Computerized Study of the Linear Optical Incremental Encoder

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Abstract: - The paper presents an algorithm that ensures the computerized measurement of some motion parameters (position, displacement, average velocity) using the signals from a linear optical incremental encoder. The working mode of the sensor is with zero initial position or with pre-established target position. This algorithm is adequate for studying the working modes of the sensor with an intelligent system composed by an IBM-PC compatible computer, an interface with a microcontroller from the 80C51 family and a signal conditioning subsystem. Such measurement system is very useful in higher education and research activities.

Key-Words: - computerized measurement, linear optical incremental encoder, working mode, displacement, position, velocity.

1 Introduction

It is well known that the measurement of the motion parameters (displacement, position, velocity, acceleration etc.) is very important for many control systems (e.g., robotic systems); the motion sensors are based on various physical effects [2,3,4,5,11]. A one-to-one relationship may not always exist between a measuring device and a measured variable. Furthermore, many motion parameters can be obtained using the same measuring device and an appropriate data processing technique. By way of example, it is well known that a linear or rotary optical incremental encoder can serve for measuring the displacement and average velocity of its mobile element and for the discrimination of the motion sense.

This paper proposes an algorithm for computerized measurement of some motion parameters using a linear optical incremental encoder. This algorithm is adequate for studying the sensor with an intelligent system composed by an IBM-PC compatible computer, an interface with a microcontroller from the 80C51 family [1,8,10] and a signal conditioning subsystem. Such intelligent system (fundamental in facts presented in [6]) is very useful in higher education and research activities. This measurement system is extremely versatile; it can be easily adapted for studying other motion sensors [6,9]. The IBM-PC compatible computer assures a simple dialog with the user and the data processing and interpretation; it also displays the measured variables and computes some sensor characteristics. The intelligent interface [7] achieves the sensor data acquisition and processing. Hardware resources of the interface enable the generation of some digital and analog commands and the acquisition of many digital or analog signals, necessary for computing some motion parameters or sensors characteristics. This interface is endowed with adequate software resources for connecting and studying different displacement sensors. Between interface and computer there is a soft interaction.

2 Measurement Principle for Motion Parameters

The optical incremental encoders are used for the precise measurement of the displacement. The linear encoder contains an incremental scale (the fixed element) and a slider that moves relative to the scale. There are three possibilities for sensor construction [11]. One among these supposes a glass scale with two parallel paths (P_A and P_B in Fig.1a) that contain opaque and clear equispaced zones with ΔL their width. Between the two paths there is a spatial shift of $\frac{\Delta L}{2}$. The slider contains two pairs light emitting diode – phototransistor, for reading the two paths of the scale. The signals from the phototransistors FT_A and FT_B are amplified and conditioned to give the pulses A and B, TTL compatible [2,4,11]. The phase shift between A and B denotes the sense of the slider motion.

