INTEGRATED MAGNETIC FIELD SENSOR WITH AMORPHOUS RING CORE IN AN ISOLATED DC AND AC CURRENT AMPLIFIER

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Abstract:
Innovative isolated DC and AC current amplifiers using magnetic field sensors in the feedback loop are presented in this research. The galvanic isolation between input and output currents uses an amorphous ring core with an air gap. The amplifier's outline is provided in the paper. The printed circuit board project was created, and the amplifier's electronic circuit was built. The designed device was examined using DC and AC current, and the findings are provided in the publication. Results show that the produced gadget is useful for the purpose described.

1. Introduction

From the perspective of the energy sector, measuring the leakage current in the power lines overvoltage protection is a crucial issue. For current measurement, this type of measurement calls for an isolated measurement system. It is challenging to put such a measurement system into practise since galvanic isolation for several kilovolts must be guaranteed.

A specific isolated current amplifier was created for these types of experiments. Many different methods for designing current amplifiers have been used in the past, such as using a cryogenic current comparator or a mesoscopic Josephson junction [1]. The most significant class of current amplifiers are CMOS-based devices [3–5].

The magnetic field Hall-effect sensor [6] is integrated into the feed-back loop of the designed current amplifier. The magnetised amorphous ring core with an air gap generates the magnetic field that the sensor uses to measure it [7]. Galvanic isolation between the primary and secondary windings is also provided by the magnetic core. The newly developed device resembles the traditional currenttransformer.

component is magnetic ring core with an air gap. Mag- netic field sensor is placed inside the air gap. Schematic block diagram of the developed device is presentedin Fig. 1.

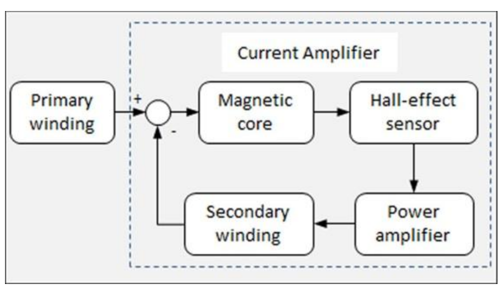

Figure. 1. Schematic block diagram of the developed iso- lated current amplifier.

There are two sets of windings created on the toroidal magnetic core: main and secondary (compensating). The primary winding is subjected to input current Iin. Its presence causes magnetic flux density to occur. Bin inside of the core based on the equationa magnetic field sensor and magnetic ring core [8, 9].

When measuring extremely low currents, such as leakage currents in surge arresters, the suggested architecture makes it possible to raise the input current value, which is crucial [10]. The proposed approach allows for the measurement of a low current of few A at voltage values up to several kV.

with magnetic ring core and magnetic field sensor [8, 9].

$$B = \mu\ \mu H = \mu\ \mu \underline{npIin}, \qquad (1)$$

where np is the number of turns in the primary winding, l is the flow channel of the magnetic flux in the core, H is the magnetising field created by the primary winding, and 0 and are the magnetic permeabilities of free space and the core's material, respectively. The equation [11] could be used to approximate the magnetic flux density Bex in the air gap.

Outline of the developed current amplifter

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sented apparatus Since a nanocrystalline material with a permeability of 8000 was chosen, Eq. (3) applies in this situation.

The Hall-effect sensor is used to measure the magnetic flux density Bex in the air gap. The TOSHIBA THS119 sensor, which is constructed of gallium arsenide (GaAs) and has a current-related sensitivity of roughly 20 V/AT, was selected for the previously mentioned application. The power amplifier's input receives the sensor's output signal (the Hall voltage), which is then sent to the secondary (compensating) winding. The primary winding's magnetising field is in opposition to the magnetic field in the secondary winding. By imposing a sufficient current flow into the secondary winding, a feedback loop connection enables compensation of the magnetising field. The outcome is a nearly zero reduction in the magnetic flux density Bex in the air gap. The compensating current can be viewed as an amplified current, which is the output parameter of the developed circuit, if the number of turns in the secondary winding is less than those in the primary winding.

2. Measurement stand

The developed isolated current amplifier was inves- tigated on the special measurement stand. Schematic block diagram of the stand is presented in Fig. 3.

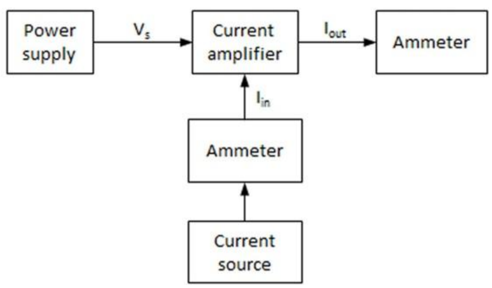

Figure. 3. Schematic block diagram of the measurement stand.

