United States Patent [19]

Kendler et al.

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[45] **July 23, 1974**

[54] **LIGHT PEN**

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[30] **Foreign Application Priority Data**

Apr. 27, 1972 Great Britain 19582/72

[52] **U.S. Cl.** ..... **250/209,** 250/227, 340/324 A

[51] **Int. Cl.** **G02b 5/14,** G08b 23/00

[58] **Field of Search** ..... 250/227, 203 CT, 220 M, 250/203 R, 209, 217 CR; 340/324 A

[56] **References Cited**

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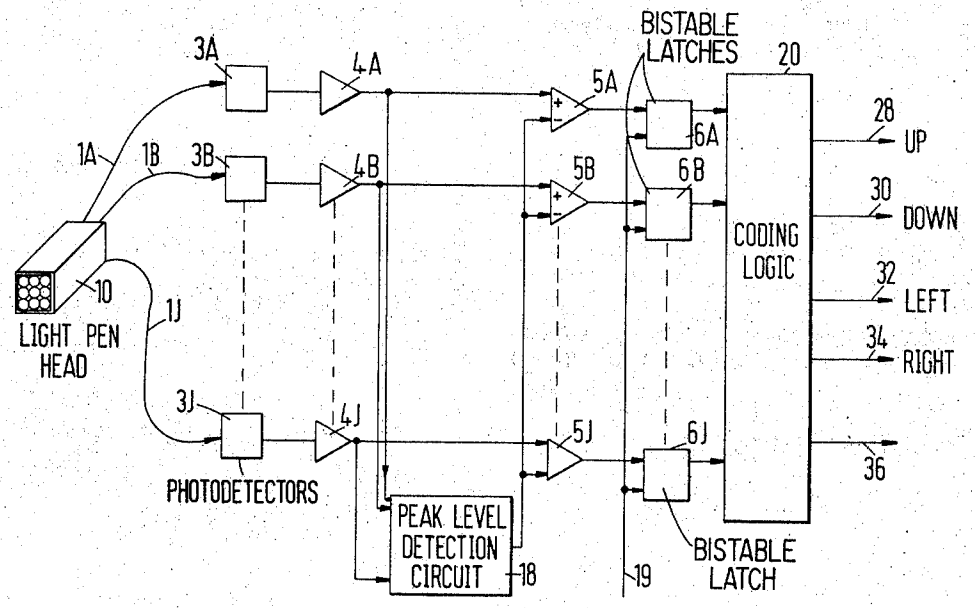
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Primary Examiner—James W. Lawrence
Assistant Examiner—T. N. Grigsby
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

A light pen for interactive computer graphics consists of an array of, for example, nine photo-electric sensors. Associated logic compares the signals from the various sensors with a common reference signal in order to generate command signals to move a spot of light incident on the array so that it is aligned with the centre of the array.

6 Claims, 9 Drawing Figures



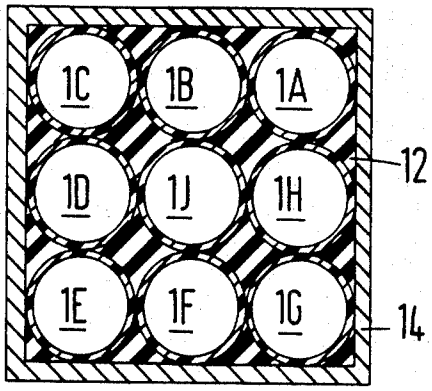
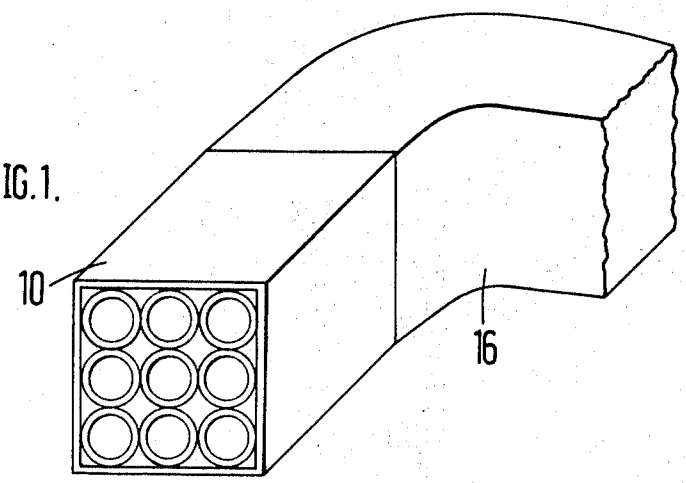


FIG. 2.

FIG. 1.



