Description

This invention relates to position sensors or encoders such as an optical shaft angle encoder which produces electrical signals indicative of the angular position of the shaft. In particular, it relates to an encoder that provides a unique signal so that the position can be determined absolutely, rather than by reference to distance traveled from an index point or the like.

Incremental optical motion encoders are used to resolve the position and movement of an object along a particular route. Such encoders generally include a light source for emitting a light beam, light modulation means for modulating the light beam in response to movement of the object along the route, and a detector assembly for receiving the modulated light and producing electrical signals indicating the amount of light received by the detectors. The electrical signals from the detectors can be used to indicate the change in location of the object along the route. Multiple detectors are used to indicate both change in location and direction of movement.

Generally speaking, for an incremental motion encoder to produce an indication of the absolute position or location of the object its route, an index pulse is generated at least once along the route. Thereafter, incremental signals can be used to count incremental movement from the index pulse. When the position of the object is known at the index pulse, the absolute position of the object at any place along the route can be determined. To provide an indication of absolute position, change in location and direction of movement, an incremental encoder generally requires three channels of information. Two channels are derived from two or more out-of-phase encoder signals that are produced throughout the route of the object, and the third is an index signal that is produced at least once along the route and at a known position.

In an exemplary embodiment, such a position encoder or movement detector may be used for measuring the angular position of a shaft. Depending on the use of such a shaft angle encoder, a high degree of resolution and accuracy may be needed. It is not unusual to specify a resolution of 2,000 increments per revolution of the shaft. Accuracy of the correlation between the signal from the encoder and the actual mechanical position of the shaft or other object is also important. Mechanical alignment discrepancies in assembling apparatus can adversely affect accuracy. This may be particularly true where the information, i.e., the position track and the index track, are physically separated from each other. In a shaft angle encoder, the center of each of these tracks must be concentric to a high degree to obtain the desired accuracy.

JP-A-59/226,822 discloses a rotational position detector which includes a rotatable disc having a series of radial slits therein around the disc. The length of the slits varies around the disc so as to produce a sinusoidal detection signal from which the rotational position of the disc can be determined.

EP-A-0143525 discloses a rotational position detector which includes a rotatable disc having a series of identical radial slits around the disc. A photodetector is formed of a plurality of adjacent detector cells having varying lengths so as to provide an oval envelope. The cells are coupled together in two sets which create equivalent but phaseshifted signals used to sense movement of the disc.

It is desirable to provide an absolute encoder having a single track for position information. Absolute encoders are known, but are quite expensive.

In a conventional shaft angle encoder where position is obtained by reference to an index location, it is necessary upon "wake-up" of the instrument to search for the index so that absolute position can be determined. It is desirable to have a shaft angle encoder where absolute position can be determined immediately when the encoder is turned on. Thus, it is not necessary to rotate the shaft to find the index so that incremental counts can be made from the index.

The present invention seeks to provide an improved optical encoder.

According to an aspect of the present invention, there is provided an optical encoder as specified in claim 1.

Thus, there is provided in practice of this invention according to a presently preferred embodiment, an optical encoder having a data track with a multiplicity of windows and opaque spaces between the windows. Each of the windows has a selected area from a set of areas which are distinguishable from each other. The areas of successive windows are in a predetermined sequence along the track. An array of photodetectors adjacent to the track spans a plurality of the windows, so that each photodetector is successively aligned or not aligned with a window during relative movement between the windows and photodetectors. Means are provided for illuminating the photodetectors through the windows and for determining the position of the windows relative to the photodetectors in response to the magnitude of illumination of each of the photodetectors.

Preferably, each window and each space between adjacent windows has the same width. A second array of photodetectors is interleaved between the photodetectors in the first array, and each of the photodetectors has the same width as a window or space. A set of selection photodetectors at an end of the array of data photodetectors is used for selecting photodetectors to. be read. Each of the selection photodetectors has half of the width of a window or space. It is convenient to have the areas of the window differ by powers of n where n can be an integer or non-integer number for generating binary digital output signals. In an exemplary embodiment, the areas of the windows differ by powers of two.

These and other features and advantages of the present invention will be appreciated as the same becomes better

understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. 1 illustrates schematically an exemplary shaft angle encoder suitable for practice of this invention;
FIG. 2 is a fragmentary cross section transverse to the code wheel of the shaft angle encoder;
FIG. 3 is a schematic illustration of an exemplary pattern of windows and photodetectors for an encoder;
FIG. 4 is a schematic illustration of windows superimposed over photodetectors;
FIG. 5 is a schematic block diagram of the electrical portion of the encoder;
FIG. 6 is a schematic illustration of photodetector connections when windows are superimposed as illustrated in FIG. 4; and
FIG. 7 is a schematic illustration similar to FIG. 6 for a different superposition of windows and photodetectors.

An exemplary shaft angle encoder has a code wheel 10 mounted on a shaft 11 for rotation between a light source 12 and a suitable array of photodetectors 13 for measuring light intensity transmitted through the code-wheel. These structures are illustrated schematically since details of construction and assembly are largely immaterial and are well known to those skilled in the art.

It will also be apparent as the disclosure is considered that the invention is not limited to an angle encoder. It is also applicable to a position encoder where there is a linear track rather than a circular track. For that matter, a linear track could be considered as a limiting case of a circular data track with an infinite radius. It is, however, convenient for purposes of the specification and claims in this application to refer to the invention in a context of an angle encoder.

