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EXPERIMENTAL RESEARCH AND COMPUTER SIMULATION OF MULTI-CASCADE COMPOSITE TRANSISTORS FOR STABILIZING THE OPERATING MODE OF OUTPUT CASCADES OF RADIO ENGINEERING DEVICES

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Abstract

Experimental results and computer simulation of multi-stage composite transistors are presented. To study the volt - ampere characteristics of multistage composite transistors, a dialogue computer simulation program, the Delphi programming environment, has been developed. It is shown that the proposed multistage composite transistors can improve manufacturability in its industrial production. It is shown that multistage homostructure transistors according to the Darlington and Shiklai circuits operate stably at collector-emitter voltages five times higher than in the case of individual transistors. The power dissipated on the collector is 3 times higher than the rated value of the maximum permissible power of the composite transistors. It is established that the efficiency of the method of stabilizing the emitter current of a three-link homostructure transistor is 7 times higher in voltage and three orders of magnitude higher in temperature compared to a conventional composite transistor. The proposed homostructure transistors are designed to operate in terminal stages of power amplifiers, radio transmitting devices, electronic equipment of industrial and automotive electronics.

Key words: *radio engineering devices, homogeneous, according to Darlington's scheme, according to Shiklai's scheme, multistage composite transistors, volt-ampere characteristic, output stages, power amplifiers, Delphi programming environment, quiescent current stabilization.*

Introduction

The output stages of radio devices are in the process of constant modernization. At the same time, it is important to maintain the unity of the scientific approach to the design of radio devices. In particular, research and development of a highly stable elemental base based on new physical processes occurring in electronic devices is relevant. In this case, it becomes possible to build a whole host of new circuitry solutions.

The circuitry of analog electronic devices, in addition to the direct task of implementing a specific system function, solves the problem of ensuring the stability of a radio device under external factors, such as uncontrolled changes in ambient temperature, supply voltage, load resistance, and other disturbing influences. The task of compensating for the effects of these disturbances is especially acute when creating power amplifiers. Uncontrolled disturbances change the quiescent currents of bipolar transistors, change the electrical and thermal modes of their operation, which is unacceptable for class A, B, and AB power amplifiers, as this causes a number of negative consequences, such as an increase in the coefficient of nonlinear distortion, a change in the gain, which can lead to degradation of bipolar transistors due to thermal instability and thermal breakdown. For this reason, the issue of stabilizing the idle mode of bipolar transistors is relevant when creating powerful output stages of radio engineering devices.

In the output stages of radio devices implemented within the framework of traditional circuitry approaches, special attention should be paid to stabilizing the operating modes of transistors by direct current, namely, stabilizing the current and the resting voltage of the output transistors.

Experimental technique and results

When implementing power amplifier circuits, output transistors of the same type must be identical. This complicates the manufacture of circuits on discrete elements, and the integrated design causes great difficulties. To eliminate this problem, a circuitry solution is used in which the same type of output transistors are used. Therefore, homostructure transistors according to the Darlington circuit are replaced by the Sciclai circuit [1,2,3]. Figure 1 shows a diagram of a multistage homostructure transistor and its macromodel.

