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Investigation of a radio-frequency temperature transducer with a thermosensitive resistive element based on a complex compound of heterometallic β -diketonate

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Abstract. The article considers a new electrical circuit of a microelectronic radio-frequency measuring temperature transducer with a thermosensitive resistive element based on a complex compound of heterometallic β -diketonate. The main characteristics of the researched radio-frequency temperature transducer with a thermosensitive resistive element based on a complex compound of heterometallic β -diketonate are obtained: the dependences of the active and reactive components of the full impedance of the radio-frequency measuring temperature transducer, the conversion function and the sensitivity equation.

1. Introduction

In recent years, wireless sensor networks (WSNs) and remote sensor systems have been used as part of several important areas, such as social services, military, critical infrastructure monitoring, environmental monitoring, and information collection and processing systems [1-2]. The availability of Internet connections and low production costs have led to a boom in smart facilities, which consist of a CPU, memory and wireless connection. These smart devices consist of sensors that process and transmit data [3].

Leading specialists of the world are developing and creating transducers of physical quantities. The values of physical quantities (such as temperature, humidity, density and others) of a gas mixture (air) significantly affect the well-being of a person and the quality of technological processes in microelectronics and various industries [4-7]. In our work, the emphasis is on temperature.

In the development of new functional materials, an important role belongs to complex compounds in which β -diketonate is a chelating and in some cases a bridging ligand. Nowadays, the field of practical using of functional materials containing β -diketonates of metals is constantly expanding [8]. The hetero-metallic β -diketonates are one of the most interesting complex compounds in this class, because they have semiconductor properties [9].

A promising scientific direction in this field is the creation of frequency measuring devices based on semiconductor structures with negative differential resistance. A great contribution to the development of the theory of negative differential resistance has been made by Ukrainian and foreign scientists [10-13]. The using of the frequency principle of conversion "temperature-frequency" in combination with the technology of microelectronics contributes to the improvement of the



metrological and economic performance of temperature transducers, manufactured in the form of integrated circuits [14-15].

Thus, the development and practical using of micro-and nano-electronic transducers of physical quantities based on new nanocomposite materials is an actual task.

2. Theoretical and experimental research

2.1. The research of circuit design of the radiomeasuring frequency transducer of the temperature

The main accent of this work is studying and developing a radio-frequency measuring temperature transducer with frequency output based on a transistor structure with negative differential resistance. This transducer is shown in Figure 1.

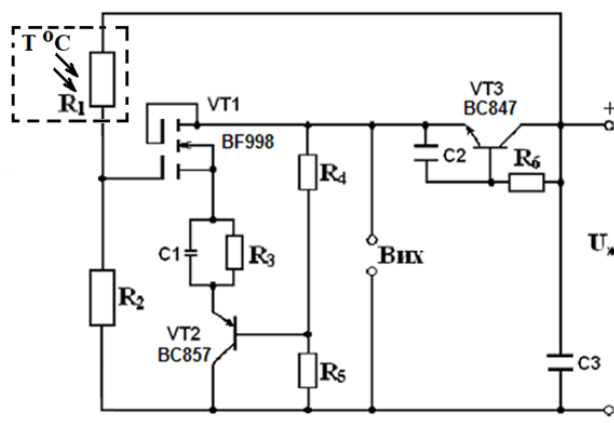


Figure 1. The electric circuit of the radio-frequency measuring temperature transducer.

To determine the behavior of the temperature transducer in the dynamic mode, it is necessary to obtain the dependence of the active and reactive components of the full impedance on the electrodes of the drain-collector of transistor structure. Also it is necessary to obtain the conversion function and sensitivity equation which depend on the temperature. Calculations were based on the nonlinear equivalent circuit of dual-gate MOSFET and bipolar transistors.

2.2. The research of thermosensitive element of the radio-frequency temperature transducer

As a sensitive element, we used the sensitive resistive element produced on a complex compound - tetrakis- μ_3 -(methoxo) (methanol)-pentakis (acetylacetonate) (threeicuprum (II), neodymium (III)) methanol (I). The chemical formula of the sensing element is as follow:



This chemical structure was obtained by the following method: portions of salts of 3.62 g (15 mmol) of copper (II) nitrate threehydrate and 2.19 g (5 mmol) of neodymium (III) nitrate hexahydrate were dissolved in 130 ml of absolute methyl alcohol containing 40 ml of orthomup ether. Then kept it for 2 hours at room temperature in a tightly closed conical flask. Then 2.7 ml (25 mmol) of acetylacetone was added to the reaction mixture. The conical flask was closed with a reversible water cooler and placed on a heated magnetic stirrer. Then, with continuous stirring and heating ($\sim 50^\circ\text{C}$), piperidine was gradually introduced into the reaction mixture to pH = 8 and continued to heat and stir for one hour. After cooling, a homogeneous blue fine crystalline precipitate precipitated, which was filtered on a glass filter, washed with a small amount of absolute methanol, diethyl ether and dried in a vacuum desiccator over silica gel [16]. The practical yield is 4.07 g, which is 80% of theoretical. The isolated complex compound (I), which is a crystalline powder that is poorly soluble in dimethylformamide, preferably in dimethyl sulfoxide, is practically insoluble in alcohols, chloroform,

benzene, acetone [16]. For the synthesized complex compound (I) in the dry powder state, elemental analysis was performed and it was found that it contains:

Cu – 18.65%; Nd – 14.25%; C – 36.68%; H – 5.24%.

