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Multi-Precision Position Measuring Method with R-HPSD Scheme

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Abstract

A 3-D position determining mean is an indispensable function in the industrial automation system to obtain the spatial information. Optical methods have been used widely for this purpose. Semiconductor position sensitive device (**PSD**) is used widely because of its simplisity in instrumentation. A new type of PSD called **R-HPSD** has invented to realize high precision detection. Relative resolution for full sensing area can be incresed extremely without any serious sacrifice of the simplicity in instrumentation and high speed operation. This scheme makes us possible to realize not only the high precision image position sensing but also a multi-precision sensing. These type of operations are useful such as for the optical stylus used in the 3-D cordinates measuring machine.

Introduction

In order to obtain the spatial information such as positions, movements, shapes, deformations and so forth, a 3-D position determining mean is an indispensable function. It is considered that the optical method can provide an effective mean to detect the spatial infomation in the industrial automation system because of its noncontact, nondetractive and remotely detecting capabilities. Many types of optical position measuring methods have been proposed and examined for the above purposes. Triangulation is the most important principle in the optical 3-D position measurement and is applied widely to obtain quite stable measurement. In order to avoid the problem of correspondence in the triangulation, light beam projecting method is adoped widely: in which the surface of an object to be measured is swept by a bright spot and image positions of the bright spot are detected by the several image position detecting apparatuses such as composed with TV cameras, CCDs, PSDs and so on. Then the 3-D position of a bright spot is determined based on the triangulation. Requirements for 3-D position determining apparatus in industrial automation systems are summarized as high precision, miniaturized, easy to instrument, high stability and so forth. Semiconductor position sensitive device (**PSD**)[2] is used widely in the optical 3-D position determining system. Measuring accuracy of 3-D position is influenced largely by the precision of the image position detecting apparatus. One of the problem in the utilization of PSD is low relative resolution of image position sensing.

In order to overcome the above problem, a hybrid type position sensitive device (**R-HPSD**: **R**iken **H**ybrid Type **P**osition **S**ensitive **D**evice) has invented[3]. A prototype of the R-HPSD was fabricated and it was proved that the method is extremely effective to increase image position sensing precision of PSD with ordinary technologies of electronics. Furthermore, the possibilities of its application for the multi-precision sensing in industrial automation system has been investigated.

Hybrid Type Position Sensitive Detector (R-HPSD)

PSD is cosisting **PIN** or **PN** junctions: P type resistance rayer (**R**), **N** type bias layer (**C**) and high resistance Si insulation layer (**P**); photoelectric current flows between resistance layer (**R**) and bias layer (**C**) at the light incident point and flow to the output terminals through the resistance layer. The values of the output current are inversely proportional to the resistance value between light incident point and the output terminals, image position can be calculated from the output currents by considering the resistance distribution. Usually, these calculations are performed by the analogue circuit in high speed (order of 10 us).

One of the special features of PSD is its simplisity of instrumentation. On the other side, one of the demerits is the lower relative resolution of image position detection; it is limited up to the order of one part in a few thousands in its detectable area; it is mainly limited by the stability and the accuracy of the signal processing circuit and the precision of A/D converter.

On the other hand, required precision of 3-D position determination in the field of automation is quite high, for instance, one part in a few ten thousands which corresponding to 0.1mm accuracy in 1m x 1m x 1m working space

is needed. In order to realize such high precision 3-D position determination system, one part in hundred thousands precision is required for image posoition sensing apparatus. It may be difficult and quite expensive to realize such high accuracy signal processing circuit and high resolution A/D converter with high conversion speed.