a) **b)**

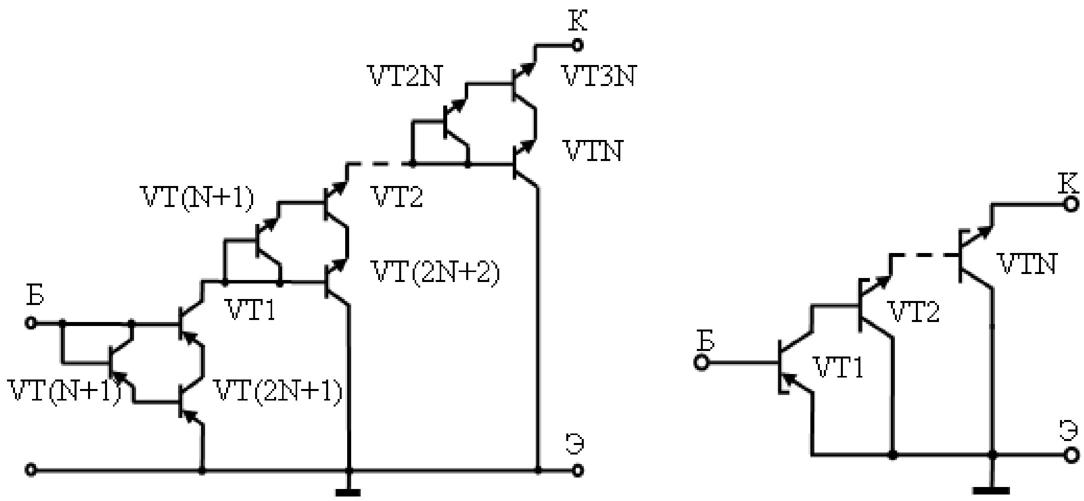


Fig. 1. A multistage homostructure transistor according to the Sciclai circuit (a) and its macro model (b).

The objective of the study is to first create a two-stage and multi-stage homogeneous bipolar transistor (Fig. 1.2) with increased stability while maintaining the current gain and speed.

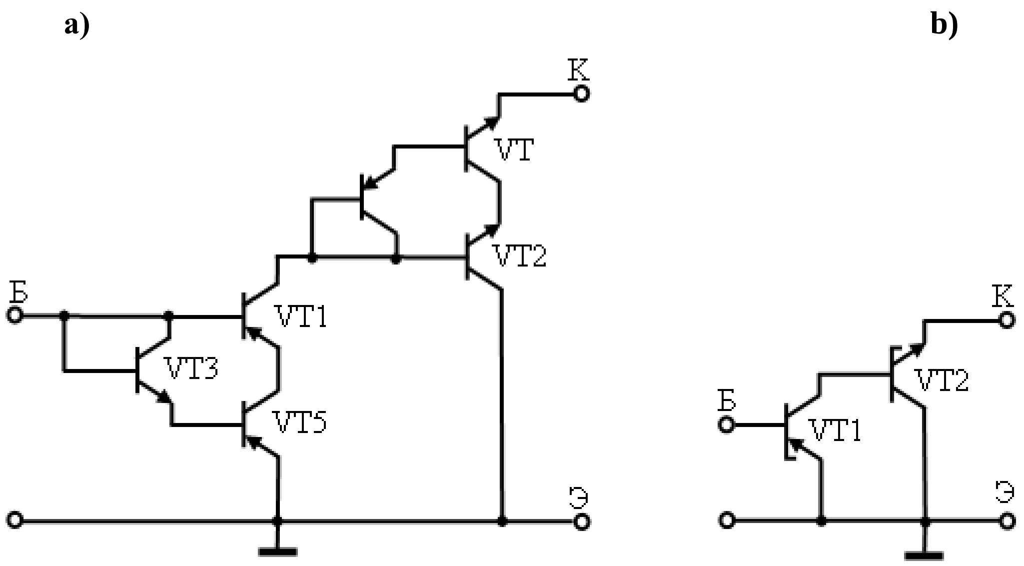


Fig. 2. Two-stage homostructure transistor according to Shiklai scheme (a) and its macro model (b).

Fig. 3 shows the switching circuit with a common emitter of a two-stage homostructure transistor according to the Shiklai circuit.

