METHODS FOR RAISING THE SPEED
OF DIGITAL FREQUENCY-MEASURING DEVICES

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The problem of producing new means and methods for digital measurements of frequencies arises in view of the ever expanding adoption of frequency transducers in the practice of electrical measurements.

The designing of digital frequency-measuring equipment on the basis of the normal method (by counting the number of oscillations of the unknown frequency over a given time interval) does not always meet the requirements of speedy measurements.

A large group of frequency transducers known under a common name of electromechanical converters has output frequencies in the audio and even lower ranges [1]. The application of the above method in such a case requires a long measuring time. For instance, for measuring a frequency of 1000 Hz with an error of 0.1%, a time of 1 sec is required, and for a frequency of 50 Hz and the same error this time increases to 20 sec. This drawback is particularly pronounced in studying rapid processes [2] in scanning-test systems and in high-speed frequency telemetering systems.

The present tendency for raising the operating speed of digital frequency-measuring devices has led to the development of new low-frequency measuring methods which are described below.

Measurements with a preliminary frequency multiplication. In case of an ideal frequency multiplication, this method provides a reduction in the measuring time by a factor equal to that of frequency multiplication. However, this property of frequency multipliers cannot always be fully utilized.

The following are the basic requirements specified for frequency multipliers in order to solve the above problem: a large multiplication factor, a wide range of multiplied frequencies (a ratio of $f_{max}$: $f_{min}$ up to 10) and a sufficiently high operating speed (a constant multiplication factor for rapid variations of the input frequency).

It is known that there are several methods of frequency multiplication (for instance, multiplication with spectrum transformation, multiplication by means of phase-shifting circuits etc.). We discuss here only methods which meet to a great measure the requirements specified above.

Figure 1 shows the schematic of a multiplier which consists of a closed control system [3, 4]. The input-frequency signal is fed through amplifier limiter 1 and band filter 2, which picks out the first harmonic, to phase compensator 3. The multiplied-frequency signal is fed from the output of the control generator 5 through the discrete frequency divider 6, whose division factor is equal to the multiplication factor, to the blocking oscillator 7. The latter shapes short pulses which are fed to the phase compensator, where these pulses are amplitude-modulated by the sinusoidal input signal. The phase-compensator output-signal pulse amplitude which is proportional to the sine of the phase-difference angle between the input and feedback signals is stored in a capacitor, transmitted through dc amplifier 4 and used for controlling generator 5. The frequencies of the input and feedback signals are equal to each other in a steady state, the phase error is constant and the output frequency is maintained K times higher than the input frequency. According to the data in [3] the multiplication factor is K = 1000, which produces a considerable saving in the measuring time. However, the low operation speed due to the presence of an input band filter and to the narrow multiplication frequency range (+ 10% of its nominal value) reduces considerably the possible application range of a multiplier of this type for measuring low frequencies.

The frequency range can be extended and dynamic properties improved by using a phase compensator with a saw-tooth characteristic and by employing in addition to the error-integral control also an input-coordinate control, the so-called proportional-integral control.
Tracking measurements of frequency. A tracking frequency meter [5], or a frequency meter with a continuous digital reading (Fig. 2) consists of a closed control system with a reversible counter 1 used as a phase comparator.

The combination of a reference frequency oscillator 2, a binary divider 3, pulse-potential switch K1-Kn and an OR gate constitute the frequency generator controlled by the code of counter 1. The controlled generator frequency is a linear function of the number N recorded by counter 1:

\[ f_{in} = \frac{N}{N_m} f_o = kn, \]

where \( N \) is the current value of the number in counter 1; \( N_m \) is the capacity of counter 1; \( f_o \) is the frequency of oscillator 2.

In a stable state we find that \( f_{in} = f_{fb} = kN \), i.e. the number in counter 1 is proportional to the input frequency. In order to eliminate the "flickering" of the counter in a stable-state condition, a so-called discrete filter (not shown on the drawing) is connected to its input in order to eliminate the alternating input and feedback frequency pulses.

The advantage of this circuit consists of a continuous digital counting, however, its dynamic properties are determined by the parameters of the tracking system which behaves like the above-mentioned multiplier as a low-frequency filter with a time constant of

\[ T = \frac{N_m}{f_o}. \]

Frequency \( f_o \) is normally selected to equal to the maximum input frequency. The counter capacity \( N_m \) determines the discreteness error. Thus, for frequency measurements down to 1000 Hz with an error of 0.1% the system's time constant amounts to 1 sec. If one takes into consideration that for measurements by the normal method (counting in a time interval) with the same precision a duration of 1 sec per measurement is required, it becomes clear that although the above system provides a certain gain in the speed of operation, this gain is extremely small.

Time-interval measurements by means of functional coding devices with a reading proportional to frequency. A natural method for reducing the time spent on measuring frequency consists of measuring its period instead. However, the requirement of additional calculations for evaluating frequency precludes in the majority of cases the application of this method.