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METHOD OF PROCESSING ACCURACY ENHANCEMENT OF PHOTOELECTRIC POSITION TRANSDUCER SIGNALS

A method and the system for accuracy enhancement and motion direction discrimination of the photoelectric position transducer have been presented in the paper. In the system sinusoidal phase voltages, with the assumed phase shift equal to 36° have been generated. The voltages enable a frequency increment of 2.5 times in relation to basic signals from the transducer measurement bar. These two signals of increased frequency are rectangular, shifted mutually by 1/4 of a period, with the pulse-duty factor equal to 0.5. On the base of these signals it is possible to further increase the accuracy twofold, in the system of pulse counting and pulse sequence discrimination, with the use of the trigger method of its motion direction identification. Presented methods and systems make it possible to increase the transducer processing accuracy five times.

Keywords: motion direction discrimination, enhancement of photoelectric transducer accuracy

1. INTRODUCTION

In position measurements, considerable weight is attached to the measurement accuracy. Code or increment photoelectric position transducers are used more and more often. Transducers of the latter type generate two signals at the output, which are shifted with respect to each other by 1/4 of the measurement bar period. Diminishing the quantization interval of the object shift could be achieved through a more precise design of the transducer (its measurement bar) or by means of appropriate processing of the signals from the photoelectric transducer, the latter being technologically simpler. The paper presents both the method and the electronic system for the transducer signal interpolation (signal frequency multiplication) and digitalisation (converting to digital form), which together with the system for the transducer (connected with the object) motion direction discrimination could be used in order to increase its accuracy.

2. METHOD AND SYSTEM FOR THE MULTIPLICATION OF THE PHOTOELECTRIC POSITION TRANSDUCER MEASUREMENT SIGNAL FREQUENCY

Photoelectric transducer output signals are composed of two sinusoidal signals, phase shifted with respect to each other by 1/4 of the period [2], [4]. The signal period is equal to the period of the transducer scale grid (measurement bar). The scanning signals from transducers are first amplified and then interpolated. The interpolation method proposed by the author relies on a network of resistors. It generates phase-shifted signals from two sinusoidal scanning signals by means of their vector summation in accordance with the description below. Voltage signals from the sensor

$$x = A\sin\varphi; \quad y = A\cos\varphi \tag{1}$$

are fed to a resistance divider generating in it a voltage equal to

$$U_d = A(\sin\varphi\, R_1 + \cos\varphi\, R_2), \tag{2}$$

where: $\varphi = 2\pi y/T$, in addition A - signal amplitude, y - displacement, T- signal period.
In the relationship above the resistances R_1, R_2 are defined as:

$$R_1 = \frac{R}{|\sin\alpha|} \quad \text{and} \quad R_2 = \frac{R}{|\cos\alpha|}, \tag{3}$$

where: α - angle of the assumed phase shift; R - adopted signal reference resistance.
Having taken into account the dependences above, and after transformation, we obtain

$$U_d = A_1 \sin(\varphi + \alpha), \tag{4}$$

where: A_1 - the amplitude of a signal generated with the assumed phase shift α.

For the sake of description clarity of the method, it is assumed that the transducer output functions (sin, cos) are of constant frequencies (periods). The case represents the transducer collaboration with the object moving with constant velocity (Fig.1, Fig.2).

In the first stage of the method, signals are amplified and reversed, producing four signals: sin, cos, -sin, -cos, afterwards two of them get interpolated. It is essential for the signals selected for interpolation to always have opposite signs in the period quarter that is of interest to us. For quarter I (0° - 90°) sin and -cos signals are used, for quarter II (90° - 180°) they are sin and cos, for quarter III (180° - 270°) the signals are -sin and cos, whereas for quarter IV (270° - 360°), they are -sin and -cos. The signals are fed to resistance dividers, the values of which are selected in such a way that sinusoidal waveforms are generated at their outputs. The waveforms are shifted with respect to each other by an assumed angle (in accordance with dependences 2, 3, 4), which in the method presented amounts to 36°. For such an assumed phase shift, for angles 0°, 180°, interpolation does not occur and the signals sin, -sin are selected for further processing. The generated signals are fed to one of ten comparators which change their shapes making them rectangular signals. In addition, a change of state takes place at the site of the input signal passing zero. In this way ten rectangular signals shifted with respect to each other by 1/10 of a period (36°) are generated. The signals are divided into two groups in such a manner that in each group each successive signal is shifted by 1/5 of a period with respect to the previous one. Two groups of signals are formed, each containing five signals shifted by 1/5 of a period within the group and by 1/10 of a period with respect to the other group (Fig.1, Fig.2).

