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Svechnikov et al.

[11] **3,878,500**

[45] **Apr. 15, 1975**

[54] **PHOTORESISTIVE-POSITION-SENSITIVE INSTRUMENT**

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[52] **U.S. Cl.** **338/15**

[51] **Int. Cl.** **H01c 7/08**

[58] **Field of Search** .... 338/15; 250/211 R, 211 K

[56] **References Cited**

UNITED STATES PATENTS

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Primary Examiner—C. L. Albritton

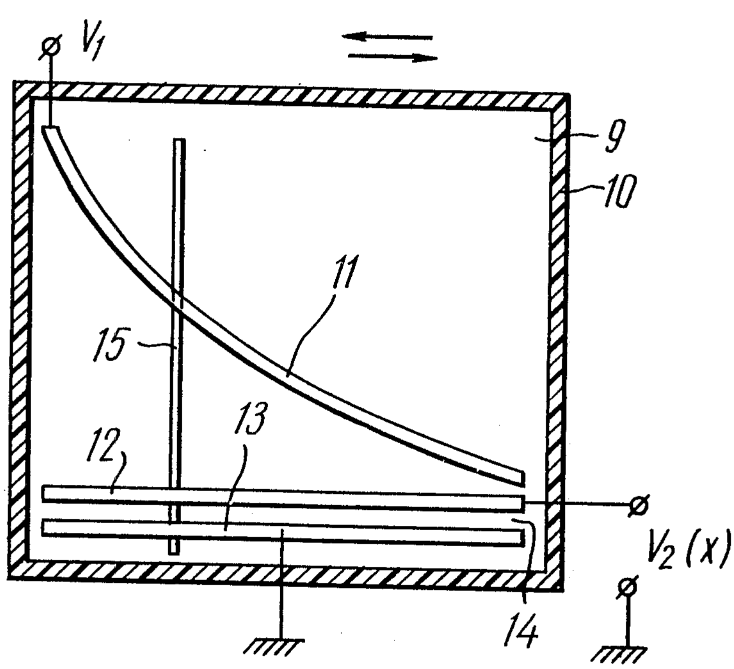
[57] **ABSTRACT**

The invention relates to photoresistive position-sensitive instruments.

A photoresistive position-sensitive instrument comprising a distributed resistive layer and an equipotential electrode, with a photoresistive layer disposed therebetween, and a movable light probe illuminating the region of the photoresistive layer, according to the invention, characterized in that it is provided with an additional electrode disposed in parallel to the equipotential electrode, between the additional and equipotential electrodes being disposed an additional layer of photoresistive material, the resistance of whose region illuminated by the movable light probe is the load output impedance.

The photoresistive position-sensitive instrument is primarily intended for use as a contactless analog of electromechanical potentiometers and rheostats, also, as a position pickup of sources of light of optical servo systems.

