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INDUCTIVE NEGA-SENSOR TYPE OF BRIDGE TYPE ON L-NEGATRON

The paper considers inductive nega-sensor of bridge type on L-negatron. Conversion factor and relative sensitivity are increased as a result of introduction in the circuit of inductive sensor – prototype of circuit engineering along of N-negatron, connected parallely to variable inductance of primary instrument transducer.

Key words: *inductive sensor, L-negatron, negasensor, sensitivity, output voltage, primary measuring converter.*

Introduction

Any automated information-measuring or control system comprises sensors, which are to provide high accuracy of conversion of various impacts into electric signals, maintain serviceability in wide range of temperatures and have high level of protection from the influence of external factors [1]. According to the principle of input magnitude conversion, sensors are divided into parametric, generator, optic and others. Parametric sensors form large group of sensors, which convert certain physical magnitude into electric parameter [2, 3].

Nowadays small-size inductive sensors, designed for creation of electric signal when metallic object approaches the sensor at a certain distance are in demand. Such inductive sensors are available, simple in operation, reliable and cheap element of drive control systems, machine-tools, automatic lines, measuring systems of physical magnitudes.

Research problem set up

There exist several schemes of the realization of inductive sensors: series, transformation, bridge, frequency, circuit based on voltage divider. Since the most reliable version of realization is bridge circuit, then it is expedient to carry out the study of inductive bridge sensor [4].

Main parameter of parametric sensors is the accuracy of measurement of physical magnitude, i.e., sensitivity. Sensitivity can be improved by means of usage of such elements of functional electronics as negatrons or their circuit engineering analog [5]. Since in inductive sensors physical magnitude is converted into inductance, then it is expedient to use L-negatron – the device, that has negative value of incremental inductance. Reactive resistance of such negatron also has negative value $X_L^{(-)} = \omega L^{(-)} < 0$, and its modulus increases with frequency increase [6]. Thus, the paper will consider the problem of increasing the sensitivity of bridge type inductive sensor using L-negatron. The connection of L-negatron may be parallel, in series to the inductor of primary measuring converter L_X or instead of it.

The aim of research is to develop inductive negasensor of bridge type, based on L-negatron possessing increased sensitivity to variations of input physical magnitude.

Mathematical modeling of sensor-prototype and negasensor

Let us consider the diagram of bridge-type inductive sensor (prototype), flow diagram of which is shown in Fig. 1.

Primary measuring converter of such sensor consists of electrical bridge, realized on two ballast resistors of the same nominal value and two inductance coils – constant L and variable L_X, values of coils inductance being the same. When metallic object is introduced in the field of variable coil, its inductance value will change that causes the change of output voltage value of the sensor:

$$U_{out1} = \frac{U_\Gamma \cdot R \cdot \omega \cdot (L_X - L)}{(R + \omega \cdot L) \cdot (R + \omega \cdot L_X)}. \quad (1)$$

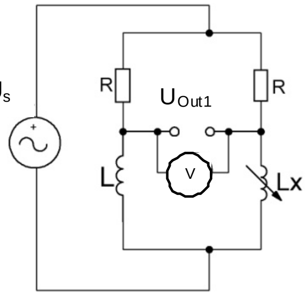


Fig. 1.Diagram of inductive bridge sensor -prototype

Absolute sensitivity of such sensor, i.e., its transformation factor, is determined by the expression:

$$K_{con1} = \frac{U_{\Gamma} \cdot R \cdot \omega}{(R + \omega \cdot L_X)^2}. \tag{2}$$

Relative sensitivity has the form:

$$S_1 = \frac{L_X \cdot (R + \omega \cdot L)}{(R + \omega \cdot L_X) \cdot (L_X - L)}. \tag{3}$$

To increase the sensitivity of such sensor-prototype we will connect in parallel to the inductance of primary measuring converter circuit-engineering analog of L-negatron, realized on immitance converter and we obtain negasensor [7], its diagram is shown in Fig. 2. On the diagram L-negatron is denoted as $L^{(-)}$.

