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ANALYSIS OF CURRENT ACHIEVEMENTS IN THE CREATION OF INFORMATION DEVICES ON THE BASIS OF UNIJUNCTION TRANSISTOR STRUCTURES

The analysis of current achievements in the creation of information devices on the basis of unijunction transistor structures is conducted; their advantages and drawbacks are identified. Recommendations on the improvement of information devices have been elaborated.

Key words: *information devices, unijunction transistor structure, unijunction transistor.*

The unijunction transistor structure (UTS) is a multifunctional electronic device, application of which makes it possible to improve technical parameters of the components and devices of computers and automatics, to increase their efficiency and to create qualitatively new components based on it. As a unijunction transistor (UT) has a volt-ampere characteristic of S-type, it possesses unique properties, which enables creation of simpler, more reliable and efficient devices on its basis than analogous devices based on diodes and triodes. Production of the wide nomenclature of UT by such companies as General Electric, Philips, ASI, Motorola [1 – 4] confirms their competitiveness along with other semiconductor devices. However, at present there is no comparative analysis of the modern information devices on their basis. Such analysis opens new possibilities for creating high-performance information elements and devices, suitable for realization in an integral form, which would ensure their widespread application.

Accordingly, the actual problem is to analyze current achievements in the development of information devices based on UTS.

The goal of the work is elaboration of recommendations on the improvement of performance of UTS-based information devices.

1.1. Classification of information devices

The structure of information system includes information devices as basic units for data conversion and processing. Two types of information devices are distinguished: information conversion devices and control devices. Information devices where the functioning algorithm does not depend on the algorithm of the information system operation, designed for converting messages into a signal and vice versa as well as for changing the physical nature or parameters of a signal, are called information conversion devices. They include: measuring transducers, immittance converters, coding and decoding devices, logic devices etc. Information devices, the functioning algorithm of which changes with time according to the law that is determined by the functioning algorithm of the information system are called control information devices. The examples of such devices are filters, switches, phase shifters, etc [5].

Taking into account that in the majority of information systems electric signal is the main carrier of information, the paper considers information devices for conversion and control of electric signals. A generalized diagram of the device is presented in fig. 1 [5]. The device comprises three types of terminals: of the input signal, output signal and control signal. Control information devices have no control signal terminals but may have a reference signal terminal.

In addition to data signals, an interference signal could enter the information device. It could get there both via the circuits of the main and control signals or occur in the information device itself.

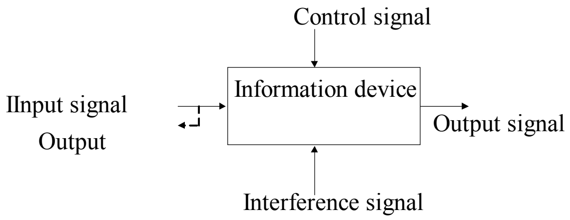

Fig. 1.Gegeneralized functional diagram of the information device

Classification of information devices is presented in fig. 2.

According to the type of electric signal information devices are divided into video-pulse and radio-frequency devices. Amplitude, frequency and phase of the signal are the informational basis of radio-frequency devices. By the reaction to the input signal radio-frequency information devices are classified as amplifying, converting and passive ones. Amplifying devices increase the input signal power due to the energy coming from the power source. According to the functional purpose measuring-converting, amplifying-converting and auxiliary elements are distinguished. They include logic circuits, devices for information storage and conversion. By the power supply type radio-frequency information devices are divided into active, passive and semi-passive ones. In contrast to passive devices, active radio-frequency devices contain their own power source.

