DOI 10.34185/1562-9945-5-162-2026-12
UDC 621.373 – 187.4

M.I. Tverdostup

HARMONIC INDUCTOR-TO-FREQUENCY CONVERTER BASED ON IMPEDANCE CONVERTER

Abstract. Objective - increased sensitivity of F-metrically inductance converter. Found management conditions Slope conversion measuring generator based on a combination of the operating circuit by varying the parametric elementary sensor inductance compensation included in the oscillator, resonant circuit.
Keywords: inductance, resistance, impedance, sensor, generator, combined operating circuit, frequency increment, compensation, sensitivity, F-meter.

Introduction. In modern devices, measurement and control method is widely used F-meters, allowing relatively easy to convert the reactans sensor frequency harmonic oscillations [1]. The disadvantage of this method is its limited sensitivity to a change in the controlled parameter. So, urgent is the establishment of tools to increase the sensitivity of the method of control F-meters.

In [2,3] laid the foundations for the synthesis of impedance converters on operational amplifiers. Conclusions [4] indicate the usefulness of the combination of the operating circuit to create a measuring generator with controlled sensitivity.

Formulation of the problem. The aim is to develop F-meter sensitive to changes in the parametric sensor inductance.

Main part. Measuring generator based on a linear combination of the operating circuit (LCOC) is shown in Fig. 1. The linear combination of the operating diagram with inductive impedance in the negative feedback loop is the presence of a characteristic combination of feedback, and the fact that the external drive signals U_1 and U_2 received in phase to both woos da operational amplifier DA2. From the findings of the work [4], the input impedance is LCOC

$$\dot{Z}_{in} = (\dot{Z}_1 - R_2 R_3/\dot{Z}_4)/(1-n)\,, \tag{1}$$

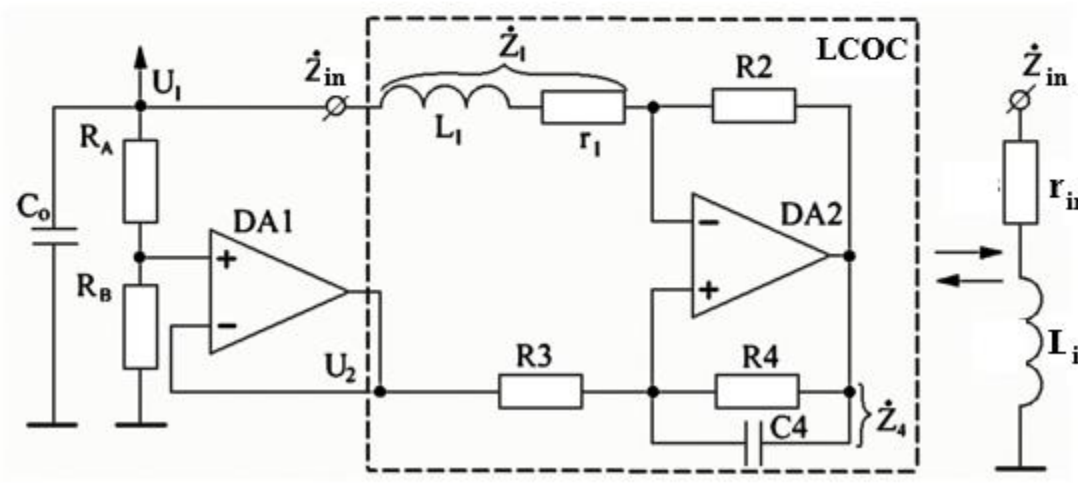
where $\dot{Z}_1 = r_1 + \mathrm{j}\omega L_1$– integrated inductor L_1 impedance and internal resistance of r_1; R_2,R_3 - the active resistance of the circuit combined feedback amplifier DA2; $\dot{Z}_4 = R_4/(1+\mathrm{j}\omega C_4 R_4)$ - complex impedance parallel-connected resistance R_4 and capacityC_4 ; $n = U_2/U_1$, U_1 and U_2 - driving voltage signals. Repeater on DA1 amplifier with a resistive divider R_A, R_B is a source of excitation voltage U_2 , U_1 -phase input voltage. The ratio of the stress field can be represented by the ratio of the divider resistors in the form of

$$n = R_B/(R_A + R_B)\,, \tag{2}$$

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

while the input impedance expressed by the parameters of the scheme will be

$$\dot{Z}_{in} = (1 + R_B/R_A)(r_1 + j\omega L_1 - R_2R_3/R_4 - j\omega C_4R_2R_3) . \quad (3)$$



a) b)

