Galvanomagnetic Current-Frequency Converter

Anatoliy Aleksandrov

***Abstract* – A current-frequency converter has been synthesized on the basis of experimental specimens of a digital magneto-sensitive IC, its sensitive element being a two-collector magneto-transistor. Experimental investigations have been carried out of the conversion characteristic, as well as of the factors affecting it. Different versions have been developed for temperature stabilization of the converter.**

Keywords – magnetic-field galvanomagnetic sensor, magneto-sensitive IC, current-frequency converter.

I. INTRODUCTIO*N*

Current-frequency converters are applied in the field of electrical engineering, instrumentation, in intelligent sensor mocrisysytems, robotics, automatics and instrument engineering as sensor devices with high sensitivity. There exists a magnetosensitive integrated sensor with a frequency output [3] for converting magnetic induction into a frequency signal, as well as a device for energy reading on the basis of a Hall element, the output signal being modulated by means of a multivibrator [7]. These converters have been developed using galvanomagnetic discrete components.

The magnetosensitive ICs are the latest and the most promising magnetic sensor. They incorporate a magnetosensitive element and an electronic circuit for signal processing, which are accomplished in one technological cycle [4, 2], and achieve multisensor properties as well [5]. Their main advantages are: low cost, high noise immunity, reduced dimensions, complete electrical disconnection between the input and the output circuits.

The present paper describes a new galvanomagnetic current-frequency converter on the basisi of a digital magneto-sensitive IC.

II. CURRENT-FREQUENCY CONVERTER:

A current-frequency converter has been developed for the realization of the new device, on the basis of experimental specimens of a digital magnetosensitive IC of the type CM 701 AM 5.1 [6], its sensitive element being a two-collector magneto-transisitor.

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The schematic electric circuit of the converter, realized with an electronic switch of a bipolar transistor connected in the common emiter circuit, is presensted in Fig. 1.

When the supply voltage of the IC is switched on its output in logical ”1” state, and the bipolar transisitor VT passes into a saturation mode. Current I begins to flow through the coil of the electromagnet W. When the magnetic induction in the magnetic circuit reaches the magnetic induction of switching on $B=B_{ON}$ the output of the magnetosensitive IC switches to the state of logical ”0”. The transisitor is turned off. The current and the magnetic induction, respectively, decrease, and when $B=B_{OFF}$, the output of the magnetosensitive IC switches again to the state of logical ”1”and the processes are repeated. A saturated operating mode of the transisitor switch must be ensured for stable operation of the generator circuit. Square pulses are generated at the IC output, having a certain pulse-repetition rate, which depends on the magnitude of the current I and the number of the windings W, i.e. $f=\varphi(I,W)$. The transisitor switch functions as a positive feedback in the square pulse generator.

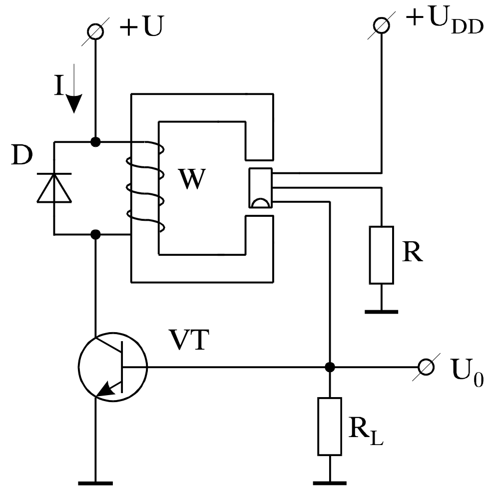


Fig. 1. Schematic Electrical Circuit of the Current-Frequency Converter

Experimental investigations have been carried out to determine the influence of I and W over the converter frequency f, an electromagnetic system being used for that purpose, having the following parameters: $\mu=400$; $\delta=10$mm; $S=1600mm^2$.These parameters have been chosen for design reasons, and they guarantee a linear and uniform magnetic field. The range of the conversion characteristic is determined by the condition that the transisitor switch should be saturated and the induction in the magnetic circuit should be greated than the magnetic induction of switching on B_{ON} of the magneto-sensitive IC.

