Maximum Current Protection by Means of digital Galvanomagnetic Integrated Circuit

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Abstract: Maximum current protection by means of digital galvanomagnetic integral circuit is investigated. This integral curcuit is one of the newest sensor element. The possibility of the control DC current protection is described. The curcuits and analitic function of the transducer are shown. The experimental results are reported.

Different types of defence are used for reliable protection of electrical circuits from overcurrent and short-circuit in automatics, electrical engineering and electronics. They can be limiting and disconnecting, the former being passive and active. Different microelectronic components and circuit solution have been used for their realization.

The development of galvanomagnetic electronics enables the creation of contactless maximum current protection. Its main advantages are: low mass and small dimensions, increased resistance to mechanical action and high reliability. Contactless disconnecting circuits are available on basis of magnetotransistors [1], magnetodiodes [2] and Hall elements [3].

Magnetosensitive integrated circuits are a relatively new class of integrated elements which incorporate a magnetosensitive element and a circuit for electronic signal processing [4]. Compared to galvanomagnetic discrete elements, they have better noise immunity, amplifying or converting the signal in a discrete form and have better temperature stability. Magnetosensitive integrated circuits posses higher sensitivity and reliability, small dimensions, low mass and low power consumption. A complete electrical separation between the input and the output circuits is realised in them.

The paper investigates the possibility of realising maximum current protection on the basis of a magnetosensitive integrated circuit UGN 3113U of the company "Spaque Electrique" - USA and its experimental characteristics are presented. The operation of the IC is not affected by the speed of changing the magnetic induction and has high temperature stability. It resists mechnical vibrations. The semiconductor chip is mounted in a small 3-pin frame. The magnetic sensor UGN 3113U has the following basic parameters: supply voltage $U_{CC} = 4,5 \div 24$ V; magnetic induction of switching on $B_{ON} = 30$mT; magnetic induction of switching off $B_{OFF} = 17$ mT; current at the output $I_0 = 25$ mA/25 V.

Circuits of uncotrollable and controllable maximum current protection have been realised.

The flow chart of the uncontrollable maximum curent protection is shown in Figure 1.

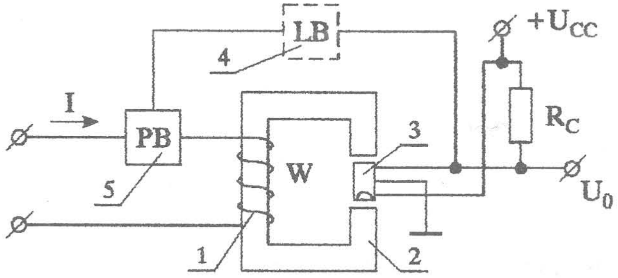

Fig. 1

When current flows through winding 1 a magnetic field B is induced in the air gap δ of magnetic circuit 2 where the magnetosensitive integrated circuit 3 is placed. In a normal operation mode the magnetic induction B induced is smaller than the magnetic induction of switching on of integrated circuit B_{ON}. When the current increases and the magnetic induction becomes equal to the magnetic induction of switching on of the magnetosensitive integrated circuit B_{ON}, the output of the IC is switched. The magnetosensitive integrated circuit returns to its initial state by reducing the magnetic induction value of the magnetic induction of switching off B_{OFF}. The signal is passed from the IC output to logical unit 4 which sends a command to power block 5. The power block disconnects the operating circuit. The output signal of the magnetosensitive IC U_0 has sufficient power and can be used directly to control the output stage. Integrated circuit UGN 3113U has an open collector and for that reason a load resistor R_C is connected. The maximum current protection can have manual repeated switching on with disconnecting protecion or automatic repeated switching on with limiting protection. This is determined in the logical unit.

The analytical form of the conversion characteristic is:

$$U_0 = k.B = k.k_{MB}.I,$$

where: k - conversion ratio of the magnetic IC [V/T]; k_{MB} - conversion ratio of the magnetic circuit [T/A].

The conversion ratio of the maximum current protection is shown in Figure 2.

I_{ON} signifies the current at which the maximum current protection is activated, and I_{OFF} - the current at which the protection is disconnected.

The magnetic induction in the air gap, when the stray flux is ignored, can be determined from the expression:

$$B = \frac{\mu . W . I}{\delta}. \qquad (1)$$

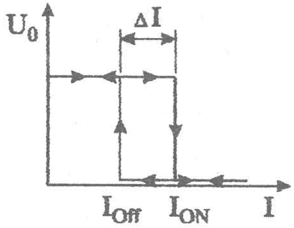

Fig. 2

The main task in designing galvanomagnetic converttеrs is the setting up of a magnetic circuit with a definite dependence $B = f(I)$. In this particular case the magnetic circuit has been solved experimentally. With the magnetic circuit chosen (μ, W, δ) the magnetic inductions of switching on B_{ON} and switching off B_{OFF} of the magnetosensitive IC , and therefore the activation of the power unit, too, depend on the current I flowing through the circuit.

