Feb. 24, 1959 P. M. G. TOULON 2,875,380

DISPLAY SYSTEMS

Filed April 11, 1958 2 Sheets-Sheet 1

Fig. 1

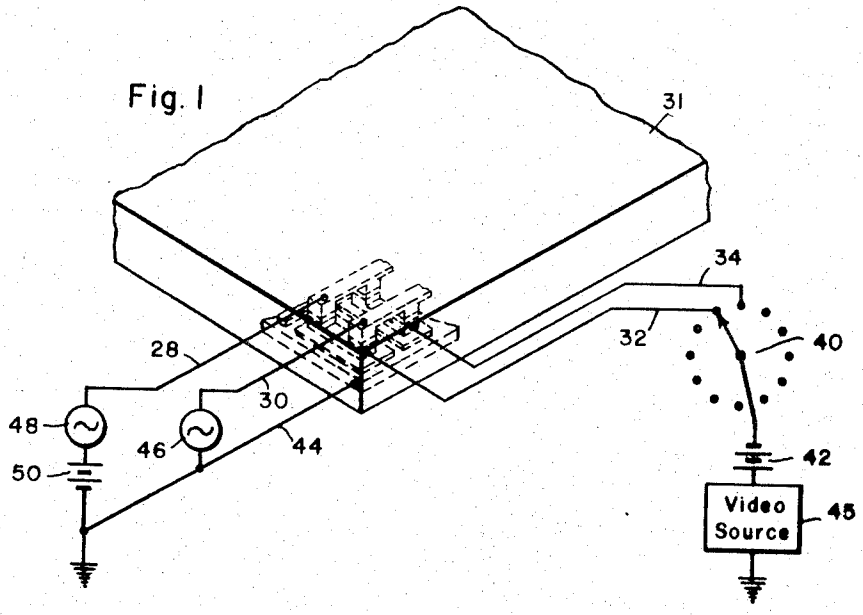
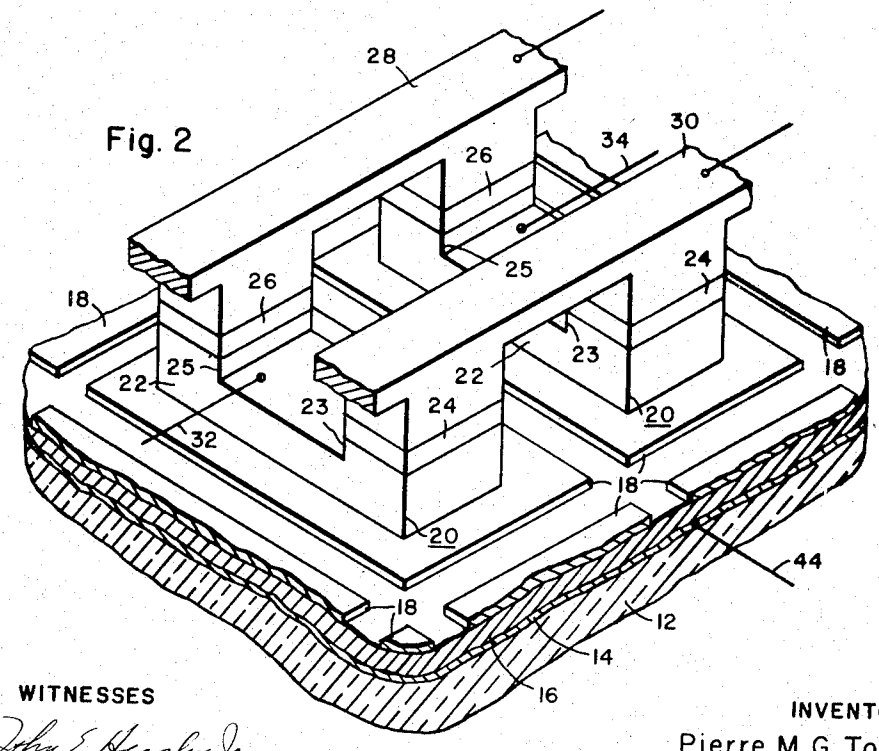