Figure 1 - Measuring LCOC generator based on (a);
LCOC equivalent representation (b)

It is also true that represented by the input parameters is

$$\dot{Z}_{in} = r_{in} + j\omega L_{in}, \quad (4)$$

where r_{in}, L_{in} - input resistance and inductance. Then (3) and (4) the expression of active and inductive component input impedance

$$r_{in} = (1 + R_B/R_A)(r_1 - R_2R_3/R_4) , \quad (5)$$

$$L_{in} = (1 + R_B/R_A)(L_1 - C_4R_2R_3) , \quad (6)$$

showing that in this scheme, L_1 inductance and internal resistance r_1 is converted into the input inductance L_{in} and resistance $r_{вх}$ with the multiplication factor equal to

$$m = (1 + R_B/R_A), \quad (7)$$

which, when $R_B >> R_A$, can take larger values. From (5) it follows that multiplication resistance r_1 is accompanied by compensation negative active component of the input impedance equal LCOC

$$R_{(-)} = -R_2R_3/R_4 , \quad (8)$$

$\left|R_{(-)}\right| \to r_1$ at the input resistance $r_{вх} \to 0$, which indicates the possibility of a significant increase in the quality factor inductance.

From (6) it follows that multiplication by m inductance L_1 ratio occurs simultaneously with a decrease in its initial value by $C_4R_2R_3$, which will be called the compensating inductance $L_к$. Expression (6) in the form

$$L_{in} = m(L_1 - L_к)\,. \tag{9}$$

Suppose that under the influence of a controlled parameter of the inductance L_1 of the sensor changes by, the ΔL_1 input inductance becomes LCOC

$$L_{in} + \Delta L_{in} = m(L_1 + \Delta L_1 - L_к)\,. \tag{10}$$

From (9), (10) it follows that the absolute and relative increment of the input inductance up

$$\Delta L_{in} = m\Delta L_1\,, \tag{11}$$

$$\Delta L_{in}/L_{in} = \Delta L_1/(L_1 - L_к), \tag{12}$$

and, when $L_к \to L_1\,, \Delta L_{in}/L_{in} \to \infty$. It can be seen that the absolute increment of the input inductance is determined by multiplying the coefficient *m*, and the relative increase - the value of the compensating inductance $L_к$. This shows that the possible scaling ЛКОС inductance sensor with control values of sensitivity to the monitored parameters.

To the input capacitance connected LCOC C_o, which with the input inductance L_{in} forms an oscillating circuit with a resonance frequency

$$f = \frac{1}{2\pi\sqrt{L_{in}C_o}}\,. \tag{13}$$

From (5) it follows that if the condition $r_1 < R_2R_3/R_4$ in the circuit there is a negative resistive component of the input impedance LCOC to compensate ohmic losses in the circuit and provides a stationary harmonic oscillations at the resonant frequency (13), which, subject to (9) is vie

$$f = \frac{1}{2\pi\sqrt{m(L_1 - L_к)C_o}}\,. \tag{14}$$

If you change the sensor inductance L_1 frequency increment can be defined as

$$\Delta f = \frac{df}{dL_{in}}\Delta L_{in} = -\frac{1}{4\pi\sqrt{m(L_1 - L_к)C_o}} \cdot \frac{\Delta L_1}{(L_1 - L_к)}\,. \tag{15}$$

From (15) we see that the frequency increment is substantially increased when $L_к \to L_1$. The latter justifies the possibility of increasing the sensitivity of F-meters based on LCOC to L_1 inductance change parametric sensor.

