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3,132,276

ELECTROLUMINESCENT DISPLAY DEVICE

Filed June 16, 1960

2 Sheets-Sheet 1

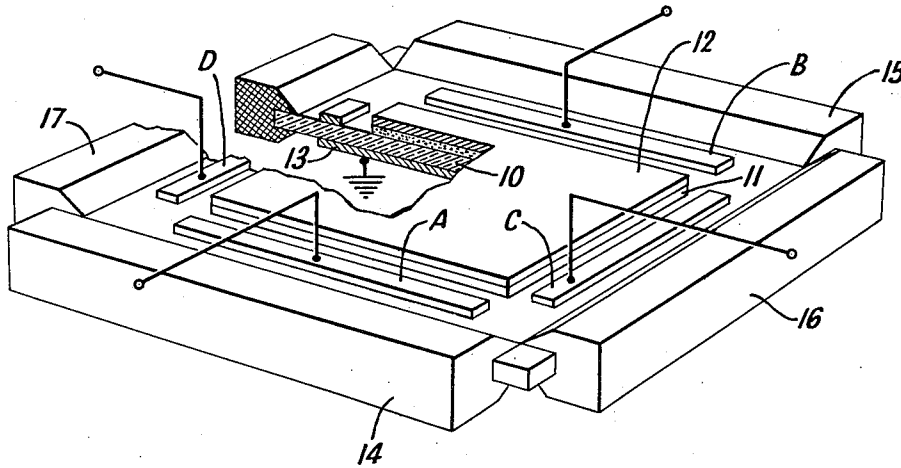


Fig.1

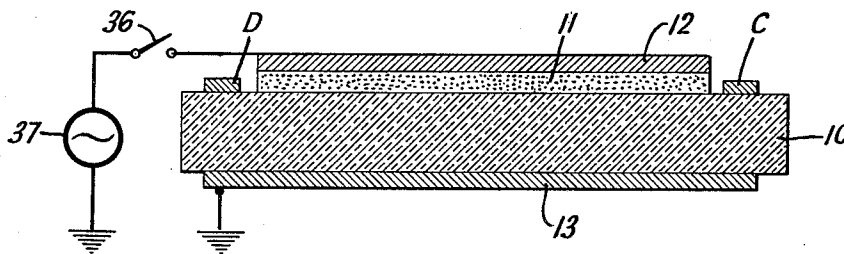


Fig. 2

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Fig. 3

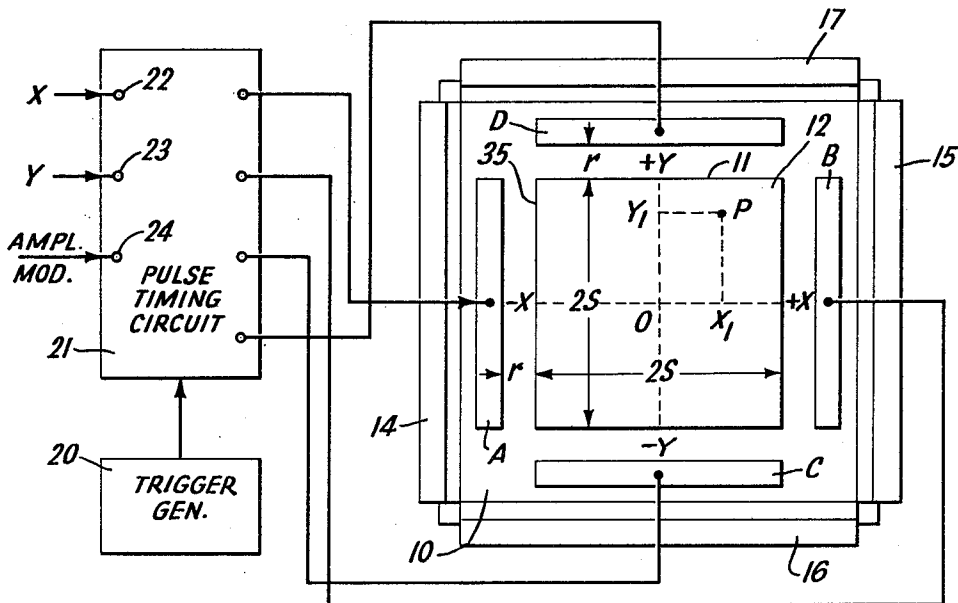
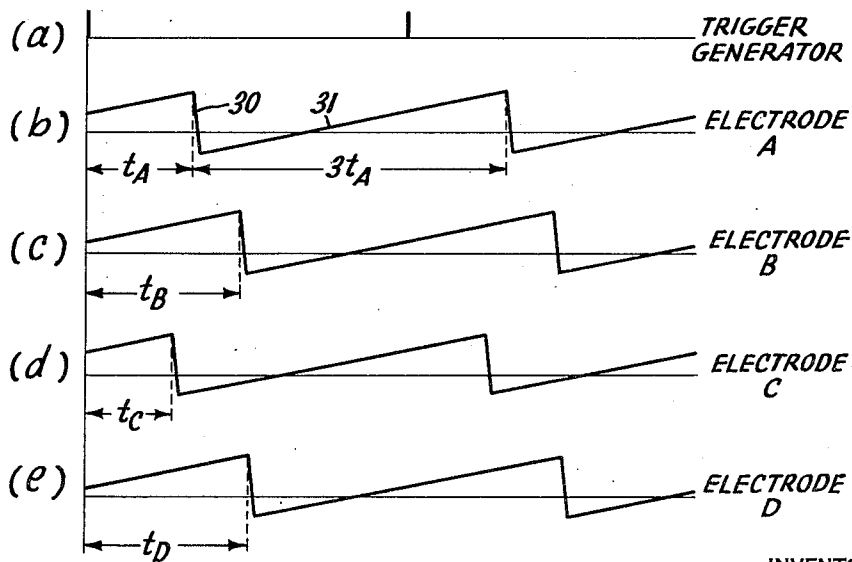


Fig. 4



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ELECTROLUMINESCENT DISPLAY DEVICE

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11 Claims. (Cl. 313-108)

This invention relates to display devices and in particular to display devices utilizing electroluminescent materials.

This application is a continuation-in-part of my copending application Serial No. 855,419, filed November 25, 1959, wherein I disclose a display device in which a spot of light is caused to diagonally traverse an electroluminescent phosphor layer affixed to one surface of a rectangular sheet of piezoelectric material. The surface of the electroluminescent layer is square and its sides are parallel to and shorter than the corresponding edges of the piezoelectric sheet. A first electrode, extending along one boundary of the electroluminescent layer, is secured to the piezoelectric sheet in the space between one edge of the sheet and the electroluminescent layer. Similarly, a second electrode is secured to the piezoelectric sheet in the space between the adjacent edge of the sheet and the electroluminescent layer. Thus, the second electrode is perpendicular to the first electrode. Electrodes connected to a common voltage reference point are secured to the other side of the piezoelectric sheet while a transparent electrode is affixed to the top of the electroluminescent layer. All four edges of the sheet are provided with terminations which absorb, substantially without reflection, any incident elastic wave.

A first voltage pulse applied between the first electrode and the voltage reference point produces a mechanical strain in the piezoelectric sheet proportional to the amplitude of the first pulse. As the strain changes, a disturbance in the form of a first plane elastic wave accompanied by a first electric field, is propagated from the first electrode toward the opposite edge of the sheet where it is absorbed by the termination. The intensity of the electric field is proportional to the time rate of change of the strain that produced it; i.e., the intensity of the first field is proportional to the first time derivative of the first pulse.

Similarly, a second voltage pulse applied between the second electrode and the voltage reference point produces a second plane elastic wave. This wave is accompanied by a second electric field which propagates from the second electrode toward the opposite edge of the sheet where it is also absorbed. The intensity of the second electric field is proportional to the first time derivative of the second voltage pulse.

