SANYO DENKI TECHNICAL REPORT No.8 November-1999
New Products Introduction

Multiple Rotation Absolute Sensor

Hideyuki Ishii Sakae Kishi Shigeharu Katou
Akihide Takayanagi

1. Introduction

When one wishes to detect the rotating position of the output shaft of a servo system, it is often enough to detect the origin (zero degrees) after the output shaft starts turning, then to determine the current position. However, there is much demand for determining the origin (zero degrees) during the stage of installation, then keep the readings constant regardless of operation or stop mode "detection of the absolute position" .

To meet these applications, Sanyo Denki has long provided the ABS-RII and ABS-M series. In addition, the company has recently developed a new-concept "Multiple Rotation Absolute Sensor," an alternative product made by using a resolver and incorporating some ideas into the gear unit.

The absolute sensor consists of one resolver that detects the position of a rotor during one rotation and three resolvers whose rotation ratios are varied via gears in order to detect the number of multiple rotations. The signal detection system of the resolvers uses changes in magnetism in the direction of thrust, unlike the radial direction of conventional models. The arrangement of three multiple rotation resolvers on the same plane has achieved a size reduction.

The multiple rotation absolute sensor needs no battery for memorizing the number of multiple rotations, requires a greatly reduced amount of maintenance, and reduces industrial wastes. The system is compatible with multiple interfaces thanks to its module configuration. It also achieves a resolution as high as 16 bits (65,536 divisions). These features make it probable for the system to find applications such as high speed and multiple-axis control.

2. Basic structure of resolvers

The resolvers used in this multiple rotation absolute sensor differ greatly from those used in older models, in terms of how the direction of changes in magnetism is taken and how signals are excited.

ABS-RII, ABS-RIII and other conventional models have a structure as illustrated in Fig.1(a) and employ the system shown below. Excitation is conducted in a two-phase excitation, single-phase output manner. Magnetism is generated by SIN excitation windings and COS excitation windings arranged alternately in the stator slots, and magnetic changes due to gap fluctuations in the stator and rotor are detected from the detection windings. Signals in a phase-shifted manner are generated according to the angle of rotation. The phase shift θ is detected with a counter as compared with the reference signal to obtain the angle of rotation.

Input: $\sin(\omega t), \cos(\omega t)$
Output: $\sin(\omega t)\cos\theta + \cos(\omega t)\sin\theta$

$$\downarrow$$

$$\sin(\omega t + \theta) \qquad (1)$$

The structure of this model is as illustrated in Fig.1(b). Its excitation system is on a single-phase excitation, two-phase output basis. Magnetism having a SIN wave form is generated from the excitation coil, and output signals are taken out of the detection coil according to the rotation angle. These signals are processed with the circuit to achieve an output as illustrated in Equation (2). That is compared with the reference signal and the phase shift θ is detected with the counter and achieve the rotation angle is obtained.

Input: $\sin(\omega t)$
Output: $\sin(\omega t)\sin\theta$
$\sin(\omega t)\cos\theta$
↓
$\sin(\omega t)\sin\theta$ are shifted by $\pi/2$ on the circuit
↓
$\cos(\omega t)\sin\theta$ is generated
↓
$\sin(\omega t)\cos\theta$ and $\cos(\omega t)\sin\theta$ is subjected to the addition theorem.
↓
$\sin(\omega t \pm \theta)$ is obtained (2)

Thermal drift was a problem with conventional models. Generating the $\pm\theta$ has resulted in cancellation of thermal drift, thus marking a great enhancement. The resolution is 16 bits (65,536 divisions), more than 14 bits (16,384 divisions) present in conventional models.

---

3. Configuration of the multiple rotation part

To enable calculation of the number of multiple rotations, the system is designed with a single-rotation resolver (RS_0) and three resolvers (RS_i) via a gear. Each resolver has its own shafts and gears and turns with a different rotation ratio via the gears connected directly to the main shaft.

Table 1 Number of teeth in each gear

	Noi	Ni
RS_1	26	25
RS_2	28	27
RS_3	28	29

The three angles presented by these three resolvers are used to calculate the number of multiple rotations. Here, assuming that θ_i is the electric angle of RS_i, No_i is the number of gear teeth on the main spindle (with regard to RS_i), and N_i is the number of gear teeth of RS_i, each resolver turns with a different rotation ratio as illustrated in Fig. 2(a) according to the number of teeth as shown in Table 1. For calculations, the angle θ_i presented by each resolver is read and the difference θ_{0i} between RS_0 and RS_i is calculated. The difference values represent angles having one cycle for 25, 27 and 29 rotations respectively by appropriate correction (Fig. 2(b)). Determining the difference positions (25, 27 or 29 rotations) calculates the number of multiple rotations by these combinations. This means that the number of rotations produced by the combination of these three differences comes in 19,575 (25 x 27 x 29) patterns, so that the maximum number of multiple rotations becomes 19,575 (>8,192). Determination of the numbers of teeth which are prime numbers (25, 27, and 29) and the specification of the number of teeth on the main spindle so as to produce a difference of one from the number of teeth in each shaft, allows one to count the number of multiple rotations more effectively. Three resolvers are used to set the number of multiple rotations to at least 8,192 and to ensure compatibility with conventional models.

