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Nodira Batirdjanovna Alimova
Tashkent State Technical University. Address: 2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan. E-mail: nali71@yandex.ru, Phone: +998 90-30-44-71., nali71@yandex.ru

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POWER AMPLIFIER BASED ON COMPOSITE INJECTION-VOLTAIC TRANSISTORS

Nodira Batirdjanovna Alimova

Tashkent State Technical University. Address: 2 Universitetskaya st., 100095, Tashkent city, Republic of Uzbekistan.
E-mail: nali71@yandex.ru, Phone: +998 90-30-44-71.

Abstract. *The problem of high-current radio engineering devices is related to the fact that the use of high-power transistors and other semiconductor devices is limited by such a phenomenon as a secondary breakdown, in which there is a sharp decrease in the voltage on the device with simultaneous internal current lacing, and the device fails. To solve the problem of secondary breakdown, schemes have been proposed that operate stably at reverse voltage values 4-5 times higher than usual and at power dissipation 2-3 times higher than the maximum allowable power for an individual device. The problem is proposed to be solved by using composite transistors. This is the most optimal way, since passive elements are not used.*

The article proposes and investigates power amplifiers based on the use of composite bipolar transistors operating in the injection-voltaic mode. A method of active emitter self-stabilization of power amplifiers based on composite transistors with the same band gap is proposed and theoretically substantiated, which makes it possible to reduce the total coefficient of non-linear distortion and the instability of the quiescent current of power amplifiers depending on the supply voltage and temperature.

Keywords: *Bipolar Transistor, Composite Bipolar Transistor, Secondary Breakdown, Injection-Voltaic Effect, Power Amplifier.*

Аннотация. *Катта токли радиотехник қурилмаларнинг муаммолари иккиламчи тешилиш ҳодисаси сабабли катта қувватли транзисторлар ва бошқа яримўтказгичли асбоблардан фойдаланишнинг чекланганлигидир. Иккиламчи тешилишда асбобдаги кучланиш кескин пасаяди, бир вақтнинг ўзида ток ички шунтланади, натижада асбоб ишдан чиқади. Иккиламчи тешилиш муаммосини ҳал қилиш учун тескари кучланиш қиймати оддий транзисторларникига нисбатан 4-5 баробар катта қийматларда ва сочилиш қуввати 2-3 мартага катта бўлган турғун ишлайдиган схемалар таклиф этилади. Муаммони таркибий транзисторлар қўллаш орқали ечиш таклиф этилган. Бу усул энг оптимал ҳисобланади, чунки унда пассив элементлар қўлланилмайди.*

Мақолада инжекция-кучланишли режимда ишлайдиган таркибий биполяр транзисторларни қўллаш асосидаги қувват кучайтиргичлари таклиф қилинган ва тадқиқ этилган. Таъқиқланган зона кенгликлари бир хил бўлган таркибий транзисторлар асосидаги қувват кучайтиргичларини фаол эмиттерли ўз-ўзини барқарорлаш усули таклиф этилган ва асосланган бўлиб, у ночизиқли бузилишларнинг умумий коэффициентини ҳамда қувват кучайтиргичи сокинлик токининг кучаланиш манбаи ва ҳароратга нисбатан нобарқарорлигини камайтириш имконини беради.

Таянч сўзлар: *биполяр транзистор, таркибий биполяр транзистор, иккиламчи тешилиш, инжекция-кучланиш самараси, қувват кучайтиргичи.*

Аннотация. *Проблема сильноточных радиотехнических устройств связана с тем, что использование мощных транзисторов и других полупроводниковых приборов ограничивается таким явлением, как вторичный пробой, при котором происходит резкое снижение напряжения на приборе с одновременным внутренним шнурованием тока, и прибор выходит из строя. Для решения проблемы вторичного пробоя предложены схемы, устойчиво работающие при значениях обратного напряжения в 4-5 раз более высоких, чем обычно и при рассеиваемой мощности, в 2-3 раза превосходящей предельно допустимую мощность для отдельного прибора. Проблему предлагается решить применением составных транзисторов. Это наиболее оптимальный способ, поскольку не используются пассивные элементы.*

