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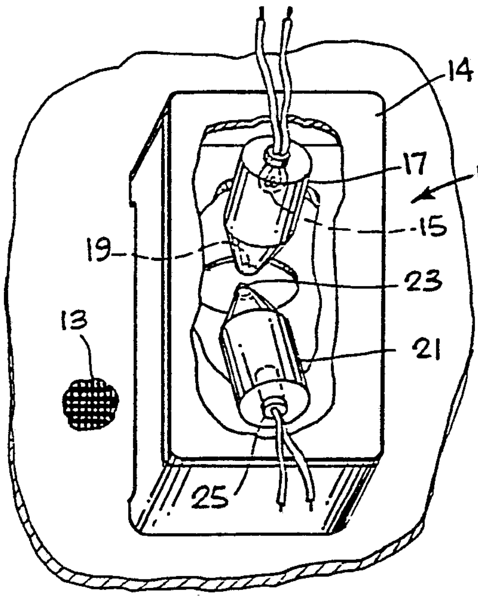
(54) Title: ELECTRO-OPTICAL MOUSE

(57) Abstract

A position control system employing a movable detector (11) which communicates optical energy to and from a pattern of passive, position-related lines on a surface (13). In one embodiment, the surface has a high-contrast line pattern forming checkerboard squares (Fig. 3c). A four-quadrant detector (Fig. 3a) within the detector means will report different states (Fig. 3b) as the detector is moved across different squares. The states are decoded in a lookup table (Fig. 3b) and electrical signals are generated for controlling X and Y counters of a cursor control or the like. In a second embodiment, the detector is moved over lines of two colors (Fig. 7), each color associated with vertical or horizontal motion. By counting line crossings of each color, X and Y motions may be determined for controlling a cursor or the like.



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Description

Electro-Optical Mouse

Technical Field

A mouse is a pointing device, typically for use with visual display systems in which a transducer converts translational motion of a housing relative to a surface into a position signal for controlling movement of a cursor or the like associated with a visual display system or a servo controlled object. More particularly, the present invention relates to such a system in which the transducer is electronic and movement of the housing relative to the surface is sensed by electromagnetic energy transmitted from and received by the transducer.

Background Art

A mouse must be distinguished from other cursor control systems, such as light pens and interactive tablets. These are devices in which electrical or electromagnetic energy is communicated from an active surface, grid or the like to energy receptors within a wand or other movable member. On the other hand, a mouse moves over a passive surface, such as a sheet of paper, or the like.

A mouse must also be distinguished from a joy stick control. A joy stick includes a lever, usually connected to a bearing. As the lever is moved, the bearing rotates correspondingly. Bearing motion may be sensed by potentiometers corresponding to different directions of bearing rotation. The output signal from a joy stick may be used for the same purpose as the output signal from a mouse. Both may be used to control a cursor. The distinguishing feature of a mouse is that two-dimensional motion over a surface corresponds directly with two-dimensional motion of a cursor in a graphic display.

A mouse should also be distinguished from bar code systems. In those systems, bar code is applied to a surface for indicating data, such as type of merchandise, price and manufacturer. The bar code typically produces an analog signal which may be read optically or magnetically. In U.S. patent 4,245,152 to Flurry et al., an ETAB (every transition a bit) code is described. Such systems do not yield directional information, as mice do.

Most of the mice of the prior art are mechanical systems involving wheels or rollers which maintain frictional contact with a surface. For example, U.S. patent 3,541,541 to D. Engelbart shows a well-known and widely accepted mechanical mouse. There are certain mechanical problems which are inherent with these mice, such as the problem in maintaining good frictional contact with a surface. If a mechanical mouse encounters a slippery portion of a surface, the resulting output signal will be inaccurate.

Mechanical mice use a relatively large number of close tolerance parts and are difficult to make in mass production. Moreover, mechanical mice are subject to mechanical "noise," such as lash and vibration, and require frequent cleaning.

An object of the present invention was to devise a non-mechanical mouse, specifically one which relied upon electromagnetic energy transmitted to and radiated back from a surface in order to translate positional motion relative to the surface into an electrical signal for control of a cursor or similar device.

Disclosure of Invention

The above object has been achieved with a position control system employing a movable detector means which detects electromagnetic energy radiated from graphic information, namely a line pattern on a surface. The detector means includes a multi-cell detector capable of noting the direction of line crossings of a focal point on the pattern due to relative motion between the line pattern and the detector. In the preferred embodiment, a light source is used to illuminate a point on an optically contrasting line pattern and a multi-cell photosensitive detector is used to detect the direction of line crossings. The position-related lines may be a checkerboard line pattern or a line pattern with different colors. If two detectors are used to track two focal points on the pattern, rotation, as well as translation can be sensed.

One of the advantages of this system over mechanical mice is that it is very reliable; there are no moving parts to break, wear, or malfunction. Another advantage is that it is relatively simple and inexpensive to manufacture in large quantities because there are no close tolerance parts. Another advantage is that there is little or no mechanical noise and little or no inherent electrical noise. Another advantage is that the present system uses off-the-shelf or easily made components. Still another advantage is that it has the same sensitivity, or perhaps better, than a mechanical mouse. Yet another advantage is that a version of the present mouse is able to detect rotation, while most mechanical mice cannot.

Brief Description of Drawings

Fig. 1 is a perspective plan view of a detector and a cooperating surface having an indicia pattern in accord with the present invention for sensing relative motion with respect to the surface.

Fig. 2 is a side view of the detector shown in Fig. 1.

Figs. 3a, 3b and 3c show detector reception and decoding plans for a first embodiment of the invention.

Fig. 4 is an electrical diagram of a logic means for a first embodiment of the invention.

Fig. 5 is the program logic for the read-only memory element of the first embodiment of the invention.

Fig. 6 is a perspective plan view of a dual detector mouse for sensing rotation, as well as translation.

Fig. 7 is a plan view of a portion of a grid pattern for use in a second embodiment of the present invention.

Fig. 8 is an electrical diagram of a circuit for activating the dual color source used in the second embodiment of the invention.

Fig. 9 is an electrical diagram of a circuit used with a four-quadrant detector.

Figs. 10a and 10b show time gated detector reception and decoding plans for a two-cell detector to be used in the second embodiment of the invention.

Figs. 11a and 11b show a steady state detector reception and decoding plans for a four-cell detector to be used in the second embodiment of the invention.

Fig. 12 is a plan view of a detector remotely located relative to a cooperating surface.

Fig. 13 is a plan view of an alternate version of a mouse for sensing rotation, as well as translation using a single detector.

Figs. 14a and 14b are timing diagrams for the light sources used in the plan of Fig. 13.

Fig. 15 is a table showing how the number of colors in the line pattern of the surface may vary in accord with the number of cells in a detector, together with motion states that can be detected.

Fig. 16a is a plan view of a portion of a grid pattern for use in an alternate embodiment of the present invention wherein grid lines overlap by one-half of a line width.

Fig. 16b is a line pattern similar to the one shown in Fig. 16a, except that two sets of mutually orthogonal lines are shown, each set having lines of two colors overlapping by half a line width.

Best Mode for Carrying out the Invention

The first embodiment of the invention is described with reference to Figs. 1-5 and is characterized by a checkerboard line surface for establishing relative mouse motion. The second embodiment is described with reference to Figs. 7—11, and is characterized by a grid of colored lines. A version of both embodiments adapted for rotation as well as translation is described with reference to Fig. 6. A variant of this version is described with reference to Figs. 13, 14a and 14b.

Mouse with Checkerboard Surface

Figs. 1 and 2 show two assemblies used in the embodiments of the invention. A first assembly is the movable detector means 11. This detector means includes a housing 14 containing a light source 15 as well as a photodetector 25. The housing is gripped by a human hand and pushed in any direction on the surface, corresponding to the direction and extent to which it is desired to move a cursor, or similar device.

Source 15 may be seen to be mounted within a light-tight tube 17 which is aimed downwardly at a spot on surface 13. Tube 17 has a forward light aperture 19 where focused light emerges for illuminating an area slightly larger than one of the squares of the surface, to be described below.

Also mounted in housing 14 is a detector tube 21 having at its forward end an imaging lens 23 which is a glass bead. Lens 23 is mounted so that it is slightly more than one focal length from surface 13. The remainder of tube 21 is generally light tight. At the rear of tube 21 is a four-quadrant detector 25 which receives a magnified image of surface 13 via the imaging lens 23. The spacing between the four-quadrant detector 25 and lens 23 is one wherein the four-quadrant detector is about eight focal lengths from lens 23. The distance is typically about 3 cm., but could be more or less. The diameter of the bead forming imaging lens 23 is approximately 3 or 4 mm., but could be more or less.

