Aug. 24, 1965 H. G. BLANK 3,202,868

ELECTROLUMINESCENT-PIEZOELECTRIC BAR GRAPH DISPLAY SYSTEM

Filed Oct. 24, 1962 2 Sheets-Sheet 1

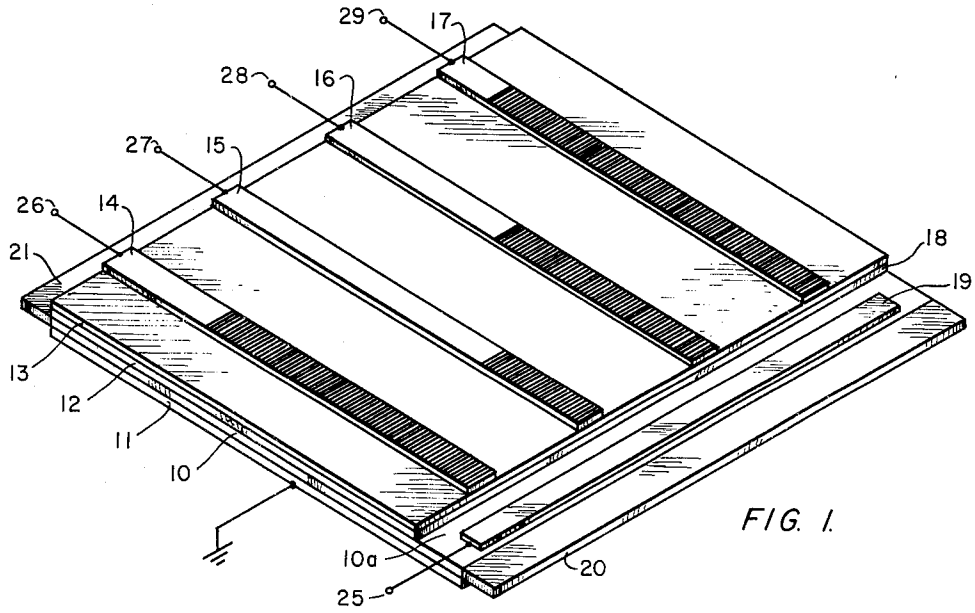


FIG. 1.