В статье предложены и исследованы усилители мощности на основе использования составных биполярных транзисторов, работающих в инжекционно - вольтаическом режиме. Предложен и теоретически обоснован *метод активной эмиттерной самостабилизации усилителей мощности на составных транзисторах с одинаковой шириной запрещенных зон, который позволяет уменьшить общий коэффициент нелинейных искажений и нестабильность тока покоя усилителей мощности от напряжения питания и температуры.*

Ключевые слова: *биполярный транзистор, составной биполярный транзистор, вторичный пробой, инжекционно-вольтаический эффект, усилитель мощности.*

Introduction

Radio engineering elements, components and 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 engineering devices. In particular, the research and development of a highly stable elemental base based on the use of new physical effects of electronic devices is topical. In this case, it becomes possible to generate a whole set of new circuit solutions [1-7].

In this regard, the solution of the problems of the stability of the functioning of powerful output stages of radio engineering devices is relevant.

Research Methods and the Received Results

The problem of high-current radio engineering devices is related to the fact that the use of high-power transistors and other semiconductor devices is limited by such a phenomenon as a secondary breakdown, in which there is a sharp decrease in voltage on the device with simultaneous internal current lacing, and the device fails.

When developing functional devices with increased requirements for the width of the region of stable operation (pulse and key devices), it is necessary to exclude the use of circuits with a common emitter (CE) controlled by the base current. When controlling the input voltage, one should: either introduce negative feedback through the emitter circuit; or use composite transistors. In this last case, the output transistor of the composite transistor pair is put into the emitter current control mode, the value of which is set by the second (triggering) transistor. This transistor is put in a mode in which the collector current does not depend or weakly depends on the collector-base voltage. For example, in the initial section of the saturation mode. And also, to increase the efficiency of the amplifier, it is necessary to reduce the value of the resistor in the emitter circuit by applying deep negative feedback (NFB) using an operational amplifier (op-amp).

The article proposes to apply another method - the method of emitter stabilization of the quiescent current RD - by a circuit (Fig. 1).

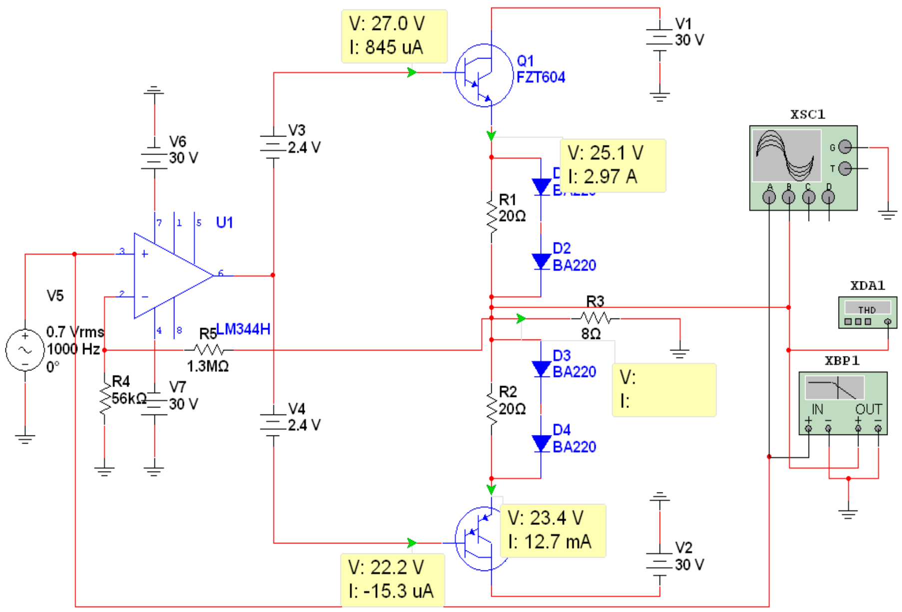
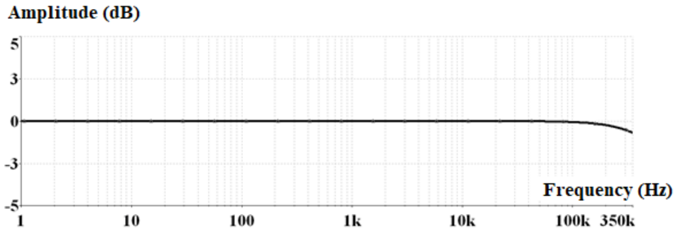


