

Radiomeasurement Transducer to Magnetic Induction with Frequency Output

Vladimir Osadchuk, Alexander Osadchuk

Abstract - In given work are presented investigations radiomeasurement transducer to magnetic induction on base reactive characteristic bipolar transistor. The analytical dependencies function of converting and equation of sensitivity are obtained. Theoretical and experimental investigations have shown that sensitivity designed radiomeasurement of the transducer of a magnetic induction forms 1,4 - 2,8 kHz/mT.

Keywords - transducer to magnetic induction, negative resistance, reactive characteristic.

I. INTRODUCTION

Radiomeasurement transducer with frequency output have a row advantage over amplitude, which are concluded in significant increasing of interference immunity that allows to increase accuracy of the measurement, as well as in possibility of the reception greater output signal. This creates the premises a refusal of amplifier device in the after-treatment signal. Use the frequency signal as informational allows abandoning to analog-to-digital converters that raises the economy of the measuring equipment.

At the moment intensive investigations are on study characteristic analog microelectronics transducers though study of the frequency converters of a magnetic induction on base reactive characteristic bipolar transistor is found in initial stage. So given work is dedicated to study main parameter radiomeasurement of the transducer on base of the transistor structure with negative resistance.

II. THEORETICAL AND EXPERIMENTAL RESEARCH

The electric circuitry of a transducer is given in fig.1. It represents itself integral scheme, which consists of four transistors with one type of the conductivities that allows to create the oscillator device on integral technology. The tuning circuit realized on base of the equivalent capacity of the impedance on electrode collector-emitter transistor VT1 and VT2 and active inductance on base of the transistor VT4 with phaseshift circuit R3C1 [1]. The Transistor VT3 with resistor R2 forms the current mirror for termocompensation.

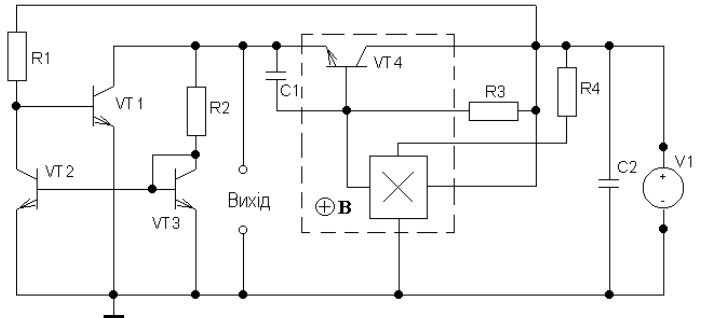


Fig.1. An electric circuitry radiomeasurement of the transducer of a magnetic induction

On transistor VT4 and element of Holl, which is connected in circuit of the base and collector VT4, acts the magnetic field. Thereby, value to inductances depends on actions of the magnetic induction that in turn brings the resonance frequency of the oscillator about change. The losses to energy in tuning circuit are filled by negative resistance [2-4].

Origin inductive properties in bipolar structure is connected with final velocity of the moving the carriers of the charge in base area. The signal attached to emitter, can not appear on collector junction while carriers of the charge pass the base with the result that appears the delay at time, which has got the name of time of the stairwell. Thereby, current of the collector lags behind at time from voltage on emitter, which has caused this current that corresponds to the inductive reaction on electrode emitter-collector of the bipolar transistor. The value to inductances and quality factor is defined on base of the nonlinear model of the inductive transistor, founded on models Ebers-Moll, which is received from the general mathematical model of the transistor. Output data for given models is a system of the main equations, which describe the behaviour of the carriers of the charge in semiconductor material, as well as mathematical correlations, which characterize the behaviour p-n junction. The Inductance to theoretical model depends on electro physical parameter semiconductor material of the base, regime of the power supply the transistor on constant and alternating voltages, as well as from geometric sizes of the transistor that allows to control its value as electric, so and technological fetter. The external parameters of the transistor, which directly are not connected with process of the carrying the carriers of the charge such as barrier to capacities emitter and collector junction, ohmic resistance of the base area, inductances electrodes greatly influence upon value of the

inductances, which appears in process of the carrying the carriers of the charge in base area. Cut-in external R3C1-circuit to transistor VT4 allows to increase both inductance, and quality factor active element on the one hand, but on the other hand - completely realize both active inductive element, and all device on integral technology.

