March 29, 1966 N. SCLAR 3,243,508

RESONANCE ELECTROLUMINESCENT DISPLAY PANEL

Filed March 22, 1963

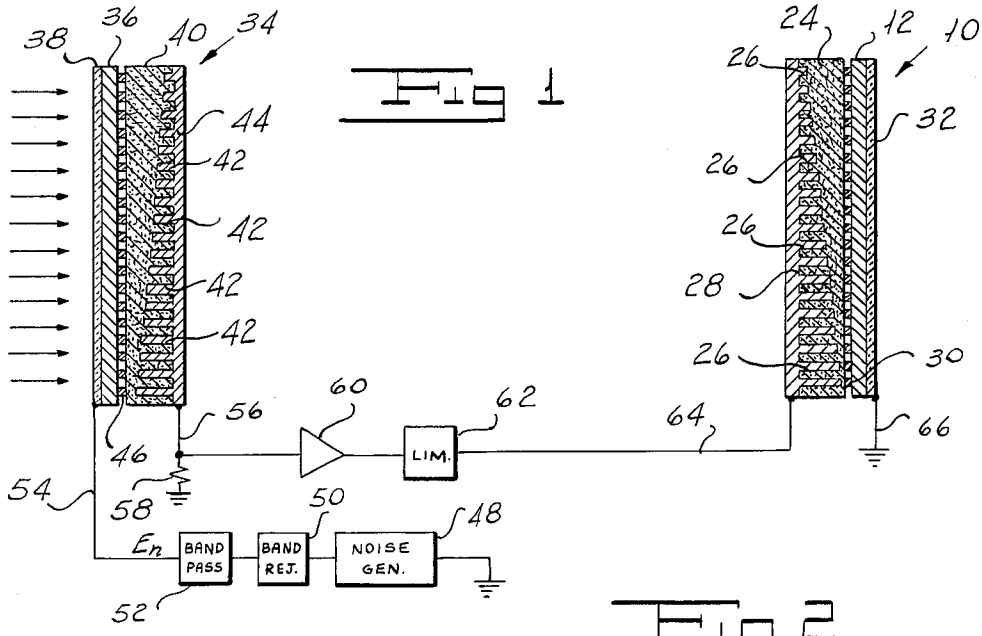


Fig 1

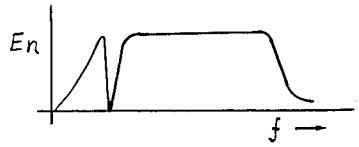


Fig 5

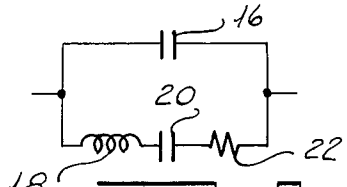


Fig 3

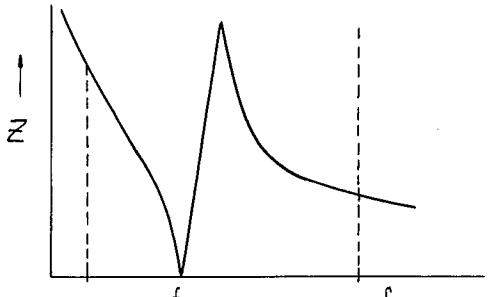


Fig 4

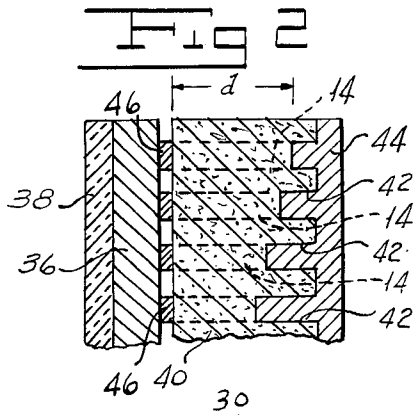


Fig 2

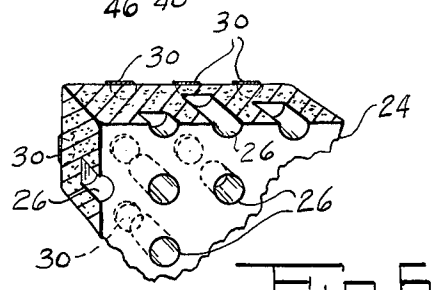


Fig 6

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RESONANCE ELECTROLUMINESCENT DISPLAY PANEL

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My invention relates to a display panel and more particularly to a resonance electroluminescent display panel which overcomes the disadvantages of display panels of the prior art.

The most widely utilized means for providing a visual display of input information in the prior art is the cathode ray display. Displays of this type embody a number of disadvantages. They have a curved surface so that a wide viewing angle cannot be achieved without the introduction of parallax. They require a relatively high power for their operation. The display may fail entirely owing to a loss of vacuum within the display tube or because of a filament burnout.

In an effort to overcome the disadvantages pointed out above of cathode ray displays it has been suggested that electroluminescent displays be provided. While a display of this type has the advantages of being flat, requiring a relatively low power input and of not being subject to severe failures, difficulty has been experienced in the prior art in activating the display. It has been necessary to provide an inordinately large number of electrical contacts to the panel, one contact being required for each of the elements in the lines and columns of the display. It will readily be apparent that the commutation problem of applying input information to such a display is extremely difficult in that large voltages of the order of hundreds of volts must rapidly be transferred to the various elements making up the display.

I have invented an electroluminescent display panel which overcomes the disadvantages of the cathode ray display of the prior art. My display panel is flat to permit a wide viewing angle without parallax. It requires only a relatively low power for its operation and is not subject to failure owing to loss of vacuum or filament burnout. My electroluminescent display does not involve the difficult commutation problems of proposed electroluminescent displays of the prior art.