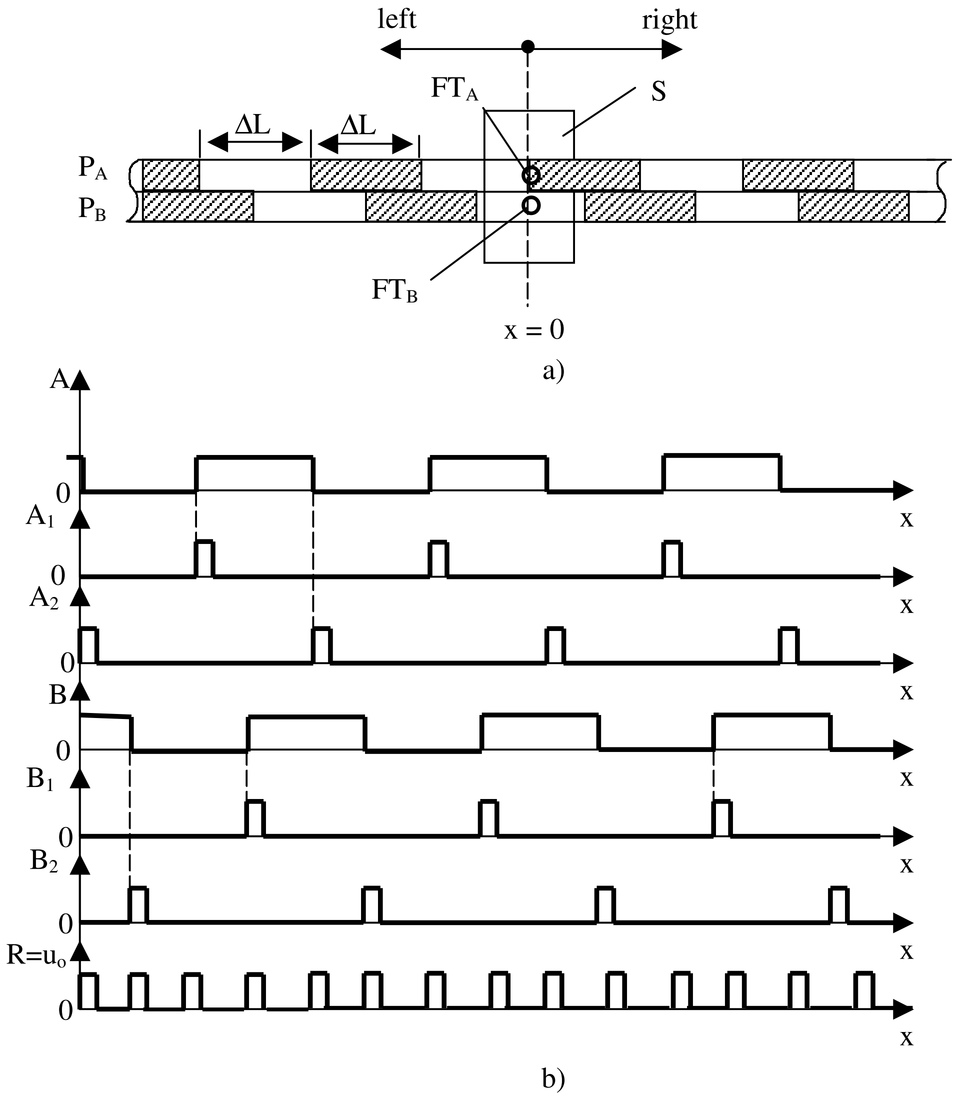

Fig.1a,b: The linear optical incremental encoder and the signal diagram

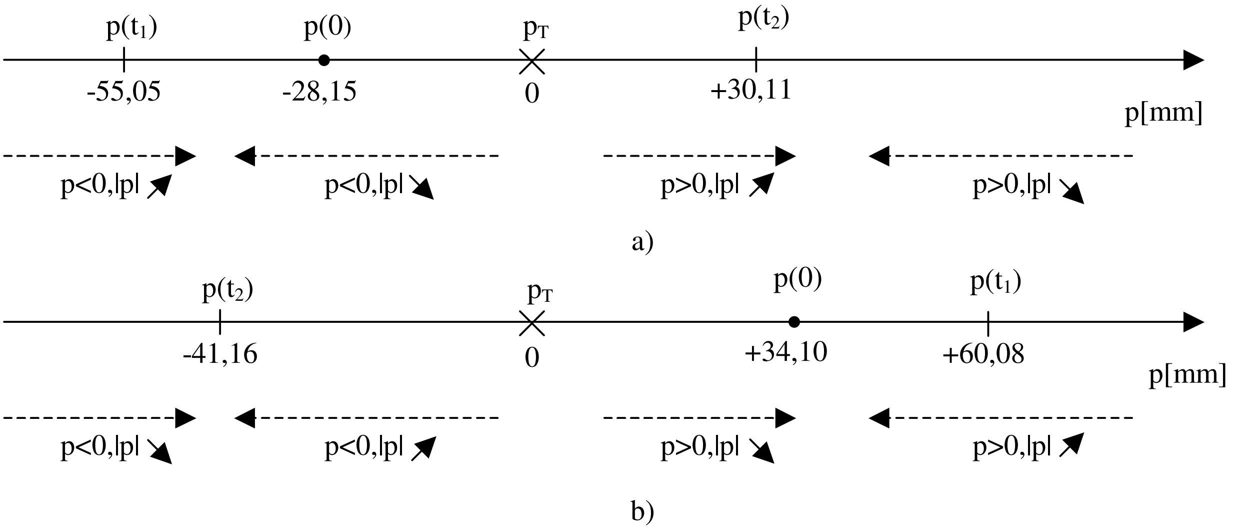

Fig.2a,b: Working mode with pre-established target position

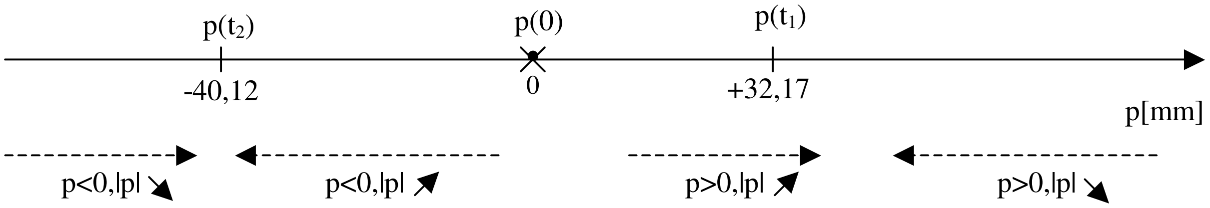

Fig.3: Working mode with zero initial position

The signal diagram from the Fig.1b corresponds to the slider motion to right (Fig.1a).

The displacement of the slider relative to the scale can be measured with different resolution. The simplest method is the countering of the pulses A or B during the displacement. The resulted number is multiplied with $2 \cdot \Delta L$ for obtain the displacement. The resolution of the measurement is $2 \cdot \Delta L$ and it is often too much.

The usual method for the displacement measurement improves electronically the resolution. The positive and negative fronts of the pulses A and B are detected and the signals A_1, A_2 and B_1, B_2, respectively are obtained (Fig.1b). The spatial period of the signal

$$u_o = A_1 + A_2 + B_1 + B_2 \tag{1}$$

is $\frac{\Delta L}{2}$. So, the number of the pulses u_o is multiplied with $\frac{\Delta L}{2}$ for obtain the displacement of the slider. In this way, the resolution of the measurement is four time improved. This second method is used for the displacement measurement in this paper.

