Reliability of the Linear Characteristics while Measuring Magnetic Fields

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ABSTRACT: *Electrical current is a diverse electrical quantity. The measurement systems have many direct methods for measurement. We have used an indirect contactless model for measuring the magnetic field by developing a flow through a conductor electrical current. We found that the contactless measurements have high sensitivity and wide frequency with high reliability. They have better linear characteristics due to the parallel bridge resistors.*

Keywords: AMR Sensors, Magnetoresistors, Contactless Measuring, Magnetic Field Measuring, Sensors of Magnetic Field

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1. Introduction

There are different electrical quantities. For their reading and treatment definite approaches are necessary. The electric current is one of the most often measured quantity in a techniques.

Classical sensors like as shunting resistors, current transformers and magnetic amplifiers are still used for electrical current measurement. Anyone of these sensors groups has their priorities but and much disadvantages as a big bulk, high price, measurement only constant or alternating values and etc. All of these disadvantages are eliminated in new generation sensors for contactless measurement of current and voltage [1, 2, 4].

The purpose of the present elaboration is to create and investigate on the basis of anisotropic magnetoresistors (AMR) a device for contactless alternating current measurement which can find a wide practical application.

2.. Presentation

The electric current flow across a conductor is connected with a magnetic field generation around it (fig.1). Its value is proportional to electric current magnitude. The modern galvanomagnetic sensors are microelectronic circuits. Its operation principle is established on a measurement of a magnetic inductance created by flowing through a conductor electrical current.

Different kinds of galvanomagnetic transducers as Hall elements, magnetodiodes, magnetoresistors, magnetotransistors and etc are used as transducers which transform a magnetic field to an electrical signal.The magnetoresistors and especially anisotropic magnetoresistors (AMR) are the most used as sensors for small currents up to 500mA. Hall elements operate as sensors for current measurement up to 1000A. Both galvanomagnetic transducers do not take part as discrete elements. They are constituent part of high technological magnetosensitive integrated circuits.

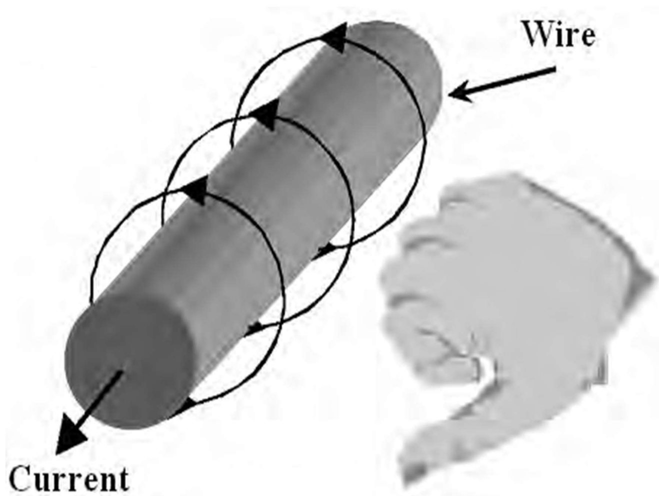

Figure 1. Magnetic field direction around conductor with electrical current

There are two methods for obtaining of dependent on a measured current sensor value (magnetic field). The first way is by means of direct effect of generated around a conductor magnetic field. The second way is to use a magnetic amplifier (concentrator) [3, 4]. Fig. 2 shows how the generated around a conductor alternating or constant magnetic field brings influence on magneto-sensitive integrated circuit.

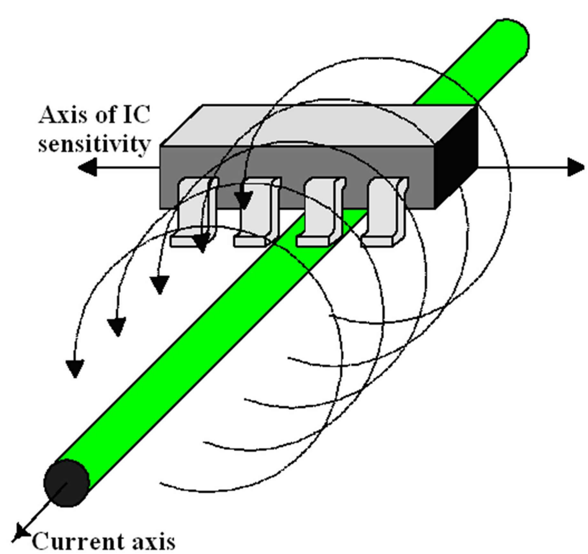

Figure 2. Magnetosensitive integrated circuit current measurement by magnetic field direct action

