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# 혼합형 엔코더에 의한 고정도 위치검출에 관한 연구

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# Position measurement with high resolution using a novel hybrid type encoder

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**Abstract** - 본 논문은 저가형 고정도 아날로그 디지털 혼합형 엔코더에서 센서 취부 오차에 의해 발생하는 정지 2축 좌표상의 두 아날로그신호의 크기, 위상오차 문제 보상에 관한 연구이다. 기존의 혼합형 엔코더에서 문제시되고 있는 두 아날로그 위치정보 신호의 크기문제는 상대 크기에 대하여 정규화함으로써 해결하였으며, 센서 취부시 발생하는 위치오차문제는 정지 2축 좌표축을 센서의 위치 오차분을 보상할 수 있도록 회전함으로써 보상할 수 있었다. 또한 제안된 새로운 방식의 위치 검출기법을 DSP의 QEP기능과 A/D변환기를 사용한 실험을 통하여 그 타당성을 검증하였다.

## *1. Introduction*

The demand for high-resolution position control is gradually increasing with the development of the mechatronics engineering and the precision manufacturing machine. Especially, in industrial precision machine tools, industrial robot, high precision control device and semiconductor manufacturing machine, the measurement of precision position value is the main element of the device performance. [1][2] In these machines, the use of poison sensing device is necessary and to acquire high resolution, the optical encoder is preferred rather than magnetic encoder. Generally, the magnetic encoder has the merits in long durability and low effectiveness on environmental condition. But the magnetic encoder is high cost and has limit in acquiring the high resolution. The optical encoder, however, is widely adapted to industrial digital machines, owing to its low cost and high-resolution measurement.[3][4] The rotary encoder has many tiny slits on the corner of the circular plate and transmitter diodes and two receiver diodes detect the optical signals. Signals of receiver diodes are converted into digital signals and the electric phase of the two signals is $90^0$. To increase the position resolution, it is considered to increase the number of slits, but it is limit in mechanical machining technology.

In this paper, a new concept of position measuring method was proposed. This method is based on the processing of the analog optical intensity signal of a low cost optical encoder. Theelectric circuit of the optical encoder is modified and a DSP(Digital Signal Processor) controller process the analog signals form the receiver diodes and converts these signals into high resolution position digital signals.

## *2. The General Optical encoder .....*

The optical encoder is composed of photo transmitting sources, receiver devices, and a rotating disk with slits. The number of output pulses of the encoder is in proportion to the rotational angle and can be detected by rotating the disk between transmitting sources and receiver diodes. Fig. 1. represents the structure of a general optical encoder.

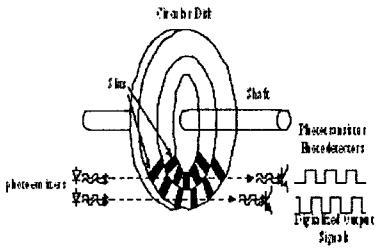

Fig. 1. The Structure of an optical encoder

The digitalized signals from a comparator are defined as ***A*** and ***B*** phase signals. From these ***A***, ***B*** phase signal, to increase the resolution of the encoder, 4 times pre-scaler circuit is used for the input of the position detecting counter. The principal of 4 times pre-scaler and ***A***, ***B*** phase signal are represented in Figure 2. Generally, these 4 times pre-scaled signals are entered into the pulse counter of the DSP controller.

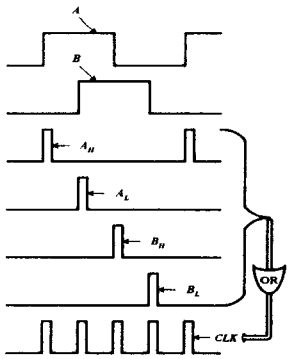


Fig. 2. Phase signal of encoder and 4 times pre-scaled signal

## 3. *The Proposed Hybrid Type Optical Encoder*

A conventional digital type incremental encoder uses digital signals, outputs of two receiver diodes. Fig. 3. represents ***a***, ***b*** signals (the output of the receiver that representing the rotational position), the ***A***, ***B*** phase signals,

and 4 times pre-scaled signal.

