March 19, 1968 MASAKAZU EJIRI ETAL 3,374,477

SHAFT POSITION DIGITIZER

Filed July 7, 1964

FIG. 1

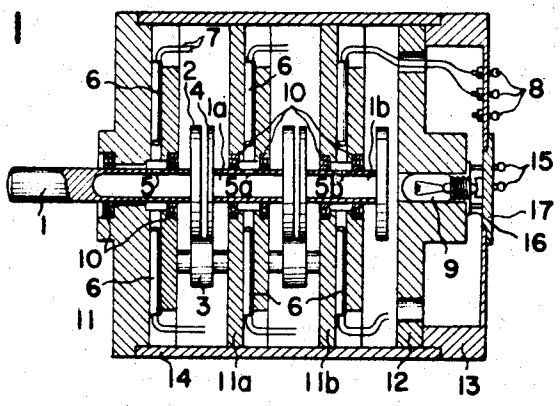


FIG. 2a

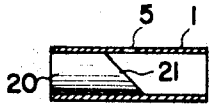


FIG. 2b

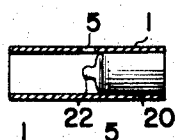


FIG. 2c

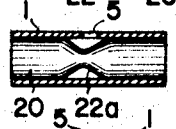


FIG. 2d

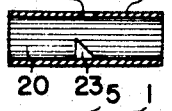


FIG. 2e

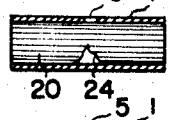


FIG. 2f

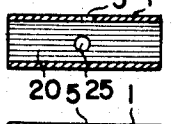
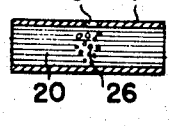


FIG. 2g



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SHAFT POSITION DIGITIZER

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8 Claims. (Cl. 340—347)

ABSTRACT OF THE DISCLOSURE

A shaft position digitizer wherein a plurality of hollow shafts is disposed along the same center line; each of these shafts is hollow and connected continuously or intermittently by reduction gears; light from a single stationary source is conducted through the interior of the shaft which is in correct position; and a number of photosensitive elements is disposed around the shaft at given distances; a rotational angle corresponding to a mechanical displacement to be digitized is imparted to one shaft. The device is suited for miniaturization.

This invention relates to a new shaft position digitizer of non-contact type which has no sliding or wiping parts such as brushes.

Heretofore, in the digitizing of mechanical displacements, it has been the common practice to change the displacements into rotary motion and, with the use of a decimal coder plate or a binary coded decimal coder plate and a brush, to obtain digital signals by rotating either of the two parts and fixing the other. This method, however, has had the disadvantage of short life of the parts because of the wear of the sliding parts.

In an attempt to eliminate this disadvantage, there has been proposed a counter type device wherein a disk provided with slits is rotated, light passed through these slits is received by a photosensitive element such as a phototransistor, and the resulting pulses are counted. Such a device, however, is disadvantageous in that the correct digitized output is lost upon recovery from a power failure and in that accumulated errors due to miscounting occur.

It is a general object of the present invention to overcome the above mentioned difficulties.

More specifically, it is an object to provide a shaft position digitizer without sliding parts, capable of high-speed operation, wherein the optical system need not be one of high precision, and, without resetting after power failure, correct signals corresponding to present positions are generated.

It is a further object to provide a digitizer of the above stated character which has a relatively simple construction and operation, requires simple maintenance procedure, and, moreover, can be miniaturized even when made for a large number of digits.

Briefly described, the invention resides in a shaft position digitizer wherein: a plural number, m of hollow shafts each having one hole and all connected by continuous or intermittent reduction gears of $1/n$ reduction ratio are coaxially disposed along the same centerline; light is passed through the hollow shaft interior; a number n of photosensitive elements are provided around each shaft at positions corresponding to n equal divisions of the periphery; and to one shaft, the rotational angle corresponding to a mechanical displacement to be digitized is imparted, thereby to digitize the displacement into m digits in the scale of n.

The nature, principle, and details of the invention will

be more clearly apparent by reference to the following description with respect to preferred embodiments of the invention, taken in conjunction with the accompanying drawing in which like parts are designated by like reference characters, and in which:

FIGURE 1 is a sectional view, taken along a plane through the axis of the shafts, showing one embodiment of the invention; and

FIGURES 2(a)–2(g) consist of axial sectional views showing various examples of an essential part of the device shown in FIGURE 1.