Value of equivalent inductance of the active inductive element is defined by expression

$$L_{EKV} = \frac{1}{\omega} \cdot \frac{A_4 A_1 - A_3 A_2}{A_1^2 + A_2^2}, \quad (1)$$

$$A_1 = \omega C_1 \left[(r_B + r_E - R_3 \alpha_1)^2 - (R_3 \alpha_2)^2 + \frac{1}{(\omega C_1)^2} \right],$$

$$A_2 = \omega C_1 [2R_3 \alpha_2 (r_B + r_E - R_3 \alpha_1)],$$

$$A_3 = \left[R_3 \alpha_1 (r_B + r_E - R_3) + (r_B + r_E) \frac{R_3^2}{r_K} - 2 \frac{R_3^3}{r_K} \alpha_1 + \frac{R_3^2 \alpha_2^2}{(\omega C_1)^2} \right],$$

$$A_4 = \left[2R_3^2 \alpha_1 \alpha_2 - (r_B + r_E) R_3 \alpha_2 + \frac{2R_3^3}{r_K} \alpha_2 \right],$$

$\alpha_1 = \frac{\alpha_0}{1 + (f/f_\alpha)^2}$ - real part of the coefficient of the transmission of the current in scheme with general base,

$\alpha_2 = \frac{\alpha_0 f / f_\alpha}{1 + (f/f_\alpha)^2}$ - imaginary part of the coefficient of the

transmission of the current in scheme with common base,

where r_B, r_K - accordingly resistance of the base and collector of the transistor VT4, f_α - a cut-off frequency of the bipolar transistor in scheme with the general base, f - a worker frequency, $\omega = 2\pi f$ - a circular frequency.

Quality factor active inductive element is defined on formula

$$Q = \frac{(A_4 A_1 - A_3 A_2) \omega C_1}{\omega C_1 (A_3 A_1 + A_4 A_2) - (A_1^2 + A_2^2)}. \quad (2)$$

Elements, falling into expression (1) and (2), as follows hang from action of the magnetic field:

$$r_B = r_{B0} (1 + c \mu_n^2 B^2), \quad (3)$$

where r_{B0} - a resistance of the base area without action of the magnetic field, μ_n - a mobility electron, c - a factor, which depends on mechanism of the diffusing of the electrons, B - a magnetic induction.

Dependency of the resistance emitter junction from action of the magnetic field is described by expression

$$r_E = \frac{kT(1 + c \mu_n^2 B^2)}{qI_0 \cdot \exp(qU_{E0}/kT)}, \quad (4)$$

where k - constant Bolicman, q - a charge of the electron, I_0 - current emitter p-n junction, U_{E0} - a constant voltage on emitter junction magnetic sensitive of the transistor.

Diffused capacity emitter junction depends on actions of the magnetic field in accordance with formula

$$C_E = \frac{qI_0 \tau_n \cdot \exp(qU_{E0}/kT)}{kT(1 + c \mu_n^2 B^2)}, \quad (5)$$

where τ_n - time to lifes electron. Capacity collector junction is described by formula

$$C_K = S \left[\frac{\varepsilon \varepsilon_0}{2U_K \mu_n \rho_0 (1 + c \mu_n^2 B^2)} \right]^{1/2}, \quad (6)$$

where S - an area collector junction, ρ_0 - intrinsic resistance of the base area, U_K - an inverse voltage collector junction of turning the transistor, $\varepsilon, \varepsilon_0$ - dielectric constant of the semiconductor material of the base area and vacuum, accordingly.

Dependency of the factor of the transmission of the current in scheme with general base in the region of low frequencies from action of the magnetic field possible to present in the manner of

$$\alpha = 1 - \frac{1}{2} \left[\frac{W_0}{L_n (1 + c \mu_n^2 B^2 / 2)} \right]^2, \quad (7)$$

where L_n - diffused length electron, W_0 - a thickness of the base without influence of the magnetic field.

The experimental dependency of the change of inductances from magnetic induction was submitted for fig.2.

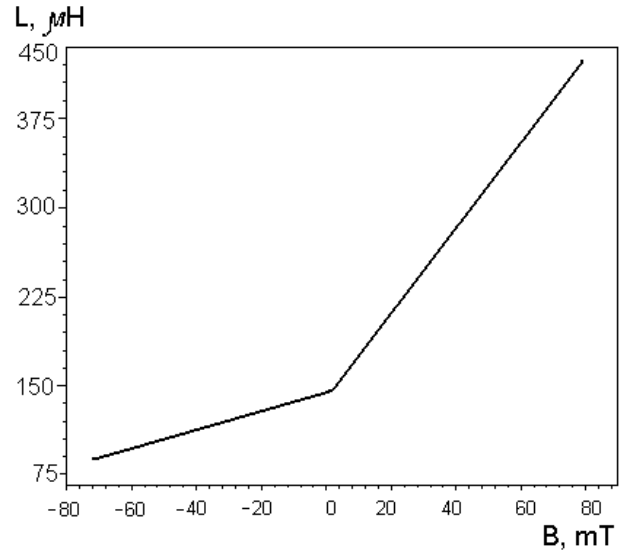


Fig.2. Dependency of an active inductance from magnetic induction

As can be seen from graphics, angle of the sloping graphics of inductance changes depending on change the direction of the magnetic field.

On base of the theories to stability Lyapunov [5] is defined function of converting device, which presents itself dependency of the frequency generation from value of the inductions of the magnetic field. Analytical dependency function of converting is of the form of

$$F_0 = \frac{1}{2\pi} \sqrt{\frac{C_{BE} + C_{BC}}{L_{EKV}(B)C_{BC}C_{BE}}}, \quad (8)$$

where C_{BE} - an equivalent capacity emitters and collectors junctions transistors VT1 and VT2, $L_{EKV}(B)$ - an equivalent inductance of the transistor VT4.