Fig. 1. ***Power Amplifier Wiring Diagram with emitter stabilization RD – circuit.***

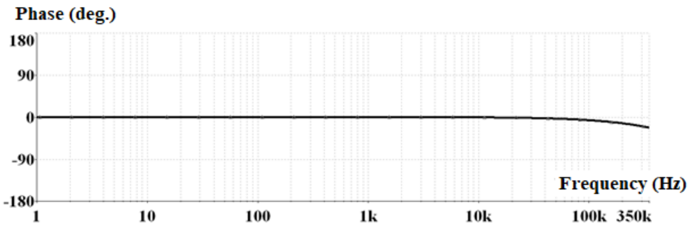
The power amplifier uses ±30V power supplies and ±2.4V bias supplies, 20Ω emitter resistors. Ток покоя $I_П$=50 мА. Quiescent current Ip=50 mA. The power amplifier is designed for two standard values of load resistance Rl.

The power amplifier is designed for two standard values of load resistance Rl. The output power of the amplifier was 30 W at Rl=8 Ohm and 60 W at Rl=4 Ohm.

The power amplifier uses FZT604 and FZT605 composite transistors, BA220 diodes, and an LM344H operational amplifier. All elements of the scheme were not subjected to selection by parameters [8-12].



a)



b)

Fig. 2. ***Frequency response (a) and phase response (b) of the power amplifier with emitter stabilization RD – circuit.***

The power amplifier on composite bipolar transistors works as follows.

Composite bipolar transistors Q1 and Q2 are connected in a common collector circuit. The value of the quiescent current in each arm of the power amplifier is determined by the ratio of the difference between the bias voltages and the base-emitter voltage of composite bipolar transistors to the value of the emitter resistance.

In the absence of an input signal, the magnitude of the quiescent currents in each arm of the power amplifier is automatically regulated by the RD - circuit covered by the NFB and the previous values of the quiescent currents are maintained.

The quiescent currents of the power amplifier arms may differ from the required values due to the spread of the parameters of composite bipolar transistors, emitter resistances and bias sources. Then the voltage at the output of the power amplifier is different from zero, current flows through the load. In this case, an op amp covered by a NFB is used to balance the output voltage of the power amplifier.

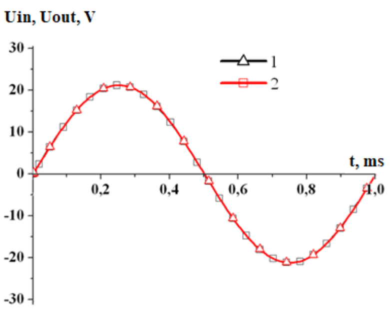


Fig. 3. ***Change in input (curve 1) and output (curve 2) voltage power amplifier over time.***

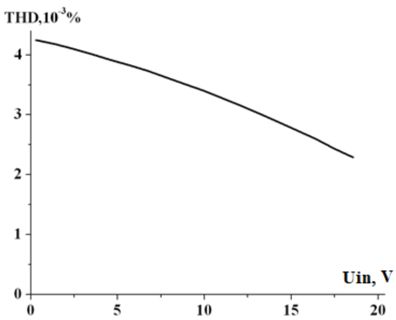


Fig. 4. ***Dependence of the total coefficient of non-linear distortion (THD) as a percentage of the change in the amplitude of the input voltage.***

