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Optimization of structure and operation algorithms for electromagnetic plated coatings thickness meters with the use of digital technologies

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Abstract

Rapid progress in microcontrollers with the developed structure of hardware and software means, as well as the integrated fast operating analog to digital and digital to analog converters allowed one to pose a problem of thickness meters development excluding entirely or practically entirely the analog circuits in the exciting circuits and conversion of primary measuring information with the use of digital test methods ensuring a considerable improvement of metrological properties. The article is devoted to development of principles for constructing impulse inductive plated coatings thickness meters providing a full offset from the coating electro-conductivity action, high-frequency and power supply noises excluding temporary and temperature drift based on the use of digital technologies.

Keywords: coatings thickness meter, converter, induction

1. Introduction

The Majority serially let out thickness gauge for galvanic coatings use induction and also eddy current a phase and parametrical measuring methods.

Traditionally devices were under construction with use of analog elements, digital technologies however are even more often used at formation of signals of excitation of electromagnetic fields and transformation of the primary measuring information, processing of results of measurement.

However, the rapid progress in microcontrollers with the developed structure of hardware and software means, as well as the integrated fast operating analog to digital (DAC) and digital to analog (ADC) converters allowed one to pose a problem of thickness meters development excluding entirely or practically entirely the analog circuits in the exciting circuits and conversion of primary measuring information with the use of digital test methods ensuring a considerable improvement of metrological properties.

The induction method is applied to measurement of thickness *H* of electro conductive not ferromagnetic coverings on products from ferromagnetic materials with success.

The harmonious current is in most cases applied to excitation of a primary winding of the converter *i (t)* with frequency up to 400 *Hz*, and the primary measuring information is the amplitude induced on secondary winding voltage *e(t, H),* inversely proportional *H*. Inductive thickness meters include into their structure low frequency sinusoid voltage generator, feeding transducer’s primary winding, amplifier and converter connected to secondary winding emitting DC voltage *U(H),* proportionate to amplitude of signal received *e(t, H),* of transform circuit for *U(H)* into digital code *N(H),* which is applied for cover thickness calculation *H* based on calibration characteristic, and stored in the memory of the gauge.

2. Design principles and measuring algorithm

The converters applied to the measuring of coverings of small-sized products in galvanic manufacture should have the sizes of a zone of the control in diameter of the order of 1 mm that causes greater internal dispersion of magnetic streams and small factors own *M* and introduce *M1 (H)* mutual induction factors that causes high requirements to parameters of converters and the device as a whole.

For maintenance of demanded sensitivity super small-sized converters actual there is a problem of development of algorithms of the transformation based on use of digital methods of stirring factors reducing influence to which it is necessary to carry, first of all, the following:

-power line noise of industrial network and the equipment that is especially actual for galvanic manufacture;

-pulse noise from converters of the power equipment (a drivers of executive mechanisms, power supplies, etc.);

-high-frequency pulse modulated noise from various it is glad the communication equipment;

-intra circuit noise of microcontrollers and converters of actually measuring transformers of devices;

-eddy currents arising in elements of converters at a feed of their primary windings by a *i (t)* changing in time;

-change of sensitivity of primary converters at asymmetrical magnetic reversal cores of converters;

-temperature and time drift of characteristics of converters elements.

Thus it is necessary to consider, that practically there is no opportunity of a raising of the attitude a signal/noise due to increase magnetic stream of a primary winding since it can lead to saturation of the magnetic stream proceeding through core of the converter, and to decrease in its sensitivity. Represents significant interest use of pulse principles of a feed of a primary winding of the converter with the purpose of reduction of consumption and digital integrating methods of transformation of the primary measuring information for elimination of influence power line noise, eddy currents and noise from the microcontroller.

In work, except for stated above, also have been put, as accompanying, following problems:

-construction of the device on the basis of the microcontroller with built in analog-to-digital (ADC) and digital-to-analog (DAC) converters, with the purpose of reduction of quantity of elements;

-a possibility of connection of converters to devices without necessity of their joint graduation;

-exceptions of influence deterioration of the converter coil on an error of measurement.

The block diagram of the device with induction converters on the basis of the microcontroller with built in ADC and DAC (for example, MSP430F169) is presented on figure 1.

