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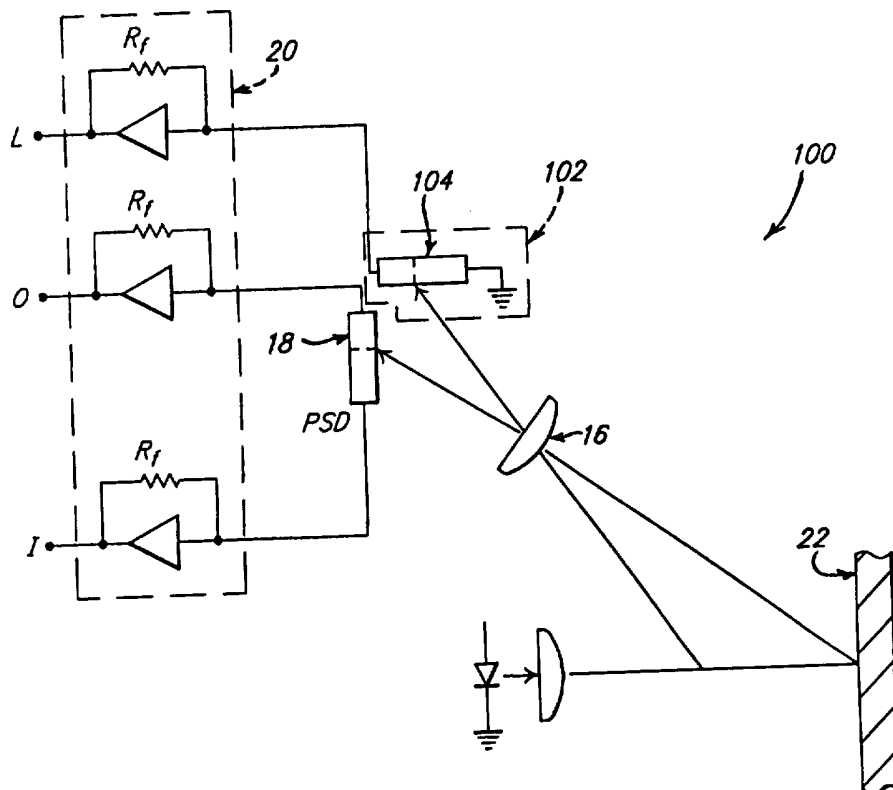
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(54) Title: OPTICAL DISTANCE MEASURING SYSTEM HAVING RANGE LIMIT DETECTION

(57) Abstract

An optical distance measuring system (100) includes a limit detector (102) positioned proximate and oriented relative to a sensing means (18) for detecting light returning from an object (22) which otherwise substantially misses the active sensing area of the sensing means (18) after imaging by a receiver lens (16). The limit detector (102) provides an output that indicates the object is located at a distance less than a minimum distance inherently needed by the system (100) to provide accurate distance measurements.



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OPTICAL DISTANCE MEASURING SYSTEM HAVING RANGE LIMIT DETECTION
BACKGROUND OF THE INVENTION

The present invention relates generally to optical distance measuring arrangements, and more particularly to calibration of optical distance measuring arrangements using position sensitive detector (PSD) elements.

Conventional optical distance measuring systems which utilize a PSD element to measure distance between the optical system and the surface of an object, such as used in autofocus cameras and other range measuring equipment, measure distance by triangulation. More specifically, as shown in Fig. 1, a block diagram of a conventional optical distance measuring system 10 includes an LED transmitter 12, a transmitter lens 14, a receiver lens 16, and a PSD element 18 with associated amplifier circuit 20. In operation, the LED emits a distancing light beam which is reflected in all directions by the surface of an object 22. The light which is reflected or otherwise returned through the principal point of the receiver lens 16 forms an angle α relative to the incident beam. The reflected light is focused by the receiving lens 16 to form a beam spot on an active area of the PSD element 18. The various physical parameters shown in Fig. 1 are defined as follows:

- x - distance of the object from principal point of transmitter lens along beam of incident distancing light;
- L - length of the active area of the PSD element;
- I - current from the inside lead of the PSD element;
- O - current from the outside lead of the PSD element;
- y - distance from the inside edge of the PSD active area to the center of the spot of reflected/scattered light;
- s - perpendicular distance from the center of the incident distancing light beam to the principal point of the receiver lens;

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- 5 f - distance between the principal point of the receiver lens and the plane of the PSD as measured parallel to the incident distancing light beam;
- q - distance from a point where a line through the principal point of the receiver lens and parallel to the incident distancing light beam intersects the plane of the PSD element to the inside edge of the PSD active area; and
- 10 z - distance from a point where a line through the principal point of the receiver lens and parallel to the incident distancing light beam intersects the plane of the PSD element to the center of the reflected light spot on the PSD element; where

$$y = L(I-O)/(I+O); \quad (1)$$

$$z = q+y; \text{ and}$$

$$\cot \alpha = x/s = f/z,$$

$$x = (f)(s)/z \quad (2)$$

20 As is evidenced by equation (2), the measurement of x is dependent upon the location on the PSD element of the returned light beam. However, due to physical limitations, conventional measurement systems inherently have a measuring range comprising a minimum and maximum distance over which the

25 system can accurately measure the distance to the target object. The inherent physical limitations placed on the design of the optical distance measuring system prevent the system from accurately imaging the returned light beam on the active sensing area of the PSD element at very short distances, i.e.

30 inside the minimum x value of the measuring range. As seen from the graph of Fig. 2 illustrating the I and O outputs over a range of x , the conventional optical distance measuring system can not adequately discriminate between target objects which are extremely close and ones that are extremely far. In

35 otherwords, in both cases the PSD element total output is a small value, and the distance measuring system is incapable of

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determining whether the low PSD output is due to a target object which is close in distance or far in distance.

SUMMARY OF THE INVENTION

5 It therefore is an object of the present invention to provide an optical distance measuring system which can distinguish between target objects which are closer than (i.e. "inside") the measuring system's effective measurement range and target objects which are farther (i.e. "outside") than the effective measurement range.

10 It is a further object of the present invention to provide an improved optical distance measuring system which utilizes a limit detector to provide an indication that a target object is located at a distance which is too close to obtain a reliable distance measurement.

15 Therefore, in accordance with the present invention, an optical distance measuring system comprises an optical transmitter for directing a distancing light beam at an object separated from the transmitter, and an optical receiver comprising a means for imaging onto a sensing means the
20 distancing light beam returning from the object. The sensing means generates an output which is a measure of the distance between the object and the transmitter. A limit detector means is positioned proximate the sensor means for generating an output responsive to the object being located within a
25 particular distance from the transmitter.

In further accordance with the present invention, the limit detector is arranged in several different embodiments. In one arrangement, the limit detector comprises a photodiode element positioned adjacent the sensing means and oriented
30 either to provide a limit detector sensing field perpendicular to the sensing field of the sensor means, or contiguous to the sensing field of the sensing means. In another arrangement a mirror is used to reflect returning light beams onto the photodiode element. In yet another arrangement, the limit
35 detector comprises an incurvate mirror positioned relative to the sensing means to reflect the returning light beams which

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substantially miss the sensing means onto a particular area of the sensing means. In all of the limit detector arrangements, the limit detector is oriented relative to the sensing means to intercept returning light beams which substantially miss the sensing means after being imaged by the imaging means.