In Fig. 2, housing 14 is seen to include a planar central shelf 27 through which tube and detector 21 extend angularly downward and are held in place therein. While specular reflection between the source and detector is preferred, it is not necessary since diffuse reflection is adequate. Housing 14 has thin, low-friction spacers 31 and 33 which make contact with surface 13. Spacers 31 and 33 may be made of Teflon or nylon so that the housing slides easily over the surface. Each of the detectors of the four-quadrant detector is independent of all the others. When placing the housing on surface 13, alignment should be such that the square formed by the four-quadrant detectors is aligned with squares of the surface. However, the housing may be rotated up to 45^{o} in either direction from this nominal orientation without affecting the decoded signal.

A second assembly of the present invention is surface 13, having a graphic, i.e. optically perceptible, horizontal and vertical repetitive pattern of passive, position-related indicia, namely lines, which extend over a portion of the surface. These lines have nearly zero thickness and may be printed at low cost without loss of precision. This is unlike prior art graphic tablets which use wires that are expensive to place in precise positions. In the preferred embodiment, these line patterns have high optical contrast, such as an optically absorptive and reflective pattern. Such a pattern could be a shiny metallic or white surface, with black marks on the surface. A preferred pattern is a checkerboard square, with the edges of each square being approximately 0.5 mm. on a side. A complete pattern is not shown, only a sample of surface 13, which is magnified in Fig. 3c. The checkerboard need not have perfect squares. The checkerboard may be stretched so that squares become quadrangles. The term "squares" should be read to include "stretched squares" or quadrangles.

The mouse system of this embodiment generates signals which electrically communicate with a cursor or the like regarding movement up or down, left or right. There is no particular starting place for the housing on the surface. It may be brought down any place on the surface, so long as there is sufficient room to move the housing in a direction wherein cursor motion is desired. A preferable size for the housing is approximately 6 cm. in width and approximately 8 cm. in length. A preferred size for the surface would be approximately 22 cm. in width and approximately 30 cm. in length. These dimensions are not critical and the housing or surface may be larger or smaller, as needed.

In Fig. 3a, the active area of detector 25 is represented by the square 35. The four quadrants of the active area are numbered in clockwise order, 1, 2, 3, 4. Eight unique patterns which may be viewed by the detectors are illustrated in Figs. 3b and 3c. In the left column of Fig. 3b is a representation of each possible pattern. The center column of Fig. 3b shows the detector condition, with a dark square being designated by a zero and a reflective square being designated by a one. The order of digits is the order in which the detectors are numbered in Fig. 3a. The two upper quadrants are both designated VB and the two lower quadrants are designated VA (V for vertical), while the right hand column is designated HB and the left hand column is designated HA (H for horizontal).

The desired output from the detectors is four bits, two horizontal bits and two vertical bits. The change in these bits with respect to time is decoded to drive X and Y counters. For horizontal motion, the bits HA (VA) and HB (VB) would have the following sequence for motion to the right (up):

00 01 11 10 00 01 11. . .

Motion to the left (down) would be denoted by the following sequence:

00 10 11 01 00 10 11. . .

The state code which is shown in the right hand column of Fig. 3b was selected, as a Gray code, which can be easily decoded with six XOR gates, 2 inverters, and a 4-bit latch into signals to drive X and Y counters. Other state codes could have been selected. One of the advantages of the state code illustrated in Fig. 3b is that the state code, or its complement, exactly corresponds to any given detector pattern. Another advantage is that this code is directly accepted by a number of computers made by LISP Machine, Inc. of Cambridge, Mass., Xerox Corporation, and BBN of Cambridge, Mass., as the code is identical to that provided by many mechanical mice.

Fig. 3c reveals possible detector states. Note how use of the Gray code causes a change of state from one state to an adjacent state to have only a single binary digit change. Note also that corresponding states are either identical or complementary. There are eight unique states; all others are complements. For example, the dark square at the bottom of Fig. 3c has the state designation 1100. The dark square to the right of Fig. 3c has the designation 0011, the latter being the complement of the former. Thus, for any detector condition, a unique state corresponds to such a condition, or the complement of such a state. A new state differs from an old state by one binary digit, unless there is a diagonal move, in which case, the new state differs in two binary digits.

The detector size illustrated in Fig. 3c, relative to the checkerboard pattern, may correspond to the actual size ratio. In Fig. 3c, the detector area is approximately 1/16 the area of a checkerboard square. This would be a preferred dimension.

With reference to Fig. 4, another assembly of the present invention, used principally in this embodiment, may be seen. This figure shows a diagram of a logic circuit for decoding the detectors. The detector outputs from the four-quadrant detector are labeled D1, D2, D3 and D4. These correspond to the four detector conditions in the middle column of Fig. 3b. The output of each detector is fed along a corresponding line 41, 43, 45, 47 to a quad comparator 49, for example integrated circuit type LM139, wherein corresponding comparators 51, 53, 55 and 57 are connected to each of the detectors. The detector signal applied to each detector is connected in parallel to high resistance resistors, 42, 44, 46 and 48. Each of these resistors may have a value of 500K ohms in order to provide a proper load resistance to a corresponding diode. Each of the comparators also has an input from a voltage source 59, termed $V_{THRESHOLD}$. The output of each of the comparators does not switch until the threshold voltage is crossed in either direction. Once such a crossing occurs, the output of a comparator where such a crossing occurs changes state and such a state is latched by the latch circuit 60.

This circuit has latches 61, 63, 65 and 67 corresponding and electrically connected to one of the amplifiers. The circuit may be integrated circuit octal latch 74LS373. A 100kHz oscillator 69 is used to clock the latch circuit. The oscillator may be integrated circuit 74S124. Each of the latch circuits is connected to a read only memory circuit (ROM) 70, which is programmed to produce an output state when presented with the last output state and the current detector outputs. The ROM may be integrated circuit 74S287.

The latch circuit 60 also contains four other latches, 62, 64, 66 and 68 which are connected from the output of the ROM back into the input of the ROM through the latches. These latches eliminate a race condition in the feedback loop. There are eight input lines to the ROM, four from the amplifiers through latches 61, 63, 65 and 67 and four from the output of the ROM through the latches 62, 64, 66 and 68. The feedback inputs to the ROM allow a new state to be compared to an old state. The latched output states from latches 62, 64, 66 and 68 are also taken as the input to X, Y counters 71, which are directly related to the position of the cursor on the screen. This is indicated by the output 73.

In Fig. 5, the ROM programming algorithm may be viewed. In decision block 81, a first assessment is made whether a significant detector pattern exists. In reviewing the center column of Fig. 3b, it will be noted that detector patterns change by two detectors at a time from one square to an adjacent square. This does not require that the detectors are placed on the mouse surface so that the detector pattern is in alignment with the edges of the square. The mouse may be rotated $\pm 45^{\circ}$ from nominal without effect. This is because only when two detectors have changed polarity is the algorithm able to determine in which direction the mouse has moved. For example, for rightward motion from a white square, detectors 2 and 3 would change state before detectors 1 and 4. The order in which detectors 2 and 3 change is not important. In action block 83, the table of Fig. 3b is used to convert the detector outputs to a possible state. Recall that the word "possible" is used because the state may be either the state in the table, or its complement which is not in the table. Thus, the table yields only an even chance of determining the actual state. After determining the new possible state, termed HA', HB', VA' and VB', the algorithm proceeds to the decision block 85 wherein a comparison is made between the number of bit positions in which there is disagreement between the present state, HA, HB, VA and VB in comparison with the new possible state HA', HB', VA' and VB'. If the number of bit positions in which there is a disagreement is three or four, we move to the action block 86 where the new state is determined to be the complement of HA', HB', VA' and VB'. On the other hand, if there is no disagreement or a one-bit position disagreement, the new state is identified in action block 87 as HA', HB', VA' and VB'. The last possibility is that the bit position disagreement amounts to exactly two bit positions. In this case, the algorithm proceeds to decision block 88 to see whether the prior possible state HA, HB, VA is in the table. If the answer is yes, we proceed to action block 86; if no, we proceed to action block 87. In either event, the new state has been defined in terms of a unique horizontal and vertical position, thereby indicating X, Y incremental motion. The frequency of determining states is sufficiently fast, e.g. three kHz or better, to detect very fast motion. As previously mentioned, the output of the ROM is latched and transmitted to X, Y counters.

In the description of this first embodiment, reference has been made to optically contrasting line patterns as well as optical sources and detectors. These optically contrasting patterns need not be visible to the human eye, only to the detector.

