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RADIOMEASURING TEMPERATURE CONVERTER

The paper presents and describes the radiomeasuring temperature converter on the basis of transistor structure with negative resistance; there had been made a computer experiment of devise's circuit operation; there had been determined the function of conversion and function of sensitiveness of radiomeasuring temperature converter; there had been conducted the experimental researches of operation of temperature device.

Key words: *radiomeasuring temperature converter, thermistor, self-oscilator, current-voltage-characterictics, conversion function, negative resistance, thermometry.*

Introduction

Temperature sensors are very important sort of measurement converters since many processes, including those in everyday life, are regulated by temperature.

Following the assessments of native and foreign specialists, technical temperature measurements make up 40 – 50% of total measurement [1]. In Ukraine, in particular temperature and thermophisical measurements are wide spread and make up 30% of all measurements [2]. This is stipulated for by powerful industrial, scientifical and technical potential of the country with the development of the following industries: metallurgy, power engineering, mechanical engineering, aeronautical and space engineering, chemical industry etc., efficient work of which largely depends upon the exactness of measuring and thermal characteristics. Therefore, very important tasks of modern instrument-making industry and modern measuring equipment is to choose the reliable method of temperature measurement in different industries, to create measuring devices of necessary accuracy, stability and performance, as well as to research the influence of aggregate of factors which accompany the measuring process on measuring results.

This paper is dedicated ti the creation and research of radiomeasuring temperature converter , operation of which is based of functional dependence of impedance of semiconductor devices on one of the most spread non-electric values – temperature, which is of theoretical and practical interest, and allows to consider this work as urgent.

Circuit of device for measuring temperature

The circuit of radiomeasuring temperature converter consists of p-n-p-bipolar transistor and dual-gate n-channel MDS-transistor, power supply of which is done by constant-current voltage supply U1 and U2, passive inductance L, capacitor C and sensitive element – thermistor TR (fig. 1).

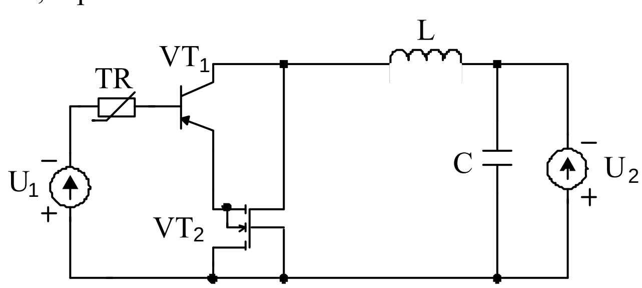


Fig. 1. Electric circuit of radiomeasuring temperature converter

Radiomeasuring temperature converter works as follows. In the initial moment of time, temperature does not influence the thermosensitive element TR. The increase of voltage of controlling sources U_1 and U_2 up to the value, when on the electrodes collector-drain of bipolar transistor VT_1 and polar transistor VT_2 there appears negative resistance, which leads to the appearance of electric oscillations in circuit, made by cascade of full resistance with capacitive character on electrodes VT_1

and VT_2 and inductive resistance of passive inductance L. Capacitor C hinders from passing the alternative current through the controlling voltage source U_2. The following influence of temperature on thermosensitive resistance TR changes its resistance which causes the change of capacitive constituent of the full resistance on electrodes collector-drains of transistors VT_1 и VT_2, and this, in turn, causes the change of resonance frequency of oscillation circuit.

Simulation of radiomeasuring temperature converter

To simulate this devise, we use the software package Orcad Family Release 9.2. we take the transistor BC857 as a bipolar and BF998 – as a polar one. During the simulation process of temperature convertion it became clear, that for the appearance of negative resistance in transistor structure VT_1-VT_2 (fig. 1) it is necessary for use the potential devider, which we have switched to the circuit of the frist gate of MDS-transistor VT_2. Fig. 2 presents the window of program environment of Orcad Family Release 9.2 with the circuit of the researched device.