The light source may, for example, comprise one or more light-emitting diodes selected for a desired wavelength of radiation. When more than one LED is used, care should be taken to assure that the illumination from the several LEDs is uniform. A lens may be used for collimating light from the source for illuminating one face of the code wheel. Typically, the photodetectors are photodiodes formed as areas on an integrated circuit chip including other electronic components for processing the signals from the photodetectors.

The code wheel may be made of an opaque material with openings for windows, or of a transparent material metallized or otherwise coated to make selected areas opaque. Alternatively, the invention may employ a code wheel with reflective and nonreflective areas, with the light source and light detectors adjacent to the same face of the code wheel. For convenience in exposition, areas that transmit or reflect light are referred to as windows, and the spaces therebetween, which are opaque or non-reflective, are referred to as spaces, bars or spokes.

In a preferred embodiment as illustrated in FIGS. 1 to 3, the code wheel has a circumferentially extending data track or code track 14 having alternating transparent windows 16 and opaque spokes 17. A plurality of such windows extending along the length of the data track as illustrated schematically in the upper portion of FIG. 3, with each of the rectangular areas indicating a window 16. The spaces 17 between adjacent windows are opaque. In the lower portion of FIG. 3, a plurality of photodetectors numbered 1 through 9 are illustrated. It will be apparent that such windows, spaces and photodetectors in a shaft angle encoder are actually trapezoidal instead of rectangular as illustrated. Also, the windows are superimposed over the photodetectors in the encoder. This schematic illustration with the windows offset from the photodetectors is used for convenience and clarity.

Each of the windows of the shaft angle encoder has the same width along the data track as the spaces between adjacent windows. Similarly, each of the data photodetectors 1 to 9 has the same width as a window or space. Thus, when the windows are aligned with the photodetectors as indicated in the two halves of FIG. 3, the odd numbered photodetectors would each be illuminated through a window, and the even numbered photodetectors would be fully occulted by a spoke between the windows.

Each of the windows has a length transverse to the data track selected from a small set of lengths. In the embodiment illustrated, there are four lengths in the set differing from each other by powers of two. Thus, the areas of the windows differ from each other by powers of two. Some of the windows have a length or area of 1X units (2^0); some have a length or area of 2X units (2^1); some have a length or area of 4X units (2^2); and some have a length or area of 8X units (2^3).

It is desirable that the windows in a set differ from each other by powers of two, since this is easily converted to a binary digital number. Other ratios of window areas may be used, so long as the illumination through the windows can be distinguished by the photodetectors and converted to distinct digital numbers.

The windows are located in the data track so that the center of each window is at the same radius from the center of the code wheel. This is done since the windows are trapezoidal in a circular wheel instead of rectangular as illustrated schematically in FIG. 3, and the areas thereby have the same relative proportions as the lengths of the windows. The illumination through the windows should be uniform in the radial as well as the circumferential direction.

A reference photodetector 18 is located at the same radial distance from the center of the encoder and at one end of the array of data photodetectors 1 to 9. The reference photodetector has a "width" along the direction of the data track twice the width of a window or space between windows. Thus, regardless of the alignment of the windows and photodetectors, the reference photodetector is illuminated through the entire width of a window. This illumination may be

through one window, or through parts of two adjacent windows. The "length" of the reference photodetector in the transverse direction across the data track is somewhat less than the length of the smallest of the windows, or 1X units. Thus, regardless of whether the reference photodiode is illuminated through a 1X window or an 8X window, it receives the same illumination. The length is less than a 1X window so that if there is some misalignment or non-concentricity, the reference photodetector is fully illuminated through a 1X window. This provides somewhat greater tolerance in manufacture and assembly than if the reference photodetector were the same length as the smallest windows.

Each of the data photodetectors has a length in the radial direction corresponding to the length of the largest of the windows, i.e., in the illustrated embodiment, 8X units. Thus, the illumination falling on a photodetector corresponds to the length of the window through which the illumination passes. This enables one to determine the area of the window aligned with a given photodetector.

The reference photodetector provides a reference current for the data photodetectors so that the magnitude of illumination of each data photodetector can be determined. One can readily determine that the illumination of a data photodetector is 1X, 2X, 4X or 8X the signal from the reference photodetector. This compensates for variation in illumination from the light source and avoids any need for absolute measurements of current.

The position of the windows relative to the photodetectors is determined from the array of even numbered data photodetectors which are interleaved between the odd numbered data photodetectors. Using only the even numbered photodetectors would work fine for determining position when the windows are well aligned with the even numbered photodetectors. It would not work well when the code wheel is rotated one-half an increment and the even numbered photodetectors are occulted by the opaque spaces between the windows, in which position there would be no signals at all from the even numbered photodetectors. The odd numbered data photodetectors are, therefore, used in combination with the even numbered data photodetectors for determining position upon "wake-up" when the encoder is first turned on. As explained hereinafter, they are also used throughout operation of the encoder.

FIG. 4 illustrates schematically the windows of the data track superimposed over the photodetectors at an arbitrary position where the windows are not well aligned with either the odd or even numbered photodetectors. In this illustration, the photodetectors are drawn with relatively heavy lines to distinguish them from the windows which are drawn with relatively light lines. In addition, the data photodetectors are illustrated with a length slightly greater than 8X units, and the reference photodetector with a length slightly more than 1X units, so that the lines are not exactly superimposed. In practice, the photodetectors may actually be made slightly larger than the windows to ease alignment requirements during assembly of the encoder. Such enlargement should be relatively small so that the ratio between different size windows is not significantly changed.