Mouse with Colored Line Surface

In this second embodiment, the mouse housing may be identical to the housing of Fig. 1 except that a light-emitting diode (LED) source is preferred. In this embodiment source 15 is a two-color LED which is aimed downwardly at a spot on surface 13. The LED may be two physically separate LEDs or two incandescent bulbs with color filters, but a bi-color LED is referred to for clarity. The LED may be mounted in a light-tight tube or may be directly aimed at the surface. If the LED has a wide angle lens, the LED should be mounted close to the surface so that light arriving at the surface will be in a relatively narrow spot, i.e., a spot with a diameter of less than 1.0 mm. A typical two-color LED is General Instruments MV5491. The preferred colors are red and infrared.

Also mounted in housing 14 is a detector tube 21 having at its forward end an imaging lens 23 which is a glass bead. The lens images a spot which has a linear dimension of preferably less than one line-width onto the active region of the detector. This is explained below with reference to Fig. 7.

A second assembly of this embodiment is surface 113, a magnified tiny portion, corresponding to portion 13 in Fig. 1, being illustrated in Fig. 7. This surface has a passive, position-related array of two groups of lines. A first group of lines is characterized by reflection of one color of light and absorption of a second color of light. A second group of lines is characterized by reflection of the second color and absorption of the first color. For example, one color may be red and the other green. The surface would have one group of lines, for example vertical lines which would be colored green and a second group of lines, such as horizontal lines, which would be red. In general, the green lines would reflect green light and absorb red light, while the red lines would reflect red light and absorb green light. The lines are drawn with inks of the desired optical property. Color should be uniform. The space between lines should be white, metallic-reflective or otherwise highly reflective such that a sufficient contrast ratio exists between lines and spaces. The preferred line pattern is a grid of blue horizontal lines and green vertical lines printed on white paper. The line pattern need not be a square grid, although this is easy to handle for computation purposes. Other repetitive line patterns, having position-related geometry, such as concentric circles, may be used. In Fig. 7, a partial grid pattern may be seen, with orthogonal dual color lines (color not shown) and white spaces between lines.

In Fig. 7 the dashed lines 136 indicate the relative area within a grid which forms the field of view of the detector illustrated in Fig. 3a, relative to a grid of lines and in particular to the width of a line. This is the same area imaged by the lens of the detector tube onto the detector array, such that each detector cell is capable of resolving or "seeing" the width of a line. This would not be possible if, for example, the size of the rectangle indicated by the dashed lines 136 were equal to the size of two grid spaces. Vertical lines 137 and 139 have a width approximately equal to grid space 138. Typically, the line width would be 0.5 mm. For vertical lines, detector cells 1 and 2 of Fig. 3a must both be able to simultaneously observe the line, deriving HA and HB signals. Correspondingly, for horizontal lines 141 and 143, cells 2 and 3 must both be able to simultaneously observe the lines so that VA and VB signals can be generated.

In producing the line pattern of Fig. 7, the entire surface starts as a reflective area. The inks or dyes used to print the lines shown in Fig. 7 are preferably transparent. Since any light reaching the detector is reflected from the underlying reflective surface, the underlying surface must have good reflectivity. Glossy white paper is adequate. Mylar may also be used. In the case where non-transparent inks or dyes are used for the lines, a problem will occur at line intersections where only the line printed last will be visible. To overcome this situation, the intersections must be made absorptive, i.e., dark, to both colors of light. This may require printing of intersections with a third, dark color, non-transparent ink or dye. In the situation where transparent dyes are used, the two colors are sufficient and a third color is not used. In Fig. 7, the dark or black line intersections do not necessarily represent a third color, but merely a light-absorptive region.

The desired output from the detectors is taken from three of the four cells, two horizontal bits from two horizontal cells and two vertical bits from two vertical cells. For example, HA and HB would be taken from cells one and two while VA and VB would be taken from cells three and two respectively. Cell four would not be used.

In the present invention, the LED source is capable of producing the two colors previously mentioned. At the time vertical lines appear at the detector, for example green illumination, the states of cells one and two in Fig. 3a would be saved (or cells three and four). At the time horizontal lines appear, for example under red illumination, the states of cells two and three are saved, or alternatively cells one and four. These saved states are compared with the last saved state to determine the direction of motion as previously discussed. The direction of a line crossing depends on the order of cell transitions. This is the reason that two cells are required for each of vertical and horizontal motions.

With reference to Fig. 8, a circuit for driving the light source is illustrated. The two colors of the LED can be supplied in the single package in a variety of ways, such as common anode, common cathode, or back-to-back diodes. The arrangement is indicated schematically with the diode 142 indicating a source of one color and the diode 144 indicating the source of another color. The anodes of each diode are connected to a common d.c. potential at terminal 146 which would typically be approximately 5 volts. The cathode of diode 142 is connected to a resistor 143, while the cathode of diode 144 is connected to resistor 145. Each of the diodes is driven by a square-wave clock signal applied at terminal 147. Such a clock signal can be derived from a computer or other clock source. The clock frequency should be above 3kHz. The clock signal for diode 142 is transmitted through inverter 151, while the clock signal for diode 144 is transmitted through inverters 152 and 153 in series, so that the phase of the clock signal across diode 142 is opposite diode 144, i.e. a bi-phase signal. In this manner, the diodes will conduct on alternate half-clock cycles. This creates sequential two-color illumination of the lines within the field of view of the detector.

In Fig. 9, the detector cell array 135 is seen to be connected to quad comparator circuit 136, which includes individual comparators 137, 138, 139 and 140. Each comparator receives a common reference signal from a voltage source, termed $V_{THRESHOLD}$. The output of each of the comparators does not switch until the threshold voltage is crossed in either direction. Once such a crossing occurs, the output of a comparator where such a crossing occurs changes state and such a state is latched by latch circuit 160. The threshold is crossed only when there is a significant change in contrast observed by the detector cells. For example, in counting vertical lines (green) to measure horizontal mouse travel, the detector would see reflective spaces between vertical lines. When crossing vertical lines, the green lines appear absorptive or dark under red light. The change in detector output signal occurring during the transition from the reflective condition to the absorptive condition crosses the $V_{THRESHOLD}$ level, switching the comparator state. Note that comparator 139 is not necessary since the output of this comparator can be taken from comparator 138. Hence, if an open collector clock signal is supplied from a computer, comparator 139 can be used to invert the clock signal. Hence, the inverter package is unnecessary.

If the amplified detector signal swing between dark and light areas exceeds 2 volts, quad comparator circuit 136 may be wired as a set of transimpedance amplifiers to directly drive TTL inputs.

Latch circuit 160 has latches 161, 163, 165 and 167 corresponding to electrically connected comparator output lines. The outputs from comparators 137 and 138 are seen to be the horizontal outputs HA and HB, respectively. The outputs from comparators 139 and 140 are seen to be the vertical outputs VB and VA, respectively. The latch circuits are clocked at clock terminals 171 and 173. Alternate half-cycles, i.e., out of phase, are applied to terminals 171 and 173 so that on one-half-cycle, HA and HB are gated into the latches, while on the alternate half cycle VA and VB are gated in. The latched signals, indicative of line crossings, are transmitted to the counters 175 which are commercially available. Computers which directly accept the output of the counters have been mentioned supra. These computers are known to accept a code from many mechanical mice and the present code is identical to that produced by such mice. The output from the counters 175 is then fed to a cursor which is displayed on a video display or video terminal.

In Fig. 9 it will be noted that only three of the four cells of the four-quadrant photodetector 135 have been utilized. It is possible to carry out this embodiment with a two-cell detector, such as detector 210 of Fig. 10a. This detector has detector cells 212, producing HB and VB signals on alternate clock cycles and detector cell 214 producing HA and VA signals on alternate cycles. It should be noted that this cell array must be oriented at 45^{o} to the lines of the grid pattern. The detector field of view is indicated schematically by the dashed lines 220 in Fig. 10b. The vertical lines 222 are of one color, while the horizontal lines 224 are of another color, the two colors being resolvable by the detector in the time-gating manner previously described. In contrast to the detectors in Figs. 9 and 11a, which can be rotated 90^{o} in either direction with no effect, the detector of Fig. 10a can only be rotated by 45^{o} in either direction, without affecting operation. The detectors are time gated at the clock frequency previously mentioned, i.e., above 3kHz. Time gating of the detector allows each detector cell to be shared by one of the colors for producing both a horizontal and a vertical output.