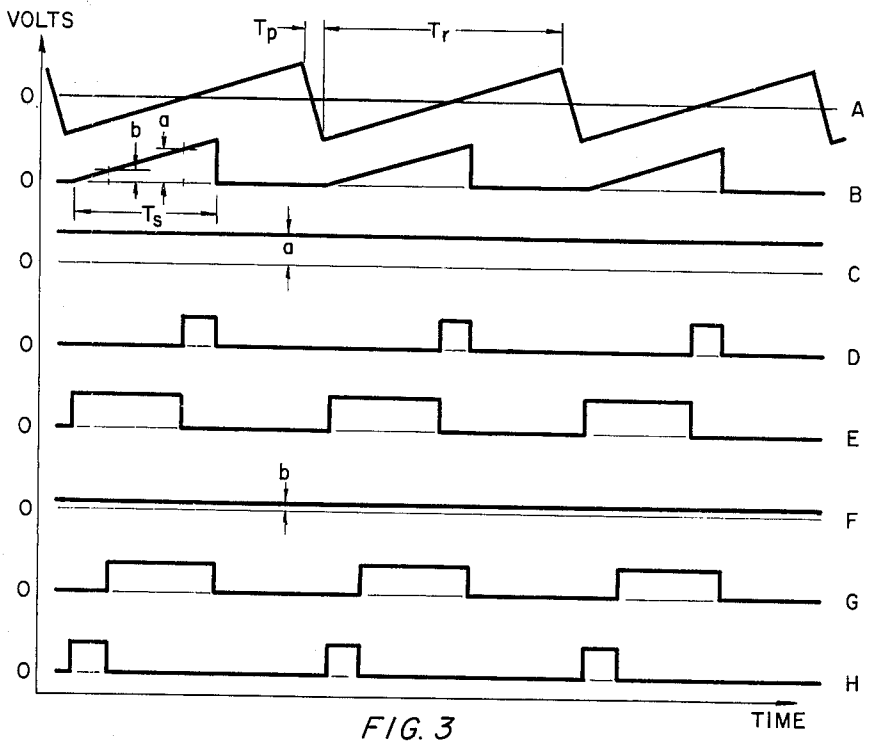


FIG. 3

INVENTOR
HANS G. BLANK
BY
R. J. Frank
ATTORNEY

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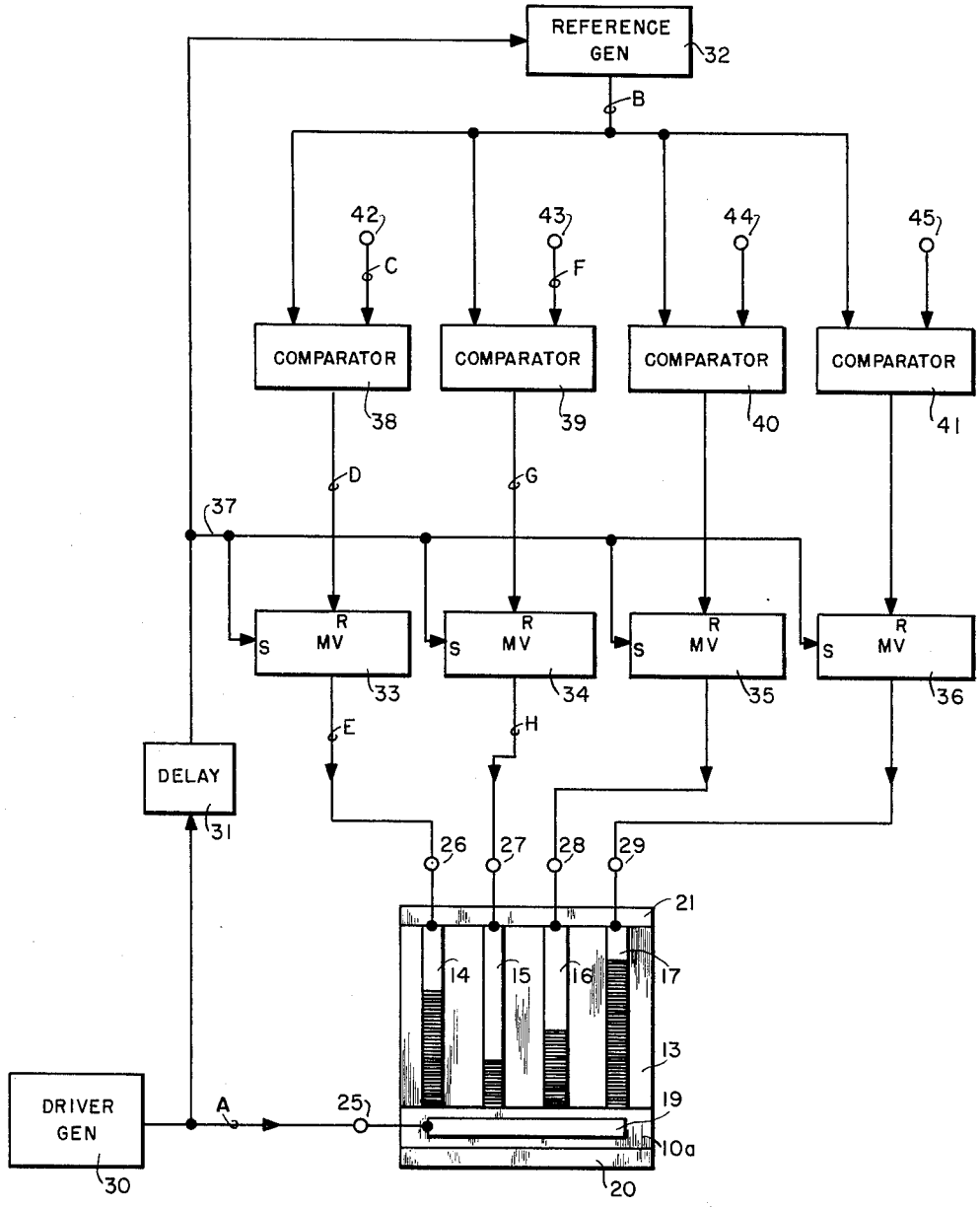


FIG. 2.

INVENTOR
HANS G. BLANK
BY
R. J. Frank
ATTORNEY

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ELECTROLUMINESCENT-PIEZOELECTRIC BAR GRAPH DISPLAY SYSTEM

Hans G. Blank, Bronx, N.Y., assignor to General Telephone and Electronics Laboratories, Inc., a corporation of Delaware

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5 Claims. (Cl. 315—55)

This invention relates to display devices.