3 Claims, 5 Drawing Figures



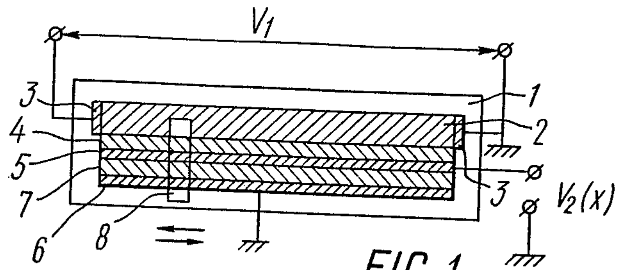


FIG. 1

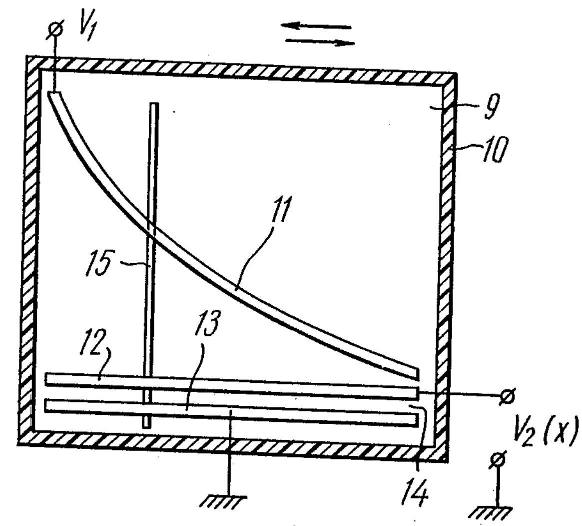


FIG. 2

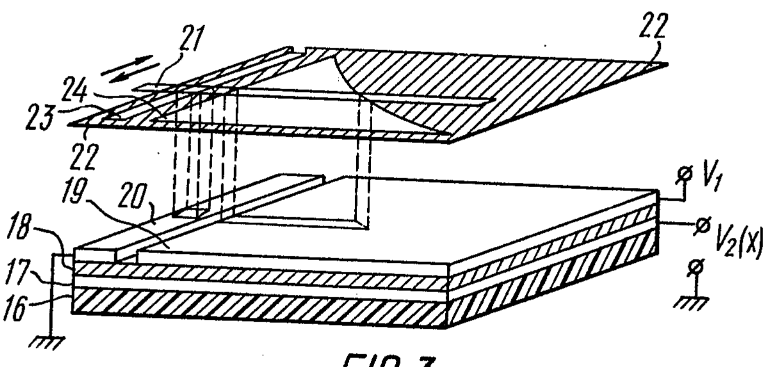


FIG. 3

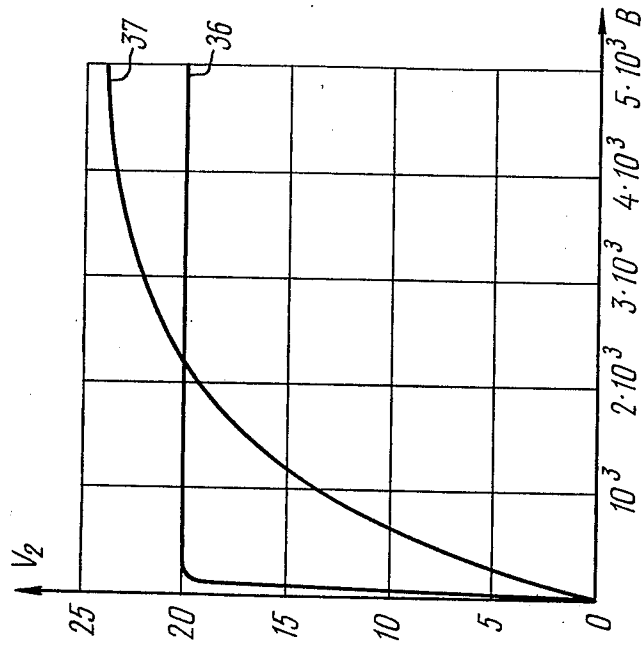

V2
B
36
37
0
5
10
15
20
25
10^3
2·10^3
3·10^3
4·10^3
5·10^3

FIG. 5

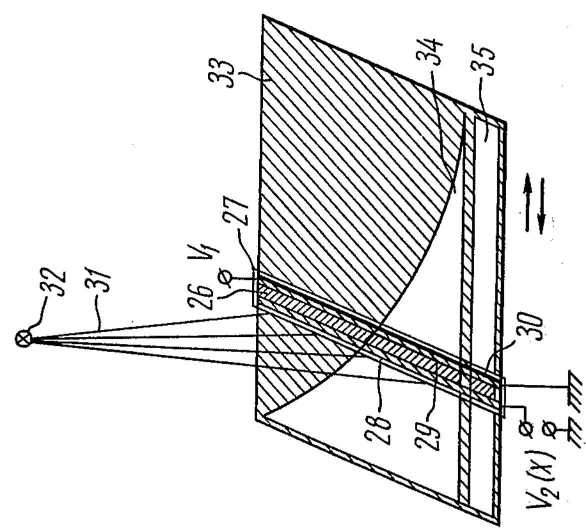

32
31
26
27
V1
28
29
30
33
34
35
V2(X)

FIG. 4

PHOTORESISTIVE-POSITION-SENSITIVE INSTRUMENT

The present invention relates to electric and photoelectric automation, and more specifically concerns photoresistive position-sensitive instruments used as contactless analogs of electromechanical potentiometers and rheostats, also, as position pickups of light sources of optical servo systems.