Figure 2 presents the family of conversion characteristics $f=\varphi(I)$ taken experimentally when W=const.

In order to determine the analytical form of the dependence $f = c.I^n$ of the frequency f on the magnitude of the converted current I when W=const, the least-squares method has been applied [1].

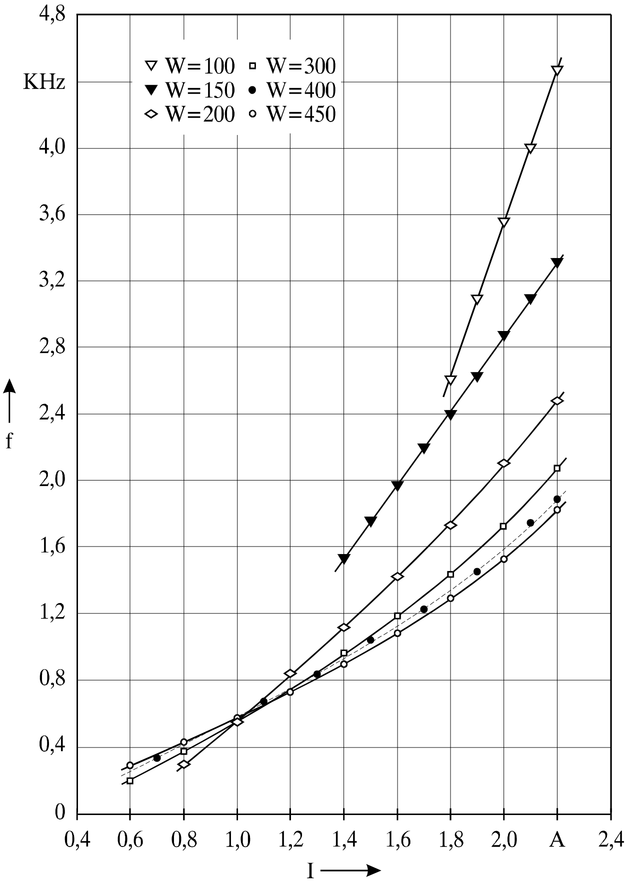


Fig. 2. Conversion Characteristic f=φ(I) when W=const.

The form of the theoretical-experimental models obtained is:

$$f = 0{,}5389 . I^{2{,}016} \quad \text{when W=200 windings;}$$

$$f = 0{,}6018 . I^{1{,}3899} \quad \text{when W=450 windings.}$$

The analysis of the graphical and empirical dependences obtained shows that when W=const the frequency f is a function of the current flowing, the increase in current causing an increase in frequency. The nature of this change in f in accordance with the change in current corresponds to the converter operating principle. When the number of widings is great the conversion characteristics is non-linear. When the number of widings decreases the converter switching on current increases, and the conversion characteristics become linear. With greater current the magnetization is carried out along a curved line having a steeper slope, the result of this being that the period of output-pulse repetition decreases, and the output frequency f increases. Therefore, the steepness of the conversion characteristic depends on the number of windings in the electromagnetic. In this particular converter optimum steepness from the point of view of the sensitivity parameter is observed when W=100 windings. On the basis of the characteristics taken experimentally (Figure 2) the following parameters have been determined for the current-frequency converter discussed here: measuring range-(1,8÷2,2)A; differential sensitivity S=3790 Hz/A; relative sensitivity S_{00}=2,37.

The conversion characteristics are non-linear when the number of windings is greater (W > 150). In order to realize a measurement convertor it is necessary to linearize the function f=φ(I,W) or to choose a characteristic range with sufficient linearity. The coversion characteristic is linear in a measurement range (0,8÷2,1)A when W=200 windings. The following parameters are determined for this case: differential sensitivity S=1446 Hz/A; relative sensitivity S_{00}=1,7965.