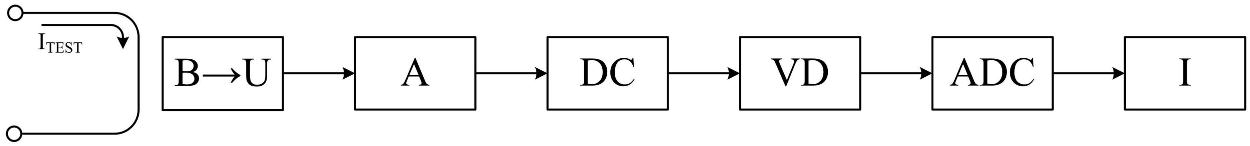

Figure 3. Block schematic diagram of device for contactless measurement of alternating electrical current

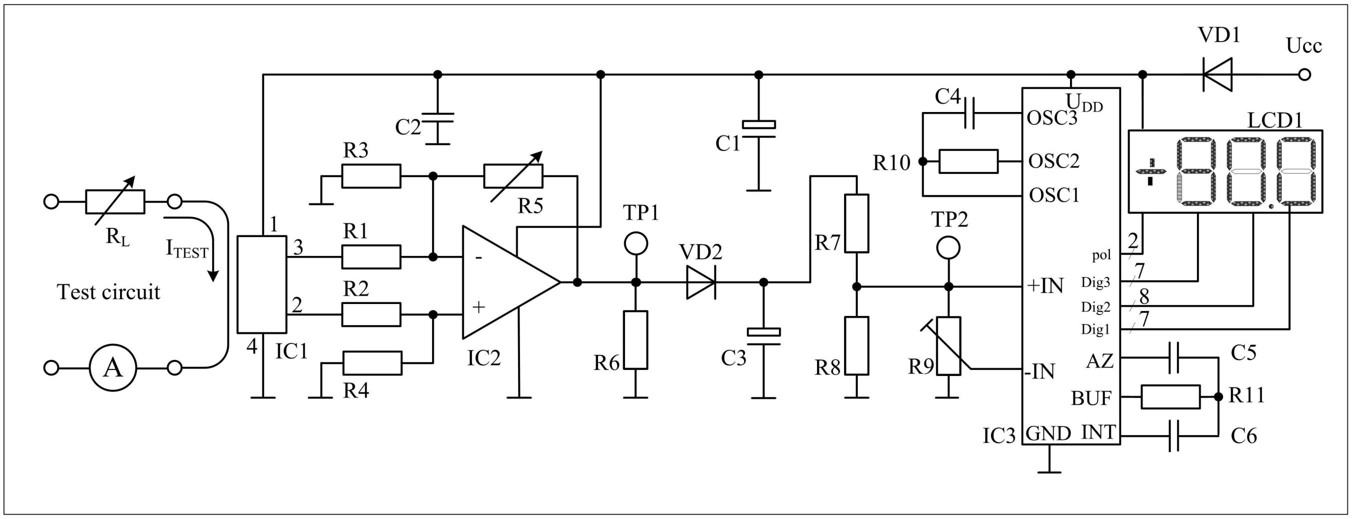

Figure 4. Simplified schematic circuit diagram of a device for contactless alternating current measurement

Block schematic diagram of device for contactless measurement of constant and alternating current is depicted in Figure 3. It is consisted of converter of magnetic field to electrical voltage (B-U). It transforms the generated by electrical current magnetic field. The output converter voltage is proportionately to the measured current value I_{TEST}. After its amplification by amplifier (A) this voltage is transformed by means of detector circuit (DC) to constant current level.

The obtained constant voltage is regulated by a voltage divider (VD) to a suitable for ADC input level after that its magnitude is measured by ADC. A indicator device (I) shows results in amperes.

The schematic circuit diagram of a device for contactless alternating current measurement is depicted in Fig.4.

