Investigation of a Magnetic Frequency Transducer on the Basis of Two-Collector Magnetosensitive of the Transistor

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Introduction

The measurement of parameters of a magnetic field, on the basis of which the considerable quantity of modern devices of an automation, diagnostics, computer equipment is constructed, is a basis of fundamental scientific investigations. Through magnetic measurements the structure and composition of substances, measurement long-range and near space, development of nuclear sources of power, magneto-hydrodynamic and cryogenic oscillators, high-speed terrestrial carrier on a magnetic pillow, accelerating engineering, aerial and sea navigating, methods of diagnostics in engineering and medicine is researched [1].

The majority of transducers of a magnetic field is analog, in which the magnetic field will be converted to an electric signal as a voltage or current. Usage of frequency transducers allows to receive a number of advantages before analog, which consist in considerable boosting of noise stability, that allows to magnify a measurement accuracy, and also in possibility of obtaining of major output signals. It establishes the premises of refusal from intensifying devices and A/D converters at an aftertreatment of a signal, that boosts profitability of the metering equipment [2, 3]. Usage magnetosensitive of the two-collector transistor both as sensing, and as an amplifier element has allowed considerably to simplify an electric circuit of a frequency converter of a magnetic field. In this connection the given article is devoted to investigation of a leading parameters of a frequency converter of a magnetic field.

Experimental investigations

The electric circuit of a transducer of a magnetic field is given in Fig. 1. It represents hybrid integrated circuit consisting from two-collector magnetosensitive transistor and field two-gate transistor, which establish the auto generating device, the frequency of which generation depends on induction of a magnetic field.

On electrodes of the first collector magnetosensitive of the bipolar transistor VT1 and drain field two-gate of the transistor VT2 there is a complete resistance, active component which has negative value, and reactive - capacitor character.
transistor from effect of a magnetic field. Radiating from analytical dependences of parameters of an equivalent circuit [4] their dependence on a magnetic field is determined. The ohmic resistor of base area depends on action of a magnetic field as follows

\[ R_b = R_{b0}(1 + c \mu_p B^2), \]  
(1)

where \( R_{b0} \) - resistance to base area without action of a magnetic field; \( \mu_p \) - mobility of holes; \( c \) - coefficient, which depends on the mechanism of a dispelling of holes; \( B \) - the magnetic strength.

The dependence of resistance of emitter junction on action of a magnetic field is featured by expression

\[ R_E = \frac{kT(1 + c \mu_p B^2)}{qI_0 \exp(qU_{E0}/kT)}, \]  
(2)

where \( k \) - Boltzmann constant; \( q \) - elementary charge; \( I_0 \) - reverse current emitter \( pn \) of junction; \( U_{E0} \) - constant voltage on emitter junction magnetosensitive of the transistor. The diffusion capacity of emitter junction depends on action of a magnetic field according to the formula

\[ C_E = \frac{qI_0 \tau_p \cdot \exp(qU_{E0}/kT)}{kT(1 + c \mu_p B^2)}, \]  
(3)

where \( \tau_p \) - lifetime of holes. The collector-junction capacitance is featured by the formula

\[ C_K = S \left[ \frac{\varepsilon \varepsilon_0}{2U_K \mu_p \rho_0(1 + c \mu_p B^2)} \right]^{1/2}, \]  
(4)

where \( S \) - square of collector junction; \( \rho_0 \) - resistivity of base area; \( U_K \) - reverse voltage of collector junction magnetosensitive of the transistor; \( \varepsilon, \varepsilon_0 \) - dielectric factor of a semiconducting material of base area and vacuum, accordingly.

It is possible to present dependence, transmission ratio of a current in the circuit common-base in the field of low frequencies from actions of a magnetic field as

\[ \alpha = 1 - \frac{1}{2} \left[ \frac{W_0}{L_p(1 + c \mu_p B^2/2)} \right]^2, \]  
(5)

where \( L_p \) - diffusion length of holes; \( W_0 \) - width of base without effect of a magnetic field.

