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The Microelectronic Radiomeasuring Transducers of Magnetic Field with a Frequency Output

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Introduction

The performances of transducers determine an accuracy and reliability of systems of a radio control, devices of monitoring of technological processes, environmental properties, operational safety of kernel, thermal, chemical installations, flight vehicles, marine plants, carrier etc. In this connection to transducers, which meter the manifold information, the rigid requirements are advanced. These devices should be costeffective, noise-resistant, to ensure a fast response time, responsivity and measurement accuracy, to have a small overall dimensions and weight, to be compatible with modern PCs and to allow ciphering the information in transfer time it on major distances [1, 2].

One of trajectories of the solution of this problem is use magneticreactive effect in transistors [3]. In this case transistors act as magneticsensitive devices, and as active elements of autogenerating arrangements of the transformer that simplifies plans of sensor controls of a magnetic field. Use of frequency as informative parameter allows to exclude application of intensifying arrangements and analog-to-digital converters at aftertreatment of the information that reduces the cost price of monitoring systems and control.

Microelectronic radiomeasuring transducers of magnetic induction

On the basis magneticreactive effect the theoretical fundamentalses and methods of build-up of magnetic transducers are designed which take into account influence of a magnetic field to allocation of density of injected carriers of charge in the basis of bipolar and channel field-effect transistors, which diagrammatize transducers. It reduces in dependence of elements of nonlinear equivalent circuits on a magnetic field, that enables to construct mathematical models and on their basis to calculate performances of magnetic transducers and to conduct their experimental research.

The operation of a magnetic field on sensing bipolar structures appears in a warpage of the trajectory of injected carriers of the charge, which will call magnifying of an effective length of basis and aberration of the part of charge carriers from the collector. The role of the last effect increases with reduction of the width of emitter and collector, that ensures the increase of magneticsensitivity.

For complete realization of the transducer for microelectronics technology one more version of the transducer of a magnetic field is designed, which circuit is submitted on fig.1. It represents the circuit, which consists of bipolar two-collector magneticsensitive transistor VT1 and bipolar transistor VT2 together with a R5C1-circuit, which implements an active inductive element. This circuit represents the auto generating device, the generation frequency of which depends on the operation of a magnetic field. On electrodes of the first collector and emitter of the transistor VT1 there is a complete resistance, an active component of which has a negative value, and a reactive - capacity character.

The resistors R1-R4 together with sources of fixed voltage U1 and U2 ensure the condition of power supply of the converter circuit. At the operation of a magnetic field on the transistor VT1 there is the variation of equivalent capacity of a tuned circuit of the self-excited oscillator, which calls variation of its resonance frequency.

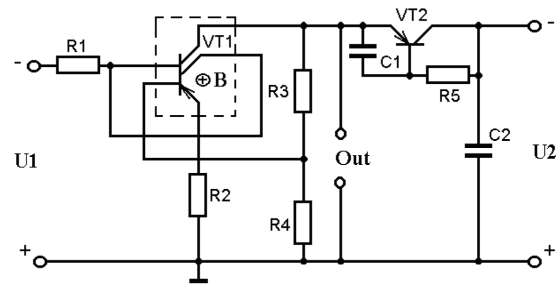

Fig. 1. An electric circuit of the transducer magnetic field

On the basis of an equivalent circuit of the transducer the function of transformation is defined which features dependence of generation frequency on the induction of a magnetic field. The analytical expression of function of transformation has view

$$F_0=\frac{1}{2\pi}\sqrt{\frac{R_B^2(B)C_B(B)-L}{LC_B^2(B)R_B^2(B)}}\ , \tag{1}$$

where R_B – resistance to the base area of magneticsensitive two–collector transistor, C_B – equivalent capacity of magneticsensitive two–collector transistor, L – magnitude of inductance of an active inductive element.