Fig. 2



WITNESSES

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DISPLAY SYSTEMS
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Fig. 3

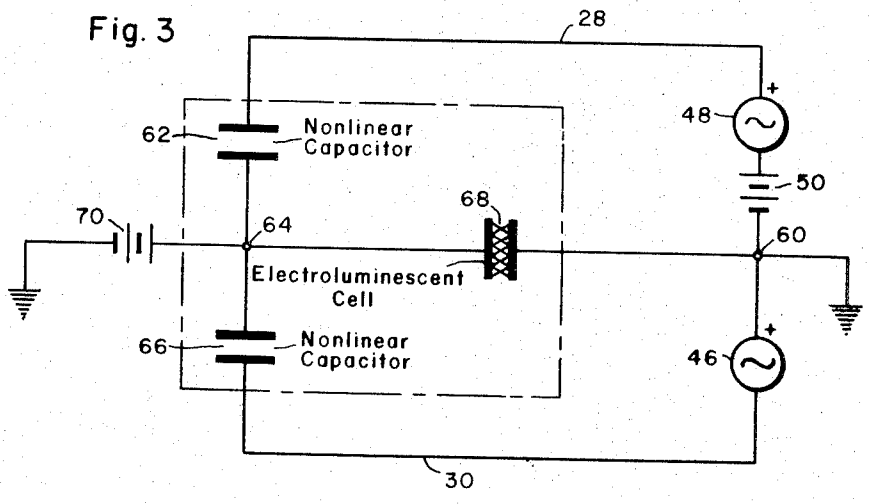


Fig. 4

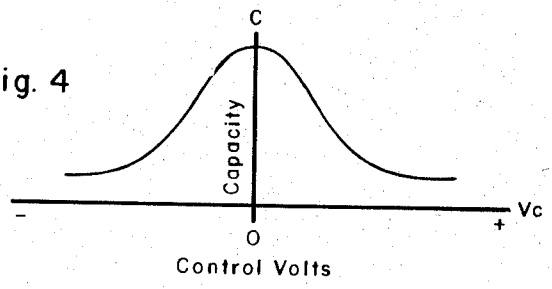
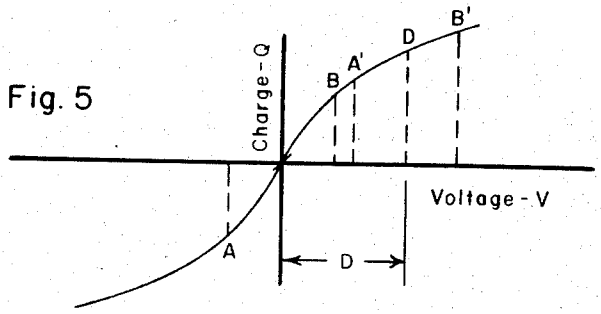


Fig. 5



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2,875,380

DISPLAY SYSTEMS

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Application April 11, 1958, Serial No. 727,916

10 Claims. (Cl. 315—169)

This invention relates to display systems, and more particularly, to storage type display devices of thin panel-like structure.

The most common display tube known in the art is the conventional cathode ray tube. In the cathode ray tube, it is necessary for an electron beam to supply the energy to produce the light output from a phosphor screen as well as distribute the video information over the entire display area. In a scanned display, this requires that the electron beam excite a particular point on the phosphor screen once every scan period and the decay time of the phosphor and the persistance of the eye must combine to produce the impression of a continuous light output from the screen. If a high average brightness is desired from the display, it is found that the design requirements for a cathode ray tube to provide sufficient electron beam power becomes prohibitive. The present cathode ray tube not only lacks in adequate brightness but also exhibits a certain amount of flicker and objectional line structure in the image as far as the viewer is concerned. The present type cathode ray tube is also the primary limitation in reduction of the depth of television receivers.