Experimental verification of the expressions (14) and (15) was carried out on the measuring generator (Fig.1), assembled on operational amplifiers ICL7650 with inductance L_1 = 21 mH, capacitance C_o= 1,106 μF and an initial rate of 460 Hz. Fig. 2 shows the experimental module increments Δf frequency generator of incremental inductance ΔL_1 sensor by varying the values of the compensating inductance $L_к$ from 0 to 17.23 mH.

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

Experimental data show that, depending $\Delta f(\Delta L_1)$ linear; while compensating inductance $L_к = 0$ (curve 5) sensitivity to ΔL_1 minimum and 7.5 Hz/mH, while increasing the value increases the sensitivity $L_к$ (depending 1 - 4), so when $L_к$ = 17.23 mH (1 relationship) increases the sensitivity of five times to 39.2 Hz/mH. This confirms that the magnitude of the compensating inductance $L_к$, relative to the initial inductance L_1 sensor can be controlled oscillator sensitivity measuring conditions within $L_1 - L_к > 0$.

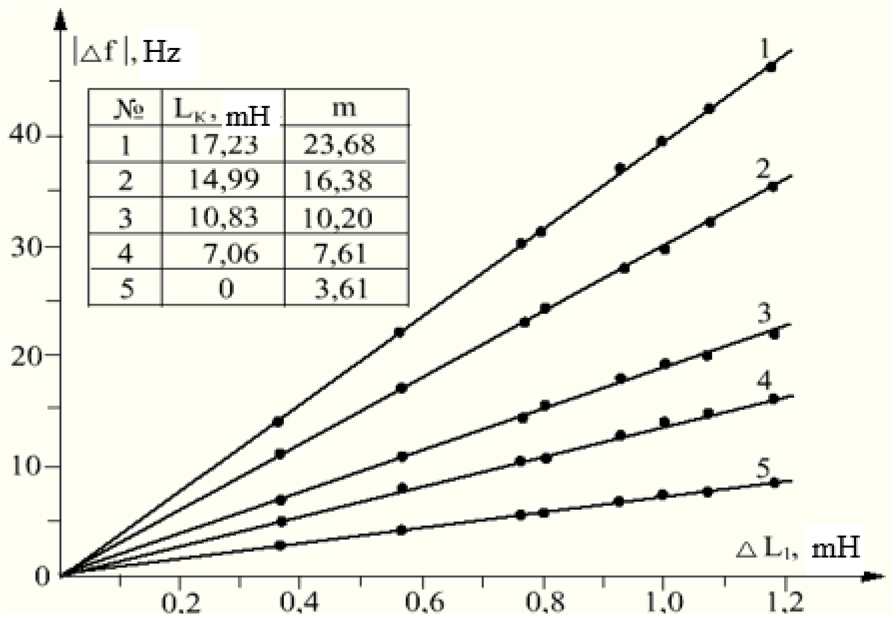


Figure 2 – Increment frequency generator as a function of Δf L_1 inductance sensor for different values compensating inductance $L_к$

Experimental family conversion features (Fig. 3) changing the compensating inductance from 0 (relation 5) to 17.23 mH (1 relationship) also support an increase in the steepness of the conversion characteristics when $L_к \to L_1$.

Calculated according to (14) and (15) are in good agreement with the experimental data, the difference (due to nonidea sectional amplifiers and precision measuring devices) are not pre-exceeds 5%.

Conclusion. Studies measuring the generator on the basis of a linear combination of the operating circuit showed after-blowing:

- compensation for sensor initial inductance while multiplying its increments allow you to manage the change, you often measuring oscillator;

- changing the frequency measuring generator sous-substantially determined by the value of the compensating inductance;

- the use of measuring generator based on linear combinate operating schemes can increase the sensitivity of F-meters to a change in inductance of the parametric transducer.