The equation of sensitivity is determined on the basis of expression (1)

$$\begin{aligned}S_B^{F_0}=\frac{1}{4}\Bigg(\bigg(&C_B(B)\left(\frac{\partial R_B(B)}{\partial B}\right)+R_B^2(B)\times\\ &\times\left(\frac{\partial C_B(B)}{\partial B}\right)\bigg)\Big/\left(LC_B^2(B)R_B^2(B)\right)-\big(2(C_B(B)R_B^2(B)-L)\times\\ &\times\left(\frac{\partial C_B(B)}{\partial B}\right)\big)\Big/\left(LC_B^3(B)R_B^2(B)\right)-\big(2(R_B^2(B)C_B(B)-L)\times\\ &\times\left(\frac{\partial R_B(B)}{\partial B}\right)\big)\Big/\left(LC_B^2(B)R_B^3(B)\right)\Bigg)\Bigg/\left(\pi\sqrt{\frac{C_B(B)R_B^2(B)-L}{LC_B^2(B)R_B^2(B)}}\right).\end{aligned} \tag{2}$$

The pictorial dependence of function of transformation is submitted on fig.2, and sensitivity of the frequency transducer of a magnetic field on fig.3. As is visible from the graph the greatest sensitivity of the device lies in a range from 40 up to 120 mT and makes 600 – 700 Hz/mT.

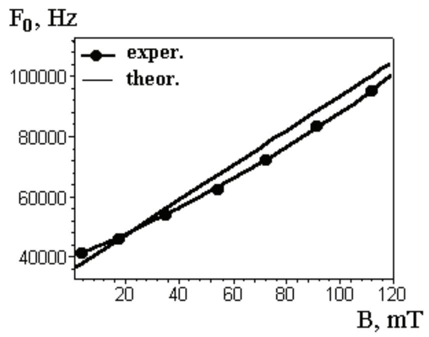

Fig. 2. Dependence of generation frequency on the induction of a magnetic field

The circuit of the transducer for increasing sensitivity is designed (fig.4). The transducer of a magnetic field consisting of two-collector magneticsensitive transistor, field two-gate transistor and bipolar transistor with a phase-shifting circuit R3C1 is designed which establish the auto generating device, the generation frequency of which depends on the induction of a magnetic field [4].

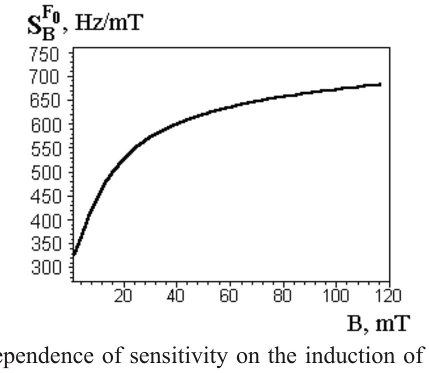

Fig. 3. Dependence of sensitivity on the induction of a magnetic field

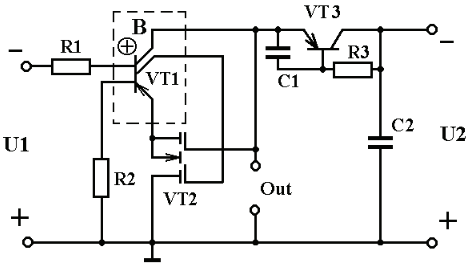

Fig. 4. An electric circuit of radiomeasuring transducer of a magnetic field

On electrodes of the first collector of magneticsensitive bipolar transistor VT1 and drain field two-gate transistor VT2 there is a complete resistance, an active component which has a negative value, and reactive - capacity character. The hook up of active inductance on the basis of the transistor VT3 and phase-shifting circuits R3C1 to the first collector VT1 and common bus through short circuiting capacity C2 establishes a tuned circuit, the power losses in which are cancelled by negative resistance. The resistors R1 and R2 ensure the condition of power supply on a direct current of the investigated circuit. At the operation of a magnetic field on the transistor VT1 there is a variation of equivalent capacity of a tuned circuit, that calls variation of resonance frequency.