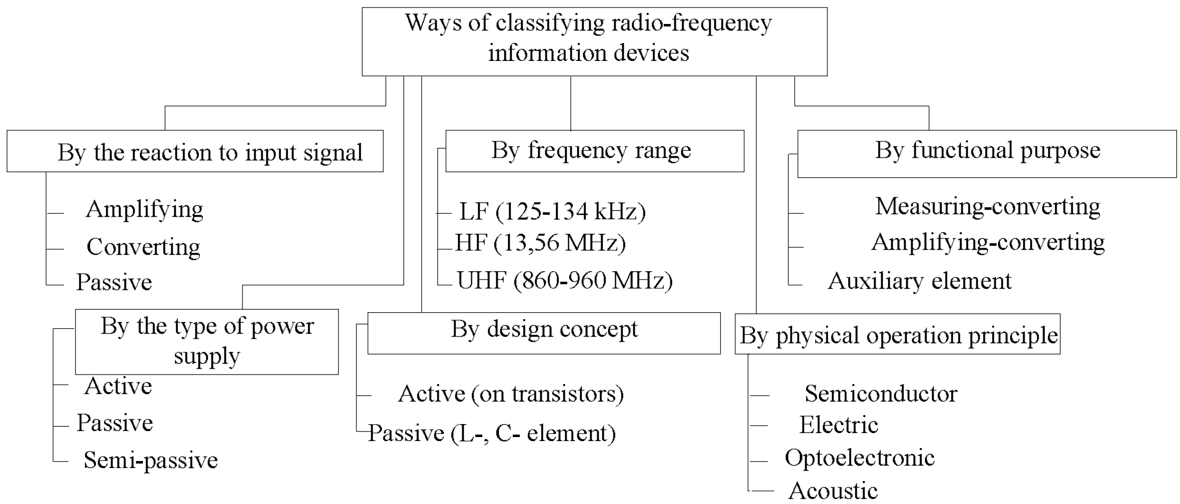

Fig. 2. Classification of radio-frequency information devices

According to their design concept radio-frequency information devices are classified as active and passive ones. The active ones are built on active devices, and namely, on transistors (bipolar, field, unijunction transistors, etc.), and passive devices are based on L-, C-elements. All types of radio-frequency information devices could be classified according to the frequency range presented in the diagram. There exists a classification of radio-frequency information devices by the physical operation principle. Semiconductor, electric, optoelectronic, acoustic and other devices are distinguished [6].

1.2. Key circuits based on a unijunction transistor

The unijunction transistor based on VAC has a negative resistance portion and, therefore, can be used for building switches. A switch based on a unijunctin transistor is shown in fig 3 [7].

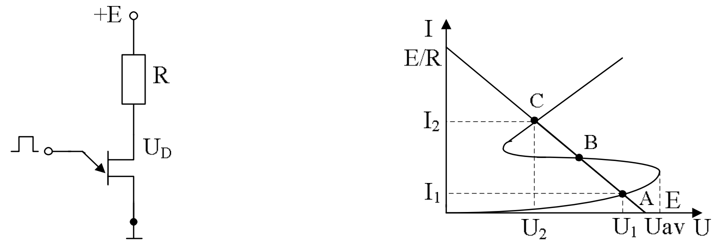

Fig. 3. The switch based on a unijunction transistor

The supply voltage is distributed between the resistor and the unijunction transistor. The current value in the circuit and voltage drop at the transistor and the resistor are determined in the points of the volt-ampere characteristic intersection with the loading curve. If differential resistance in the negative resistance portion $|R_D| > R$, then for the corresponding value of E there will be three intersection points of VAC of the unijunction transistor with the loading curve. When the power source is switched, a working point A is established and there will be small current in the circuit. If a positive pulse with the value of $U_i > U_{av} - U_1$ is supplied to the unijunction transistor, voltage at the transistor will be higher than U_{av} and the transistor will be switched on. The current will be growing and the working point will jump to point B. Current $I_2 > I_1$ will be established in the circuit. Switching of the current to the opposite direction from I_2 to I_1 occurs by supplying a negative pulse to the transistor. Working point B is unstable. Any fluctuation in this point will result in the growth of this fluctuation. If the fluctuation is positive, the working point will pass from point Б to point В, and if it is negative, the working point will pass from point B to point A. Thus, when switching occurs, the system passes from one stable state to another [7].

Key circuits of UT are used in lighting systems [8, 9], in the devices for charging batteries [10], thyristor regulators of generator voltage [11], downhole device monitoring systems, etc. [12]. The advantage of key circuits, based on UT, is their ability to operate at low currents.

1.3. Sensors based on UT

Circuits based on unijunction transistors are usually simpler and more reliable than those based on field-effect and bipolar transistors. These advantages make them prospective for developing sensors of physical quantities. On the basis of unijunction transistors, sensitive to the strength of magnetic field (unijunction magnitortransistors), sensors with the output signal frequency that depends on the magnetic field intensity have been created [13 – 16].