In most systems of measuring and computer techniques, in automatic controlling and regulating devices currently in use, functional voltage converters, i.e., instruments, whose output voltage changes according to a preset law, have gained a wide acceptance. Conventional functional converters are wire-wound or film-type electromechanical potentiometers having a profiled resistive element. However, a rubbing electric contact inherent in these instruments presents substantial difficulties in solving the problems associated with the increase of the service life, reliability and degree of protection against interference. Said disadvantage is markedly perceptible in up-to-date compound electronic and electrical measuring systems. Not infrequently, it is the service life term of potentiometers that determines the trouble-free operation of the system as a whole.

The presence of rubbing electrical contact elements becomes exceptionally undesirable in solving problems associated with a complex microminiaturization of control apparatuses. At present, anywhere near efficient microminiaturization of electromechanical converters cannot be achieved by a conventional means due to the limits imposed by the mechanical strength of structural elements. It is therefore of particular importance to apply novel principles of constructing functional converters free of rubbing electrical contacts.

Rapid development of optoelectronics, typical of modern stage of scientific and technical progress, makes possible to solve this problem. A distinguishing feature of optoelectronic functional converters is that they are made contactless, which removes any limitations inherent in electromechanical potentiometers. The optoelectronic principle on which the operation of optoelectronic functional converters is based makes possible not only to increase the service life of instruments, their reliability and degree of protection against interference, but offers a means for executing fundamentally new methods of functional conversion.

Incorporation of a photoconductive material in the structure of optoelectronic functional converters allows these instruments to be employed in a non-orthodox way, namely, as position-sensitive pickups of optical servo systems. These instruments exhibit high sensitivity to displacements of a source of light, a high level output signal excluding its further amplification and, last but not least, a required law of the output voltage change can be preset in constructing the pickup.

Known in the art are photoresistive position-sensitive instruments comprising a distributed resistive layer and an equipotential electrode, with a photoresistive layer disposed therebetween, and a movable light probe illuminating the photoresistive layer region. A photoelectric contact used therein instead of a sliding electrical contact makes possible to markedly improve the reliability and prolong the service life of the instrument. However, owing to the fact that the resistance of the photoresistive layer, which is a necessary structural element, is the function of intensity of illumination and temperature, any fluctuations of the latter parameters cause sharp variations of the output voltage. The principal requirement placed upon photoresistive position-sensitive instruments is thus infringed, namely, independence of the output voltage from fluctuations of the intensity of illumination of the light probe and ambient temperature and high sensitivity to relative displacements of the source of light.

In order to eliminate the influence of fluctuations of the intensity of illumination of the exciting light probe on the operation of photoresistive position-sensitive instruments, compensating circuits are used wherein the signal emitted by the photoresistive position-sensitive instrument furnishing information about the position of the source is compared with the signal produced by an additional photo-cell which does not exhibit position sensitivity and responds to a fluctuation of intensity of illumination of the light probe emitted by the source of light which is being tracked. However, the problems of temperature and time stabilization of the output voltage remain unsolved.

Yet another approach to the problem of improving the stability of photoresistive position-sensitive instruments lies in that an additional photocell furnishing information about the fluctuations of illumination intensity of the light source is included into a negative feedback controlling the magnitude of current passing through the source of light. This method of stabilization of the output voltage of photo-resistive position-sensitive instruments is appropriate only in the case when provision is made to control the intensity of illumination of the light source. In this case, as in the case hereinabove described, the temperature and the time stabilization of the output voltage is not provided. Common to both types of instruments described is the use of additional photocells and special devices for comparing and producing a difference signal, which is not conducive to circuit microminiaturization, being a disadvantage of photoresistive position-sensitive instruments known in the art.

