PHYSICAL QUANTITIES SENSORS PARAMETERS MEASURER

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Abstract – The questions of physical quantities sensors (mainly of capacitive and inductive sensors) output parameters measuring are considered. It is measured transient instant values voltage in measuring circuit. The realization of proposed measuring mode allows to provide high operating speed and to raise the measuring accuracy. The measurer can be used in systems of centralized acquisition and processing of measuring information.

One of the main metrological characteristics of measuring instruments (MI) – operating speed - is determined by duration of time interval required by measuring instrument for formation of measuring physical quantity current value, at that the less the time the higher is the operation speed. The task of operating speed MI creation is very important, especially in systems of centralized acquisition and processing of measuring information. Usually the operating speed of MI, as of metrological system, is determined mainly by response of sensor (primary measuring converter) - the least operating speed node MI. Owing to wider use of various physical quantities sensors in engineering the question of their output parameters (R, L, C) measuring obtains the primary significance. At the same time the requirements to metrological characteristics of corresponding measurers are increasing. For solution of such tasks it is widely used the measuring devices with measuring circuit (MC) supply by sinusoidal voltage and measuring realization in set regime [1]. However in some cases such devices prove to be compound, have small operating speed because of primary converter response and rather narrow measuring range.

The development of elementary base of modern radio electronics makes possible the use of transients, appearing in MC in solution of such tasks (dynamic measuring method). The use of modern integral chips allows to create in this case the simple, safe and small-sized measuring devices, possessing the high operating speed at rather good metrological characteristics [2].

At realization of dynamic measuring method MC parameters are determined by separate instant value of transient in the circuit at connection to it the voltage of direct current [3-5]. In this case the measuring time doesn't depend on time constant of unknown element of circuit, but is determined mainly by instant values measuring time of transient and realization of measured values processing algorithm.

In known devices, constructed by this method [5] and which use two measurings of instant values of transient voltage, on sequential active-capacitive and inductive-active circuit, one element of which is known, presents the known value U_0 of direct current voltage (fig. 1). At arbitrary moment of time the first instant value of voltage on midpoint of MC is measured. In a reference interval of time from the moment of first measuring the second instant value of voltage on circuit midpoint is measured and the unknown element of circuit is defined the

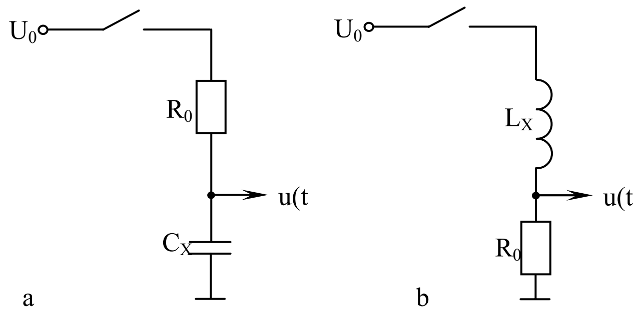

Fig. 1. Active-capacitive (a) and inductive-active (b) circuits

unknown element of circuit by two measured values and known value of reference voltage. In these measurers it is supposed that the value of reference voltage U_0 is known in advance and is stabile in time. However, in general case for raising the measuring accuracy it is necessary to define the value of reference voltage before each measuring of MC parameters, which increases the general time of measuring.

In this paper it is described the mode and device allowing to determine MC parameters also by two measurings, but at arbitrary value of reference voltage.

For active-capacitive circuit (fig. 1a) at connection to it the source of reference voltage U_0 of direct current the signal $u(t)$ on circuit midpoint increases according to dependence (fig. 2)

$$u(t) = U_0 \left(1 - e^{-t/\tau}\right), \qquad (1)$$

where $\tau = R_0 C_X$ - time constant of circuit, consisting of known resistance R_0 and unknown capacity C_X (fig. 1a); $\tau = L_X / R_0$ - time constant of circuit, consisting of known resistance R_0 and unknown inductivity L_X (fig. 1b).

At arbitrary moment of time t_1 the instant value of voltage on circuit midpoint (fig. 2)

$$U_1 = U_0 \left(1 - e^{-t_1/\tau}\right).$$

At that moment of time first ratio of voltages is measured

$$k_1 = U_1 / U_0 = 1 - e^{-t_1/\tau}. \qquad (2)$$

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In a reference interval of time Δt from the moment of first measuring at time moment $t_2 = t_1 + \Delta t$ the instant value of voltage on circuit midpoint

$$U_2 = U_0 \left(1 - e^{-t_2/\tau}\right) = U_0 \left(1 - e^{-\frac{t_1+\Delta t}{\tau}}\right).$$

At that moment of time the second ratio of voltages is measured

$$k_2 = U_2 / U_0 = 1 - e^{-(t_1+\Delta t)/\tau}. \qquad (3)$$

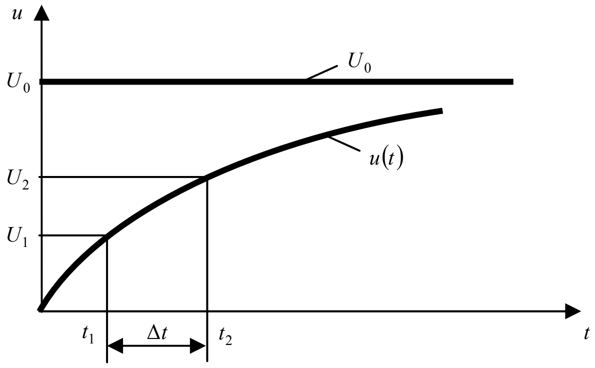

Fig. 2. The voltage change on MC midpoint

From formulas (2) and (3) we'll find the ratio

$$\frac{1-k_1}{1-k_2} = \frac{e^{-t_1/\tau}}{e^{-t_1/\tau} \cdot e^{-\Delta t/\tau}} = e^{\Delta t/\tau}.$$