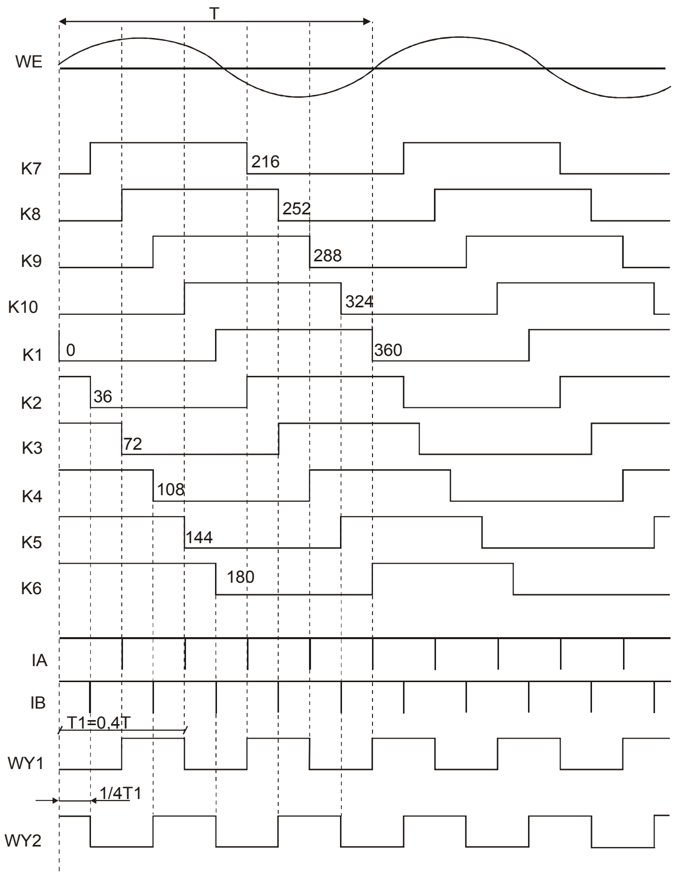

Fig. 1. Method for 2.5 times enhancement of transducer signal frequency.

The next stage consists in such differentiation of waveforms so that each run would yield only one pulse in the period, i.e. one group will produce five pulses dividing one period of the input reference signal into five equal parts, on the assumption that the frequency of input signals is constant. Pulses from two groups are summed to form two pulse waveforms of the frequency that is five times higher than that of the input signal (Fig.1, Fig.2). They operate as clock signals for JK triggers arranged in such as manner that each pulse of the input clock signal causes a change of state to the opposite one at the trigger output. As a result, two symmetrical rectangular waveforms are created of the input frequency that is 2.5 times higher, i.e. there is one input sinusoidal signal period to 2.5 periods of output rectangular signal. The signals are shifted with respect to each other by 1/4 period and the displacement direction depends on the direction of the input signal shift, which is dependent on the transducer motion direction (Fig.1.)

Although a considerable number of digital circuits is found in the module and some operations are performed with digital signals, the most vital principle of the system operation is the fact that the system can collaborate with analogue input signals and interpolate them with an analogue method. The role of the digital part of the system is restricted to preparation of the signal for collaboration with subsequent modules [1], [2], [3], [4].