It is an object of the present invention to provide a photoresistive position-sensitive instrument, wherein for effecting the stabilization of the output voltage no additional photocells, nor external comparison and difference signal initiating devices are required, and which would ensure improved stability of the output voltage of photoresistive position-sensitive instruments in the presence of fluctuations of the intensity of illumination, the width of the light region, the ambient temperature, and ensure the time stability of the output voltage.

This object is attained in that a photoresistive position-sensitive instrument comprising a distributed resistive layer and an equipotential electrode, with a photoresistive layer disposed therebetween, and a movable light probe illuminating a region of the photosensitive layer, according to the invention, is provided with an additional electrode disposed in parallel to the equipotential electrode, an additional layer of photoresistive material being disposed between the additional and equipotential electrodes, the resistance of the region there of illuminated by a movable light probe being the output load impedance.

It is expedient to provide the distributed resistive layer having a conductivity much higher than that of the illuminated photoresistive layer, the width of the photoresistive layer disposed between the distributed resistive layer and equipotential electrode being changed according to a preset law.

It is also advantageous to make the equipotential electrode transparent and to place on the path of the movable light probe an opaque mask having two transparent sections, the shape of one of the sections being determined by the law of the output voltage fluctuations, while the other is made in the form of a rectangular slit disposed so that it allows the light to pass onto an additional layer of the photoresistive material, whose resistance is the load output impedance.

Experimental tests of the claimed photoresistive position-sensitive instrument have shown the output voltage fluctuations with a fixed light probe to be within 1 percent, with fluctuations of intensity of light probe in the range of 200 to 5,000 lux; the width of light probe in the range of 0.2 to 4.0 mm; the ambient temperature within minus 85 to plus 80°C. The time stability has been increased more than three times. The maximum allowable speed of the light probe has been increased by one order. High resolution of the instrument (of the order of 5 microns) and substantially high dynamic voltage range (90 to 95 percent) have been thus preserved.

The invention will now be explained in greater detail with reference to embodiments thereof which are represented in the accompanying drawings, wherein:

FIG. 1 is a schematic representation of a photoresistive position-sensitive instrument, according to the invention, a cross-sectional view;

FIG. 2 is a schematic representation of a second embodiment of a photoresistive position-sensitive instrument, a cross-section;

FIG. 3 is a schematic representation of a third embodiment of a photoresistive position-sensitive instrument, a cross-section;

FIG. 4 is a schematic representation of a fourth embodiment of a photoresistive position-sensitive instrument, a cross-section;

FIG. 5 is a curve of output voltage vs illumination intensity of a region of movable light probe.

A photoresistive position-sensitive instrument comprises a dielectric substrate **1** (FIG. **1**) whereon is disposed a distributed resistive layer **2**, outfitted with two electrodes **3** with the aid of which voltage V_1 is supplied from an external source (not shown in the Figure) to said distributed resistive layer. In contact with the distributed resistive layer **2** is a photoresistive layer **4** outfitted with an equipotential electrode at the opposite end. Between an equipotential electrode **5** and an additional electrode **6** is disposed an additional layer **7** of photoresistive material, whose region illuminated by a movable light probe **8** is the output impedance of the load.

A second embodiment of the photoresistive position-sensitive instrument is presented in FIG. **2**. The instrument comprises a photoresistive layer **9** deposited on a dielectric substrate **10**, a distributed resistive layer **11** and an equipotential electrode **12**. In parallel to the equipotential electrode **12** is disposed an additional electrode **13**, with an additional layer **14** of photoresistive material disposed therebetween, whose region illuminated by a movable light probe **15** serves as the load output impedance.

The distributed resistive layer **11** has a conductivity coefficient considerably higher than that of the illuminated section of the photoresistive layer **9**. The distance between the distributed resistive layer **11** and the equipotential electrode **12** is altered along the instrument according to a preset law.

