Development of “PP031T” and “PP031H” Small-size Multiplier Incremental Encoders

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1. Introduction

The main industry of Japan is the automobile industry, and in order to create more precise parts, customers are demanding higher machining precision in the machine tools. Furthermore, precision positioning and precision moving are requested for industrial robots and manufacturing devices for semiconductors. In order to achieve this, manufacturers demand a higher resolution compared to conventional models for the encoders acting as positioning detectors on servo motors that are built into machinery.

While there are demands, of course, to reduce power consumption for protecting the environment of the Earth, there are also increasing demands to miniaturize devices, and therefore there are requests to make encoders that are miniaturized with a smaller diameter.

Encoders are generally classified into two types of methods: the incremental encoder that outputs pulses according the amount of rotation, and the absolute encoder that outputs an absolute position for a rotational angle. An absolute encoder built-in standard on our “SANMOTION R” series motors, but there were many requests for incremental encoders for combination with a host device or due to control methods. In particular, many customers abroad requested incremental encoders that could be built-in on a “SANMOTION R” series motor.

To meet these requests, we developed the incremental encoders “PP031T” and “PP031H” that realize high resolution while performing electricity multiplication with a miniature size and small diameter.

This document introduces the specifications and features of “PP031T” and “PP031H” .

2. Specifications

As part of the encoder high resolution technology, electrical multiplication is used to obtain the integral multipled signal from the original signal. There are two main methods for the electrical multiplier that is used on an encoder: the interpolation with resistance dividing and the interpolation with AD converting. This time, we developed encoders with two types of multiplier methods. “PP031T” uses the interpolation with resistance dividing, while “PP031H” uses the interpolation with AD converting. The interpolation with resistance dividing outputs a signal in real time based on the rotational angle. Therefore, this method is used in situations such as when the speed controls directly use the output pulses or when the controls are performed based on triggers from specific pulses. On the other hand, the interpolation with AD converting uses an output delay time for conversion time and outputting pulse, but as a result, this method produces higher resolution compared to the interpolation with resistance dividing uses.

Our previously developed the small-size incremental encoder “PP031” that works without multiplier up to 2048 P/R and the high-resolution “PP038” that uses the interpolation with AD converting uses up to 25,000 P/R. Table 1 shows a comparison of specifications between the newly developed model and the conventional model.

For an optical incremental encoder, the resolution can be increased by increasing the number of slits on a rotary disc. However, if the number of slits is increased for the same diameter, the interval between each slit becomes narrower, and if the interval is narrow, then the signal amplitude decreases due to light diffraction. In order to reduce the effects of diffraction, the gap between the rotary disc and stationary mask must be made narrower, and as a result, we have spent a lot of time working on the structural adjustments so that the each assembled components do not fluctuate to thrust direction and trying

Table 1: Comparison of specifications

	New model		Conventional model	
Item	PP031T	PP031H	PP031	PP038
Pulse (P/R)	1000 to 10000	1000 to 25000	200 to 2048	5000 to 25000
No. of slits	500, 512, 625	500, 512, 625, 1024,1250	200, 500, 1000, 2000, 2048	2048, 2500
Multiplier method	Interpolation with resistance dividing	Interpolation with AD converting	–	Interpolation with AD converting
Multiplier amount	×2, 4, 8, 16	×2, 4, 5, 8, 10, 16, 20	None (×1)	×2, 4, 8, 10
Consumption current*1	200 mA max.	200 mA max.	280 mA max.	380 mA max.
Gap between rotary disc and stationary mask*2	5×	5× 2.5× (1024 P/R min.)	1 (2000 P/R min.)	1
Dimensions	ϕ31 × 22 mm	ϕ31 × 22 mm	ϕ31 × 22 mm	ϕ38 × 26 mm
Response frequency	1,600 kHz*3	2,000 kHz*3	300 kHz	2,000 kHz
Output delay time	None	1 μs	None	6 μs

*1: Including the line driver current. *2: With the gap for PP031 as 1. *3: Max. frequency before multiplier: 100 kHz.

to solve the difficulty in performing gap adjustment when combining with the encoder. Therefore, it was difficult to achieve a high resolution of 2048 P/R or higher with the conventional model “PP031” . Furthermore, “PP038” has a high resolution up to 25,000 P/R, but there were problems because the gap was narrow, like “PP031” , and the current consumption was quite high.

The newly developed “PP031T” and “PP031H” use the electrical multiplier method with a reduced number of slits on the rotary disc, so the gap can be set five times as wide (2.5 times as wide with some products) and both models can achieve high resolution with max. 10,000 P/R for “PP031T” and max. 25,000 P/R for “PP031H” . Furthermore, the circuit components were reworked and the current consumption was reduced about half compared to “PP038” .

Fig. 1 shows the appearance of “PP031T” . The dimension are ϕ31 × 22 mm, the same as “PP031” , so compared to “PP038” , the volume ratio is at least 40% smaller.