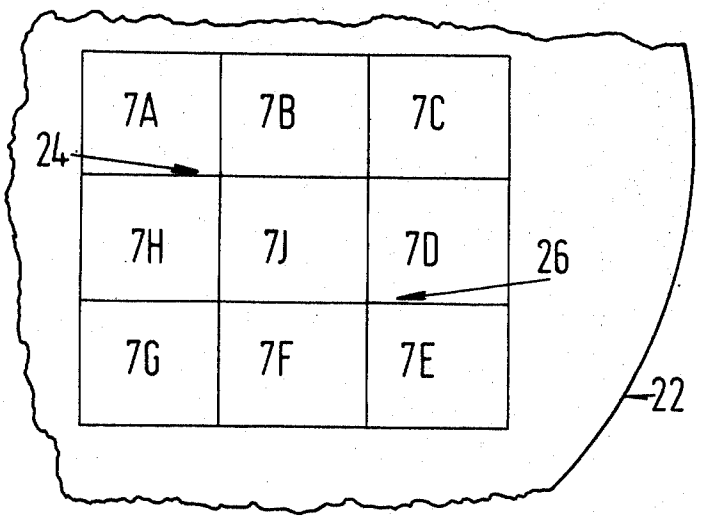


FIG. 4.

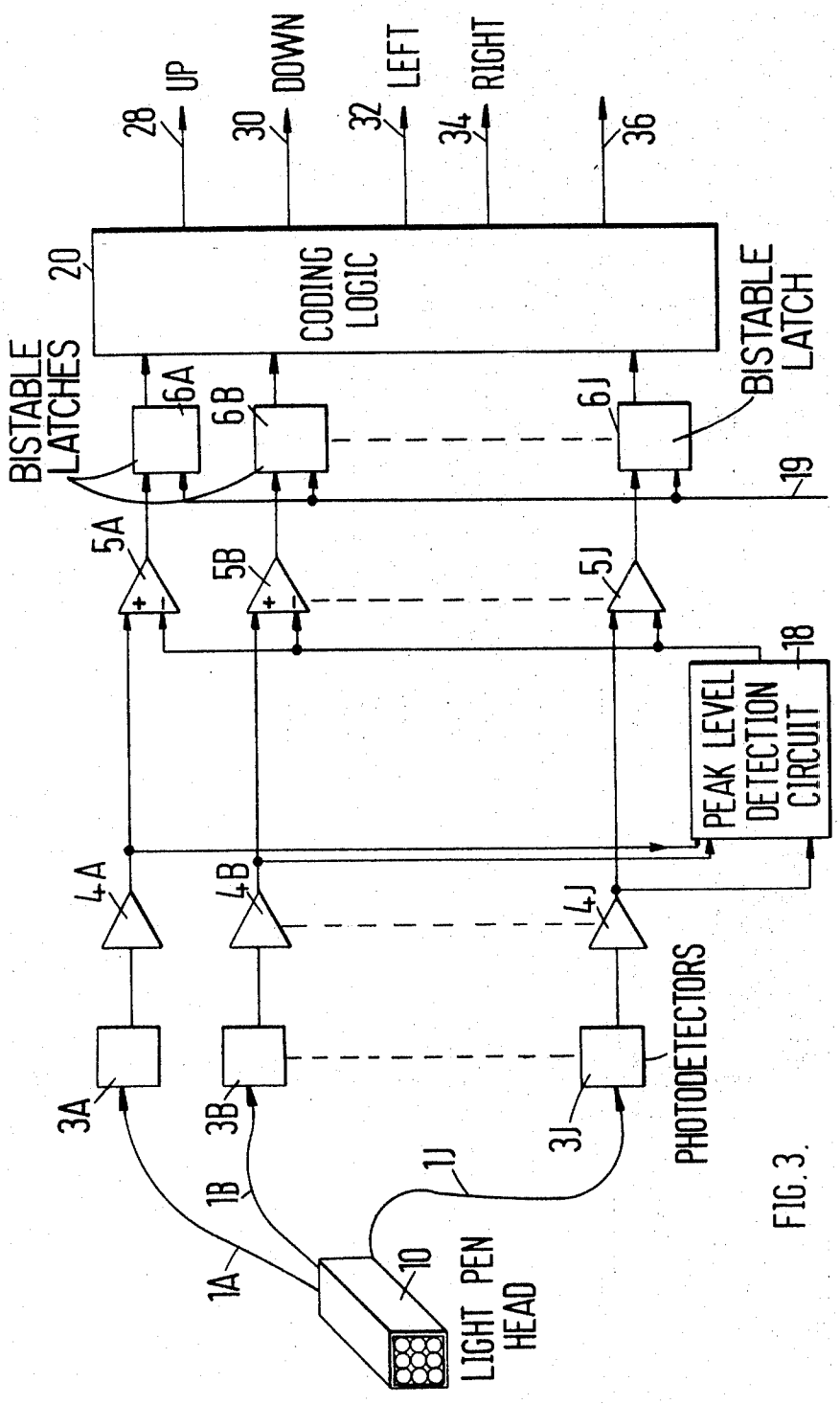

28
UP
30
DOWN
32
LEFT
34
RIGHT
36
20
CODING LOGIC
BISTABLE LATCHES
6A
6B
6J
BISTABLE LATCH
19
5A
5B
5J
18
PEAK LEVEL DETECTION CIRCUIT
4A
4B
4J
3A
3B
3J
PHOTODETECTORS
1A
1B
1J
10
LIGHT PEN HEAD

FIG. 3.