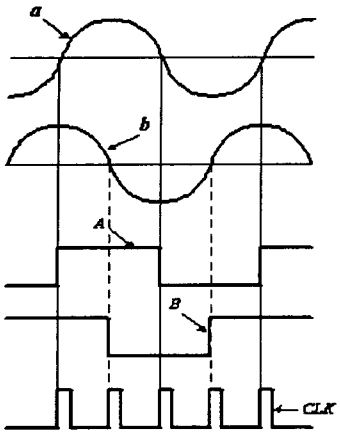


Fig. 3. A, B Phase, 4 Division and received waveform (a, b) according to electrical position of the slit

By using the two *A*, *B* phase signals, a general encoder can detect the angular position and rotational direction. The *a* and *b* signals are two phase voltage signals having phase difference of $90^0$. Put outputs of receiving diodes as *a* and *b* respectively, shown as Fig. 3. Actually, these signals have DC offset. This DC offset can be eliminated by a DSP controller. The offset free signals are defined as $\alpha, \beta$.The phase angle of 2 phase voltage is easily obtained by following equation.

$$\Delta\theta = \tan^{-1}(\frac{\alpha}{\beta}) \tag{1}$$

From equation (1), the angular position of the equation (1) is very sensitive to the noise, if $\alpha \approx 0$. To compensate this noise effect, the equation (2) can be used without generosity.

$$\Delta\theta = \cos^{-1}(\frac{\alpha}{\sqrt{(\alpha^2+\beta^2)}}) \tag{2}$$

The equation (2) is calculated by a DSP controller and the resolution is depend on the bit resolution of the A/D converter. If the bit number of the A/D converter is $Q$, the resolution can be determined by the following equation.

$$r = \frac{2\pi}{2^Q} \text{ [rad]} \tag{3}$$

If the number of pulse per a round of the encoder is defined as N, The resolution of the encoder is inverse proportion to the number of slit.

$$n = \frac{2\pi}{N}[rad] \tag{4}$$

If the counted number of *A* phase signals of the encoder is defined as *P*, the present rotator angle is represented as following,

$$\theta_i = \frac{2\pi}{N} p[rad] \tag{5}$$

The actual position angle of rotator is obtained by the combination of the position angle from digital encoder signal($\theta$), and electric position angle of slit($\Delta\theta$) is also represented by following equation,

$$\theta = \theta_i + n\Delta\theta[rad] \tag{6}$$

Therefore, the resolution of the hybrid (digital and analog) type encoder is obtained by following equation.

$$Z = nr[rad] \tag{7}$$

Fig. 4. illustrates the signal detection block diagram for the proposed hybrid type encoder.

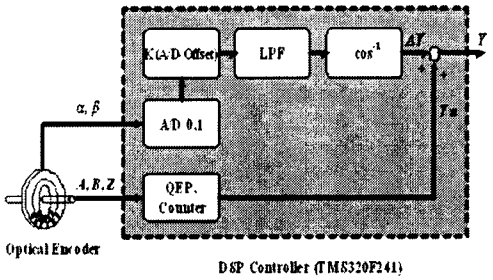


Fig. 4. Signal detection block using a DSP controller

The QEP port was used for digital signal input and A/D converter port was used for analog input to detect position angle. From two analog signals, the DC offset was eliminated and multiplying a scale factor K, symmetric 2 phase signals, $\alpha, \beta$ are induced. A low pass filter(LPF) was used for canceling of noise signals by equation (2). and the electric phase angle between slits was calculated. The high-resolution position angle , ($\theta$), was derived using the sum of the electric phase angle between slit ($\Delta\theta$) and the rotator position angle of digital encoder($\theta_i$).

### *4. The Experimen*

To verify the performance of the proposed hybrid type encoder, an analog amplifier was installed at a general encoder (Tektronix, 1024 pulse) and a DSP controller (Texas Instrument, TMS320F241) was used as a digital signal processor.

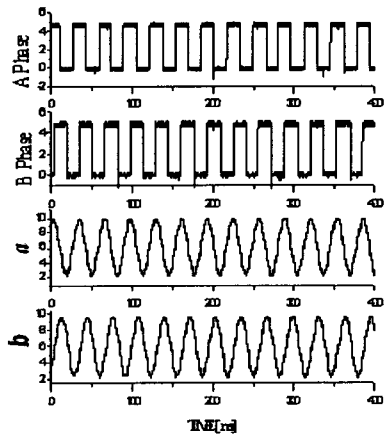


Fig. 5 *A* , *B*phase and *a*, *b* waveforms of the hybrid encoder.