It is accordingly an object of this invention to provide an improved display device of thin panel-like structure.

It is another object to provide an improved display device which substantially removes flicker in the viewed image.

It is another object to provide an improved display device in which storage is incorporated to provide a continuity of light output over the entire display screen for a desired time interval.

It is another object to provide an improved display device which provides high brightness in comparison with presently known display devices.

It is another object to provide an improved display device utilizing electroluminescent phosphor materials in which voltage or charge sensitive capacitors are utilized to control the amount of light from the electroluminescent display and in which the voltage or charge sensitive capacitors are responsive to control signals to control the amount and time of light emission.

These and other objects are exemplified by this invention as will be apparent from the following description taken in accordance with the accompanying drawings throughout which like reference characters indicate like parts, and in which:

Figure 1 illustrates a display screen embodying the principles of my invention;

Fig. 2 is an enlarged perspective view of a portion of the screen structure illustrated in Fig. 1;

Fig. 3 illustrates a circuit equivalent of the screen structure illustrated in Figs. 1 and 2;

Fig. 4 is a curve illustrating properties of a ferroelectric element; and

Fig. 5 is a curve illustrating properties of a nonlinear type capacitor.

Referring in detail to Figs. 1 and 2 there is shown

an embodiment of this invention constructed in accordance with my invention. The structure shown in Fig. 2 illustrates two complete light producing elements with associated control elements. The number of light elements and associated control elements utilized in a display screen will depend on the conditions to be met. It should be appreciated that hundreds of light elements could be assembled into one screen to meet certain display problems that may be presented.

In the specific embodiment shown, the portion of the display screen is comprised of a light transmissive support layer **12** of a suitable material such as glass. On one surface of the glass support layer **12** opposite with respect to the viewer is deposited a thin electrically conductive coating **14** of light transmissive material for providing one electrode hereinafter referred to as the front electrode of the light producing element. Any suitable electrically conductive material that is light transmissive may be utilized such as stannic oxide. A layer **16** of suitable phosphor material which exhibits the property of electroluminescence is deposited on the front electrode **14**. In the specific embodiment shown the front electrode **14** and the phosphor layer **16** are in the form of continuous layers extending across the entire screen and are common to all of the light producing cells. It is obvious that if so desired, each of the cells in the screen could be provided with separate and distinct layers. Examples of suitable phosphors which exhibit the property of electroluminesence are zinc sulfide copper and manganese activated or zinc sulfide copper activated to mention a few of these well known phosphors. The phosphor material may be dispersed within a suitable plastic dielectric material or an inorganic material such as glass.

On the exposed surface of the phosphor layer **16**, there is deposited a plurality of electrically conductive electrodes **18** which are insulated from each other. These electrodes **18**, hereinafter referred to as back electrodes of the light producing elements, may be placed on the phosphor layer **16** by evaporating a suitable material such as aluminum through a suitable mesh structure as is well known in the art. The size and the shape of the electrodes **18** and the number will depend on the type of display device desired. In the embodiment shown, the electrodes **18** are small in area and spaced from each other a sufficient distance so that applied current to one of the electrodes **18** will excite only that elemental area of the display screen. The light producing structure just described which consists of a phosphor layer **16** with two electrically conductive electrode contacts **14** and **18** provides a light producing element which will emit light in response to field excitation applied by voltage to the electrodes **14** and **18**. This type of light producing device is discussed more fully in an article entitled "Electroluminescence and Related Topics" by G. Destriau and H. F. Ivey in the December 1955 issue of the Proceedings of the I. R. E.