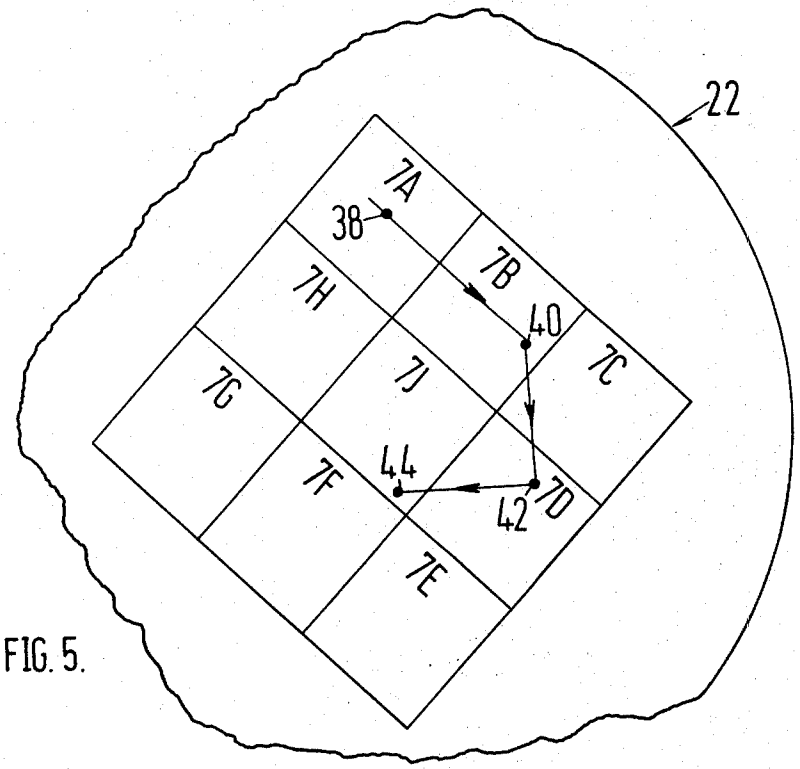

22
7A
38
7B
40
7H
7J
7C
7G
44
7F
42
7D
7E

FIG. 5.

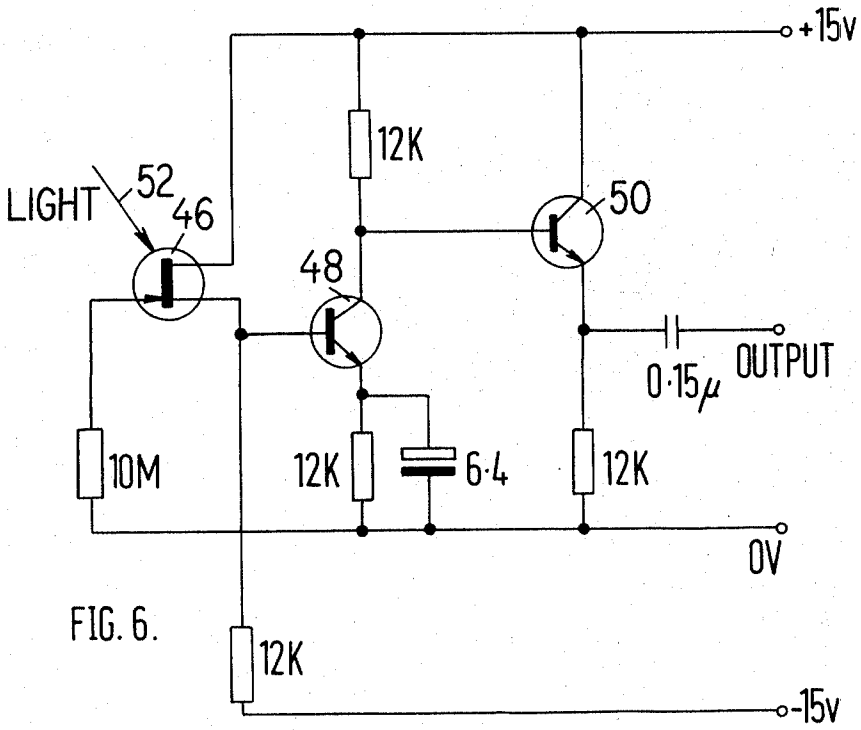

+15v
12K
LIGHT
52
46
50
48
0·15μ
OUTPUT
10M
12K
6·4
12K
0V
12K
-15v

FIG. 6.

