SYSTEMS WITH RASTER CONVERTERS FOR MEASURING DISPLACEMENTS

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Instruments whose conversion function, i.e., relationship of the measured physical quantity (luminous flux, inductance, capacitance, etc.) to the displacement of the instrument's moving part, is a periodic function are known as raster converters.

Systems with raster converters for measuring displacements are widely used in program-controlled machines as feedbacks and as independent measuring devices for evaluating lengths and displacements. The error in setting moving parts of machines by means of raster conversion systems does not exceed 2.5 μ for optimum conditions and a sensitivity of the order of 0.25 μ.

The moving part of the raster converter at the instant of reading can be stationary (static measuring system) or moving (dynamic measuring system).

Measuring systems can be classified according to the type of their converters into raster and code systems. Raster converters comprise optical, inductive, capacitive and resistive converters. Since code converters are seldom used, and resistive converters have a low precision, they will not be described in this article.

The converter variable quantities consist of luminous flux, inductance, capacitance and resistance. Displacements in raster converters are evaluated both from the number of periods and from the value of the electrical quantity within a conversion function period.

Below, we examine systems for measuring displacement by means of raster converters.

The simplest optical system for measuring displacement is shown in Fig. 1. The beam of light is transmitted from a miniature incandescent lamp 1 through condenser lens 2 and optical wedge 3 to plate 4, which separates it into two parts. One part of the luminous flux passes through the plate and optical rasters 5 and 6 onto measuring photocell 7. The other part of the flux is reflected from plate 4 and transmitted through optical wedge 8 onto compensation photocell 9. Wedge 3 is used for changing the system's sensitivity, and wedge 8 for setting the system to zero for overlapping rasters which are displaced with respect to each other by force P applied to sample 10. The rasters which are made photographically by the method described in [1] have a size of 15 x 15 mm, a pitch of 0.2 mm and serve to measure displacements in the range of 10 mm with a sensitivity of 0.1 μ.

The intermediate values of the electrical quantity within the conversion function period are determined in this system by means of an unbalanced bridge circuit which serves to compare two voltages (currents) by their amplitudes (displacement proportional to the amplitude).

Figure 2 shows a converter [2] with a reflecting grating. It has "rough" gratings with some 100 lines per 25 mm. The long grating 3 is made of a polished metal strip with engraved lines, whereas indicator raster 6 is engraved on a transparent base. The graduations of indicator raster 6 are divided into four groups which are staggered with respect to each other by one-quarter of a grating space. The light beam from lamp 1 is transmitted through condenser 2 onto the metal grating and is reflected from it through raster 6 onto four photocells 4 placed in a row. Cylindrical lens 5 serves to focus the rays onto the photocells. Since illuminance determines the values of photocell currents, their maxima are staggered with respect to each other by a quarter spacing, which is used for operating the reading system with respect to the raster displacement with an error of 5 μ.

In addition to the raster systems described above there are also systems with an indicator raster and a light modulator [3]. A general view of such a system is shown in Fig. 3. Glass ring 3 is connected to the axle whose
angular displacement it is required to measure. For measuring linear displacements, ring 3 is replaced by a transparent rule with opaque lines. At a certain distance from ring 3 a second ring 5 with a smaller diameter is located. Graduations with the same pitch are engraved on the circumferences of both rings, and those on ring 5 are divided along their height into two groups which are staggered with respect to each other by a half spacing.

In the course of the system's operation, the light from lamp 2 is transmitted through prism 4, both raster gratings, prism 7 and the slots of modulator 6 onto photomultiplier 1. Since the modulator drum rotates continuously, photomultiplier 1 is illuminated by a flux which passes through grating 3 and the lower half of grating 5. When the luminous fluxes of the upper and lower parts of the gratings are equal, the photomultiplier voltage is constant and corresponds to a balanced position of the gratings. When grating 3 is displaced with respect to grating 5, the photomultiplier produces a signal whose phase and amplitude indicate respectively the direction and magnitude of the unbalance. The reference voltage for determining the phase of the shift is obtained from electromagnetic converter 9, whose rotor is driven by motor 10. The signal produced by unit 11 is fed after detection and amplification to actuating motor 12, which rotates grating 5 through a reduction gear and worm gear 8 until balance is restored. For the diameter of gratings 3 and 5 of 220 and 441 mm respectively and a line spacing of 0.45 mm, the sensitivity to unbalance amounts approximately to 0.5 μ.

Figure 4 shows an inductive raster converter which is widely used, owing to its precision and reliability. In this converter both coils 2 and 5 together with their casings 1 and 4 are fitted over screw 6 and separated by non-magnetic packing 3 with an air gap between the screw and the casing. The raster converter coils, whose impedances are $Z_1$ and $Z_2$, are usually connected in a bridge circuit. Since the sensitivity of the converter is at a maximum near the zero values of the conversion function, it is advisable to use circuits described in [4] with the zero points displaced by means of resistances. This arrangement is suitable for evaluating dimensions which fall between the graduations by means of resistance boxes. The error of an inductive raster system amounts to 2-5 μ for an inductive-converter screw with a diameter of 40 mm and a thread pitch of 4 mm.

Similar precision is obtained in using inductive-converter raster systems with a flat pattern [5] which is plotted over a glass or another transparent insulating material.

Figure 5 shows components of such a raster converter, which is known by the name of "inductosyn." When the system is used for linear measurements the converter stator is made in the form of a rule with a single pattern