In the alignment illustrated in FIG. 4, it will be noted that a 2X size window 16 illuminates a portion of each of data photodetectors 2 and 3. Similarly, a 1X window illuminates a portion of each of photodetectors 4 and 5. It will also be observed that the total illumination of the combination of photodetectors 2 and 3 corresponds to the area of the 2X window. Means are, therefore, provided for reading the sum of illumination of each even numbered window and a chosen adjacent odd numbered window. It is also necessary to determine whether the left or right adjacent odd numbered window is selected to add to the illumination of each even numbered window. This is significant since additional rotation of the code wheel causes the 2X window which is presently illuminating photodetectors 2 and 3 to later illuminate photodetectors 3 and 4. At such later rotation, the illumination photodetectors 4 and 3 should be added instead of photodetectors 2 and 3.

For this selection purpose, an additional array of four selection photodetectors A, B, C, D is provided at one end of the array. In the embodiment illustrated in FIG. 4, the selection photodetectors are located at the same end of the array as the reference photodetector 18. They could just as well be located at the opposite end of the array of data photodetectors.

Each of the selection photodetectors has a width along the direction of the data track one-half of the width of a window or space between windows. Preferably, the length of the selection photodetectors transverse to the data track is about 1X units, and the centers of the selection photodetectors are at the same radial distance from the center of the code wheel as the centers of the other photodetectors (and the windows).

The selection photodetectors are positioned so that when the windows are exactly aligned with the even numbered data photodetectors, a window is aligned with the center pair B, C of the selection photodetectors and the outside pair A, D is occulted by the opaque spaces between windows. When the windows are aligned with odd numbered data photodetectors, the center pair B, C of the selection photodetectors is occulted by a space between adjacent windows, and the outside pair A, D are each illuminated through one of a pair of adjacent windows.

In the arbitrary alignment illustrated in FIG. 4, it will be noted that one of the center selection photodetectors, C, is completely illuminated through a window, and the other center photodetector, B, and one of the outside photodetectors, D, are partially illuminated through the window. Comparing the illumination on photodetectors A+D and B+C provides the selection criterion for selecting the left or right odd numbered photodetector.

FIG. 5 illustrates schematically the electrical connection for providing a position signal from the encoder in response to illumination of the data photodetectors 1 through 9. Each even numbered photodetector is switchably connected to

a separate operational amplifier 19. For each even numbered photodetector, the adjacent odd numbered photodetectors are also switchably connected to the respective op-amp 19. Each op-amp output is connected to an analog-to-digital converter 21.

The switches 24 connecting each data photodetector with the respective op-amp are controlled by the selection photodetectors A, B, C, D. For example, when the windows are overlying the photodetectors as illustrated in FIG. 4, the total illumination on the center pair of selection photodetectors B and C is greater than the total illumination on the outside selection photodetectors A and D. When that condition exists, as indicated at the bottom of FIG. 6, the switches are activated to the positions illustrated in FIG. 6.

Because of this exemplary illumination of the selection photodetectors, the switches connecting photodetectors 2 and 3 to the first op-amp are closed, and the switch connecting the number 1 data photodetector to that op-amp is open. Thus, the total current due to illumination of photodetectors 2 and 3 is applied to the first op-amp. The illumination on data photodetector 1 is ignored. Thus, in this example, the signal from the first op-amp indicates that photodetector 2 plus its adjacent odd numbered photodetector 3 are illuminated by a window having an area of 2X. In a similar manner, the input signals to the comparator would show that photodetectors 4, 6 and 8 and their adjacent odd numbered photodetector are illuminated by windows having areas of 1X, 4X and 2X, respectively.

FIG. 7 is analogous to FIG. 6, and illustrates the switch positions when the windows are positioned over the photodetectors so that each window illuminates a portion of an even numbered photodetector and a portion of the odd numbered photodetector to its left. In this position, two adjacent windows cast more total illumination on the outside selection photodetectors A and D than on the inner pair of selection photodetectors B and C. This causes the switches for data photodetectors 1 and 2 to close, while the switch to data photodetector 3 is open. In this situation, the current due to illumination of photodetectors 1 and 2 is applied to the op-amp, and the illumination on photodetector 3 is ignored.

Since the window areas are essentially quantized by powers of 2, the output of each A/D converter 21 is a three-bit binary number. These numbers are fed to a comparator 22 which compares the four numbers from the four A/D converters with stored numbers in a look-up table 23 to determine the position of the code wheel relative to the photodetectors. The output of the comparator is a digital position signal indicative of the code wheel position. The position signal may be used in any conventional manner for indicating the shaft angle or other related information. Changes in the position signal may be differentiated to measure velocity according to the needs of the user of the shaft angle encoder.

Table I shows how the windows are superimposed over the data photodetectors as the code wheel rotates. The table is arranged as if the windows were stationary and the photodetectors moving. Whether rotation is clockwise or counter clockwise is arbitrary. The numbers in each row in the table represent the areas of sequential windows along the data track of the code wheel. The sequence of numerical values tabulated corresponds to the sequence illustrated in FIGS. 3 and 4.

Assuming that the encoder is started when the windows are in the position illustrated in FIG. 4, the first row in the table shows that the four even numbered photodetectors (and an adjacent odd numbered photodetector) are illuminated by windows having areas 2X, 1X, 4X and 2X, respectively. This is indicated by the vertical bars indicating the ends of the photodetector array and the underlining of the numerical values of the illuminating windows.