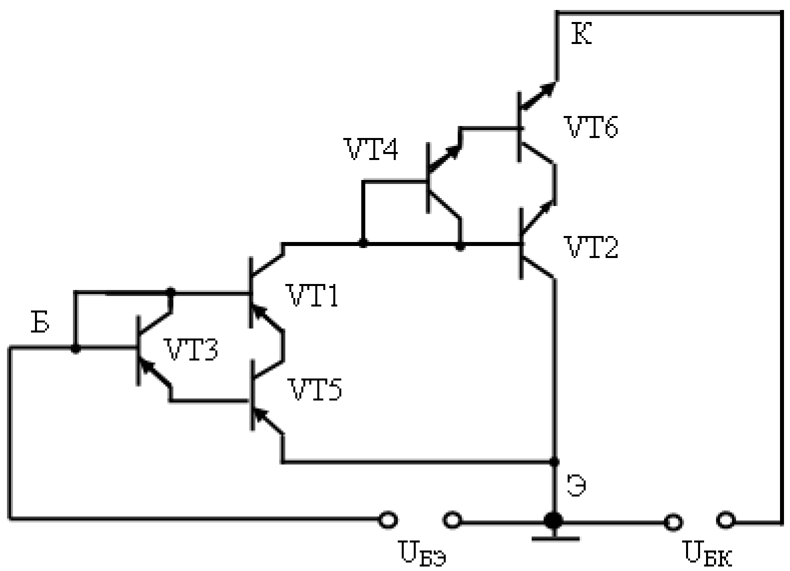


Fig. 3. Switching circuit with a common emitter of a two-stage homostructure transistor according to the Shiklai circuit.

A computer simulation of a multistage homostructure transistor according to the Shiklai scheme in the Delphi programming environment was performed, taking into account the technological parameters of drift transistors using transistors of the type KT 315G and KT361G (Fig. 3).

Figure 4 shows the calculation of the output characteristic of a multistage homostructure transistor for the following values of the parameters of the transistors and voltages U_{BE} : β_1=100; β_2=100; β_3=100; β_4=100; β_5=100; β_6=100; I_{K01}=1,719*10^{-9}mA; $b_{Э5}$= $b_{Э6}$ =31,56 B^{-1}; b_{K1}=31,56 B^{-1}; I_{E05}=1,719*10^{-9} mA; I_{E06}=1,719*10^{-9}mA ; U_{BE} : 1-0,9 V, 2-0,925 V, 3-0,95 V, 4-0,975 V, 5-1,0 V, 6- 1,025 V, 7-1,05 V, 8-1,075 V, 9-1,1 V and 10- 1,125 V.

Figures 5 and 6 show the calculated dependences of the currents I_E and I_B on the collector-emitter voltage U_{KE}, as well as in fig. 5 shows the calculated dependence of the base current I_B on the voltage of the base-emitter U_{BE} of a two-stage homotransistor according to the Shiklai scheme at constant values of U_{KE} = 10V.

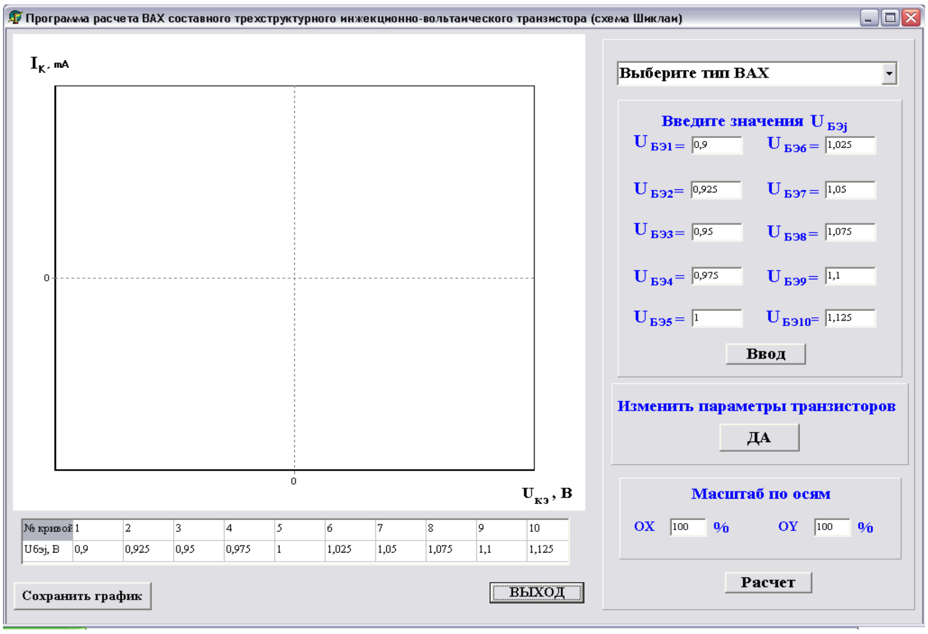


Fig. 5. Appearance of the user interface of the calculation program.