In [17 – 19] pressure transducers with the frequency output on the basis of unijunction tensor transistors are proposed. They have practical value in terms of high sensitivity, ability to work in the conditions of high-level electromagnetic interference, relatively low cost, connectivity with digital systems and high noise immunity due to low sensitivity of the frequency-modulated signal to noise.The value of relative sensitivity of a unijunction tensor transistor is S_{Rp}=4*10^{-10}, S_{Rv}≥10^{-10} (Pa^{-1}). Relative sensitivity of a unijunction tensor transistor with respect to on voltage S_{Rp} and off voltage S_{Rv} is determined by the formula:

$$S_{Rp(Rv)} = \frac{1}{U_{p(v)}} \left| \frac{\partial U_{p(v)}}{\partial \sigma} \right|_{\sigma \to 0}, \qquad (1)$$

where σ is mechanical stress in the base region of the tensor transistor.

The steepness of conversion of a tensor transistor with a controlled *p-n*-junction is determined as

$$S_f = \frac{1}{f}\left|\frac{\partial f}{\partial \sigma}\right|_{\sigma \to 0}, \qquad (2)$$

and written in the form of $S_f = S_{f\beta} + S_{fv} + S_{fp}$, where $S_{f\beta}$ is the steepness of conversion determined by deformation of the variable transfer coefficient.

The values of conversion steepness for a unijunction tensor transistor with the controlled *p-n*-junction are: S_{Rp}=4*10^{-10}, S_{Rv}≥10^{-10}, $S_{f\beta}$=1,5*10^{-8} (Pa^{-1}).

In [20] characteristics of light transducers with frequency output based on a unijunction transistor are investigated. The developed circuit improves linearity of the dependence of the output signal frequency on the light flux as well as increases the luminous sensitivity (about 10 kHz / mW) and extends the spectral range of optical signals. Dependence of the frequency on the light flux is shown in fig. 5 b.

The generator based on unijunction phototransistors is used as an optoelectronic sensor with frequency output. Semiconductor crystal of n-type conductivity has two ohmic contacts of n +-type conductivity as well as the injecting emitter p-n-junction (the region of p +-type) with electrical leads. Sensitivity of the sensor frequency is 7 kHz / mW [21, 22].

A temperature sensor based on a unijunction and a field transistor has been designed. Its circuit is presented in fig. 4a. All three transistors of this circuit are heat-sensitive. Generation frequency of this sensor increases linearly with increasing temperature Thermal sensitivity is 300 Hz / deg. The temperature sensor has linear dependence of the output signal on the temperature. Operability of this sensor is preserved under the action of radiation: the transistors were irradiated with a flow of electrons with the energy of 5 MeV, γ-quanta with the energy of 1 MeV and the flow of neutrons with the energy of 1.1 MeV (Fig. 4b) [23].

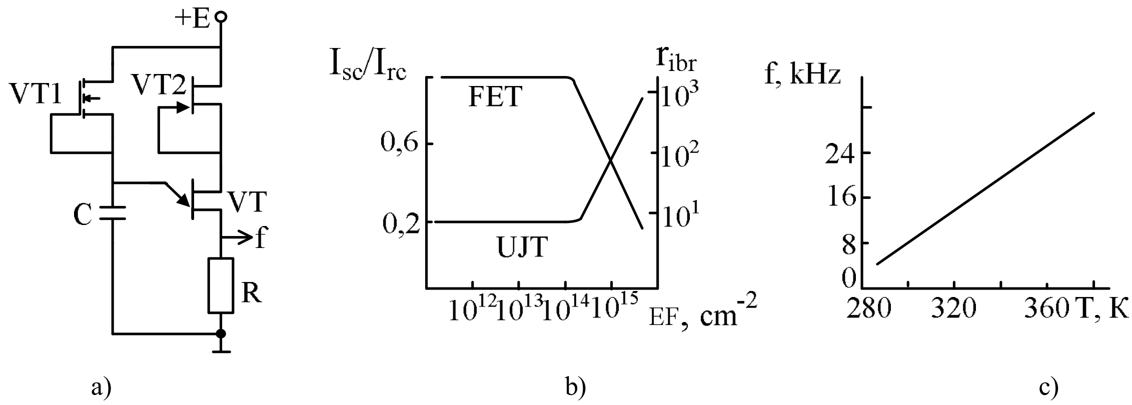

Fig. 4. Temperature sensors based on unijunction and field transistors (a), dependences of the influence of the electron flow in the field transistor FET and the cross-resistance of UT (b), generation frequency dependence on the temperature (c)

Magnetosensitive pickup [24] with improved sensitivity (Fig. 5) consists of a unijunction transistor based on n-conductor with two ohmic base contacts and p-emitter as well as of a bipolar magnetotransistor based on n-conductor with p-emitter and p-collector. The base of the unijunction transistor is connected to a power source through a resistor; the capacitor in the emitter circuit of the unijunction transistor is connected to the same pole of the power source through a bipolar magnetotransistor. The output of the sensor is picked up from the capacitor in the form of sawtooth pulses with frequency *f*.