For interfacing to equipment with a microprocessor (e.g. many modern keyboards) the two or three outputs of the quad comparator circuit 136 can be directly connected to the microcomputer chip which can be programmed to produce ΔX and ΔY information on request. The microprocessor can also supply the clock signal for the LED. Examples of common microprocessors include the Intel 8048 and Motorola 6801. Such microprocessors may be used in lieu of discrete logic circuits in all cases.

Fig. 11a shows a slightly modified four-cell detector 211 having four cells 213, 215, 217 and 219. The array is arranged so that the cells are at a 45° angle to the grid pattern on the surface, such as the surface of Fig. 7. The dashed lines 221 of Fig. 11b indicate detector orientation with respect to the grid pattern, a portion of which is indicated by lines 223 and 225. Cells 213 and 217 are sensitive to one color of light, while cells 215 and 219 are sensitive to the second color of light. Sensitivity may be described by placing filters in front of the detector elements. These filters may be produced by printing on clear stock with the same ink as is used to print the surface 13. Cells 213 and 217 produce VB and VA signals respectively, while cells 215 and 219 produce signals HB and HA respectively. The 45° orientation with respect to the grid pattern would permit use of an incandescent source or LEDs of the two corresponding colors which are on continuously. Time gating of the sources or the detectors would not be required. However, the assembly is more complex since it is necessary to cut and align filter patterns over the photosensitive detectors. Since time gating is not required, ambient light, such as room light, could be used as the source. Hence, it will be realized that while light sources are preferable, in some instances pre-existing sources can be used. It should also be realized that the surfaces in both embodiments can be backlit, thereby eliminating the need for a source within the detector housing. The housing illustrated in Figs. 1, 2 and 6 is arbitrary. A light pen type of housing, as illustrated in U.S. patent 3,182,291 could also be used. The patent shows a four-cell detector with a compact source passing through the center of the cell array, using a fiber optic cable. In some instances, such a housing might be preferable to the housing illustrated in Figs. 1, 2 and 6.

With regard to light sources, two sources may be provided which are on continuously. Two two-segment detectors are used, each focussed at a different point on the surface, as shown in Fig. 6, except that each detector is illuminated by only a single color LED (or incandescent bulb with a filter). Each detector would have only two active cells. One detector would have two cells aligned for HA and HB detection, while the other detector would have orthogonal cells for VA and VB detection.

Fig. 12 shows an alternate construction for the mouse housing of the present invention. The housing 231 is a hand-held telescope which views a mouse surface 233 remotely, i.e., from a distance equal to a telescopic focal length. The field of the telescope is sufficiently small or the markings are sufficiently spaced apart relative to the telescope detector field of view such that lines of the surface can be adequately resolved. The surface may be any of the surfaces described in this patent application providing an appropriate detector is used. Telescope 231 may have an eyepiece 235 as well as a multi-cell detector 237, arranged at right angles to the eyepiece 235 and sharing collected light by means of a beam splitter 239. The telescope may be moved in an arc as indicated by the arrows A and B, or laterally translated parallel to the plane of surface 233. Other housings, such as light pens or wands may also be used. The housing may have switches, or a keyboard, for signalling a connected microprocessor.

In this embodiment, the lines and sources have been referred to as red and green lines. The lines are not restricted to these colors. As previously mentioned, colors which are reflective or absorptive of red and infrared are preferred.

It should be noted that in the present invention diagonal motion of the mouse detector is not a problem because horizontal and vertical motions are completely orthogonal and separately reported.

Mouse for Rotation as Well as Translation - First and Second Embodiments

The mouse housing of this first embodiment is shown to have only one source and detector. However, the light source and detectors are so small and non-interacting that two pairs of sources and detectors can be accommodated in the same housing, as in Fig. 6. This figure shows two sources 91 and 92 spaced from each other and from two detectors 93 and 94. The construction of the sources and detectors is as described with reference to Figs. 1 and 2. By spacing these at a distance, the electrical circuits described herein can be duplicated so that the X, Y motion of two points or spots whose distance from each other is fixed can be determined.

By knowing the relative X, Y motion of the two points, it is easy to determine the rotational orientation of the mouse so that both translation and rotation of the mouse may be noted.

For example, once two mouse positions are defined, say (X_1Y_1) and (X_2Y_2), the rotational angle (θ) of the mouse is:

$$\theta = \text{arc tan} \left(\frac{Y_2-Y_1}{X_2-X_1}\right)$$

Of course, the separation of the focal spots must be fixed and known so that angular changes can be computed using the above formula.

With reference to Fig. 13, a plan view of a slightly different mouse adapted for rotation as well as translation is illustrated. However only one detector is required. Two sources 191 and 192 are arranged as in Fig. 6. The two sources are arranged so that the clocking of each is out of phase with the clocking of the other. For example, the clocking of source 191 is illustrated in Fig. 14a, while the clocking of source 192 is illustrated in Fig. 14b. It will be noted that when source 191 is on in the interval between 0 and T, source 192 is off. On the other hand, while source 192 is on during the interval between T and 2T, source 191 is off. For the second embodiment, each of the sources alternates in color during its time slot unless a four-quadrant filtered detector is used. Both the sources and the detector cells are clocked using the same clock, with an on-board flip-flop to switch sources. The sources and detector cells are indicated schematically with reference to the surface 191 and focussing optics 197. The orientation of detector 151 depends on the particular non-rotatable embodiment used. Furthermore, the detector means could be fixed and the surface placed on the bottom of a hand-held housing. In this case, the mouse mimics the behavior of mechanical mice; only hand motion relative to the housing axes is detected.

It will be realized by those skilled in the art that variations of the systems described herein are possible. For example, while this application has described the advantage of using a multi-cell detector for detecting multiple colors, such a multi-cell detector is not necessary if the number of colors in the color pattern of a surface is exchanged for the number of cells in the detector. The table of Fig. 15 illustrates the types of motions which can be detected with different combinations of colors and cells. A double-headed arrow indicates motion in either direction indicated by the arrowheads. A single-headed arrow indicates motion only in the direction indicated by the arrow. For example, the first line of the table in Fig. 15 indicates that a single-cell detector and a line pattern of a single color can be used to detect motion in one line, but the direction of motion along that line cannot be unambiguously determined. The second line of the table indicates that by adding another cell to the detector, the direction of motion along a line can be unambiguously determined. The third line corresponds to a checkerboard grid pattern as illustrated in Fig. 3c wherein motion in two directions can be determined. The fourth line of the table indicates that by use of two colors and a single cell, motion can be detected unambiguously in one direction, using the line pattern indicated in Fig. 16a. Note that the dashed lines in Fig. 16a indicate the field of view of the detector cell. The two colors are indicated by hatched lines. Note that the lines overlap. The pattern of Fig. 16a is produced by printing lines in one color and then printing another color of the same pattern displaced from the first pattern by half a line width. Hence, when the detected illumination color changes, the line pattern seems to shift. This shifting line pattern is functionally equivalent to having a single color and a two-cell detector. The lines could also be orthogonal to each other which allows two-dimensional motion sensing. The fifth line of the table is exemplified by the embodiment of the invention described with reference to Figs. 10a, 10b, 11a and 11b. The sixth line of the table represents a line pattern wherein two sets of lines, each set identical to Fig. 16a are superimposed on top of each other in an orthogonal relationship, as shown in Fig. 16b. In other words, four colors are used, with two colors to print the horizontal pattern and the other two colors used for the vertical pattern, as in Fig. 16b. The colors of the first set of lines are selected as described above. The second set of lines has a second set of colors, different from the first set, but selected in the same way as the first set. With this pattern, a single cell can detect unambiguous motion in the direction of the line patterns.

Lastly, it will be realized that the mouse of the present invention need not be used only to control a cursor. Rather, the signals derived from the mouse system may be used to control servos for pointing various members. The motion which is sensed by the present invention is the relative motion between the detector means and the surface and is somewhat independent of the orientation of the detector means housing. However, the orientation of the housing relative to the surface may be found by using two detector means.

Claims

1. A relative motion sensing device comprising,

a surface having a repetitive, optically perceptible pattern of passive lines, and

detector means movable relative to the surface for sensing the direction of crossings of said passive lines and generating electrical pulses corresponding to the motion of the detector means relative to the surface.

2. The apparatus of Claim 1 further comprising an electrical means connected to the detector means for making a count of electrical pulses and for converting said count to a position signal for a cursor or the like.

3. The apparatus of Claim 1 wherein said lines are symmetric about a point.

4. The apparatus of Claim 3 wherein said lines form a checkerboard pattern of squares.

5. The apparatus of Claim 1 wherein said lines form a grid pattern of vertical lines having a first color and horizontal lines having a second color, said first and second colors being contrasting colors in the detector means.

