

# PATENT SPECIFICATION

(11) 1354 997

1354 997

- (21) Application No. 40340/72 (22) Filed 31 Aug. 1972  
 (31) Convention Application No. 183491 (32) Filed 24 Sept. 1971 in  
 (33) United States of America (US)  
 (44) Complete Specification published 30 May 1974  
 (51) International Classification H05B 33/16//G09F 9/34  
 (52) Index at acceptance  
 G5C 31B 31Q



## (54) SOLID STATE DISPLAY DEVICES

(71) We, HEWLETT - PACKARD COMPANY, of 1501 Page Mill Road, Palo Alto, California, United States of America, a corporation organised and existing under the laws of the State of California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention is concerned with improvements in or relating to solid state display devices.

The readability of a decimal point in a string of characters depends on the relative position of the decimal point to its nearby characters. In long character strings, for example, it may be difficult to quickly determine the exact location of the decimal point because it blends into the character string and becomes "lost" in the maze of characters. To remedy this, a decimal point is usually displayed well below the lowest portion of the characters. This distance below the character is often one-fifth the character height.

Positioning the decimal point below the characters sometimes increases the manufacturing cost of a display. If a character is formed from a single piece or chip of material, as in monolithic displays, either the chip size must be increased to accommodate both the character and the decimal point, or a special process must be used to provide a separate, smaller, decimal point chip. Either method increases the product cost.

It is an object of the present invention to provide an improved display device.

The present invention provides a display device comprising eight only regions capable of emitting light, seven of which are linear and are arranged in figure-of-eight formation, and the eighth of which is located within the confines of the lower part of the figure-of-eight formation to provide a decimal point or punctuation mark, the regions of the figure-of-eight formation being selectively light emissive to display a numeric character.

Preferably a display device according to the

present invention is provided by a solid state, monolithic display chip, the eight only regions being provided on one face of the chip by a plurality of p—n junctions. 50

Preferably each of said seven linear regions is continuous. Alternatively each of said seven linear regions comprises a plurality of light emissive sources aligned to form a linear region. 55

The present invention further provides a visual display apparatus comprising a plurality of numeric display means disposed in lineal array to display a plurality of adjacent digits, the display means being substantially similar and each including eight only regions which emit light in response to applied excitation and which are arranged to provide a seven-segment font and in an eighth region which emits light in response to applied excitation and which is located within the periphery of the surrounding seven regions for displaying a decimal point when excited in lieu of a digit in the digit place occupied by the associated display means. 60 65 70

Preferably the decimal point is located within the lower area of the font bounded by said regions. 75

Readability of long character strings is improved because the decimal point is well separated from its nearby characters.

When a character string is displayed using a plurality of devices according to the invention provided by chips, either a decimal point or a selected character is energized in each chip. Thus the same size chip is used to display a character or a decimal point. This eliminates the extra process needed to make a special decimal point chip. Since the decimal point is located within the character boundaries in a chip, a larger chip is not needed to accommodate the decimal point. As a result of this invention, the product cost of solid state displays for medium to long character strings can be decreased. 80 85 90

There now follows a detailed description which is to be read with reference to the accompanying drawings of prior art chips and a device according to the invention; it is to 95

be clearly understood that the illustrated device according to the invention has been selected for description to illustrate the invention by way of example.

5 In the drawings:—

Figure 1 is a side view of a prior art light-emitting diode;

10 Figures 2 and 3 show conventional forms of incorporating a decimal point in monolithic displays;

Figure 4 is a perspective view of an improved device in the form of a monolithic character chip made according to the invention;

15 Figure 5 shows a character string using conventional decimal point placement;

20 Figure 6 shows the same character string as shown in Figure 5, but with the improved decimal point placement provided by a device, made in the form of a chip, according to this invention.

Referring to Figure 1, a light-emitting diode, well-known in the art, is made from a material that emits photons when minority and majority carriers recombine. Such a material is gallium arsenide phosphide. To make a light-emitting diode, an *n*-type alloy of gallium arsenide phosphide 7 is grown epitaxially on a gallium arsenide substrate 3. A *p* region 5 is then created by diffusing a charged material, such as *p*-type zinc, into the chip. This region is capped with a metal contact 1. The contact 1 provides the anode terminal for the diode while a substrate contact 4 acts as the cathode terminal.

When a forward bias is applied to the diode, the potential barrier at the *p-n* junction is reduced so that current can flow. Just as in the operation of a standard diode, electrons are injected into the *p* region and holes are injected into the *n* region. However, when these minority carriers recombine with the majority carriers, energy is given off as photons. Some of these photons are emitted from the surface of the doped gallium arsenide phosphide. Thus the diode emits light in response to forward bias voltage.