As can be seen from the above, the ratio of metals in compound (I) Cu:Nd = 1:3, and its composition corresponds to the following formula: $\text{Cu}_3\text{NdO}_{16}\text{C}_{31}\text{H}_{55}$. In addition, magnetochemical, IR spectroscopic and thermogravimetric studies were performed for this isolated heterometallic compound (I) [16]. The analysis of the obtained experimental data of physicochemical research methods allows us to propose the following scheme of arrangement of chemical bonds for complex compound (I) as is shown in Figure 2 [16].

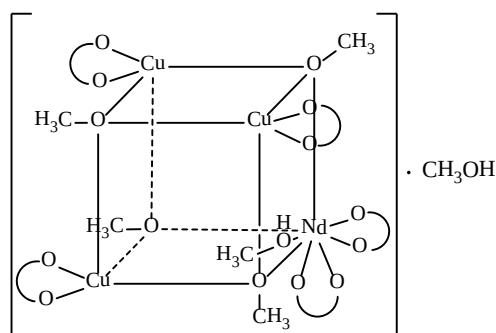


Figure 2. Schematic arrangement of chemical bonds in tetrakis- μ_3 -(methoxo) (methanol)-pentakis (acetylacetonate) (threecuprum (II), neodymium (III)) methanol (I).

This sensitive element was used in our radio-frequency temperature transducer.

2.3. The research of the characteristics of the radio-frequency measuring temperature transducer

The active component of full impedance at the electrodes of the drain-collector of transistors VT1 and VT2 has negative value. The reactive component is capacitive. The oscillatory circuit of the device is based on the equivalent capacitance and the active inductance based on the phase-shifting transistor VT3 on R6C2. The equivalent capacitance consists of the capacitance between the drain electrodes of the field-effect transistor VT1 and the emitter of the bipolar transistor VT2[17-18]. Static volt-ampere characteristic is shown in Figure 3(a). Dynamic volt-ampere characteristic is shown in Figure 3(b).

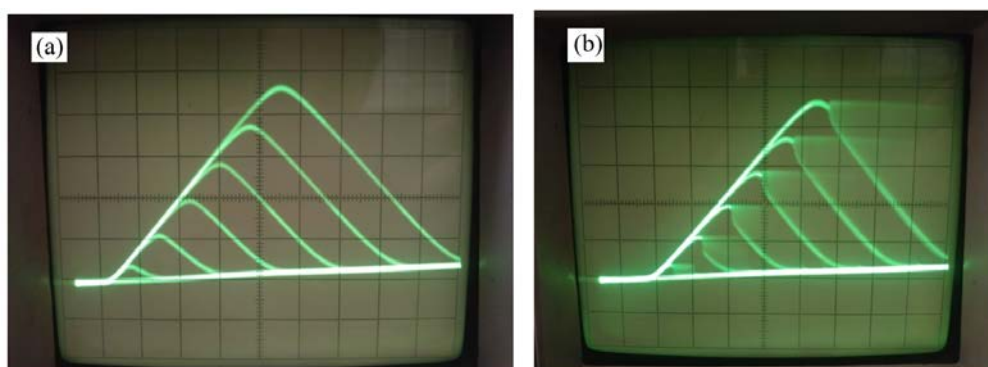


Figure 3. Static (a) and dynamic (b) volt-ampere characteristics of the radio-frequency measuring transducer of the temperature (on vertical axis one division – 2mA, on horizontal axis– 2V).

To determine the conversion function and sensitivity equation, a nonlinear equivalent circuit of the radio-frequency measuring transducer of the temperature is presented in Figure 4. This circuit realizes the dependence of the frequency on the temperature change [19-20].