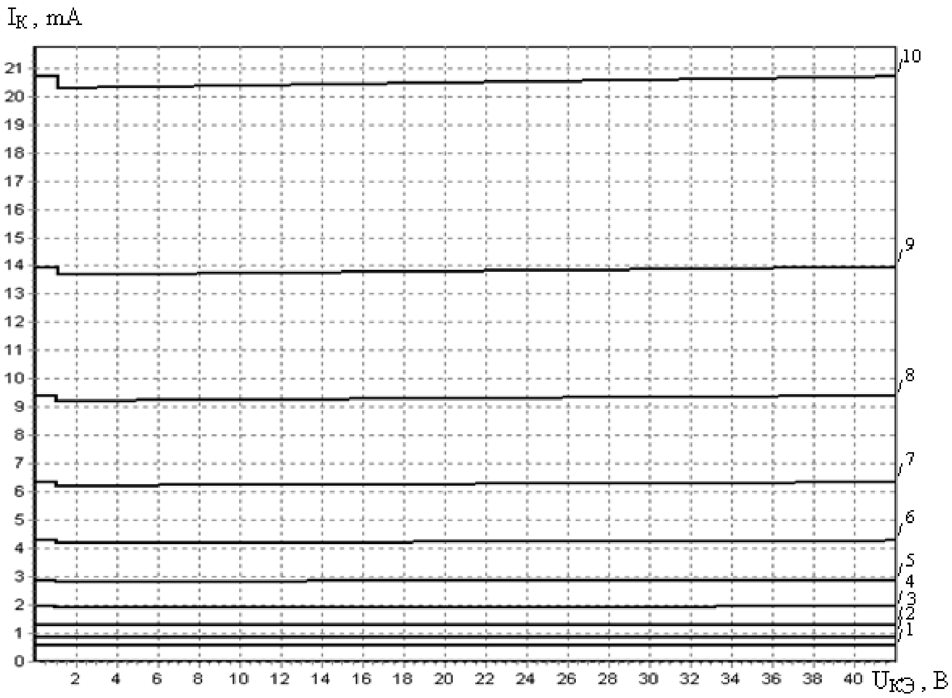


Fig. 6. The calculated dependence of the collector current I_K on the collector-emitter voltage U_{KE} of a two-stage homotransistor according to the Shiklai scheme with constant values of U_{BE} equal,

respectively: 1-0.9 V, 2-0.925 V, 3-0.95 V, 4-0.975 V, 5-1.0 V, 6-1.025 V, 7-1.05 V, 8-1.075 V, 9- 1.1 V and 10 - 1.125 V.