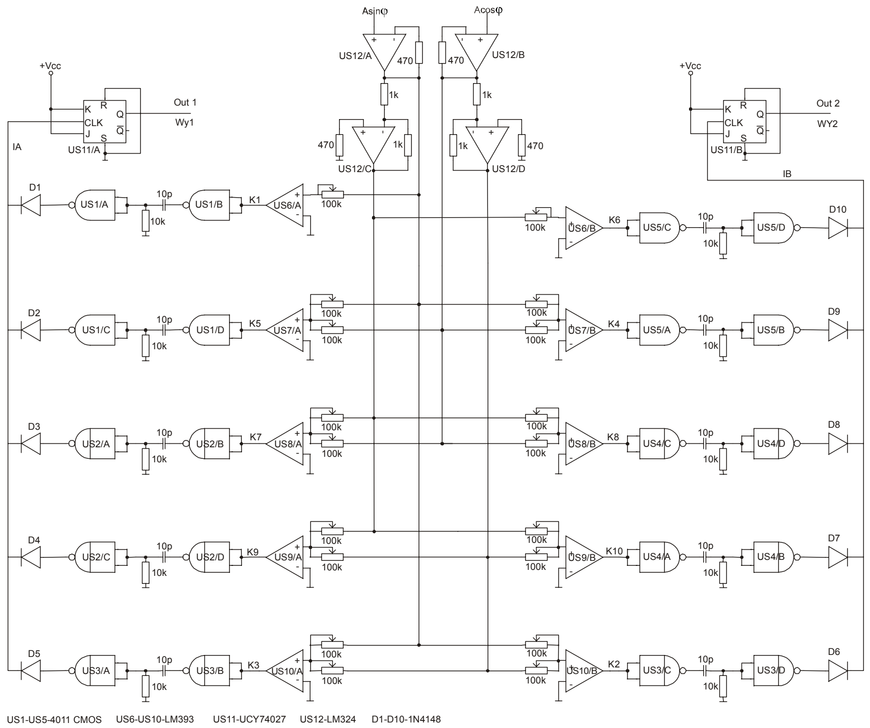

Fig. 2. System for 2.5 times enhancement of transducer signals frequency.

Input circuits (Fig.2) account for the collaboration with sinusoidal symmetrical signals. They are composed of 4 operational amplifiers contained in one package of the system LM324. Two of those operate as followers so that the system would not load the measurement transducer. Two others reverse the signal by180°.

Appropriate two signals are led to resistors interpolating these functions forming a third signal of an assumed phase shift. For the angles: 0°, 180°, interpolation does not occur and the signals: sin, -sin, respectively, undergo further processing.

The computed values of resistors are precisely set with trimmer potentiometers. That results in 10 sinusoidal functions shifted by 36° (1/10 period) with respect to each other. They enter inputs of comparators, which are LM393 circuits. Rectangular signals from comparator outputs are fed to the inputs of differentiating circuits made of NAND gates, capacitors and resistors. As there occur signals of values up to 15V, 4011 CMOS circuits, each containing 4 NAND gates, are applied.

Signals from the outputs of the differentiating systems are properly summed by 1N4148 diodes yielding two clock signals for JK (4027) triggers. At trigger outputs, signals are formed that are characterised by 1/4 period phase shift with respect to each other.

The module was made on double-side printed circuit board, where semiconductor components were mounted in sockets.

3. METHOD AND SYSTEM OF PHOTOELECTRIC TRANSDUCER MOTION DIRECTION DISCRIMINATION BASED ON LOGICAL FUNCTIONS OF THE TRANSDUCER SIGNALS AND MOTION PULSES GENERATED IN THE TRIGGER CIRCUITS

Signals with the 1/4 period phase shift with respect to each other make it possible to specify the direction of the photoelectric transducer motion.

Figure 3 presents the diagram of the system of direction discrimination and the way of output pulse forming in + IA and – IG channels. There are NAND gates with Schmitt triggers at the system input. Their task is to form steep slopes of input signals and to narrow the switching zone from 1 to 0 and inversely. It is important in case of possible object vibrations or change in the motion direction. The pulse counted in the given direction must be counted again, in the opposite motion direction.