Analog display devices, in which information is presented in the form of bar graphs, have potentially wide application in the control of industrial processes, in aircraft instrumentation, and, in general, in the display of a large number of related variables. Many electromechanical devices have been developed for providing bar displays, but these usually have relatively low speeds of response and are bulky and heavy. Electronic devices are also available for performing this function but have the disadvantage that they require sealed glass envelopes operating at low internal pressures.

Accordingly it is an object of my invention to provide an improved bar type display.

It is another object of my invention to provide a display device which may be easily and accurately read and which permits rapid comparison of two or more variables.

Still another object of the invention is to provide a bar type display which has a relatively high speed of response, is compact and light in weight.

Yet another object is to provide a display device utilizing a minimum number of components but which permits the display of a large number of variables.

The present invention is directed toward a panel for displaying a plurality of variables as parallel bars of light. The length of each bar is proportional to the magnitude of the variable being measured.

In one embodiment of the present invention, there is provided a transducing member comprising a sheet of piezoelectric material having first and second surfaces. An elongated driving electrode is affixed to the first surface of the sheet adjacent one edge and a common electrode is secured to the other surface of the sheet. An electroluminescent layer is affixed to the first surface of the piezoelectric sheet adjacent the driving electrode. A plurality of spaced transparent input electrodes are secured to the surface of the electroluminescent layer, these electrodes extending in a direction normal to the driving electrode. The edges of the piezoelectric sheet parallel to the driving electrode are provided with terminations which absorb, substantially without reflection, any incident elastic wave.

In another embodiment of the invention, a non-linear resistance layer is interposed between the piezoelectric sheet and the electroluminescent layer. As shall be explained hereinafter, the non-linear resistance layer increases the contrast of the display.

When a voltage step is applied to the driving electrode, a mechanical strain is produced in the piezoelectric sheet which is proportional to the amplitude of the step. This 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 the 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 step. This traveling electric field, however, is not of sufficient magnitude to cause the electroluminescent layer to emit light.

Input voltages are applied to each of the transparent input electrodes, each of these voltages having a duration which is proportional to the magnitude of the variable

to be displayed. These voltages are applied to the input electrodes at the instant the traveling elastic wave in the piezoelectric sheet reaches the edge of the electroluminescent layer. The sum of the voltage produced by the traveling wave and any one of the input voltages is sufficient to cause the portion of the electroluminescent layer under the excited transparent electrode to emit light.

When each input voltage drops to zero, the portion of the electroluminescent layer still being swept by the electric field propagated in the piezoelectric sheet ceases to emit light because the traveling electric field is of insufficient magnitude to sustain light emission. Since the velocity of wave propagation in the piezoelectric material is a constant, the length of the light emitting portion of the electroluminescent layer under the transparent electrode is proportional to the duration of the input voltage and hence to the magnitude of the displayed variable.

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 perspective view of my display device;

FIG. 2 is a plan view of the display device of FIG. 1 together with a block diagram of the excitation circuits; and

FIG. 3 depicts idealized voltage waveforms useful in explaining the operation of the circuit of FIG. 2.

Referring to FIG. 1, there is shown a thin, rectangular, polarized, ceramic piezoelectric sheet **10** consisting of a lead titanate-lead zirconate mixture. A common grounded electrode **11** is affixed to one surface of piezoelectric sheet **10** and a non-linear resistance layer **12** is secured to the other surface of the sheet. Layer **12** covers almost the entire surface of sheet **10**, a narrow strip **10***a* along one edge of sheet **10** being left uncovered. The non-linear resistance layer **12** may be of the type disclosed in copending application Serial No. 72,789 filed November 30, 1960, by Stephen Yando consisting of an essentially non-photoconductive cadmium sulfide powder embedded in an epoxy resin. The resistance of this layer decreases as the voltage applied across it increases or, stated another way, the current through the non-linear resistance layer varies according to the equation $I=kV^n$ where I is the current through the layer, V is the voltage across it and n is a number greater than 1.

