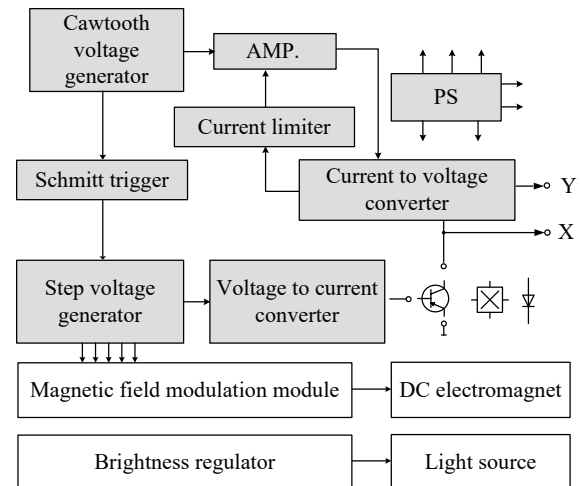


Fig. 1. Block diagram of an electronic module for oscillography of the characteristics of electronic semiconductor components

A positive gate pulse is supplied to the Schmitt trigger from a sawtooth voltage generator (SVG), which serves to control the step voltage generator (SVG), which creates the control current through the voltage-current converter (VCT). After each straight stroke of the sawtooth cut, the supply voltage (U_s) and supply current (I_s) parameters change. As a result of the overall measurement on the oscilloscope screen, a family of characteristics is obtained. To stabilize the resulting image, the SVG frequency is selected $F_{GEN}=500Hz$.

The schematic diagram of the developed module is presented in Fig. 2. SVG consists of an integrator (IC2) and a comparator (IC1). Depending on the position of the switch SW2, the output sawtooth voltage has a positive or negative polarity ($+U_{GEN}$, $-U_{GEN}$). It is fed to the amplifier block. It is a

complementary emitter follower, implemented with transistors VT1 and VT2. The potentiometer RP1 determines the voltage amplitude, which is directly related to the distance from each other of the curves in the family of characteristics on the oscilloscope screen. The CVC implemented by integrated circuit IC3 operates in subtraction mode, amplifying the voltage drop across the measuring resistor R1 by 10 times. For the output voltage, which is fed to the Y input of the oscilloscope, we can write:

$$U_{OIIIIT} = U_Y = k \cdot R1 \cdot I_S \quad (1)$$

where: k – gain coefficient; R1 – value of the measuring resistor, I_S – magnitude of the supply current (not more than 40mA). Transistors VT3 and VT4 provide current limitations. The voltage coefficient for the horizontal scan U_X is adjusted internally by the trimmer potentiometer RP4.

By means of potentiometer RP2, a load line is plotted in the field of the characteristic family (when studying transistors and magnetotransistors). The change in the voltage drop across R1 causes a proportional change in the supply current I_S . The voltage drop across resistor R1 is subtracted from the sawtooth voltage, and the resulting difference is fed to the measured sensor as voltage U_S (for Hall elements and magnetoresistors, photoresistors, phototransistors) or U_{CE} (for magnetotransistors). Increasing the collector current through potentiometer RP2 leads to a decrease in the maximum value of the voltage U_{CE} :

$$U_{CEM} = U_{IITHM} = RP2 \cdot I_{CM} \quad (2)$$

The display field on the abscissa of the obtained characteristics decreases in proportion to the magnitude of the ordinate. The load line is obtained by mentally connecting the end points of each displayed characteristic, as is usually drawn when determining the operating mode of a simple bipolar transistor. The Schmitt trigger, im-

plemented with discrete elements (transistors VT5, VT6 and resistors R29-R31) can be controlled in two ways depending on the position of the SW5 switch. To obtain a family of characteristics, the Schmitt trigger is controlled by SVG through the diode D9. When activated by pressing the SW4 button, only one conversion characteristic is displayed on the oscilloscope screen. Each time the button is pressed, the next characteristics of the family are displayed on the oscilloscope screen one by one, and the previous ones are extinguished.