On the basis of an equivalent circuit the function of transformation of the device is defined which represents dependence of generation frequency on the induction of a magnetic field. The analytical dependence of function of transformation has a view

$$F_0=\frac{1}{2\pi}\sqrt{\frac{A_1+\sqrt{A_1^2+4L_{ekv}C_{GD}(C_B(B)R_B(B))^2}}{2L_{ekv}C_{GD}(R_B(B)C_B(B))^2}}\ , \tag{3}$$

where $A_1=L_{ekv}C_{GD}-(C_B(B)R_B(B))^2-C_{GD}C_B(B)R_B^2(B)$, C_B, R_B – equivalent capacity and resistance to base area of magneticsensitive transistor, C_{GD} – capacity a gate–drain of a field–effect transistor.

The pictorial dependence of function of transformation is submitted on fig.5. The sensitivity (fig.6) of the transducer of a magnetic field is determined on the basis of expression (3) and is featured by the equation

$$\begin{aligned}S_B^{F_0}=-0.0198\bigg(&-2C_B(B)R_B^3(B)C_{GD}\left(\frac{\partial C_B(B)}{\partial B}\right)\times\\ &\times\sqrt{A_1+2A_2}-2C_B^2(B)R_B^3(B)\left(\frac{\partial C_B(B)}{\partial B}\right)-2C_B^3(B)\times\\ &\times R_B^2(B)\left(\frac{\partial R_B(B)}{\partial B}\right)-3C_B(B)R_B^3(B)C_{GD}\left(\frac{\partial C_B(B)}{\partial B}\right)-\\ &-2C_{GD}C_B^2(B)R_B^2(B)\left(\frac{\partial R_B(B)}{\partial B}\right)+8C_B^2(B)R_B^3(B)\times\\ &\times L_{ekv}C_{GD}\left(\frac{\partial C_B(B)}{\partial B}\right)+8L_{ekv}C_{GD}C_B^2(B)R_B^2(B)\left(\frac{\partial R_B(B)}{\partial B}\right)+\\ &+4L_{ekv}C_{GD}R_B(B)\left(\frac{\partial C_B(B)}{\partial B}\right)\sqrt{A_1+2A_2}+4R_B(B)\times\end{aligned}$$

$$\times\left(\frac{\partial C_B(B)}{\partial B}\right)L_{ekv}C_{GD}+4C_B(B)L_{ekv}C_{GD}\left(\frac{\partial R_B(B)}{\partial B}\right)\times$$

$$\times\sqrt{A_1+2A_2}+4L_{ekv}C_{GD}C_B(B)\times$$

$$\times\left(\frac{\partial R_B(B)}{\partial B}\right)\Bigg)\Bigg/\Bigg(\Bigg(2\sqrt{A_1+\sqrt{A_1+2A_2}}\Big/A_2\Bigg)\times$$

$$\times L_{ekv}C_{GD}C_B^3(B)R_B^3(B)\sqrt{A_1+2A_2}\Bigg), \qquad (4)$$

where $A_2 = 2L_{ekv}C_{GD}(C_B(B)R_B(B))^2$.

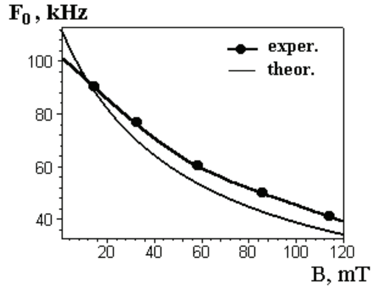

Fig. 5. Dependence of generation frequency on the induction of a magnetic field

As it is visible from the graph, the greatest sensitivity of the device lies in a range from 0 up to 60 mT and makes 2000-600 Hz/mT.