6. The apparatus of Claim 1 wherein a dimension of said lines is less than one centimeter.

7. The apparatus of Claim 1 wherein said detector means comprises at least one multi-cell detector and at least one light source, the light source and the detector having means for detecting said lines on the surface at one or more focal points on the surface.

8. The apparatus of Claim 5 wherein said detector means comprises a four-quadrant detector having two cells responsive at any single time.

9. The apparatus of Claim 1 wherein said detector means comprises a pair of detectors arranged for sensing two different positions on said surface whereby rotational orientation of the two detectors can be determined.

10. The apparatus of Claim 9 wherein said two detectors comprise a single multi-cell detector cell array shared therebetween.

11. The apparatus of Claim 10 wherein said multi-quadrant detector cell array is a four-cell detector cell array.

12. The apparatus of Claim 7 wherein said light source is a two-color light source clocked with a bi-phase signal, each color of the source being responsive to a different phase of said bi-phase signal.

13. The apparatus of Claim 5 wherein said detector means comprises a two-cell detector having two clocked cells first responsive to the first color, then responsive to the second color, said colors generated by a two-color light source clocked with a bi-phase signal, each color of the source being responsive to a different phase of said bi-phase signal.

14. The apparatus of Claim 2 wherein said electrical means comprises X, Y counters, a latch and a read-only memory device containing a present position state table addressed by an electrical signal from the detector means and a prior position state retained in the latch.

15. The apparatus of Claim 1 wherein said detector means is disposed within a housing having a dimension in the plane of the surface substantially less than the surface dimension, whereby the housing can be moved over the surface.

16. The apparatus of Claim 1 wherein said detector means comprises at least one light-collecting lens disposed in front of a multi-cell detector.

17. The apparatus of Claim 16 wherein said housing includes an optical energy transmitter aimed at the surface whereby the detector means detects optical energy originating from the transmitter and re-radiated from the lines on the surface.

18. A relative motion sensing device comprising,

a repetitive pattern of optically contrasting checkerboard squares,

a photosensitive detector means movable relative to the squares for sensing crossings of said squares and generating electrical pulses corresponding to said crossings, and

a memory device connected to the detector means, said electrical pulses addressing a position state table in the memory device, said position state table yielding state information suitable for driving X, Y counters and

computer means for summing said position states in a register or the like.

19. The apparatus of Claim 18 wherein said memory device comprises a read-only memory driven by prior state and current detector signals to produce new state signals.

20. A relative motion sensing device comprising,

a surface having a pattern of passive, position-related lines thereon, with a first group of lines characterized by reflection of one color and absorption of a second color and a second group of lines characterized by reflection of the second color and absorption of the first color,

a detector means, movable relative to the surface, having a light source directed at the surface, alternately emitting light of said first and second colors, upon receipt of clock pulses, and a light detector positioned for receiving light reflected from the surface and producing electrical output signals representing reflection from lines in said first and second groups of lines,

clock means connected to said source and detector for generating clock pulses timing said light source and synchronizing the detector output signals to the source, and

counter means connected to receive said electrical signals for counting said lines during detector motion over the surface, thereby deriving a position signal for a cursor or the like.

21. The apparatus of Claim 20 wherein said first and second groups of lines are parallel, overlapping lines.

22. The apparatus of Claim 21 wherein said overlapping lines each have one-half of a line width of overlap relative to a neighboring line.

23. The apparatus of Claim 20 wherein said first and second groups of lines are parallel, mutually orthogonal lines.

24. The apparatus of Claim 20 wherein said light source alternately emits light of four colors and said first and second groups of lines are parallel, overlapping lines having third and fourth groups of parallel, overlapping lines orthogonal to the first and second groups of lines, said third and fourth groups of lines characterized by absorption only of respective third and fourth colors.

25. The apparatus of Claim 20 wherein the said colors are red and green.

26. The apparatus of Claim 20 wherein the said colors are red and infrared.

27. The apparatus of Claim 20 wherein said light detector comprises a multi-cell detector.

28. A relative motion sensing device comprising,

a surface having a pattern of passive, position-related lines thereon, with a first group of lines characterized by reflection of one color and absorption of a second color and a second group of lines characterized by reflection of the second color and absorption of the first color,

a detector means, movable relative to the surface, having a pair of light sources emitting light of said two different colors, the sources directed to one or two points on the surface, and a pair of light detectors each sensitive to one of said two different colors, the detectors positioned for receiving light reflected from said points and producing electrical output signals representing reflection from lines in said first and second groups of lines,

counter means connected to receive said electrical signals for counting said lines during detector motion relative to the surface, thereby deriving a position signal for a cursor or the like.

29. The apparatus of Claim 20 or 28 wherein said detector means comprises at least one multi-cell detector and a pair of said light sources, said sources each aimed at a different focal point on the surface whereby rotational orientation of the detector means can be determined by relative positions of the two focal points.

30. The apparatus of Claim 20 or 28 wherein said detector means comprises two multi-cell detectors, each aimed at one of said focal points.

31. The apparatus of Claim 28 wherein said first and second groups of lines are parallel, overlapping lines.

32. The apparatus of Claim 31 wherein said overlapping lines each have one-half of a line width of overlap relative to a neighboring line.

33. The apparatus of Claim 28 wherein said first and second groups of lines are parallel, mutually orthogonal lines of equal width.

34. The apparatus of Claim 28 wherein said colors are green and red.

35. The apparatus of Claim 28 wherein said colors are red and infrared.

36. The apparatus of Claim 28 wherein said light detectors are arranged with two groups of two cells each, arranged as a single four-quadrant detector cell array.

37. The apparatus of Claim 28 wherein said light detectors are arranged with two groups of two cells each, arranged as two separate detectors.

38. A method of relative motion sensing comprising,

disposing a repetitive pattern of optically contrasting, position-related lines disposed over a surface,

optically scanning said pattern of position-related lines,

generating an undulating electrical signal corresponding to two-dimensional line crossings of the scanned, position-related lines,

electrically counting undulations of the electrical signal, and

deriving an output signal for cursor control from the electrical count.