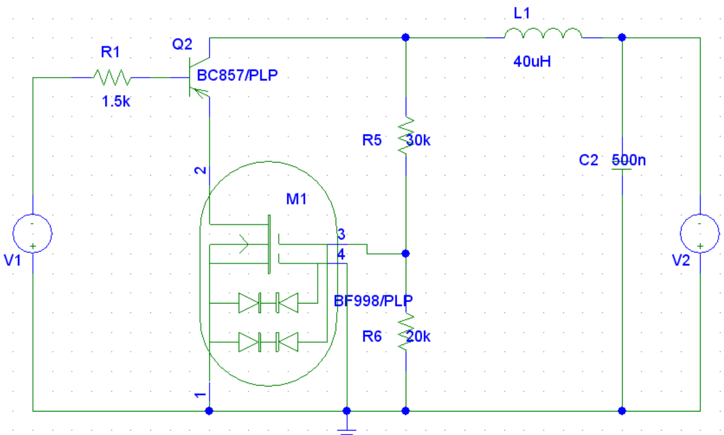


Fig.3 Circuit of temperature converter, made in solumatics

Fig. 4 presents the family of current-voltage characteristics of the research device, received in the result of simulation in Orcad Family Release 9.2. Bottom-up on fig. 4 tne CVC change depending on applied controlling voltage V_1: the bottom characteristic is taken when V_1 = 1,5 V, further on the controlled voltage increased by 0,5 V up to the upper characteristic, taken when V_1 = 3,5 V.

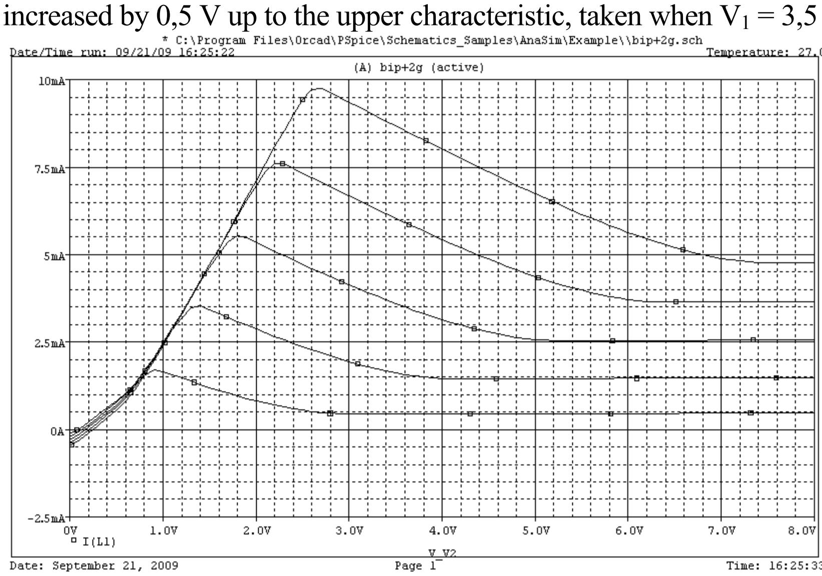


Fig. 4 CVC of temperature converter with different values of controlling voltage

Fig. 5 presents the dependence of change of output current in time of the researched temperature converter, received in the environment PSpice.

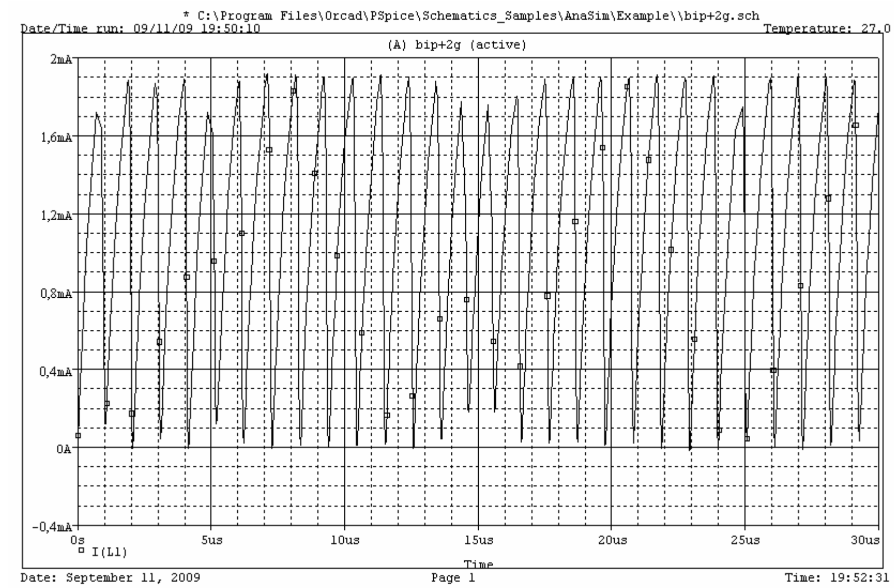


Fig. 5 Dependance of change of output current in time of temperature converter, received in PSpice

Thus, simulation of radiomeasuring temperature converter (fig. 1) in Orcad Family Release 9.2 proved the possibility of creation of this device, and thanks to the conducted modulation if became clear which element base must be used.