The resolvers for multiple rotations are arranged as described as follows: For the conventional ABS-M type, a resolver for multiple rotations (RSi) is arranged on a single-rotation resolver (RS0) via a gear as illustrated in Fig. 3(a) (the number of multiple rotations is 256).

On the other hand, as shown in Fig. 3(b), this model contains three multiple rotation resolvers inside the single-rotation resolver. The result is a size reduction (L2 < L1) as compared to conventional models.

4. Processing circuit

The processing circuit is constructed as shown in Fig. 4. It basically consists of an analog IC which gives and receives signals that indicate the detection of excitation in resolvers, a digital IC for digital processing, flash memory that contains calibration data, EEPROM which contains the parameters, a gate array for communications, and a CPU, as well as other components.

The angle data from the resolvers are corrected by calibration data, then generate multiple rotation data, resulting in the generation of absolute position data. As for fail-safe capability, this processing circuit incorporates resolver wire break error detection and speed/acceleration error detection.

In communications, this circuit is compatible with multiple interfaces, including Manchester and start/stop synchronization.

5. Conclusion

This paper has so far described the configuration of the multiple-rotation absolute sensor. The generation of multiple rotation data for this sensor consists of the angles presented by the resolvers. This obviates the need for a battery to memorize the number of multiple rotations, so that this sensor can perhaps be applied to fields where explosion-proof specifications are required. At the same time, this sensor will greatly help reduce maintenance work, resulting in a cut in industrial waste. This, together with a size reduction, will reduce the amount of resources consumed, making the system eco-friendly. The processing circuit can be mounted not only on a sensor but also on the servo amplifier or relay, so that the this circuit unit can perhaps be applied to applications under special conditions (such as those where resistance to heat, oil or vacuum conditions are required). For the communications system, a modular configuration is used to make the system compatible with multiple interfaces.

Thus, the newly developed multiple rotation absolute sensor is adaptable not only to traditional applications but also to new applications and fields. However, if one wishes to place the processing circuit on anything other than a sensor, replacement of the resolvers currently requires replacement of the processing circuit as well. This is because the resolvers correspond to the processing circuits on a one-to-one basis. Therefore, to obviate the need of for replacement of the processing circuit, a certain degree of precision guarantee for the master calibration data is required. In the future, the authors are determined to address the challenge of setting up mechanical and electrical conditions that include these requirements.

Hideyuki Ishii
Joined company in 1989
Servo Systems Division, 1st Design Dept.
Worked on production engineering,
component engineering, and production,
then on development and design of sensors

Sakae Kishi
Joined company in 1983
Servo Systems Division, 1st Design Dept.
Worked on development and design of sensors

Shigeharu Katou
Joined company in 1980
Servo Systems Division, 1st Design Dept.
Worked on development and design of sensors

Akihide Takayanagi
Joined company in 1997
Servo Systems Division, 1st Design Dept.
Worked on development and design of sensors