A third embodiment of the photoresistive position-sensitive instrument is presented in FIG. **3**. The instrument comprises a dielectric substrate **16** whereon successively disposed are a distributed resistive layer **17**, a layer of photo-resistive material **18**, a transparent equipotential electrode **19** and an additional electrode **20**. The distributed resistive layer **17** has a conductivity coefficient much higher than that of the illuminated photoresistive layer **18**. On the path of a movable light probe **21** is placed an opaque mask **22** having two transparent sections **23** and **24**. The shape of the transparent section **24** is determined by a preset law of output voltage $V_2(x)$ fluctuations. The transparent section **23** of the opaque mask **22** has a shape of a rectangular slit, whose geometric dimensions are determined by the required value of load resistance, whose functions in the present embodiment of photoresistive position-sensitive instrument are performed by an additional layer of photoresistive material disposed between the transparent additional electrode **20** and the distributed resistive layer **17** and illuminated by the light probe **21**.

A fourth embodiment of the photoresistive position-sensitive instrument is presented in FIG. **4**. The instrument comprises a layer of photoresistive material **26**, disposed on a dielectric substrate **27**. The photoresistive material layer **26** is contained between an equipotential electrode **28**, a resistive layer **29** and an additional electrode **30**. As in the embodiments of photoresistive position-sensitive instrument described hereinabove, the conductivity of the distributed resistive layer **29** is much higher than that of the illuminated photoresistive layer **26**. A narrow light probe **31** is formed by a source of light **32** and a collimator (not shown in the Figure). On the path of the light probe **31** is placed an opaque mask **33** having two transparent sections **34** and **35**. The shape of the transparent section **34** is determined by a preset law of output voltage $V_2(x)$ fluctuations. The transparent section **35** of the opaque mask **33** has a shape of a rectangular slit, whose width is determined by the required value of load resistance, the function of which is performed by the illuminated section of the photoresistive material layer **26** contained between the equipotential electrode **28** and the additional electrode **30**.

FIG. **5** illustrates the curves of output voltage versus intensity of illumination of the region of a movable light probe in the claimed photoresistive position-sensitive instrument (curve **36**) and in the known instrument (curve **37**).

The photoresistive position-sensitive instrument hereinabove described operates as follows. An external voltage source (not shown in the Figure) produces a distribution of potential on the resistive layer **2** (FIG. **1**), determined by the shape of said resistive layer **2**. The distributed resistive layer **2** is square-shaped, owing to which the potential is distributed according to the linear law, thus ensuring linear fluctuations of the output voltage $V_2(x)$. In case of the law of output voltage fluctuations being other than linear, the distributed resistive layer **2** should be made profiled in width, employing known methods therefor. The photoresistive material layer **4** in the opaque regions of the instrument possesses high resistance and reliably insulates the distributed resistive layer 2 from the equipotential electrode 5. The resistance in the region of the light probe 8 drops sharply, allowing the current from the distributed resistive layer 2 to flow to the equipotential electrode 5, through the illuminated region of the additional layer 7 of photoresistive material contained between the equipotential electrode 5 and additional electrode 6 to the earth. On the illuminated region of the additional layer 7 of photoresistive material is produced a drop of voltage $V_2(x)$ which is the output voltage of photoresistive position-sensitive instrument. With the displacement of the light probe 8 along the photoresistive position-sensitive instrument towards the equipotential electrode 5, points of different polarities of the distributed resistive layer 2 are connected. This causes the current flowing along the illuminated section of the additional layer 7 of photoresistive material, and hence the amplitude of output voltage $V_2(x)$, to change.

The output voltage of photoresistive position-sensitive instrument with $R_\phi << R_{\phi\,n}$ and $R_n << R_H$ (R_ϕ and $R_{\phi\,n}$) are resistances of illuminated and opaque regions of the photoresistive material layer 4, R_n is the resistance of the distributed resistive layer 2, R_H is the load resistance) is determined by the following equation:

$$V_2(x) = V_1 \cdot \frac{1 - \frac{x}{L}}{1 + \frac{R_\Phi}{R_H}}$$

where x is the center of the light probe region; L is the length of photoresistive position-sensitive instrument.