Assuming, then, the one window to window increment, windows having areas of 1X, 4X, 2X and 8X, respectively, overlie the even numbered data photodetectors (and an adjacent odd numbered photodetector). Similarly, an additional increment of clockwise rotation brings windows having areas 4X, 2X, 8X and 1X over the photodetectors, and still another increment illuminates the even numbered photodetectors through windows having areas 2X, 8X, 1X and 4X, respectively, as indicated in rows three and four of the table. Assuming then that the rotation of the code wheel reverses to counter-clockwise, the first increment returns windows having areas of 4X, 2X, 8X and 1X over the even photodetectors, etc.

Table I

Startup	8X	4X	|2X	1X	4X	2X|	8X	1X	4X	4X	8X . . .
Clockwise	8X	4X	2X	|1X	4X	2X	8X|	1X	4X	4X	8X . . .
Clockwise	8X	4X	2X	1X	|4X	2X	8X	1X|	4X	4X	8X . . .
Clockwise	8X	4X	2X	1X	4X	|2X	8X	1X	4X|	4X	8X . . .
Counter-Clockwise	8X	4X	2X	1X	|4X	2X	8X	1X|	4X	4X	8X . . .
Counter-Clockwise	8X	4X	2X	|1X	4X	2X	8X|	1X	4X	4X	8X . . .

Table II indicates the signals corresponding to the positions of the windows shown in Table I. At startup, the current signals from the four op-amps are 2, 1, 4 and 2, respectively. These are converted to binary numbers and the comparator looks up this sequence of numerical values in the look-up table and discovers (for purposes of this example) that this corresponds to position 1 of the encoder. It therefore provides an output digital signal of 1 as set forth in Table II. When the code wheel moves an increment clockwise, the new sequence, 1, 4, 2, 8, is found to be position 2, etc.

Table II

	Current Signals				Binary Output									
Startup	2	1	4	2	0	0	0	0	0	0	0	0	0	1
Clockwise	1	4	2	8	0	0	0	0	0	0	0	0	1	0
Clockwise	4	2	8	1	0	0	0	0	0	0	0	0	1	1
Clockwise	2	8	1	4	0	0	0	0	0	0	0	1	0	0
Counterclockwise	4	2	8	1	0	0	0	0	0	0	0	0	1	1
Counterclockwise	1	4	2	8	0	0	0	0	0	0	0	0	1	0

The sequence of areas of windows around the code wheel is selected so that no sequence of four adjacent windows repeats at any point along the data track. With a set of four even numbered data photodetectors and the capability of detecting four levels of analog signals representing illumination of those photodetectors, one can identify 4^4 or 256 unique code wheel positions. As the number of analog values detected increases, or the number of even numbered data photodetectors increases, the possible number of discrete locations to be detected increases geometrically. Thus, for example, with a set of five photodetectors capable of detecting five different levels of analog signals, the number of positions increases to 5^5 or 3,125. An encoder with eight photodiodes and capable of detecting four levels of analog values permits detection of 4^8 or 65,536 unique locations.

The absolute encoder can identify any position around the code wheel upon startup, with the possible exception when each of the even numbered photodetectors and their adjacent odd numbered photodetectors are exactly half-way illuminated. In that rare circumstance, the photo currents from the two sets of selection photo detectors would be equal; i.e., B+C = A+D. There are a number of possible ways to resolve this dilemma. The photo currents of odd numbered photodetectors adjacent to an even numbered photodetector may be compared and appropriate switches closed for connecting the odd numbered photodetectors with illumination equal to the even numbered photodetectors to the respective op-amps. Alternatively, one may simply wait for a slight movement of the code wheel to unbalance two selection photodetectors and resolve the uncertainty. Also, one may arbitrarily "tilt" the balance optically or electrically in one direction or the other and resolve the uncertainty. Alternatively, such a state may be inherently metastable and randomly "fall" to one side or the other. At worst, the position error is only one half of a window to window increment.

The resolution of this absolute encoder is one complete electrical cycle; that is, the sum of the widths of a window and an adjacent spoke. If desired, an approximate position interpolation may be provided by comparing the photo current of an even numbered photodetector with the appropriate adjacent odd numbered photodetector. The ratio indicates approximately the position of the window relative to the photodetectors. The interpolation photodetectors may be a pair of data photodetectors providing the analog signals to the op-amps, or a nearby set of additional photodetectors at an end of the array.

Although only one embodiment of optical encoder embodying principles of this invention has been described and illustrated herein, it will be understood that many modifications and variations may be made. Thus, as suggested throughout the description, the number of photodetectors and analog window areas may be varied to provide the angular resolution desired. Similarly, the data track may be used in a linear position encoder instead of the rotating shaft angle encoder described for illustrative purposes. The signal processing is merely exemplary and may differ appreciably from what is described. It will therefore be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

Claims

1. An optical encoder comprising a data track (14) with a multiplicity of windows (16), each window having an area selected from a set of areas which are distinguishable from each other, the areas of successive windows being in a predetermined sequence; an array of data photodetectors (1-9) adjacent to the data track sufficient to span a plurality of windows, each photodetector being successively aligned or not aligned with a window during relative movement between the windows and photodetectors; means (12) for illuminating the photodetectors through the windows; and means (19-24) for determining the position of the photodetectors relative to the windows in response

