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M.I. Tverdostup

ANALYSIS OF DEPLOYING INDUCTANCE-TO-PULSE SEQUENCE CONVERTER ON NE555 INTEGRATED TIMER

Annotation. The peculiarities of construction of inductive impedance converter Based on integral timer are analysed. Conditions of linear transformation of inductive impedance into a sequence of rectangular pulses are found.
Keywords: integral timer, pulse, inductance, impedance, deployment converter.

Introduction. The task of increasing the reliability of measurement and control devices, which to a great extent depends on the number of constituent elements and simplicity of circuit realisation, is topical. Promising for the construction of simple and reliable converters is an integrated single-cycle analogue timer NE555 (and its analogues), used to convert the capacitance and resistance of an electrical circuit into a controlled sequence of rectangular pulses [1,2]. However, there is practically no sufficient information about the use of the integrated timer as an inductance converter. This requires an analysis of the peculiarities of the construction of inductive impedance converters on the integral timer.

Problem statement. The purpose of the work is to determine the conditions for the construction of an inductance converter into a sequence of rectangular pulses on the basis of an integral timer.

The main part. In analogue timers, the excitation signal is fed to the input of an internal dual-threshold comparator, which allows the design of deployment-type converters with a linear or exponential deployment function. One of the possible simple realisations of the inductance converter in the period of rectangular pulses is shown in Fig. 1. Here *L* is the inductance to be converted with its own active resistance *r*. The inductance *L* and the timing resistor *R* form an integrating circuit, the input of which is connected to the timer output, and the output to the input of an internal two-threshold comparator with switching voltages *U*/3 and 2*U*/3, where *U* is the output voltage of the timer. When the timer is switched on, a high level of voltage *U* is set at its output, equal to the supply voltage $E_п$, which is distributed to the elements of the integrating circuit according to the equation

$$L\frac{di}{dt} + (R + r)i = U \, , \tag{1}$$

Where $i(t)$ is the current flowing from the timer output through the elements of the integrating circuit. The solution of the differential equation (1) at zero initial conditions determines the instantaneous value of current $i(t)$ in the form of

$$i(t) = I[1 - \exp(-\frac{t(R+r)}{L})], \tag{2}$$

where $I = U/(R+r)$. The current $i(t)$ creates a voltage drop on the resistance R, which is the deploying voltage of the converter

$$u(t) = \frac{UR}{R+r}[1 - \exp(-\frac{t}{\tau})], \tag{3}$$

where $\tau = L/(R+r)$ is the time constant of the integrating circuit. According to (3), the voltage $u(t)$ increases exponentially and at time t_1 reaches the level of the lower triggering threshold $U/3$, for which

$$u(t_1) = \frac{U}{3} = \frac{UR}{R+r}[1 - \exp(-\frac{t_1}{\tau})], \tag{4}$$

As time passes, the deployment voltage continues to increase and at the next time instant t_2 reaches the level of the upper triggering threshold $2U / 3$, for which

$$u(t_2) = \frac{2U}{3} = \frac{UR}{R+r}[1 - \exp(-\frac{t_2}{\tau})], \tag{5}$$

after which the output voltage U of the timer jumps to zero. This leads to a change in the current direction $i(t)$ as well as a change in the deployment direction until the next switchover at $u(t)= U/3$. The time moments t_1 and t_2 at which the timer switches can be found by solving equations (4) and (5), whereby

$$t_1 = \tau \ln \frac{3R}{2R-r}, \quad t_2 = \tau \ln \frac{3R}{R-2r}.$$

The duration of the generated output pulse is $t_2 - t_1$ and their period $T = 2(t_2 - t_1)$, hence

$$T = \frac{2L}{R+r} \ln \frac{2R-r}{R-2r}. \tag{6}$$

The obtained conversion characteristic (6) has the form $T = kL$, where

$k = \frac{2}{R+r} \ln \frac{2R-r}{R-2r}$ is the conversion coefficient of inductance L during the period T of rectangular pulses.

It follows from (6) that the conversion of inductance L occurs according to the linear law; the conversion factor k is determined by the absolute values of the resistance of the integrating circuit R and the own active resistance r of the inductance, as well as their ratio R/r, and the conversion factor k will be a positive number only if the condition is fulfilled

$$R > 2r. \tag{7}$$

Obviously, at $R < 2r$ values of k do not exist; at $R = 2r$ conversion factor $k = \infty$, which means infinite period T, otherwise, oscillation failure. When $R \gg 2r$, the expression of the conversion coefficient is simplified and transformed to the form $k \approx 2\ln2/R$. The value of the conversion coefficient k can be controlled by the value of resistance R, and, in order to obtain

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high values of *k*, the ratio of resistance *R*/*r* should be as close as possible to the value 2, taking into account the condition (7), while the absolute values of *R* and *r* should be minimal.