The step voltage generator is implemented with a TTL decimal counter SN7490. The resistor matrix connected to its outputs provides different output voltage levels for each incoming control pulse from the Schmitt trigger, thus obtaining a step-changing voltage. The division factor is finely adjusted with trimmer potentiometers RP10, RP11, RP12 and RP13 so that the output voltage is proportional to the current combination of the Q-outputs of the integral counter. After the resistor matrix, the step voltage UCT is obtained, it is converted into a step current from VCC. When the switch SW2 is in position 1, the operational amplifier IC4 operates as a non-inverting one. Its output voltage U_3 is determined by the difference between the input voltages U_4 and U_{CT} . Integrated circuit IC5 operates in a negative current feedback circuit. The output voltage U_4 , obtained from the amplifier IC5, when studying magnetotransistors or photoresistors is calculated by the expression:

$$U_4 = (U_3 - U_5) K_{OY5} = I_{Btest} [(R_2 + R_{ib} + r_1) - r_1] K_{OY5} \quad (3)$$

where: K_{OY5} – value of voltage gain; $r_1 = r_{BB} + \beta r_e$ – input resistance of the tested element. At $U_{CT} = U_4$ for the base current of the magnetotransistor I_{BTEST} we obtain:

$$U_{CT} = I_{Btest} (R_2 + RP6) K_{OY5}, \quad (4)$$

$$I_{BTEST} = U_{CT} \cdot \frac{1}{K_{OY5}} \cdot \frac{1}{R_2 + RP6} \quad (5)$$