The transducer IC1 is a magnetosensitive integrated circuit of the type ZMC20M manufactured by Zetex [4] which represent a connected in a parallel bridge four anisotropic magnetoresistors circuit. The amplifier IC2 is constructed on a basis of an operating amplifier connected as a differential amplifier. Its operation modes are tuned by resistors R1-R5.

The detector circuit as realized by elements R6, C3 and VD2. Resistors R7 and R8 are used as a voltage divider. The ADC is tuned by alternating resistor R9 and the results are indicated in amperes. ADC is built of a basis of MC7106R (IC3) used in many modern electronic multimeters.

A device printed board is projected so that on one side are placed strong current power and measuring wires while the small current wires are placed on another side.

The measured current conductor must be placed exact under a magnetosensitivi integrated circuit (Figure 5). So it is guaranted a maximum influence of a generated around a conductor magnetic field to semiconductor chip. The measuring conductor and sensor arrangement is depicted in Figure 5. The measuring conductor is arranged on another layer towards to the sensor.

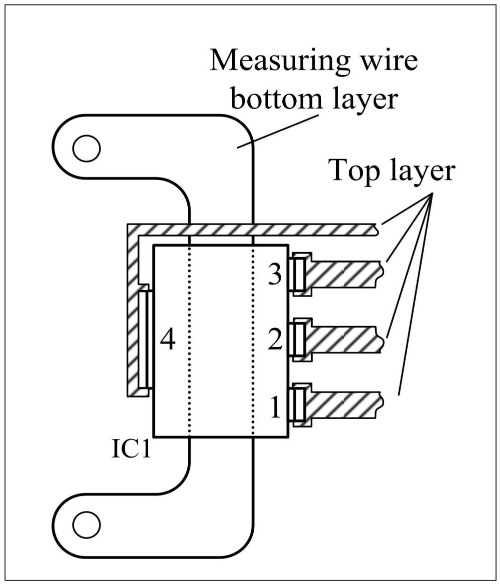

Figure 5. AMR sensor assembling draft

3. Experiments

Experiments are fulfilled. The voltages in special control points TP1 and TP2 are measured. Analog-to-digital converter reading at a change of a current I_{TEST} through measuring circuit is registered.

At an experiment accomplishment a water rheostat as a load is used. So a fluent resistance adjustment respectively a current through it is possible.

In Table 1 are shown a received value of the experimental transducers characteristic. The graphic result of experiments ($U_{TP1} = f(I_{TEST})$ and $U_{TP2} = f(I_{TEST})$) are depicted in Figure 6. They represent the changes of a voltage at an amplifying block (TP1) output and of a voltage at an ADC input (TP2) as a result of double conversion of measuring current I_{TEST}.

I_{TEST}, A	0,248	0,3	0,35	0,4	0,45	0,5
U_{TP1}, V	0,0555	0,0674	0,0778	0,0878	0,0959	0,107
I_{TEST}, A	0,55	0,6	0,65	0,7	0,75	0,8
U_{TP1}, V	0,118	0,128	0,139	0,149	0,157	0,168
I_{TEST}, A	0,85	0,9	0,95	1	1,1	1,2
U_{TP1}, V	0,178	0,19	0,2	0,21	0,228	0,248
I_{TEST}, A	1,3	1,4	1,5	1,6	1,7	1,8
U_{TP1}, V	0,269	0,291	0,31	0,33	0,35	0,369
I_{TEST}, A	1,9	2	2,5	3	3,5	4
U_{TP1}, V	0,389	0,408	0,53	0,632	0,694	0,793
I_{TEST}, A	4,5	5	5,5	6	6,5	7
U_{TP1}, V	0,888	0,963	1,07	1,16	1,26	1,35
I_{TEST}, A	7,5	8	8,5	9	9,5	10
U_{TP1}, V	1,42	1,53	1,61	1,71	1,79	1,89
I_{TEST}, A	11	12	13	14	15	16
U_{TP1}, V	2,05	2,25	2,35	2,49	2,6	2,73
I_{TEST}, A	17	18	19	20		
U_{TP1}, V	2,81	2,91	2,99	3,14		