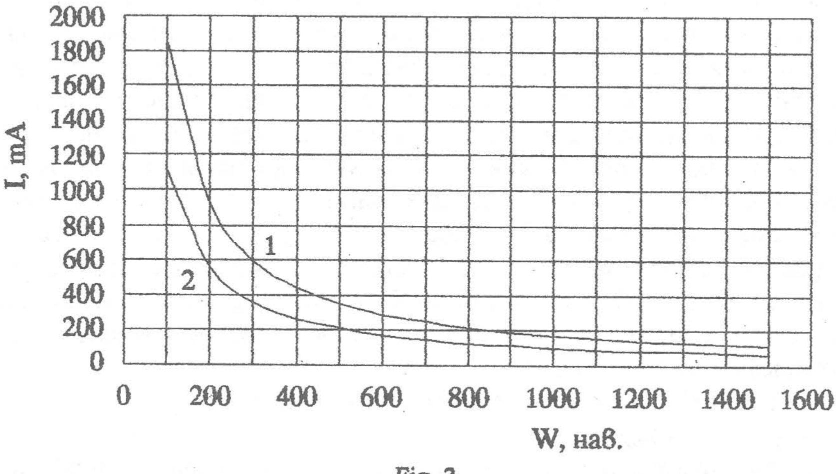

Fig. 3

By means of a step change in the number of windings the maximum current protection can be activated at different current. The results obtained experimentally $I = f(W)$ for the prototype realised are presented in Figure 3, curve 1 being $I_{ON} = f(W)$, and curve 2 - $I_{OFF} = f(W)$.

The dependence between current I and the number of windings W for a magnetic circuit can also be obtained by means of the parameter magnetomotive force F = W.I A.winding. It is a physical scalar quantity which evaluates quantatively the ability of the winding with current to induce a magnetic flux. The magnetomotive force for the maximum current protection realised is F=183A.winding.

If an additional winding W_P is added to the magnetic circuit discussed, through which current I_P can be regulated smoothly, a controllable maximum current protection is obtained and its flow chart is shown in Figure 4.

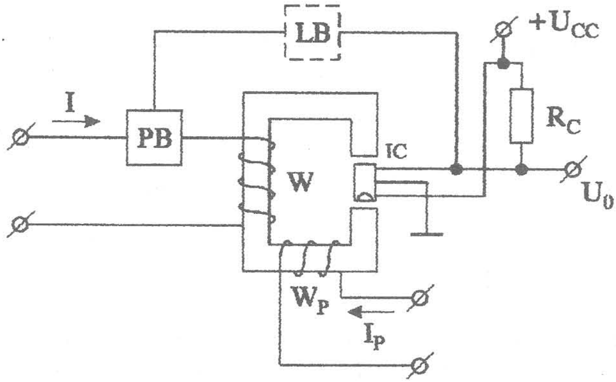

Fig. 4

The operation principle of the maximum current protection with controllable current of switching on is based on the main laws in magnetic circuits, the total magnetic flux Φ_E being determinated by the dependence $\Phi_E=\Phi \pm \Phi_P$ (Φ is a magnetic flux induced from the main circuit; Φ_P - a magnetic flux from the controllable winding introduced additionally).

The magnetic induction of switching on B_{ON} of the magnetosensitive IC is a function of the currents I and I_P with a chosen magnetic circuit. By regulating I_P smoothly the current at which the maximum current protection is activated also changes smoothly.

Since the magnetic fluxes depend on the direction of current, too, then if I_P induces a magnetic flux Φ_P having a direction identical with the direction of the magnetic flux in the main circuit Φ, then the two magnetic fluxes are added together and current I decreases. If the directions of the magnetic flux Φ_P induced from W_P and of the main magnetic flux Φ do not coincide., then two magnetic fluxes are substracted, and, as a result of this, the current at which the maximum current protection is activated also increases.

Figure 5 presents the characteristic $I = f(I_P)$ obtained experimentally when W = 500 windings, and W_P = 1000 windings. The curve 1 signifies the dependence of the maximum current protection activation current on the regulating current

$I_{ON}=f(I_P)$, and the curve 2 signifies the dependence of the protection current of switching off on the regulating current $I_{OFF}=f(I_P)$, pronded that the maximum current protection has automatic recovery of the circuit after current I decreases.

The minus sign in front of the regulating curent I_P signifies that it induces a magnetic flux with a direction oopposite to the main one. The displacement between characteristcs 1 and 2 on Figures 3 and 4 is due to the hysteresis of the magnetic IC. The dependence obtained experimentally is linear and it enables the current of switching on to be regulated from 0 to 717 mA.

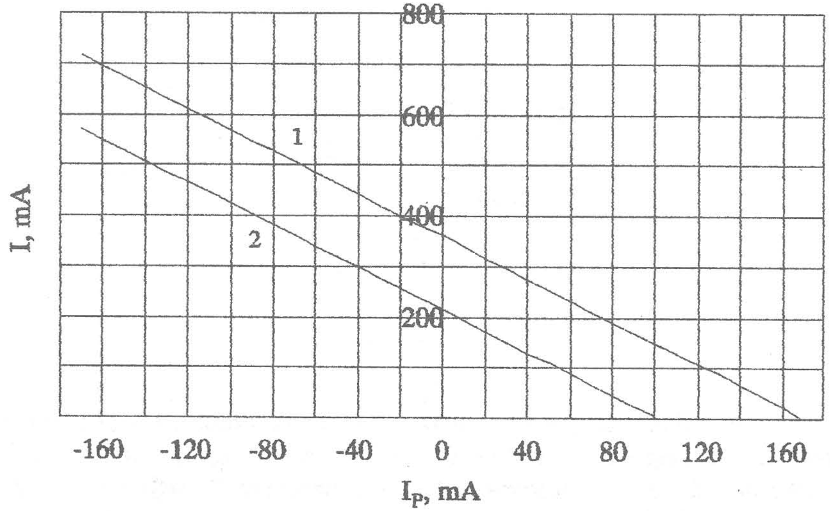

Fig. 5

The circuit proposed allows the successful realization of maxumum current protection for AC, as well.

The analysis of the experimental results obtained shows that the galvanomagnetic maximum current protection realised satisfies completely the requirements set for this class of devices: short response time and reliable operation under complex conditions, low power consumption, small dimensions and weight. Their main advantage is the absence of a conductive coupling between the control power circuit.

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