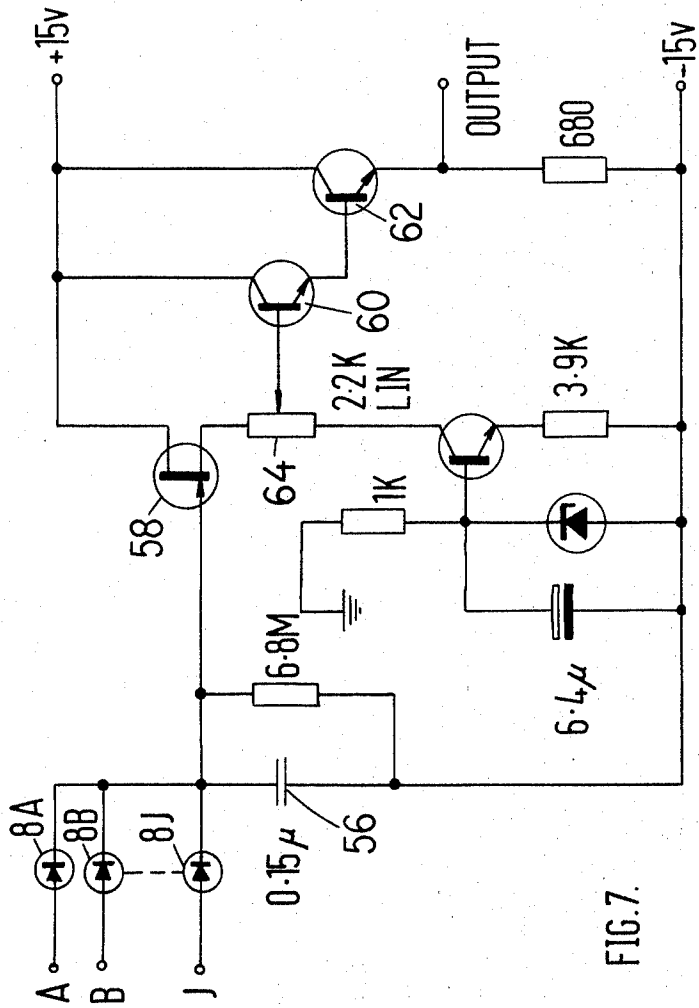

+15v
OUTPUT
680
-15v
62
60
2·2K
LIN
3·9K
64
58
1K
6·8M
6·4μ
8A
8B
8J
0·15μ
56
A
B
J

FIG.7.

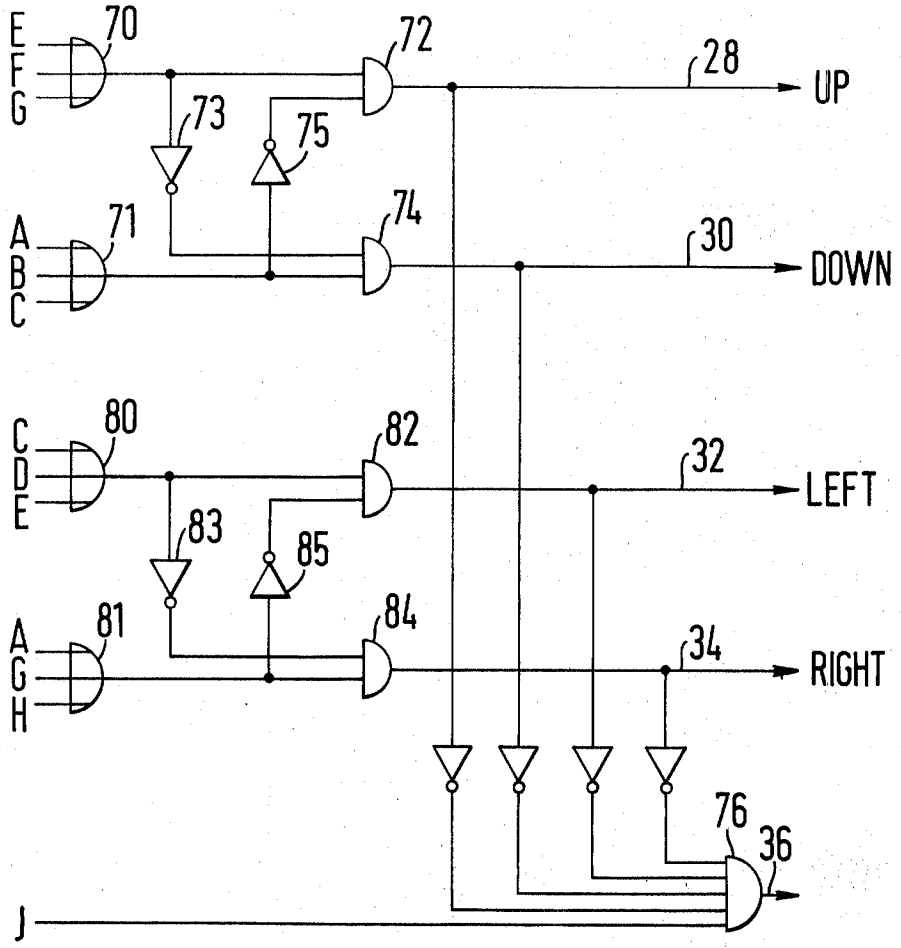

E
F
G
70
72
28
UP
73
75
A
B
C
71
74
30
DOWN
C
D
E
80
82
32
LEFT
83
85
A
G
H
81
84
34
RIGHT
76
36
J

FIG.8.