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Clockwise	1	4	2	8	0	0	0	0	0	0	0	0	1	0
Clockwise	4	2	8	1	0	0	0	0	0	0	0	0	1	1
Clockwise	2	8	1	4	0	0	0	0	0	0	0	1	0	0
Counterclockwise	4	2	8	1	0	0	0	0	0	0	0	0	1	1
Counterclockwise	1	4	2	8	0	0	0	0	0	0	0	0	1	0

The sequence of areas of windows around the code wheel is selected so that no sequence of four adjacent windows repeats at any point along the data track. With a set of four even numbered data photodetectors and the capability of detecting four levels of analog signals representing illumination of those photodetectors, one can identify 4^4 or 256 unique code wheel positions. As the number of analog values detected increases, or the number of even numbered data photodetectors increases, the possible number of discrete locations to be detected increases geometrically. Thus, for example, with a set of five photodetectors capable of detecting five different levels of analog signals, the number of positions increases to 5^5 or 3,125. An encoder with eight photodiodes and capable of detecting four levels of analog values permits detection of 4^8 or 65,536 unique locations.

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The resolution of this absolute encoder is one complete electrical cycle; that is, the sum of the widths of a window and an adjacent spoke. If desired, an approximate position interpolation may be provided by comparing the photo current of an even numbered photodetector with the appropriate adjacent odd numbered photodetector. The ratio indicates approximately the position of the window relative to the photodetectors. The interpolation photodetectors may be a pair of data photodetectors providing the analog signals to the op-amps, or a nearby set of additional photodetectors at an end of the array.

Although only one embodiment of optical encoder embodying principles of this invention has been described and illustrated herein, it will be understood that many modifications and variations may be made. Thus, as suggested throughout the description, the number of photodetectors and analog window areas may be varied to provide the angular resolution desired. Similarly, the data track may be used in a linear position encoder instead of the rotating shaft angle encoder described for illustrative purposes. The signal processing is merely exemplary and may differ appreciably from what is described. It will therefore be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

Claims

1. An optical encoder comprising a data track (14) with a multiplicity of windows (16), each window having an area selected from a set of areas which are distinguishable from each other, the areas of successive windows being in a predetermined sequence; an array of data photodetectors (1-9) adjacent to the data track sufficient to span a plurality of windows, each photodetector being successively aligned or not aligned with a window during relative movement between the windows and photodetectors; means (12) for illuminating the photodetectors through the windows; and means (19-24) for determining the position of the photodetectors relative to the windows in response

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to the magnitude of illumination of each of the photodetectors through the windows; wherein the sequence of areas of windows (16) in any interval corresponding to the number of data photodetectors (1-9) in the array does not repeat throughout the length of the data track (14).

2. An optical encoder as recited in claim 1, wherein there is a space (17) between each of the windows (16), each space and each window being substantially the same width, and each data photodetector (1-9) is substantially the same width as a space or window.

3. An optical encoder as recited in claims 1 or 2, wherein the array of data photodetectors (1-9) comprises two sets of interleaved photodetectors (1,3,5,7,9; 2,4,6,8).

4. An optical encoder as recited in claims 2 and 3, wherein one set of data photodetectors is aligned with a plurality of windows when the other set of data photodetectors is aligned with the spaces between said windows.

5. An optical encoder as recited in claims 3 or 4, further comprising means (24) for summing the illumination of a data photodetector (1,3,5,7,9) from one set with the illumination of a data photodetector (2,4,6,8) from the other set.

6. An optical encoder as recited in claims 2 to 5, further comprising: an array of selection photodetectors (A-D) each having a width of one half the width of a window (16) or space (17); and means (24) for matching a data photodetector from one set (2,4,6,8) with a data photodetector from the other set (1,3,5,7,9) in response to illumination of the selection photodetectors.

7. An optical encoder as recited in claim 6, wherein the array of selection photodetectors (A-D) is at one end of said array of said data photodetectors (1-9).

8. An optical encoder as recited in any of claims 2 to 7, wherein each window (16) and each space (17) between adjacent windows has the same width.

9. An optical encoder as recited in any preceding claim, wherein the areas of the windows (16) differ by powers of n where n is an integer or non-integer number.

10. An optical encoder as recited in claim 9, wherein n = 2.

11. An optical encoder as recited in any of claims 2 to 10, further comprising a reference photodetector 20 REF) at an end of the array having a width twice the width of a window (16) or a space (17).

12. An optical encoder as recited in any preceding claim, further comprising: means (21) for converting the relative illumination of a plurality of data photodetectors (1-9) to a digital signal; and means (22,23) for correlating the digital signal to a relative position of the windows (16) and data photodetectors.

13. An optical encoder as recited in any preceding claim, further comprising means for distinguishing relative movement between the data track (14) and data photodetectors (1-9) in one direction from movement in the opposite direction.

14. An optical encoder as recited in any preceding claim comprising: a data track (14) having alternating windows (16) and opaque spaces (17) between windows, the width of each window and each space between windows being the same along the length of the track, the length of each window transverse to the length of the track being selected from a set of lengths which are distinguishable from each other, and the length of successive windows along the track being in a predetermined sequence; an array of side-by-side data photodetectors (1-9) adjacent to the track, each data photodetector having a width corresponding to the width of a space or window and a length corresponding to the length of the longest windows in the set; means (19,24) for summing the photo currents due to illumination of a pair of adjacent data photodetectors; and means for determining the position of the data track (14) relative to the photodetectors in response to the sum of photo currents of several pairs of data photo-detectors in the array.