Determination of function of conversion of radiomeasuring temperature converter

For simulation of radiomeasuring temperature converter we use the method of loop current. The last resistance Z, active part of which has negative value and reactive – capacitive character, is determined from the converted equivalent circuit of the device, presented on fig. 6.

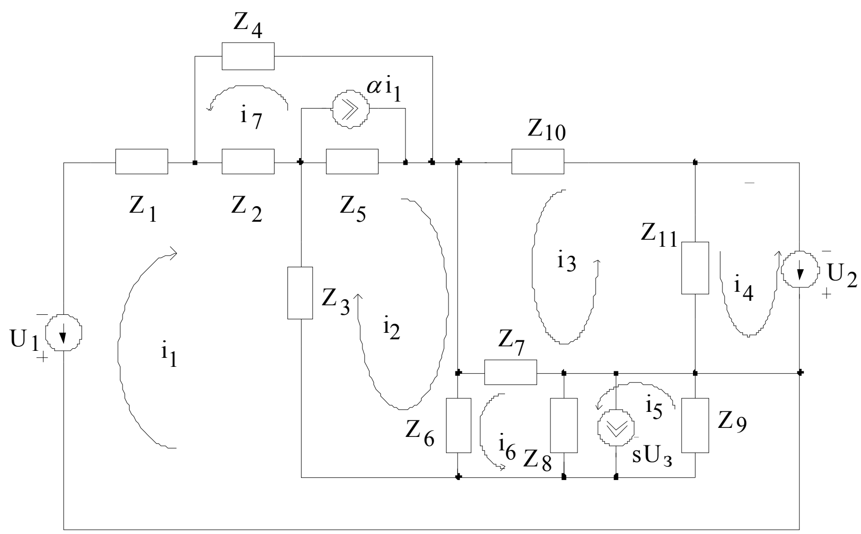


Fig. 6 Converted equivalent circuit of temperature converter

According to the chosen directions of loop currents, the system of Kirchhoff equation looks like:

$$\begin{cases} U_1 = (Z_1 + Z_2 + Z_3 + Z_9)\cdot i_1 + Z_2 \cdot i_7 - Z_3 \cdot i_2 + Z_9 \cdot i_5 + Z_9 \cdot s \cdot Z_6 \cdot i_2, \\ 0 = (Z_3 + Z_5 + Z_6)\cdot i_2 - Z_3 \cdot i_1 - Z_5 \cdot \alpha \cdot i_1 + Z_5 \cdot i_7 + Z_6 \cdot i_6, \\ 0 = (Z_7 + Z_{10} + Z_{11})\cdot i_3 - Z_7 \cdot i_6 - Z_{11} \cdot i_4, \\ U_2 = Z_{11} \cdot i_4 - Z_{11} \cdot i_3, \\ 0 = (Z_8 + Z_9)\cdot i_5 - Z_8 \cdot i_6 - Z_8 \cdot s \cdot Z_6 \cdot i_2 + Z_9 \cdot s \cdot Z_6 \cdot i_2 + Z_9 \cdot i_1, \\ 0 = (Z_6 + Z_7 + Z_8)\cdot i_6 + Z_6 \cdot i_2 - Z_7 \cdot i_3 - Z_8 \cdot i_5 + Z_8 \cdot s \cdot Z_6 \cdot i_2, \\ 0 = (Z_2 + Z_4 + Z_5)\cdot i_7 + Z_2 \cdot i_1 + Z_5 \cdot i_2 - Z_5 \cdot \alpha \cdot i_1, \end{cases} \tag{1}$$