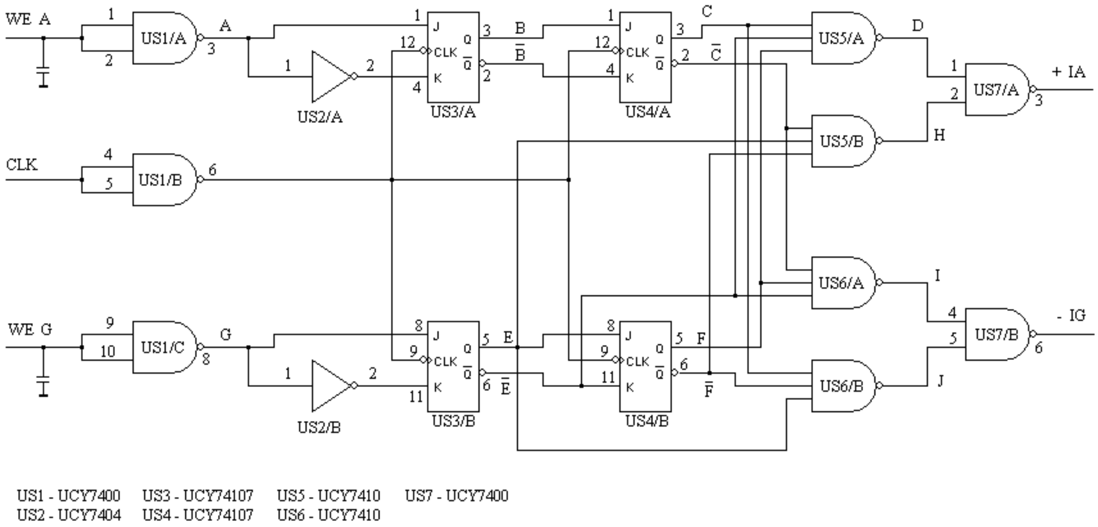

Fig.3. System of photoelectric transducer motion direction discrimination based on logical functions of the transducer signals and motion pulses generated in the trigger circuits.

The Schmitt gate formed output pulses at A and G points (Fig.3) have the polarity of rotary-pulse transducer output pulses because of the negations performed by the photoinsulator (optoelectronic coupler).

The system of JK triggers and logical gates perform basic functions of the movement direction discrimination. The JK triggers are synchronised with the CLK clock pulses. The combinational circuit performs the following function:

$$+\mathrm{IA} = (\mathrm{C}\,\overline{\mathrm{E}}\,\mathrm{F})\ \mathrm{v}\ (\overline{\mathrm{C}}\,\mathrm{E}\,\mathrm{F}) \tag{5}$$

$$-\mathrm{IG} = (\overline{\mathrm{C}}\,\overline{\mathrm{E}}\,\mathrm{F})\ \mathrm{v}\ (\mathrm{C}\,\mathrm{E}\,\overline{\mathrm{F}}) \tag{6}$$

The rule of output pulse forming is presented in Fig.4. Pulses for the positive direction are obtained at A = „1" and the falling slope of the G signal and at A = „0" and the rising slope of the G signal. Pulses for the direction conventionally assumed to be negative are obtained at A = „1" and the rising slope of the G signal and at A = „0" and the falling slope of the G signal.

The system allows us to form two output pulses in the given direction during one period of the input signal. The pulses are then counted in the pulse counters. The reverse counter state is the object position measure.