In order to overcome the above problems, a hybrid (analogue and digital) type semiconductor position sensitive device **R-HPSD** was invented[3]. Auxiliary output terminals are provided between the output terminals in the conventional type PSD as shown Fig.1 (a). By selecting appropriate pair of output terminals, each divided interval or several

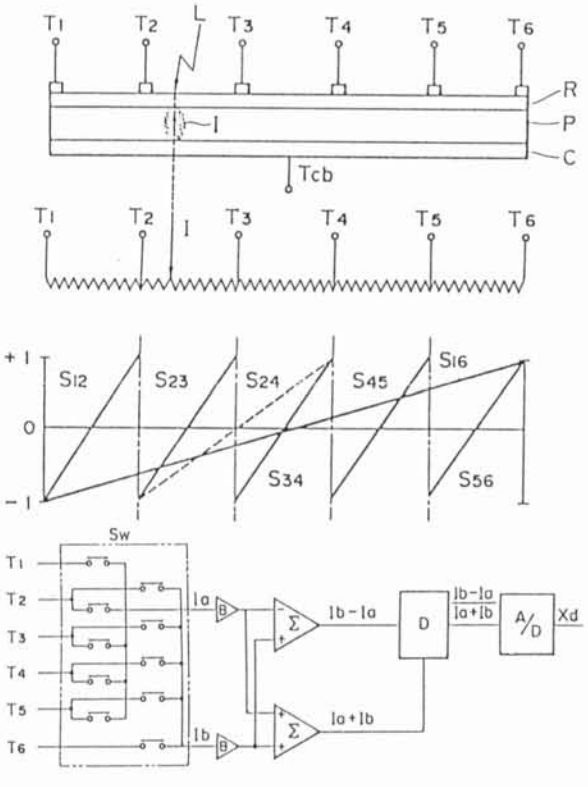


Fig. 1 Principle of **R-HPSD**: Riken Hybrid Type **P**osition **S**ensitive **D**evice, **(a)** conceptual figure showing sectional configuration of **R-HPSD** element and its equivalent circuit, **(b)** conceptual graph showing various sensitivity features for different terminal selection in **R-HPSD** **(c)** schematic drawing of the signal processing circuit for **R-HPSD** { **R**: resistance layer, **P**: photo-sensitive layer, **C**: bias layer, **L**: incident light, $T_1,\ldots,T_j,\ldots,T_6$: output terminals, C_B: bias terminal, S_w: output terminal selecting circuit, S_{ij}: position detecting sensitivities for i-th and j-th terminal selection, **B**: buffer amplifier, **A**: operational amplifier, **D**: divider, **A/D**: analogue to digital converter, I_A,I_B:output current}

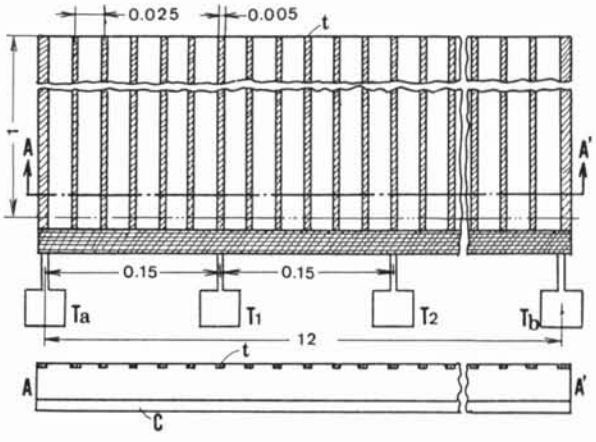
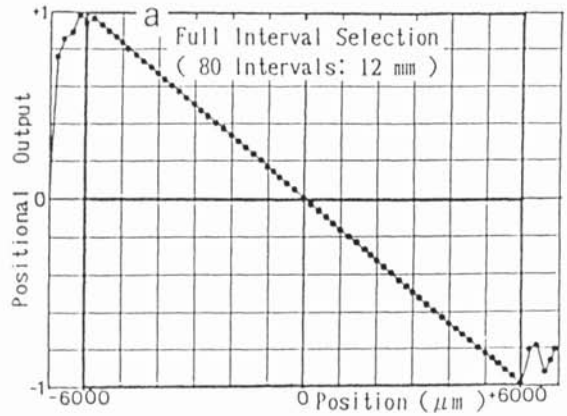