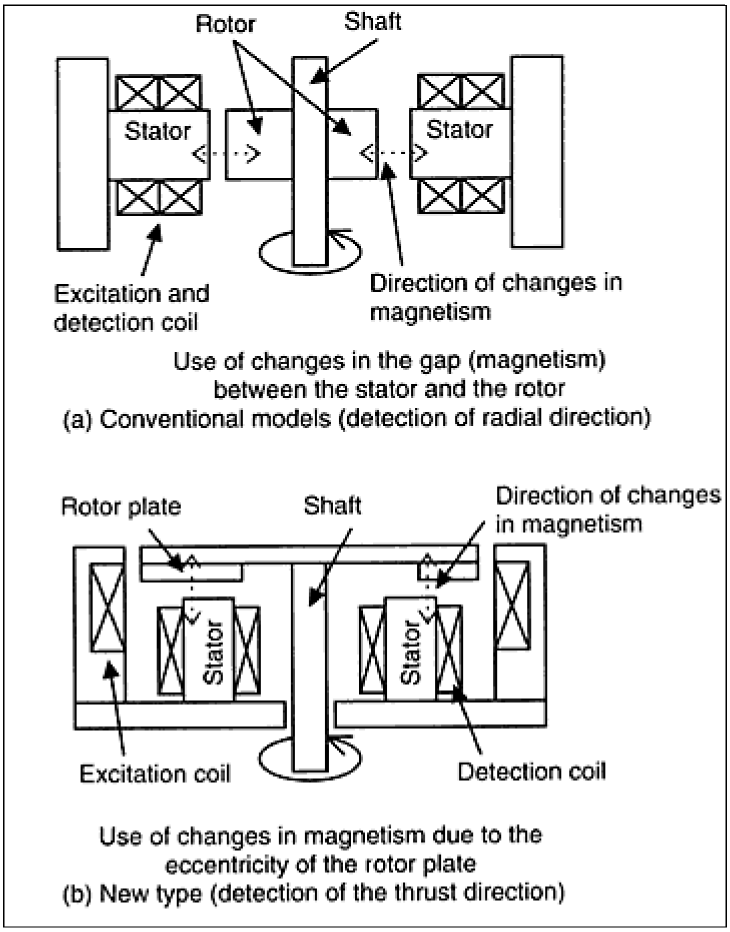

fig.1 Differences in the resolver structure between conventional and new models

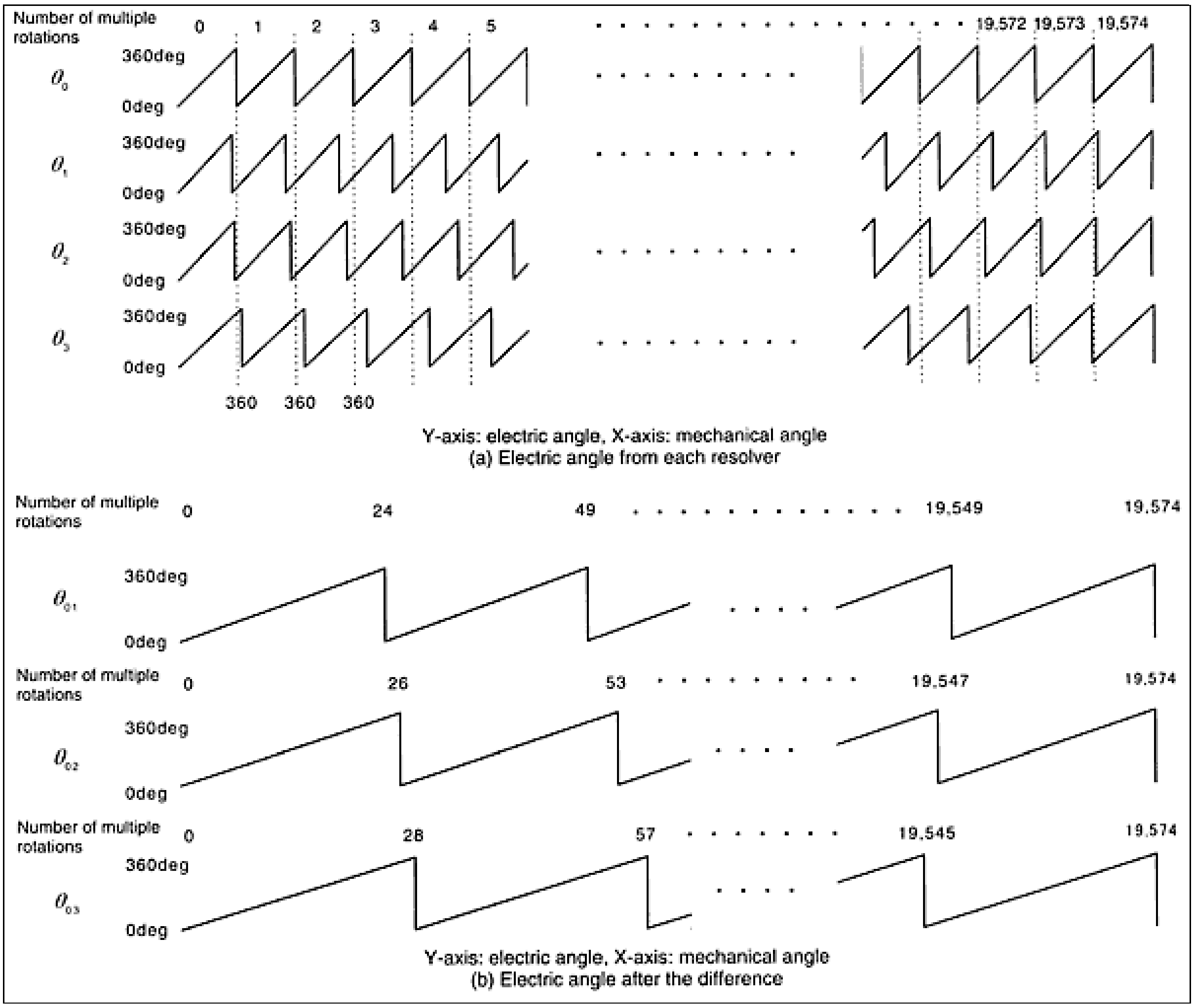