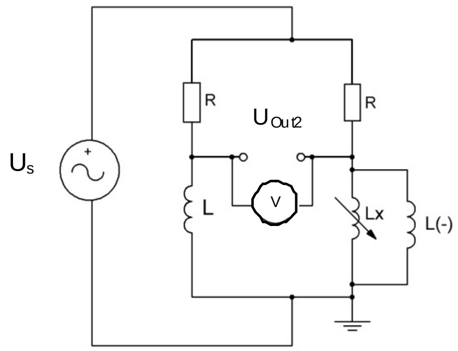


Fig. 2. Diagram of inductive bridge-type negasensor, based on circuit engineering L-negatron, connected in parallel to the inductor of primary measuring converter L_X

The value of output voltage of such negatron is determined by the realition:

$$U_{out2} = -\frac{(L \cdot L^{(-)} + L \cdot L_X - L^{(-)} \cdot L_X) \cdot R \cdot U_{\Gamma} \cdot \omega}{(R + \omega \cdot L) \cdot (L_X \cdot R + L^{(-)} \cdot R + \omega \cdot L^{(-)} \cdot L_X)}. \tag{4}$$

Transformation factor of the negatron is determined by the expression:

$$K_{con2} = \frac{L^{(-)^2} \cdot U_{\Gamma} \cdot \omega \cdot R}{(L_X \cdot R + L^{(-)} \cdot R + \omega \cdot L^{(-)} \cdot L_X)^2}. \tag{5}$$

The expression for determination of relative sensitivity has the form:

$$S_2 = -\frac{L^{(-)^2} \cdot L_X \cdot (R + \omega \cdot L)}{(-L^{(-)} \cdot L_X + L \cdot L^{(-)} + L \cdot L_X)) \cdot (L_X \cdot R + L^{(-)} \cdot R + \omega \cdot L^{(-)} \cdot L_X)}. \tag{6}$$

Fig. 3 shows graphical dependences of output voltage U_{out}, transformation factor K_{con}, relative sensitivity S of the negasensor and sensor-prototype, S_2/S_1 on inductance L_X in case of parallel connection of L-negatron for various values of negative inductance (–390 μH, –450 μH, –250 μH and –200 μH).