Since the first and second electrodes are at right angles to each other, the first and second elastic waves are propagated in mutually perpendicular directions. The locus of the intersection of these waves as they travel through the piezoelectric sheet is a diagonal line extending across the sheet, the position of the line being a function of the difference in time between application of pulses to the first and second electrodes. The intensities of the first and second electric field are additive along the line of intersection and, as a result, a bright line of light is produced in the electroluminescent layer along the intersection. Modulation is provided by applying a voltage between the transparent and grounded electrodes.

While this device is well suited for scanning a television type image display, it is sometimes desirable to obtain a higher contrast ratio; i.e., a higher ratio of signal to background illumination. Accordingly, it is an object of this invention to provide an improved electroluminescent device in which the contrast ratio is greater than that heretofore obtainable.

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Another object of this invention is to provide an improved electroluminescent device suitable for displaying selected discrete points having coordinates corresponding to applied input signals.

Still another object is to provide an improved electroluminescent display device in which the minimum scanning rate does not depend upon the velocity of propagation though the piezoelectric material.

A further object of the invention is to provide an electroluminescent display device capable of exhibiting continuously varying applied input signals.

Yet another object is to provide an electroluminescent display device adapted for exhibiting an amplitude modulated signal.

In the present invention, there is provided a transducing member comprising a sheet of piezoelectric material having first and second surfaces. An electroluminescent layer is affixed to the first surface of the sheet and common electrode means are secured to the second surface of the sheet. At least three electrodes are secured to the first surface of the piezoelectric material, these electrodes being adjacent to the electroluminescent layer and spaced about its outer perimeter.

In one form of the invention, the sheet of piezoelectric material is rectangular having first, second, third, and fourth edges. First, second, third and fourth electrodes are secured to the first surface adjacent the first, second, third and fourth edges respectively. An electroluminescent layer having a surface area less than that of the piezoelectric sheet is affixed to the sheet in the space encompassed by the electrodes. The four edges of the sheet are provided with terminations which absorb, substantially without reflection, any incident elastic wave.

A voltage pulse applied between any one of the first, second, third or fourth electrodes and the common electrode produces a mechanical strain in the piezoelectric sheet proportional to the amplitude of the pulse. The change in strain produces a disturbance in the form of an elastic wave accompanied by an electric field which is propagated at constant speed toward the opposite edge of the sheet. The intensity of this field is proportional to the time rate of change of the strain producing it and, therefore, is proportional to the first time derivative of the applied pulse.

By applying voltage pulses to all four electrodes simultaneously, four elastic waves are generated which intersect in a small region near the center of the square electroluminescent layer. The intensities of the four electric fields produced by the four waves are additive resulting in a bright spot of light at the center of the layer. By adjusting the relative timing of the voltage pulses applied to each of the four electrodes, in a manner to be explained hereinafter, any selected area of the electroluminescent layer may be caused to glow. Further, by continuously varying the relative timing of the four pulses, the spot of light can be caused to "scan" the panel at an apparent velocity determined by the timing of the applied pulses.

In another form of the invention, the fourth electrode is omitted, the remaining three electrodes being sufficient to define any point on the electroluminescent layer. However, while the use of three electrodes simplifies both the display device itself and the necessary excitation equipment, the brightness of the display is somewhat reduced since only three electric fields intersect at the point instead of four.

The efficiency of the display device is greatly improved by the inclusion of a transparent conductive electrode over the electroluminescent layer since the electric field intensity in the layer is thereby increased. Also, when this electrode is added, the scanning voltages may be

amplitude modulated by applying a signal voltage between the conductive electrode and the common electrode.

