[Scientific-technical journal](https://uzjournals.edu.uz/ferpi)

Volume 3 | Issue 5 Article 2

12-1-2020

RESEARCH OF THE RANGE OF SUSTAINABLE WORK OF THE CASCADE INJECTION-VOLTAIC TRANSISTOR IN THE FIELD OF THE ORIGIN OF AN ELECTRIC AVALANCHE BREAKDOWN

Z Kh Aripova
Department of Electronics and Radio Engineering, TUIT named after Muhammad al-Khwarizmi, Tashkent, Uzbekistan, radiofizik2012@mail.ru

U Kh Aripova
Department of Electronics and Radio Engineering, TUIT named after Muhammad al-Khwarizmi, Tashkent, Uzbekistan.

Sh T. Toshmatov
Doctoral student, TUIT named after Muhammad al-Khwarizmi, Tashkent, Uzbekistan E-mail: Khayrulla-aripov@yandex.ru

Materials of the V International Conference "Optical and photoelectrical phenomenas in semiconductive micro- and nanostructures". Ferghana, November 13-14, 2020.

UDC 621.385

RESEARCH OF THE RANGE OF SUSTAINABLE WORK OF THE CASCADE INJECTION-VOLTAIC TRANSISTOR IN THE FIELD OF THE ORIGIN OF AN ELECTRIC AVALANCHE BREAKDOWN

[1] Aripova Z. Kh., [1]Aripova U. Kh., [2]Toshmatov Sh. T.

[1]Department of Electronics and Radio Engineering, TUIT named after Muhammad al-Khwarizmi, Tashkent, Uzbekistan.
[2]Doctoral student, TUIT named after Muhammad al-Khwarizmi, Tashkent, Uzbekistan
E-mail: Khayrulla-aripov@yandex.ru

ИССЛЕДОВАНИЕ ДИАПАЗОНА УСТОЙЧИВОЙ РАБОТЫ КАСКАДНОГО ИНЖЕКЦИОННО-НАПРЯЖЕННОГО ТРАНЗИСТОРА В ОБЛАСТИ ПРОИСХОЖДЕНИЯ ЭЛЕКТРИЧЕСКОЙ ЛАВИНЫ

[1]Арипова З. Х., [1]Арипова У. Х., [2]Тошматов Ш. Т.

[1]Кафедра электроники и радиотехники, ТУИТ им. Мухаммада аль-Хорезми, Ташкент, Узбекистан.
[2]Докторант, ТУИТ им. Мухаммада аль-Хорезми, Ташкент, Узбекистан
E-mail: Khayrulla-aripov@yandex.ru

ЭЛЕКТР ҚУЮНИ ҲОСИЛ БЎЛИШ СОҲАСИДА КАСКАДЛИ ИНЖЕКЦИОН-КУЧЛАНИШ ТРАНЗИСТОРИНИНГ ТУРҒУН ИШЛАШ ДИАПОЗОНИНИ ТАДҚИҚ ЭТИШ

[1]Арипова З. Х., [1]Арипова У. Х., [2]Тошматов Ш. Т.

[1]Мухаммад ал-Хоразмий номидаги ТАТУ электрон ва радиотехника бўлими, Тошкент, Ўзбекистон.
[2]Докторант, Мухаммад ал-Хоразмий номидаги ТАТУ, Тошкент, Ўзбекистон
E-mail: Khayrulla-aripov@yandex.ru

Abstract. *In this work, the mechanisms of stabilization of the operating modes of cascode injection-voltaic transistors are identified. The results of a study of the current-voltage characteristics of a cascade injection-voltaic transistor are presented. It is shown that the proposed transistor works stably at collector-base reverse voltage values 2-3 times higher than individual transistors.*

Аннотация. *В данной работе идентифицированы механизмы стабилизации режимов работы каскодных инжекционно-гальванических транзисторов. Приведены результаты исследования вольт-амперных характеристик каскадного инжекционно-гальванического транзистора. Показано, что предложенный транзистор стабильно работает при значениях обратного напряжения коллектор-база в 2-3 раза выше, чем у отдельных транзисторов.*

Аннотация. *Ушбу ишда каскадли иноекцион-волтаик транзисторларнинг ишлаш режимларини барқарорлаштириш механизмлари аниқланган. Каскадли иноекцион-волтаик транзисторнинг оқим кучланиш хусусиятларини ўрганиш натижалари келтирилган. Тавсия этилган транзисторнинг индивидуал транзисторларга қараганда 2-3 баравар юқори бўлган тескари кучланиш қийматларида барқарор ишлаши кўрсатилган.*