Fig. 5. represents *A*, *B*phase signals and signals of receiver diodes, *a* and *b*. *a*, and *b*signals have the same frequency of *A*, *B* signals and have the shape of sine wave. The phase difference of two signals is also 900.

Fig. 6. represents 2 phase $\alpha, \beta$ signals. These signals have the same magnitude of *a*, *b*and the phase difference is 900. From the signal, DSP controller calculates and eliminates the DC offset and multiply a proper scale factor *K*.

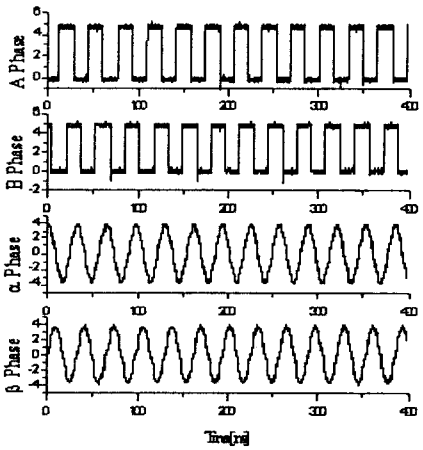


Fig. 6. *A* , *B* phase and $\alpha, \beta$ phase waveforms of the hybrid encoder

Fig. 7. represents the electric phase angle in a pitch of the enc oder slit. These signals are derived by the $\alpha, \beta$ signals. It is sho wn that the phase angle signal has the same frequency of *A* phas e signal. As shown in Fig. 7, the angle signal has reasonable beh avior, it has gradually increasing and resetting patterns.

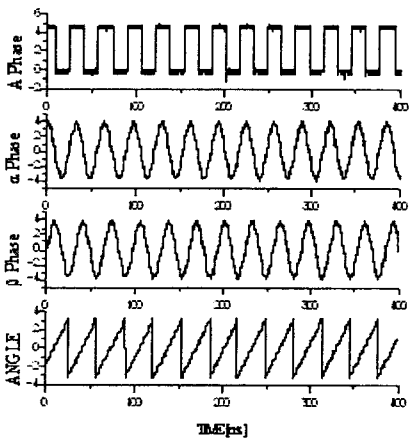


Fig. 7. *A* phase, $\alpha, \beta$ and angle waveforms of the hybrid encoder

In position control of a motor, frequent forward and backward rotational operation near the reference command is general cases. Therefore, in these cases, it is also necessary to verify the proposed hybrid type encoder's reasonable behavior and performance.

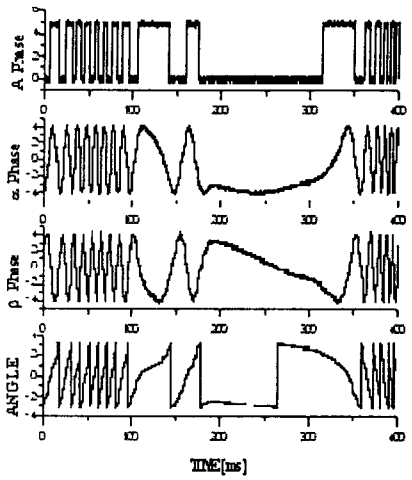


Fig. 8. *A* phase, $\alpha, \beta$ phase and angle waveforms of the hybrid encoder at the transient state

Fig. 8. represents the A phase signal, $\alpha, \beta$ and slit pitch phase angle signal. The behavior of the phase angle signal is reasonable in spite of the transient operation, when the operation time is about 200 seconds.

## 4. Conclusions

In this paper, the new method based on the combination of the digital and analog signal of the general low cost encoder was proposed. For the digital signal, the electric circuit part was modified and the analog signal is converted into digital signal with a A/D converter in a DSP controller. Therefore, in this new method, the high-resolution position detection is possible and this method can be applied to the semiconductor manufacturing machine and precision industrial robot etc. The experiment was performed by using the proposed hybrid encoder. The position resolution between the two slits can be obtained within the resolution of the A/D converter bit resolution of the DSP controller. In this experiment, a 10 bit A/D converter (TMS320F241) was used. The upper 2 bits were dropped for noise cancellation. Therefore, in this new hybrid encoder, the 256( 28 ) times more resolution than that of the general low cost encoder was obtained.

## [References]


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