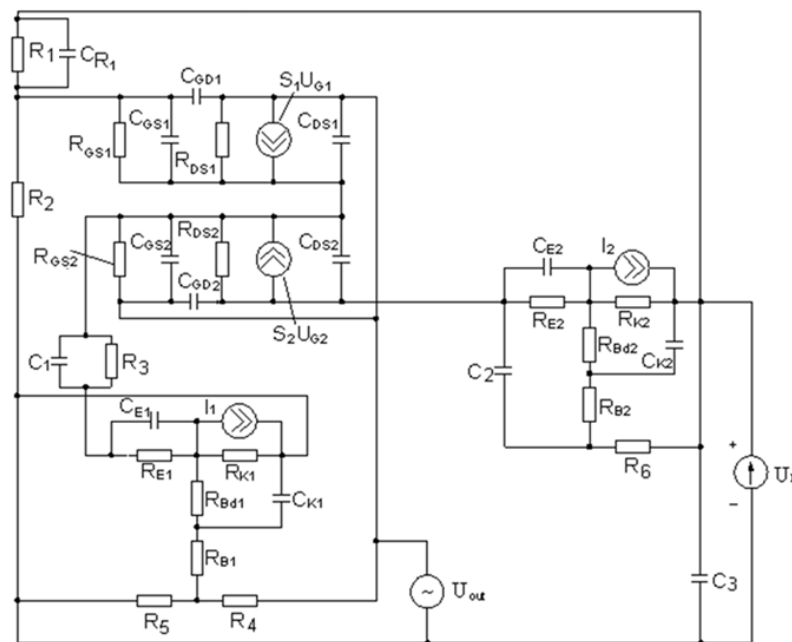


Figure 4. Nonlinear equivalent circuit of the radio-frequency measuring transducer of the temperature.

This circuit takes into account the nonlinear properties of the circuit solution of the radio-frequency measuring temperature transducer based on a transistor structure with negative differential resistance, because the autogenerator of transducer can operate in both linear and nonlinear modes. For the convenience of mathematical modelling, the nonlinear equivalent circuit is transformed into the form is shown in Figure 5.

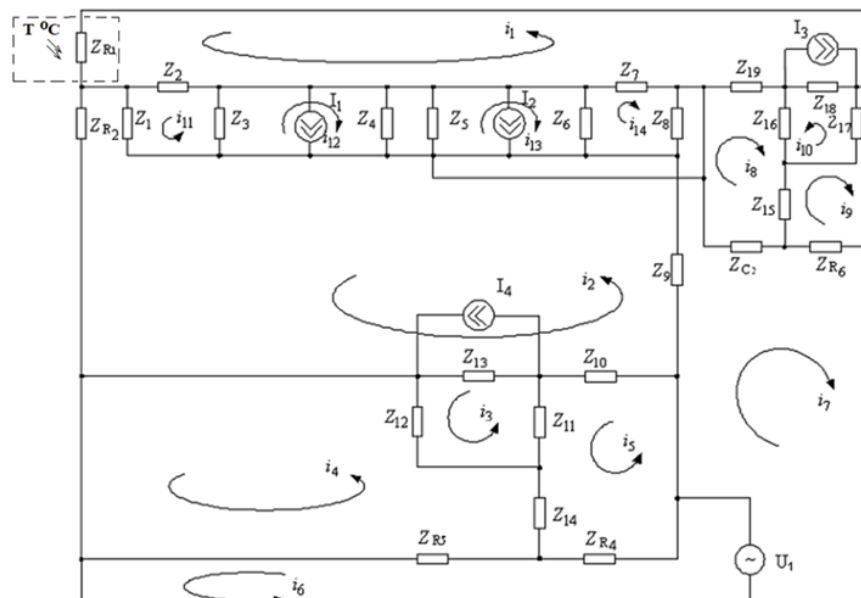


Figure 5. Converted nonlinear equivalent circuit of the radio-frequency measuring transducer of the temperature.

To determine the conversion function of the radio-frequency measuring transducer of the temperature, it is necessary to find the dependence of the generation frequency on the temperature

change. This can be done by solving a system of equations that is compiled for alternating current based on a nonlinear equivalent circuit which is shown in Figure 5. Solving the system of equations allows to obtain the value of the total resistance at the electrodes of the collector-collector of the transducer. By decomposing the total resistance into real and imaginary components, it is possible to determine the equivalent capacitance of the oscillatory circuit, which depends on the temperature. The system of equations, according to the directions of the contour currents, has the form

