The Microelectronic Radiomeasuring Transducers of Magnetic Field
with a Frequency Output

V. S. Osadchuk, A. V. Osadchuk

Vinnitsa National Technical University,
Khmelnitskiy highway, 95, Vinnitsa - 21021, Ukraine, phone: (0432) 59-84-81, e-mail: osadchuk69@mail.ru

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 fundamentals 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, 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 RSC1-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
\[
F_0 = \frac{1}{2\pi} \sqrt{\frac{R_{eq}^2(B)C_{eq}(B) - L}{LC_{eq}(B)R_{eq}^2(B)}}
\]

(1)

where \( R_d \) – resistance to the base area of magnetic-sensitive two-collector transistor, \( C_{eq} \) – equivalent capacity of magnetic-sensitive two-collector transistor, \( L \) – magnitude of inductance of an active inductive element.

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

\[
S_{eq}^B = \frac{1}{4} \left( C_{eq}(B) \left( \frac{\partial R_d(B)}{\partial B} \right) + R_{eq}^2(B) \times \right)

\left( \frac{\partial C_{eq}(B)}{\partial B} \right) \left( \frac{L}{C_{eq}(B)R_{eq}^2(B)} \right) - \left( 2(C_{eq}(B)R_{eq}^2(B) - L) \times \right)

\left( \frac{\partial R_d(B)}{\partial B} \right) \left( \frac{L}{C_{eq}(B)R_{eq}^2(B)} \right) \left( \frac{C_{eq}(B)R_{eq}^2(B) - L}{LC_{eq}(B)R_{eq}^2(B)} \right)
\]

(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.

The circuit of the transducer for increasing sensitivity is designed (fig.4). The transducer of a magnetic field consisting of two-collector magnetic-sensitive 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].

On electrodes of the first collector of magnetic-sensitive 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

\[
F_0 = \frac{1}{2\pi} \sqrt{A_1 + \sqrt{A_1^2 + 4L_{sh}C_{GD}(C_{eq}(B)R_d(B))^2}} \left( \frac{\partial C_{eq}(B)}{\partial B} \right) \times
\]

\[
\left( \frac{\partial R_d(B)}{\partial B} \right) \left( \frac{L}{C_{eq}(B)R_d^2(B)} \right) + \left( \frac{\partial R_d(B)}{\partial B} \right) \left( \frac{L}{C_{eq}(B)R_d^2(B)} \right) \left( \frac{C_{eq}(B)R_d^2(B) - L}{LC_{eq}(B)R_d^2(B)} \right)
\]

(3)

where \( A_1 = L_{sh}C_{GD} - (C_{eq}(B)R_d(B))^2 - C_{GD}C_{eq}(B)R_d^2(B), \) \( C_{eq}, R_d \) – equivalent capacity and resistance to base area of magnetic-sensitive 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

\[
S_{eq}^B = -0.0198 \left( -2C_{eq}(B)R_d^2(B)C_{GD} \left( \frac{\partial C_{eq}(B)}{\partial B} \right) \times \right)
\]

\[
\sqrt{A_1 + 2A_2 - 2C_{eq}(B)R_d^2(B) \left( \frac{\partial C_{eq}(B)}{\partial B} \right) - 2C_{eq}(B)^2} \times \]

\[
\left( \frac{\partial R_d(B)}{\partial B} \right) \left( \frac{L}{C_{eq}(B)R_d^2(B)} \right) \right) - 3C_{eq}(B)R_d^2(B)C_{GD} \left( \frac{\partial C_{eq}(B)}{\partial B} \right) - \left( \frac{\partial R_d(B)}{\partial B} \right) \left( \frac{L}{C_{eq}(B)R_d^2(B)} \right) \left( \frac{C_{eq}(B)R_d^2(B) - L}{LC_{eq}(B)R_d^2(B)} \right)
\]

\[
-2C_{GD}C_{eq}(B)R_d^2(B) \left( \frac{\partial R_d(B)}{\partial B} \right) + 8C_{eq}(B)^2 \times \]

\[
\left( \frac{\partial R_d(B)}{\partial B} \right) + 8L_{sh}C_{GD}C_{eq}(B)R_d^2(B) \left( \frac{\partial R_d(B)}{\partial B} \right) + \left( \frac{\partial R_d(B)}{\partial B} \right) \right) \right) \right) \right) \right) \right) \right)
\]

(4)
\[
\frac{1}{2\pi} \int_{A_1}^{A_2} \left( A + 2A_1 + 4L_{GD} C_{GD}(B) R_{Dy}(B) \right) \frac{dF}{dB} \left( A + 2A_1 \right)
\]

where \( A_2 = 2L_{cK} C_{GD}(C_R(B) R_{Dy}(B))^2 \).

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
\[
F_B = \frac{1}{2\pi} \sqrt{A_0^2 + 4L_{GD} C_{GD}(B) R_{Dy}(B) C_R(B)^2},
\]
where \( A_0 = L_{GD} C_{GD}(B) R_{Dy}(B) \), \( L \) - inductance of an active inductive element, \( C_R \) - equivalent capacity and resistance to base area of magnetosensitive 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
\[
S_B = -0.0198 \left(-2C_R(B) R_{Dy}(B)C_{GD} \frac{dC_R(B)}{dB}\right) \frac{dF}{dB} \left( A + 2A_1 \right) -
\]

\[
-2C_R^2(B) R_{Dy}^2(B) \frac{dC_R(B)}{dB} \left( R_{Dy}(B) \right) -
\]

\[
-3C_R(B) R_{Dy}(B) C_{GD} \frac{dC_R(B)}{dB} - 2C_R^2(B) R_{Dy}^2(B) \frac{dR_{Dy}(B)}{dB} +
\]

\[
+8C_R^2(B) R_{Dy}^2(B) L_{GD} C_{GD} \frac{dC_R(B)}{dB} + 8L_{GD} C_R^2(B) R_{Dy}^2(B) \frac{dR_{Dy}(B)}{dB} +
\]

\[
+4L_{GD} C_{GD} \frac{dR_{Dy}(B)}{dB} \left( R_{Dy}(B) \right) -
\]

\[
\times \left( A + 2A_1 + 4R_{Dy}(B) \frac{dC_R(B)}{dB} \right) L_{GD} +
\]

\[
+4C_R(B) L_{GD} \frac{dR_{Dy}(B)}{dB} \left( R_{Dy}(B) \right) \frac{dF}{dB} \left( A + 2A_1 \right)
\]

where \( A_2 = 2L_{GD} C_{GD}(B) R_{Dy}(B)^2 \).

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.
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.

References

Received 2011 02 05


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).


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. II. 9, bibl. 7 (anglų kalba; santraukos anglų ir lietuvių k.).