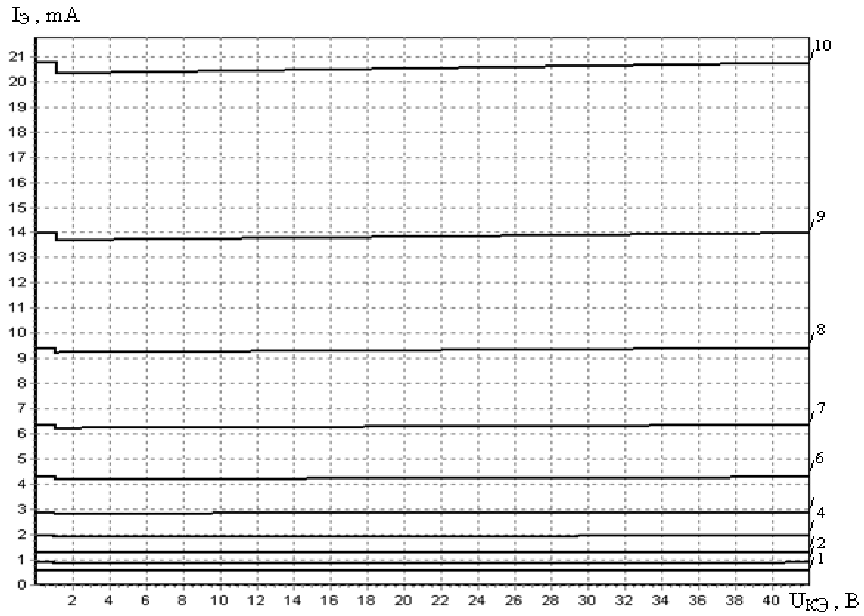


Fig. 7. The calculated dependence of the emitter current I_E on the collector-emitter voltage U_{KE} of a two-stage homotransistor according to the Shiklai scheme at constant values of U_{BE} equal, respectively: 1-0.9 V, 2-0.925 V, 3-0.95 V, 4-0.975 V, 5-1.0 V, 6-1.025 V, 7-1.05 V, 8-1.075 V, 9- 1.1 V and 10 - 1.125 V.

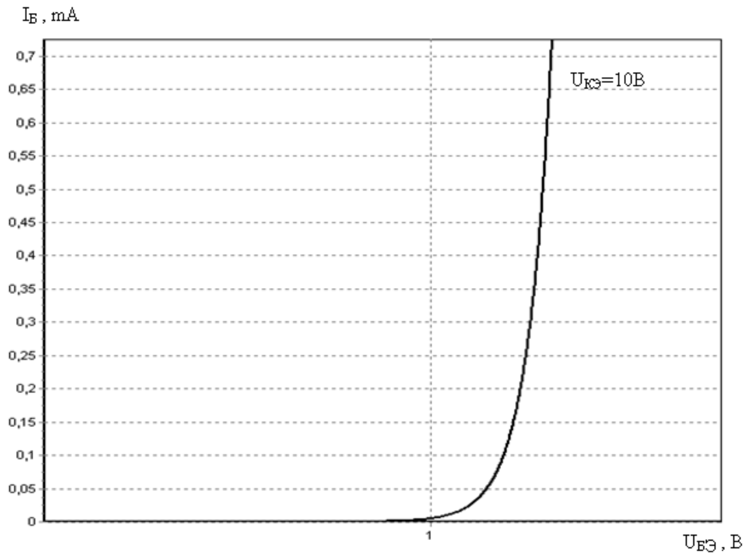


Fig. 8. The calculated dependence of the base current I_B on the voltage base-emitter U_{BE} of a two-stage homotransistor according to the Shiklai scheme at constant values of U_{KE} = 10V.

In fig. Figure 9 shows the experimental output statistical characteristics of a two-stage homostructure transistor according to the Shiklai scheme for given and constant values of U_{BE} of a composite bipolar transistor (1-7) based on KT315G and KT361G (VT1, VT2, VT3, VT4, VT5, VT6, VT7): 1-0 9 V, 2-0.95 V, 3-1.0 V, 4-1.05 V, 5-1.075 V, 6-1.1 V and 7-1.125 V.

