RADIO MEASUREMENTS

MICROPROCESSOR MULTIMETERS BASED ON DIGITAL PROCESSING OF THE INSTANTANEOUS VALUES OF SIGNALS

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A microprocessor multimeter is proposed capable of carrying out a wide range of functions by means of software based on digital processing of the codes of the instantaneous values of the signals in accordance with certain algorithms. An estimate of its errors is given.

An important trend in the development of instrument construction is the increased range of practical functions or universality of measuring instruments, i.e., the introduction of multimeters. Modern multimeters, which differ in their specific constructional principles, are based on the intermediate functional conversion of the measured physical quantity into, if possible, a single unified parameter, usually a DC voltage (or current), which is then measured by an analog or digital method [1, 2]. Such multimeters have the following main drawbacks. First, the complexity of the apparatus required, since a primary measuring transducer is necessary for each measured physical quantity (voltage, frequency, phase shift, power etc.). Second, their accuracy is comparatively low, and is determined by the errors of the analog measuring converters, which depend moreover on different characteristics of the input signal (the harmonic coefficient, the frequency etc.). Third, the lower limit of the frequency of the input signals is restricted (to approximately 20 Hz). Fourth, a considerable amount of time is necessary to make the measurements, since such multimeters carry out a sequential algorithm for measuring physical quantities.

These and other drawbacks can be eliminated to a considerable extent by changing to a universal method of measuring different electrical and radio quantities, based on digital processing of the instantaneous value of the signals [3]. This method reduces to a direct conversion of the alternating input signals (without any intermediate analog conversion) at n sampling points per period into proportional codes, which are then subjected to digital processing using appropriate algorithms, governed by the physical quantities being measured. Here it is best to use the method of rectangles for such processing [4]. In this method the algorithms for the digital processing of the codes of the instantaneous signals are described by the following expressions for a number of physical quantities:

- the root mean square value of the alternating voltage (current) \( x(t) \)
  \[
  A = \sqrt{n \sum_{q=1}^{n} x_q^2} 
  \]
  where \( x_q = x(t_q) \) is the instantaneous value of the voltage (current) at the sampling point \( t_q \), \( q = 1, n \); and \( n \) is the number of sampling points per period of the signal;

- the mean value (the constant component) of the voltage (current) \( x(t) \)
  \[
  A_0 = \frac{1}{n} \sum_{q=1}^{n} x_q; 
  \]

- the active power of the total current
  \[
  P = \frac{1}{n} \sum_{q=1}^{n} u_q i_q; 
  \]

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the reactive power of the sinusoidal current

\[ Q = \frac{1}{n} \sum_{q=1}^{n} u_{q} i_{q} \left( 1 - \frac{n}{4} \right), \]

where \( n/4 \) denotes a \( \pi/2 \) phase shift (or a quarter of a period \( T/4 \)) of the instantaneous values of the current with respect to the instantaneous values of the voltage;

the root mean square value of the voltage (current) of the \( \nu \)-th harmonic

\[ A_{\nu} = \sqrt{\left( A_{\nu x}^{2} + A_{\nu y}^{2} \right)/2}, \]

where \( A_{\nu x}, A_{\nu y} \) are the in-phase and quadrature (real and imaginary) components of the amplitude of the voltage (current), defined by the well-known Fourier expansion formulas

\[ A_{\nu x} = \frac{2}{n} \sum_{q=1}^{n} u_{q} \sin \omega q t_{q}; \]
\[ A_{\nu y} = \frac{2}{n} \sum_{q=1}^{n} u_{q} \cos \omega q t_{q}. \]

From these quantities (we will call them primary quantities) we can calculate other, secondary, physical quantities, for example:

the power factor (the cosine of the equivalent angle)

\[ \cos \phi = P/(UI); \]

the active and reactive power of the \( \nu \)-th harmonic

\[ P_{\nu} = (I_{\nu x} U_{\nu x} + I_{\nu y} U_{\nu y})/2; \]
\[ Q_{\nu} = (I_{\nu x} U_{\nu y} - I_{\nu y} U_{\nu x})/2; \]

the initial phase of the voltage (current) of the \( \nu \)-th harmonic

\[ \Psi_{\nu A} = \arctan(A_{\nu y}/A_{\nu x}); \]

the phase shift between the voltage and the current of the \( \nu \)-th harmonic

\[ \Psi_{\nu} = \Psi_{\nu U} - \Psi_{\nu I}; \]

the harmonic coefficient of the voltage (current) curve

\[ k_{h} = \sqrt{A^{2} - A_{0}^{2} - A_{1}^{2}/A_{1}}. \]