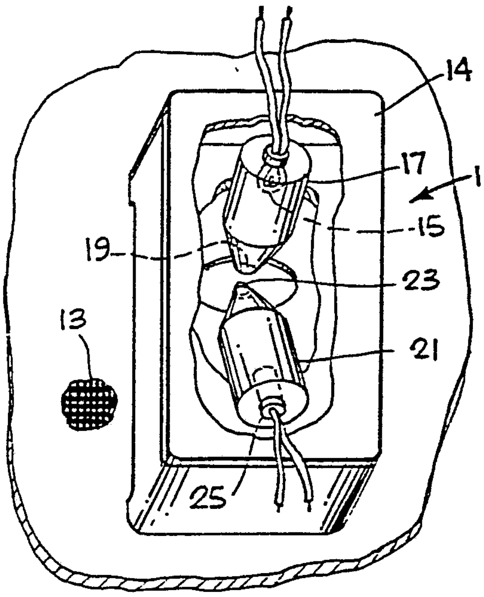


Fig.1

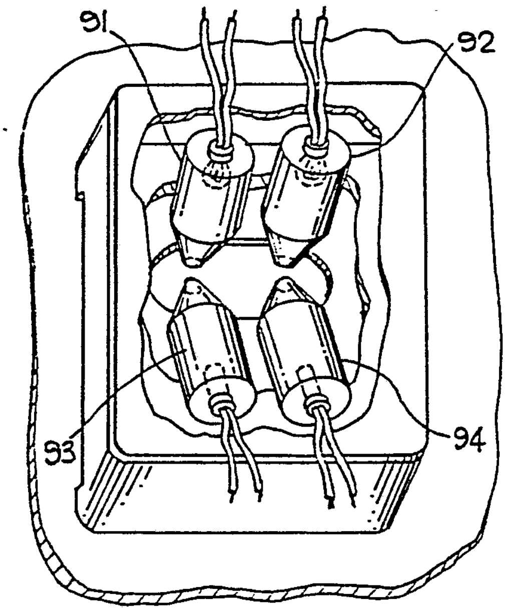


Fig.6

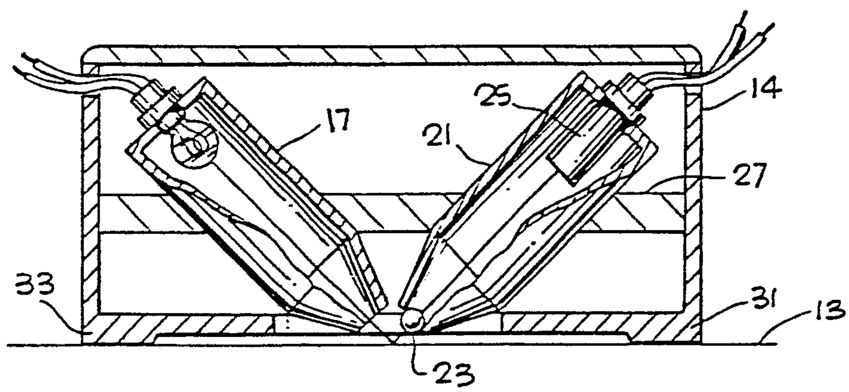


Fig.2

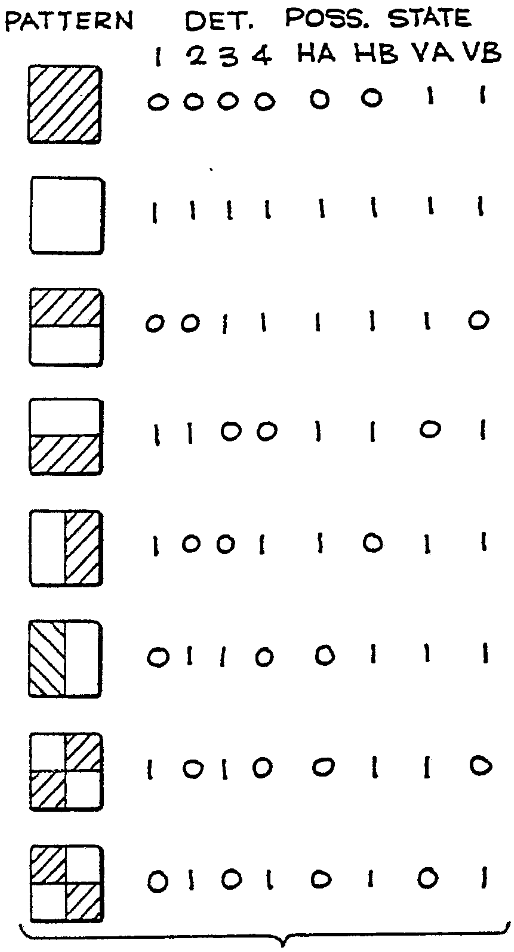


Fig. 3b

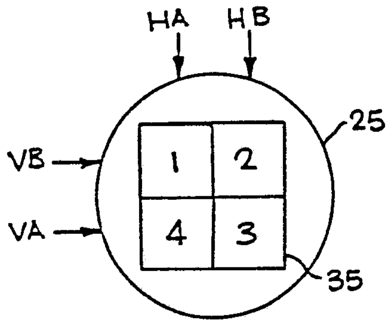


Fig. 3a

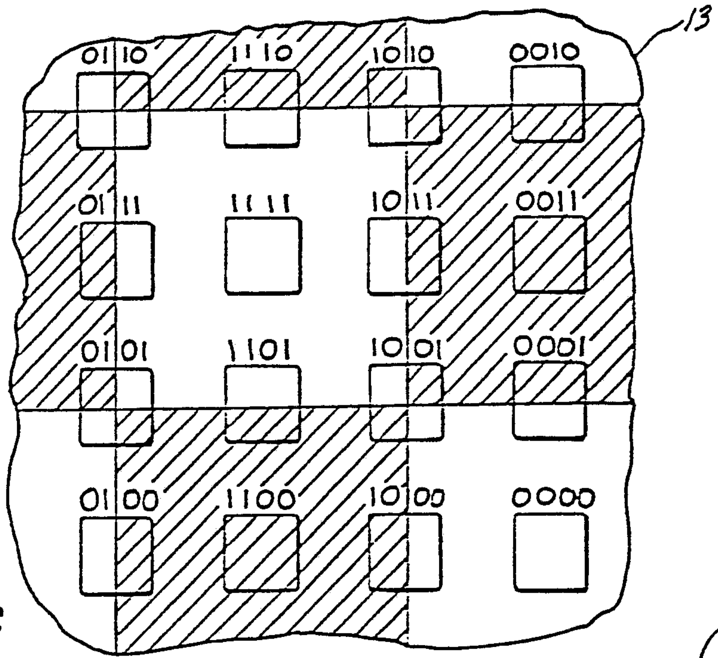


Fig. 3c

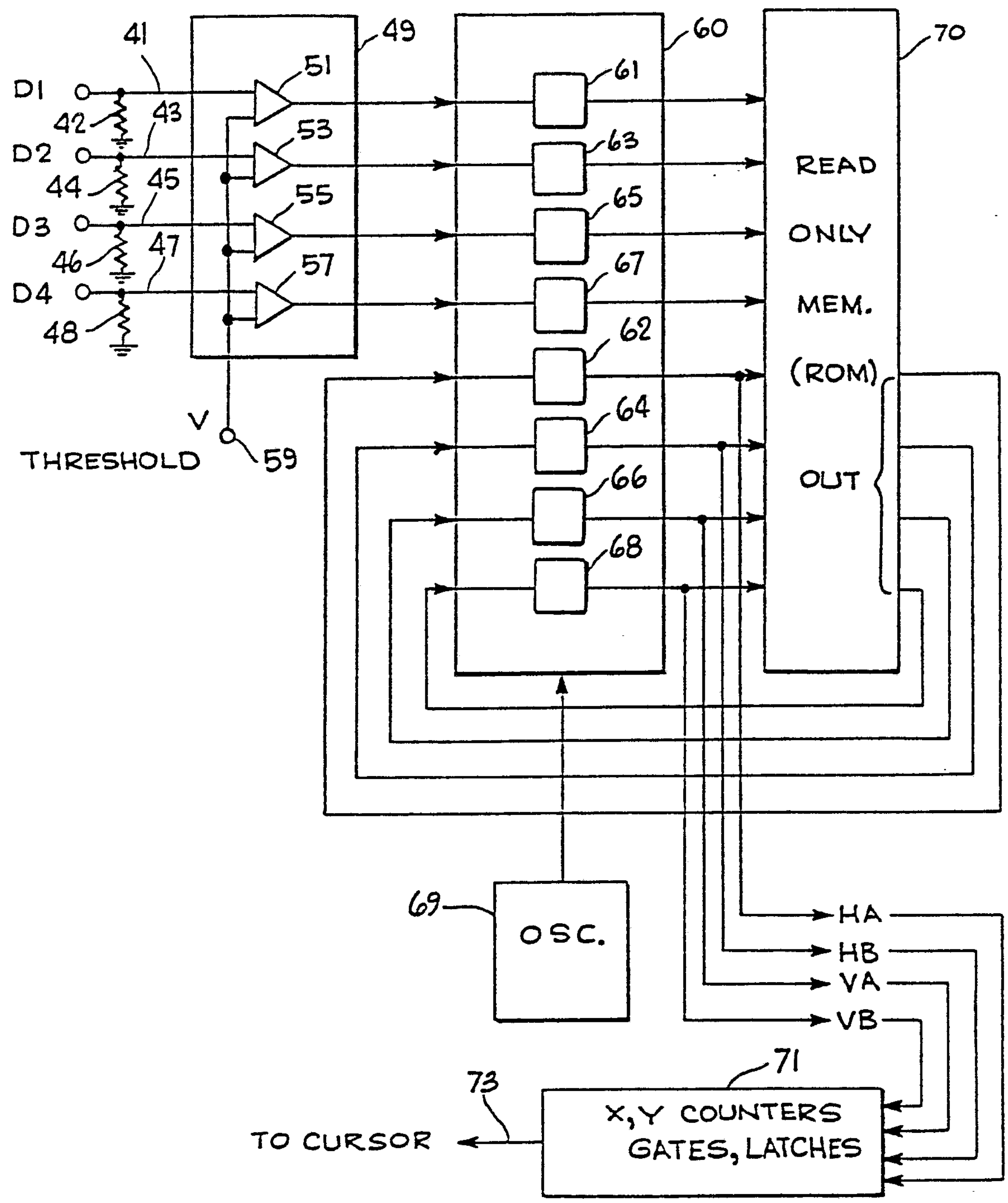

D1
D2
D3
D4
41
42
43
44
45
46
47
48
49
51
53
55
57
V
THRESHOLD
59
60
61
63
65
67
62
64
66
68
70
READ
ONLY
MEM.
(ROM)
OUT
69
OSC.
HA
HB
VA
VB
71
73
TO CURSOR
X,Y COUNTERS
GATES, LATCHES