Introduction

High-frequency and high-speed devices are linear and digital devices operating in the frequency region where the effects of interelectrode capacitances, wire inductance, charge accumulation and

Materials of the V International Conference "Optical and photoelectrical phenomenas in semiconductive micro- and nanostructures". Ferghana, November 13-14, 2020.

wavelength begin to affect. In this frequency range, the Miller effect also manifests itself in semiconductors, which often plays a major role in the decrease in gain. There are three ways to suppress the Miller effect. One of them, known as a cascode connection scheme, in which a cascade with a common emitter controls a cascade with a common base, thereby eliminating the Miller effect.

The disadvantage of cascode schemes is a small range of stable operation in the field of occurrence of electrical avalanche breakdown [1-5].

The objective of the study is to identify the stabilization mechanism of the operating modes of cascode-injection-voltaic transistors (CIVT) in the area of occurrence of electrical avalanche breakdown.

1. Research methodology

In this paper, theoretically and experimentally, the main factors of electric avalanche breakdown are considered that affect the patterns of the formation of current-voltage characteristics (CVC) of the CIVT in a circuit with a common emitter.

At the first stage of this study, the active mode and CIVT saturation mode are considered, since these modes are typical of power amplifiers of classes A, A +, AB, B, and G.

At the second stage of the CVC of CIVT study, electronic circuits are simulated using simulation programs Labview, SignalExpress, MultiSim, Ultiboard by National Instruments.

At the third stage, for the experimental study, as the proposed CIVT, we used integrated microassemblies of bipolar transistors KTS 622B and K1NT251 .

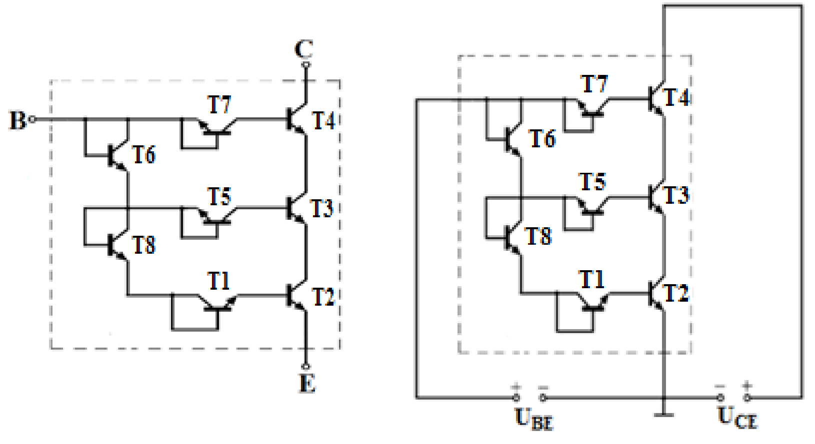
2. Results and discussion

CIVT contains eight electrically interconnected eight-type bipolar transistor structures (figure 1) on the same semiconductor material.

With an increase in the output voltage U_{CE} of CIVT, collector-emitter voltages U_{CE2}, U_{CE3}, U_{CE4} - three series-connected (cascade) transistors T2, T3, T4 alternately, as a "telescopic antenna", go from the injection-voltaic mode (IVM) to the active mode, then during breakdown, they stabilize at the level of $U_{CE}=U_{CB.treshold}$ (figure 2a and 2b, curves 1÷4 of points A, B, C; A`, B`, C` and A``, B``, C``).

The potentials of the collectors U_{C2} and U_{C3} of the transistors T2, T3 are always lower than the potentials of the base U_{B3} and U_{B4} of the transistors T3 and T4 by the direct voltage of the emitter-base junctions U_{EB3} and U_{EB4} respectively T3, T4 (figure 2, curves 2,3 and 2`, 3`).

Therefore, at any values of U_{CE} (figure 2, curve 1.4) and U_{BE} in the active mode, the intersection points of the characteristics of transistors T2 with T3 and T3 with T4 will be located on the horizontal section of the IVM due to the offset: $U_{CE1}+U_{CE8}-U_{CE5}$, as well as $U_{KE5}+U_{KE6}-U_{KE7}$.



a) b)

Figure 1. The connection diagram of the transistors (a) and the connection of CIVT (b)

Transistors T1, T2, T5, T8, as well as T3, T5, T6, T7 play the role of stable current generators supplying emitters T3 and T4, respectively.