The embodiment of the digitizer according to the invention shown in FIGURE 1 illustrates the case of its application to decimal three digits. The digitizer is provided with three (m in the case of m digits) hollow shafts **1**, $\mathbf{1}_a$, and $\mathbf{1}_b$ arranged coaxially on the same centerline and respectively having small holes **5**, $\mathbf{5}_a$, and $\mathbf{5}_b$ on certain parts thereof.

The rotational angle corresponding to a mechanical displacement is applied to the shaft **1**, the rotation of which is transmitted through reduction gears **2**, **3**, and **4** (shown in diagrammatic form) and reduced in speed by the ratio 1/10 ($1/n$ in the case of a scale of n) to rotate the shaft $\mathbf{1}_a$. The rotation is further reduced by the ratio 1/10 to rotate the shaft $\mathbf{1}_b$.

In the plane which is perpendicular to the shaft centerline and passes through each of the holes **5**, $\mathbf{5}_a$, and $\mathbf{5}_b$ and in radial arrangement, there are provided 10 photosensitive elements **6** such as phototransistors in circumferential positions corresponding to 10 equal divisions (n equal divisions in the case of a scale of n) about the respective shaft. The photosensitive elements **6** are adapted to receive light projected from a light source **9** through the hole in the respective shaft and are provided with leads **7** and output terminals **8**. In the example shown, the light source is in the form of a lamp **9** fitted into a socket **16** to which terminals **15** are connected.

The aforementioned hollow shafts **1**, $\mathbf{1}_a$, and $\mathbf{1}_b$ are supported rotatably on bearings **10**, which in turn are supported at the centers of supports **11**, $\mathbf{11}_a$, and $\mathbf{11}_b$ for the photosensitive elements **6**. The supports **11**, $\mathbf{11}_a$, and $\mathbf{11}_b$, a lamp holder **12**, a terminal plate **13**, and a cover **14** in combination form the rigid structure of the device. A socket holder **17** is fitted in a freely attachable and detachable manner onto the terminal plate **13**.

By the above described arrangement and construction, one phototransistor for each digit is illuminated in accordance with the rotational angle of the respective hollow shaft, said angle corresponding to a mechanical displacement, and a digital output signal is obtained through the corresponding terminal **8**.

For causing the light from the light source **9** to be scattered or be reflected and to be directed outwardly through the holes **5**, $\mathbf{5}_a$, and $\mathbf{5}_b$, the inner surfaces of the hollow shafts can be provided with various means for this purpose. For example, the inner surfaces of the hollow shafts may be coated with a paint which scatters light well, or they may be plated.

If said photosensitive elements do not receive enough light by the above described measures, particularly for a large number m of the digits, the measures indicated in FIGURES 2(a)–2(g) may be resorted to. That is, a transparent material **20** such as glass, polystyrene, or polymethyl methacrylate resin in cylindrical form of any of the various shapes shown is inserted in the hollow shafts. In the example illustrated in FIGURE 2(a), the transparent cylinder **20** is cut at an angle of 45 degrees to form a prism face **21** whereby a part of the incident light which comes from the said light source directly or through the previous stage is reflected toward the hole **5** and the remainder of the light is permitted to pass axially through

the cylinder **20** to the next stage, this type of cylinder being inserted in the shaft of each stage. By the methods indicated in FIGURES 2(*b*) and 2(*c*), the end part **22** and the middle part 22_a of the transparent cylinder **20** are necked or made narrow so as to utilize the resulting concentration of light at these narrowed parts. By the methods indicated in FIGURES 2(*d*) and 2(*e*), cutouts or notches **23** and **24** are provided in the transparent material **20**, and the total reflection and irregular reflection are utilized. By the methods indicated in FIGURES 2(*f*) and 2(*g*), a hole **25** and bubbles **26** are formed in the central part of the transparent material **20**, and the total reflection and irregular reflection are utilized.

By these methods, the reflection and light transmission occurring when light enters a transparent material from air or the total reflection and irregular reflection occuring when light leaves a transparent material and enters air are utilized to increase the light intensity only in the vicinity of the shaft hole **5**. By using any of the above described means in the digitizer shown in FIGURE 1, it is possible to extract with a high degree of accuracy and reliability the rotational positions of the hollow shafts as digital quantities.