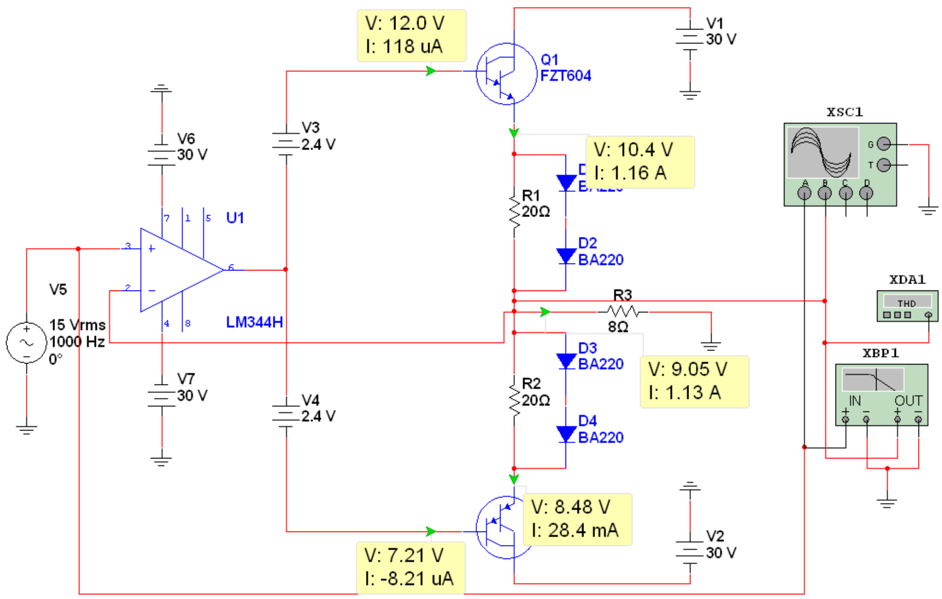


Fig. 5. ***The electrical circuit of the power amplifier with emitter stabilization RD - circuit, covered by the NFB.***

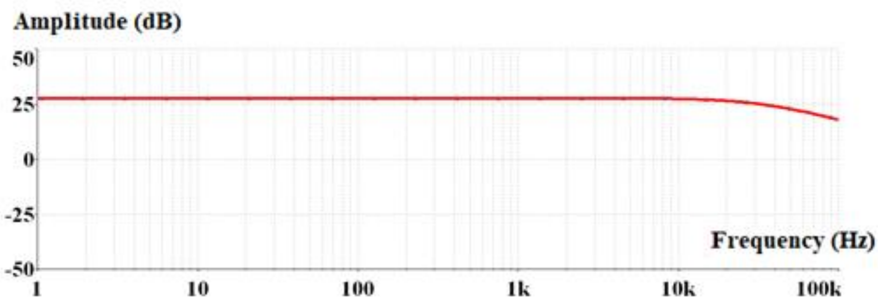
On Fig. 2 shows the amplitude - frequency and phase - frequency characteristics (frequency response and phase response) of a power amplifier with emitter stabilization RD - circuit. When an input signal is applied, the voltage at the output of the power amplifier repeats. The power amplifier operates without distortion in the frequency range from 0 to 300 kHz (Fig. 2).

The time dependences of the input (curve 1) and output (curve 2) voltages of the power amplifier coincide (Fig. 3), the voltage transfer coefficient of the power amplifier is 0 dB (K_U=1).

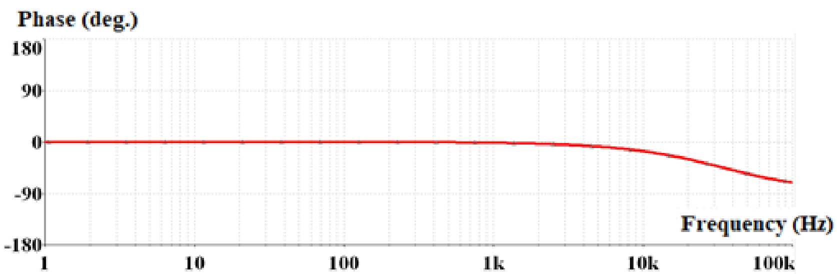
The total harmonic distortion (THD) of the power amplifier is 4.2·10-3% at an input voltage of 2 V and decreases to 2.5·10-3% as the input voltage increases to 15 V (Fig. 4).

To obtain a given voltage gain, the power amplifier is equipped with a negative feedback circuit formed by resistors R4=56 kΩ and R5=1.3 MΩ (Fig. 5).

The power amplifier operates without distortion in the frequency range from 0 to 300 kHz (Fig. 6).



a)



b)

Fig. 6. ***Frequency response (a) and phase response (b) of a power amplifier with emitter stabilization RD - circuit, covered by the NFB.***

The time dependences of the input (curve 1) and output (curve 2) voltages of the power amplifier are the same (Fig. 7), the voltage transfer coefficient of the power amplifier is 0 dB (K_U=1).