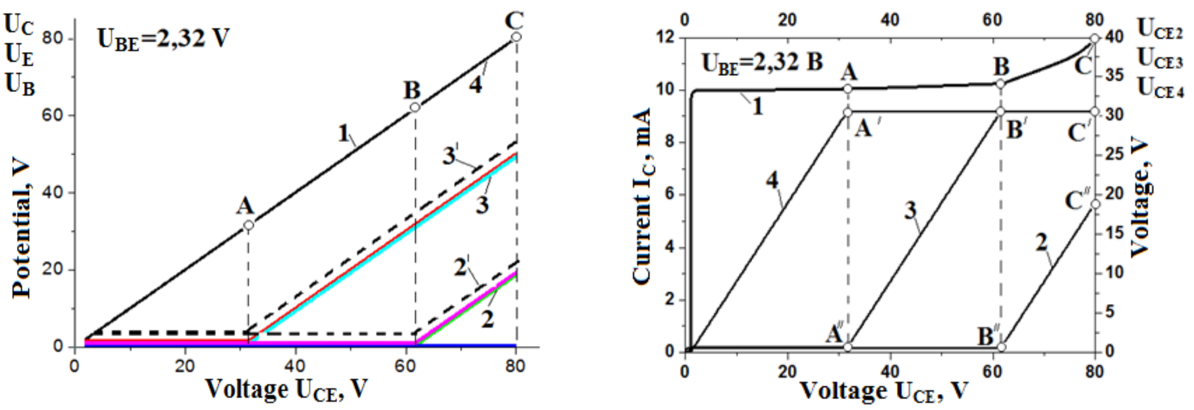
In the area of variation of the collector-emitter voltage from zero to U_A, i.e. at $0>U_{CE}<U_A$ (figure 2b), transistors T2 and T3 operate in IVM and the collector-emitter voltage of these transistors U_{CE2}, U_{CE3} remain constant (figure 2b curves 3 and 2). In this case, the collector-emitter voltage of T4 varies linearly (figure 2b curve 4) and is in the active mode. Therefore, the CIVT also functions in the active mode and the value of

the output dynamic resistance of which is of the order of hundreds of kOhm (figure 2b curve 1) and the Earley effect is practically absent. The CIVT is controlled by the current of the I_B base, which branches out along the T2, T3, T4 bases through T1, T8, T6, T5 and T7 (see figure 3a curves 1,2,3,4; figure 3b curves $I_{B2}=f(U_{CE})$; $I_{B3}=f(U_{CE})$; $I_{B4}=f(U_{CE})$ sections OA, OA\`, OA\`\`, and figure 4, curves 1÷4):

$$I_B=I_{B2}+I_{B3}+I_{B4}, \quad (1)$$

where $I_{B4}=I_{K7}$; $I_{B3}=I_{C5}$; $I_{B2}=I_{E1}=I_{E8}$.