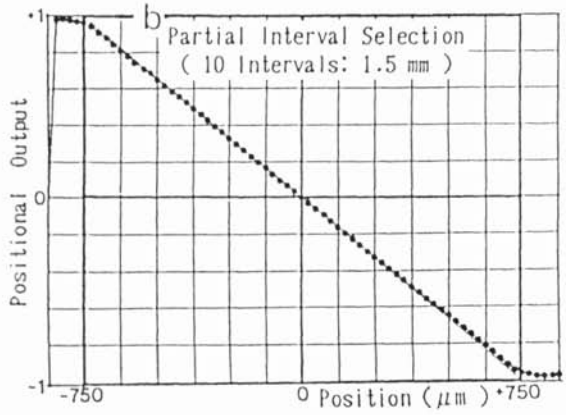
Fig. 2 Conceptual configuration of 1-D Comb-Type PSD fabricated in trial based on **R-HPSD** { T_a, $T_1,\ldots,T_j,\ldots,T_b$: output terminals, **R**: dividing resister, **C** : bias layer, **t** : conductive teeth, indicated dimensions are in **mm** }

continuous intervals can works entirely the same as in the ordinary type PSD. By selecting output terminal pair covering whole intervals, the divided interval on which target image is falling can be detected. Then, the output terminal pair which covers narrower intervals including the target image are selected and the image position in the selected interval is detected. Finally, image position in full sensing area is determined from the detected position in the selected interval and the position of the interval. The position detecting accuracy is influenced only by that in the selected interval which is limited by the accuracy and stability of analog signal processing circuit and the precision of A/D converter. Then, the relative resolution can be increased extremly higher than that of an ordinary type PSD without any improvement of the precision of the A/D converter and the stability of signal processing circuit. Conceptual graph representing variation of the sensitivities for different terminal selection in R-HPSD are shown in Fig.1 (b).

Prototypes of linear position sensitive device based on R-HPSD were fabricated and its conceptual configuration is shown in Fig.2. Examples of the characteristics of positional output signal for different output terminal selection are shown in Fig.3 (a), (b) and (c). Then the effectiveness of R-HPSD has been confirmed experimentally.

In order to make construction of the selection circuit for number of output terminals simpler, it may be suitable to divide them into several groupes and to provide analog switch circuit for selecting two of these groupes[5].





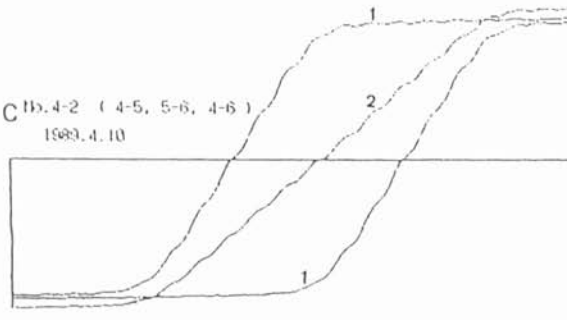


Fig. 3 Examples of positional output characteristics of a prototype of **R-HPSD** for different interval selection, **(a)** full interval (80 intervals: 12mm) selection and **(b)** partial interval selection (10 intervals: 1.5mm) **(c)** partial interval selection(2 intervals:

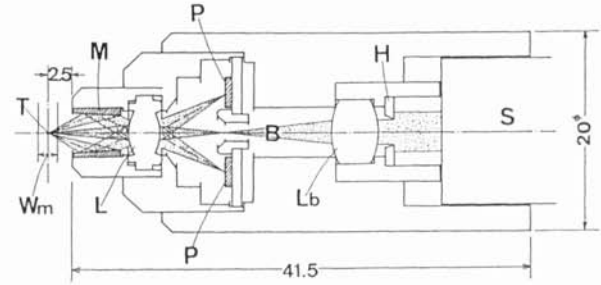


Fig. 4 Conceptual configuration of a trial optical range sensing probe based on **RORS** (**S**: light source, **B**: light beam, **L**: observation lens, **T**: bright spot, **LD**: laser diode)