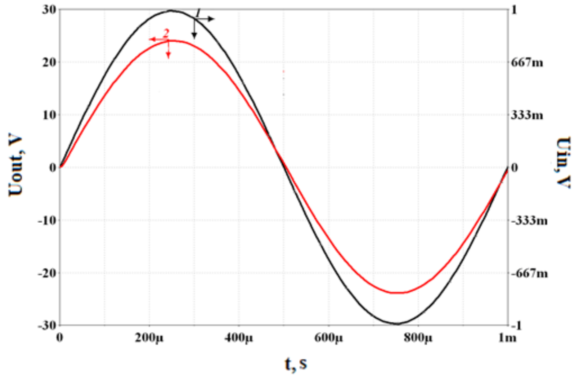


Fig. 7. ***Changing the input (curve 1) and output (curve 2) voltage power amplifier over time.***

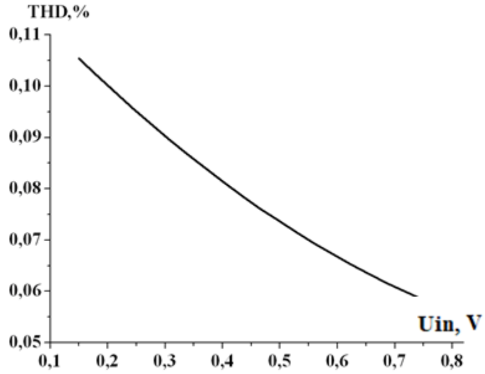


Fig. 8. ***Dependence of total harmonic distortion (THD) as a percentage of the change in the amplitude of the input voltage.***

The total harmonic distortion (THD) of the power amplifier is 0.1% at an input voltage of 0.2 V and decreases to 0.06% when the input voltage increases to 0.7 V (Fig. 8).

The efficiency of a power amplifier with emitter stabilization RD - circuit, covered by the NBF with changes in supply voltage from 3 V to 60 V, is an order of magnitude higher than the efficiency compared to a power amplifier with conventional stabilization Re = 0.33 Ohm/ And in the case of a temperature change from 210 K to 400 K, this is more than two orders of magnitude.

To solve the problem of secondary breakdown, schemes have been proposed that operate stably at reverse voltage values 4-5 times higher than usual and at power dissipation 2-3 times higher than the maximum allowable power for an individual device. The problem is proposed to be solved by using composite transistors. This is the most optimal way, since passive elements are not used.

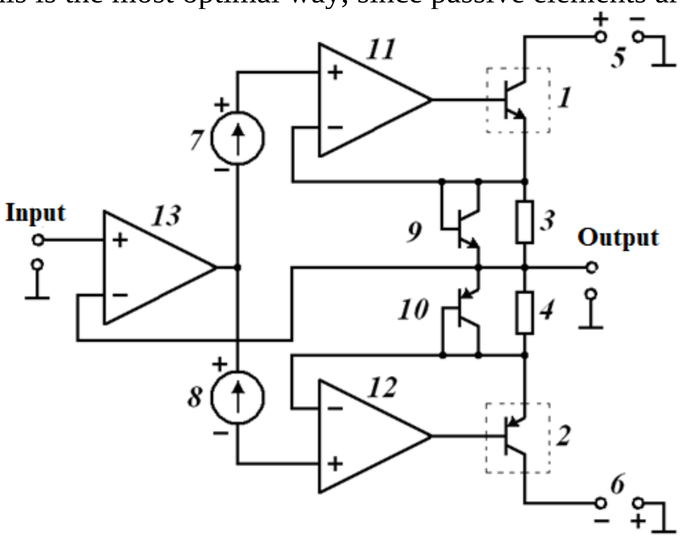


Fig. 9. ***Power amplifier on composite bipolar transistors.***

On Fig. 9 shows the electrical circuit of the power amplifier on composite bipolar transistors [13]. The power amplifier uses 5,6 ± 30 V power supplies and 7,8 ± 0.5 V bias sources, 3,4 emitter resistors with a value of 5 Ohms. Quiescent current Ip=100 mA. The power amplifier is designed for two standard values of load resistance Rl. The output power of the amplifier was 30 W at Rl=8 Ohm and 60 W at Rl=4 Ohm.

The power amplifier uses transistors of the KT829A and KT853B brands, complementary transistors of the TIP41C and TIP42C brands, and three KR1408UD1 operational amplifiers.