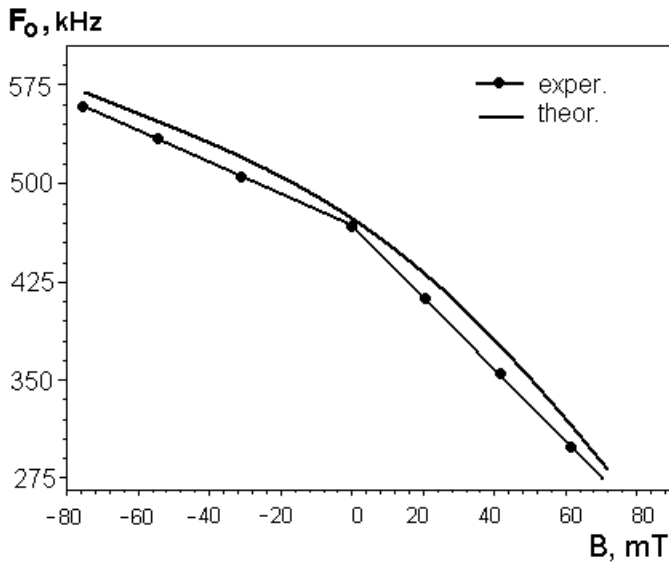


Fig.3. Dependency theoretical and experimental curves of the function of converting

The graphic dependency theoretical and experimental curves function of converting was submitted for fig.3.

Sensitivity of the transducer is defined on base of the expression (8) and is described by expression

$$S_{F_0}^B = -\frac{1}{4} \frac{(C_{BE} + C_{BC}) \left(\frac{\partial L_{EKV}(B)}{\partial B} \right)}{L_{EKV}^2(B) C_{BE} C_{BC} \sqrt{\frac{C_{BE} + C_{BC}}{L_{EKV}(B) C_{BC} C_{BE}}}}. \quad (9)$$

The graphic dependencies of sensitivity radiomeasurement transducer to magnetic induction was submitted for fig.4 as can be seen from graphics, sensitivity of the converter forms 1,4 - 2,8 kHz/mT.

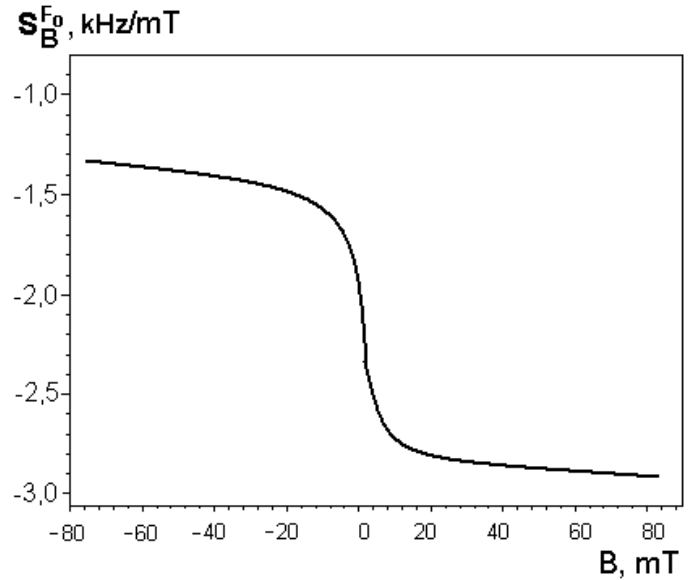


Fig.4. Dependency of sensitivity of the transducer from magnetic induction

III. CONCLUSION

In given work are presented investigations radiomeasurement transducer of a magnetic induction on base reactive characteristic bipolar transistor. The analytical dependencies function of converting and equation of sensitivity are obtained. Theoretical and experimental investigations have shown that sensitivity designed radiomeasurement of the transducer of a magnetic induction forms 1,4 - 2,8 kHz/mT.

REFERENCES

- [1] Осадчук В.С., Осадчук О.В. Реактивні властивості транзисторів і транзисторних схем. –Вінниця: «Універсум-Вінниця», 1999. – 275с.
- [2] Осадчук О.В. Мікроелектронні частотні перетворювачі на основі транзисторних структур з від'ємним опором. – Вінниця: «Універсум-Вінниця», 2000. – 303 с.
- [3] Пат. №41013 А України, МКИ Н01L 29/82. Мікроелектронний вимірювач магнітної індукції / Осадчук В.С., Осадчук О.В. Заявка - №2001010065; Заявл. 03.01.2001; Опубл. 15.08.2001. Бюл. №7.
- [4] Пат. №40239 А України, МКИ G01R 33/06. Мікроелектронний пристрій для виміру магнітної індукції / Осадчук В.С., Осадчук О.В. Заявка. - №2000106041; Заявл. 26.10.2000; Опубл. 16.07.2001. Бюл. №6.
- [5] Каяцкас А.А. Основы радиоэлектроники. –М.: Высшая школа, 1988. – 464 с.