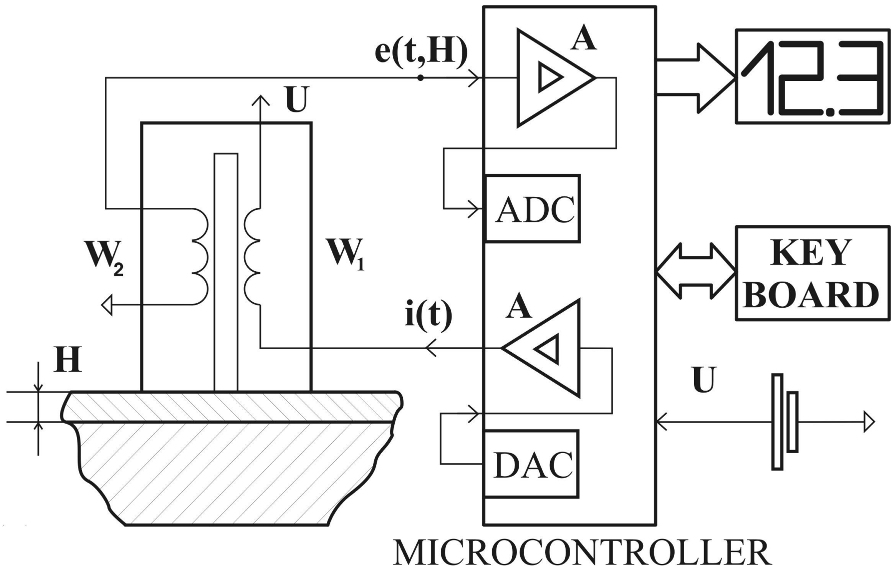

Figure 1. Structural scheme of thickness meter
A – amplifier, ADC – analog to digital converter, DAC – digital to analog converter, W_1, W_2 – windings

DAC forms a voltage, transform in amplifier in a current *i (t)* which form on an interval of an individual cycle of transformation is presented on figure 2.

On an interval of an individual cycle of transformation full symmetric magnetic reversal core the converter, excluding residual magnetization and change of sensitivity is provided. It allows to use for manufacturing core the steel, supposing training, for reduction deterioration of contact surfaces (the central core) converters. Speed of change *i (t)* and its form on these sites can be adjusted by the microcontroller under the program for optimum work ADC in its dynamic range. On an output of a secondary winding of the converter the voltage *e (t, H),* inversely proportional to thickness of covering *H*

$$e(t,H) = k*(M + M_1(H))W_1W_2\frac{di}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where *k* - factor of transformation.

A feed of the gauge by a current *i (t)* according to figure 2 provides reception of a constant voltage *e (t, H) = U (H)* practically on all on a time interval of transformation $\tau = t_2 - t_1$. In the informative parameter, allowing to reduce influence described above stirring factors, optimum to choose the value, proportional to the area of an impulse *e (t, H)* on a time interval of transformation τ. If τ is more than time of existence of eddy currents at change *i (t)* from value $+I_o$ up to $-I_o$ and on the contrary provides exception of influence of eddy currents on an error of measurement. The given voltage *e (t, H)* through built in the amplifier acts on input ADC by means of which it will be transformed with high frequency to a digital code n_j *(t, H),* and the microcontroller makes summation of received codes, i.e. calculation of areas *S1 (H), S2 (H)* and *S3 (H).* Thus suppression of influence high-frequency pulse noise, having casual character is made. Further, for exception of influence noises of industrial network, because of impossibility of maintenance of exact concurrence of intervals and τ_0 = 20 ms and the period of mains voltage, and also displacement of voltage of the electric circuits causing additive errors, it is calculated

$$\Delta S(H) = (S_1(H) - S_2(H)) + (S_3(H) - S_2(H)) \qquad (2)$$

$\Delta S(H)$ multiply sum of absolute sizes of the areas e (t, H) on time intervals of transformation τ

