This article examines the principle behind the design and operation of a cyclic digital time-pulse goniometer which has a rotating optical modulator and provides for time scanning of the angle.

The development of high-precision devices for measuring and specifying the angles of rotation of platforms and the shafts of different types of equipment remains an important part of instrument manufacturing, especially to ensure the accuracy of the instruments and their sensitive elements. The increasingly exacting standards on instrument accuracy also tighten the requirements that must be met in regard to the accuracy of goniometers. The solution of the main problems encountered in gyrometry usually involves specifying fixed angular positions and performing static measurements of angles.

Digital goniometers (DGNs) designed for use in such instruments should provide for the following: measurement range \(0-360^\circ\); measurement error - no greater than \(0.5-1^\circ\); measurement time - no greater than \(1-1.5\) sec. The measurements are performed automatically, the measurements are analyzed in digital form, and the results of the analysis are displayed in the form of angular degrees, minutes, seconds, and tenths of a second, as well as in the form of an angle code that allows the results to be sent to an external computer. The current measurement results should not depend on the previous measurements, and the moment of resistance (load) from the DGN should have almost no effect on the measurement shaft. In addition, the DGN must be of relatively simple design and comparatively compact and lightweight.

An important aspect of the design of high-precision goniometers is efficient selection of the principle on which their design will be based. That principle should take the given requirements into account as much as possible. Photoelectric reading goniometers have come into wide use, as have cyclic goniometers that perform the sequential conversion angle-phase-time-code [2].

The principle of the cyclic time-pulse conversion of an angle into code, together with time scanning of the angle, has gained a certain amount of favor for goniometer design. New technical advances being made in this area can improve the accuracy of the angle measurement.

In the simplest variant of such conversion, the angle between the beginning of the readings and the current value of the angle being measured is converted into a time interval with the use of pair of pulse transducers and a modulator rotating at a constant velocity \(\omega\). One of the transducers is fixed in place (FT) and the other is mobile (MT), i.e., the second transducer is mounted on the shaft being checked. The time interval is converted to digital code by the well-known method of sequential counting. In each measurement cycle, cyclic angle-code converters generate a code that corresponds to the current value of the angle. The result of the conversion in each cycle depends on the conversion in the other cycles. The time interval \(t\) between successive pulses arriving from the FT and MT is the measure of the angle \(\alpha\) being measured. It is apparent from the expression \(\alpha = \omega t\) that the accuracy of the angle-time conversion is determined mainly by the instability of the rotational velocity of the modulator. Here, the main component of the error is due to the instability of the velocity of the modulator during its revolution, which in turn depends and the design features of the electric motor, the errors made during its manufacture, and a whole range of other factors. As a result, the simpler models of cyclic transducers are not very accurate and are thus rarely used [2].

An improvement to the cyclic angle-code conversion that makes the angle measurement more accurate was proposed in [3]. The improvement involves scanning of the angle being measured by a circular periodic measure and changing over to a dual-reading system of angle measurement. The essence of the proposed method of measurement is as follows: the modulator is made in the form of an \(n\)-period measure, such as an \(n\)-blaze grating; the pulses at the output of the transducer from one of
the periods (blazes) of the measure are marked in some way; the time intervals between the pulses arriving in succession from the FT and the MT are measured; a calculation is performed to determine the arithmetic mean of the $n$ measured time intervals ($n$ is the number of periods of the measure) — this will be the exact reading (ER) of the angle being measured; at the same time, a count is made of the number of pulses arriving from one of the transducers during the time interval between two successive marked pulses — thus providing a group reading (GR) of the angle. Thus, the data that is obtained (the ER and the GR) can be used to determine the angle of rotation of the shaft being checked. Here, the measurement equation has the form

$$\alpha = \alpha_0 m + \omega \bar{t}_i,$$

where $\alpha_0$ of the angular step of the periodic measure; $\alpha_0 = 360/n$, where $n$ is the number of periods of the measure; $m$ is the number of angles $\alpha_0$ within the angle $\alpha$ that is being measured — the number of units of the GR of the angle; $\bar{t}_i$ is the arithmetic mean of the $n$ successive time intervals $t_i$ between pulses arriving alternately from the FT and the MT — the number of units of the ER of the angle; $\omega$ is the conversion factor, or the nominal value of the angular velocity of the modulator.

Figure 1 shows a block diagram of the instrument, while Fig. 2 presents diagrams of the DGN pulses that realize the proposed method of angle measurement.

The instrument has a housing 5 which houses a modulator 4, synchronous motor 7, and two pulse transducers — FT 8 and MT 1. Stationary transducer 8 is located on the housing. The mobile transducer, moved by means of carrier 2, is mounted on the shaft being measured. Modulator 4 is installed on the shaft of motor 7 coaxially with the measurement shaft. The modulator is in the form of a grating which has a constant angular step $\alpha_0$ and is located on a load-bearing surface, such the surface of a drum.

Different methods can be used to mark the pulses from one of the periods of the measure. In the given instrument, all of the blazes 6 of the measure are identical except for blaze 3. That blaze is wider than the other blazes. Both of the pulse transducers are coupled to the blaze field of the grating.

The outputs of transducers 1 and 8 are connected to the input of amplitude discriminator 10. The first input of the discriminator is connected to the first input of computer 13 through series-connected time-interval meter 11 and averaging block 12, while the second input of the discriminator is connected through block 15 to the second input of computer 13. The output of computer 13 is connected to recorder 3.

Amplitude discriminator 10 is designed to discriminate the marked pulses from the rest of the pulses in the flow arriving from the two transducers. The second output of the discriminator, which receives the pulses, is connected to the second input of block 15. The first output of the discriminator is also connected to the first input of block 15.

As an example, we will examine electrooptic pulse transducers, such as a transducer in the form of an optical pair. In this case, the blazes of the grating should be light-contrasting elements. The transducers may be designed for operation in transmitted or reflected light and may be provided with additional optical elements (lenses, diaphragms, etc.).

The synchronous motor 7 is connected to frequency-stabilized power unit 9. Blocks 11–14 are shown in Fig. 1 only to explain the operation of the instrument. In reality, the problems that they solve are solved by a single digital computer.