By way of explanation, electroluminescence was first completely disclosed by G. Destriau in the London, Edinburgh and Dublin, Philosophical Magazine, series 7, volume 38, No. 285, pages 700–737, October 1947, in an article entitled "The New Phenomena of Electroluminescence." In the phenomena of electroluminescence selected phosphor materials are placed within the influence of an electric field such as by sandwiching the phosphor materials between two spaced electrodes and applying an alternating or time varying potential between these electrodes. The resulting electric field which is created across the electrodes excites the phosphor material to luminescence, and the phosphor materials which display this electroluminescence are thus termed field responsive. Such phosphor materials are normally ad-

mixed with a dielectric material or a separate layer of dielectric material which is included between the electrodes in order to prevent any arcing thereacross, which might short out the electroluminescent cell. A separate dielectric material is only desirable and not mandatory for the cells may be operated under some conditions without any dielectric where the applied electric field is as high as a hundred kilovolts per centimeter. Normally the spaced electrodes are parallel but they need not be as where graded field intensities are desired.

The phosphor material layer **16** may be deposited on the front electrode **14** by any suitable method. For example, a finely divided phosphor material such as zinc sulfide activated by copper may be admixed with a solvent such as butyl acetate and with a polyvinyl chloride lacquer. The proportions of the constituents are not critical and may vary within wide limits, but as a specific example, three parts by weight of phosphor may be mixed with 50 parts by weight of thinner and 35 parts by weight of polyvinyl chloride lacquer. The foregoing admixture may be sprayed in a plurality of coatings, for example four, according to the desired thickness, drying between each of the coatings. Other dielectrics and solvents may be substituted for the foregoing specific examples as is well known. It is also possible to utilize a sintered type phosphor layer.

The control portion of the display screen comprises a separate control structure for each of the back electrode members **18** provided on the phosphor layer **16** to control the light output from each light element. In the specific embodiment shown, the control element structure is comprised of a U-shaped member **20** of electrically conductive material having its central portion **22** in electrical contact with the back electrode member **18** and with the leg portions **23** and **25** projecting outwardly from the electrode member **18**. A layer **24** of a nonlinear dielectric material is provided on the end of one of the leg members **23** and a similar layer **26** of material is provided on the other leg **25**. An electrical conductive bus bar **28** is provided for each of the leg portions **25** and is in physical contact with the opposite surface of the layer **26** to form a capacitor in the leg portion **23**. The capacitor consists of the conductive bus bar **28**, the leg member **25** which form the electrodes with the nonlinear dielectric material layer **26** sandwiched between. An electrical conductive bus bar **30** is provided for each of the leg portions **23** and is in physical contact with the opposite surface of the layer **24** to form a capacitor in the leg portion **25**. The capacitor consists of the conductive bus bar **30**, the leg member **23** which form the electrodes with nonlinear dielectric material layer **24** sandwiched between. The bus bars **28** and **30** are normally parallel and extend across the screen structure contacting each control element in the row in a similar manner. The design of the structure is primarily for mechanical reasons and the electrical equivalent of a single screen element is two separate nonlinear capacitors having a common connection to a light producing element provided by the U-shaped conducting member **20** in contact with electrode member **18** and having their remaining terminals connected to two bus bars.

The nonlinear dielectric material in layers **24** and **26** may be of any suitable material such as ferroelectric dielectric material selected from the group which includes, for example, barium titanate, barium-strontium titanate, barium stannate, sodium columbate, sodium tantalate, potassium columbate and potassium tantalate. An ideal or lossless nonlinear dielectric material may be defined as a material in which the functional relationship between the electric displacement in a given principal direction and the electric field in the same direction while single valued is not that of a straight line in Cartesian coordinates. One particular class of materials that has been found satisfactory in this application are ferroelectric dielectric materials. The preparation of titanate ceramics is fully disclosed in an article entitled "Preparation of Reproducible Barium Titanate" by R. M. Callahan and J. F. Murray, page 131 of the May 1954 issue of the "Bulletin" of the American Ceramic Society.