where

$$Z_1 = R_{TR}, Z_2 = R_b, Z_3 = \frac{R_e}{1+(\omega C_e R_e)^2} - j\frac{R_e^2 \omega C_e}{1+(\omega C_e R_e)^2}, Z_4 = \frac{1}{j\omega C_k}, Z_5 = R_k,$$

$$Z_6 = \frac{R_{gs}}{1+(\omega C_{gs} R_{gs})^2} - j\frac{R_{gs}^2 \omega C_{gs}}{1+(\omega C_{gs} R_{gs})^2}, Z_7 = \frac{1}{j\omega C_{gd}}, Z_8 = R_{ds}, Z_9 = \frac{1}{j\omega C_{ds}},$$

$$Z_{10} = j\omega L_1, Z_{11} = \frac{1}{j\omega C_1}, \alpha = \frac{\alpha_0}{1 + j\left(\frac{f}{f_0}\right)^2}.$$

α – complex value of coefficient of current transmission, s – slope of polar transistor.

The solution of the equation system (1) is made by Ganss method with partial choose of the main element on personal computer. The values of parameters in equivalent circuit (fig. 6), necessary for calculations, are received from works [3, 4].

To determine the conversion function it is necessary to find the dependance of generation frequency on temperature. It is possible to do after solution of Kirchhoff equation system, composed for the alternative current on the base of equivalent circuit (fig. 6). Solution of the equation system (1) allows to receive a value of full resistance on electrodes collector-drain of a converter. Deviding the full resistance into the real and imaginary components, it is easy to determine the equivalent capacity of oscillatory circuit, which depends on temperature. Conversion function in this case will look like:

$$F = \frac{1}{2\pi} \cdot \frac{1}{R_{eq}(T) \cdot C_{eq}(T)} \sqrt{\frac{R_{eq}^2(T) \cdot C_{eq}(T)}{L} - 1} \tag{2}$$

Sensitivity of radiomeasuring temperature converter is determined according to formula:

$$S_{P_{випр}}^{F_0} = \frac{T}{F_0} \cdot \frac{dF_0}{dT} = -\frac{1}{2}\left[\frac{T}{C_{eq}(T)} \cdot \frac{dC_{eq}(T)}{dT}\right] \tag{3}$$

Fig. 7 presents theoretical dependences of structure conversion function with negative resistance on the base of bipolar and FET, the thermosensitive element of which is thermistor.

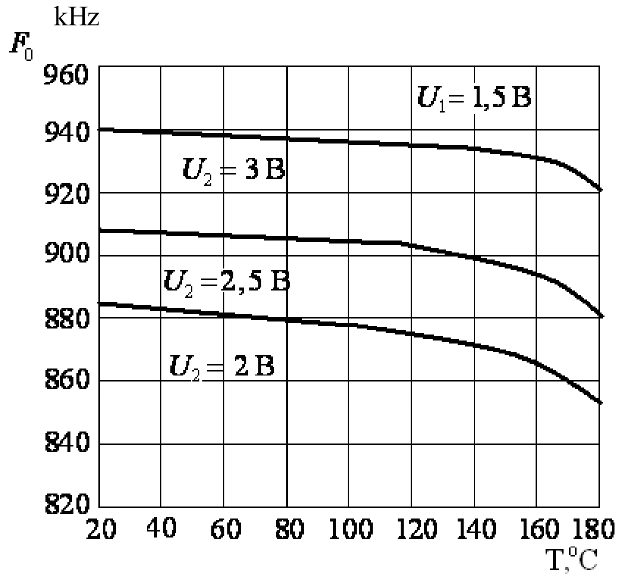


Fig. 7. Theoretical dependence of generation frequency on temperature

Experimental researches

During the experimental researches there where used the national thermistors MMT-1, MKT-12 and foreign thermistor (Siemens) with nominal 1,5 kOhm). Instead of MIS transistor BF 998 there was used the nation two-gate n-channel field-effect transistor КП 327АИ, which allowed to refuse from using the potential devider R5, R6 (fig. 3).

Experimental plant for researching CVC of converter is presented on fig. 8. during the experiment there were used the constant-current voltage supply system ВИП009, Б5-43, milliammeter UT70B, voltmeters of the B7-35 type, values of circuit parameters: TR = 1,5 kOhm, resistance of inductance L was 7 Ohm, C_1 = 470 nF.