Both methods presented above ensure only the displacement measurement, during the motion, without identifying the motion sense. But there are many situations when the motion sense must be known. If in relation (1) the addition of each signal A_1 or A_2 is conditioned by the level of B and the addition of each signal B_1 or B_2 is conditioned by the level of A, the motion sense can also be detected. If there are two outputs,

$$R = A_1 \cdot B + B_1 \cdot \overline{A} + A_2 \cdot \overline{B} + B_2 \cdot A \tag{2}$$

and

$$L = A_1 \cdot \overline{B} + B_1 \cdot A + A_2 \cdot B + B_2 \cdot \overline{A}, \tag{3}$$

all the pulses A_1, A_2, B_1, B_2 appear

- at the output R and $L = 0$, when the slider moves to right (figure 1b),
- at the output L and $R = 0$ if the slider motion is to left.

When the slider does not move, $R = L = 0$.

The signals L^* and R^* memorize the motion sense between two successive pulses u_o; $L^* = 1$ memorizes the sense to left, and $R^* = 1$ memorizes the sense to right.

This method for the discrimination of the motion sense is used in the algorithm presented below.

The linear optical incremental encoder can work in two modes: with pre-established target position and with zero initial position.

The first working mode enables the reaching of an imposed target (or stop) position, $p_T = 0$; this origin of the position axis imposes the sign of other positions, including $p(0)$ (Fig.2a,b). At the moment $t = 0$, the content of the CP counter represents the absolute value of the target position and $p(0) = -p_T$.