One method of preparing the control structure for the entire screen is to provide a thin flat dielectric sheet approximately 10 mils in thickness. The sheet is coated on both sides with a suitable paint such as one which contains finely divided silver, frit and possibly a flux. After the paint has air-dried, the coated dielectric member may be baked in an oven for 15 to 30 minutes at a temperature of about 700° C. Both sides of the ceramic sheet are then tinned with a suitable solder, such as one containing 36% lead, 62% tin and 2% silver. Two sheets of electrically conductive material such as brass are also tinned on one side with a solder similar to that used on the dielectric sheet. The ceramic sheet is then positioned between the two brass sheets with the tinned side of the brass sheets adjacent the dielectric sheet. The sandwich of the two brass sheets with the ceramic sheet is heated to a temperature of about 230° and then cooled. The resulting lamination may then be machined to form a structure illustrated in Fig. 2. In the specific device shown in Fig. 2, two perpendicular cuts would be sufficient to fabricate the entire control structure. The resulting control structure may be attached to the electrodes **18** of the light producing structure of the screen by an electrically conductive varnish or cement applied between the U-shaped portions **20** of the control structure and the electrodes **18**. The entire screen structure may be imbedded in a suitable light transmissive plastic material **31** as illustrated in Fig. 1.

An electrical conductive lead is provided from each of the elements **20** of the control structure illustrated as leads **32** and **34** and are connected to fixed contacts of a suitable switching means **40** illustrated as a mechanical switch. An electronic switch may be used. Other control elements of screen could be connected to the other fixed contacts. The movable contact of the switch **40** is connected through a bias source **42** to a source **45** of video signals. The conductive bus bars **28** and **30** are also brought out of the screen structure as well as an electrically conductive lead **44** from the front electrode **14** and connected to ground. The conductive bus bar **28** is connected to a light power source **48** for providing a time-varying voltage. The opposite terminal of the power source **48** is connected to the positive terminal of a bias source **50** illustrated as a battery. The negative terminal of the bias battery **50** is connected to ground. The conductive lead **44** from the front plate electrode is also connected to ground. The other conductive bus bar **30** is connected to a light power source **46** which also provides a varying voltage and the other terminal of the power source **46** is connected to ground.

The operation of the device can be best described by reference to Fig. 3. The equivalent circuit of each light producing element and its associated control element is illustrated in Fig. 3. That portion of the circuit which is contained within the dotted lines represents one element of a multi-elementary screen. The remainder of the circuit may be and is usually common to all the elements of the screen with of course the control voltage being selectively impressed by means of the switching means **40**. The circuit shown may be considered to be comprised of an upper branch, a lower branch and a center branch. The upper branch of the circuit includes, beginning at the junction **60** which is connected to ground, the bias source **50**, the light power source **48**, the nonlinear dielectric capacitor **62** (formed by the members **28**, **26** and **25** in Fig. 2) and ends at junction **64**. These circuit elements are connected in series arrangement by suitable conducting members of which conductor **28**

corresponds to the bus 28 of Figs. 1 and 2. The junction 64 is the member 22 of the control element of the screen in Figs. 1 and 2.

In a like manner, the lower branch of the circuit comprises in series arrangement beginning at junction 60, the light power source 46, a nonlinear dielectric capacitor 66 (formed by the members 30, 24 and 23 in Fig. 2) and ends at junction 64.

Extending from the junction 60 to the junction 64 between the two nonlinear dielectric capacitors 62 and 66 is the center branch of the circuit containing an electroluminescent element or cell 68 (formed by members 14, 16 and 18 in Fig. 2).

The complete circuit has the nature of a bridge circuit in which the upper and lower branches determine what current, if any, passes through the center arm which contains the electroluminescent light producing element 68. At the ungrounded junction 64 of the upper and lower branches and the center branch is the connection to the control voltage which is here represented by a battery 70 having its negative terminal connected to ground.

In order to explain the operation of the circuit it will be first assumed that the control voltage from the source 70 is zero potential. Then in view of the design or the adjustment of the members of the circuit system, the periodic voltage applied at the junction 64 will be substantially the same as the voltage at junction point 60, and zero or substantially zero light power potential is applied across the electroluminescent cell 68. Thus, the circuit system is in balance.