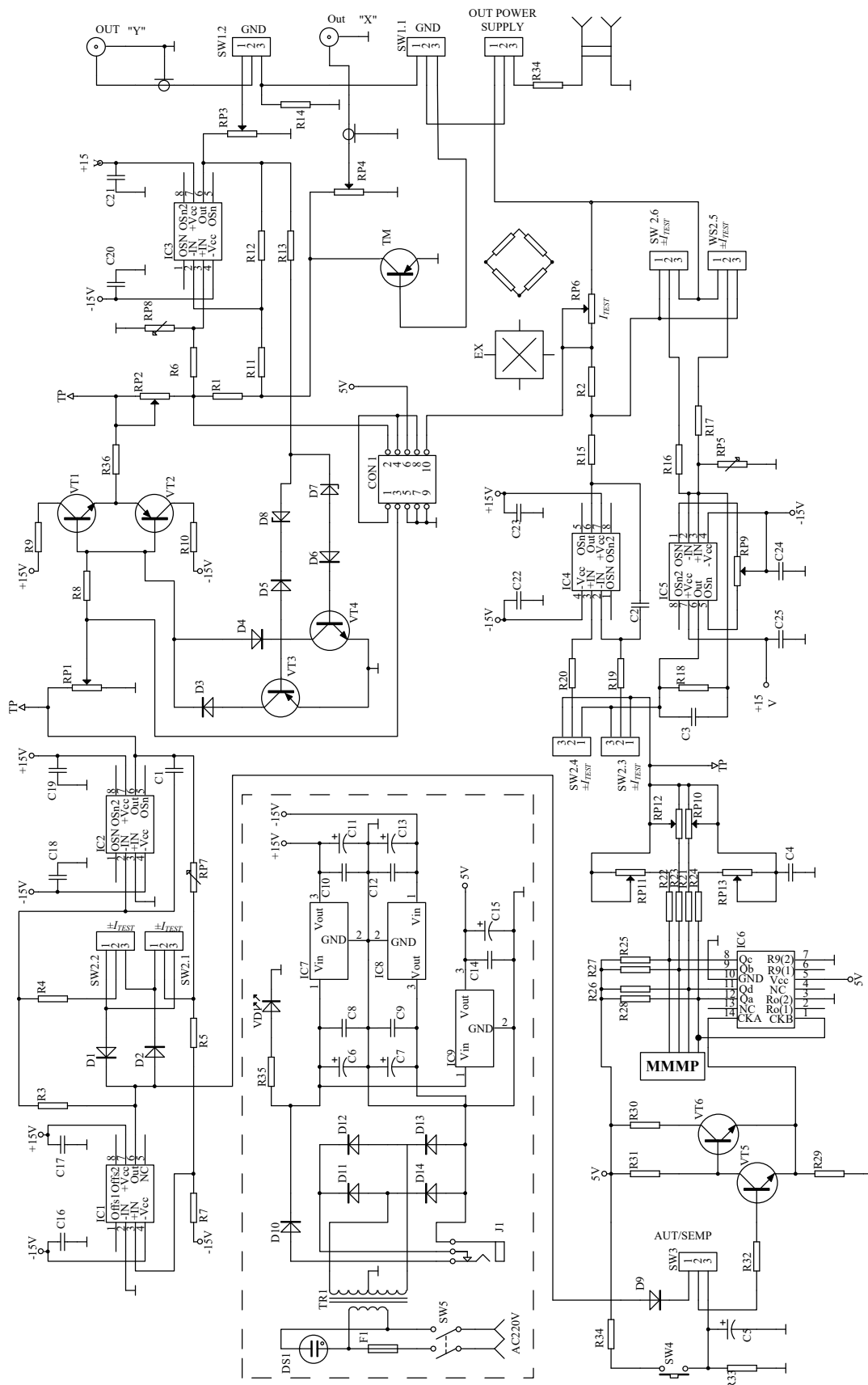


Fig. 2. Schematic diagram of an electronic module for oscillography of the