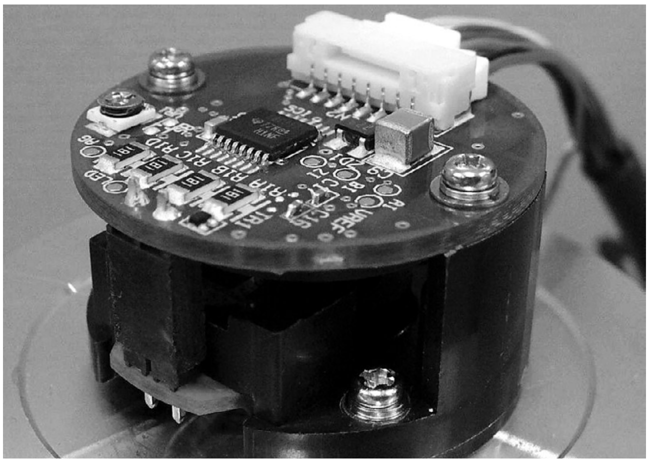

Fig. 1: External view of “PP031T”

3. Features

3.1 Improved tolerance for thrust fluctuation

As already noted, when there are a large number of slits in the rotary disc, the gap between the rotary disc and the stationary mask must be made narrower due to the effects of light diffraction. However, the new model uses the multiplier method to achieve high resolution, and therefore, the number of slits for “PP031T” can be kept low with a maximum of 625 P/R, and the gap between the rotary disc and the stationary mask can be made five times wider than conventional models. With these changes, the gap adjustment can be performed easily when assembling, while the acceptable thrust fluctuation for the motor is made larger. Therefore, the model does not need any structural adjustments to suppress the thrust fluctuation and it can be built into the “SANMOTION R” series motor with only slight changes to the surrounding installation. Furthermore, it can also be built-in directly into a large motor that has a comparatively large thrust fluctuation.

3.2 Optimum integration of circuit components

Fig. 2, Fig. 3, and Fig. 4 show the circuit blocks for "PP031", "PP031T", and "PP031H". With a conventional encoder such as "PP031", the output signal from the light reception element is amplified by the waveform shaping circuit. For "PP031T" and "PP031H", we developed the photodiode IC (hereinafter referred to as "PDIC"), which is a single package with the light-reception element, amplifier, and comparator. In the conventional light-reception element, a slight current flow in the board pattern, but since an amplified voltage signal is output from the PDIC, this provides an advantage of immunity against external noise. In addition, using a PDIC enables a drastic number of parts to be eliminated, which reduces production cost and contributes to achieving smaller size and low current consumption. Furthermore, "PP031H" has the function of multiplier and wire-saving on a single ASIC, and its circuit components were mount with on a single PCB. The equivalent function on "PP038" was composed of three PCB, and therefore, the new model reduces number of components and achieves a smaller size. Table 2 shows a comparison of component count.

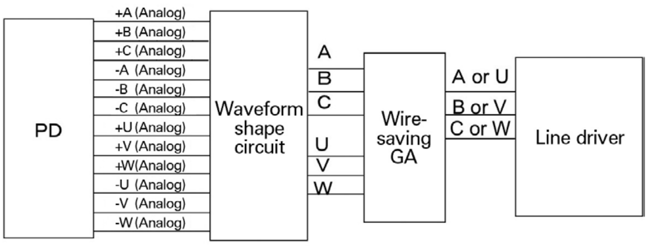

Fig. 2: "PP031" circuit block diagram

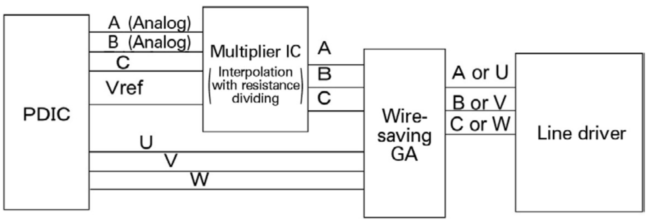

Fig. 3: "PP031T" circuit block diagram (new model)

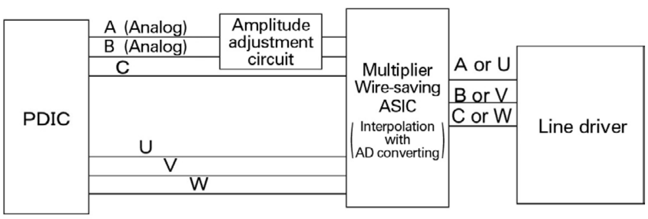

Fig. 4: "PP031H" circuit block diagram (new model)

Table 2: Comparison of component count

	New model		Conventional model	
Item	**PP031T**	**PP031H**	**PP031**	**PP038**
Electronic parts	Approx. 60	Approx. 80	Approx. 70	Approx. 130
IC	5	6	6	11
PCB	1	1	1	3

3.3 Modulated light function

The PDIC noted in the previous section has a function that calculates the received light signal, and automatically adjusts the LED current depending on the value. With this function, the LED current can be increased in order to achieve stable output even when the LED luminous efficiency go down. Furthermore, when the sensing element is at the optimal position, this function minimizes the LED current, so the LED current can be used as a parameter when adjusting the position of the sensing element.