One object of my invention is to provide an electroluminescent display panel which overcomes the disadvantages of cathode ray displays of the prior art.

Another object of my invention is to provide an electroluminescent display which is flat to permit a wide viewing angle without parallax.

A further object of my invention is to provide an electroluminescent display panel requiring a relatively low power for its operation.

A still further object of my invention is to provide an electroluminescent display panel which is not subject to failure owing to loss of vacuum or filament burnout.

Yet another object of my invention is to provide an electroluminescent display which does not involve difficult commutation problems.

Other and further objects of my invention will appear from the following description.

In general my invention contemplates the provision of an electroluminescent display panel in which means providing a plurality of circuits which are series resonant at various respective frequencies is connected to an electroluminescent screen. In response to a signal having components at the respective frequencies and having respective component amplitudes representing the input information the series circuits apply voltages to the electroluminescent

screen to activate the screen to produce a visual image of the input information. This screen-activating signal can be obtained, for example, from photoconductive material connected to a series resonant circuit providing means of the type used in the display and energized from a white noise generator.

In the accompanying drawings which form part of the instant specification and which are to be read in conjunction therewith and in which like reference numerals are used to indicate like parts in the various views:

FIGURE 1 is a schematic view with parts shown in section of a closed circuit system including my resonance electroluminescent display panel.

FIGURE 2 is an enlarged fragmentary sectional view of my resonance electroluminescent display panel.

FIGURE 3 is a schematic view of one equivalent circuit of one of the resonant elements of my resonance electroluminescent panel.

FIGURE 4 is a curve illustrating the approximate impedance-to-frequency relationship of one of the elements, the equivalent circuit of which is illustrated in FIGURE 3.

FIGURE 5 is a curve illustrating the characteristic of the filtering arrangement I employ in conjunction with my resonance electroluminescent panel.

FIGURE 6 is a fragmentary perspective view illustrating a portion of my resonance electroluminescent panel.