characteristics of electronic components

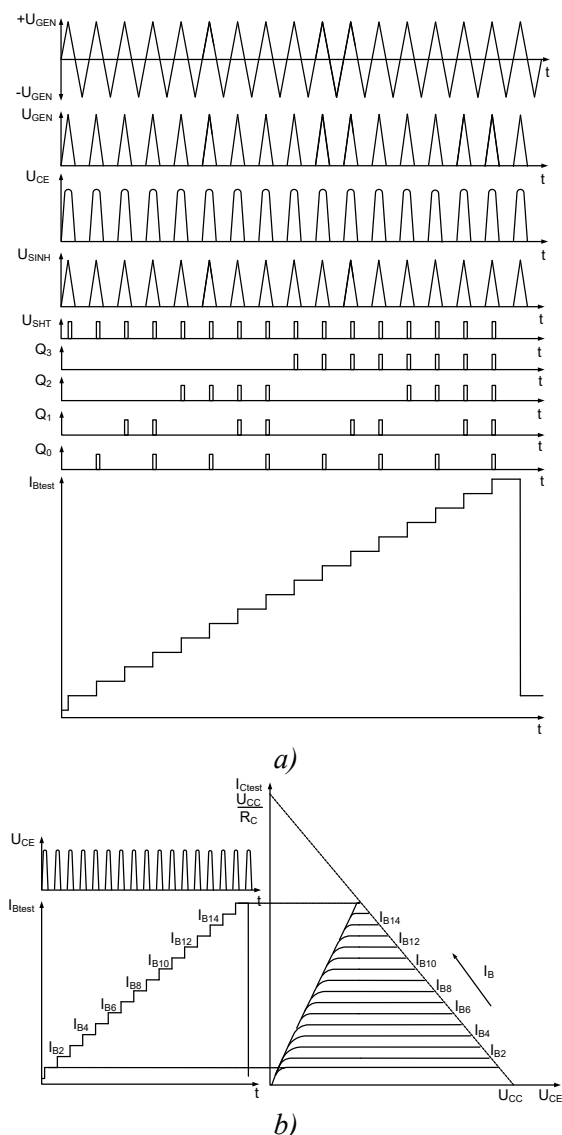
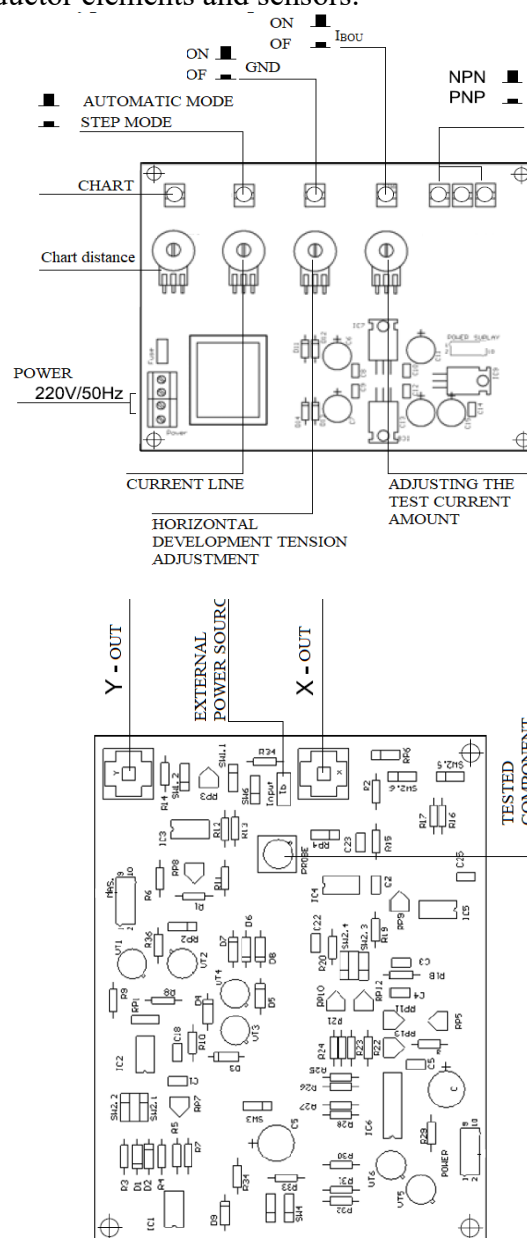