The present invention will be more fully understood upon reading the following detailed description of the preferred embodiment in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic illustration of a conventional optical distance measuring system;

Fig. 2 is a graph showing the outputs of a PSD element with respect to target object distance;

Fig. 3 is a schematic illustration of a first embodiment of the present invention;

Fig. 4 is a graph illustrating the PSD element outputs and a limit detector output with respect to target object distance in accordance with the present invention;

Fig. 5 is a schematic illustration of a second embodiment of the present invention;

Fig. 6 is a schematic illustration of a third embodiment of the present invention; and

Fig. 7 is a schematic illustration of a fourth embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring to Fig. 3, an improved optical distance measuring system 100 in accordance with a first embodiment of the present invention is shown as utilizing an "inside the measuring range" limit detector 102 in conjunction with a conventional PSD-type distance measuring system, such as system 10 shown in Fig. 1. It is noted for brevity of description that system elements common to both systems 10 and 100 have been denoted with identical references numbers. In accordance with the present invention, the inside limit

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detector comprises an optical or opti-electrical component arranged and/or positioned relative to the PSD sensor element 18 to provide an output indicative of a target object being located at an extremely short distance, i.e., x is very small.

As shown in Fig. 3, limit detector 102 comprises a photodetector element 104 located adjacent to the outside (O) edge of the PSD element 18. The photodiode element 104 extends from the sensing field of the PSD element 18 towards the measurement field to provide a substantially perpendicular sensing field relationship to the sensing field of the PSD element 18. The photodiode 104 effectively intercepts light rays which are reflected/scattered by a target object which is at a distance so close that the light rays substantially miss the active sensing area of the PSD element after imaging by the receiver lens 16. Such a position is denoted as position A in Fig. 3. The photodiode 104 provides an output L which is processed by an amplifier circuit 106. As will readily be appreciated by one having ordinary skill in the art, the receiver lens 16 can be tilted to optimize the viewing angle for the limit detector relative to the inside limit range while still providing adequate imaging for targets over the entire length of the operable measuring range, such as represented by position B.

Fig. 4 illustrates a graph of the three outputs O, I, and L as plotted over target distance x from the transmitter lens 14. As shown in Fig. 4, when L is greater than I or O, than the target object is within the system's inside limit range. Stated another way, the point at which L becomes less than I or O marks the beginning of the distance measuring system's optimal measuring range.

Figs. 5-7 show alternative embodiments for implementing the limit detector in accordance with the present invention. More specifically, Fig. 5 illustrates a limit detector 200 formed from a photodiode 202 being positioned adjacent the outside (O) edge of the PSD element 18 and oriented in substantially the same sensing plane to provide a

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limit detector sensing field which is contiguous to the sensing field of the PSD element 18. Limit detector 200 will generally require a larger photodiode sensing surface than photodiode 104. Fig. 6 illustrates a limit detector 300 which
5 utilizes a mirror 302 to reduce the necessary size of the photodiode 304. The mirror surface 302 is positioned relative to the photodiode 304 to effectively reflect the light rays which substantially miss the photodiode sensing area after being imaged by the receiver lens 16. Fig. 7 illustrates a
10 limit detector 400 which replaces the photodiode of the above embodiments with an incurvate mirror surface 402 positioned proximate to the outside (O) edge of the PSD element 18. The incurvate mirror surface 402 is oriented relative to the PSD element 18 so as to redirect the light rays which substantially
15 miss the active sensing area of the PSD element onto a spot near the edge of the active sensing area. As shown in Fig. 7, limit detector 400 does not provide a separate output L, but rather a substantially constant O and I output will be generated when a target object is at a distance inside the
20 optimal measuring range.

While the present invention is generally applicable to any optical distance measuring system such as used in autofocus cameras, the present invention is particularly advantageous when utilized in a vehicle occupant position
25 detection system. More specifically, the optical distance measuring system 100 is mounted to a fixed structure within a vehicle, such as an automobile dashboard, and is used by a vehicle crash discrimination system as a means for determining/monitoring the distance between a vehicle occupant
30 and the fixed structure within the vehicle. The distance measurement provides an indication of occupant position and is useful in enhancing deployment decisions for occupant safety restraint devices such as an air bag. The detection of occupant position can be used to warn occupants that they are
35 too close to an air bag or are otherwise in an unsafe seating condition, and/or as an input to the crash detection algorithm

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for disabling/adjusting air bag inflation profiles and/or determining optimal air bag firing times.