All elements of the scheme were not subjected to selection by parameters.

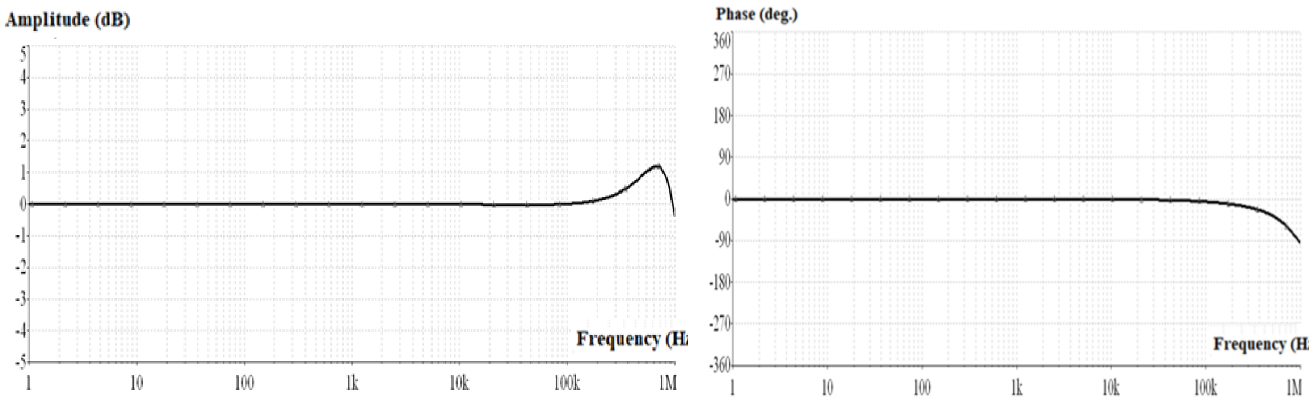
The power amplifier operates without distortion in the frequency range from 0 to 300 kHz (Fig. 10).

On Fig. 11 shows the amplitude - frequency and phase - frequency characteristics (frequency response and phase response) of the power amplifier bipolar transistors, which show the change in the input (curve 1) and output (curve 2) voltage of the power amplifier over time. The time dependences of the input (curve 1) and output (curve 2) voltages of the power amplifier are the same, the voltage transfer coefficient of the power amplifier is 0 dB (K_U=1).

On Fig. 12 shows the total harmonic distortion (THD) as a percentage of the change in the amplitude of the input voltage. The THD of the power amplifier is 7.5·10-3% at 2 V input voltage and decreases to 2·10-3% when the input voltage rises to 15 V.

On Fig. 13 a and b show changes in the quiescent current with changes in the supply voltage and temperature for amplifiers made according to the schemes of the closest analogue (curve 1) and the proposed technical solution (curve 2).

In the power amplifier according to the scheme of the closest analogue, the values of the emitter resistances were 0.33 Ohm. It can be seen from the graphs that with a change in the supply voltage from 3 V to 60 V and temperature from 210 K to 400 K, the value of the quiescent current of the proposed power amplifier is almost unchanged, and for the power amplifier according to the circuit of the closest analogue, it monotonically increases. The efficiency of the inventive power amplifier with changes in the supply voltage in the specified range is two orders of magnitude higher than the efficiency of the closest analogue, and in the case of temperature changes, this is more than three orders of magnitude.



a) b)

Fig. 10. ***Frequency response (a) and phase response (b)of a power amplifier based on composite bipolar transistors.***

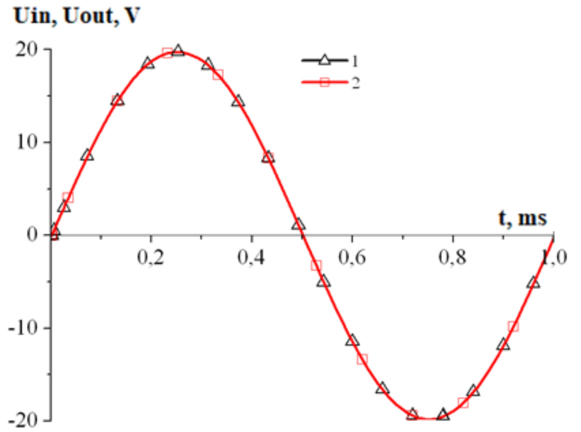


Fig. 11. ***Change in input (curve 1) and output (curve 2) voltage power amplifier over time.***