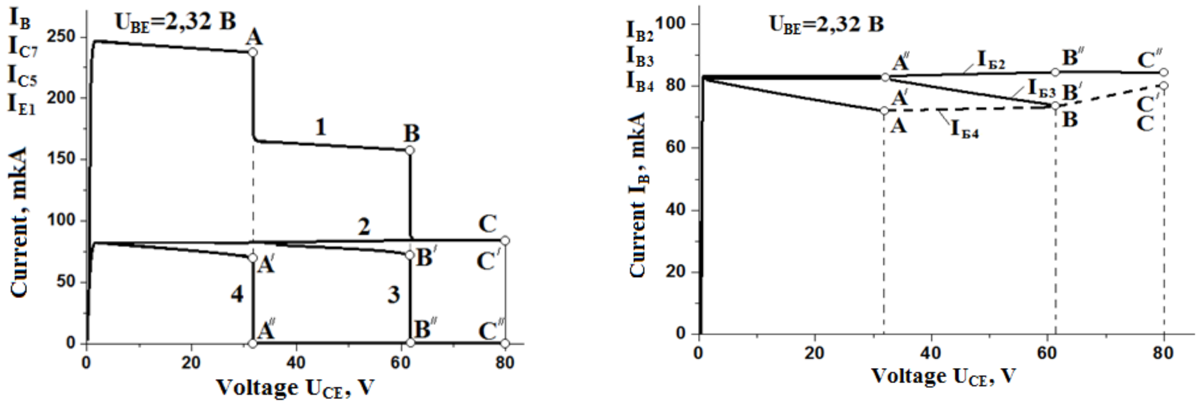
When the collector-emitter voltage is $U_{CE} = U_A$, an electric avalanche breakdown of the collector-base transition T4 occurs. Since the emitter current I_{E4} of transistor T4 is set by the collector current I_{C3} of transistor T3, the base-emitter voltages U_{BE4} and collector-emitter U_{CE4} of this transistor will be automatically set to provide this current value. Therefore, in the range of the voltage value of the collector-emitter voltage U_{CE} of CIVT from U_A to U_B (figure 2÷3) of T3 operates in IVM and the voltage value of the collector-emitter voltage U_{CE3} of the specified transistor remains constant. In this case, the collector-emitter voltage of T4 U_{CE4} also stabilizes at the level $U_{CE4}=U_{CB4.threshold}$, where $U_{CB4\ threshold}$ is the breakdown threshold voltage of the collector-base transition of T4. In the area of changing the voltage value of the collector-emitter from U_A to U_B, i.e. for $U_A<U_{CE}<U_B$, the potentials of the collectors of CIVT, T3, T4 and voltages U_{CE3} of T3 change linearly (figure 2, curves 3 and 4) and is in active mode. Therefore, CIVT also operates in the active mode and the value of the output dynamic resistance of which is of the order of hundreds of kOhm (figure 2b curve1) and the Earley effect is practically absent.



a) b)

Figure 2. Potential distributions of electrodes of bases U_{B3}, U_{B4} (dashed curves 2\`, 3\`), emitters U_{E3}, U_{E4} (curves 2,3) and collectors U_{C2}, U_{C3}, U_{C4} (curves 1÷3) (a); dependence of collector current I_C (1) and voltage U_{CE2}, U_{CE3}, U_{CE4} T2, T3, T4 on collector-emitter voltage U_{CE} of CIVT (curves 2÷4) (b).

The CIVT is controlled by the current of the I_B base, which branches out along the T2, T3 bases through T1, T8, T6, T5 (see figure 3a curves 1,2,3,4; figure 3b curves $I_{B2}=f(U_{CE})$; $I_{B3}=f(U_{CE})$; sections AB, A\`B\`, A\`\`B\`\` and figure 4, curves 1÷4): $I_B=I_{B2}+I_{B3}$, where $I_{B3}=I_{B5}$; $I_{B2}=I_{E1}=I_{E8}$. In this case, the collector-emitter voltage values of the U_{CE2} and U_{CE4} transistors T2, T4 - also remain constant (figure 2b curves 2 and 4), and the base currents I_B of CIVT and I_{B4} of T4 decrease by a point jump - A, A\`, A\`\`, due to locking of T7 ($I_{C7}=0$) (figure 3a, curves 1 and 4). Then, support of the current of the I_{B4} of T4 base is provided by the hole component of the breakdown current of the collector-base U_{CB4} junction (figure 3b dashed curve I_{B4}; figure 4, curve 4 - CVC of $I_{B4}=f(U_{B4})$, transistor T4), through the “floating” potentials of the emitter and T4 electrodes (figure 2a, curves 3 and 4\`). With a collector-emitter voltage of $U_{CE}=U_V$, an electrical avalanche breakdown of the collector-base transition T3 occurs. Since the emitter current I_{E3} of T3 is set by the collector current I_{C2} of T2, the base-emitter voltage U_{BE3} of this transistor will automatically be set to provide this current value. Therefore, in the region of changing the voltage value of the collector-emitter U_{CE} of CIVT from U_B to U_C (figure 2÷3), the T2 operates in the active mode and the voltage values of the collector-emitter U_{CE} of CIVT of the specified transistor increase linearly. In this case, the collector-emitter voltage of T3 also stabilizes at the level $U_{CE3}=U_{C3\ threshold}$, where $U_{C3\ threshold}$ is the breakdown threshold voltage of the collector-base transition of T3. In the field of changing the voltage values of the collector-emitter from U_B to U_C, i.e. at $U_B<U_{CE}\leq U_C$, the potentials of the collectors CIVT of transistors T4, T3, T2 and voltage U_{CE2} of T2 change linearly (figure 2a, curves 2-4). In this case, the collector-emitter voltages of the transistors T3 and T4 also remain unchanged (figure 2b curves 3 and 4), and the base currents CIVT and T3 decrease abruptly (figure 3a curves 1 and 3) due to the locking of T5 ($I_{C5}=0$).