Referring now to FIGURE 1 my resonance electroluminescent display panel indicated generally by the reference character **10** includes a layer or screen **12** formed from a suitable electroluminescent material. As is known in the art a phosphor having traces of an activator impurity will emit light in response to a strong alternating electric field applied across the material. This is the phenomenon known as electroluminescence.

In the prior art in order to provide an electroluminescent display a plurality of discrete elements of electroluminescent material are activated by respective signals having amplitudes which represent the input information. This procedure involves the serious and difficult commutation problems pointed out hereinabove. I have discovered a unique way of activating the electroluminescent layer **12** without involving difficult commutation problems. In so doing I take advantage of the properties of ferroelectric materials.

Substances such as Rochelle salt, potassium di-hydrogen phosphate, barium titanate and several other compounds exhibit an effect known as ferroelectricity which is evidenced by spontaneous polarization and spontaneous strain in a certain temperature range. Referring now to FIGURES 2 to 4 I have shown a cylinder **14** of a suitable ferroelectric ceramic of the type described above having electrical contacts at its ends and having a length *d*. This cylinder is rendered active during its fabrication by "poling," a dipole alignment process in which the ceramic is cooled below its Curie temperature in the presence of an applied electric field. In FIGURE 3 I have shown an equivalent circuit for the cylinder **14** at a frequency close to the resonant frequency. A capacitor **16** represents the capacitance between the contacts at the ends of the element across which a voltage is impressed. At frequencies near resonance the impedance of the equivalent circuit can be represented as a self-inductance **18**, a capacitor **20** and resistance **22** forming a series circuit in parallel with the capacitance **16**.

Referring to FIGURE 4 I have illustrated an impedance characteristic of the circuit of FIGURE 3 with respect to frequency. It will be seen that the circuit has a series resonant frequency f_r at which the impedance is very low. At some higher frequency the circuit will be parallel resonant to provide a high peak impedance. At all other frequencies than the series resonant frequency within the

band of frequencies I shall consider the impedance is relatively high. The resonant frequency f_r is equal to K/d where K is in kilocycle inches. Thus a plurality of circuits resonant at different frequencies can be formed by making a number of cylinders 14 of various lengths.

Referring again to FIGURE 1 my display panel 10 includes a relatively thick layer or plate 24 of a suitable ferroelectric ceramic of the type described hereinabove. In the course of forming the plate 24 I simultaneously press a plurality of holes 26 into one side of the plate. These holes 26 provide effective lengths of the ferroelectric material from the bases of the holes to the other surface of the plate 24 to provide a plurality of lengths of ferroelectric material. In one form of my device I make all the holes 26 of different lengths to provide a plurality of respective elements each of which has a different length. I pole the ferroelectric material in the course of manufacture in the manner described hereinabove. From the discussion of the characteristics of a length of ferroelectric material described hereinabove it will readily be apparent that each of these elements provides a resonant circuit which is series resonant at a particular frequency.

FIGURE 4 illustrates the impedance-to-frequency relationship of a particular one of the elements. It will readily be apparent that the other elements exhibit similar characteristics within the range of frequencies defined by the broken lines in FIGURE 4.

I plate conductive material 28 on the side of the plate 24 having the holes with the conductive material filling the holes. A plurality of small discs or spots 30 of conductive material connect the other side of the plate 24 to the electroluminescent layer 12. I apply transparent conductive film 32 to the face of the plate 12 which is remote from the conductive discs 30. For example, the film 32 may be an extremely thin metallic deposit so as to be at once conductive and transparent. Each disc 30 is aligned with one of the holes 26 so that the length of material 24 between the base of the hole and the corresponding conductive disc forms an element such as the element 14 shown in FIGURE 2. From the discussion hereinabove it will be clear that each of the elements forms a circuit which is resonant at a different frequency. Now if a signal containing components at the frequencies corresponding to the respective resonant frequencies of the elements defined by the holes 26 is applied between the conductive material 28 and the conductive film 32 the elements will separate the components to apply signals across the electroluminescent screen 12 at the various points or areas corresponding to the discs 30. It will readily be apparent that each disc 30 defines a picture element of the screen 12. Now if the various respective components have amplitudes which are determined by the input information then the screen 12 will luminesce to present a picture of the input information which is visible through the transparent conducting film 32.