A device for recording thermal properties of skin [25] consists of a temperature sensor, realized on the basis of a unijunction transistor, which is located at the geometric center of the contact side of the substrate made of a dielectric material. On the substrate there is a ring of a rectangular cross-section made from a dielectric heat-resistant material with a system of grooves on the outer surface with a heating element wound around them. The advantages of this device include extended functionality, increased reliability of measurement and reduced measurement errors.

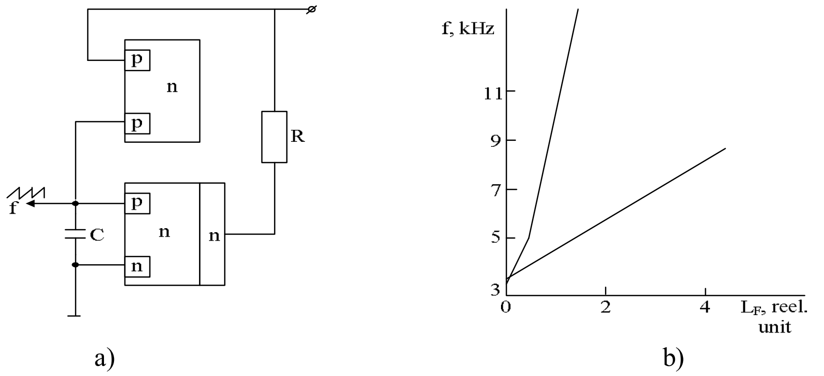

Fig. 5. Magnetosensitive transducer (a), frequency dependence on the light flux of the light converter with frequency output on the basis of UT (b)

A unijunction tensortransistor [26, 27] is used as a strain sensor and has an improved sensitivity due to its application together with the emitter of the contact to base in the form of a metal-conductor junction. Strain sensitivity of the metal-semiconductor junction is many times higher than sensitivity of the tensoresistor, the role of which is played by the base of the unijunction transistor. For pressure value of 20 MPa the transducer sensitivity is 0,03 KHz / MPa. The economic effect from this unijunction transistor application is explained by the fact that in the devices for low pressure measurements, where it is used, a smaller number of amplifying components is required, which decreases the cost of the device.

1.4. Generators based on UT

Due to their high reliability, stable frequency, and low interference level UT are used for constructing generators. Classification of generators, based on UT, is presented in fig. 6.

LC-generator, based on UT, is characterized by simplicity and the absence of feedback loop, which is its advantage over the analogs. However, the circuits operate in a rather narrow frequency range – 200 – 300 KHz. It is explained by the fact that frequency properties of UT are limited and do not exceed 100 KHz. High absolute negative resistance of UT input agrees only with the high resistance of losses in low-frequency loops; strong nonlinearity of S-shaped current-voltage characteristic is the obstacle for obtaining sinusoidal oscillations with a low number of harmonics.