$$\begin{cases} 0 = (Z_{R_1} + Z_2 + Z_7 + Z_{19} + Z_{18})i_1 + Z_{19}i_8 - Z_{18}(I_3 + i_{10}) - Z_2i_{11} + Z_7i_{14}; \\ 0 = (Z_{R_2} + Z_1 + Z_9 + Z_{10} + Z_{13})i_2 - Z_{13}i_3 - Z_{10}i_5 + Z_9i_7 - Z_1i_{11}; \\ 0 = (Z_{11} + Z_{12} + Z_{13})i_3 - Z_{13}(I_4 + i_2) - Z_{12}i_4 - Z_{11}i_5; \\ 0 = (Z_{12} + Z_{14} + Z_{R_5})i_4 - Z_{12}i_3 - Z_{14}i_5 - Z_{R_5}i_6; \\ 0 = (Z_{10} + Z_{11} + Z_{14} + Z_{R_4})i_5 - Z_{10}i_2 - Z_{11}i_3 - Z_{14}i_4 - Z_{R_4}i_6; \\ \dot{U}_1 = (Z_{R_4} + Z_{R_5})i_6 - Z_{R_5}i_4 - Z_{R_4}i_5; \\ \dot{U}_1 = (Z_{C_2} + Z_{R_6} + Z_8 + Z_9)i_7 + Z_9i_2 - Z_{C_2}i_8 - Z_{R_6}i_9 - Z_8i_{14}; \\ 0 = (Z_{C_2} + Z_{15} + Z_{16} + Z_{19})i_8 + Z_{19}i_2 - Z_{C_2}i_7 - Z_{15}i_9 + Z_{16}i_{10}; \\ 0 = (Z_{R_6} + Z_{15} + Z_{17})i_9 - Z_{R_6}i_7 - Z_{15}i_8 + Z_{17}i_{10}; \\ 0 = (Z_{16} + Z_{17} + Z_{18})i_{10} + Z_{18}(I_3 - i_1) + Z_{16}i_8 + Z_{17}i_9; \\ 0 = (Z_1 + Z_2 + Z_3)i_{11} - Z_2i_1 - Z_1i_2 + Z_3(i_{12} + I_1); \\ 0 = (Z_3 + Z_4Z_5 / (Z_4 + Z_5))i_{12} + Z_3i_{13} - (Z_4Z_5 / (Z_4 + Z_5))i_{13} + Z_3(I_1 + i_{12}) - (Z_4Z_5 / (Z_4 + Z_5))(i_{12} + I_2); \\ 0 = (Z_4Z_5 / (Z_4 + Z_5) + Z_6)i_{13} - Z_4Z_5 / (Z_4 + Z_5)i_{13} - Z_6i_{14} + Z_4Z_5 / (Z_4 + Z_5)(i_{13} + I_2); \\ 0 = (Z_6 + Z_7 + Z_8)i_{14} - Z_6(i_{13} + I_2) + Z_7i_1 - Z_8i_7, \end{cases} \quad (1)$$

where

$$\begin{aligned} Z_1 &= \frac{R_{GS_1}}{1 + \omega^2 R_{GS_1}^2 C_{GS_1}^2} - j \frac{R_{GS_1}^2 \omega C_{GS_1}}{1 + \omega R_{GS_1}^2 C_{GS_1}^2}; \quad Z_2 = -\frac{j}{\omega C_{GD_1}}; \quad Z_{R_2} = R_2; \quad Z_3 = R_{DS_1}; \quad Z_{R_5} = R_5; \\ Z_4 &= -\frac{j}{\omega C_{DS_1}}; \quad Z_5 = -\frac{j}{\omega C_{DS_2}}; \quad Z_6 = R_{DS_2}; \quad Z_7 = -\frac{j}{\omega C_{GD_2}}; \quad Z_{R_4} = R_4; \quad Z_{R_6} = R_6; \quad Z_{R_3} = R_3; \\ Z_8 &= \frac{R_{GS_2}}{1 + \omega^2 R_{GS_2}^2 C_{GS_2}^2} - j \frac{R_{GS_2}^2 \omega C_{GS_2}}{1 + \omega R_{GS_2}^2 C_{GS_2}^2}; \quad Z_9 = \frac{R_3}{1 + \omega^2 R_3^2 C_1^2} - j \frac{R_3^2 \omega C_1}{1 + \omega R_3^2 C_1^2}; \quad Z_{C_2} = -\frac{j}{\omega C_2}; \\ Z_{10} &= \frac{R_{E1}}{1 + \omega^2 R_{E1}^2 C_{E1}^2} - j \frac{R_{E1}^2 \omega C_{E1}}{1 + \omega R_{E1}^2 C_{E1}^2}; \quad Z_{11} = R_{Bd_1}; \quad Z_{12} = -\frac{j}{\omega C_{K1}}; \quad Z_{13} = R_{K1}; \\ Z_{14} &= R_{B_1}; \quad Z_{15} = R_{B_2}; \quad Z_{16} = R_{Bd_2}; \quad Z_{17} = -\frac{j}{\omega C_{K2}}; \quad Z_{18} = R_{K2}; \\ Z_{19} &= \frac{R_{E2}}{1 + \omega^2 R_{E2}^2 C_{E2}^2} - j \frac{R_{E2}^2 \omega C_{E2}}{1 + \omega R_{E2}^2 C_{E2}^2}; \quad Z_{R_1} = \frac{R_1(T)}{1 + \omega^2 R_1^2(T) C_{R_1}^2(T)} - j \frac{\omega R_1^2(T) C_{R_1}(T)}{1 + \omega R_1^2(T) C_{R_1}^2(T)}. \end{aligned}$$