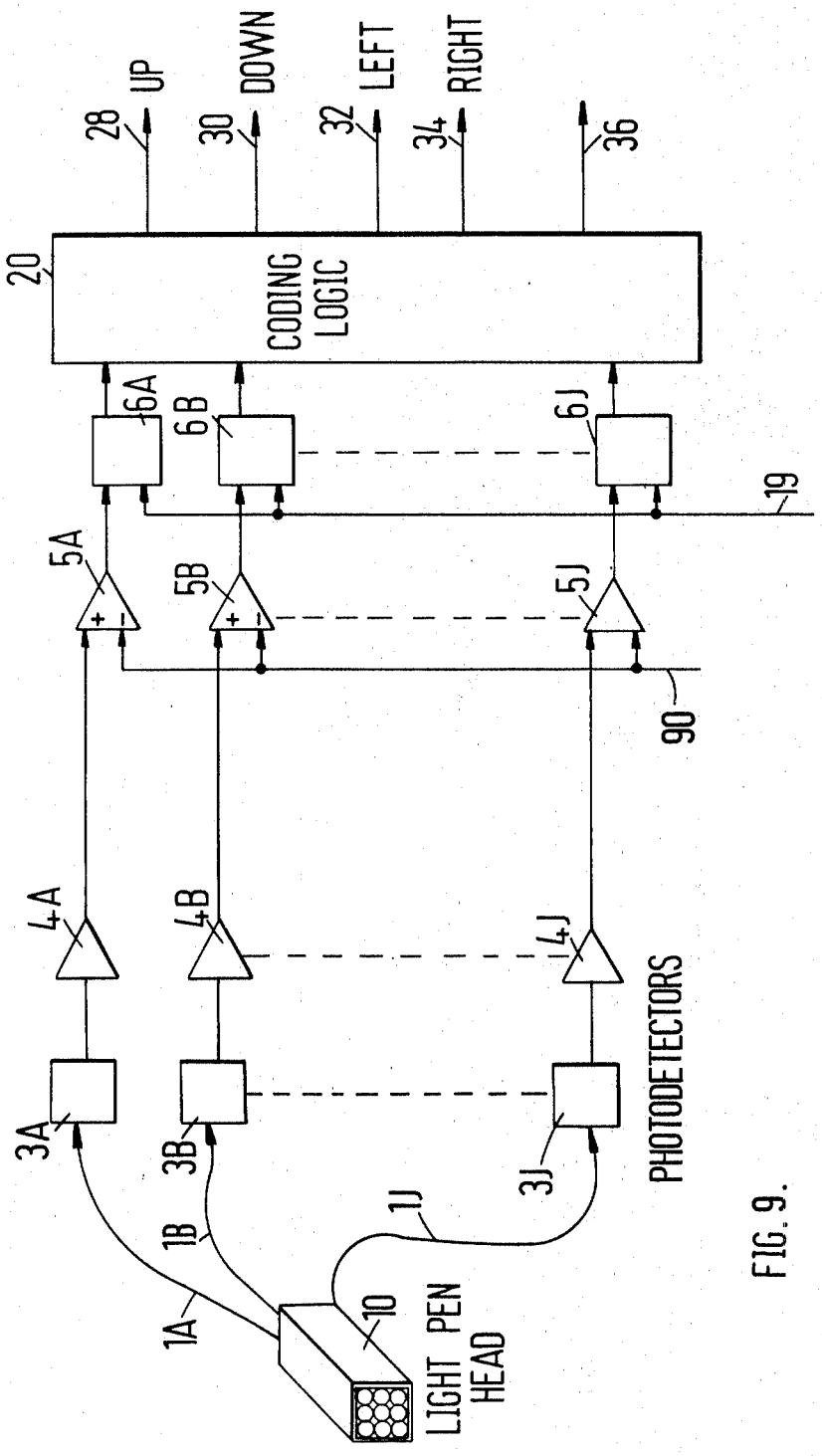

UP
DOWN
LEFT
RIGHT
28
30
32
34
36
20
CODING LOGIC
6A
6B
6J
19
5A
5B
5J
90
4A
4B
4J
PHOTODETECTORS
3A
3B
3J
1B
1J
1A
10
LIGHT PEN HEAD

FIG. 9.

LIGHT PEN

This invention relates to light pens of the kind used in interactive computer graphics.

The use of light pens in interactive computer graphics is well known. By pointing such a pen at a cathode-ray-tube display, an operator is able to cause the computer producing the displayed picture to implement certain predefined operations such as erasure and duplication of parts of the image. Each of these functions requires the operator to be able to indicate to the computer the precise position at which the demanded alteration is to be effected. Conventionally, this is achieved using a light pen containing a single photo detector. In one mode of operation, the controlling computer causes a number of dots in a defined pattern, such as a cross, to be shown sequentially upon the display screen. After each pattern point appears, the pen output is interrogated to determine whether this point has been detected by the sensor. Thus it is possible to establish which of the pattern points falls within the detection field of the pen and, using the known geometric properties of the pattern, to compute shift values to be added to the component points to centre the pattern beneath the sensor in the detection head of the pen. If the pen is moved, the pattern follows or 'tracks' it across the screen and thus can be placed at positions of interest.