This initial balance may be accomplished in several ways, for example, the value of the capacitance of the nonlinear dielectric capacitors 62 and 66 may be selected to be the same. If the nonlinear dielectric capacitors 62 and 66 are of the same value of capacitance, the bias source 50 will cause the dielectric capacitor 62 to drop in capacitance to a point where it is in effect smaller than the capacitance of the nonlinear dielectric capacitor 66 in the lower branch. In order to compensate for this change in the value of capacitance of the capacitor 62 in the upper branch, the light power voltage source 48 in the upper branch is made capable of generating a greater voltage than the light power source 46 in the lower branch and the difference between the potential of the light power sources 46 and 48 are so proportioned that there is very little unbalance between the upper and lower subsidiary circuits described hereinbefore and the voltage across the electroluminescent cell or capacitor 68 is negligible.

If it is now assumed that a control potential or control signal is delivered to the junction 64 from the source 70 then this control potential will appear directly on the two capacitors 62 and 66. The effect on the capacitor 62 in the upper branch will be to subtract from the bias impressed on the capacitor from the bias source 50 in the upper branch, and thus will tend to increase the capacitance of the capacitor 62. The effect of the control potential on the other capacitor 66 in the lower branch is to decrease the value of the capacitance and therefore the effect on the two capacitors 62 and 66 are in an opposite direction and therefore they tend to aid in unbalancing the circuit. This results in a portion of the light power potential supplied from the light power sources 46 and 48 being applied across the electroluminescent cell 68 rendering it luminous and in an amount corresponding to the control bias applied to the circuit from source 70.

By varying the control signal delivered by the source 70, which may be the video source as illustrated in Fig. 1, the luminosity of the electroluminescent cell 68 may be varied as desired. Therefore, when a plurality of light power producing elements are provided and illuminated in accordance with predetermined signals any predetermined image may be presented on the display screen. As the control signal contact is removed from one of the elements, the electroluminescent cell will emit light until the control charge gradually leaks off or the charge is modified by the next signal contact to the individual element.

As illustrated in Fig. 1, it may be suitable to use in addition to the signal, a constant voltage or bias source 42 which is continuously on only during the time that the signal pulse is being applied to the individual element. The purpose of this bias is to assure that the control element operates over the optimum portion of its characteristic.

As a representative example, an electroluminescent cell 68 may have an electrode contact of an area of 1/16 square inch and a capacitance of about 80 micromicrofarads. The dielectric capacitors 62 and 66 would have an apparent capacity of about 400 micromicrofarads with no direct current voltage and 100 volts R. M. S. at a frequency of 6000 cycles. The area of the dielectric layer in the capacitors 62 and 66 would be about 320 square mils and the layer 12 mils in thickness. The sources 46 and 48 would be of the phase shown in Fig. 3 with the source 46 of about 150 volts R. M. S. at a frequency of 6000 cycles. The source 48 would be of a voltage of 300 volts R. M. S. at a frequency of 6000 cycles. The direct current bias source 50 would be of about 300 volts. The direct current control bias range could be from zero volt to 300 volts.

Other modes of operation of the circuit shown in Fig. 3 work equally as well as that described above. For example, the two light power sources may have equal outputs while the nonlinear dielectric capacitors have different unbiased capacitances for example the capacitor in upper branch may be greater than one in lower branch. If no control signal is applied, the bridge may be balanced since the larger capacitance (and smaller impedance) or the upper capacitor may be so modified by means of the bias source 50 as to compensate the unbalancing effect of the relative size of that capacitor. Application of a control signal will destroy the balance as in the previously described mode of operation.

Under some circumstances it may be desirable to have a light output when no control signal is applied. This may be readily effected by having equal capacitors and equal light power sources. The initial unbalance will be due to the applied bias. Application of control signal will tend to drive the circuit toward a balanced state and reduce light output.

