LINEAR AND ANGULAR MEASUREMENTS

DESIGN OF INDUCTOSYN MICROTRANSDUCERS

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The designs of a speed-control system and its control circuit are analyzed, and aspects of improving the measurement accuracy of noncontact sensors (microtransducers) that convert displacement into coded signals are examined. Current trends in the development of new generations of transducers and inductosyn microtransducers are discussed along with features of their design and fabrication.

The measurement of angular and linear quantities—angles of rotation, number of rotations, angular and linear velocities, etc.—occupies an important place among mechanical measurements. Designing and improving the parameters of instruments that make such measurements is a significant problem, since existing (conventional) transducers do not satisfy current requirements with respect to some of their parameters.

One of the shortcomings of existing transducers is that the guide is too wide or too great in diameter, which is due to the need to accommodate the front parts of the windings. The active conductors are also too large along the disk or across the width of the guide, which must be long enough to obtain a certain coefficient of electromagnetic induction. Among the other problems with existing transducers is that they are not accurate enough, their design and the technology used to make them are too complex, they consume a large amount of electric power, and they are too expensive [1-3].

We have developed a new integrated microelectronic semiconductor transducer—an inductosyn microtransducer. These instruments do not yet have a generally accepted name [4] and are named on the basis of the following:

- use (multipole angle transducer, impulse displacement transducer, displacement-code transducer);
- functional conversion scheme (accumulating transducers, cyclic transducers, angle-scale transducers);
- principle of operation (inductosyn, reductosyn, moiré transducer), etc.

One principle common to all of the instruments being discussed is that regardless of the sensitivity distribution over the conversion range of the sensitive element (SE) or the measurement (quantizing) scale, the informative signal is received from all of the SEs simultaneously. Discrimination with respect to level takes place only for SEs which are in the same location in space relative to the equivalent moving elements of the transducer.

This principle eliminates from our discussion transducers in which the number of pulses varies during one revolution of the shaft or displacement cycle, as well as transducers with the number of sensitive elements \( p = 1 \). The duration of a pulse signal (a signal representing one binary code for the angle of rotation of the shaft) will be equal to

\[
\theta = \frac{2\pi}{Qp}
\]

where \( Q \) is the duty cycle of the pulses in radians.

The discreteness of the output signal with respect to time can be determined from the expression

\[
\tau = \frac{\theta}{\Omega} = \frac{2\pi}{Qp\Omega},
\]

where \( \Omega \) is the angular velocity in radians per second. If \( \Omega = \Omega_{\text{min}} \) within the given speed control range, then \( \tau_{\text{max}} \) determines one bit of velocity, while \( \tau_{\text{min}} \) at \( \Omega = \Omega_{\text{max}} \) determines one bit of the period of velocity.
In the cyclic conversion of velocity, the counter gives readings only after a certain time interval. This interval is determined by Eq. (1).

The frequency of the output signals of integral displacement transducers (IDTs) is equal to

\[ f_n = \frac{p n}{60}, \]

where \( n \) is the velocity in revolutions per minute.

A high degree of accuracy in maintaining the specified velocity is usually necessary within the range corresponding to 15–20\% of its maximum value \( n_{max} \). In this case, it is best if the entire velocity control circuit is built in the form of "coarse" and "fine" control systems.

The "coarse" system includes the following: a generator producing pulses of standard frequency, a switch, rotation control block, counter, readout device, directional frequency multiplier, and a code-voltage converter. The components of the "fine" system are: a demodulator, channel switch, and control-voltage generator. Both systems have a shaper that forms the front of the pulses and an adder.

The mechanical part includes: an actuator, electric motor, thyristor converters for the forward and reverse motion channels, and a control-voltage generator.

The maximum dynamic error in a coarse reading at \( f_n > f_s \) is determined from the formula [5]:

\[ \Delta \Omega_{max} = (f_n \pm f_{s_{max}}) N \Delta \Omega_{max} \pm \frac{1}{N}, \]

where \( f_n \), \( f_s \), and \( \Delta \Omega_{max} \) are the frequency, the nominal frequency, and the deviation from the nominal frequency of the standard-frequency pulse generator; \( N \) is the code of velocity in the coarse-reading system; \( \Delta \Omega_{max} \) is the maximum error of the displacement.

One of the components of \( \Delta \Omega_{max} \) is the error in the manufacture of the scales, which is determined by the allowable scatter in the locations of the sensitive elements for a normal distribution

\[ \Delta \Omega_1 = \frac{\delta}{\sqrt{p}}. \]

Another component of \( \Delta \Omega_{max} \) is the quantization error for the level \( \Delta \Omega_2 \), this error being due to fluctuations in the signal voltage \( E_s \) of the IDT (scatter of the thresholds for activation of the formulating elements, differences in the voltage gains, differences in the characteristics of individual SEs, etc.). Let us determine this error. In the case of amplitude modulation of a voltage with the carrier frequency \( \omega_c \), the output signal of a SE in an IDT is determined from the formula

\[ E_s = A_m \sin \alpha \sin(\omega_c t + \omega), \]

where \( A_m \) is the amplitude of the modulated signal; \( \psi \) is the phase shift of the moment at which the signal and the modulating voltage of the reference frequency \( \omega_c \) pass through zero.

After demodulation, the output signal of the IDT is calculated from the expression

\[ E_{sd} = A_m \sin(\omega \alpha \pm \psi). \]

Assuming the maximum error for the level of the signal voltage \( \Delta E_s \), we find \( \Delta \Omega_2 \) from (2):

\[ \Delta \Omega_2 = \frac{\arcsin(\Delta E_s / A_m) \pm \psi}{p}. \]