An electroluminescent layer **13** is placed in intimate contact with non-linear resistance layer **12** and a plurality of spaced elongated transparent input electrode strips **14**, **15**, **16** and **17** are affixed to the top surface of electroluminescent layer **13**. While only four electrode strips are shown, it shall be understood that any desired number may be employed.

Edge **18** of non-linear resistance layer **12** and the edge of electroluminescent layer **13** are spaced from the corresponding edge of piezoelectric sheet **10**. An elongated driving electrode **19** is secured to strip **10***a* adjacent edge **18**. As shown, input electrodes **14**–**17** extend in a direction normal to that of driving electrode **19**.

The edges of piezoelectric sheet **10** which are parallel to driving electrode **19** are terminated in such manner as to absorb, substantially without reflection, any incident elastic wave propagated in the sheet. This is accomplished by coating the edges and immediately adjacent portions of the sheet with lead to provide terminations **20** and **21**.

The application of a voltage step between electrode **19** and grounded electrode **11** causes an elastic wave to be propagated down the piezoelectric sheet **10** at constant speed toward absorbing termination **21**. This wave is

accompanied by an electric field having an intensity proportional to the time rate of change of the step applied to electrode **19**. A reverse wave also emanates from electrode **19** but is absorbed by termination **20** without affecting the display.

The electric field produced by the traveling elastic wave is applied across the electroluminescent and non-linear resistance layers in series. Due to the high resistance of non-linear layer **12**, the current charging the electroluminescent layer **13** is quite low and therefore the voltage appearing across the electroluminescent layer is insufficient to produce light. When the elastic wave reaches edge **18**, voltages are applied between one or more of the transparent input electrodes **14–17** and ground. The voltage applied to each input electrode adds to the voltage generated by the elastic wave thereby increasing the voltage across the non-linear resistance layer **12**. This increased voltage decreases the resistance of layer **12** causing a large charging current to flow into the portion of electroluminescent layer **13** under the energized input electrode. This charging current produces a rapid increase in the voltage across electroluminescent layer **13** and causes it to emit light over the area immediately below the energized electrode.

In operation, a voltage step is applied between terminal **25** of electrode **19** and ground thereby initiating a traveling elastic wave accompanied by an electric field in piezoelectric sheet **10**. When this wave reaches edge **18**, step voltages are applied to one or more input terminals **26**, **27**, **28** and **29**. As a result, the portions of the electroluminescent layer under the energized electrodes **14–17** emit light as shown by the shaded areas in FIG. 1. The durations of the voltages applied to terminals **26–29** are made proportional to the magnitudes of the input variables and consequently, the length of each bar is proportional to the magnitude of the input variable. When the voltage on any of input terminals **26–29** drops to zero the portion of electroluminescent layer **13** under the corresponding electrodes **14–17** ceases to emit light. This is because, as previously explained, the voltage provided by the elastic wave alone is insufficient to produce light in the electroluminescent layer.

In some applications, where the non-linearity of electroluminescent layer **13** is sufficient, non-linear resistance layer **12** may be omitted. Greater brightness is thereby obtained from the display although the contrast may be somewhat decreased.

FIG. 2 is a block diagram of the apparatus used in presenting input information on the display device in the form of lighted bars having lengths proportional to the magnitudes of the input variables. Although all of the blocks are illustrated as connected by a single lead, it will be understood that each component is connected to a common ground point and that all voltages are measured with respect to this ground.

FIG. 3 shows voltage waveforms existing at the points designated by A–H in FIG. 2.

Referring to FIGS. 2 and 3, a driver generator **30** is coupled directly to terminal **25** of driver electrode **19**. Generator **30** produces a sawtooth-shaped voltage waveform at point A having a first step portion in which the magnitude of the sawtooth changes rapidly over a period T_p and a second portion in which the magnitude changes slowly over a recovery period T_r. Since the electric field generated in piezoelectric sheet **10** is proportional to the rate of change of the applied voltage, it is the voltage applied to electrode **19** during the period T_p which produces the elastic wave in the sheet. The slowly changing portion of the sawtooth during the interval T_r does not give rise to a traveling wave, this portion being the recovery period of the generator.