Because an occupant position sensing system inherently has a range over which accurate distance measurements can be made, such as $10 \text{ cm} \leq x \leq 100 \text{ cm}$, the limit detector of the present invention allows the system to distinguish between an occupant who is "too close" for accurate measurement (e.g., $x < 10 \text{ cm}$) and an occupant who is "too far" for accurate measurement (e.g., $x > 100 \text{ cm}$).

It is further noted that while the preferred embodiments have been described in connection with a PSD element, the limit detector teachings of the present invention are suitably applicable to optical distance measuring systems utilizing other sensing arrangements which rely on the imaging of returned light onto a sensor means. In this regard, it will be understood that the foregoing description of the preferred embodiment of the present invention is for illustrative purposes only, and that the various structural and operational features herein disclosed are susceptible to a number of modifications, none of which departs from the spirit and scope of the present invention as defined in the appended claims.

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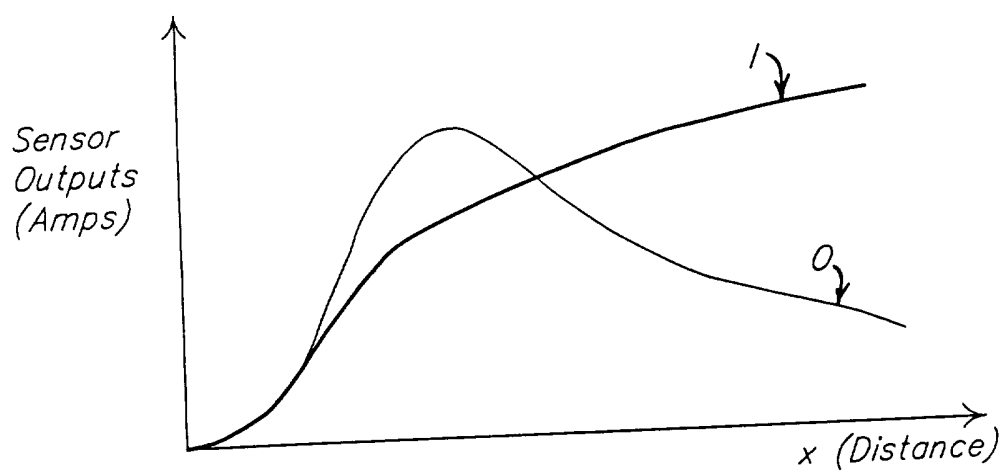
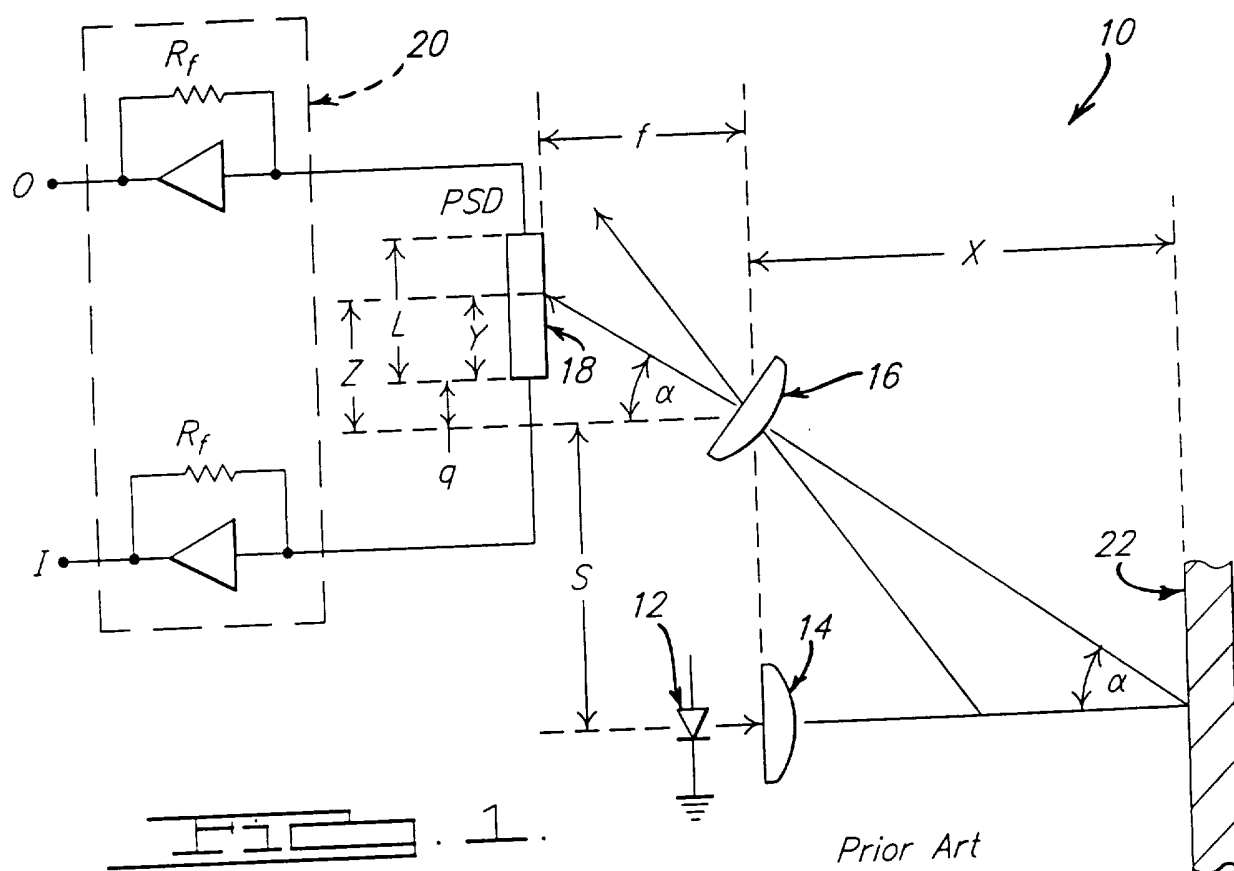
WE CLAIM:

1. An optical distance measuring system comprising:
an optical transmitter for directing a distancing light
beam at an object separated from said transmitter;
an optical receiver comprising a means for imaging onto a
sensing means the distancing light beam returning from
the object, said sensing means generating an output
which is a measure of the distance separating the
object and said transmitter; and
a limit detector means positioned proximate said sensor
means for generating an output responsive to the object
being located within a particular distance from said
transmitter.
2. The system of claim 1 wherein said limit detector
means is oriented relative to said sensing means to detect
returning light beams which substantially miss said sensing
means after being imaged by said imaging means.
3. The system of claim 1 wherein said limit detector
means comprises a photodiode element positioned adjacent said
sensing means.
4. The system of claim 3 wherein said photodiode element
is oriented to provide a limit detector sensing field which is
substantially perpendicular to a sensing field of said sensing
means.
5. The system of claim 3 wherein said photodiode element
is oriented to provide a limit detector sensing field
contiguous to a sensing field of said sensing means.
6. The system of claim 3 wherein said limit detector
means further comprises a mirror positioned relative to said
photodiode element to reflect returning light beams onto said
photodiode element.

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7. The system of claim 1 wherein said limit detector means comprises an incurvate mirror positioned relative to said sensing means to reflect returning light beams which substantially miss the sensing means onto a particular area of the sensing means.

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FI . .