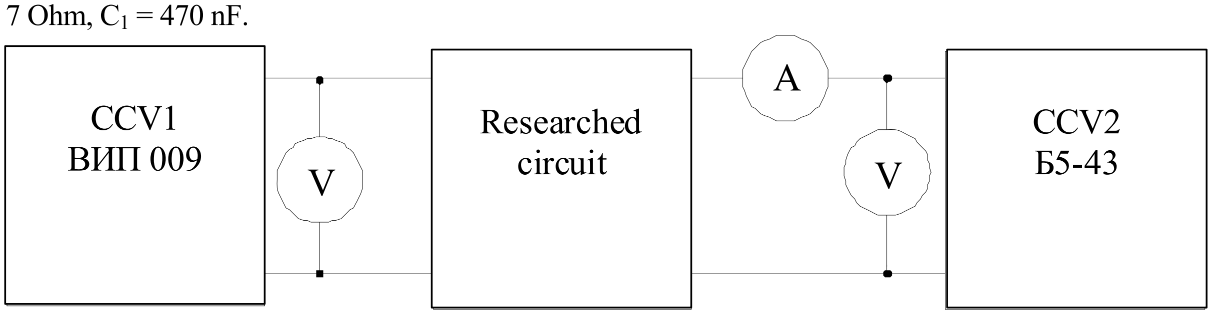


Fig. 8. Block-diagram of measuring plant for research of CVC of converter

Fig. 9 presents the experimental CVC of frequency temperature converter on the base of БиМОН structure with OC (BC 557B и КП 327АЫ).

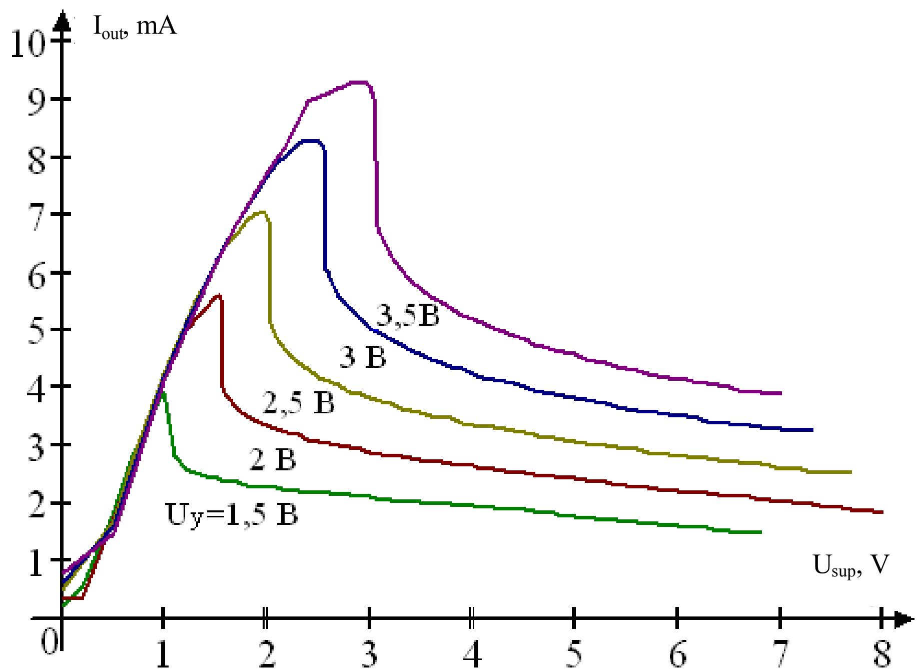


Fig. 9. Experimental CVC of frequency temperature converter on the base of transistors BC 557B и КП 327АИ

Experimental plant for research of converter generation frequency from temperature is presented on fig. 9. During the experiment there were used constant-current voltage supply systems of the ВИП009, Б5-43 type, milliammeter UT70B, voltmeters of the В7-35 type, electronic reading cymometer Ч3-35, oscillograph С1-93, values of circuit circuit parameters: R1 = 1,5 kOhm, inductance L = 100 mcHr, C1 = 450 nF. Sensitive component of the researched circuit was fixed in specially made contact frame and was placed in a furnace. Temperature measuring was conducted by handheld pyrometer of «Smotrych 4ПМ» type.