Elements of the nonlinear equivalent circuit are described by the following values: R_{GS} , C_{GS} are the resistance and capacitance between the gate and source areas of the MOSFET; R_G is the ohmic

resistance of the MOSFET gate; R_{DS} , C_{DS} are the drain-source resistance and capacitance of MOSFET; R_S is the resistance of source p-n junction of the field-effect transistor; R_D is the resistance of the p-n junction of the drain of the field-effect transistor; R_n is the resistance of the MOSFET substrate; R_C , R_E , R_B are the resistances of the collector, emitter, base junctions of the bipolar transistor; R_2 , R_3 , R_4 , R_5 are there sistances of the divider of the radio-frequency temperature transducer; I_{DS} is the drain-source current of MOSFET; I_{BS} and I_{BD} are substrate-source and substrate-drain of MOSFET junction current; R_1 is the thermosensitive resistive element based on a complex compound - tetrakis- μ_3 -(methoxo) (methanol) -pentakis (acetylacetonate) (threecuprum (II), neodymium (III)) methanol (I); C_K , C_E are the capacitances of the collector and emitterjunctions of the bipolar transistor; C_{GD} is the gate-drain capacitance of MOSFET; C_{R_1} is the capacitance of thermosensitive resistive element.

Currents I_{BS} and I_{BD} transitions of substrate-source and substrate-drain MOSFET in linear mode, if the condition $U_{ds} < (U_{gs} - U_T)$ is met, are described by expressions [18]

$$I_{bs} = I_{ss} (\exp U_{bs} / (NU_t) - 1), \quad (2)$$

$$I_{bd} = I_{ss} (\exp U_{bd} / (NU_t) - 1), \quad (3)$$

where U_{bs} is the substrate-source voltage MOSFET; U_{bd} is the voltage substrate-drain MOSFET; I_{ss} is the saturation current p-n junction of the field-effect transistor substrate; N is the coefficient of imperfection of the substrate-drain junction of the field-effect transistor; U_t is the temperature potential p-n junction of the substrate of the field-effect transistor.

The static output characteristic of a MOSFET transistor in linear mode is described by [21]

$$I_{ds} = \frac{\mu \cdot C_0 \cdot W}{L} \left((U_{gs} - U_T) \cdot U_{ds} - \frac{U_{ds}^2}{2} \right), \quad (4)$$

where W is the field-effect transistor channel width; μ is the media mobility in the MOSFET channel; L is the the length of the channel of the field-effect transistor; U_{gs} is the gate-source voltage; C_0 is the specific capacity of the oxide; U_{ds} is the MOSFET drain-source voltage; U_T is the threshold voltage.

The expression for determining the threshold voltage of the MOSFET transistor for analytical models has the form [20]

$$U_T = \varphi_{SiO_2} + 2\varphi_B - \frac{Q_s + \sqrt{4\varepsilon_s q N_A \varphi_B}}{C_0}, \quad (5)$$

where ε_s is the relative electrical permeability of semiconductor material; Q_s is the specific surface charge; N_A is the concentration of impurities in the semiconductor material.

The Fermi potential included in expression (5) is described by the formula [20-21]

$$\varphi_B = \pm \frac{kT}{q} \ln \left(\frac{N_A}{n_i} \right), \quad (6)$$

where k is the Boltzmann constant; T is the temperature; n_i is the intrinsic carrier concentration in an undoped semiconductor; q is the electron charge.

The drain current of the field-effect transistor in the saturation mode when the condition $U_{ds} \geq (U_{gs} - U_T)$ is met is described by the expression [21]

$$I_{dsSAT} = \frac{\mu \cdot C_0 \cdot W}{6L} ((U_{dsSAT} + 2\phi_B)^2 + U_{gs}(U_{dsSAT} + 2\phi_B) - 12\phi_B(U_{gs} - \phi_B - \frac{4}{3}K\phi_B^{1/2})), \quad (7)$$

where

$$U_{dsSAT} = U_{gs} - 2\phi_B + K^2[1 - (1 + 2U_{gs}/K^2)^{1/2}], \quad (8)$$

$$K = (\varepsilon_s q N_A / C_0)^{1/2}. \quad (9)$$

The drain-source resistance of the field-effect transistor R_{ds} in the linear region is determined by the expression [18]

$$R_{ds} = \frac{L}{W \mu C_0} (U_{gs} - U_T), \quad (10)$$

and in the saturation region [18]

$$R_{ds} = \frac{12 \left[L(U_d - U_{dsAT})^{1/2} - 2(\varepsilon_s / q N_A)^{1/2} (U_d - U_{dsAT}) \right]}{W \mu C_0 (2\varepsilon_s / q N_A)^{1/2}} \times \frac{1}{(U_{dsAT} + 2\phi_B)^2 + U_{gs}(U_{dsAT} + 2\phi_B) - 12\phi_B(U_{gs} - \phi_B - 4/3 K \phi_B^{1/2})}, \quad (11)$$

where U_d is the voltage on the drain of the field-effect transistor; U_{dsAT} is the drain-source voltage of the field-effect transistor in saturation mode.