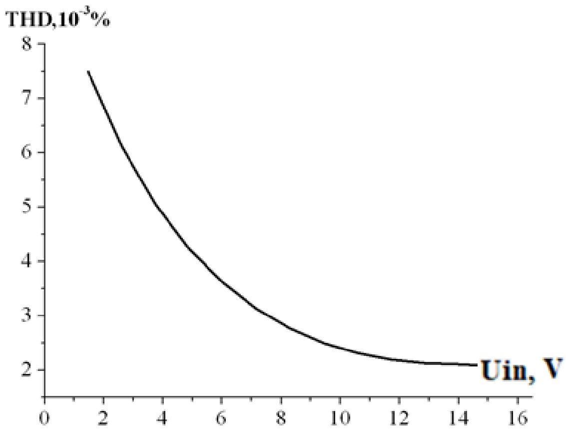


Fig. 12. ***Dependence of total harmonic distortion (THD) as a percentage of the change in the amplitude of the input voltage***

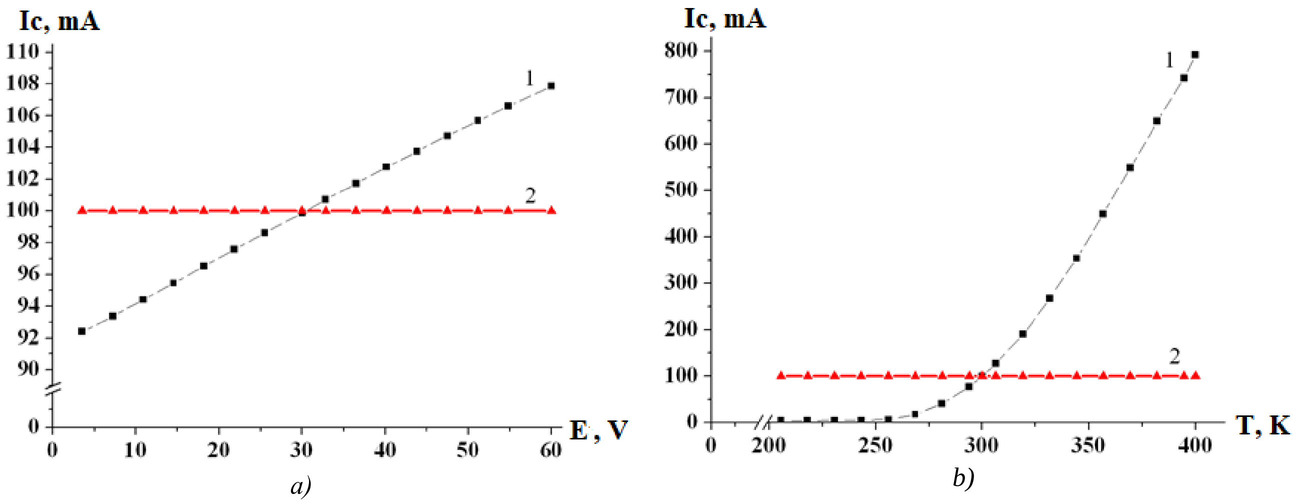


Fig. 13. ***The instability of the quiescent current from the supply voltage (a) and temperature (b).***

Conclusion

Radio engineering devices based on the use of photo- and injection-voltaic effects have been developed and investigated: power amplifiers based on IVT and composite IVT. A method for emitter self-stabilization of power amplifiers based on transistors with the same band gap is proposed.

It has been established that the frequency response and phase response of the proposed power amplifiers practically do not change up to frequencies of 350 kHz, and the change in the total coefficient of nonlinear distortion is about 0.008%. The quiescent current practically does not change with changes in the supply voltage from 2 V to 60 V and temperature from 200 K to 400 K.