According to Eq. (4), the constructed device has a gain factor of 100 and a primary winding with 1000 turns and a secondary winding with 10 turns. By altering the proportion of primary to secondary windings, the gain factor can be changed.

According to the above description, an amplifier prototype was created. Fig. 2 shows an image of the entire gadget.

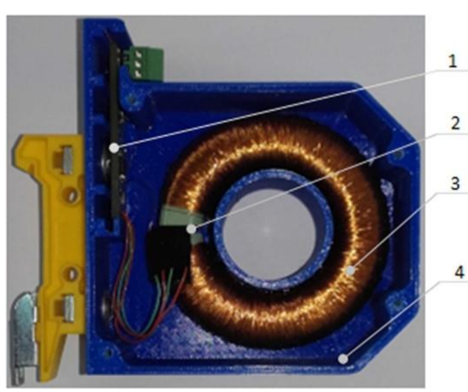

Figure. 2. Photo of the developed isolated current amplifier

1.20 mA. Input current I_{in} was measured with precise FLUKE 8808A multimeter and delivered to the input of the developed current amplifier. The output current I_{out} was measured with another FLUKE 8808A device.

3. Experimental results

On the described measurement setup, a newly developed isolated current amplifier was investigated. With an input current range of 0 to 1.20 mA, the dependence between input and output current was measured. The results obtained are shown in Fig. 4. The generated current amplifier exhibits excellent linear characteristics throughout the entire examined range, as can be demonstrated. The characteristic's R2 linear determination coefficient is 0.999, confirming the good linearity of the data. This is also evident in the equation shown in Fig. 4: obtained values of output current Iout are slightly different from expected values IoJ ut. The amplifier's input current error was computed for each tested value using the equation

$$\Delta = \frac{I_{out} - I_{o}^{J}ut}{I_{out}} 100\% = \frac{I_{out} - 100 \cdot I_{in}}{I_{out}} 100\%. \quad (5)$$

The device's electronic component's printed circuit board (PCB) was designed and created. The air gap of the nanocrystal core was where the Hall-effect sensor was installed. The device was installed in the custom housing.

The designed amplifier has a rather high inaccuracy for low input current values (around 11% for Iin = 19.2 A). Error decreases exponentially with input current and reaches a value of 0.35 percent when input current is equal to 1.0 mA. The magnetic core's hysteresis and the Hall-effect sensor's offset voltage, which affect the output current value, are the causes of the amplifier's inaccuracy.1176 *O. Petruk, M. Kachniarz, R. Szewczyk*

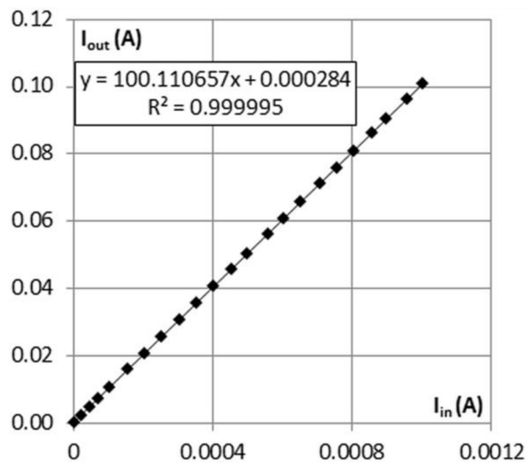

Figure. 4. Characteristic of relation between output and input current of the developed current amplifier.

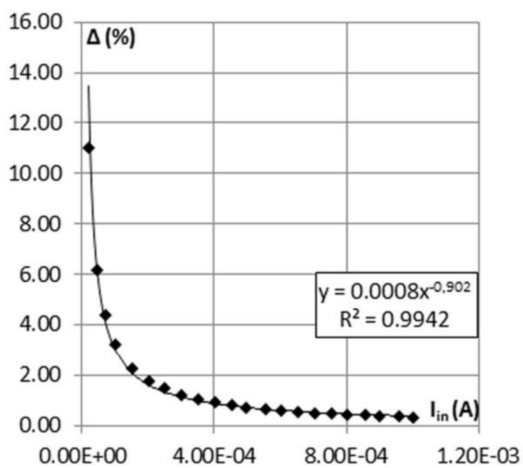

Figure 5. Input current dependence of the error of devel- oped current amplifier.

Conclusions

The created current amplifier described in the study operates as intended. Low levels of the error, particularly for the larger input currents, confirm that the outcomes are nearly identical to those anticipated. High linearity of the characteristic is demonstrated by the gadget. Measurement of extremely low currents is possible with a gain factor of 100, even numerous A. The magnetic core's galvanic isolation makes it possible to conduct measurements at voltage levels up to several kV. Both DC and AC currents with a frequency of no more than 5 Hz can be used with the gadget (for higher frequencies the amplifier tends to oscillate). An innovative take on the traditional design of the DC current transformer is the newly created isolated current amplifier.

References

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