The above objects of and the brief introduction to the present invention will be more fully understood and further objects and advantages will become apparent from a study of the following description in connection with the drawings, wherein:

FIG. 1 is a cut-away perspective view of one embodiment of the display device comprising the invention;

FIG. 2 is a cross sectional view of the display device of FIG. 1;

FIG. 3 is a plan view of the display device of FIG. 1 together with a block diagram of the excitation circuits; and

FIG. 4 depicts idealized voltage waveforms useful in explaining the operation of the circuit of FIG. 3.

Referring to FIGS. 1 and 2, there is shown a thin, square, polarized, ceramic piezoelectric sheet 10 consisting of a lead titanate-lead zirconate mixture. An electroluminescent layer 11, having a square surface area smaller than that of the piezoelectric sheet 10, is placed in intimate contact with one surface of the sheet. A transparent conductive electrode 12 is affixed to the electroluminescent layer 11 while a common grounded electrode 13 is secured to the opposite side of the piezoelectric sheet 10. Each edge of the sheet is terminated in such manner as to absorb, substantially without reflection, any incident elastic wave propagated in the sheet. This can be accomplished, for example, by coating the edges and immediately adjacent portions of sheet 10 with lead to provide terminations 14, 15, 16 and 17.

A first linear electrode A extending across the entire width of the electroluminescent layer 11 is secured to the piezoelectric sheet 10 in the space between the termination 14 and the side of layer 11. Similarly, linear electrodes B, C, and D are secured to the piezoelectric sheet 10 in the space between terminations 15, 16, and 17 respectively and electroluminescent layer 11.

The application of a voltage pulse between electrode A and grounded electrode 13 causes a first elastic wave to be propagated across the piezoelectric sheet 10 at constant speed toward absorbing termination 15. This wave is accompanied by an electric field having an intensity proportional to the time rate of change of the pulse applied to electrode A. A reverse wave also emanates from electrode A but is absorbed by termination 14 without affecting the display. Similarly, voltage pulses applied to electrodes B, C, and D cause second, third, and fourth elastic waves, accompanied by corresponding electric fields, to be propagated at the same speed as the first wave toward terminations 14, 17, and 16 respectively.

When voltage pulses are applied to electrodes A, B, C, and D simultaneously, the four elastic waves meet at the center resulting in a spot of light in electroluminescent layer 11 having a brightness proportional to the total electric field produced by the four waves. By applying voltage pulses to the four electrodes A-D at different instants of time, the four waves can be made to intersect at any selected point on the electroluminescent layer.

In FIG. 3 there is shown a plan view of the display device together with a block diagram including a trigger generator 20 and pulse timing circuit 21. A detailed description of these circuits is provided in co-assigned copending application Serial No. 36,663, filed June 16, 1960, by S. Talesnick and, therefore, will not be repeated here. The electroluminescent layer 11 together with its conductive film 12 is $2s$ units on each side and each electrode is spaced r units from the edge of the layer 11. Also, the velocity of propagation of the elastic waves through the piezoelectric material 10 in all directions has a constant magnitude v .

Coordinate axes x and y , having their origin at the center of the electroluminescent layer 11, have been superimposed on the display device to provide a reference grid for defining points on the face of the device. In FIG.

3, a point P located x_1 units to the right of the origin and y_1 units above the origin, has been arbitrarily selected as the point to be illuminated.

In order to display the selected point P, the voltage pulses must be applied to the electrodes A-D at specific instants of time which will permit the elastic waves propagated through the piezoelectric sheet 10 to converge simultaneously upon the point. (Although the illuminated area is considered to be a point, it is actually a square having a length on each side of 30-40 mils or less.) As previously described, the elastic waves are accompanied by electric fields which are coincident in space with the wave fronts and, therefore, are additive at the point P; the resultant field producing a spot of light in the electroluminescent layer at the selected point. Since the electric fields are additive at the point of intersection, a proportionally brighter spot is obtained using four electrodes than would be obtained if a lesser number of electrodes were employed.