References:

1. Aripov, Kh.K., Bustanov, Kh.Kh., Nasyrkhodzhaev, F.R. (2003). Poluprovodnikovyye pribory na osnove inzhektsionno-vol'taicheskogo effekta [Semiconductor devices based on the injection-voltaic effect]. *Collection of proceedings of the scientific conference "Fundamental and applied problems of physics", Research and production association "Physics-Sun" Academy of Sciences of the Republic of Uzbekistan named after. S.A.Azimova*. Tashkent, 260-262. (in Russian).
2. Alimova, N.B. (2008). Elementnaya baza na osnove inzhektsionno – vol'taicheskogo effekta [Element base based on the injection-voltaic effect]. *Bulletin of TUIT*. 4, 82-84. (in Russian).
3. Aripov, Kh.K., Alimova, N.B., Bustanov, Kh.Kh., Obedkov, E.V., Toshmatov, Sh.T. (2009). Injection-voltaic effect based on multilayer semiconductor structures. *Applied Solar Energy*. 1, 15-21.
4. Alimova, N.B. (2009). Issledovaniye inzhektsionno-vol'taicheskogo effekta v mnogosloynykh p-n strukturakh [Study of the injection-voltaic effect in multilayer p-n structures]. *Bulletin of TUIT*. 4, 84-85. (in Russian).
5. Alimova, N.B. (2009). Issledovaniye vozmozhnosti usileniya signala bipolyarnogo tranzistora v inzhektsionno-vol'taicheskom rezhime [Investigation of the possibility of amplifying the signal of a bipolar transistor in the injection-voltaic mode]. *Bulletin of TUIT*. 1, 101-105. (in Russian).
6. Alimova, N.B. (2009). Svyaz' foto-vol'taicheskogo effekta v solnechnykh elementakh s inzhektsionno-vol'taicheskim effektom v mnogosloynykh poluprovodnikovykh strukturakh [Relationship between the photovoltaic effect in solar cells and the injection-voltaic effect in multilayer semiconductor structures]. *Bulletin of AIES*. 3, 43-48. (in Russian).
7. Aripov, Kh.K., Toshmatov, Sh.T. (2016). Elementnaya baza na osnove inzhektsionno-vol'taicheskogo effekta [Element base based on the injection-voltaic effect]. *X international branch scientific and technical conference, Proceedings. MTUCI*, 165-166. (in Russian).
8. Kardashev, G. (2004). Komp'yuternoye skhemotekhnicheskoye modelirovaniye electron-nykh ustroystv [Computer circuit modeling of electronic devices]. *Circuitry*. 3, 18-19. (in Russian).
9. Aripov, Kh.K., Bustanov, Kh.Kh., Kasimov, S.S., Yarmukhamedov, A.A. (2001). Sostavnoy bipolyarnyy tranzistor [Composite bipolar transistor]. *Provisional patent of the Republic of Uzbekistan № IDP 04949*, 24.09.2001. Published Bull., 5. 31.10.2001. (in Russian).
10. Aripov, Kh.K., Bustanov, Kh.Kh., Kasimov, S.S., Yarmukhamedov, A.A. (2001). Sostavnoy bipolyarnyy tranzistor [Composite bipolar transistor]. *Provisional patent of the Republic of Uzbekistan № IDP 04950*, 24.09.2001. Published Bull., 5. 31.10.2001. (in Russian).
11. Bustanov, Kh.Kh., Yarmukhamedov, A.A. (2002). Issledovaniye sostavnogo bipolyarnogo tranzistora po skheme Darlingtona [The study of a composite bipolar transistor according to the Darlington circuit]. *Problems of Informatics*

and Energy. 5, 30-34. (in Russian).
12. Yarmukhamedov, A.A. (2005). Matematicheskaya model' sostavnogo inzhektsionno – vol'taicheskogo tranzistora po skheme Darlingtona [Mathematical model of a composite injection-voltaic transistor according to the Darlington scheme]. *Collection of proceedings of the epublican scientific and technical conference of graduate students, masters and bachelors "Information and switching technologies".* 88-89. (in Russian).
13. Aripov, Kh.K., Alimova, N.B., Aripova, Z.Kh., Bustanov, Kh.Kh., Mavlanov, A.R., Obedkov, E.V., Toshmatov, Sh.T. (2013). Usilitel' moshchnosti [Power amplifier]. *Patent of the Republic of Uzbekistan № IAP 04640*, 29.12.2012. Published Bull, 1. 31.01.2013. (in Russian).