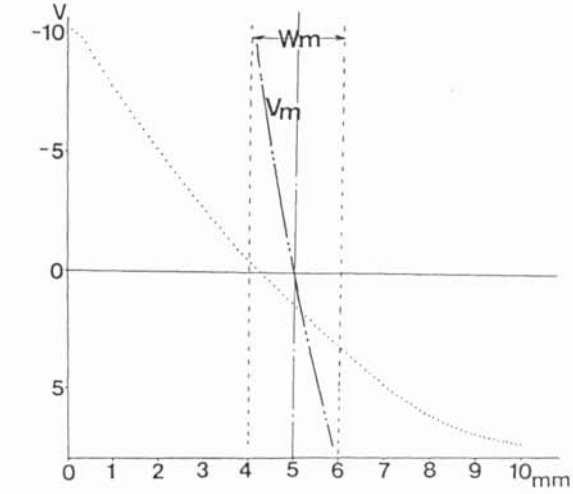


Fig. 5 An example of multi-resolution range sensing characteristics of trial range sensing probe based on **RORS**{ **Vt**: characteristics in the whole sensing range, **Wm**: measuring range, **Vm**: characteristics in the measuring range }

possible to extend new approaches in the industrial automation systems.

In the practical automation system, it is often required to make sensing system so that it can be operate in multi-precision mode: rough sensing mode and measuring mode. In the rough sensing mode, wider detectable range is required but detection precision is lower. On the other hand, in the measuring mode, higher precision is required but

ralize uniform detection sensitivity it is required to use an image position sensitive mean which has sensitivity of position detection corresponding to the distance.

One of the application of multi-precision position detecting capability in R-HPSD is the miniaturized optical range sensor based on RORS(Riken Optical Range Sensing Scheme)[4] as shown in Fig. 4. This optical range sensor is fabricated aiming to use as a probe for 3-D cordinates measuring machine and detecting the distance to an object surface. In the surface following mode, no such high precision is needed but wide detectable range is required. On the other hand, in the case of measuring mode, detectable range is not so wide but high precision sensing is required. Measurements are made after confirming that the surface of an object is placed in the measuring range. An optical range sensing probe fabricated in trial is shown in Fig.4. In this case, it is designed so that detectable range is 0 to 10 mm and the detecting accuracy is around 50 um. On the other hand, it is designed so that measuring range is 4 mm to 6 mm (2 mm) and measuring accuracy is around 10 um. In this case, resolution in measuring mode is about 5 times higher than that of in the surface following mode. Detecting characteristics is shown in Fig.5. If the spacing between the additional output terminals is more closer, detection precision in measuring mode becomes more higher.

Figure 6 represents a conceptual configuration of robot system in which robot hand has reduldant degrees-of-freedom is controled in feedback mode by detecting the position and situation of a object and the robot hand. For instance, multi-precision sensing such as rough positioning mode (1 mm accuracy) and precise adjusting mode (0.1 mm accuracy) in the 1 m x 1 m x 1 m working space can be realized easily by adopting R-HPSD for image position detecting apparatus.

Conclusion

In this paper, a hybrid type position sensitive device (**R-HPSD**) has invented and a prototype of R-HPSD element has been fabricated. By the R-HPSD scheme

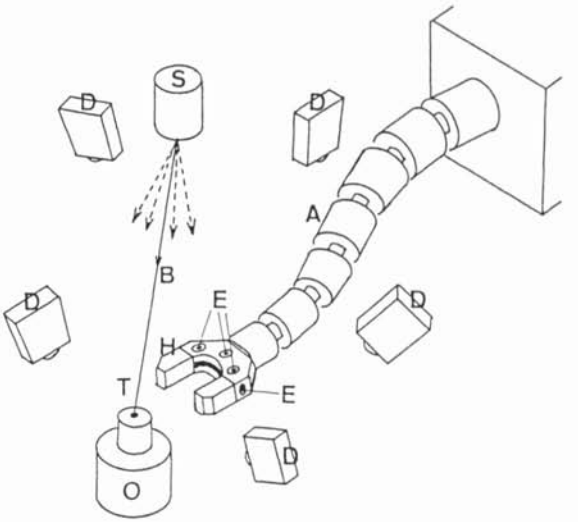


Figure 6. Conceptual figure of robot arm which is controled by detecting its end effector position using the optical 3-D position determining system { **A**: robot arm, **H**: robot hand, **O**: object to be handled, **S**: light beam scanner, **T**: projected bright spot, **E**: LED targets, **D**: high precision image position detecting apparatus with **R-HPSD** }

of 3-D shape measurement, robotics and automation.

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