Research of Joint Operation of Hall Elements with Orthogonal Magnetic Sensitivity

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Abstract- **Microelectronics development creates possibility for fulfilling of the industrial schemes with high input resistance, high stability of the output signal, low fading. But the problem stays connected with the optimization of the sensor block which transforms investigated physical entity to electrical signal.**

Hall elements are widely applied both in discreet and integrated circuitry. Various kinds of sensor systems are constructing on their bais. Creating of new schemes including discreet Hall element is very interesting in galvanomagnetic sensoric and can contribute to increase of their applied effectiveness and improvement of parameters and operating characteristics.

Various schemes for combined operation of two discreet Hall elements with parallel connected current circuit have been offered and investigated. Conversion characteristics and absolute and relative galvanomagnetic sensitivity have been shown.

Keywords- **Galvanomagnetig sensors, New magnetic sensors, Hall elements with orthogonal galwanomagnetic sensitivity.**

I. INTRODUCTION

As input block of each system for measuring and detecting of magnetic field Hall elements find widely application and defy uninterrupted research interest [3, 5, 6]. Various kinds of sensor systems and devices are constructing on their basis. The combined operation of experimental samples of the type VHE 101 in various circuits has been studied [1, 2]. Static conversion characteristics have been obtained and absolute and relative sensitivity have been defined. Parameters widely change is achieved which expands their applicability in electronics. Creating and research of combined operation of two Hall sensors with parallel connected current circuits is very interesting.

This paper deals with the research problems of new Hall elements circuit design with orthogonal galvanomagnetic sensitivity and parallel connected current circuits.

II. PRESENTATION

Schemes in case of combined operation of two galvanomagnetic sensors with parallel connected current circuits have been created and investigated. Using principled electrical circuit shown in Fig. 1a static conversion characteristics of experimental samples with parallel connected current circuits and free output leads have been measured. The power supply to the circuit is provided by the supply source U_S, the chain of resistors R_I, R_S and parallel connected current electrodes 1 and 3 of Hall elements E_{H1}, E_{H2}. Current I_S, controlling both Hall elements, is produced by the current generator, realized by means of high-resistance resistor R_I. It is measured as a voltage drop across the measurement resistor R_S. The using samples are choused with equal parameters and their controlling currents are accepted as equal. A Hall voltage is measured directly from Hall elements output leads 2 and 4. Resistors R_1, R_2, R_3, R_4 and trimmer potentiometer RP_1, RP_2 provide reset of the output drift. The family of experimental conversion characteristics obtained $U_{H1}=f(B)$, $U_{H2}=f(B)$ at $T=const$ are shown in Fig 2a for three values of the control current – $I_S=1mA$, $I_S=5mA$, $I_S=10mA$ and at flux density $B=(0\div 1,5)T$, respectively. Their analysis shows that in case of parallel connected current circuit and free output electrodes symmetry and changes characters of conversion characteristics are kept. A reduction in the Hall voltage by reason of a sensors equivalent resistance decrease is observed and a better linearity of the characteristics in comparison with that in classic circuit [1] is obtained.

At low control current ($I_S=1mA$) these results are most observable. At $I_S>5mA$ a linear section narrows but a characteristics slope decreases at weak magnetic field ($-0,5<B<0,5$).

Another principled electrical design with such kind of current supply and parallel connection of the output electrodes is shown in Fig. 1b. Both Hall elements` output electrodes are parallel connected and in such direction. An electrode 2 from E_{H1} is to electrode 2 of E_{H2} and electrode 4 from E_{H1} is to electrode 4 of E_{H2} respectively. The output signal U_O is measured between 2 and 4. The family of conversion characteristics $U_O=f(B)$ obtained by experiment at $T=const$ and $I_S=1; 5; 10mA$ are shown in Fig.2b.

Their analysis shows the same symmetry and characteristics change at both directions of applied magnetic field ($B=0\div\pm 1,5T$). The output signal values are almost such as those in classic circuit – $U_O=\pm(0,28\div 2,1)V$ at $B=1,5T$ and $I_S=(1\div 10)mA$. A decrease of the linear section on conversion characteristics is observed. At $I_S=1mA$ the linearity begins at flux density $B=0,35T$, and at $I_S=10mA$ - not until at $B=0,85T$. A combined operation of two elements in this circuit makes their parameters more stable.