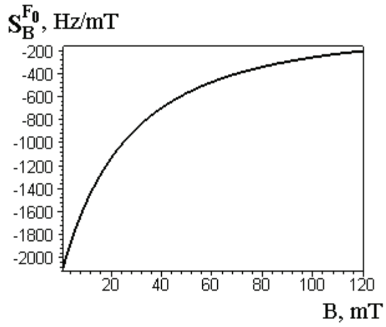

Fig. 6. Dependence of sensitivity on the induction of a magnetic field

For further magnifying sensitivity the transducer of a magnetic field the circuit on fig.7 is offered, which consists from bipolar two-collector magneticsensitive transistor VT1, two-gate field-effect transistor VT2, bipolar transistors VT3 and VT4. The bipolar transistor VT4 together with R11C1 - circuit implements an active inductive element [5–7].

This circuit represents the auto generating device, the generation frequency of which depends on the operation of a magnetic field. On electrodes of a drain field two-gate of the transistor VT2 and the collector of the bipolar transistor VT3 exists a complete resistance, an active component of which has a negative value, and on reactive - capacity character.

The hook up of an active inductive element on the basis of the bipolar transistor VT4 and R11C1-circuit to a drain field two-gate transistor VT2 and to a common bus through capacity C2 establishes a tuned circuit, the power losses in which are cancelled by negative resistance. The resistors R1-R3, R6, R7 ensure the condition of power supply on fixed voltage of magneticsensitive transistor VT1, and resistors R4, R5, R8-R10 - transistors VT2, VT3, VT4. During the operation of a magnetic field on the transistor VT1 there is the variation of equivalent capacity of a tuned circuit, which calls variation of its resonance frequency.

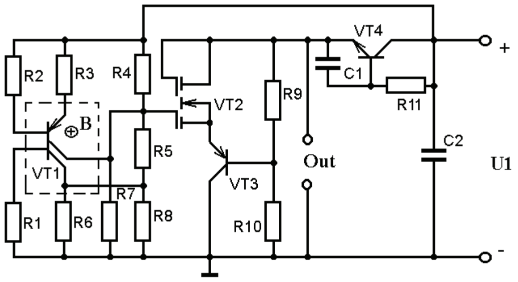

Fig. 7. An electric circuit of the frequency transducer of a magnetic field with active inductive element

The analytical expression of the function of transformation has view

$$F_0=\frac{1}{2\pi}\sqrt{\frac{A_1+\sqrt{A_1^2+4LC_{GD}(C_B(B)R_B(B))^2}}{2LC_{GD}(R_B(B)C_B(B))^2}}, \qquad (5)$$

where $A_1 = LC_{GD}\text{ - }(C_B(B)R_B(B))^2\text{ - }C_{GD}C_B(B)R_B^2(B)$, L – inductance of an active inductive element, C_B, R_B – equivalent capacity and resistance to base area of magneticsensitive transistor, C_{GD} – capacity a gate–drain of a field–effect transistor.

The pictorial dependence of function of transformation is submitted on fig.8. The sensitivity of the frequency transducer of a magnetic field is determined on the basis of expression (5) and is featured by the equation

$$S_B^{F_0} = -0.0198\Bigg(-2C_B(B)R_B^3(B)C_{GD}\left(\frac{\partial C_B(B)}{\partial B}\right)\sqrt{A_1+2A_2}-$$

$$-2C_B^2(B)R_B^3(B)\left(\frac{\partial C_B(B)}{\partial B}\right)-2C_B^3(B)R_B^2(B)\left(\frac{\partial R_B(B)}{\partial B}\right)-$$

$$-3C_B(B)R_B^3(B)C_{GD}\left(\frac{\partial C_B(B)}{\partial B}\right)-2C_{GD}C_B^2(B)R_B^2(B)\left(\frac{\partial R_B(B)}{\partial B}\right)+$$

$$+8C_B^2(B)R_B^3(B)LC_{GD}\left(\frac{\partial C_B(B)}{\partial B}\right)+8LC_{GD}C_B^2(B)R_B^2(B)\left(\frac{\partial R_B(B)}{\partial B}\right)+$$