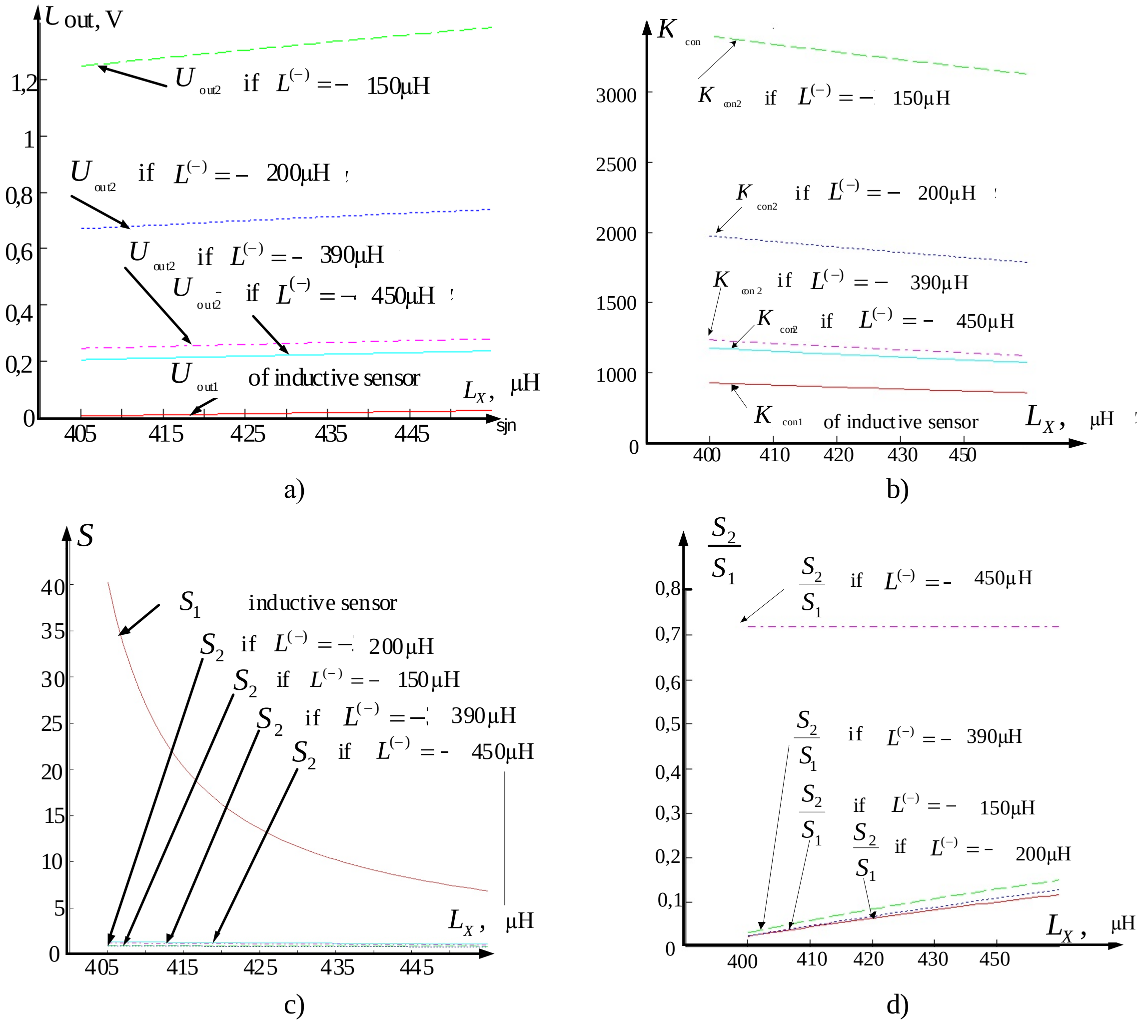


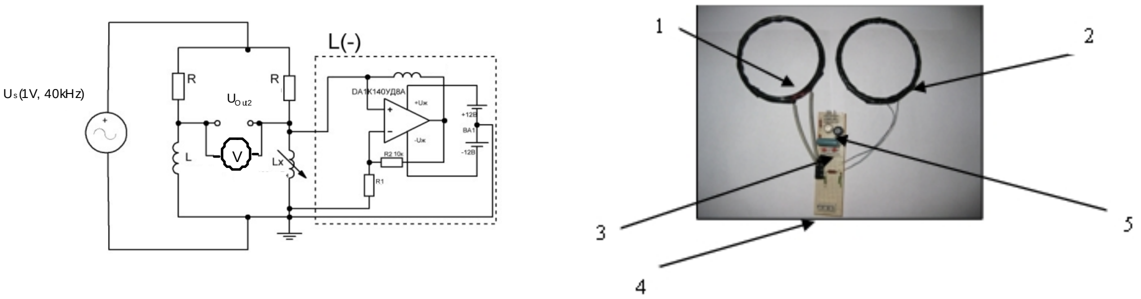
Fig. 3. Dependences of output voltage U_{out} a), \transformation factor K_{con} b), relative sensitivity S c) and ratio of sensitivity S_2/S_1 d) on inductance L_X for various values of relative inductance $L^{(-)}$

The analysis of dependences shows that absolute sensitivity of the negasensor is almost eight times greater than the sensitivity of sensor-prototype and output voltage is dozens times greater than the output voltage of sensor-prototype (depending on the magnitude of negative inductance $L^{(-)}$).

Experimental research

To confirm the obtained theoretical postulates, the engineering model is constructed, this model contains both sensor-prototype and negasensor. Fig. 4 shows flow diagram of negasensor, based on circuit-engineering L-negatron in the form of immitance converter (a)and photograph of the experimental model (b).

The model is sensor-prototype and circuit-engineering analog of L-negatron, assembled on one board, connected to the sensor by means of a switch for negasensor realization. Inductive sensor consists of the inductance of the first measuring converter L_X (1), constant inductance coil (2), two ballast resistors *R*. Coils *L* and L_X are identical, regarding their construction, they are coils, consisting, of 50 turns of ПЕЛ-0,8 wire, wound around the core of 10 cm of diameter; resistors MLT of nominal resistance 30 Ohm, power 0,125 W are used as ballast resistors



a) b)