A principled electrical scheme with parallel connected input circuits and parallel but in opposing direction connected output leads is shown in Fig. 2c. The output signal is measured directly between leads 2 and 4 of E_{H1}. The

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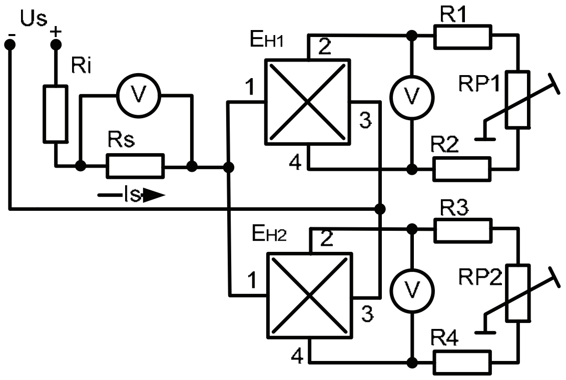

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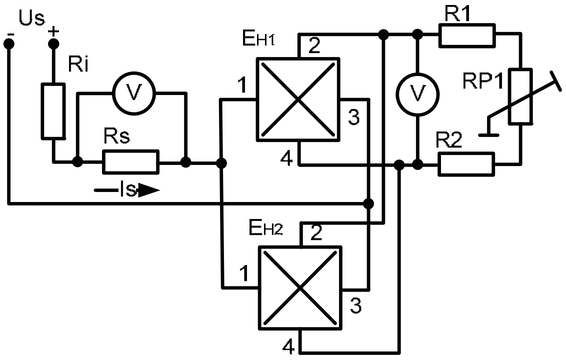

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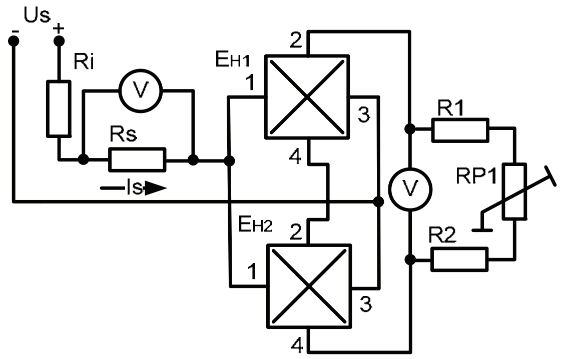

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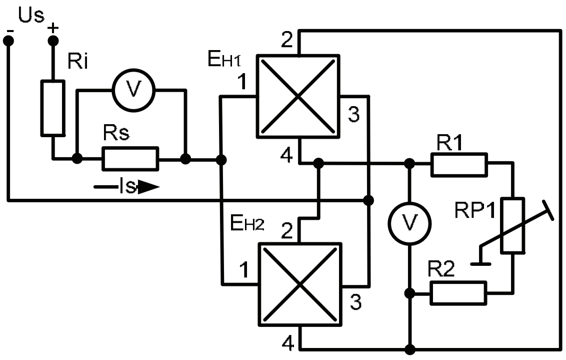

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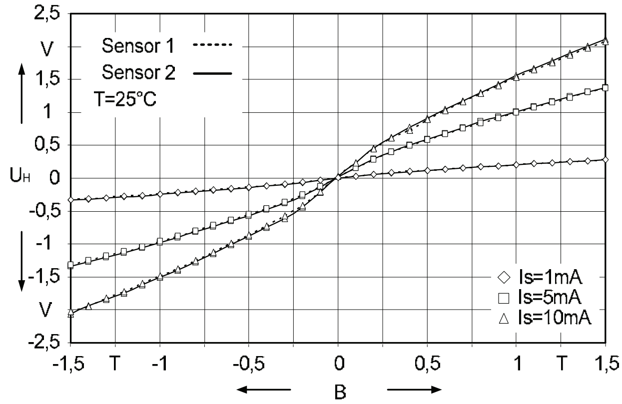
Fig. 1. Experimental circuit of set



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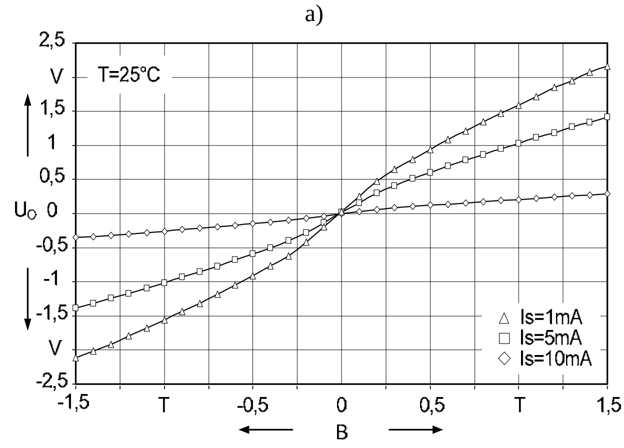