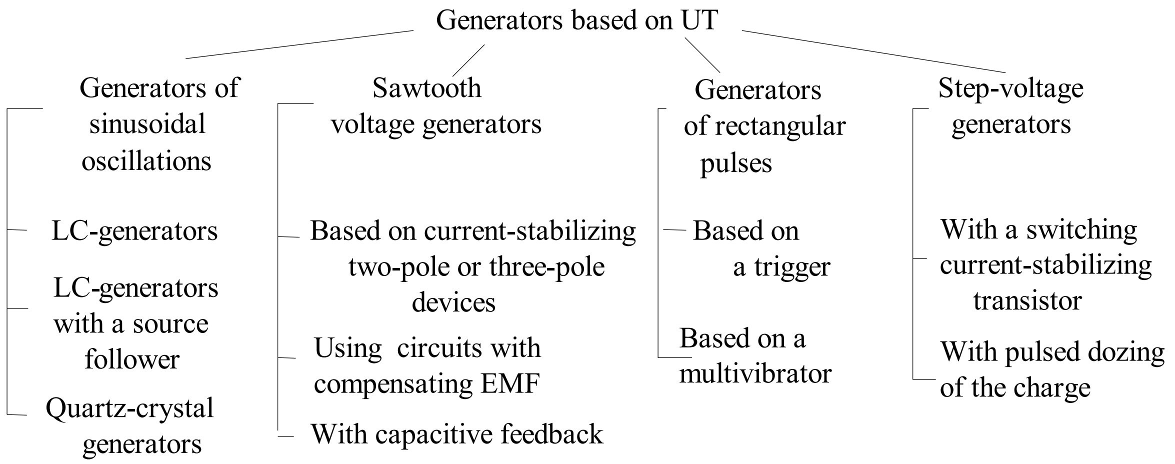

Fig. 6. Classification of generators based on a unijunction transistor

However, the circuit based on UT can be used for obtaining almost sinusoidal oscillations in the loop without external feedback components such as those based on a single inductance coil. Such circuits exist in ordinary transistors as well, though they are too complicated and do not work reliably at low frequencies where UT are used. Low-frequency circuits are used while controlling inductance coils, chokes and transformers with magnetic core in the process of their production [28].

Another drawback of such circuits is their low loading capacity. Connection to the load network reduces considerably the quality factor of the resonant circuit [28].

LC-generators with a source follower [28] have high loading capacity, which is caused by connecting the output, via the capacitor, to the source follower that has high input resistance and practically does not load the circuit (fig. 7 a). The disadvantage of these schemes is increased power consumption due to introduction of a field-effect transistor.

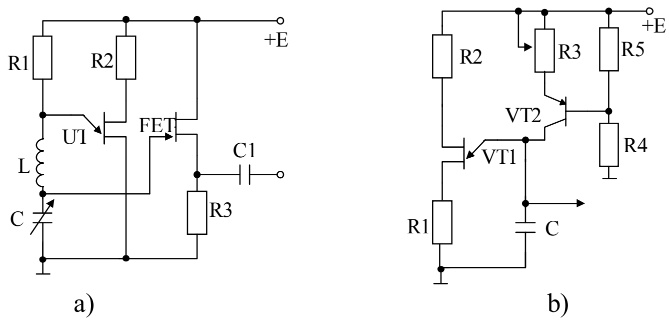

Fig. 7. LC-generator with a source follower (a), a self-oscillatory generator of saw tooth voltage with a current-stabilizing transistor b)

Unijunction transistors are used for building sawtooth voltage generators that are employed in measuring equipment. Three methods are used to construct sawtooth generators: application of current-stabilizing two-pole or three-pole devices, application of the circuit with compensating EMF, introducing a capacitor into the negative feedback loop of the constant-voltage amplifier.

For construction of sawtooth voltage generators common-emitter bipolar transistor is used as a three-pole current stabilizing device. The scheme of common-base bipolar transistor connection is not employed as it requires an additional power source in the emitter circuit. A drawback of the circuit shown in fig. 7b is the pulse amplitude dependence on the supply voltage. This drawback could be overcome by introducing an additional diode (between the bipolar transistor base and the fifth resistor R5), that compensates for the voltage of the current-stabilizing transistor. This improvement reduces dependence of the oscillation frequency of this scheme on the supply voltage and frequency variations [28].

Paper [28] presents the circuit of auto-oscillation sawtooth generator with a digit unijunction transistor КТ117. Current stabilizer is implemented on a bipolar transistor. Zener diode stabilizes the emitter voltage in the circuit, which makes the current stabilizer circuit similar to the scheme with a common base. The disadvantage of this generator is considerable duration of reversal.

Application of measures on the improvement of loading capacity of sawtooth generators with current-stabilizing two-pole device results in considerable complication of the circuits.

One of the best circuits with compensating EMF is presented in fig. 8a. There EMF is supplied to point A through zener diode. The voltage on zener diode remains practically unchanged, and therefore deterioration of the linearity does not occur. The disadvantage of this scheme is reduction of the supply voltage efficiency and the necessity to increase it [28].