The use of a bias means in the circuit of Fig. 3 facilitates the attaining of good control of the light output of the electroluminescent element. However, the use of a bias means is not essential to the circuit's operation. If the capacitance of the capacitor in the upper branch is less than the capacitance of the capacitor in the lower branch and the output of the light power source in the upper branch is greater than the output of light power source in the lower branch an initial balance may be attained with the bias means out of the circuit and no control signal applied. Application of control signal will unbalance the bridge.

In Fig. 4 a plot of capacitance C of a ferroelectric capacitor with respect to control voltage or bias V_c impressed across the capacitor is illustrated. The video information supplied from a conventional television receiver is a wave going both negative and positive and in the absence of a bias the same change of capacitance might be obtained in both negative and positive direction. To remedy this, a constant bias potential is either subtracted or added to the video yielding a control potential of either entirely negative or positive values.

A linear or normal capacitor of mica or air dielectric has a charge versus voltage curve theoretically in the form of a straight line. In the case of a non-linear capacitor, the charge Q versus voltage V curve might be similar to that shown in Fig. 5. If it is assumed that an alternating potential light power supply is applied to the capacitor, then the potential applied to the capacitor in

each cycle would move the element from point A to a point B on the curve and return. If it is now assumed for purposes of explanation that in addition to the previously mentioned alternating potential applied to the capacitor a constant control signal of magnitude D is applied, then the alternating potential causes the excursion from A' to B' on the curve during each cycle. Since effective capacitance may be defined as $\Delta Q/\Delta V$, it is apparent that the capacitance is then smaller than in the first case where a constant potential was not applied, since ΔV remains the same but ΔQ is diminished. Since the capacitance is smaller the reactance which the capacitor presents to the external circuit is larger as a result of applying a control signal on this type of capacitor known as a nonlinear capacitor.

While I have shown my invention in only one form, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various other changes and modifications without departing from the spirit and scope thereof.

I claim as my invention:

1. In a solid state display element in combination, a plurality of circuit systems connected in cooperative relationship with a common conductor between them, one circuit system comprising a nonlinear dielectric capacitor, an alternating current light power potential source and a direct current power source connected in series circuit relationship, the other circuit system comprising a nonlinear dielectric capacitor and an alternating current source of light power potential connected in series circuit relationship, an electroluminescent cell connected in the common conductor, the members of the circuit system being so proportioned that they are in substantial balance with substantially no light power potential applied to the electroluminescent cell and means for delivering signals to the circuit system to effect an unbalance and impress a light power potential across said electroluminescent cell to render it luminous.

2. In a solid state display element in combination, an electroluminescent cell and nonlinear dielectric capacitors connected in circuit relationship, the electroluminescent cell being responsive to an alternating current light power potential, said nonlinear dielectirc capacitors being responsive to a direct current voltage, means for impressing an alternating current light power potential across the electroluminescent cell, signal means connected in circuit relationship with said electroluminescent cell and nonlinear dielectric capacitors to control the alternating current light power potential impressed across the electroluminescent cell and the direct current voltage impressed across the nonlinear dielectric capacitors to regulate the luminosity of the electroluminescent cell.

3. In a solid state display screen in combination, two nonlinear dielectric elements connected in series circuit relationship, two alternating current light power potential sources connected in series circuit relationship, a direct current source connected in series circuit relationship between the two alternating light power sources and means connecting the light power potential sources and a direct current power source across the nonlinear dielectric elements connected in series circuit relationship to form a substantially balanced circuit system, an electroluminescent cell connected between a point disposed between said two nonlinear dielectric elements and a point between said direct current power source and one of said alternating current light power potential sources to provide a plurality of loop circuits in substantial balance and means for delivering signals to the loop circuit at a point between the nonlinear dielectric elements to effect the impressing of the light power potential across the electroluminescent cell in accordance with the signal delivered.