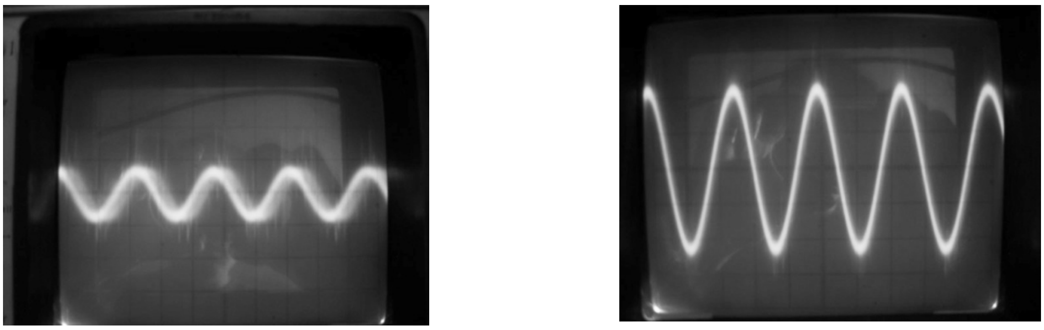
Fig. 4. Flow diagram of negasensor based on circuit-engineering L-negatron in the form of immitance converter (a) and photograph of experimental model (b)

Circuit-engineering analog of L-negatron is realized on operational amplifier DA1 of К140УД8А type with positive feedback in the form of throttle L1 by non-inverted input and voltage divider (R1, R2), that defines amplification factor of operational amplifier. DA1 supply is provided by bipolar supply source $BA1 - \pm 12V$. The board contains plugs for connection of generator, oscillograph (4) and supply source. Low-frequency generator Г3-118 and oscillograph С1-93 were used as measuring equipment. Generator supplied a sinusoidal signal of 40 kHz and amplitude of 1V to sensor input, voltage variation was controlled at the output by means of oscillograph. Metal plate, 12 cm of diameter was used as an object, the sensor reacted to.

The model is realized in such a manner that it is possible to study both the sensor-prototype and negasenor separately, as it is provided by jumper switching (3).

Fig. 5a presents the picture of oscillograph of output voltage of inductive sensor-prototype at maximum distance of metallic object form L_X. Amplitude of output signal in this case was 40 mV.

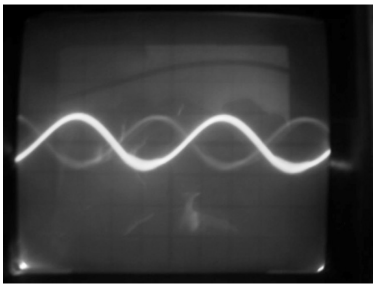
When metallic object is introduced in the field L_X, the voltage at the output increases, maximum distance, the inductive sensor reacts to the object being 4,5 cm, and voltage variation at this distance is 1–5 mV. At maximum approach of the object to the coil (when metallic plate is on the coil) voltage variation is 50 mV. The photograph of output voltage oscillogram in this case is shown in Fig. 5b.



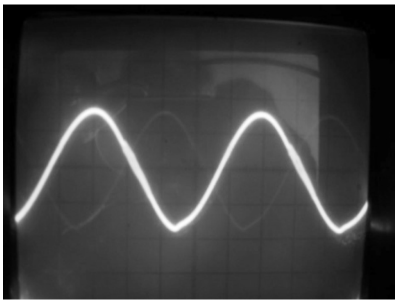
a) b)

Fig. 5. Oscillograms of output voltage at maximum distance of metallic object from sensor-prototype a) and at maximum approach of the object to sensor-prototype b). Value of a division 0,05 V

If metallic object is introduced in the field L_X, the maximum distance, negasensor reacts to the object, was 8-9 cm, and voltage variation at the distance was 1-5 mV (Fig 6a), that was 2 times greater than in inductive sensor – prototype. Maximum variation of output voltage of negasensor at maximum approach of metallic object to L_X field is 400 mV, that is eight times greater, than in inductive sensor-prototype. Oscillogram of negasensor output voltage at maximum approach of metalic object to L_X fileld is shown in Fig. 6b.



a)



b)

Fig. 6. Oscillograms of output voltage in case of absence of metallic object impact on negasensor a) and at maximum approach of the object to negasensor b). Value of a division- 0,5 V

Thus, the obtained negasensor of bridge type has two times greater absolute and relative sensitivity and eight times greater output voltage than inductive sensor-prototype has.

Conclusions

The obtained mathematical dependences for inductive bridge-type negasensor showed that at the expense of additional introduction of L-negatron in the circuit of inductive sensor-prototype several times increase of sensitivity can be achieved , if certain conditions are met.

Inductive bridge-type negasensor realized on L-negatron has two times greater absolute and relative sensitivity to variation of input physical magnitude, as compared with the circuit of sensor-prototype without L-negatron.

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