Taking the logarithm of two parts of this expression we'll get $\frac{\Delta t}{\tau} = \ln\frac{1-k_1}{1-k_2}$, from where

$$\tau = \frac{\Delta t}{\ln\frac{1-k_1}{1-k_2}}. \qquad (4)$$

If capacity C_X is unknown, and active resistance R_0 of MC is known, so $\tau = R_0 C_X$ and

$$C_X = \frac{\Delta t}{R_0 \ln\frac{1-k_1}{1-k_2}}. \qquad (5)$$

If active resistance R_X is unknown, and capacity C_0 of MC is known, so $\tau = R_X C_0$ and

$$R_X = \frac{\Delta t}{C_0 \ln\frac{1-k_1}{1-k_2}}. \qquad (6)$$

For inductive-active sequential circuit $\tau = L/R$ the formula (4) is right. If in this case inductivity L_X is unknown, and active resistance R_0 of MC is known, so $\tau = L_X / R_0$ and

$$L_X = \frac{R_0 \Delta t}{\ln\frac{1-k_1}{1-k_2}}. \qquad (7)$$

If active resistance R_X is unknown, and inductivity L_0 of MC is known, so $\tau = L_0 / R_X$ and

$$R_X = \frac{L_0 \ln\frac{1-k_1}{1-k_2}}{\Delta t}. \qquad (8)$$

In considered device the raising of measuring accuracy of MC unknown element is attained due to that at same two measurings the reference voltage U_0 is also controlled, and in the result of it the instability of this voltage doesn't cause the inaccuracy of measuring.

The devise which realises the described measuring mode R, L, C contents (fig. 3) the reference voltage source of direct current 1, key 2, measuring circuit 3, performed in the form of sequential connection of active resistance (or inductivity) 4 and capacity (or active resistance) 5, voltage divider 6 with input of dividend 7 and input of divisor 8, analog-to-digital converter (ADC) 9, computing unit 10, control unit 11, "Start" bus 12. The outputs of ADC positions are connected to informational inputs of computing unit 10, and the controlling input – to first output of control unit 11. The second output of control unit 11 is connected to controlling input of key 2, and the third output is connected to controlling input of computing unit 10, the initial setup input of which is connected to "Start" bus 12.

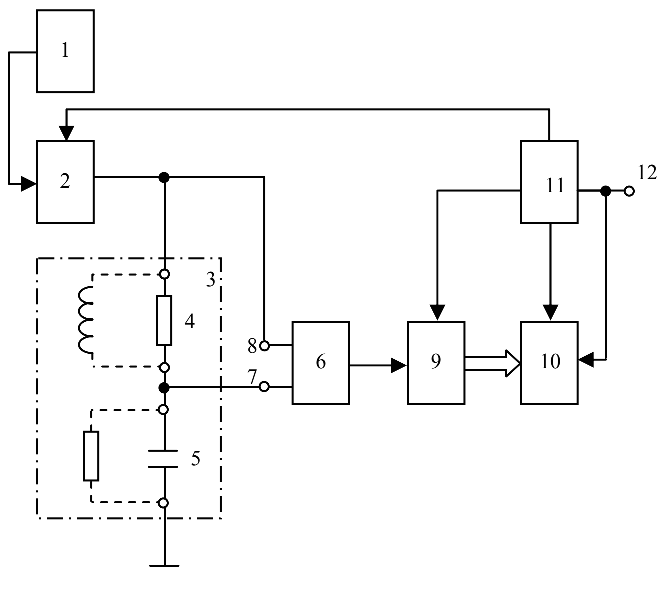

Fig. 3. Block-scheme of R, L, C parameters measurer

The voltage divider 6 is the divisor of analog voltages, the conversion coefficient of which is chosen equal to 1 V. As ADC it is used the coded-pulse ADC of parallel type with output memory register. As computing unit 10 the microcomputer or programmable-controlled computing devise can be used. Computing unit 10 and control unit 11 can be replaced by one programmable microcontroller.

The devise operates in the following way.

At giving of pulse on “Start” bus the computing unit 10 goes to program run starting. At the command from control unit 11 key 2 is locked and voltage U_0 from source 1 goes to MC input and to input of divisor 8 of voltage divider 6.

The voltage on MC midpoint changes according to formula (1). Voltage divider 6 continuously divides this voltage by reference voltage U_0.

In some interval of time, assigned by control unit 11, at arbitrary moment of time t_1 ADC 9 is launching, at input of which the instant value of voltage is equal to $k_1 = U_1/U_0$. This voltage is converted into code, which after request signal for entry, coming from control unit 11, goes to control input of computing unit 10 and is recording in this unit.

In a time interval Δt, assigned by control unit 11, at time moment t_2 ADC 9 is launching again, at input of which the instant value of voltage is equal to $k_2 = U_2/U_0$. This voltage is converted into code, which after request signal for entry is recording in computing unit 10.

In computing unit 10 the calculations are making according to formulas (5), (6), (7) and (8) depending on MC type and unknown parameter. The codes, proportional to values of known element of circuit and time interval Δt, are saved in the memory of computing unit. The measuring result of measured value in physical units is fixing in computing unit 10, after which the initial state of device is restoring.

As it follows from getting formulas, in described device the measuring result doesn’t depend on reference voltage value. The measuring time of MC unknown element doesn’t depend on time constant of this circuit and defined mainly by ADC converting time.

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