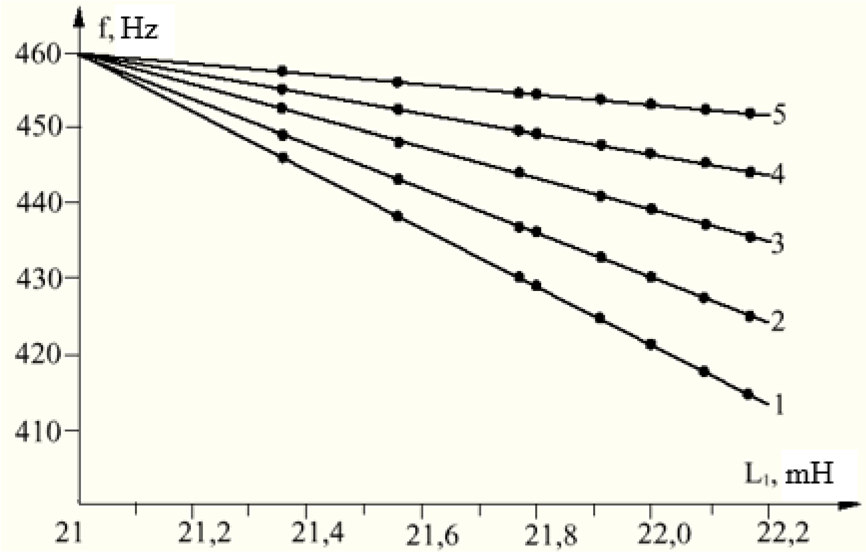


Figure 3 - Characteristics of the measuring conversion generator

REFERENCES

1. Izmereniya v elektronike: Spravochnik / Kuznetsov V.A. i dr. Pod red. V.A. Kuznetsova. – M. : Energoatomizdat, 1987. – 512 s.

2. Filanovskii I.M., Persianov A.Yu., Ribin V.K. Skhemy s preobrazovatelyami soprotivleniia. – L. : Energiia,1973. – 192 s.

3. Marshe Zh. Operatsionnye usiliteli i ikh primenenie – L. : Ener- giia,1974. – 216 s.

4. Tverdostup N.I. Obobshchennaya model preobrazovatelei impedansa. *Visnyk Dnipropetr. un-tu. Fizyka. Radioelektronika.* – 2010 – vyp. 17, №2. S.103 – 108.

ЛІТЕРАТУРА

1. Измерения в электронике: Справочник / Кузнецов В.А. и др. Под ред. В.А. Кузнецова. – М.: Энергоатомиздат, 1987. – 512 с.

2. Филановский И.М., Персианов А.Ю., Рыбин В.К. Схемы с преобразователями сопротивления. – Л.: Энергия, 1973. – 192 с.

3. Марше Ж. Операционные усилители и их применение – Л.: Энергия, 1974. – 216 с.

4. Твердоступ Н.И. Обобщенная модель преобразователей импеданса. *Вісник Дніпропетр. ун-ту. Фізика. Радіоелектроніка.* – 2010. – Вип. 17, №2. С. 103 - 108.

Received 06.01.2026.
Accepted 14.01.2026.

Гармонійний перетворювач індуктивності в частоту на основі конвертора імпедансу

Недоліком F-метра, як вимірювальної системи , є невисока чутливість до варіації індуктивності параметричного давача. Для підвищення чутливості проведено аналіз гармонійного генератора, який містить коливальний LC – контур, під'єднаний до конвертора імпедансу, вхідний опір якого має від'ємні активну і індуктивну складові. Від'ємна активна складова, при певних умовах, забезпечує виникнення гармонійних коливань, від'ємна індуктивна складова компенсує необхідну частину індуктивності параметричного давача. Теоретично показано і експериментально підтверджено, що

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

компенсація певної частини індуктивності давача з одночасним множенням її приросту дає можливість керувати зміною частоти коливань вимірювального генератора. Чутливість зміни частоти вимірювального генератора суттєво залежить від величини компенсуючої індуктивності. Використання вимірювального генератора на основі конвертора імпедансу дає можливість збільшити чутливість F – метра до варіації індуктивності параметричного давача.

Твердоступ Микола Іванович – доцент, к.т.н., доцент кафедри електронних обчислювальних машин Дніпровського національного університету імені Олеся Гончара.
ORCID: https://orcid.org/0009-0002-2571-634X

Tverdostup Mykola Ivanovych – Associate Professor of Computer Systems Engineering Department of the Oles Honchar Dnipro National University.
ORCID: https://orcid.org/0009-0008-2444-7925