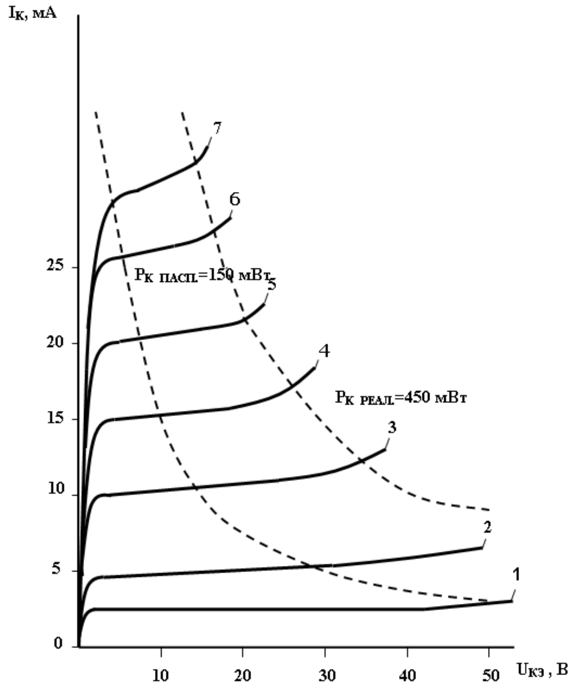


Fig. 9. Experimental output statistical characteristics of a two-stage homostructure transistor according to the Shiklai scheme.

In fig. 10–12 shows the I – V characteristics of a high-current three-stage homostructure transistor according to the Shiklai circuit. Simulation of the operation of a homogeneous transistor according to the Shiklai scheme was carried out using Multisim 10.1. Silicon BT grades were used for modeling: 1-cascade 2N3702 p-n-p structures; 2-stage BD139 and 3-stage ZTX869 n-p-n-structure.

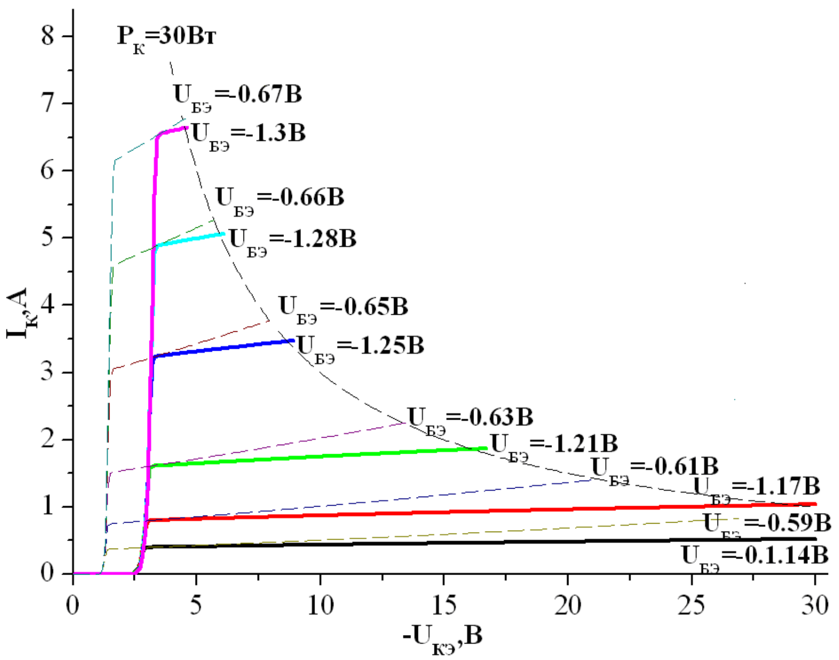


Fig. 10. The results of a computer simulation of the dependence of the collector current I_K on the

collector-emitter voltage of the U_{KE} at constant values of U_{BE} of a three-stage homogeneous component (solid lines) and a single (dashed line) transistor according to the Shiklai scheme.