The solution of the system of equations (1) made it possible to obtain the theoretical dependence of the active and reactive components of full impedance, the frequency of generations on the temperature, and also the sensitivity function of the radio-frequency temperature transducer. The experimental dependences of the active and reactive components of the full impedance of the radio-frequency temperature transducer from temperature change is shown in Figure 6.

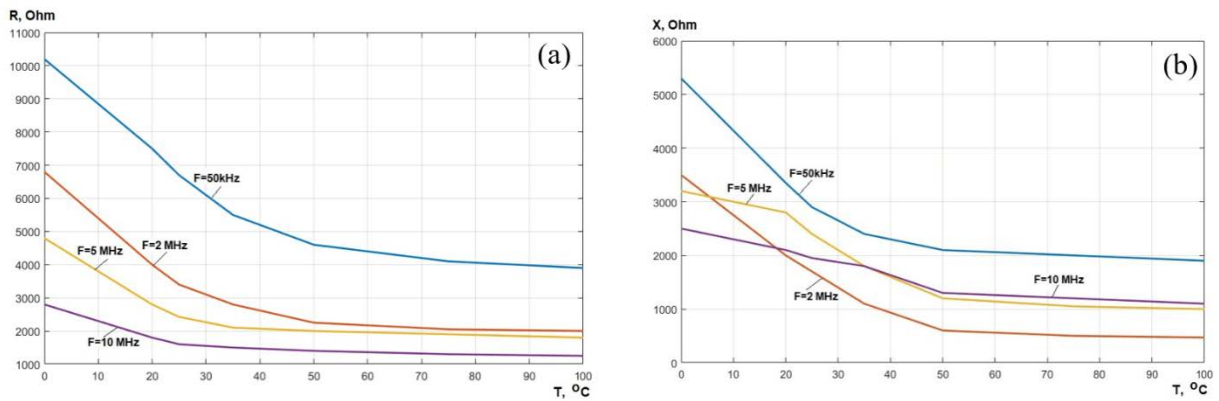


Figure 6. The experimental dependences of the active (a) and reactive (b) components of the full impedance of the radio-frequency measuring transducer of the temperature.

Base on the nonlinear equivalent circuit which is shown in Figure 5, according to Lyapunov's method, the conversion function of the radio-frequency temperature transducer is determined. The conversion function is the dependence of the output frequency of the radio-frequency measuring

transducer on the temperature value. The analytical dependence of the conversion function is described by the expression

$$F = \frac{1}{2\pi} \sqrt{\frac{(C_{R1}^2(T)R_{R1}^2(T) + R_{R1}^2(T)C_{R1}(T)C_{DS2} - L_{ek6}C_{DS2}) + D}{2L_{ek6}C_{DS2}C_{R1}^2(T)R_{R1}^2(T)}}, \quad (12)$$

where T is the temperature; C_{DS2} is the drain-source capacitance of MOSFET; C_{R1}, R_{R1} are the capacitance and resistance of the thermosensitive resistive element based on a complex compound - tetrakis- μ_3 -(methoxo) (methanol) -pentakis (acetylacetonate) (threecuprum (II), neodymium (III)) methanol (I); L_{ek6} the value of the equivalent inductance based on the bipolar transistor BC847;

$$D = \sqrt{(C_{R1}^2(T)R_{R1}^2(T) + R_{R1}^2(T)C_{R1}(T)C_{DS2} - L_{ek6}C_{DS2})^2 + 4L_{ek6}C_{DS2}C_{R1}^2(T)R_{R1}^2(T)}.$$

The graphical dependence of the conversion function is presented in Figure 7.