The output of driver generator **30** is coupled through a delay circuit **31** to a reference generator **32** which produces a sawtooth voltage output as shown at B in FIG. 3. The start of the sawtooth is delayed by delay circuit **31**

for an interval equal to the time it takes the elastic wave to travel from electrode **19** to the edge **18** of non-linear resistance layer **13**. The delayed output of driver generator **30** is also connected to the SET inputs S of pulse generators **33**, **34**, **35**, and **36** by means of a lead **37**. Pulse generators **33–36** may be multivibrators of the type disclosed in FIG. 1.1, page 10 of the book "Switching Circuits with Computer Applications" by Watts S. Humphrey, published by McGraw-Hill Book Co. in 1958. These generators have a first or SET input which initiates the output pulse when energized and a second or RESET input R which terminates the output pulse when energized. As a result, pulses are applied to input terminals **26–29** by multivibrators **33–36** simultaneously with the triggering of reference generator **32**. The pulses generated by multivibrators **33** and **34** are shown at E and H in FIG. 3.

The output of reference generator **32** is coupled to comparator circuits **38**, **39**, **40** and **41**. Comparators **38–41** may be of the type employing two input and one output connection as shown in FIGS. 9–6, page 332 of the book "Waveforms" by Chance et al., published by McGraw-Hill Book Co. When the two input voltages in this circuit are equal, an output voltage pulse is initiated which continues at constant magnitude until one of the inputs is reduced to zero. Thus, comparators **38–41** each produce an output pulse whenever a signal applied to a corresponding one of terminals **42**, **43**, **44** or **45** is equal to the magnitude of the sawtooth output voltage B of reference generator **32**. The output of each of the comparators **38–41** is coupled to the RESET input of the corresponding multivibrators **33–36**, the outputs of the multivibrators falling to zero upon energization of their RESET input.

The length of the light bar under electrode **14** is proportional to the magnitude of the input signal applied to terminal **42**. This light bar is obtained as follows. Assume, as indicated in FIG. 3C, that the signal voltage C applied to terminal **42** has a magnitude *a*. When the magnitude of the sawtooth reference voltage reaches a value *a* (see FIG. 3B), the comparator **38** generates a pulse (FIG. 3D) which ends when the reference sawtooth falls to zero. The leading edge of the comparator output pulse D resets multivibartor **33** reducing its output pulse E to zero. Since the rate of rise of the reference sawtooth B is linear, the duration of the pulse E applied to terminal **26** of electrode **14** is proportional to *a*. Thus, the length of the light emitting portion of electroluminescent layer **13** immediately under electrode **14** is also proportional to the magnitude of the input variable. A smaller input voltage F having a magnitude *b* is shown applied to terminal **43** of comparator **39**. Since this voltage is smaller in magnitude than C, the comparator output voltage is initiated earlier in the cycle resulting in the waveform shown in FIG. 3G. The earlier initiation of the comparator voltage resets multivibrator **34** earlier resulting in a relatively short pulse (FIG. 3H) being applied to terminal **27** of electrode **15**. The location of this pulse, and therefore, the length of the light emitting portion of electroluminescent layer **13** under electrode **15**, is proportional to the signal voltage *b*. Similarly, other signals may be applied to electrodes **16** and **17** to display additional input variables as bars of light.

In a typical device of the type described, the electrodes **14–17** are about 4 inches in length, the frequency of the driver generator **30** about 10 kilocycles per second, and the velocity of the elastic wave in piezoelectric sheet **10** approximately $\frac{1}{7}$-inch per microsecond. Thus it requires 28 microseconds for the elastic wave to travel from one end of the electroluminescent layer to the other and, therefore, the duration T_S of the reference sawtooth voltage (FIG. 3B) is about 28 microseconds.

Although only a single driver electrode **19** has been shown, it shall be understood that a plurality of parallel spaced driver electrodes might also be used as described

in the copending application Serial No. 183,229 filed March 28, 1962, by Stephen Yando.

As many changes could be made in the above described 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 device for displaying a plurality of input signals as illuminated bars comprising

(a) a sheet of piezoelectric material having first and second surfaces and at least one edge,

(b) an electroluminescent layer having first and second surfaces, the second surface of said electroluminescent layer being affixed to the first surface of said sheet,

(c) an elongated driving electrode secured to the first surface of said sheet between said electroluminescent layer and the edge of said sheet,

(d) common electrode means secured to the second surface of said sheet, and

(e) a plurality of spaced transparent input electrodes secured to the first surface of said electroluminescent layer, said input electrodes extending in a direction normal to said driving electrode.