Fig. 3. Timing diagrams at the control points of the circuit (a) and conversion characteristics of an experimental magnetotransistor

Therefore, the control current I_{BTEST} is proportional to the step voltage and inversely proportional to the sum of the resistances $R_2 + RP_6$. The amplitude of the control current is adjusted by potentiometer RP_6 . The switch SW_6 determines where the control current is supplied from. The multi-channel switch SW_2 swaps the non-inverting inputs of IC_4 and IC_5 with the inverting ones, and the resulting step current changes its polarity. The external current source is connected to the I_{BOUT} terminals of the circuit with the indicated polarity, and it is supplied to the

tested magnetotransistor through the I_{BOUT} button. The magnitude of the control current is measured when the "GND" button is turned on, and is displayed on the screen as a segment corresponding to voltage. The scale unit has a value $b_Y = 2V/m$.

Fig. 3 a and b present timing diagrams, at separate control points, describing the operation of the developed electronic module for automated recording of the conversion characteristics of electronic semiconductor elements and sensors.



The developed electronic module consists of two printed circuit boards (panels), shown in Fig. 4. The control elements for managing the operating modes during the study are located on them.

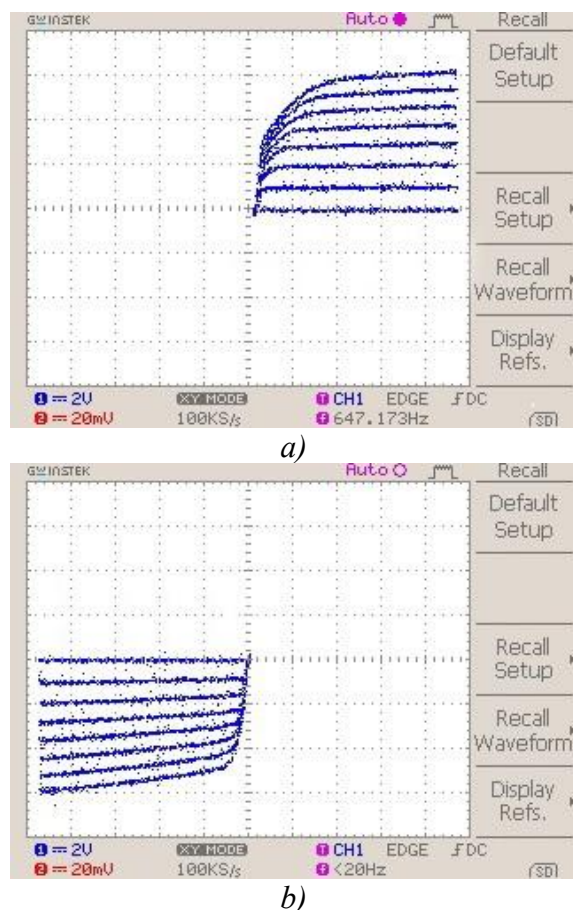


Fig. 5. Experimentally oscillographed output characteristics of NPN (a) and PNP (b) bipolar transistor

CONCLUSION

An electronic module for oscillography of the characteristics of electronic semiconductor elements and sensors has been created. A block and schematic electrical diagram has been developed. Timing diagrams clarifying the principle of operation of the device are presented. The following capabilities should be noted for the developed device: 1. Regulation of the control current both from the built-in voltage-current converter and from the external DC source (I_{BOUT}). 2. Control of the load line of the studied components. 3. Regulation of the

distance of the characteristics is possible when controlling the current-voltage con

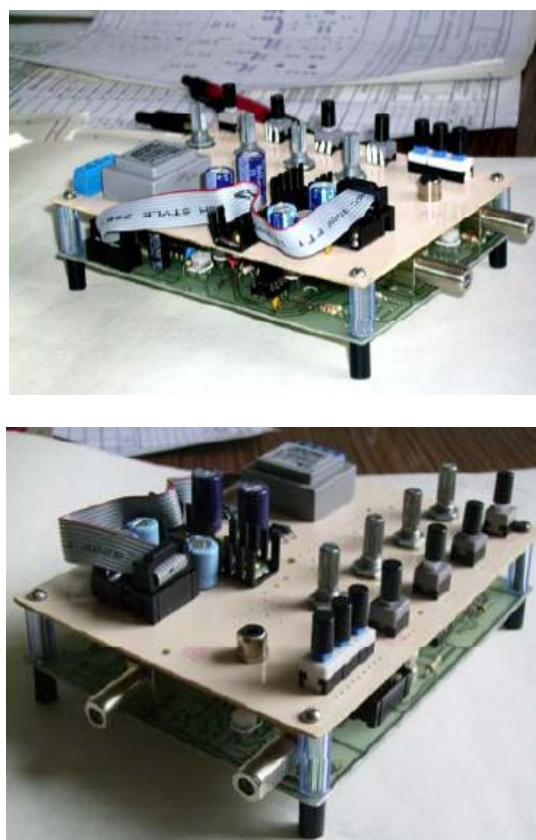


Fig. 6. Appearance of the developed electronic module

verter. 4. The step mode used for displaying the conversion characteristics is convenient when it is necessary to display only one characteristic from the entire family of characteristics. The designed device finds wide application both in education, practice and scientific research. With its help, various characteristics of electronic components and sensors can be captured, such as: input characteristics, volt-ampere characteristics, transient characteristics, output characteristics, the conversion characteristics of various types of discrete sensor components (optoelectronic and galvanomagnetic) through minimal change in the output circuits. The rapid display of the characteristics of the studied elements using only an electronic oscilloscope allows for application in various research laboratories and production centers.

Fig. 6 shows pictures of the developed electronic module for oscillography of the characteristics of electronic components.

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