Thus, by spotting dependences of elements of an equivalent circuit on effect of a magnetic field, we shall transfer to determination of function of conversion and equation of sensitivity.

On the basis of an equivalent circuit according to a method of positive stability Lapunov [5] the function of conversion of the device is defined which represents dependence of frequency of generation on induction of a magnetic field. The analytical dependence of function of conversion has sort

\[ F_0 = \frac{1}{2\pi} \sqrt{\frac{A_1 + \sqrt{A_1 + 4LC_{GD}(C_B R_B \mu_p B^2)}}{2LC_{GD}(R_B \mu_p B^2)}}^2, \]  
(6)

where \( A_1 = LC_{GD} - (C_B R_B \mu_p B^2)^2 - C_B C_{GD} R_B \mu_p B^2 \); \( L \) - external inductance; \( C_B, R_B \) - equivalent capacity and resistance to base area magnetosensitive of the transistor; \( C_{GD} \) - capacity a gate-drain of the field-effect transistor.

The graphics dependence of function of conversion is represented in Fig. 3. The sensitivity of a converter of a magnetic field is determined on the basis of expression (6) and is featured by the equation

\[ S_{b}^c = -0.0198 \left\{ -2C_B R_B \mu_p B^2 \right\} C_{GD} \left( \frac{\partial C_B \mu_p B^2}{\partial B} \right) \times \sqrt{A_1 + 2A_2 - 2C_B R_B \mu_p B^2 \left( \frac{\partial C_B \mu_p B^2}{\partial B} \right) - 2C_B R_B \mu_p B^2} \times R_B \mu_p B^2 \left( \frac{\partial R_B \mu_p B^2}{\partial B} \right) - 3C_B R_B \mu_p B^2 C_{GD} \left( \frac{\partial C_B \mu_p B^2}{\partial B} \right) \times \right. 
\]
\[ -2C_B R_B \mu_p B^2 R_B \mu_p B^2 \left( \frac{\partial R_B \mu_p B^2}{\partial B} \right) + 8C_B R_B \mu_p B^2 L \times \]
\[ \left. L C_{GD} \left( \frac{\partial C_B \mu_p B^2}{\partial B} \right) + 8LC_{GD} C_B R_B \mu_p B^2 \left( \frac{\partial R_B \mu_p B^2}{\partial B} \right) \times \right. 
\]
\[ + 4LC_{GD} R_B \mu_p B^2 \left( \frac{\partial C_B \mu_p B^2}{\partial B} \right) L C_{GD} + 4C_B R_B \mu_p B^2 \left( \frac{\partial R_B \mu_p B^2}{\partial B} \right) \times \right. 
\]
\[ \left. \sqrt{A_1 + 2A_2 + 4LC_{GD} C_B \mu_p B^2} \times \right. 
\]
\[ \left. \left( \frac{\partial R_B \mu_p B^2}{\partial B} \right) / \left( \left( 2 \sqrt{A_1 + \sqrt{A_1 + 2A_2}} / A_2 \right) \times \right. 
\]
\[ \left. \times L C_{GD} C_B \mu_p B^2 R_B \mu_p B^2 \left( \sqrt{A_1 + 2A_2} \right) \right), \]  
(7)

where \( A_2 = 2LC_{GD} (C_B R_B \mu_p B^2)^2 \).
Fig. 4. Dependence of sensitivity on induction of a magnetic field

The schedule of dependence of sensitivity is represented in Fig. 4. As the greatest sensitivity of the device is visible from the schedule lays in a range from 0 up to 60 mT and makes 200-60 Hz/mT.

Conclusions

The possibility of direct conversion of induction of a magnetic field in frequency is shown on the basis of a hybrid integrated circuit consisting from two-collector magnetosensitive of the transistor and field two-gate of the transistor. The analytical dependences of function of conversion and equation of sensitivity are obtained. The theoretical and experimental investigations have shown, that the sensitivity of a converter makes 30-200 Hz/mT.

References