Any suitable means can be employed for providing the signal which is applied to my panel 10 to cause it to luminesce to present a picture of the input information. In the particular closed circuit arrangement of FIGURE 1 I have illustrated a photoconductive pickup indicated generally by the reference character 34 including a layer of a suitable photoconductive material 36 which is covered with a transparent conductive film 38. A light image indicated by the arrows of FIGURE 1 passes through the film 38 and impinges on the surface of layer 36 to affect the conductivity thereof in accordance with the intensity at the various points in the image represented by the arrows. The pickup device 34 includes a relatively thick plate 40 of ferroelectric ceramic similar to that of which the plate is formed. In the course of manufacture of the plate 40 I press a plurality of holes 42 in one surface thereof to define a number of ferroelectric resonance elements. It will readily be understood that both the plate 24 and the plate 40 during the manufacturing thereof are poled by the process referred to hereinabove in connection with the discussion of the element 14 shown in FIGURE 2. I plate the surface of layer 40 having the holes therein with conductive material 44 which fills the holes to make contact with the bases thereof which form one end of each of the ferroelectric elements. As is the case with the display panel 10 the holes 42 of the plate 40 all are of different depths to provide elements which are resonant at a plurality of different respective frequencies. Conductive discs or spots 46 similar to the spots 30 make contact between the plate 40 and the photoconductive layer 36. From the arrangement just described it will be apparent that the pickup device 34 comprises a plurality of resonant elements which resonate at different respective frequencies. With a signal of a particular frequency corresponding to the resonant frequency of an element applied to the pickup device 34 then the element will pass the signal with the amplitude of the output determined by the conductivity of the portion of layer 36 in line with the element which in turn has its conductivity determined by the intensity of the light impinging thereon.

In FIGURE 1 I have shown a simplified arrangement for applying a suitable input signal to the pickup device 34. This system includes a white noise generator which provides equal electrical power over the resonant frequencies which I employ in my display. There are available commercial types of noise generators providing this characteristic up to a frequency of about 10 megacycles per second. It will readily be appreciated that the portions of the plate 40 between the holes 42 themselves form elements which are resonant at a particular frequency which is less than the frequency of any of the elements defined by the holes. It is desirable that these portions provide no information as such information would confuse the display. For this reason I pass the output of the noise generator 48 through a rejection filter 50 which rejects signals of a frequency corresponding to the resonant frequency of the portions of the plate 40 between holes 42. It is also desirable that unused or unwanted frequencies are not applied to the display. For this reason I pass the output of the rejection filter 50 through a band pass filter 52 which passes only those frequencies which are within the range of frequencies I employ in my display. Referring to FIGURE 5 I have illustrated the characteristic of the filter system I employ to achieve the results outlined above. Respective conductors 54 and 56 apply the output of the filter 52 across the pickup 34 of my display. When a light picture is focused on the pickup device, conductor 56 carries an output signal including all frequencies corresponding to the elements of the plate 40 and each frequency component has its magnitude determined by the input information which in this case is the light pattern impinging on the photoconductor 36. I connect resistor 58 having a low resistance value between conductor 36 and ground to develop a suitable voltage from the current output on conductor 56. I pass the output of the pickup device 34 appearing on conductor 56 through an amplifier 60 and a limiter 62 to a conductor 64 which applies the signal to the conductive material 28. Limiter 62 prevents application to the display device of such a large signal as would tend to depolarize the ferroelectric material of the display. A conductor 66 connects the transparent conductive material 34 to ground.