$$+4LC_{GD}R_B(B)\left(\frac{\partial C_B(B)}{\partial B}\right)\sqrt{A_1+2A_2}+4R_B(B)\left(\frac{\partial C_B(B)}{\partial B}\right)LC_{GD}+$$

$$+4C_B(B)LC_{GD}\left(\frac{\partial R_B(B)}{\partial B}\right)\sqrt{A_1+2A_2}+4LC_{GD}C_B(B)\times$$

$$\times\left(\frac{\partial R_B(B)}{\partial B}\right)\Bigg)\Bigg/\Bigg(\Bigg(2\sqrt{A_1+\sqrt{A_1+2A_2}}\Big/A_2\Bigg)\times$$

$$\times LC_{GD}C_B^3(B)R_B^3(B)\sqrt{A_1+2A_2}\Bigg), \qquad (6)$$

where $A_2 = 2LC_{GD}(C_B(B)R_B(B))^2$.

The graph of dependence of sensitivity from the the induction of magnetic field is submitted on fig.9. As the greatest sensitivity of the device is visible from the graph and lies in a range from 0 up to 60 mT and makes 7,2 - 6,3 kHz/mT.

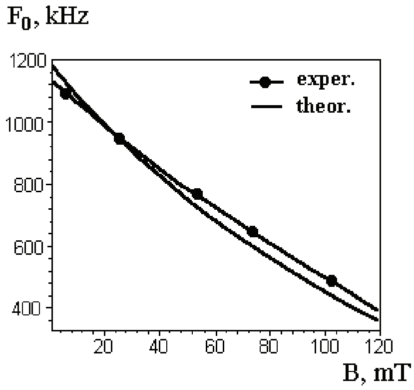

Fig. 8. Dependence of frequency of generation on the induction of a magnetic field

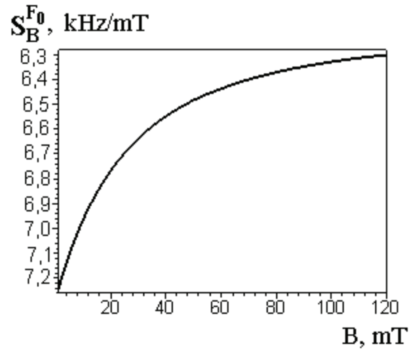

Fig. 9. Dependence of sensitivity on the induction of a magnetic field

Conclusions

The integrated circuits of transducers of a magnetic field in which magneticsensitive transistors act in a role of active elements of autogenerating arrangements of transducers that simplifies circuits of sensor controls of a magnetic field are offered. It is shown, that for the complete embodying transducers in an integrated view the passive tuned-circuit inductance of the arrangement is implemented as the reactive transistor. The greatest sensitivity which changes from 7,2 kHz/mT up to 6,3 kHz/mT, the circuit design about a magnet a sensing element has on the basis of two collector bipolar transistors with the active inductive element.

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In the given article the integrated circuits of transducers of a magnetic field in which magnetic sensitive transistors act in a role of active elements of autogenerating arrangements of transducers that simplifies circuits of sensor controls of a magnetic field are offered. It is shown, that for the complete embodying transducers in an integrated view the passive tuned-circuit inductance of the arrangement is implemented as the reactive transistor. The greatest sensitivity which changes from 7,2 kHz/mT up to 6,3 kHz/mT , the circuit design about a magnet a sensing element has on the basis of two collector bipolar transistors with the active inductive element. Ill. 9, bibl. 7 (in English; abstracts in English and Lithuanian).

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Aprašomas magnetinio lauko matavimas taikant radijo matavimams skirtus mikroelektronikos keitiklius, pagamintus iš magnetiškai jautrių tranzistorių. Tokio tranzistoriaus didžiausias jautrumas yra nuo 7,2 kHz/mT iki 6,3 kHz/mT. Il. 9, bibl. 7 (anglų kalba; santraukos anglų ir lietuvių k.).