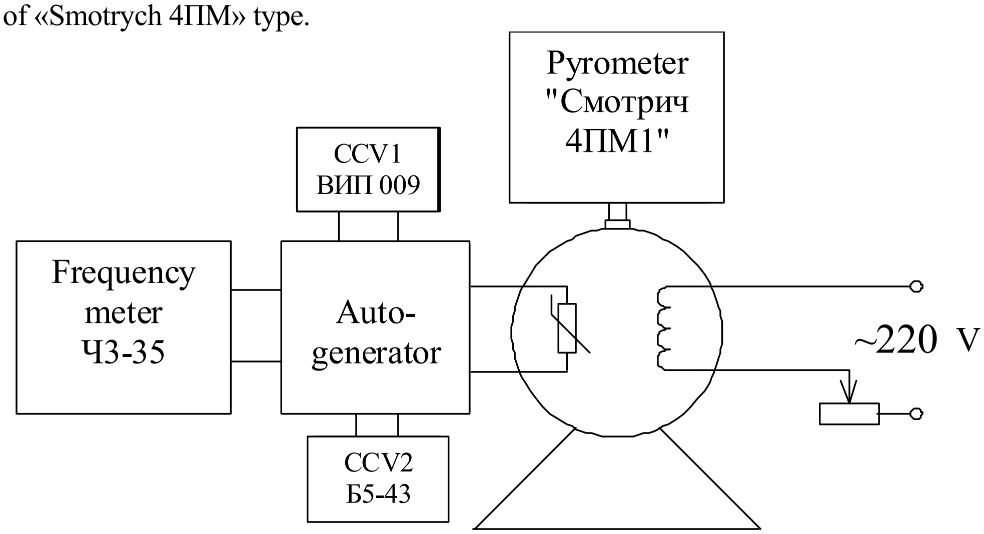


Fig. 10. Block-diagram of measuring plant for research of dependence of generation frequency on temperature

Fig. 11, 12 present the experimental dependences of generation frequency on voltage supply and controlling voltage.

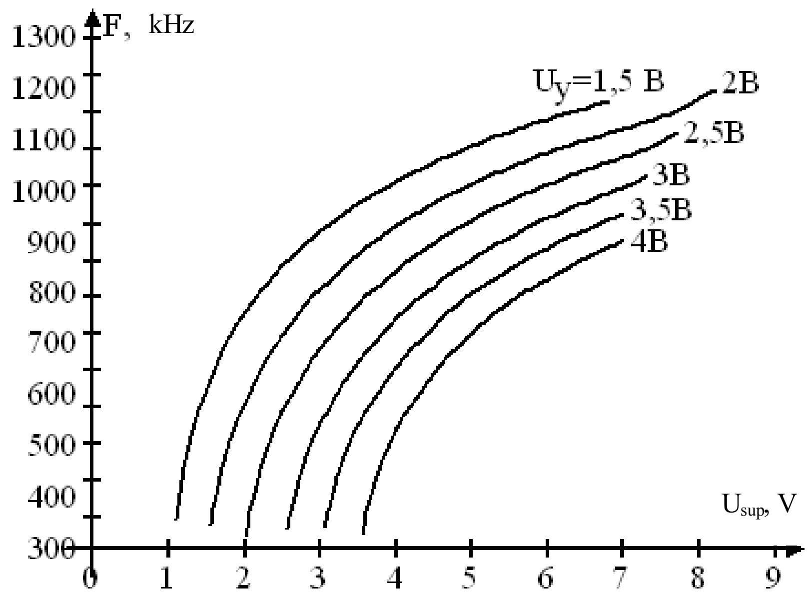


Fig. 11. Experimental dependence of generation frequency of temperature conversion on voltage supply