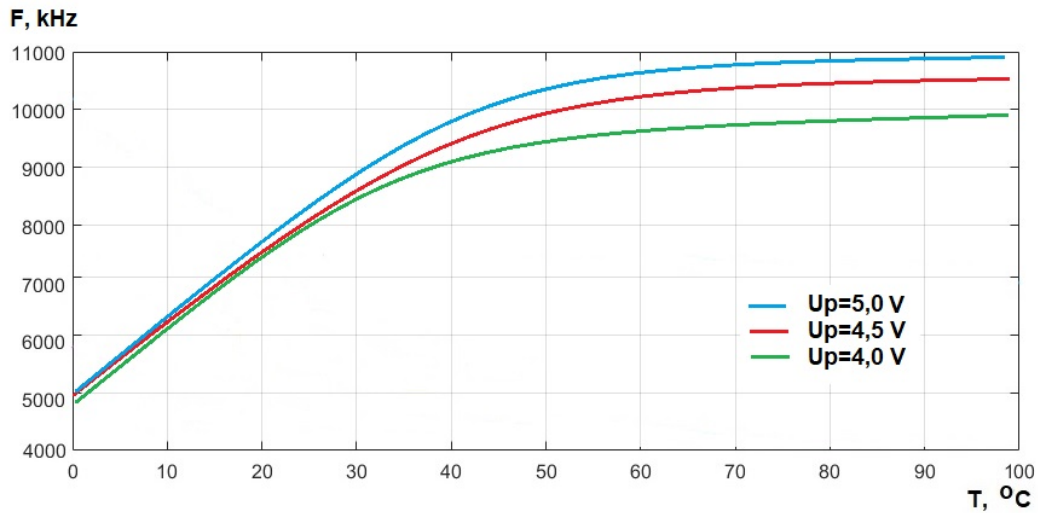


Figure 7. The dependence of the output frequency of the radio-frequency measuring transducer of the temperature.

The sensitivity of the radio-frequency temperature transducer is determined on the basis of the expression (12) and is described by equation (13). The graph of sensitivity dependence is presented in Figure 8.

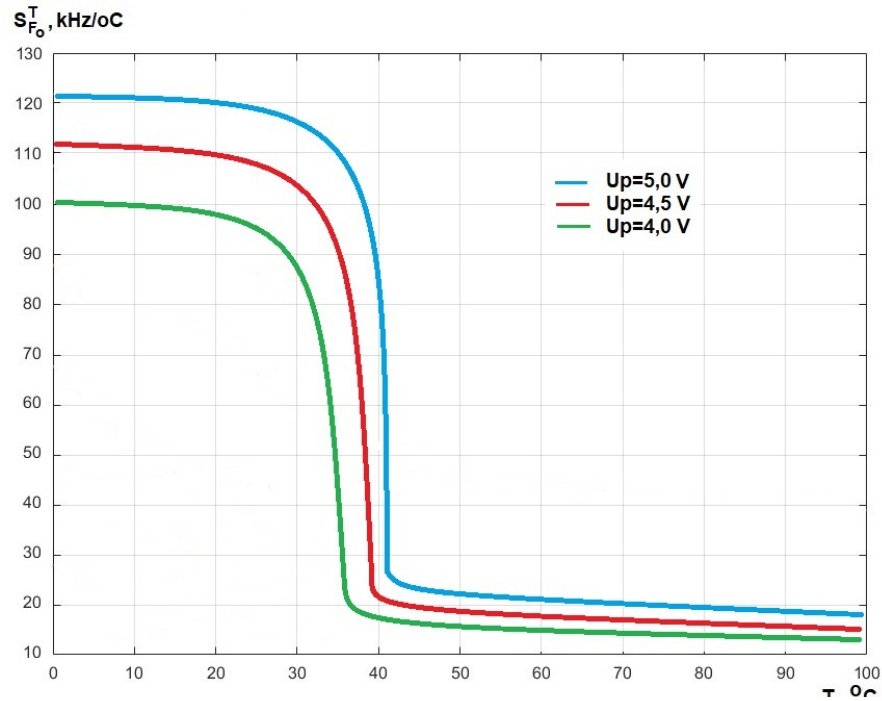


Figure 8. The dependence of the sensitivity of the radio-frequency measuring transducer of the temperature.