4. In a display device in combination, two separate nonlinear dielectric material members, an alternating current light power source, a direct current power source and another alternating current light power source all connected in series circuit relationship providing a loop circuit, an electroluminescent material member connected across the loop circuit from a point between said nonlinear dielectric material members to a point between said direct current power source and one of said alternating current light power potential sources providing loop circuits having a common conductor, the loop circuits being in substantial balance whereby substantially no light power potential is impressed across the electroluminescent material member and means for impressing a signal on said loop circuits to effect an unbalance and the impressing of a light power potential across the electroluminescent material member, the light power potential impressed on the electroluminescent material member having a predetermined relationship to the signal delivered to the plurality of circuits when in substantial balance whereby the luminosity of the electroluminescent material member varies with the signal.

5. A solid display element for producing light in accordance with a controlling electrical signal, comprising a light producing element of a field responsive phosphor, a control element means associated with said light producing element, said control element exhibiting a varying capacitance in accordance with said control signal applied thereto, means for applying electric fields across said light producing element and said control element, means for applying said control signal to said control element whereby the magnitude of the electric field applied across said light producing element is modified in accordance with the magnitude of said control signal applied to said control element.

6. A display device comprising, a plurality of independently controllable light producing elements, said light producing elements responsive to a time variation of an electric field, control elements electrically connected to said light producing elements, a source of time varying potential connected to said light producing elements and said control elements to impress a field across said light producing elements, said control elements responsive to variations of electrical signals applied thereto to cause corresponding variation in the impedance of said control device whereby the magnitude of the electric field applied across said light producing element is modified in accordance with the magnitude of control signals applied thereto and means for impressing electrical signals on said control element corresponding to light values desired of said light producing element.

7. An element for producing light in accordance with a controlling signal, comprising a light producing element of a field responsive phosphor, control element means associated with said light producing element, said control element means comprising a bridge type circuit arrangement for controlling the light output of said light producing element comprising a first circuit comprised of a first time varying power source and a nonlinear dielectric capacitor serially connected across said light producing element, a second circuit comprised of a second time varying power source, a direct current source and a second nonlinear dielectric capacitor serially connected across said light producing element, the components of said first and second circuits selected to provide substantial balance in the bridge circuit, means for applying said control signal to said first and second circuits to modify said balance and impress light power potential across said light producing element in accordance with said control signal.

8. In a solid state display device, an electroluminescent element having a first electrode and a second electrode, means for controlling power applied across said first and second electrodes comprising a first circuit branch, a second circuit branch and a control signal source, said first circuit branch comprising a nonlinear dielectric capacitor, a light power source, and a bias means connected

in series circuit relationship with said first and second electrodes of said electroluminescent element, said second circuit branch comprising a nonlinear dielectric capacitor and a light power source connected in series circuit relationship with said first and second electrodes of said electroluminescent element in a manner such that the nonlinear dielectric capacitor of said second circuit branch and the nonlinear dielectric capacitor of said first circuit branch have a common connection with said first electrode of said electroluminescent element and with the output of said control signal source.

9. In a display device, an electroluminescent element having a first electrode and a second electrode, means for controlling power applied across said first and second electrodes comprising a first nonlinear dielectric capacitor, a second nonlinear dielectric capacitor, a first light power source, a second light power source, a bias means, and a control signal source connected in bridge circuit arrangement in a manner such that the amount of the outputs of said first and second light power sources

impressed across said first and second electrodes is modified in response to signals from said control signal source applied to said first and second nonlinear dielectric capacitors.

10. An element for producing light in accordance with a controlling signal comprising a light producing element of a field responsive phosphor, a first circuit means comprising a nonlinear capacitor and a first source for supplying a time varying electric field across said light producing element, a second circuit means comprising a nonlinear capacitor and a second source for supplying a time varying electric field across said light producing element, said first and second time circuit means connected to impress opposing time varying electric fields across said light producing element, means for impressing a control voltage to modify the capacity of said capacitors in an opposite sense to modify the electric field across said light producing element.

No references cited.