This tracking procedure requires considerable involvement of the computer central processor and is expensive in the terms of the processing time which it uses. The maximum possible tracking speed is therefore often low. It is an object of the present invention to provide a light pen assembly, consisting of a light pen and associated logic circuits, in which the spatial properties of the system reside in the pen head and not in the tracking pattern so that the system is capable of tracking a single point on the display screen.

In Gordon A. Rose 'Light Pen Facilities for Direct View Storage Tubes' I.E.E.E. Transactions on Electronic Computers, August 1965, page 637, there is disclosed a light pen comprising a set of four photosensors arranged in horizontal and vertical pairs. Each pair is connected to a respective difference amplifier which produces a difference signal indicating horizontal or vertical displacement. The pair of photodetectors and associated control circuit for indicating vertical displacement is quite separate from that indicating horizontal displacement. Consequently, it is necessary for the light pen to be oriented with a reasonable degree of accuracy. It is a further object of the present invention to provide a light pen which is not subject to this limitation.

According to the invention, a light pen assembly comprises a light pen having an array of at least three photo-electric sensors and comparator means operative to determine which of the sensors is receiving the greatest illumination.

Preferably the light pen assembly also includes logic means operative in response to the comparator means to produce control signals indicating the required movement of the source illumination to bring it to a predetermined position relative to the array of sensors.

In a preferred embodiment of the invention, the light pen has nine sensors arranged in a three by three array and the logic means is arranged to produce control signals indicating the movement of a source of illumination required to align it with the central sensor of the array.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. **1** is a perspective view of a light pen head in accordance with the invention;

FIG. **2** is an elevational view of the light pen head shown in FIG. **1**;

FIG. **3** is a schematic diagram of a light pen assembly in accordance with the invention;

FIG. **4** is a schematic diagram illustrating part of a cathode ray tube display screen;

FIG. **5** is another schematic view of a cathode ray tube display screen illustrating the effect of rotating the light pen head;

FIG. **6** is a circuit diagram of a light sensor amplifier forming part of the assembly illustrated in FIG. **3**;

FIG. **7** is a circuit diagram of a peak level detection circuit forming part of the assembly illustrated in FIG. **3**;

FIG. **8** is a schematic diagram of a coding logic unit forming part of the assembly shown in FIG. **3**; and

FIG. **9** is a schematic diagram of an alternative form of light pen assembly in accordance with the invention.

The light pen illustrated in the drawings has nine sensor channels A to J. Referring to FIGS. **1** and **2**, the sensing head **10** of the light pen consists of the exposed ends of nine flexible plastic light pipes **1A** to **1J** rigidly set in a matrix **12** of silicone rubber, epoxy resin or other similar material and encased in a thin-walled metal tube **14** of square cross-section. The exposed ends of the light pipes **1A** to **1J** are arranged in a 3 × 3 element array. The other end of each light pipe is connected to a respective photo-detector as will be explained with reference to FIG. **3**. Between the tube **10** and the unit (not shown) housing the photo-detectors, the light pipes are gathered together and sheathed in protective plastic sleeving **16**.

Referring to FIG. **3**, each of the light pipes **1A** to **1J** is connected to a respective photo-detector **3A** to **3J**. The outputs of the photo-detectors **3A** to **3J** are connected to respective variable gain amplifiers **4A** to **4J** which are used to compensate for differences in sensitivity between the various sensor channels. The outputs of the amplifiers **4A** to **4J** are applied both to one input of respective comparators **5A** to **5J** and to respective inputs of a peak level detection circuit **18** which is arranged to apply to the second input of each of the comparators **5A** to **5J**, a signal of marginally lower level than its greatest input signal level. The effect of this is that unless two or more of the light pipes **1A** to **1J** receive equal illumination, only the comparator in the sensor channel producing the greatest signal can produce a logical '**1**' output, all of the others producing a logical '**0**'. If two or more of the light pipes are equally illuminated so as to be producing the greatest signal output, the corresponding comparators will each produce logical '**1**' outputs. The outputs of the comparators **5A** to **5J** are connected to respective bistable latches **6A** to **6J**, the reset inputs of which are connected via lead **19** to receive a resetting signal coincident with the bright-up strobe of the tracking spot so that the comparator output is sampled during each field period of the cathode ray tube display immediately

after display of the tracking spot. The outputs of the bistable latches **6A** to **6J** are connected to a coding logic unit **20**, the function of which will be explained hereinafter.

FIG. **4** shows part of a cathode ray tube screen **22** confronted by the light pen, the areas **7A** to **7J** being confronted by the exposed ends of the light pipes **1A** to **1J** respectively. It should be understood that the boundaries of these areas are not marked on the screen in any way and are shown in the drawing for convenience of representation only. Thus, when the tracking spot of the display is in its required position confronting the light pen, it occupies the area **7J** on the display screen. In this condition, comparators **5A** to **5J** will determine that the photo-detector **3J** is producing the largest output and consequently the latch **6J** will be set.