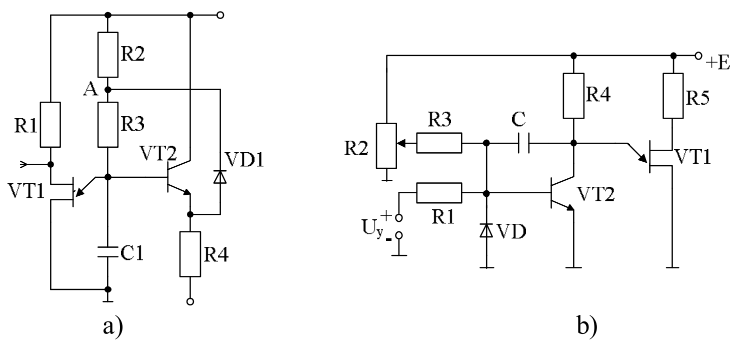

Fig. 8. An improved variant of the sawtooth generator circuit with compensating EMF a), a sawtooth generator based on a unijunction transistor with capacitive feedback (b)

In [28] a sawtooth voltage generator circuit based on a unijunction transistor with capacitive feedback is presented (fig. 8b). Circuits of this class have a number of advantages. They can give non-linearity of the order of 1% or less. At the same time such circuits have a sufficiently high loading capacity.

In [29] several types of generators, based on the unijunction transistor are presented. Ways to improve linearization by introducing a source of increased voltage or feedback (using a capacitor or a zener diode) are considered. The use of additional power source can increase rating of the resistor that sets the current, which is equivalent to the charge of the current generator.

The tasks of improving reliability of the generator start and increasing pulse noise immunity are solved in [30] by introducing a unijunction transistor, the emitter of which is connected to R- or S-input of the trigger, the first base – to a zero-bus and the second base - to the direct (or inverse) output of the trigger. RS-trigger is made on the basis of CMOM transistors.

The disadvantage of the pulse generator based on a trigger and a multivibrator is complication of the circuits and increased energy consumption.

Application of step voltage generators as frequency dividers provides a division for changing frequency which is several times and, in some cases, even ten times higher. In their turn, frequency dividers based on trigger stages can divide frequency from zero to a certain maximum value and are much more expensive than circuits based on UT [28].

Wide-spread is a relaxation oscillator circuit based on UT [31 - 33]. It is characterized by stable frequency, since U_o and $U_{av.}$ of a unijunction transistor are more stable to temperature changes than similar parameters of other devices with the characteristic of S-type. Relaxation oscillators based on a unijunction transistor are used as sawtooth voltage generators, multivibrators, timers.

1.5. Generalized immittance converters

UT can be represented as quadripoles, which allows creating generalized immittance converters on their basis. A detailed classification of immittance converters and their definitions are given in [34].

Generalized immittance converters based on a common-source injection transit-time transistor structure are considered in [35]. The authors have analyzed the properties of the common-source injection transit-time transistor structure as a generalized immitance converter and obtained the tables of immitance conversion. Injection transit-time transistor has the properties of a generalized immitance converter in the modes of both direct and reverse bias of the emitter junction. Changing the sign of the emitter junction potential leads to a change in the qualitative and quantitative characteristics of the immittance converter, which, in turn, leads to the change in the properties from immittance converter properties to those of the immittance inverter.

In [36] a generalized immittance converter on the basis of a unijunction transistor from the parameters of its physical equivalent circuit is investigated. As a generalized immittance converter UT with a common first base is used. The conducted studies have confirmed the possibility of controlling the magnitude of UT impedance for forward and reverse conversions by changing the nominal values of its equivalent circuit.

Immittance converter based on UT with a common first base is presented in [37]. The dependence of the "quality" of immittance converter on the basis of UT on its physical parameters is investigated. Increasing the parameter of the second base resistance leads to a higher quality of the converter based on UT.

Conclusions

The analysis has shown that UT are characterized by simplicity, reliability, low level of interference, wide operating temperature range (from -600 C to +125 C), high stability of frequency and low cost, which enables their application for building information devices with improved parameters. The main drawback is their low cutoff frequency value. This disadvantage can be overcome through the use of unijunction transistor structures operating at high frequencies and having low-resistance region of the base.

However, there are no systematic studies of the properties of UTS for different connection circuits where the realized quadripoles can be potentially unstable. At the same time these properties open up new opportunities for the realization of highly efficient information elements and devices that are suitable for implementation in an integral form, which would ensure their widespread use.

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