15. An optical encoder as recited in claim 14 further comprising means (A-D, 24) for selecting the pairs of photo currents summed.

16. An optical encoder as recited in claim 15, wherein the means for selecting comprises an array of side-by-side selection photodetectors (A-D) at an end of the array of data photodetectors (1-9), each selection photodetector having

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one half the width of a window or space.

17. An optical encoder as recited in any of claims 14 to 16, further comprising a reference photodetector (REF) at an end of the array of data photodetectors (1-9) having a width along the track twice the width of a window (16) or space, and a length transverse to the track (14) less than the length of the shortest length of window in the set.

18. An optical encoder as recited in any of claims 14 to 17, wherein the lengths of the windows (16) differ by powers of two.

19. An optical encoder as recited in any of claims 14 to 18, further comprising means (21) for converting the photo currents of a plurality of pairs of adjacent data photodetectors (1-9) to a digital signal; and means (22,23) for correlating the digital signal to a relative position of the windows (16) and photodetectors (1-9).

Patentansprüche

1. Ein optischer Codierer mit folgenden Merkmalen: einer Datenspur (14) mit einer Mehrzahl von Fenstern (16), wobei jedes Fenster einen Bereich aufweist, der aus einem Satz von Bereichen gewählt ist, welche voneinander unterscheidbar sind, wobei die Bereiche von aufeinanderfolgenden Fenstern in einer vorbestimmten Sequenz sind; einem Array von Daten-Photodetektoren (1 - 9), die benachbart zu der Datenspur angeordnet sind und ausreichen, um eine Mehrzahl von Fenstern zu überspannen, wobei jeder Photodetektor während einer relativen Bewegung zwischen den Fenstern und den Photodetektoren nacheinander mit einem Fenster ausgerichtet oder nicht ausgerichtet ist; einer Einrichtung (12) zum Beleuchten der Photodetektoren durch die Fenster; und einer Einrichtung (19 - 24) zum Bestimmen der Position des Photodetektors bezüglich des Fensters als Reaktion auf die Größe der Beleuchtung jedes Photodetektors durch die Fenster, wobei sich die Sequenz von Fensterbereichen (16) in einem beliebigen Intervall, das der Anzahl von Daten-Photodetektoren (1 - 9) in dem Array entspricht, überall auf der ganzen Länge der Datenspur (14) nicht wiederholt.

2. Ein optischer Codierer gemäß Anspruch 1, bei dem sich ein Raum (17) zwischen jedem Fenster (16) befindet, wobei jeder Raum und jedes Fenster im wesentlichen die gleiche Breite aufweisen, und jeder Daten-Photodetektor (1 -9) im wesentlichen die gleiche Breite wie ein Raum oder ein Fenster aufweist.

3. Ein optischer Codierer gemäß Anspruch 1 oder 2, bei dem das Array von Daten-Photodetektoren (1 - 9) zwei Sätze von verschachtelt angeordneten Photodetektoren (1, 3, 5, 7, 9; 2, 4, 6, 8) aufweist.

4. Ein optischer Codierer gemäß Anspruch 2 oder 3, bei dem ein Satz von Daten-Photodetektoren mit einer Mehrzahl von Fenstern ausgerichtet ist, während der andere Satz von Daten-Photodetektoren mit den Räumen zwischen den Fenstern ausgerichtet ist.

5. Ein optischer Codierer gemäß Anspruch 3 oder 4, der ferner eine Einrichtung (24) zum Summieren der Beleuchtung eines Daten-Photodetektors (1, 3, 5, 7, 9) von einem Satz und der Beleuchtung eines Daten-Photodetektors (2, 4, 6, 8) von dem anderen Satz aufweist.

6. Ein optischer Codierer gemäß einem beliebigen der Ansprüche 2 bis 5, der ferner folgende Merkmale aufweist: ein Array von Auswahl-Photodetektoren (A - D), wobei jeder eine Breite aufweist, die der Hälfte der Breite eines Fensters (16) oder eines Raums (17) entspricht; und eine Einrichtung (24) zum Anpassen eines Daten-Photodetektors von einem Satz (2, 4, 6, 8) mit einem Daten-Photodetektor von dem anderen Satz (1, 3, 5, 7, 9) als Reaktion auf eine Beleuchtung der Auswahl-Photodetektoren.

7. Ein optischer Codierer gemäß Anspruch 6, bei dem sich das Array von Auswahl-Photodetektoren (A - D) an einem Ende des Arrays von Daten-Photodetektoren (1 - 9) befindet.

8. Ein optischer Codierer gemäß einem beliebigen der Ansprüche 2 bis 7, bei dem jedes Fenster (16) und jeder Raum (17) zwischen benachbarten Fenstern die gleiche Breite aufweisen.

9. Ein optischer Codierer gemäß einem beliebigen der vorhergehenden Ansprüche, bei dem sich die Bereiche der Fenster (16) um Potenzen von n unterscheiden, wobei n eine ganzzahlige oder nicht-ganzzahlige Zahl ist.

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10. Ein optischer Codierer gemäß Anspruch 9, bei dem n gleich 2 ist.

11. Ein optischer Codierer gemäß einem beliebigen der Ansprüche 2 bis 10, der ferner einen Referenz-Photodetektor (20 REF) an einem Ende des Arrays aufweist, welcher eine Breite aufweist, die doppelt so groß wie die Breite eines Fensters (16) oder eines Raums (17) ist.