Fig. 4

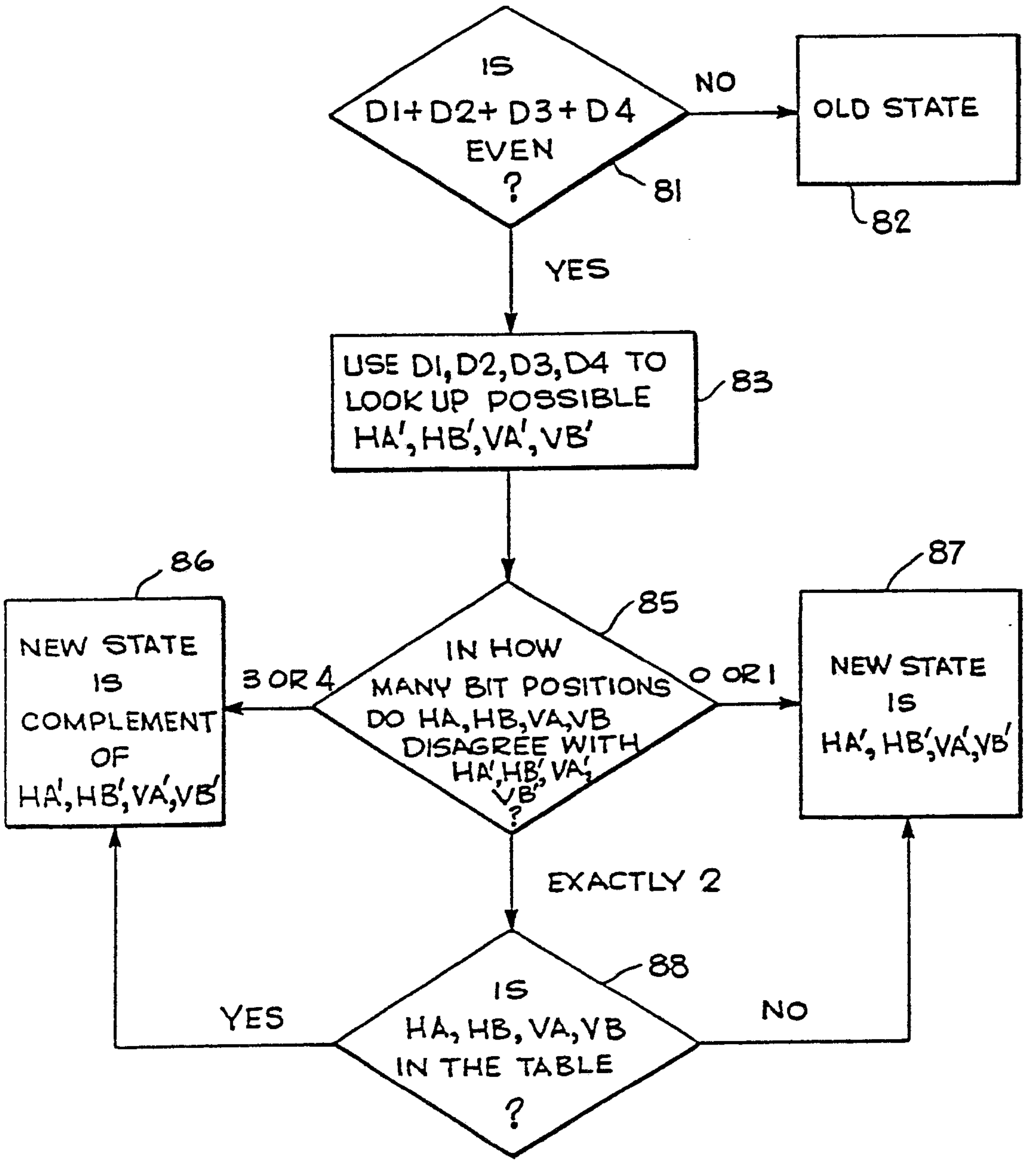

IS D1+D2+D3+D4 EVEN ?
81
NO
OLD STATE
82
YES
USE D1,D2,D3,D4 TO LOOK UP POSSIBLE HA',HB',VA',VB'
83
86
87
85
IN HOW MANY BIT POSITIONS DO HA,HB,VA,VB DISAGREE WITH HA',HB',VA',VB' ?
3 OR 4
0 OR 1
NEW STATE IS COMPLEMENT OF HA',HB',VA',VB'
NEW STATE IS HA',HB',VA',VB'
EXACTLY 2
88
IS HA,HB,VA,VB IN THE TABLE ?
YES
NO

Fig. 5

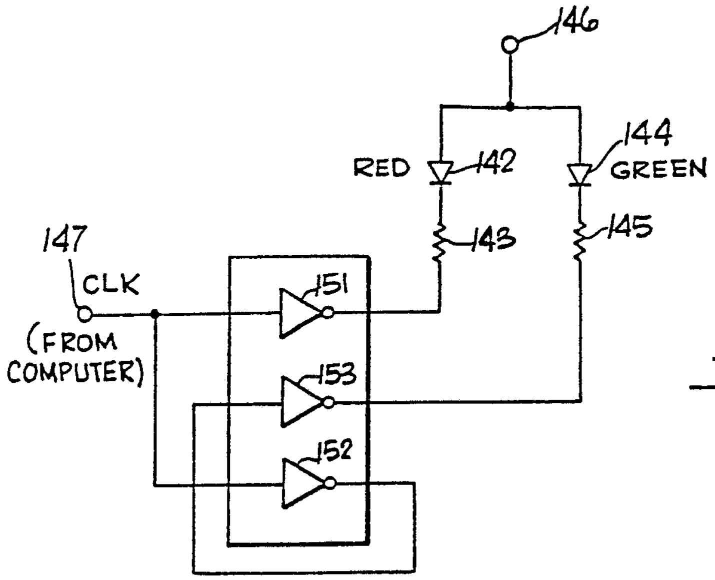

146
RED
142
144
GREEN
143
145
147
CLK
(FROM COMPUTER)
151
153
152

Fig. 8

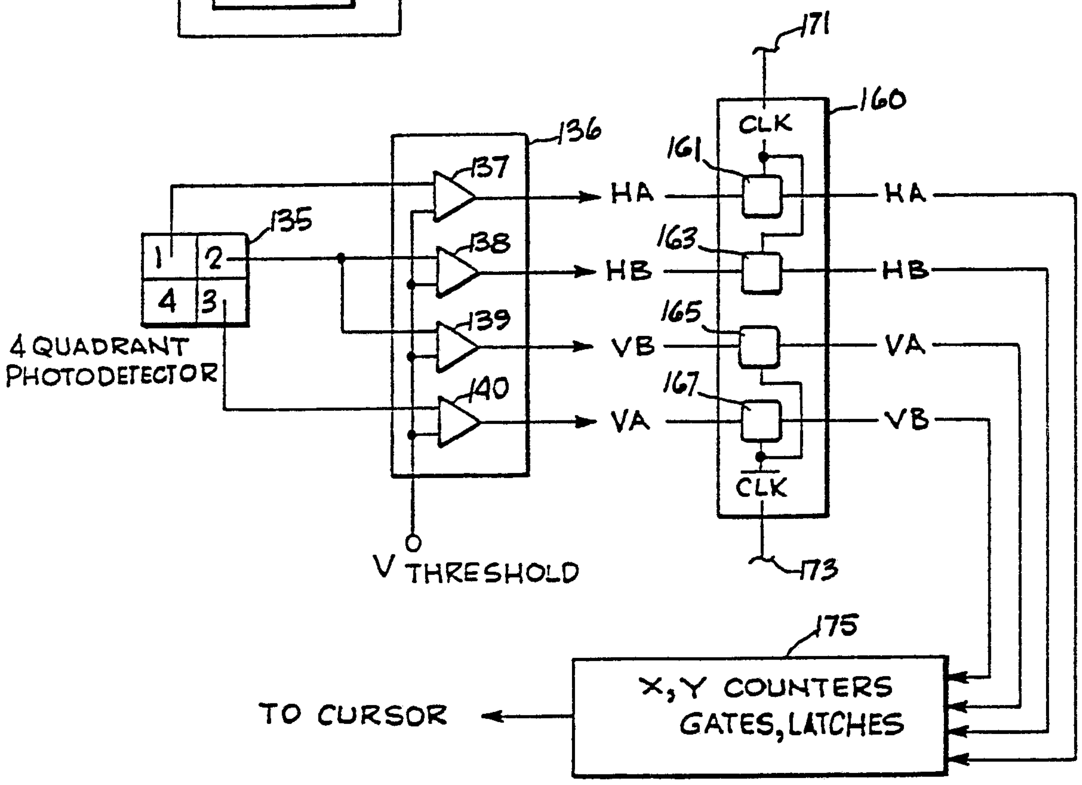

171
160
CLK
136
161
137
HA
HA
135
163
138
HB
HB
165
139
VB
VA
167
140
VA
VB
4 QUADRANT PHOTODETECTOR
CLK
V THRESHOLD
173
175
X, Y COUNTERS GATES, LATCHES
TO CURSOR