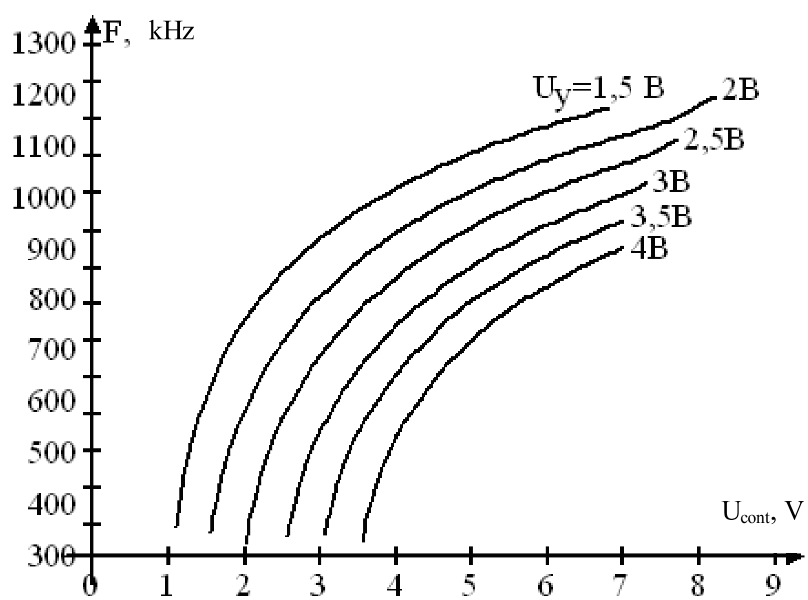


Fig. 12. Dependence of generation frequency of temperature convertor on controlled voltage

Choosing of operative point of converter is made on the base of the obtained characteristics of dependences of the devices generation frequency on voltage supply and controlled voltage (fig. 11, 12).

Fig. 13 – 15 present the experimental dependences of generation frequency with different voltage supply on temperature for different thermistors, as is seen from the figure, the optimal range of operative temperatures is the interval from +20 ^{0}C to 160 ^{0}C.

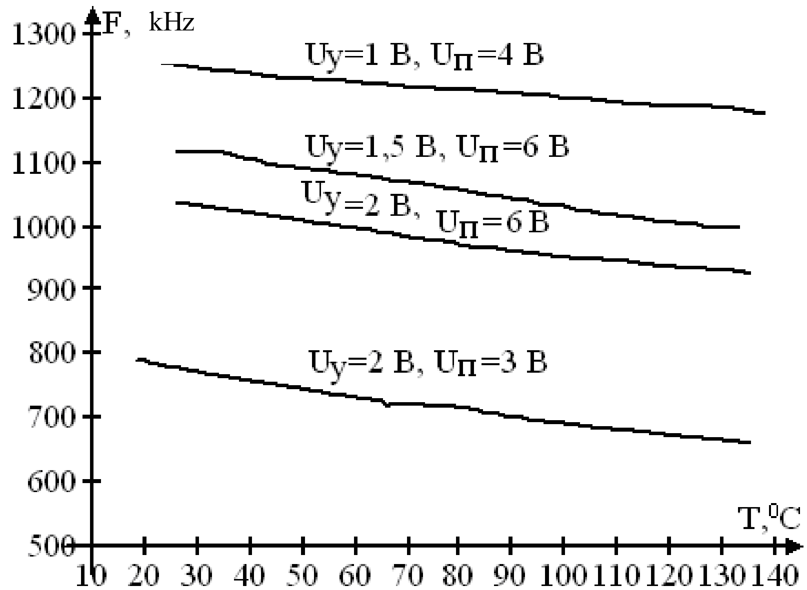
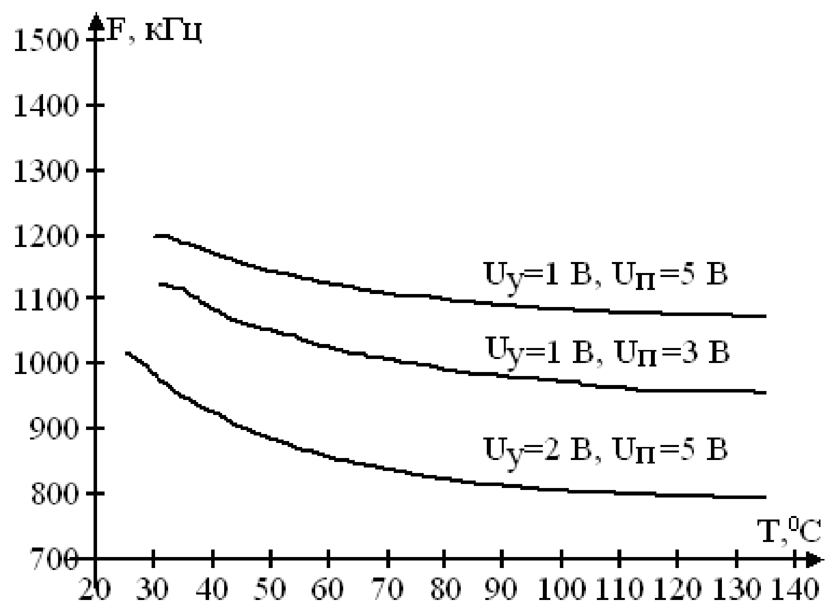