Experimental verification of expressions (6) and (7) is carried out in the converter circuit (Fig. 1), assembled on the NE555 integrated timer. Fig. 2 shows the experimental dependences of the duration *T* of the period of rectangular pulses from the output of the timer on the value of the transformed inductance *L* at different conversion factors *k*. The dependences confirm the linear character of inductance conversion in a wide enough range and the validity of expression (6). At the same time, thedeviation of experimental data from the calculated data according to expression (6) does not exceed 10%.

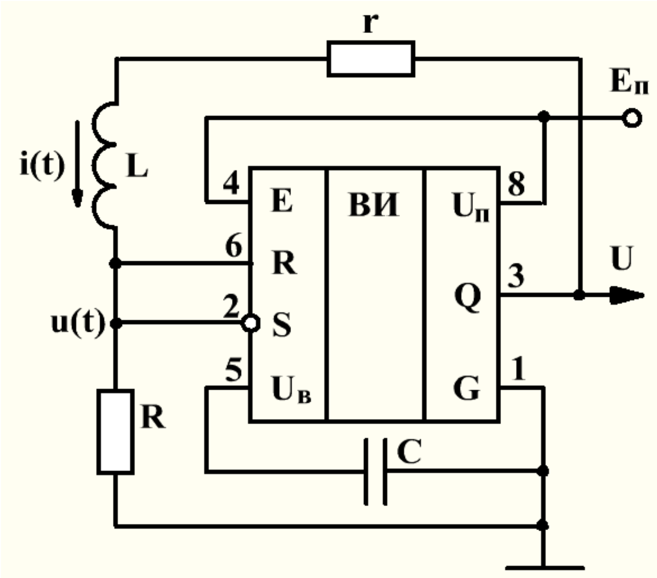

Figure 1- Converter of inductance *L* into a sequence of rectangular pulses

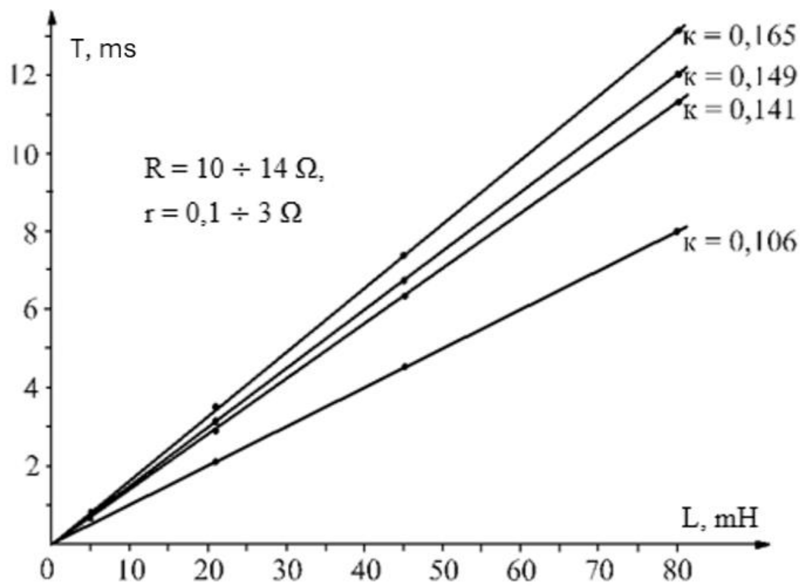

Figure 2 - Conversion characteristics of inductance *L*
at different conversion factors *k*

Fig. 3 shows the experimental dependences of the conversion coefficient on the logarithm of the resistance ratio *R*/*r*. It can be seen that the closer lg(*R*/*r*) to 0,301 (otherwise, *R*/*r* to 2), the more oscillations in the circuit were absent, which confirms the validity of condition (7). To transform the grounded inductance *L* (Fig. 4), the circuit should be supplemented with an inverting amplifier with a single gain ($R_1 = R_2$) and bias circuit $R_4 < 0.5R_3$. In this case, a sweeping voltage similar to expression (3) will be formed at the amplifier output.