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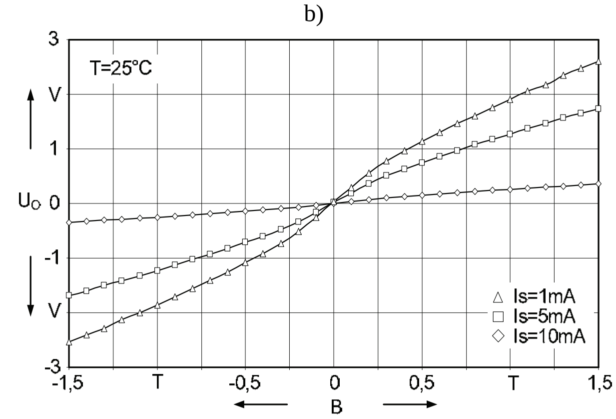

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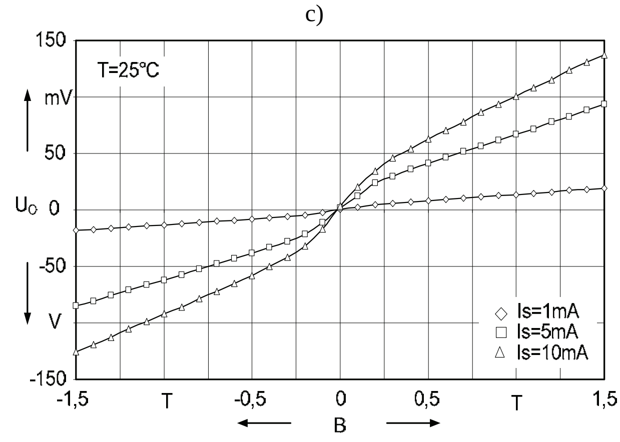

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Fig. 2. Experimental conversion characteristics