The shaft position digitizer of the present invention has various advantageous features as is apparent from the foregoing disclosure. For example, since there are no sliding or wiping parts, the digitizer has a long serviceable life and can be used for high-speed operation. Furthermore, since the light from the light source is not required to be in the form of a parallel beam, a precision optical system is not required, and even when the digitized output is lost in the event of power failure, digitized signals of correct correspondence to the present positions can be generated upon recovery from the power failure.

A further advantage of this digitizer is that the construction and operation are simple, and repair and maintenance thereof are facilitated. Moreover, the construction can be readily adapted to operate wtih any number of digits, and miniaturization can be maintained even with a considerable increase in the number of digits.

It should be understood, of course, that the foregoing disclosure relates to only a preferred embodiment of the invention with representative examples of an essential part thereof and that the disclosure is intended to cover all changes and modifications of the examples of the invention herein chosen for the purposes of the disclosure, which do not constitute departures from the spirit and scope of the invention as set forth in the appended claims.

We claim:

1. A digitizer of *m* digits in the scale of *n* comprising a number *m* of hollow shafts coaxially alined on one centerline, each hollow shaft having one through hole through its wall, a continuous speed reduction mechanism of $1/n$ reduction ratio intercoupling each shaft with its adjacently succeeding shaft, means to project light from a single stationary source outwardly through each said through hole, a number *n* of photosensitive elements disposed circumferentially about each hollow shaft at *n* positions equally spaced in angle, and adapted to sense said light outwardly projected, and means to cause at least one of the hollow shafts to rotate in response to a mechanical displacement to be digitized.

2. A digitizer of *m* digits in the scale of *n* comprising a number *m* of hollow shafts coaxilly alined on one centerline, each hollow shaft having one through hole through its wall, an intermittent speed reduction mechanism of $1/n$ reduction ratio intercoupling each shaft with its adjacently succeeding shaft, means to project light from a single stationary source outwardly through each said through hole, a number *n* of photosensitive elements disposed circumferentially about each hollow shaft at *n* positions equally spaced in angle, and adapted to sense said light outwardly projected, and means to

cause at least one of the hollow shafts to rotate in response to a mechanical displacement to be digitized.

3. The digitizer according to claim **1** wherein the inner surfaces of the hollow shafts are coated with a substance selected from the group consisting of metals assuming highly reflective surfaces and paints having good light scattering property.

4. The digitizer according to claim **2** wherein the inner surfaces of the hollow shafts are coated with a substance selected from the group consisting of metals assuming highly reflective surfaces and paints having good light scattering property.

5. The digitizer according to claim **1** wherein said means to project light outwardly through said through holes comprises a single stationary light source adapted to project light along the hollow interiors of the hollow shafts and a transparent member inserted in each of the hollow shafts, each transparent member having in its region in the vicinity of the through hole of its respective shaft a geometrically irregular part adapted to cause a portion of the said light to be directed outwardly through said hole.

6. The digitizer according to claim **2** wherein said means to project light outwardly through said through holes comprises a single stationary light source adapted to project light along the hollow interiors of the hollow shafts and a transparent member inserted in each of the hollow shafts, each transparent member having in its region in the vicinity of the through hole of its respective shaft a geometrically irregular part adapted to cause a portion of the said light to be directed outwardly through said hole.

7. The digitizer according to claim **5** wherein each transparent member is a transparent cylinder fully occupying the interior of the respective shaft in the vicinity of its through hole, and the geometrically irregular part of the cylinder is selected from the group consisting of: a prism face formed on the light source end of the cylinder by cutting the cylinder along a plane at an angle of 45 degrees relative to the shaft centerline; a necked or narrowed part formed at the central port of the cylinder; a protruding part formed at the end of the cylinder away from the light source; a cutout or notch formed in the side of the cylinder; a hole through the cylinder in its central part; and air bubbles formed in the central part of the cylinder.

8. The digitizer according to claim **6** wherein each transparent member is a transparent cylinder fully occupying the interior of the respective shaft in the vicinity of its through hole, and the geometrically irregular part of the cylinder is selected from the group consisting of: a prism face formed on the light source end of the cylinder by cutting the cylinder along a plane at an angle of 45 degrees relative to the shaft centerline; a necked or narrowed part formed at the central part of the cylinder; a protruding part formed at the end of the cylinder away from the light source; a cutout or notch formed in the side of the cylinder; a hole through the cylinder in its central part; and air bubbles formed in the central part of the cylinder.

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