a) b)

Figure 3. Dependences of base current I_B (1), emitter I_{E1} (2), collectors I_{C5} (3) and I_{C7} (4) of T1, T5, T7 (a) and dependences of base currents I_{B2}, I_{B3} and I_{B4} of T2,T3,T4 from voltage U_{CE} of CIVT (b).

Then the support of the current of the I_{B3} of T3 base is carried out, as mentioned above, due to the hole component of the breakdown current of the collector-base transition (figure 3b dashed curve I_{B3}; figure 4, curve 3-CVC $I_{B3}=f(U_{B3})$, of T3), due to the “floating” potentials of the emitter electrodes and base of T3 (figure 2a, curves 2 and 3`) and it is in active mode. Therefore, CIVT also works in the active mode, in which manifestations of the Earley effect are already present. The CIVT is controlled by the current of the I_B base, which flows through the base of T2, $I_B=I_{B2}$ (figure 3a, curves 1 and 2).

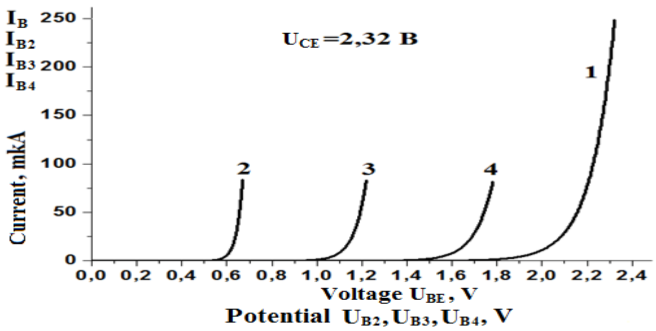


Figure 4. Input CVC of CIVT $I_B=f(U_{BE})$ (curve 1) and the dependences of the base currents I_{B2}, I_{B3}, I_{B4}, respectively, on the potentials of the bases U_{B2}, U_{B3}, U_{B4} (curves 2,3,4).

When the collector-emitter voltage is $U_{CE}=U_C$, an electrical avalanche breakdown of the collector-base transition T2 occurs. Since the emitter current I_{E2} T2 is limited by the current generator, the transistor T2 with $U_{CE2}=U_{CE\ threshold}$ goes into an unstable mode and thermal breakdown of the transistor structure occurs (figure 2 ÷ 3).

4. Conclusion

The cascode injection-voltaic transistor, when controlling the base-emitter voltage, works stably at collector-base reverse voltage values 2-3 times higher than individual TIVTs and with power dissipated on the collector 2-3 times higher than the maximum permissible for a separate transistor structure and Darlington transistors.

The proposed transistor can be used in preliminary and output stages of low-frequency amplifiers, control circuits of radio and radio transmitting devices, in electronic equipment, industrial and automotive electronics, as well as in the creation of information and telecommunication devices as an element base.

References

[1] Toshmatov Sh T 2017 The main regularities the generalities of I-V curve formation characteristics of power amplifiers (Toshkent: *Fan va texnologiya*) p 252 (In Russ.)

[2] Aripov H K, Abdullaev A M and Toshmatov Sh T 2017 Regularities the generalities of I-V curve formation in MOSFET with a common drain (*Rroceedings of the 3 International Scientific and Practical Conf.*) c.Sterlitamak. Vol I) pp 251–256 (In Russ.)

[3] Aripov H K and Toshmatov Sh T 2017 Regularities the generalities of I-V curve formation in BJT with a common collector (*Collection of papers scientific and practical conf. vol 2*, TUIT) pp 200–201 (In Russ.)

[4] Andreev I S, Aripov H K, Abdullaev A M, Mahsudov Zh T, Rahmatov Sh B and Toshmatov Sh T 2019 Multilayer semiconductor device structure: transistors and thyristors (Tashkent: *Navro'z*) p 280(In Russ.)

[5] Mohammed Ismail, Delia R de Llera Gozalez 2007 Radio design in Nanometer Technologies (*Springer Science&Business Media*) p 316