Fig. 13. Experimental dependence of generation frequency on temperature for convertor on the base of thermistor MMT-1 (1,5 kOhm)



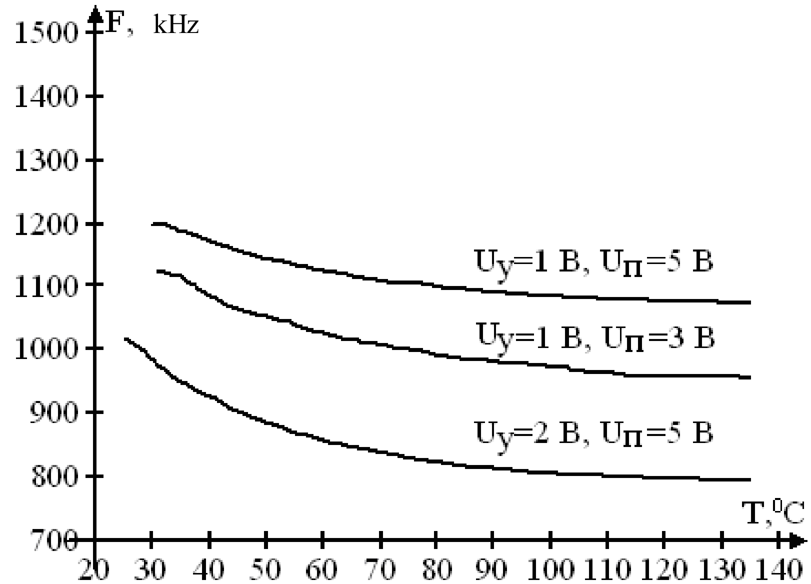


Fig. 14. Experimental dependence of generation frequency on temperature for convertor on the base of thermistor MKT-12 (1,5 kOhm)

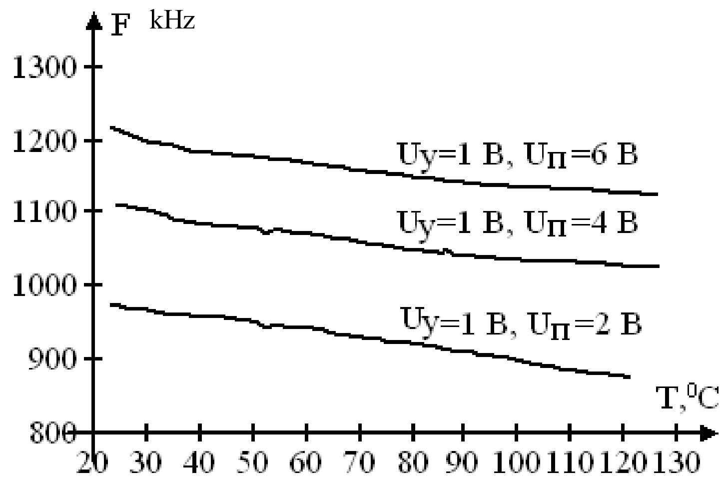


Fig. 15. Experimental dependence of generation frequency on temperature for convertor on the base of thermistor (Siemens, 1,5 kOhм)

So, as it follows from diagrams of dependences, received in the result of experimental researches, for microelectronic temperature convertor, it is appropriate to use national thermistor MMT-1 as a sensitive element.

Conclusions

The paper presents simulation of radiomeasuring temperature convertor in the program package Orcad Family Release 9.2. By methods of loop currents, following the Kirchhoff laws there had been received the function of conversion and the function of sensitivity of the device. There had been conducted the experimental researches, in the result of which there was received the CVC family, frequency dependences on voltage supply mode, dependence of convertor generation frequency on temperature for different sensitive elements.

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