Table 1. Experimental Results

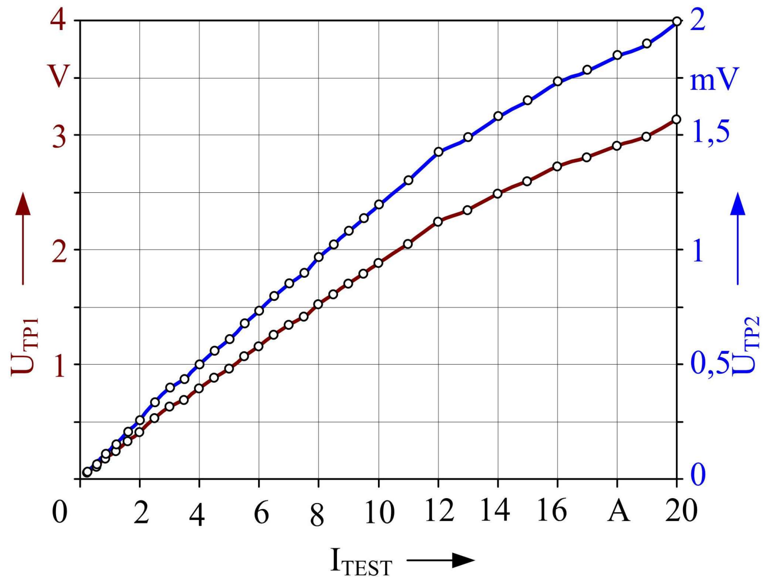

Figure 6. Experimental characteristics $U_{TP1}=f(I_{TEST})$ and $U_{TP2}=f(I_{TEST})$

It may be remarket that the both dependences have an similar character, but the voltages have a different change range in relation to the measuring value (from 0,05V to 3,14V for TP1 and from 0,025V to 2V for TP2) at I_{TEST} = (0,15÷20)A. This difference is artificially made, because of the ADC high input resistance and the possibility to use the whole range of input voltage (U_{IFNS} = 0, 2 ÷ 2V).

The characteristic $I_M=f(I_{TEST})$ is depicted in Figure 7.

The quantity I_M represents the registered on a created device display testimony of a ADC. The measured current value I_{TEST} is determined by water rheostat and is obtained by current pliers with inexactness of 2%.

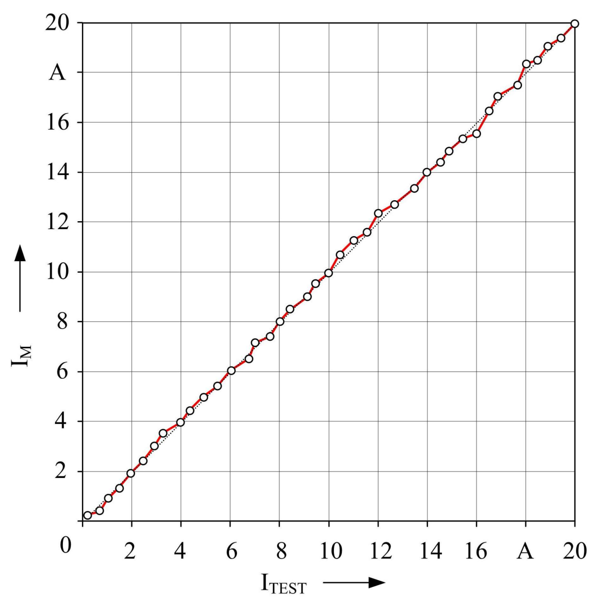

Figure 7. Experimental characteristic $I_M=f(I_{TEST})$

4. Analyses

The obtained results analysis shows that at a measured current I_{TEST} change in interval from 0,15mA to 20A the reading I_M of a created device for contactless current measurement is changed linear with minimum deviation towards to the straight line (Figure 7). Maximum deviations are obtained at measured currents 12A, 14A, 18A. They are respectively +250mA at 12A and 18A and -250mA at 14A, which be due to perturb of surroundings.

5. Conclusion

A device for contactless alternating electrical current measurement on the basis of bridge AMR sensor of type ZMC20M produced by Zetex [4] and of integrated 10 bits analog-to-digital converter of type MC7106R has been created.

The elaborated device operates on the basis of energy double conversions from electrical current into magnetic field and back into electrical voltage.

The device for contactless alternating electrical current measurement is widely applied in industry, instrumentation, motorcar electronics and etc. It can be a useful instrument at high frequency currents measurements in power electronics. By means of minimum changes it can operate as with battery supply and so with local power supply. So it is very suitable for an assembling in motorcars or for application in a portable measuring instruments.

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