$$\Delta S(H) = S_1(H) + 2S_2(H)) + S_3(H) \qquad (3)$$

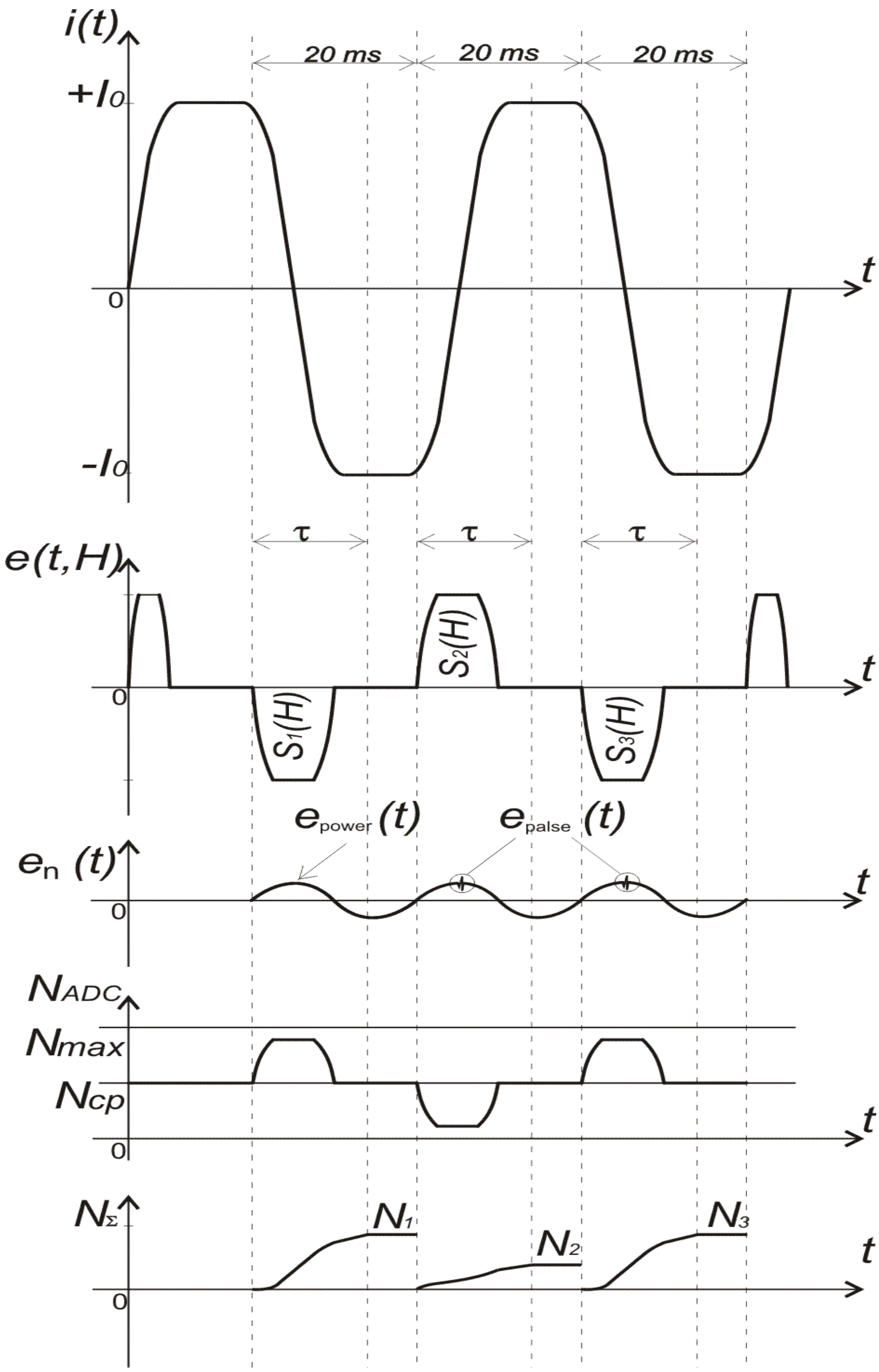

Figure 2. Scheme of operation of thickness meter

For reduction of multiply components of an error of the measurement, the characteristics of converters caused first of all by temperature stability (change of sensitivity) as informative parameter attitude

$$N(H) = \Delta\, S(H = \infty)/\, \Delta\, S(H), \ldots\ldots (4)$$

where $\Delta\, S(H = \infty)$. It is calculated automatically at rise the converter from a coating and an output for limits calibration characteristics and enters the name in memory of the device. An opportunity of change of values of a current $+I_o$ and $-I_o$, and also speeds V of increase (decrease) of a current $i\ (t)$ on a time interval of transformation τ allows to provide optimum size of a voltage on input ADC for any of connected converters, and also by splitting calibration characteristics on some sites on thickness H with values corresponding them $+I_o$,-I_o and V to provide close values of sensitivity of the connected converter in all range of thickness. Application of the powerful microcontroller has allowed to make approximation calibration characteristics a polynom of the third degree that has essentially reduced number of removed points calibration characteristics. Also the algorithm is developed, allowing to predict the characteristic of the converter at essential it deterioration (in the field of "negative" thickness).

The offered realization of thickness meter allowed, apart from significant simplifying of hardware and reduction of elements' number to obtain the following additional performance capabilities.

Application of transformers built in the microcontroller, provided for practically identical factors of thickness meters secondary transformers, which, in its turn, allowed for refusing from traditional method of tools' calibration with specific indicators, included into supply set. Indicators are calibrated at one bench instrument. Calibration characteristic is recorded into built-in memory, where it is stored and is read off at connection to any tool prior to operation start.

3. Conclusion

According to the stated principles it is developed induction thickness meter of protective galvanic coverings CONSTANTA K6G, and the complete set small-sized converters to it for the control of coverings on small size products, on internal surfaces of pipes with a diameter from 8 mm, on carving connections, etc. the minimal diameter of a zone of the control of converters is equal about 1 mm. Thickness meter differs high metrological characteristics, the big nomenclature of converters, small consumption of energy from the battery and the compact sizes.