12. Ein optischer Codierer gemäß einem beliebigen der vorhergehenden Ansprüche, der ferner folgende Merkmale aufweist: eine Einrichtung (21) zum Umwandeln der relativen Beleuchtung einer Mehrzahl von Daten-Photodetektoren (1 - 9) in ein Digitalsignal; und eine Einrichtung (22, 23) zum Korrelieren des Digitalsignals mit einer relativen Position der Fenster (16) und der Daten-Photodetektoren.

13. Ein optischer Codierer gemäß einem beliebigen der vorhergehenden Ansprüche, der ferner eine Einrichtung zum Unterscheiden der relativen Bewegung zwischen der Datenspur (14) und den Daten-Photodetektoren (1 - 9) in einer Richtung von einer Bewegung in der entgegengesetzten Richtung aufweist.

14. Ein optischer Codierer gemäß einem beliebigen der vorhergehenden Ansprüche, der folgende Merkmale aufweist: eine Datenspur (14) mit sich abwechselnden Fenstern (16) und undurchsichtigen Räumen (17) zwischen den Fenstern, wobei die Breite jedes Fensters und jedes Raums zwischen den Fenstern entlang der Länge der Spur gleich ist, wobei die Länge jedes Fensters transversal zu der Länge der Spur aus einem Satz von Längen gewählt ist, welche voneinander unterscheidbar sind, und die Längen von aufeinanderfolgenden Fenstern entlang der Spur in einer vorbestimmten Sequenz sind; ein Array von Seite-an-Seite angeordneten Daten-Photodetektoren (1 - 9), die benachbart zu der Spur angeordnet sind, wobei jeder Daten-Photodetektor eine Breite aufweist, die der Breite eines Raums oder Fensters entspricht, und eine Länge, die der Länge der längsten Fenster in dem Satz entspricht; eine Einrichtung (19, 24) zum Summieren der Photoströme aufgrund der Beleuchtung eines Paars von benachbarten Daten-Photodetektoren; und eine Einrichtung zum Bestimmen der Position der Datenspur (14) relativ zu den Photodetektoren als Reaktion auf die Summe der Photoströme von mehreren Paaren von Daten-Photodetektoren in dem Array.

15. Ein optischer Codierer gemäß Anspruch 14, der ferner eine Einrichtung (A - D, 24) zum Auswählen der Paare von summierten Photoströmen aufweist.

16. Ein optischer Codierer gemäß Anspruch 15, bei dem die Einrichtung zum Auswählen ein Array von Seite-an-Seite angeordneten Auswahl-Photodetektoren (A - D) an einem Ende des Arrays der Daten-Photodetektoren (1 - 9) aufweist, wobei jeder Auswahl-Photodetektor die Hälfte der Breite eines Fensters oder Raums aufweist.

17. Ein optischer Codierer gemäß einem beliebigen der Ansprüche 14 bis 16, der ferner einen Referenz-Photodetektor (REF) an einem Ende des Arrays von Daten-Photodetektoren (1 - 9) und eine Breite entlang der Spur aufweist, die dem Doppelten der Breite eines Fensters (16) oder Raums entspricht, und der eine Länge transversal zu der Spur (14) aufweist, die kleiner als die Länge der kürzesten Fensterlänge in dem Satz ist.

18. Ein optischer Codierer gemäß einem beliebigen der Ansprüche 14 bis 17, bei dem sich die Längen der Fenster (16) um Potenzen von Zwei unterscheiden.

19. Ein optischer Codierer gemäß einem beliebigen der Ansprüche 14 bis 18, der ferner folgende Merkmale aufweist: eine Einrichtung (21) zum Umwandeln der Photoströme einer Mehrzahl von Paaren von benachbarten Daten-Photodetektoren (1 - 9) in ein digitales Signal; und eine Einrichtung (22, 23) zum Korrelieren des Digitalsignals mit einer relativen Position der Fenster (16) und der Photodetektoren (1 - 9).

Revendications

1. Codeur optique comprenant une piste de données (14) avec une multiplicité de fenêtres (16), chaque fenêtre comportant une surface sélectionnée parmi un ensemble de surfaces qui peuvent se distinguer les unes des autres, les surfaces de fenêtres successives étant dans un ordre prédéterminé; un réseau de photo-détecteurs de données (1-9) suffisamment adjacents à la piste de données pour s'étendre sur plusieurs fenêtres, chaque photo-détecteur étant successivement aligné ou non aligné avec une fenêtre pendant le mouvement relatif entre les fenêtres et les photo-détecteurs; des moyens (12) pour illuminer les photo-détecteurs à travers les fenêtres; et des moyens (19-24) pour déterminer la position des photo-détecteurs par rapport aux fenêtres, en réponse à la valeur de l'illumination

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de chacun des photo-détecteurs à travers les fenêtres; dans lequel la séquence de surfaces de fenêtres (16) dans un intervalle quelconque correspondant au nombre de photo-détecteurs de données (1-9) du réseau, ne se répète pas sur l'ensemble de la longueur de la piste de données (14).

2. Codeur optique selon la revendication 1, dans lequel il existe un espace (17) entre chacune des fenêtres (16), chaque espace et chaque fenêtre étant sensiblement de même largeur, et chaque photo-détecteur de données (1-9) est sensiblement de même largeur qu'un espace ou qu'une fenêtre.