2. A device for displaying a plurality of input signals as illuminated bars comprising

(a) a sheet of piezoelectric material having first and second surfaces and first and second parallel edges,

(b) an electroluminescent layer having first and second surfaces,

(c) a non-linear resistance layer interposed between the first surface of said sheet and the second surface of said electroluminescent layer, said electroluminescent layer and said non-linear resistance layer being spaced from the first edge of said sheet,

(d) elongated driving electrode means secured to the first surface of said sheet in the space adjacent said electroluminescent and non-linear resistance layers, said elongated driving electrode means extending in a direction parallel to said first edge of the sheet,

(e) common electrode means secured to the second surface of said sheet,

(f) a plurality of spaced elongated input electrodes secured to the first surface of said electroluminescent layer, said input electrodes extending in a direction normal to said driving electrode means, and

(g) first and second termination means affixed to the first and second edges of said sheet respectively, said termination means absorbing substantially without reflection any incident elastic wave supplied thereto from said sheet.

3. A display device comprising

(a) a sheet of piezoelectric material having first and second surfaces and first and second parallel edges,

(b) an electroluminescent layer affixed to the first surface of said sheet, said electroluminescent layer being spaced from the first edge of said sheet,

(c) driving electrode means secured to the first surface of said sheet in the space adjacent said electroluminescent layer 5 said driving electrode means extending in a direction parallel to said first edge of the sheet,

(d) common electrode means secured to the second surface of said sheet,

(e) means for applying a driving voltage between said driving electrode means and said common electrode means, said means including a driver generator coupled between said driving electrode means and said common electrode means,

(f) a plurality of spaced elongated input electrodes secured to the surface of said electroluminescent layer, said input electrodes extending in a direction normal to said driving electrode means, and

(g) means for applying input voltage pulses between each of said plurality of spaced input electrodes and said common electrode means, each of said means including a pulse generator having first and second inputs and an output, said first input being coupled to the output of said driver generator and the output of said pulse generator being coupled to a corresponding one of said input electrodes; and a comparator circuit having a first input adapted to receive a reference signal, a second input adapted to receive an applied input signal and an output coupled to the second input of said pulse generator, said comparator circuit generating an output pulse when the magnitude of said reference signal equals the magnitude of said input signal, said pulse generator applying an output pulse to said corresponding input electrode a predetermined interval after said driver generator applies a pulse to said driving electrode and terminating said pulse when the output of said comparator circuit is applied to the second input of said pulse generator.

4. A display device comprising

(a) a sheet of piezoelectric material having first and second surfaces and first and second parallel edges,

(b) an electroluminescent layer affixed to the first surface of said sheet, said electroluminescant layer being spaced from the first edge of said sheet,

(c) driving electrode means secured to the first surface of said sheet in the space adjacent said electroluminescent layer 5 said driving electrode means extending in a direction parallel to said first edge of the sheet,

(d) common electrode means secured to the second surface of said sheet,

(e) means for applying a driving voltage between said driving electrode means and said common electrode means, said means including a driver generator coupled between said driving electrode means and common electrode means,

(f) a plurality of spaced elongated input electrodes secured to the surface of said electroluminescent layer, said input electrodes extending in a direction normal to said driving electrode means,

(g) a plurality of pulse generators each having first and second inputs and an output coupled to a corresponding input electrode, the first input of each of said pulse generators being coupled to the output of said driver generator,

(h) a plurality of comparator circuits each having first and second inputs and an output coupled to the second input of a corresponding pulse generator, and

(i) a sawtooth reference generator having an output coupled to the first inputs of each of said comparator circuits, each of said comparator circuits applying a voltage to the second input of the corresponding pulse generator when the magnitude of the output of the reference generator equals the magnitude of a signal applied to the second input of said comparator circuit, each of said pulse generators applying a signal to the corresponding input electrode when its first input is energized by said driver generator and terminating said pulse when its second input is energized by the output of said comparator circuit.

5. A display device as defined by claim 4 wherein delay means couples the first inputs of said plurality of pulse generators to the output of said driver generator and the input of said reference generator to the output of said driver generator, said delay means providing a delay equal to the time required for an elastic wave to travel through said sheet of piezoelectric material from said

driver electrode to the adjacent edge of said electroluminescent layer.

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GEORGE N. WESTBY, *Primary Examiner.*

JOHN W. HUCKERT, *Examiner.*