The light-emitting regions can be selectively arranged in a monolithic chip by the positioning of the diffused *p* regions. In this manner chips can be constructed to provide numeric and alphanumeric displays. To provide a numeric display chip, a plurality of light-emitting regions are sometimes arranged in the shape of a rectangular or rhomboidal figure-of-eight. (See Figures 2—6.) By forward biasing only selected regions, any digit from 0 to 9 can be displayed. This type of display is commonly called a seven-segment font because the figure eight is usually made by seven linear regions. Sometimes small dot-like light-emitting regions are aligned to form the seven segment font.

A problem with this type of font is decimal point location. To maintain readability of a

decimal point in a string of characters, the decimal point is often located below the bottom of the character string. In conventional monolithic displays, either the chip size must be increased to accommodate both the character and the decimal point, as shown in Figure 2, or a separate smaller chip must be made for the decimal point, as shown in Figure 3. Either form increased the cost of a display.

Referring now to Figure 4, eight diffused regions 11 are positioned to form a seven-segment display and a decimal point. The decimal point is located within the lower half of the character font to keep the chip the same size as a conventional seven-segment display chip without a decimal point. Since the decimal point is contained in the character chip, no additional process is needed to manufacture a special decimal point chip.

This improved decimal point placement improves the readability of long character strings. As shown in Figure 5, the readability of a decimal point in a character string using conventional decimal point positioning depends primarily on the vertical separation between the decimal point and the character string. In the improved positioning, as shown in Figure 6, the readability is increased by greater horizontal spacing between the decimal point and its nearby characters. One character position is dedicated to the decimal point in a string of characters. A device, in the form of a chip, according to this invention does require an extra character position to display the decimal point, but the cost of this extra position is less than the extra chip area or assembly time required by conventional displays when used in displays of more than seven characters.

#### WHAT WE CLAIM IS:—

1. A display device comprising eight only regions capable of emitting light, seven of which are linear and are arranged in figure-of-eight formation, and the eighth of which is located within the confines of the lower part of the figure-of-eight formation to provide a decimal point or punctuation mark, the regions of the figure-of-eight formation being selectively light emissive to display a numeric character.

2. A display device according to claim 1 and provided by a solid state, monolithic display chip, the eight only regions being provided on one face of the chip by a plurality of *p-n* junctions.

3. A display device according to either one of claims 1 and 2 wherein each of said seven linear regions is continuous.

4. A display device according to either one of claims 1 and 2 wherein each of said seven linear regions comprises a plurality of light emissive sources aligned to form a linear region.

5. A visual display apparatus comprising



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35 When a forward bias is applied to the diode, the potential barrier at the *p*—*n* junction is reduced so that current can flow. Just as in the operation of a standard diode, electrons are injected into the *p* region and holes are injected into the *n* region. However, when these minority carriers recombine with the majority carriers, energy is given off as photons. Some of these photons are emitted from the surface of the doped gallium arsenide phosphide. Thus the diode emits light in response to forward bias voltage.

40 The light-emitting regions can be selectively arranged in a monolithic chip by the positioning of the diffused *p* regions. In this manner chips can be constructed to provide numeric and alphanumeric displays. To provide a numeric display chip, a plurality of light-emitting regions are sometimes arranged in the shape of a rectangular or rhomboidal figure-of-eight. (See Figures 2—6.) By forward biasing only selected regions, any digit from 0 to 9 can be displayed. This type of display is commonly called a seven-segment font because the figure eight is usually made by seven linear regions. Sometimes small dot-like light-emitting regions are aligned to form the seven segment font.

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2. A display device according to claim 1 and provided by a solid state, monolithic display chip, the eight only regions being provided on one face of the chip by a plurality of *p*—*n* junctions.

3. A display device according to either one of claims 1 and 2 wherein each of said seven linear regions is continuous.

4. A display device according to either one of claims 1 and 2 wherein each of said seven linear regions comprises a plurality of light emissive sources aligned to form a linear region.

5. A visual display apparatus comprising



- 5 a plurality of numeric display means disposed in linear array to display a plurality of adjacent digits, the display means being substantially similar and each including eight only regions which emit light in response to applied excitation and which are arranged to provide a seven segment font and an eighth region which emits light in response to applied excitation and which is located within the periphery of the surrounding seven regions for displaying a decimal point when excited in lieu of a digit in the digit place occupied by the associated display means.
- 10 6. A visual display apparatus according to

claim 5 wherein the decimal point is located within the lower area of the font bounded by said regions. 15

7. A display device according to claim 1 substantially as hereinbefore described with reference to Figures 4 and 6 of the accompanying drawings. 20

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Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1974.  
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.