Fig. 9

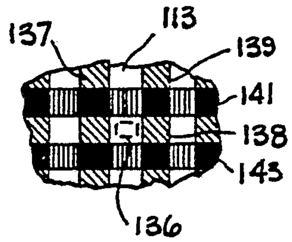


Fig. 7

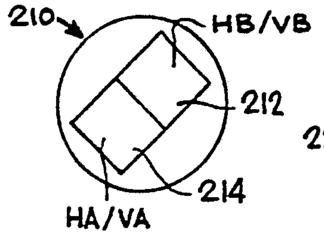


Fig. 10a

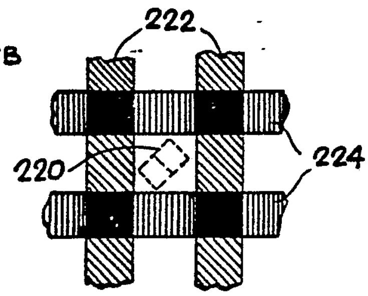


Fig. 10b

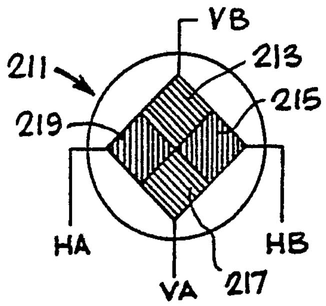


Fig. 11a

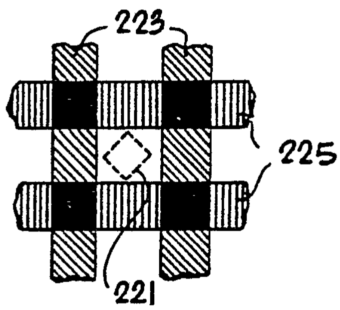


Fig. 11b

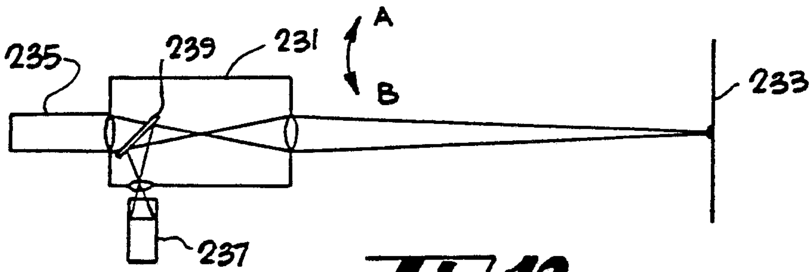
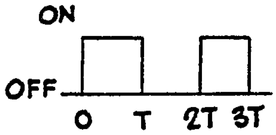
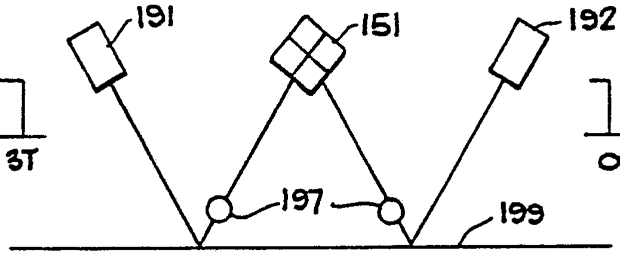


Fig. 12





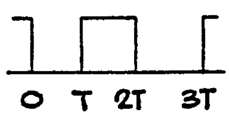


Fig. 14a

Fig. 13

Fig. 14b

	SURFACE NO. OF COLORS	DETECTOR NO. OF CELLS	MOTION
1.	1	1	↔ OR ↕
2.	1	2	⇄ OR ⇅
3.	1	4	⇄ ⇅
4.	2	1	⇄ OR ⇅ OR ↕ ↔
5.	2	2 OR 3	⇅ ⇄
6.	4	1	⇅ ⇄

Fig. 15

Fig. 16a

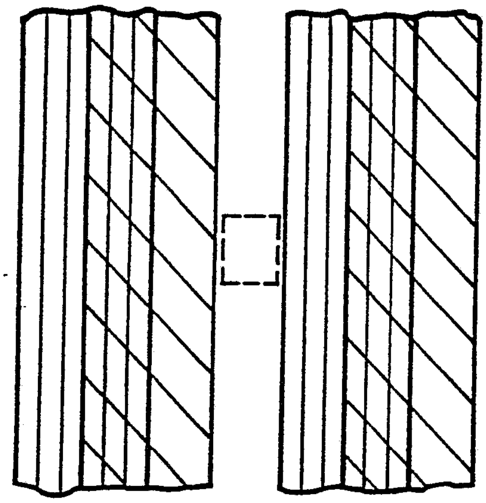
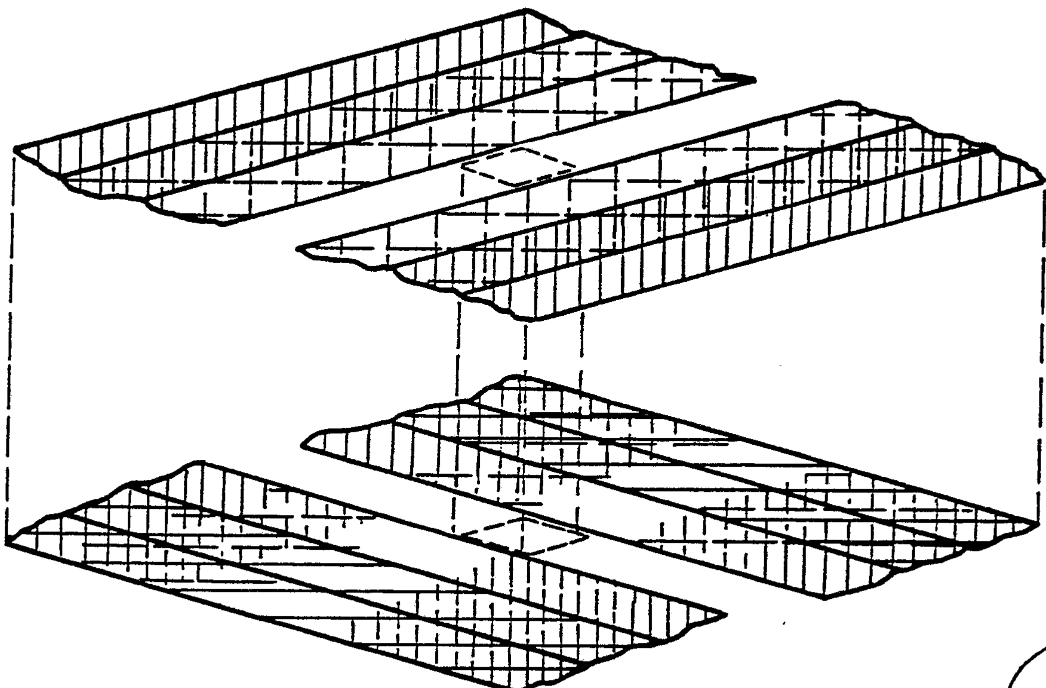


Fig. 16b



INTERNATIONAL SEARCH REPORT

International Application No PCT/US82/00146

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[3] G08C 19/36
US 340/710,365P;178/18;250/237R

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	178/18;250/237R,557,568;340/365P,707, 709,710;356/375

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
P	US, A, 4,306,147, Published 15 December 1981, Fukuyama et al	1-38
P	US, A, 4,303,914, Published 01 December 1981 Page	1-38
A	US, A, 3,825,746, Published 23 July 1974, Kendler et al	1-38
A	US, A, 3,541,521, Published 17 November 1970, Koster	1-38
A	US, A, 3,297,879, Published 10 January 1967, Meyer	1-38
X	JP, A, 54-126426, Published 01 October 1979	1-38

* Special categories of cited documents: [15]

"A" document defining the general state of the art

"E" earlier document but published on or after the international filing date

"L" document cited for special reason other than those referred to in the other categories

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
07 May 1982	19 MAY 1982
International Searching Authority [1]	Signature of Authorized Officer [10]
ISA/US	David L. Trafton

Form PCT/ISA/210 (second sheet) (October 1977)