3.4 Stationary mask for multiplier

In order to obtain a high-precision signal, the input signal used by the electrical multiplier should be substantially sinusoidal waveform. The signal generated by the conventional stationary mask pattern theoretically becomes a triangular waveform and therefore contains a large amount of distortion. This distortion is caused by high-order components other than the fundamental components. For the fundamental components, third-order waves have an amplitude of approximately 11%, fifth-order have an amplitude of approximately 4%, and seventh-order have an amplitude of approximately 2%. The distortion rate (up to 27th order) that appears depending on the mean square of the ratio for the harmonic components of the fundamental wave becomes approximately 12%.

The stationary mask pattern for multiplier in the new models ("PP031T", "PP031H") has been designed with the reduction of the distortion rate in mind. In the conventional stationary mask pattern, it were placed at the same pitch as the rotary disc slit. In the stationary mask for the multiplier, the intervals are placed in order to eliminate third-order and fifth-order components. Fig. 5 shows the stationary mask pattern for the multiplier that is used in PP031T. Fig. 5 shows an example of 500 P/R, where the third-order components can be eliminated by positioning at a pitch just slightly less than the pitch of the rotary disc slit. This method realizes a distortion rate of 1% or less and contributes to a high-precision signal after multiplying (Pat. Pend.).

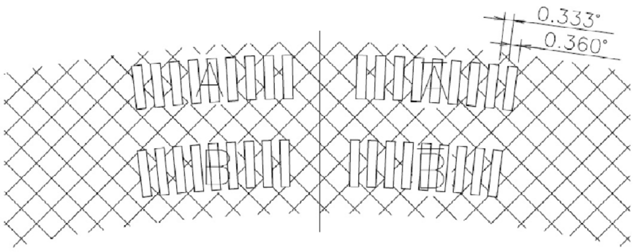

Fig. 5: Stationary mask pattern for multiplier

Theoretically, the output phase offset between A phase signal and B phase signal is always 25%. However, the actual value varies due to issues such as the precision of the disc and wobbling in the core. Interpolation error on the multiplier encoder can cause even greater variation on the output phase offset. The main cause of interpolation error is the input signal distortion that was described previously. When looking at the problem in terms of angle precision, the accumulated variation in the output phase offset is deviation from the true value, and therefore minimizing the variation is the same as making the value more precise. Fig. 6 shows the output phase offset (actual value) for one rotation when using a stationary mask for multiplier and when using a conventional mask. As you can see from the results of the stationary mask for multiplier in Fig. 6, the variation is reduced in the output phase offset.

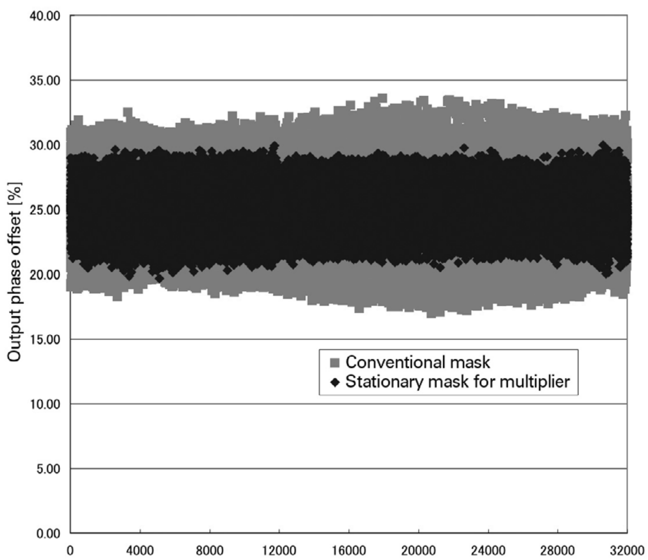

Fig. 6: The difference in the output phase offset by the mask (500 × 16 P/R)

4. Conclusion

This document introduced the specifications and features of the small-size multiplier incremental encoders “PP031T” and “PP031H” that were developed among demands for higher resolutoin and smaller size.

The new model is designed to reduce the number of slits on the disc and widen the gap between the rotary disc and the stationary mask. By also employing the electrical multiplier method, it realized high resolution. Also, by employing a PDIC, some circuit can be integrated, thus achieving a smaller size. PDIC includes a modulated light function that ensures reliability in face of going down LED illumination efficiency. In addition, by using a stationary mask for multiplier, the interpolation error is reduced and the signal achieves high precision.

“PP031T” and “PP031H” are small-sized, high-resolution incremental encoders that can be used on the “SANMOTION R” series motors, which have the top performance in the industry. We believe that these new models can contribute to educe new potential from our customers’ devices.

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