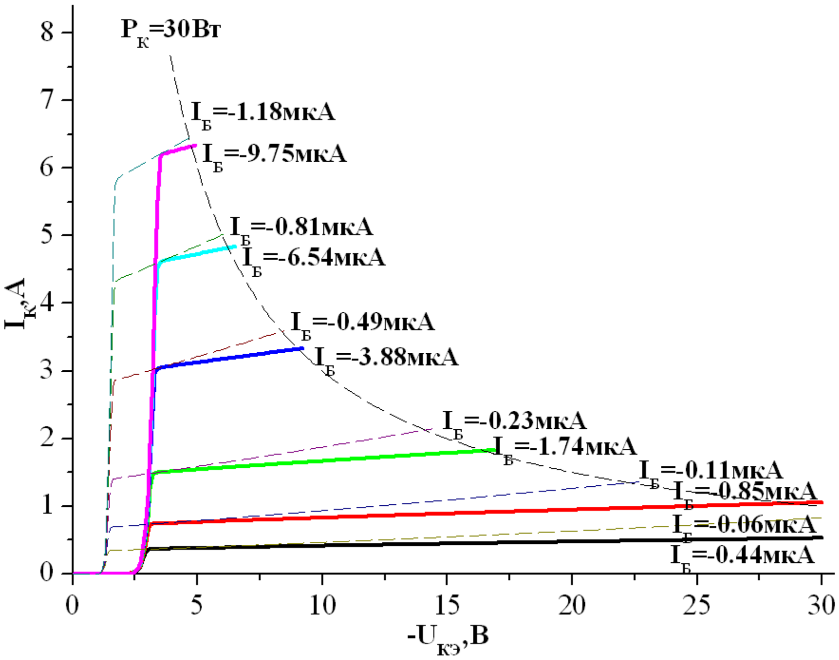


Fig. 11. The results of a computer simulation of the dependence of the collector current I_K on the collector-emitter voltage U_{KE} at constant values of I_B of a three-stage homogeneous component (solid lines) and a single (dashed line) transistor according to the Shiklai scheme.

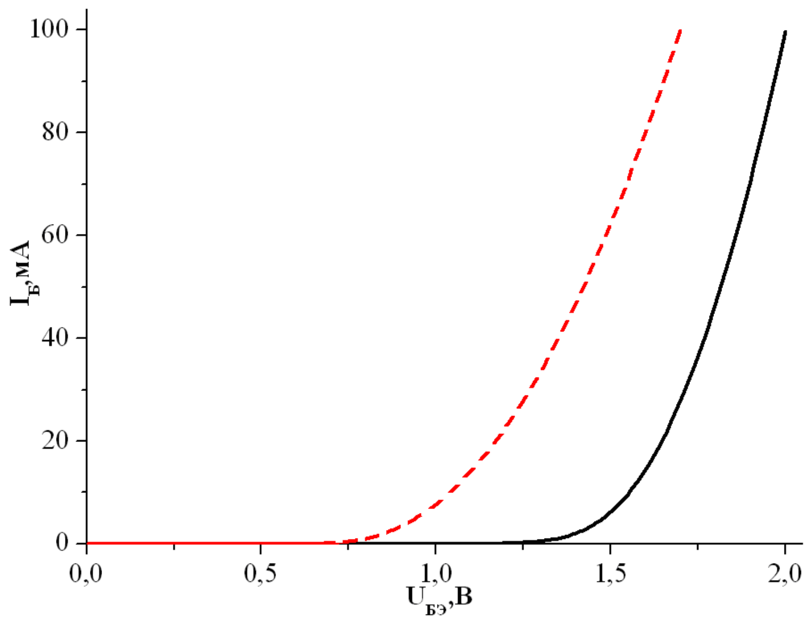
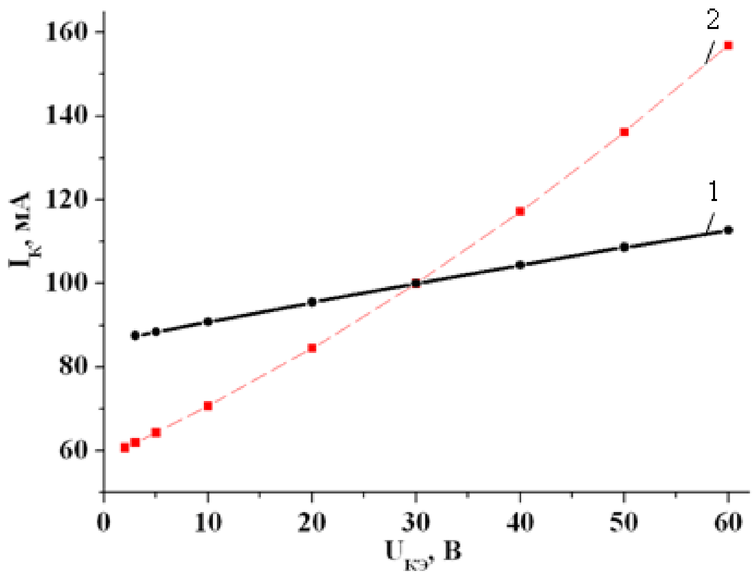