It is to be understood that in the closed circuit arrangement illustrated in FIGURE 1 the plate 24 has elements corresponding to all the elements of the plate 40. While I have shown a relatively simple circuit arrangement in FIGURE 1 it will readily be understood that any other arrangement can be employed to transmit the signal carrying the information from the pickup device 34 to the display device 10 where they are positioned at locations which are remote from each other. Further, while I have illustrated the devices 10 and 34 as including plates 24 and 40 all of which have cylindrical holes of different

depths I may as well vary the frequencies to which the respective elements correspond by using holes of different shapes such as tapered holes or holes with triangular cross sections, for example. It is to be understood further that while I have shown a form of the device wherein the input information is in the form of a light image which is applied to a photoconductive element **36** the input information can be in any other form such, for example, as digital and the like. One feature of my device is that I am able to obtain a very high Q for each of the elements. Owing to this fact I am able to provide a very large number of picture elements for a given area. Moreover, I can achieve a very high brightness contrast from off to on.

In use of my resonant electroluminescent display panel **10** in the closed circuit arrangement illustrated in FIGURE 1 a light image impinges on the photoconductive layer **36** through the transparent conductive layer **38** producing a conductivity pattern in the material corresponding to the pattern of the light image. As a result the output of the band pass filter **52** passes through the photoconductive layer **36** to provide signal components at all frequencies, and being amplitude modulated over the area of the layer **36** in accordance with the light image. The resonant circuits formed by the elements of ferroelectric ceramic **40** separate the signal into its various frequency components to develop a current output on conductor **56** including all frequencies corresponding to the resonant circuits. A particular frequency component corresponding to an element has an amplitude which is determined by the intensity of the light falling on the corresponding area of the ferroelectric ceramic. This current on output conductor **56** develops a voltage across resistor **58** which is amplified by amplifier **60**. The limiter **62** passes the amplified output to the display device **10**. As is pointed out hereinabove the limiter **62** prevents excessively large signals such as might depolarize the ceramic **24** from being applied to the display device.

The ceramic **24** which has elements providing resonant circuits corresponding to all the frequencies passed by the pickup **34** separates the input signal on conductor **64** into the various frequency components. Each component has an amplitude which represents the intensity of the light falling on a particular area or "picture element" of the layer **36**. It will readily be apparent that the various separated frequency components are applied across the electroluminescent layer **12** in the same manner as they were generated at the pickup device **34**. As a result the panel **12** lumineses to provide a visual image of the light pattern which fell on the surface of the photoconductive layer **36**.

As has been pointed out hereinabove where the pickup **34** and the display device **10** are disposed at remote locations other circuit configurations may be employed to transmit the required signals from the pickup to the display device. For example, the output could be mixed with a radio frequency signal and transmitted to a receiving station.

As has also been pointed out hereinabove the input information could take other forms than that of light image impinging on a photoconductive surface. That is, the noise signal could be passed through a distribution network which varied the amplitude of the respective frequency components in accordance with any input pattern.

It will be seen that I have accomplished the objects of my invention. I have provided an electroluminescent display panel which overcomes the disadvantages of cathode ray displays of the prior art. My display device does not require extensive commutation to apply input information to the panel. My display device requires relatively low power for its operation. It is flat so as to permit a wide viewing angle without introducing parallax. It is not subject to failure owing to loss of vacuum or film burnout.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of my claims. It is further obvious that various changes may be made in details within the scope of my claims without departing from the spirit of my invention. It is, therefore, to be understood that my invention is not to be limited to the specific details shown and described.

Having thus described my invention, what I claim is:

1. In a display system a unitary body of ferroelectric material and means forming said body into a plurality of elements resonant at various respective frequencies.

2. A display device including in combination a body of electroluminescent material having opposite sides one of which provides a display area, a unitary body comprising a plurality of elements for applying an energizing signal across said electroluminescent body between said sides, said elements being resonant at different respective frequencies, means providing an information signal having components at said resonant frequencies and means for coupling said signal to said signal-applying means.