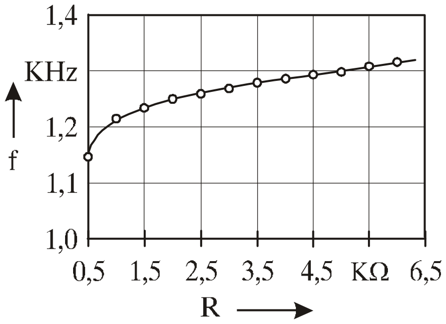
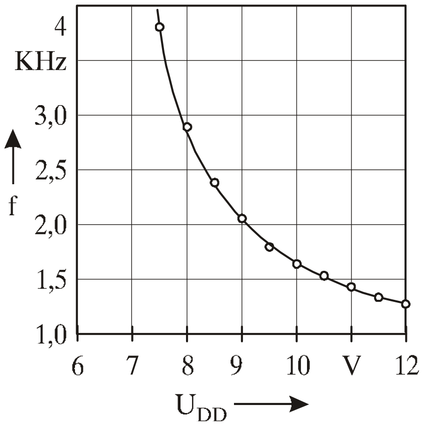


Fig. 3. Influence of R over frequency

In order to achieve a complex and plausible assessment for operation of the current-frequency converter it is necessary to investigate not only the influence of the number of windings W and the current I, but also the effect of the voltage U_{DD} and the resistance R over the frequency f of the current-frequency converter. The experimental dependences obtained f=φ(R) when U_{DD}=12V and f=φ(U_{DD}) when I=1,5A, W=250, R=4,7kΩ and R_L=10kΩ are presented in Fig. 3 and 4, respectively. When R increases the frequency f increases, too, the extent of change in f being greater with smaller values of R=(0,5÷2,5)kΩ. The frequency f decreases with the increase in the supply voltage.

Fig. 4. Influence of U_{DD} over frequency



Temperature investigations of the current-frequency converter have also been carried out. The characteristic f=φ(T) obtained experimentally is shown in figure 5 (curve 1). The rise in temperature from 25 to 65 °C causes a decrease in frequency by 9%. Therefore temperature stabilization must be carried out for the converter discussed.

The nature of the change in the frequency f according to the resisitance and the supply voltage f=φ(R) (Figure 3) and f=φ(U_{DD}) (figure 4) shows that these dependences can be used for temperature stabilization.

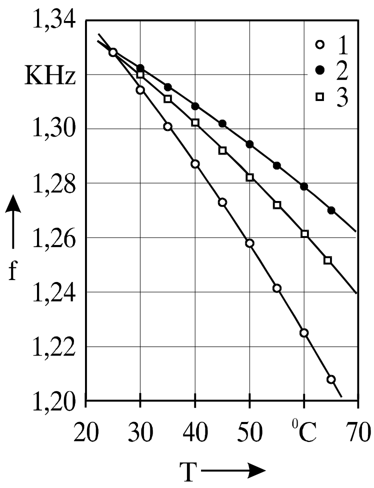


Fig. 5. Influence of Themperature over Frequency

Two circuits for temperature stabilization of the converter have been realized: with a posistor R′=300Ω connected in series to the resisitance R, and with a posistor connected in series to the supply circuit. The respective experimental characteristics f=φ(T) for the two circuits for temperature stabilization are shown in Figure 5 (curve 2 - for the circuit with a posistor connected in series to the resisitance R ; curve 3 - for the circuit with a posistor connected in series to the supply circuit). Better temperature stabilization is achieved by applying the circuit with a posistor connected in series to the resisitance R , the frequency f of the converter changing within 5% when the temperature rises in the range investigated (25÷65)°C.

The experimental results obtained show that following the approaches proposed and with a properly chosen posistor the desired temperature stability can be achieved.

III. ANALYSIS AND CONCLUSIONS:

A galvanomagnetic current-frequency (voltage-frequency) converter has been developed on the basis of a digital magnetosensitive IC with a simple circuit solution.The output frequency is stable, provided the transistor switch operates in a saturated mode. With a selected design version of the magnetic system the conversion characteristic can change within certain limits by changing the values of the resistor resistance R and of the supply voltage U_{DD}.

The practical possibility of the temperature stabilization of the conversion characteristic has been proved experimentally by means of a thermo-dependent element - posistor. A stable operationn mode of the converter can also be ensured by thermostating.

The current-frequency converter discussed here can also be used for realizing converters with a frequency output of linear displacement and current measurement.

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