fig.2 Generation of angle data

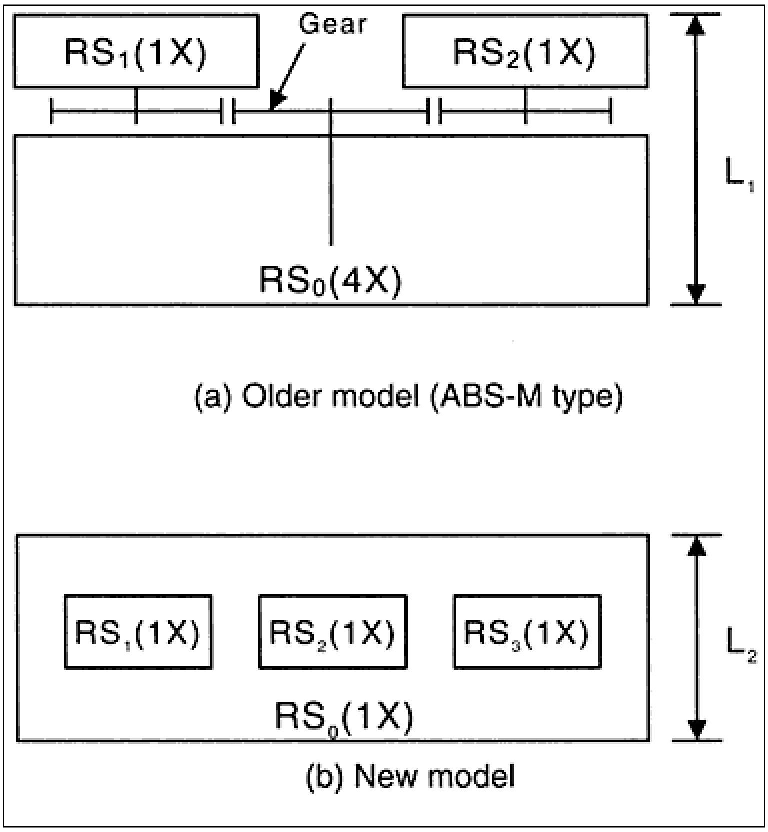

fig.3 Arrangement of resolvers

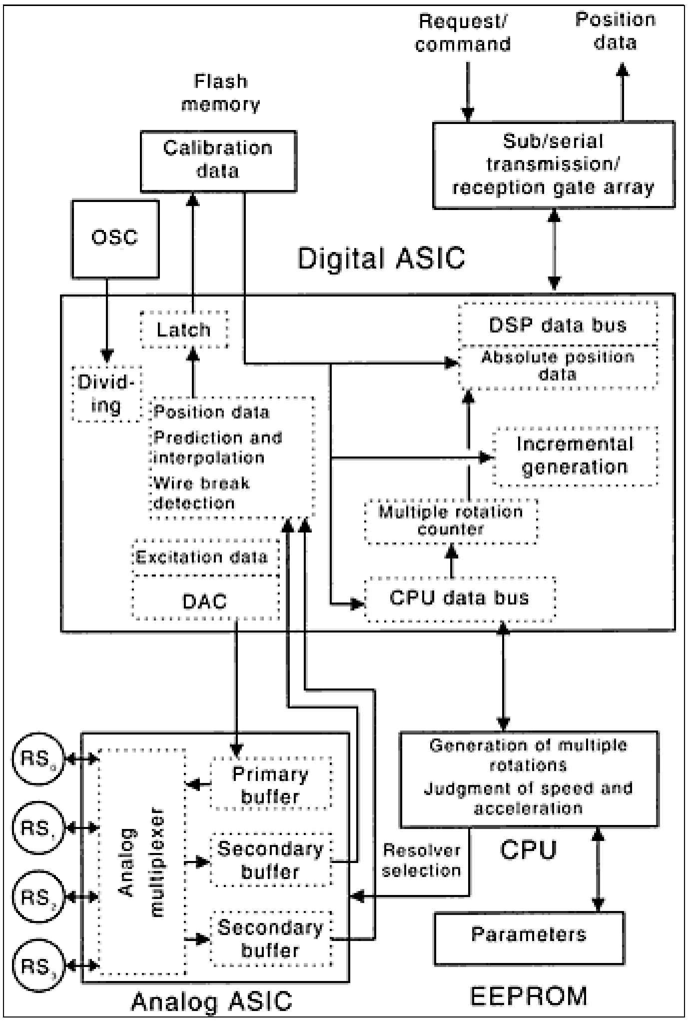

fig.4 Block diagram of processing circuit