The application of voltage pulses to the display device is initiated at time $t=0$ by a timing pulse (FIG. 4a) generated by trigger generator 20 and applied to the pulse timing circuit 21. The timing circuit 21 has four output leads coupled to electrodes A-D respectively and a pair of input terminals 22 and 23. Signal voltages proportional to the desired x and y coordinates are applied to terminals 22 and 23 respectively, these signals being used to control the sequence and relative timing of the signals applied to electrodes A-D in the manner described in the aforementioned copending application Serial No. 36,663. In addition, the x and y signals may be amplitude modulated by applying a modulation voltage to the terminal 24.

The waveform of the voltage applied to electrode A by pulse timing circuit 21 is shown in FIG. 4(b). This voltage comprises a first sawtooth portion 30 having a steep negative slope and a second sawtooth portion 31 having a gradual positive linear slope. The start of the first sawtooth portion 30 of the voltage applied to electrode A is delayed by a fixed amount t_A relative to the timing pulse occurring at time $t=0$, the interval t_A being equal to the time required for a wave to travel the distance $2s$ from one side of the electroluminescent layer 11 to the opposite side. This fixed delay is required if the point to be displayed is along the left hand side 35 of the electroluminescent layer. To display such a point, a wave must leave electrode B with such timing as to travel the distance $r+2s$ and arrive at edge 35 simultaneously with the arrival of the wave from electrode A which traveled only the relatively short distance r .

From inspection of FIG. 3, it is seen that the time required for a wave to reach the point P starting from electrode A is equal to

$$1/v(r+s+x_1)$$

while the time required for a wave to reach the same point starting from electrode B is only

$$1/v(r+s-x_1)$$

Therefore, the elastic wave must leave electrode B a time interval $2x_1/v$ later than the wave leaving electrode A. Thus, a voltage pulse is applied to electrode A by timing circuit 21 an interval t_A after the timing pulse ($t=0$) and to electrode B an interval

$$t_B = 2x_1/v_1 + t_A$$

after $t=0$.

Similarly it can be shown that pulses must be applied to electrodes C and D at times

$$t_C = 1/v(x_1 - y_1) + t_A$$

and

$$t_D = 1/v(x_1 + y_1) + t_A$$

respectively, to assure that the waves emanating from electrodes A, B, C, and D will arrive at point P simultaneously.

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FIGS. 4(b)–4(e) depict the voltage waveforms applied to electrodes A–D respectively. The rapidly changing sawtooth voltage shown at 30 (FIG. 4b) is differentiated in the piezoelectric sheet 10 and, therefore, the voltage pulse applied to the electroluminescent layer is similar in shape to the trigger pulse shown in FIG. 4a. The duration of the retrace portion 31 is equal to $3t_A$, this time being required for the waves to completely clear the display area regardless of the location of the point P. Since the slope of retrace portion 31 is small, its derivative and, therefore, the voltage applied to the electroluminescent layer is negligible during the retrace period.

If the input voltages x and y applied to pulse timing circuit 21 vary with time, a curve corresponding to these input voltages may be traced on the display device. This is accomplished by adjusting the relative timing of the voltage pulses applied to electrodes A–D for each consecutive series of pulses. A series of discrete points will actually be obtained on electroluminescent layer 11 but these will appear to the eye as a continuous curve due to the persistence of the electroluminescent layer 11. The scanning velocity and the intensity of the light spot are determined by the amplitudes and relative timing of the pulses.

Referring again to FIG. 2, the display device may also be amplitude modulated by closing switch 36 thereby connecting voltage source 37 between the conductive layer 12 and the grounded electrode 13. As the amplitude of voltage source 37 varies, the varying electric field produced in electroluminescent layer 11 by this signal is added to the summation of the four electric fields produced by application of voltage pulses to electrodes A–D. Consequently, the light intensities at the points of intersection are modulated in accordance with the amplitude variations of the source 37.