Prior Art

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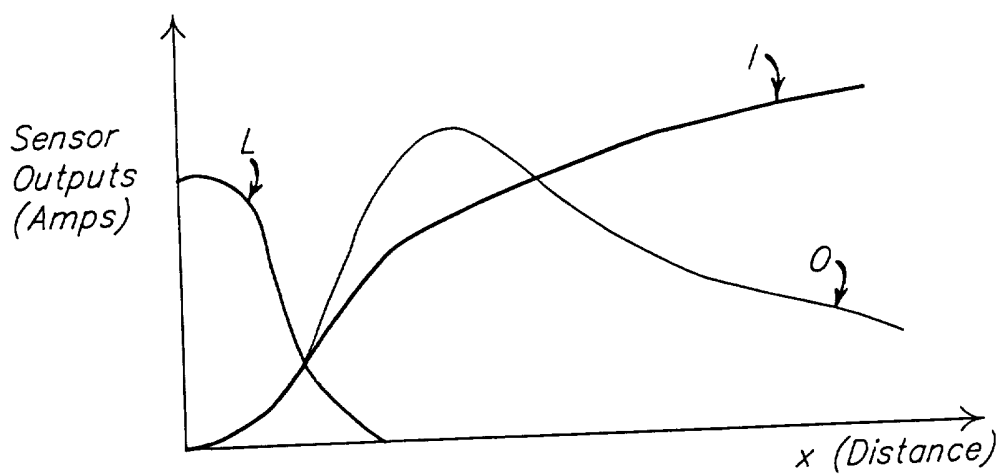
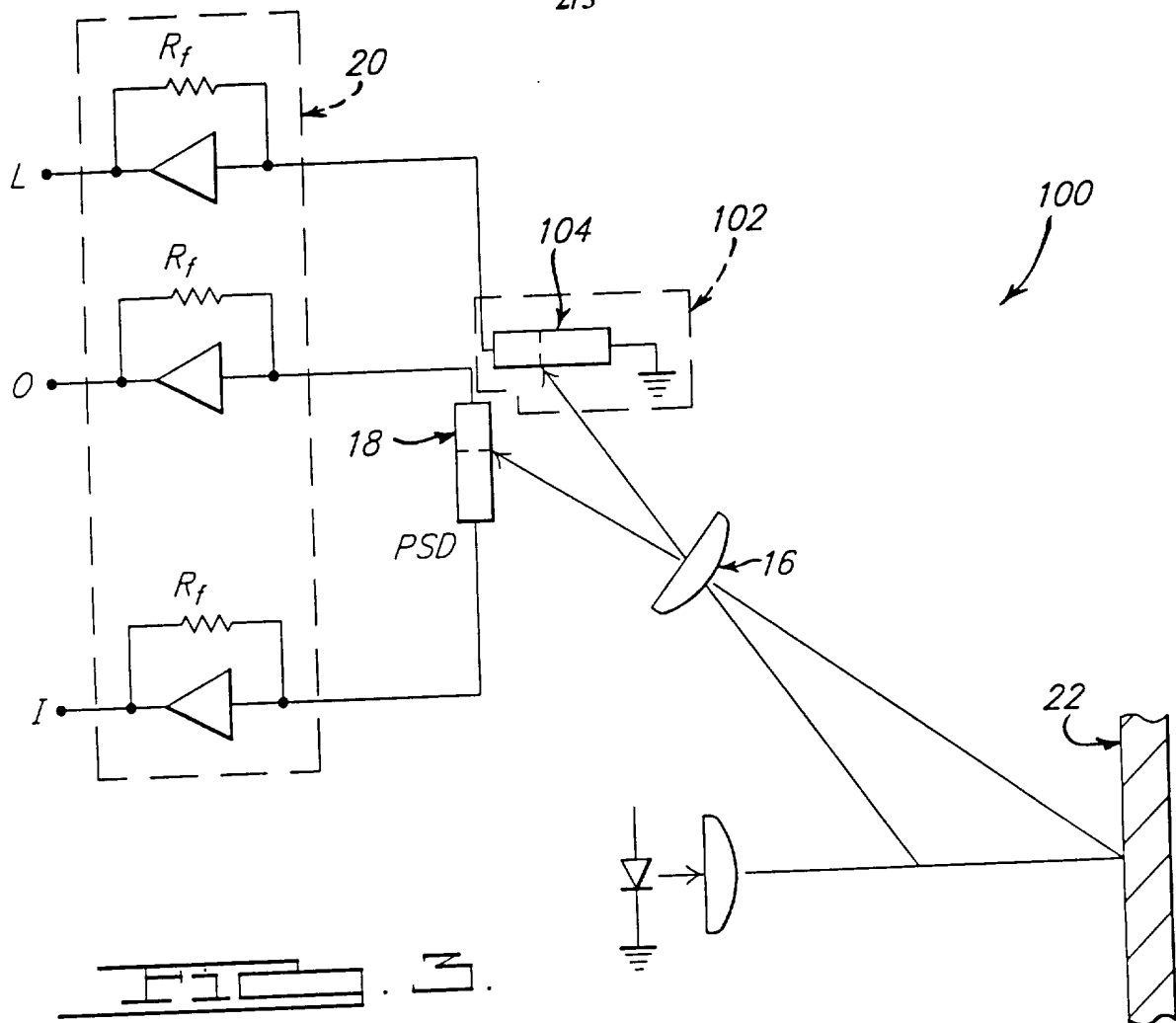
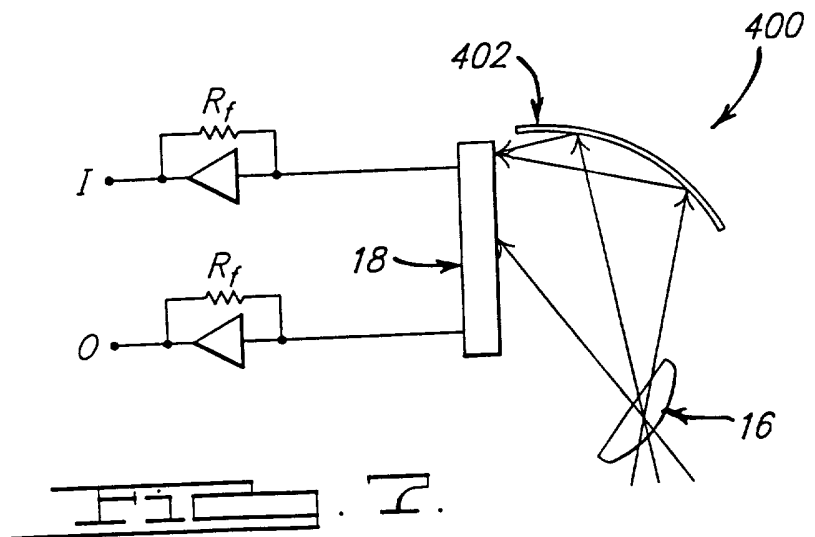
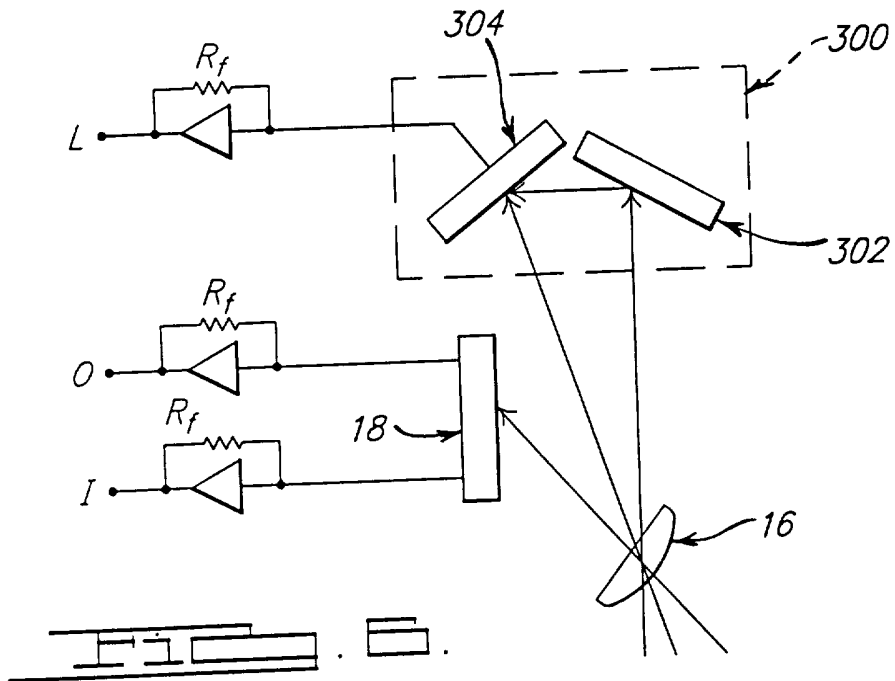
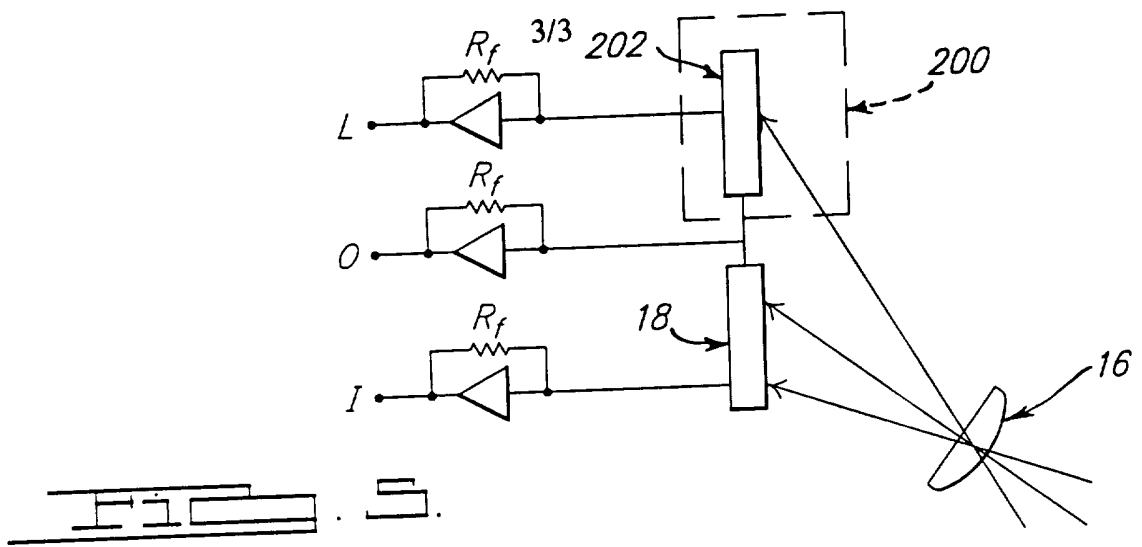


FIG. 4.



INTERNATIONAL SEARCH REPORT

Intern. application No.
PCT/US95/11353

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : G01C 3/00

US CL : 356/3.08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 356/3.08, 3.04; 250/201.6

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS
search term: distance

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US, A, 4,660,954 (FUJITA ET AL.) 28 April 1987, Figures 1-3 and column 3 lines 38-62.	1,2,3,5 ----- 1,4,6,7
X, P	US, A, 5,373,344 (KAKIUCHI) 13 December 1994, entire document, see especially Figure 1 and the abstract.	1-2
Y	US, A, 4,896,031 (PETTERSSON) 23 January 1990, Entire document: see the figures and the discussion in column 3 - particularly, at line 21.	1,4,6,7
A	US, A, 5,210,585 (SUZUKI) 11 May 1993.	
A	US, A, 4,829,172 (MILLER) 09 May 1989.	

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,529,304 [(OGAWA ET AL.) 16 June 1985.	
A	US, A, 3,736,057 (HARVEY) 29 May 1973.	
A	US, A, 5,235,377 (IDE ET AL.) 10 August 1993.	