In operation, the light pen head **10** is positioned so that at least one of the exposed ends of the light pipes **1A** to **1J** is illuminated by the tracking spot. The coding logic unit **20** sends commands to the computer indicating the required movement of the tracking spot to bring it into alignment with the end of the central light pipe **1J**. Thus, for example, if initially the spot is located in the area **7C** so that it illuminates the light pipe **1C**, the required movement of the spot is downwards and to the left. The required movement of the spot for each of the nine areas is indicated in table **1** where zero indicates no movement and one indicates movement by a single increment.

Area of display	Illuminated light pipe	Movement Required			
		UP	DOWN	LEFT	RIGHT
7A	1A	0	1	0	1
7B	1B	0	1	0	0
7C	1C	0	1	1	0
7D	1D	0	0	1	0
7E	1E	1	0	1	0
7F	1F	1	0	0	0
7G	1G	1	0	0	1
7H	1H	0	0	0	1
7J	1J	0	0	0	0

The increment size which is used is preferably slightly less than the spacing between the centres of the exposed ends of adjacent light pipes. With this spacing, centring of the spot in general occupies only a single iteration. Larger increments may cause oscillation of the spot or even may cause it to escape from the detection field. Smaller increments increase the time taken to centre the spot since several iterations may be required.

In general, if more than one light pipe receives maximum illumination so that more than one of the latches **6A** to **6J** is set, the appropriate command will be produced. For example, if the spot centre is located at the point **24** in FIG. **4**, maximum illumination will be simultaneously received by the photo-detectors **3A**, **3B**, **3H** and **3J**. This will cause the spot to be moved down and to the right so that its centre is located at point **26** in FIG. **4**. After the next scan, if the pen head **10** remains stationary, the spot centre will be moved back to the point **24**. However, this cycle is harmless.

Excessive spot brightness or defocussing might lead to simultaneous illumination of, for example, photo-detectors **3A**, **3G** and **3H**, thus producing commands up, down and right. In order to prevent this, the requirement for an up command is arranged to inhibit the production of a down command and vice versa. Thus, this situation would result in the production of a command to move the spot to the right. Thus, the logic provided by the coding logic unit **20** is as follows:

$$UP = (E + F + G) \cdot \overline{(A + B + C)}$$

$$DOWN = (A + B + C) \cdot \overline{(E + F + G)}$$

$$LEFT = (C + D + E) \cdot \overline{(A + G + H)}$$

$$RIGHT = (A + G + H) \cdot \overline{(C + D + E)}$$

The coding logic unit **20** provides logical **1** on output lead **28** when an UP movement is required, on **30** when a DOWN movement is required, on **32** when a LEFT movement is required and on **34** when a RIGHT movement is required. In addition, the coding logic unit **20** has a fifth output lead **36**. In normal operation, logical **1** is produced on this output lead when maximum illumination is received by the central light pipe **1J**. This can be used to provide a signal to the computer to indicate that the tracking spot is properly centred with respect to the light pen head. In addition, by using this output alone, the apparatus may be used as a conventional light pen. Alternatively, if a light pen with a large detection field and correspondingly low resolution is required, the outputs from all nine photo-detectors **3A** to **3J** may be combined and used to provide logical **1** on the output lead **36** if the cathode ray tube spot is detected by any of the photo-detectors **3A** to **3J**.

FIG. **5** illustrates the effect of rotating the light pen head through 45°. If the centre of the tracking spot is initially at position **38** in the area **7A** on the cathode ray tube screen, it will be moved to the right and down so that at the end of the first iteration, it is at position **40** in area **7B**. In the next iteration, it is moved down to position **42** in area **7D** and in a third iteration, to the left so that its final position is position **44** in area **7J**. Thus, what would take one iteration if the pen **10** was correctly oriented has taken three iterations with the pen rotated through 45° but the tracking spot has nevertheless been correctly positioned within the required area **7J**. A similar result is obtained if the tracking spot is initially in any of the other outer areas **7A** to **7H**. In practice, the inherent rigidity provided by the light pipes **1A** to **1J** gathered together in their plastic sheath **16** is sufficient to make accidental rotation of the light pen by as much as 45° highly unlikely.

Referring to FIG. **6**, each of the photo-detectors **3A** to **3J** consists of a photosensitive field effect transistor **46** and an associated amplifier consisting of a first common-emitter stage comprising a bipolar transistor **48** and a final emitter follower stage employing a similar transistor **50**. The field effect transistor **46** is optically coupled to receive illuminations from its associated light pipe as indicated by the arrow **52**. Transitory illumination of the field effect transistor **46** due to passage of the cathode ray tube spot past the sensor head generates extra carriers at the gate-channel junction. This causes an increase in the reverse gate leakage current and a consequent rise in gate potential. A similar rise in source potential occurs due to the source follower configuration in which the field effect transistor is connected. A very high sensitivity and noise performance is obtained because of the very high resistance biasing networks which can be used. The positive voltage pulse produced by the field effect transistor **46** is ampli-

fied by the transistor **48** and a negative output voltage pulse of about one volt appears at the emitter of the transistor **50.** To enable this pulse to be applied as a positive voltage to the differential comparators **5A** to **5J**, the adjustable amplifiers **4A** to **4J** are chosen to be inverting amplifiers.