$$\begin{aligned}
 S_B^F = & \frac{1}{\sqrt{8}} \left(\left(2C_{R1}(T)R_{R1}^2(T) \left(\frac{\partial C_{R1}(T)}{\partial T} \right) + 2C_{R1}^2(T)R_{R1}(T) \left(\frac{\partial R_{R1}(T)}{\partial T} \right) + 2R_{R1}(T)C_{R1}(T)C_{DS2} \times \right. \right. \\
 & \times \left(\frac{\partial R_{R1}(T)}{\partial T} \right) + R_{R1}^2(T) \left(\frac{\partial C_{R1}(T)}{\partial T} \right) C_{DS2} + \frac{1}{2} \left(2(C_{R1}^2(T)R_{R1}^2(T) + C_{R1}(T)R_{R1}^2(T)C_{DS2} - L_{ek6}C_{DS2}) \times \right. \\
 & \times \left(2C_{R1}(T)R_{R1}^2(T) \left(\frac{\partial C_{R1}(T)}{\partial T} \right) + 2C_{R1}^2(T)R_{R1}(T) \left(\frac{\partial R_{R1}(T)}{\partial T} \right) + 2R_{R1}(T)C_{R1}(T)C_{DS2} \left(\frac{\partial R_{R1}(T)}{\partial T} \right) + \right. \\
 & + R_{R1}^2(T) \left(\frac{\partial C_{R1}(T)}{\partial T} \right) C_{DS2} \left. \right) + 8L_{ek6}C_{DS2}C_{R1}(T)R_{R1}^2(T) \left(\frac{\partial C_{R1}(T)}{\partial T} \right) + 8L_{ek6}C_{DS2}C_{R1}^2(T) \times \\
 & \times R_{R1}(T) \left(\frac{\partial R_{R1}(T)}{\partial T} \right) \left. \right) \left/ \left((C_{R1}^2(T)R_{R1}^2(T) + C_{R1}(T)R_{R1}^2(T)C_{DS2} - L_{ek6}C_{DS2})^2 + 4L_{ek6}C_{DS2} \times \right. \right. \\
 & \times C_{R1}^2(T)R_{R1}^2(T) \left. \right)^{1/2} \left/ \left((L_{ek6}C_{DS2}C_{R1}^2(T)R_{R1}^2(T) - 2(C_{R1}^2(T)R_{R1}^2(T) + C_{DS2}C_{R1}(T)R_{R1}^2(T) - \right. \right. \\
 & - L_{ek6}C_{DS2} + (C_{R1}^2(T)R_{R1}^2(T) + C_{DS2}C_{R1}(T)R_{R1}^2(T) - L_{ek6}C_{DS2})^2 + 4L_{ek6}C_{DS2}C_{R1}^2(T)R_{R1}^2(T) \left. \right)^{1/2} \times \right. \\
 & \times \left(\frac{\partial C_{R1}(T)}{\partial T} \right) \left/ \left((L_{ek6}C_{DS2}C_{R1}^3(T)R_{R1}^2(T) - 2(C_{R1}^2(T)R_{R1}^2(T) + C_{DS2}C_{R1}(T)R_{R1}^2(T) - L_{ek6}C_{DS2} + \right. \right. \\
 & + (C_{R1}^2(T)R_{R1}^2(T) + C_{DS2}C_{R1}(T)R_{R1}^2(T) - L_{ek6}C_{DS2})^2 + 4L_{ek6}C_{DS2}C_{R1}^2(T)R_{R1}^2(T) \left. \right)^{1/2} \right) \left/ \left((L_{ek6}C_{DS2} \times \right. \right. \\
 & \times C_{R1}^2(T)R_{R1}^3(T) \left. \right) \left/ \left((C_{R1}^2(T)R_{R1}^2(T) + C_{DS2}C_{R1}(T)R_{R1}^2(T) - L_{ek6}C_{DS2} + \right. \right. \\
 & + ((C_{R1}^2(T)R_{R1}^2(T) + C_{DS2}C_{R1}(T)R_{R1}^2(T) - L_{ek6}C_{DS2})^2 + \\
 & + 4L_{ek6}C_{DS2}C_{R1}^2(T)R_{R1}^2(T) \left. \right)^{1/2} \left/ \left((L_{ek6}C_{DS2}C_{R1}^2(T)R_{R1}^2(T) \right)^{1/2} \right. ,
 \end{aligned} \tag{13}$$

where T is the temperature; C_{DS2} is the drain-source capacitance of MOSFET; C_{R1} , R_{R1} are the capacitance and resistance of the thermosensitive resistive element based on a complex compound - tetrakis- μ_3 -(methoxo) (methanol) -pentakis (acetylacetonate) (threecuprum (II), neodymium (III)) methanol (I); $L_{екв}$ the value of the equivalent inductance based on the bipolar transistor BC847.

As can be seen from the graph, the highest sensitivity of the device is in the range from 0 to 30 °C. Maximal sensitivity 121.85 kHz/°C.

3. Conclusion

The optimal for practical implementation is the frequency method of the temperature measuring based on the dependence of the reactive properties of semiconductor structures with differential resistance on the temperature. Devices based on this method have increased sensitivity.

The circuit of the radio-frequency measuring transducer of the temperature was proposed in the article. As a thermosensitive element was proposed the sensitive resistive element produced on a complex compound - tetrakis- μ_3 -(methoxo) (methanol)-pentakis (acetylacetonate) (threecuprum (II), neodymium (III)) methanol (I). Static and dynamic volt-ampere characteristics of the radio-frequency measuring transducer of the temperature were obtained. As a result of calculating of the system of equilibrium equations of the equivalent circuit, analytical expressions of the conversion function and the sensitivity equation of the device were obtained. Graphical dependences of the active and reactive components of full impedance on temperature were also presented. It was found that the highest sensitivity of the radio-frequency temperature transducer is in the range from 0 to 30 °C and is 89.05~121.85 kHz/°C.

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