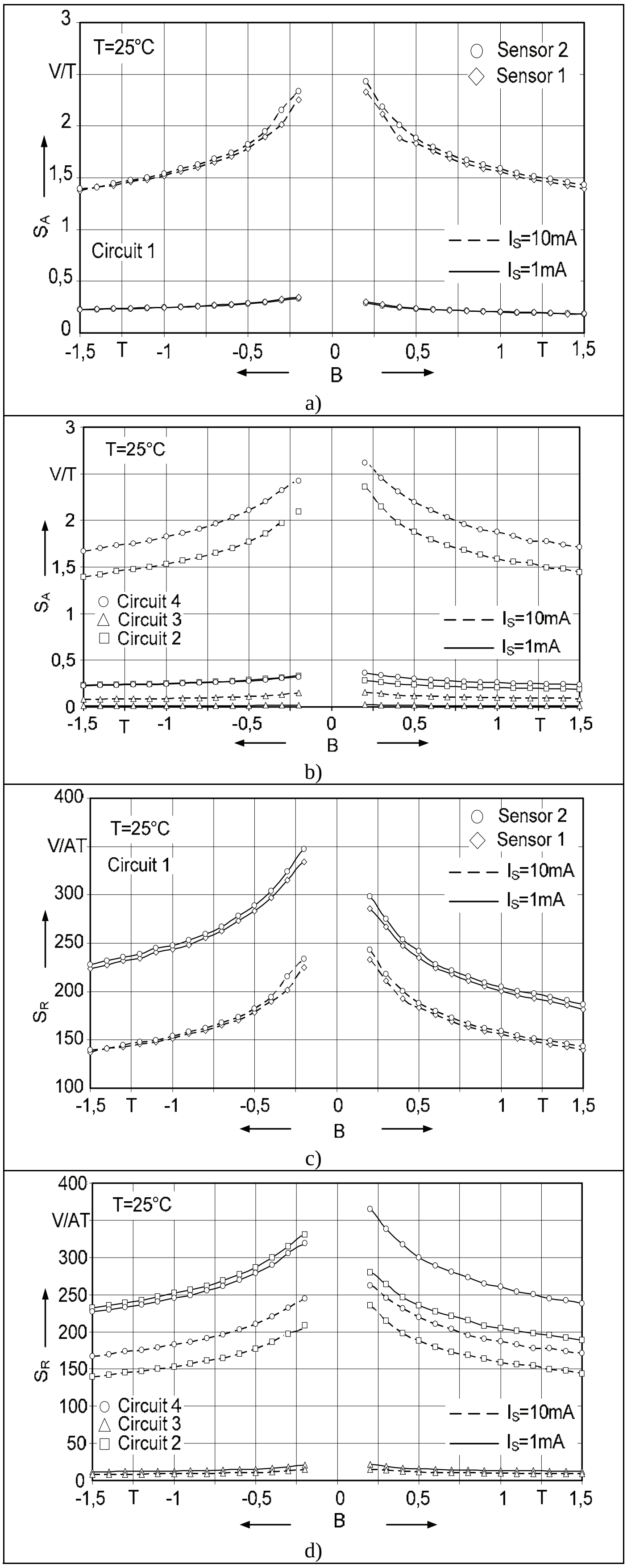

Fig. 3. Dependency of S_A and S_R on *B*, $I_S=const$

conversion characteristics $U_O=f(B)$, obtained by experiment at $T=25^oC$ and $I_S=1;\ 5;\ 10mA$ are shown in Fig. 2c. Their analysis shows again symmetry and characteristics` change typical to Hall elements. In spite of output signal low value ($U_O=(\pm 18\div\pm 125)mV$) at $B=1,5T$ and currents change $I_S=(1\div 10)mA$ a widely linear section on conversion characteristic is observed. At $I_S=1mA$ this widening is at low values of magnetic field ($B=0,2T$). At $I_S\geq 1mA$ the linearity occurs at $B=0,5T$. The same results are observed at a negative field ($B<0$).

Usually Hall elements are considered as a voltage source. A new scheme with serial connected output electrodes is shown in Fig. 1d. Now lead 4 from E_{H1} is to lead 2 of E_{H2}.

The output signal is measured between lead 2 of E_{H1} and lead 2 of E_{H2}. The family of conversion characteristics $U_O=f(B)$ obtained by experiment, are shown in Fig. 2d at $T=const$ and $I_S=1;\ 5;\ 10mA$. Analysis shows the same symmetry and more wide linear section. The conversion characteristics` linearity at $I_S>5mA$ is observed at $B\geq 0.5T$ and $B\leq -0.5T$. At lower current ($I_S=1mA$) the characteristic is linear at all range of magnetic field.

On the basis of the conversion characteristics obtained, absolute S_A and relative S_R sensitivity have been determined [4, 5]:

$$S_A=\frac{\Delta U_H}{\Delta B},\frac{V}{T} \tag{1}$$

$$S_R=\frac{S_A}{I_S},\frac{V}{AT} \tag{2}$$

where: ΔU_H – change in output voltage; ΔB - change in flux density; I_S – control current.

A graphic interpretation of the functions $S_A=f(B)$, $S_R=f(B)$ at $I_S=const$ are shown in Fig. 3a, Fig 3b, Fig 3c for the circuits shown in Fig.1a, Fig 1b, Fig 1c, respectively. The analysis of the graphical dependences shows that greater sensitivity is obtained at low value of magnetic field. In case of circuit shown in Fig. 1b absolute sensitivity has a peak value $0,36V/T$ at $I_S=1mA$ but at $I_S=10mA$ it is $2,6V/T$. The scheme shown in Fig. 1d has at B=0,2T sensitivity $S_A=0,27V/T$ and $S_A=2,48V/T$ at $I_S=1mA$ and $I_S=10mA$, respectively (Fig. 3b). In case of circuit shown in Fig. 1c at weak magnetic field ($B=0,2T$) and $I_S=1;\ 5;\ 10mA$ absolute sensitivity S_A changes from $0,022V/T$ to $0,154V/T$ while at high values of magnetic field its variation is from $0,0127V/T$ to $0,089V/T$ (Fig 3b). The family of characteristics $S_R=f(B)$ obtained is shown in Fig.3c, Fig.3d. Greater values of S_R are observed at weak magnetic field and lower control current. It is obligated to the experimental samples symmetry. At $I_S=1mA$ and $B=1,5T$ the greatest value of $S_R=237V/T$ and the lowest $S_R=8,9V/T$ are obtained in case of circuits shown in Fig. 1d, Fig. 1c, respectively.

The results at negative magnetic field ($B<0$) are analogous and are shown in Fig. 3c in the same order.

III. CONCLUSION

1. Various circuits design for combined operation of Hall elements with orthogonal sensitivity and parallel connected current circuits have been synthesized and studied.

2. The conversion characteristics $U_O=f(B)$ obtained by experiment are depicted for three values of control current $I_S=1;\ 5;\ 10mA$ and at flux density $B=(0\div\pm1{,}5)T$. Their analysis shows:

A considerable improvement of the linearity in comparison with classic circuit by keeping of their change and output levels:

- in case of circuit shown in Fig.1a, Fig.1b output voltage gets over *2V* at maximum value $B=\pm1{,}5T$ by keeping of more linear section and symmetry;
- in case of circuit shown in Fig.1c is achieved more wide linear section but the design possibility don't suggest output voltages over *140mV*;
- in circuit shown in Fig.1d the wide linear section begins at lower values of magnetic field ($B=\pm0{,}4T$).

3. The absolute S_A and relative S_R sensitivities have been determined and dependences $S_A=f(B)$, $S_R=f(B)$ at control current $I_S=1;\ 5;\ 10mA$ have been depicted.

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