In the second working mode, the initial position $p(0) = 0$ is the origin of the position axis and $Z = 0$ at the moment $t = 0$. All the positions $p(t)$ situated on the positive semi-axis have the sign plus, and those situated on the negative semi-axis have the sign minus (Fig.3).

Both working modes ensure the measurement of the position and average velocity of the slider relative to the scale.

The pulses obtained at the output R or L must be counted up or down by the counter CP for position. The countering sense depends on the sign of the last measured position and the state of the counter CP. $Z = 1$ at the counter reset. The sign of the displayed position is plus when $P = 1$ and $M = 0$, or minus when $P = 0$ and $M = 1$.

After an analyze of all possible motion situations, the pulses that must be counted up form the signal

$$U = R \cdot (P + Z) + L \cdot (M + Z) \tag{4}$$

and those that must be counted down form the signal

$$D = \overline{Z} \cdot (R \cdot M + L \cdot P). \tag{5}$$

The content of the CP counter is multiplied with $\frac{\Delta L}{2}$ for obtain the absolute value of the measured position relative to the origin.

The sign of the computed position depends on the sign of the previous (the last displayed) position, the motion sense and the state of the counter CP. The signals associated with the position signs are M ($\mathrm{M}=1$ for the sign *minus*) and P ($\mathrm{P}=1$ for the sign *plus*):

$$\mathrm{M}=\mathrm{M_P}\cdot\left(\mathrm{R}^*\cdot\overline{\mathrm{Z}}+\mathrm{L}^*\right)+\mathrm{Z}\cdot\mathrm{L}^*, \tag{6}$$

$$\mathrm{P}=\mathrm{P_P}\cdot\left(\mathrm{L}^*\cdot\overline{\mathrm{Z}}+\mathrm{R}^*\right)+\mathrm{Z}\cdot\mathrm{R}^*. \tag{7}$$

If the last displayed position is positive, $\mathrm{P_P}=1$, and if it is negative, $\mathrm{M_P}=1$.