As can be seen from the equation, with a constant value of load resistance R_H, the variation of resistance value R_H of the illuminated section of the photoresistive layer 4, which takes place at variations of ambient temperature and intensity of illumination of the light probe 8, results in the variation of amplitude of the output voltage $V_2(x)$. In the photoresistive position-sensitive instrument hereinabove described the load impedance is the illuminated area of the additional layer 7 of photoresistive material possessing the same luxampere, temperature and time characteristics of the photoflux as the photoresistive material layer 4. This is achieved by depositing said layers 4 and 7 during the same process cycle. Owing to similarity of characteristics of the layers 4 and 7 the ratio R_ϕ to R_H, and hence, the amplitude of the output voltage $V_2(x)$ remain constant within a wide range of fluctuations of illumination intensity of the light probe 8, its width and ambient temperature.

The photoresistive position-sensitive instrument illustrated in FIG. 2 operates as follows. Electric current passes from an external voltage source V_1 over low-resistance distributed resistive layer 1, over a limited region of the photoresistive material layer 9 illuminated by the movable light probe 15, through the equipotential electrode 12 and a limited region of the additional layer 14 of photoresistive material illuminated by the movable light probe, the region being contained between the equipotential electrode 12 and the additional electrode 13 and further to earth.

As a result, a voltage $V_2(x)$ being the output voltage of the instrument, is derived from the resistance of the section of the illuminated additional layer 14 of photoresistive material contained between the equipotential electrode 12 and additional electrode 13, serving as the load impedance.

Owing to high resistance of opaque regions of the layers 9 and 14 of photoresistive material, practically no current flows along them. The intensity of current flowing through the photoresistive position-sensitive instrument depends on resistances of the illuminated sections of the layers 9 and 14 of photoresistive material, contained between the distributed resistive layer 11 and equipotential electrode 12, also, between the equipotential electrode 12 and additional electrode 13. Since the width of the layer 9 of photoresistive material contained between the distributed resistive layer 11 and equipotential electrode 12 is variable, the displacement of the light probe 15 along the instrument (the direction being shown by arrows in the Figure), between the distributed resistive layer 11 and equipotential electrode 12 results in the sections of the layer 9 of photoresistive material of various width, and hence, resistance, illuminated by the movable light probe 15 becoming connected. This causes the current flowing through the photoresistive position-sensitive instrument, and hence, the output voltage $V_2(x)$ to change.

The output voltage is determined, with $R_\phi << R_{\phi\,n}$ by the following equation:

$$V_2(x) = \frac{V_1}{1 + \frac{R_\Phi(x)}{R_H}}$$

where $R_\phi(x)$ and R_H are resistances of regions of the layers 9 and 14 of photoresistive material illuminated by the movable light probe 15 and disposed between the distributed resistive layer 11 and equipotential electrode 12 and between the equipotential electrode 12 and equipotential electrode 14 and additional electrode 13. Since $R_\phi(x)$ and R_H possess similar luxampere, temperature and time characteristics of the photoflux, a change in the intensity of illumination and the width of the light probe 15, and also of the ambient temperature, does not affect the amplitude of the output voltage $V_2(x)$. High sensitivity of the photoresistive position-sensitive instrument to displacements of the light probe 15 is thus preserved.

What is claimed is:

1. A photoresistive position-sensitive instrument comprising: a distributed resistive layer; an equipotential electrode; a photoresistive layer disposed between said distributed resistive layer and said equipotential electrode; a movable light probe illuminating a region of said photoresistive layer an additional electrode disposed in parallel to said equipotential electrode; an additional layer of photoresistive material disposed between said additional electrode and said equipotential electrode, the resistance of whose region illuminated by the movable light probe serves as the load output impedance; the intensity of said light probe and the environmental temperature being measurable by said instrument.

2. An instrument as claimed in claim 1, comprising said equipotential electrode, made transparent; an opaque mask having two transparent sections; the first said transparent section having a shape determined by

the law of output voltage fluctuations; the second said transparent section having the shape of a rectangular slit disposed so as to allow illumination to pass to the additional layer of photoresistive material, whose resistance serves as the load output impedance.

3. A photoresistive position-sensitive instrument as claimed in claim **1**, wherein said distributed resistive layer has a conductivity coefficient substantially higher than that of photoresistive layer when illuminated, the width of said photoresistive layer disposed between said distributed resistive layer and said equipotential electrode changing according to a preset law.

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