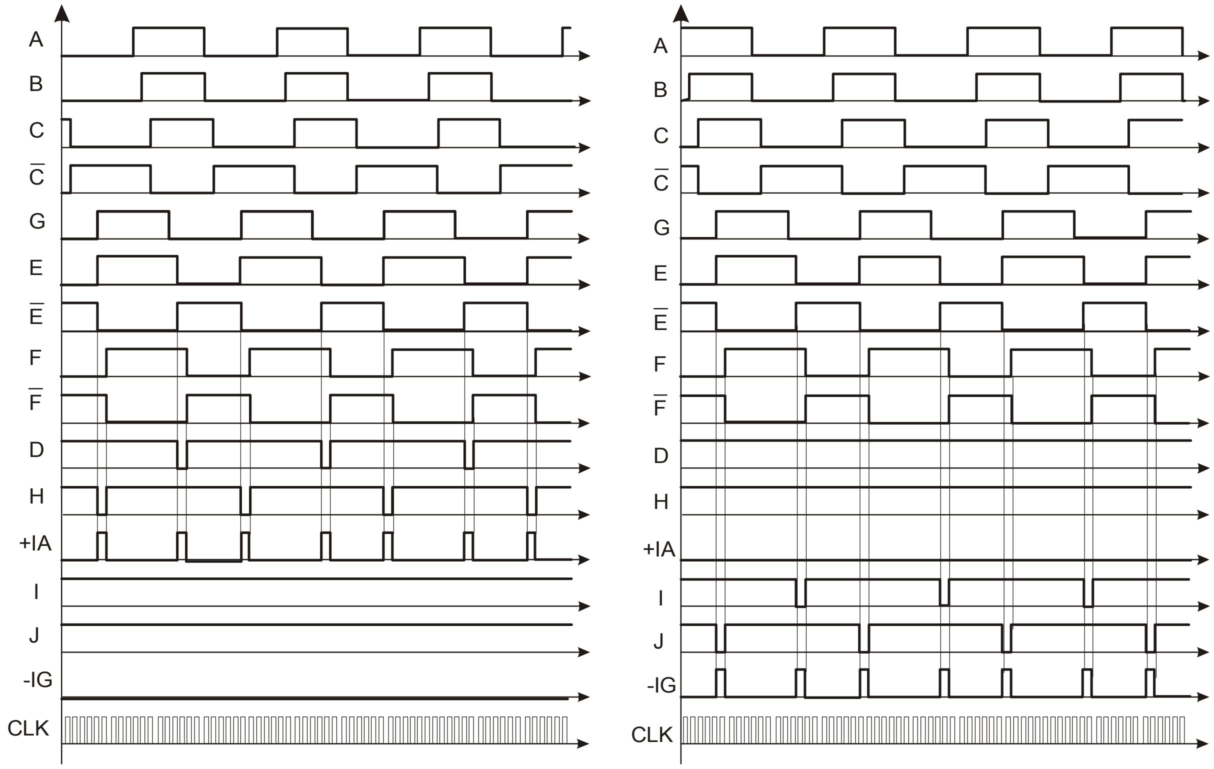

Fig.4. Method of photoelectric transducer motion direction discrimination based on logical functions of the transducer signals and motion pulses generated in the trigger circuits for movement to the right and to the left.

4. CONCLUSIONS

The following conclusions can be drawn on the basis of the analysis of the system put forward by the author:

1. Two ways can be chosen to diminish the quantization interval of the displacement of the drive that collaborates with the photoelectric transducer. The aim can be achieved by means of either more precise design of the transducer (its measurement bar) or by appropriate transducer signal processing. The latter option is technologically simpler.
2. The electronic method of interpolation (multiplication of signals frequency) and digitalisation (conversion to digital from) presented in the paper makes it possible to enhance the accuracy of the photoelectric transducer. The method of 2.5-times frequency increase is universal and can be applied to another scale of transducer signal frequency multiplication.
3. With the method of pulse counting and their sequence discrimination, thus transducer motion direction, it is possible to enhance the transducer accuracy twice.
4. The interpolation and digitalisation method together with the pulse counting method provide the means of fivefold enhancement of the transducer processing accuracy.

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METODA ZWIĘKSZANIA DOKŁADNOŚCI PRZETWARZANIA SYGNAŁÓW OPTOELEKTRONICZNEGO PRZETWORNIKA POŁOŻENIA

Streszczenie

W artykule przedstawiono metodę i układ zwiększenia dokładności oraz wyróżnienia kierunku ruchu optoelektronicznego przetwornika położenia. W układzie tym wytworzono sinusoidalnie zmienne napięcia fazowe o założonym przesunięciu 36°, które umożliwiają 2.5-krotne zwiększenie częstotliwości w stosunku do sygnałów podstawowych wynikających z liniału pomiarowego przetwornika. Sygnały o zwiększonej częstotliwości, to dwa sygnały o przebiegu prostokątnym, wzajemnie przesunięte o 1/4 okresu i współczynniku wypełnienia 0.5. Na bazie tych sygnałów, możliwe jest dalsze, dwukrotne zwiększenie jego dokładności w układzie zliczania i rozróżniania kolejności impulsów, z wykorzystaniem przerzutnikowej metody identyfikacji kierunku jego ruchu. Przedstawione metody i układy umożliwiają pięciokrotne zwiększenie dokładności przetwarzania przetwornika.