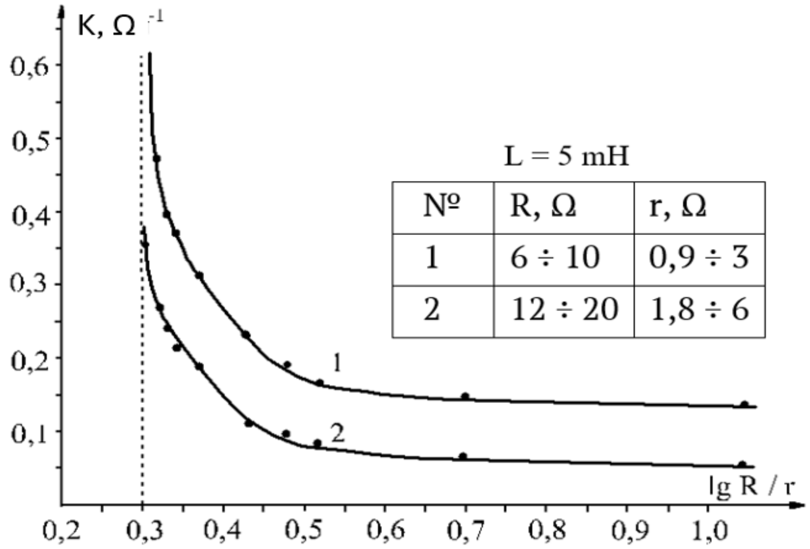

Figure 3 - Dependences of conversion coefficient *k* on the ratio of resistances *R/r* at their different absolute values

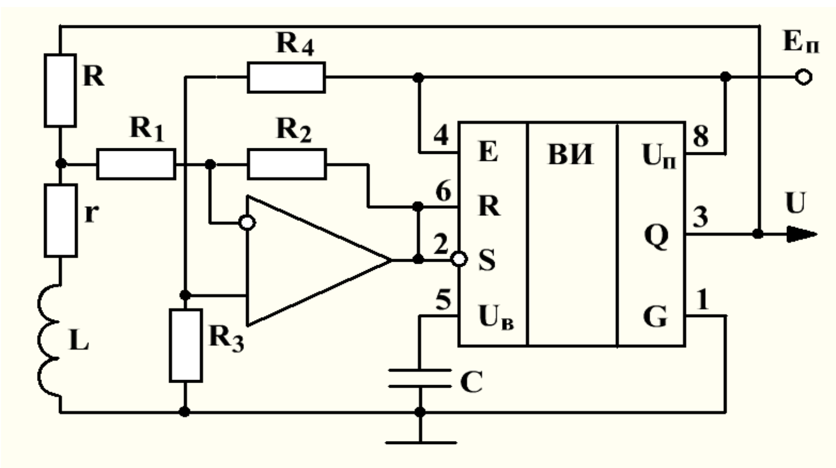

Figure 4 - Inverter with grounded inductance *L*

Conclusions. As a result of the analysis the following has been established:

a) the converter based on a single-cycle analogue timer converts the inductance into a period of rectangular pulses following a linear law in a wide enough range with a conversion coefficient inversely proportional to the sum of active resistances of the integrating circuit;

b) to ensure oscillations, the time-dependent resistance of the integrating circuit must always be greater than twice the active resistance of the inductance to be converted;

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c) the inductance converter on the timer is characterised by good functional capabilities with extremely simple circuit implementation, which implies its sufficiently high reliability in the construction of converters of passive parameters of electrical circuits into a controlled sequence of pulses.

ЛІТЕРАТУРА

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Аналіз розгортуючого перетворювача індуктивності в послідовність імпульсів на інтегральному таймері NE555

Про використання інтегрального таймера NE555 як перетворювача індуктивності в послідовність прямокутних імпульсів відомості практично відсутні. Це вимагає проведення аналізу особливостей побудови на інтегральному таймері перетворювачів індуктивного імпедансу. Досліджено схему таймера з інтегруючим колом у вигляді індуктивності, що перетворюється, і опору, під'єднаних до входу двопорогового компаратора таймера. Для такого кола складено диференціальне рівняння, розв'язування якого дало змогу визначити експоненціальний характер розгортальної напруги на входах компараторів таймера, а також одержати вираз характеристики перетворення у вигляді залежності періоду слідування вихідних прямокутних імпульсів від величини індуктивності, яку перетворюють. Встановлено, що коефіцієнт перетворення визначається величинами опору часозадавального кола і власним активним опором індуктивності, що перетворюється, при цьому для існування коливань опір часозадавального кола має бути більшим за подвоєний активний опір індуктивності. Експериментально підтверджено лінійність характеристики перетворення і обернено пропорційний вид зв'язку коефіцієнта перетворення з відношенням активних опорів часозадавального кола та індуктивності.

Твердоступ Микола Іванович – доцент, к.т.н., доцент кафедри електронних обчислювальних машин Дніпровського національного університету імені Олеся Гончара.

Tverdostup Mykola Ivanovych – Associate Professor of Computer Systems Engineering Department of the Oles Honchar Dnipro National University.