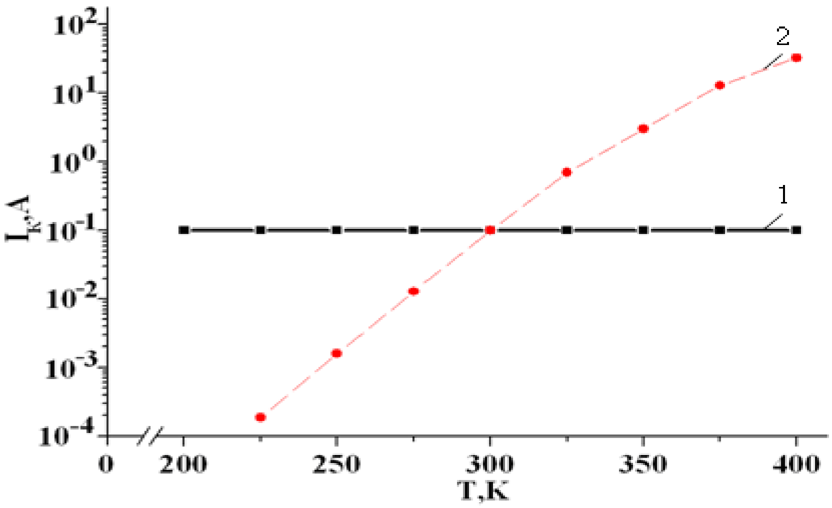
Fig. 12. The results of a computer simulation of the dependence of the base current I_B on the voltage of the base-emitter U_{BE} at U_{KE} = 10V of a three-stage homogeneous component (solid

lines) and a single (dashed line) transistor according to the Shiklai scheme.

In fig. 13. The experimental results are given: the dependences of the instability of the collector current on the voltage U_{KE} (a) and temperature T (b) at I_K = 30 mA, U_{KE} = 30 V, and T = 300 K.



a)



b)

Fig. 13. The instability of the collector current from the voltage U_{KE} (a) and temperature T (b) at I_K = 30 mA, U_{KE} = 30 V and T = 300 K.

Conclusion

The analysis shows that the stabilization efficiency of the collector current of a three-link composite transistor on a homogeneous composite transistor is 7 times higher in voltage and three orders of magnitude higher in temperature than in a conventional composite transistor (Fig. 13). The proposed homogeneous bipolar transistor stably operates at UKE voltage values 3 times higher than in the case of individual transistors. The power dissipated by the collector is 3 times higher than the certified value of the maximum permissible power for a two-stage homostructure bipolar transistor according to the Shiklai scheme.

Multistage homostructure transistors according to the Darlington and Shiklai circuit have been developed and investigated. To study the I – V characteristics of multistage homostructure transistors, an interactive computer simulation program was developed in the Delphi-6 programming environment and computer simulation was performed in the LabVIEW environment using the Multisim 10.1 program. It is shown that multistage homostructure transistors according to the Darlington and Shiklai circuits operate stably at collector-emitter voltages five times higher than in the case of individual transistors. The power dissipated on the collector is 3 times higher than the rated value of the maximum permissible power of the composite transistors. It is established that the efficiency of the method of stabilizing the emitter current of a three-link homostructure transistor is 7 times higher in voltage and three orders of magnitude higher in temperature compared to a conventional composite transistor. It was revealed that a homostructure transistor retains the positive properties of heterostructure transistors. This allows you to increase manufacturability in its industrial production. The proposed homostructure transistors are designed to operate in terminal stages of power amplifiers, radio transmitting devices, electronic equipment of industrial and automotive electronics.

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