As many changes could be made in the above construction and many different embodiments could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A display device comprising a sheet of piezoelectric material having first and second surfaces; an electroluminescent layer having at least three edges affixed to the first surface of said sheet; at least three electrodes secured to the first surface of said sheet adjacent to corresponding edges of said electroluminescent layer, said electrodes being spaced about said electroluminescent layer, each of said electrodes extending substantially along the length of a corresponding edge of said electroluminescent layer; and common electrode means secured to the second surface of said sheet.

2. A display device as defined in claim 1 further comprising a transparent conductive electrode affixed to said electroluminescent layer.

3. A display device as defined in claim 1, wherein said sheet of piezoelectric material has at least three edges and wherein termination means are affixed to each edge of said sheet, said termination means absorbing substantially without reflections any incident elastic wave supplied thereto from said sheet.

4. A display device comprising a sheet of piezoelectric material having first and second surfaces; an electroluminescent layer having first, second, third and fourth edges affixed to the first surface of said sheet; first, second, third and fourth electrodes secured to the first surface of said sheet adjacent to said first, second, third and fourth edges respectively of said electroluminescent layer, said elec-

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trodes being spaced about said electroluminescent layer, each of said electrodes extending substantially along the length of a corresponding edge of said electroluminescent layer; and common electrode means secured to the second surface of said sheet.

5. The display device defined in claim 4 wherein said sheet of piezoelectric material and said electroluminescent layer have rectangular cross-sectional areas.

6. A display device as defined in claim 4 wherein said sheet of piezoelectric material and said electroluminescent layer have rectangular surface areas, the sides of said electroluminescent layer being parallel to corresponding edges of said sheet, and wherein said first, second, third, and fourth electrodes are linear and parallel to said first, second, third, and fourth edges respectively.

7. A display device as defined in claim 4, wherein said sheet of piezoelectric material has first, second, third and fourth edges adjacent said first, second, third and fourth edges of said electroluminescent layer and wherein first, second, third and fourth terminations are affixed to the first, second, third and fourth edges of said sheet, said terminations absorbing substantially without reflections any incident elastic wave supplied thereto from said sheet.

8. A display device comprising a sheet of piezoelectric material having first and second surfaces; a rectangular electroluminescent layer having first, second, third, and fourth edges affixed to the first surface of said sheet; and first, second, third, and fourth linear electrodes secured to the first surface of said sheet adjacent corresponding edges of said electroluminescent layer, said first, second, third, and fourth electrodes extending along and being parallel to the first, second, third, and fourth edges of said electroluminescent layer respectively.

9. Apparatus for displaying first and second input voltage signals comprising in combination, a sheet of piezoelectric material having first and second surfaces and first, second, third and fourth edges; a rectangular electroluminescent layer having first, second, third, and fourth edges affixed to the first surface of said sheet; a conductive layer affixed to said electroluminescent layer; first, second, third, and fourth linear electrodes secured to the first surface of said sheet adjacent the first, second, third and fourth edges of said electroluminescent layer, each of said electrodes extending substantially along the length of a corresponding edge of said electroluminescent layer; common electrode means secured to the second surface of said sheet; and excitation means coupled to said first, second, third, and fourth electrodes, said excitation means selectively applying pulses to said first, second, third and fourth electrodes and said common electrode in response to said first and second input voltage signals.

10. A display device as defined in claim 9 further comprising means for applying a modulation voltage between said conductive layer and said common electrode means.

11. A display device as defined in claim 9, wherein first, second, third and fourth terminations are affixed to the first, second, third and fourth edges respectively of said sheet, said terminations absorbing substantially without reflections any incident elastic wave supplied thereto from said sheet.

References Cited in the file of this patent

UNITED STATES PATENTS

2,810,883	Carnine	Oct. 22, 1957
2,816,236	Rosen	Dec. 10, 1957
2,863,711	Hurvitz	Dec. 9, 1958
2,922,923	Yando	Jan. 26, 1960
2,951,168	Yando	Aug. 30, 1960