3. Codeur optique selon les revendications 1 ou 2, dans lequel le réseau de photo-détecteurs de données (1-9) comprend deux ensembles de photo-détecteurs entrelacés (1, 3, 5, 7, 9; 2, 4, 6, 8).

4. Codeur optique selon les revendications 2 et 3, dans lequel un ensemble de photo-détecteurs de données est aligné avec plusieurs fenêtres lorsque l'autre ensemble de photo-détecteurs de données est aligné avec les espaces situés entre lesdites fenêtres.

5. Codeur optique selon les revendications 3 ou 4, comprenant en outre des moyens (24) pour effectuer la somme de l'illumination d'un photo-détecteur de données (1, 3, 5, 7, 9) provenant d'un ensemble, avec l'illumination d'un photo-détecteur de données (2, 4, 6, 8) provenant de l'autre ensemble.

6. Codeur optique selon les revendications 2 à 5, comprenant en outre: un réseau de photo-détecteurs de sélection (A-D), ayant chacun une largeur de la moitié de la largeur d'une fenêtre (16) ou d'un espace (17); et des moyens (24) pour faire correspondre un photo-détecteur de données d'un ensemble (2, 4, 6, 8) à un photo-détecteur de données de l'autre ensemble (1, 3, 5, 7, 9), en réponse à l'illumination des photo-détecteurs de sélection.

7. Codeur optique selon la revendication 6, dans lequel le réseau de photo-détecteurs de sélection (A-D) se trouve à une extrémité dudit réseau desdits photo-détecteurs de données (1-9).

8. Codeur optique selon l'une quelconque des revendications 2 à 7, dans lequel chaque fenêtre (16) et chaque espace (17) entre fenêtres adjacentes a la même largeur.

9. Codeur optique selon l'une quelconque des revendications précédentes, dans lequel les surfaces des fenêtres (16) diffèrent par des puissances de n, n étant un nombre entier ou non entier.

10. Codeur optique selon la revendication 9, dans lequel n = 2.

11. Codeur optique selon l'une quelconque des revendications 2 à 10, comprenant en outre un photo-détecteur de référence (20 REF) situé à une extrémité du réseau, ayant une largeur égale à deux fois la largeur d'une fenêtre (16) ou d'un espace (17).

12. Codeur optique selon l'une quelconque des revendications précédentes, comprenant en outre: des moyens (21) pour convertir l'illumination relative de plusieurs photo-détecteurs de données (1-9) en un signal numérique; et des moyens (22, 23) pour corréler le signal numérique avec une position relative des fenêtres (16) et des photo-détecteurs de données.

13. Codeur optique selon l'une quelconque des revendications précédentes, comprenant en outre des moyens pour distinguer le mouvement relatif entre la piste de données (14) et les photo-détecteurs de données (1-9) dans un sens, par rapport au mouvement dans le sens inverse.

14. Codeur optique selon l'une quelconque des revendications précédentes, comprenant: une piste de données (14) comprenant des fenêtres alternées (16) et des espaces opaques (17) situés entre les fenêtres, la largeur de chaque fenêtre et de chaque espace entre fenêtres étant la même le long de la longueur de la piste, la longueur de chaque fenêtre transversale à la longueur de la piste étant sélectionnée parmi un ensemble de longueurs qui peuvent être distinguées les unes des autres, et la longueur des fenêtres successives le long de la piste étant dans un ordre prédéterminé; un réseau de photo-détecteurs de données cote à cote (1-9) adjacents à la piste, chaque photo-détecteur de données ayant une largeur correspondant à la largeur d'un espace ou d'une fenêtre et une longueur correspondant à la longueur des fenêtres les plus longues de l'ensemble; des moyens (19-24) pour effectuer la somme des photo-courants dus à l'illumination d'une paire de photo-détecteurs de données adjacents; et des moyens pour déterminer la position de la piste de données (14) par rapport aux photo-détecteurs, en réponse à la somme des

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photo-courants de plusieurs paires de photo-détecteurs de données du réseau.

15. Codeur optique selon la revendication 14, comprenant en outre des moyens (A-D, 24) pour sélectionner la paire de photo-courants additionnés.

16. Codeur optique selon la revendication 15, dans lequel les moyens de sélection comprennent un réseau de photo-détecteurs de sélection cote à cote (A-D) situés à une extrémité du réseau de photo-détecteurs de données (1-9), chaque photo-détecteur de sélection ayant une largeur égale à la moitié de la largeur d'une fenêtre ou d'un espace.

17. Codeur optique selon l'une quelconque des revendications 14 à 16, comprenant en outre un photo-détecteur de référence (REF) situé à une extrémité du réseau de photo-détecteurs de données (1-9), ayant une largeur le long de la piste égale au double de la largeur d'une fenêtre (16) ou d'un espace, et une longueur transversalement à la piste (14) inférieure à la longueur de la plus courte longueur de fenêtre de l'ensemble.

18. Codeur optique selon l'une quelconque des revendications 14 à 17, dans lequel les longueurs des fenêtres (16) diffèrent par des puissances de deux.

19. Codeur optique selon l'une quelconque des revendications 14 à 18, comprenant en outre des moyens (21) pour convertir les photo-courants de plusieurs paires de photo-détecteurs de données adjacents (1-9) en un signal numérique; et des moyens (22, 23) pour corréler le signal numérique avec une position relative des fenêtres (16) et des photo-détecteurs (1-9).