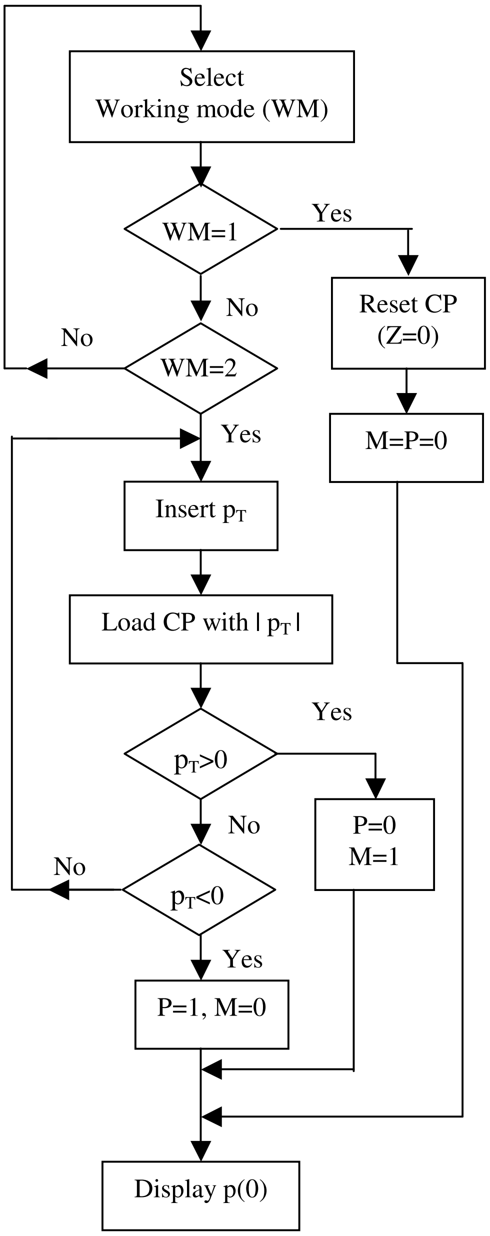

Fig.4: Flow chart of the Initialization Procedure

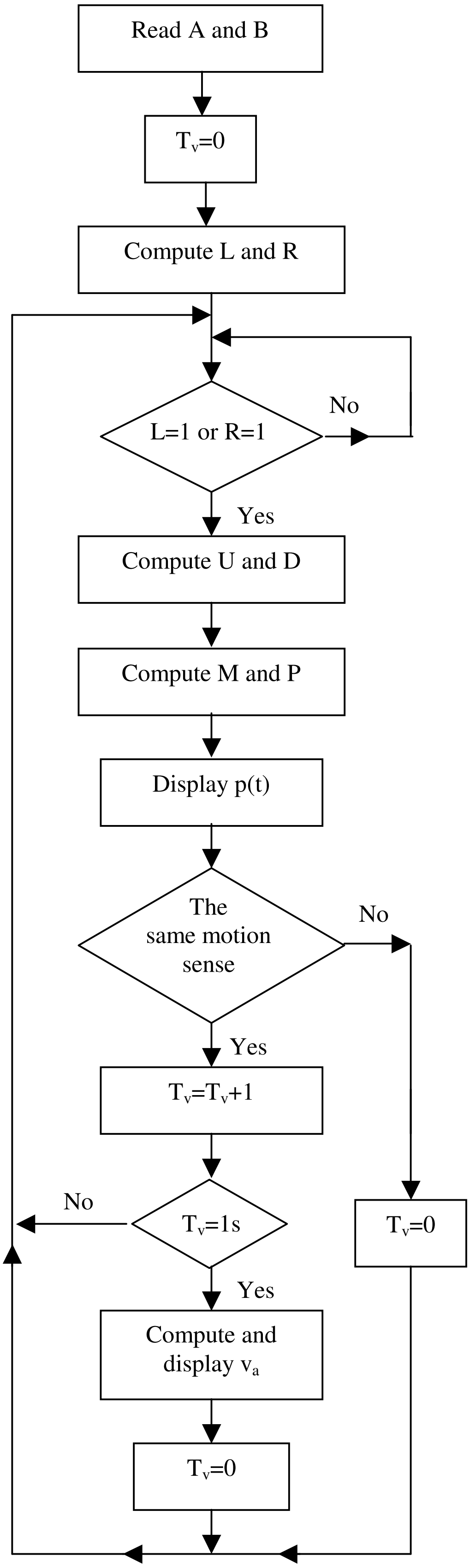

Fig.5: Flow chart of the Signal Processing Procedure

The average velocity v_a is computed only if the slider moves in the same sense during $T_v = 1s$. This motion parameter is computed with

$$v_a = \frac{|p(t_2) - p(t_1)|}{t_2 - t_1}, \qquad (8)$$

where $t_2 - t_1 = T_v$.

3 Algorithm for Studying the Working Modes of a Linear Optical Incremental Encoder

The algorithm for this computerized measurement contains two procedures: *Initialization* and *Signal Processing*.

The Initialization Procedure is presented in Fig.4. The selected working mode (WM) of the sensor can be with zero initial position ($WM = 1$) or with pre-established target position ($WM = 2$). The user must insert the target position p_T if $WM = 2$. This procedure also establishes the absolute value and sign of the initial position $p(0)$.

The flow chart of the Signal Processing Procedure (when the slider moves) is presented in Fig.5. The slider position and average velocity are computed and displayed for each working mode.

The slider motion can be continuous or not. When the slider stops, the last measured position rests displayed, the sign and absolute value of position are memorized and the average velocity is zero.

The algorithm for computerized measurement presented in this paper has the following advantages:

- improves electronically the resolution;
- ensures the discrimination of the motion sense;
- enables the studying of two working modes of the linear optical incremental encoder;
- computes the position and average velocity.

4 Conclusion

This paper proposes an algorithm for computerized measurement of displacement, position and velocity and for the discrimination of the motion sense using a linear optical incremental encoder. This algorithm is adequate for studying the sensor with an intelligent system composed by an IBM-PC computer, an interface with a microcontroller from the 80C51 family and a signal conditioning subsystem. Such measurement system is very useful in higher education and research activities.

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