3. A display device including in combination a body of electroluminescent material having opposite sides one of which provides a display area, a unitary body comprising a plurality of ferroelectric elements so constructed as to be resonant at various respective frequencies, means connecting the respective elements to the other side of said body and means for applying an information signal across said elements and said body.

4. A display device including in combination a body of electroluminescent material having opposite sides one of which provides a display area, a unitary body comprising a plurality of ferroelectric elements resonant at various respective frequencies and respective discrete elements of conductive material for connecting said ferroelectric elements to the other side of said body.

5. A display device including in combination a body of electroluminescent material having opposite sides one of which provides a display area, a unitary body comprising a plurality of resonant ferroelectric elements of different lengths and a plurality of conductive elements for respectively connecting an end of each of said ferroelectric elements to the other side of said body.

6. A system for displaying an image including in combination a pickup comprising a body of photoconductive material, means comprising a first plurality of elements for applying a signal across said body of photoconductive material, said elements being resonant at various respective frequencies, a source of signal containing frequencies corresponding to said resonant frequencies, means for coupling said signal to said signal-applying means to cause said pickup to produce an information signal, a display device comprising a body of electroluminescent material and means comprising a second plurality of elements for applying said information signal across said electroluminescent body, said elements of said second plurality being resonant at various respective frequencies corresponding to those at which the elements of said first plurality are resonant.

7. A display device including in combination a body of ferroelectric material having opposite surfaces, one of said surfaces being formed with a plurality of holes of various respective depths to form a plurality of resonant elements extending respectively from the bases of said holes to said other surface, conductive material filling said holes and disposed on said one surface, a body of electroluminescent material having opposed surfaces, a plurality of discrete areas of conductive material for connecting said elements to one surface of said body of electroluminescent material and a layer of transparent conductive material carried by the other surface of said body of electroluminescent material.

8. A pickup device including in combination a body of ferroelectric material having opposite surfaces, one of said surfaces being formed with a plurality of holes of

various respective depths to form a plurality of resonant elements extending from the bases of said holes to said other surface, conductive material filling said holes and disposed on said one surface, a body of photoconductive material having opposed surfaces, a plurality of discrete areas of conductive material for connecting said elements to one surface of said body of photoconductive material and a layer of transparent conductive material carried by the other surface of said body of photoconductive material.

9. In a display system a body of ferroelectric material having opposite surfaces, one of said surfaces being formed with a plurality of holes of various respective depths to form a plurality of resonant elements extending respectively from the bases of said holes to said other surface, conductive material filling said holes and disposed on said one surface and a plurality of areas of conductive material on said other surface at the ends of said elements on said surface.

10. In a display system, a body of ferroleceric material having a certain thickness to provide opposite surfaces, one of said surfaces being formed with a plurality of holes of various respective depths to form a plurality of resonant elements extending respectively from the bases of said holes to said other surface, a noise generator for producing a signal including frequencies at which said elements are resonant and means for applying said signal to said elements, said signal applying means including a filter for rejecting any portion of said signal having a frequency corresponding to the resonant frequency of a length of said ferroelectric material equal to said certain thickness.

11. A display system including in combination a first

body of ferroelectric material having opposite surfaces, one of said surfaces being formed with a plurality of holes of various respective depths to form a plurality of first resonant elements extending from the bases of said holes to said other surface, a body of photoconductive material having opposed surfaces, means connecting said elements to one surface of said photoconductive body, a source of a signal containing those frequencies at which said first elements are resonant, a second body of ferroelectric material having opposite faces, one of said second body surfaces being formed with a plurality of holes of various respective depths to form a plurality of second resonant elements extending from the bases of said holes to said other surface of the second body, a body of electroluminescent material having opposed surfaces, means connecting said second elements to said electroluminescent body and means connecting said second elements and said first elements.

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