The peak level detection circuit **18** is illustrated in FIG. **7.** The outputs from the various adjustable gain amplifiers **4A** to **4J** are applied via respective diodes **8A** to **8J** to a 0.15μF capacitor **56** which becomes charged within 0.7 volts of the greatest signal level. A high input impedance source follower circuit including a field effect transistor **58** monitors the voltage on the capacitor **56** and drives a compound emitter follower stage comprising transistors **60** and **62** which supplies the reference voltage to the comparators **6A** to **6J** (FIG. **3**). The connection between the field effect transistor **58** and the transistor **60** is via a potentiometer **64** which is used to provide a constant D.C. offset of 0.5 volts between the inputs to the diodes **8A** to **8J** and the output to **62.** This insures that there is an adequate difference between the inputs of the comparator in the channel receiving the highest illumination to ensure reliable setting of the associated latch **6.**

The coding logic unit **20** is illustrated in FIG. **8.** In order to provide the UP and DOWN commands, the three channels E, F and G requiring an UP command when the tracking spot is detected by the corresponding photo-detector are connected to a first OR gate **70** and the three channels requiring a DOWN command are connected to a second OR gate **71.** The output of the OR gate **70** is connected directly to an AND gate **72,** which provides the UP command on lead **28,** and via an inverter **73** to an AND gate **74,** which provides the DOWN command on lead **30.** Thus illumination of any of the photo-detectors **3A, 3B** and **3C** inhibits production of an UP command even if one of the photo-detectors **3E, 3F** or **3G** is also illuminated and illumination of any of the photo-detectors **3E, 3F** or **3G** inhibits production of a DOWN command even if any of the photo-detectors **3A, 3B** and **3C** is also illuminated.

A similar arrangement, comprising OR gates **80** and **81,** AND gates **82** and **84** and inverters **83** and **85** controls the production of LEFT and RIGHT commands.

To produce the signal on lead **3G** indicating that the spot is centred, the J channel is connected directly to a five input AND gate **76,** the other four inputs of which are connected, via respective inverters **77, 78 79** and **80** to the outputs of the AND gates **72, 74, 82** and **84.**

FIG. **9** illustrates an alternative embodiment of the invention in which the peak level detection circuit **18** is omitted. Instead, the second input of each of the comparators **5A** to **5J** is connected to lead **90** to which a fixed reference voltage is applied. This reference voltage is chosen to have a magnitude higher than that of the output from any photo-detector due to ambient illumination. Thus, if the spot is symmetrically disposed on the division between the two sensors, both of the corresponding comparators will produce logical '**1**' outputs. If the spot size is larger than the end of a light pipe, a greater number of the comparators **5A** to **5J** may produce logical '**1**' output. As already explained, the coding logic **20** is designed to prevent contradictory commands appearing on the leads **28** to **34** in the event that more than one of the comparators **5A** to **5J** is producing a logical '**1**' output.

Instead of using a single reference voltage on lead **70,** a separate reference voltage may be provided for each of the comparators **5A** to **5J.** Since these reference voltages can be individually adjusted to compensate for differences in sensitivity between the channels, the variable gain amplifiers **4A** to **4J** can be omitted. Each of the photo-detectors **2A** to **2J**, with its associated comparator, now forms a variable threshold light operated switch and can be replaced by a composite device performing this function.

The manner in which a computer can be programmed to respond to the outputs on leads **28** to **36** to control the position of a tracking spot on a cathode ray tube display is well known.

We claim:

1. A light pen assembly having a two-dimensional array of at least three photo-electric sensors and control means for comparing the output of each sensor with a common reference signal and logic means operative in response to the control means to produce control signals indicating the required movement of illumination to bring it to a pre-determined position relative to the array of sensors.

2. A light pen assembly as claimed in claim **1,** in which the array comprises at least four photo-electric sensors, one of said sensors being disposed at the centre of the array.

3. A light pen assembly as claimed in claim **1,** in which each photo-electric sensor comprises a light pipe having a photocell at one end thereof, the ends of the various light pipes remote from the photocells being grouped to form the array.

4. A light pen assembly as claimed in claim **2** in which the level of the reference signal is dependent on the output from the photo-electric sensor which is receiving the greatest illumination.

5. A light pen assembly as claimed in claim **4,** in which the control means includes a peak level circuit comprising a respective diode for each sensor connecting the sensors to a common circuit point and having polarity such that the diodes connected to all sensors having lower output levels than the output level of the sensor receiving the greatest illumination are reversed biased, and means for providing a reference signal at a level higher by a predetermined amount than the highest level output from the diodes.

6. A light pen assembly as claimed in claim **1,** in which the reference signal is at a predetermined threshold level and the logic means is operative in response to those of the photo-electric sensors having outputs above said reference level to produce said control signals and includes means for inhibiting both of any such pairs of control signals indicating motion in opposite directions.

* * * * *