Feb. 7, 1961 W. R. AIKEN 2,971,125

METHOD OF AND APPARATUS FOR ENERGIZING HIGH CAPACITY LOADS

Filed March 9, 1959

FIG. 1

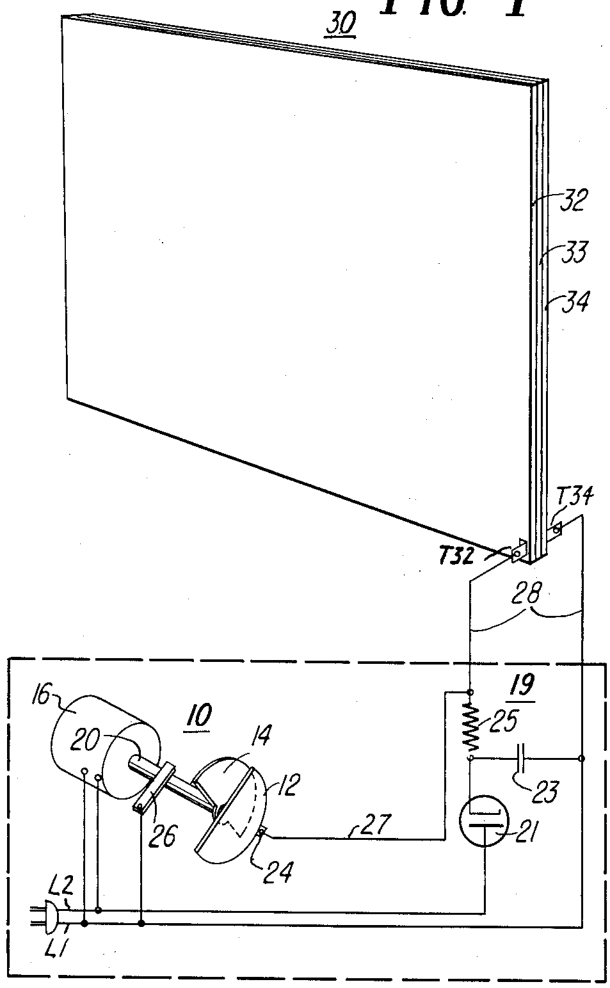


FIG. 2

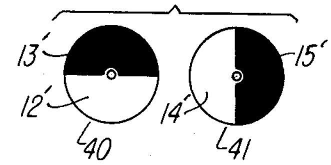


FIG. 3a

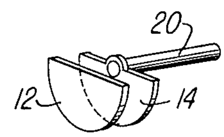


FIG. 3b

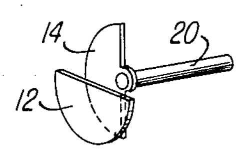


FIG. 3c

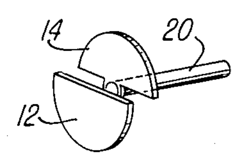
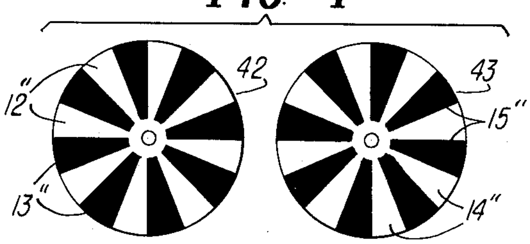


FIG. 4



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METHOD OF AND APPARATUS FOR ENERGIZING HIGH CAPACITY LOADS

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The present invention relates to a method of and an apparatus for effecting the excitation of high capacitive loads, and particularly solid-state lighting panels which constitute a high capacitive load.

With the recent development of electroluminescent solid-state lighting panels, it has become increasingly more apparent that the generation of light with such type devices provides many advantages over the known fluorescent and incandescent type lighting devices which are now more generally used in the field. The solid-state display devices, for example, may be constructed in any desired size or shape, including flat or curved structures which may be of variable thicknesses and of variable overall dimensions. Manifestly such flexibility in size and shape permits a wider range of use and application in the industrial and home lighting fields. Further, the light emission of solid-state panels is effected from a larger portion of the surface of the device rather than from a point, arc, or filament source such as are now used in the field, and a more even light distribution is effected therewith. Since each of the composite parts of the display device is of a solid material, no vacuum is required, and extreme mechanical ruggedness is exhibited. In addition to the resultant reduction in the possibility of breakage of the display units of such structure, the solid-state nature of the device permits the use thereof in equipment which is normally operated in environments of extreme shock, vibration and other types of damaging forces. These advantages and others including the ability to effect more extensive modulation of the light output both as to color and brightness are further advantages of the novel panel lighting equipment.

One type of solid-state lighting panels is known in the field as "intrinsic" electroluminescent lighting. The operating unit in such lighting normally comprises a cell which is basically comprised of electroluminescent powder material which is suspended in liquids or solids between a pair of electrode members. A fluctuating electric field is applied to the electrode member for coupling to the electroluminescent material to excite the same and thereby effect light emission by the electroluminescent material. The electrode members in certain panel embodiments are made of a transparent conducting material so that any light emitted by the electroluminescent material is visible through both surfaces of the cell to provide an increased light output by the cell. The fluctuating electric field applied to the electrode members may comprise a conventional 110 volt 60 cycle, sinusoidal signal, which establishes a variable voltage on the electrode members to effect excitation of the electroluminescent material.

Light emission by the electroluminescent material in panels of such type is apparently effected by the movement of electrons of the atoms of the powders from one energy state to another. Whenever such an electron absorbs a quantum of energy from some outside source, such as an applied electric field, the electron jumps to a higher, or "excited" state. Later, as the energization

from the outside source is reduced, the electron may drop back to its original state, or to some other lower, or less "excited" state. In so doing, it re-emits the absorbed energy, and, in certain materials, at least a part of this re-emitted energy may be emitted as light.

One of the major problems in the development of electroluminescent display devices to date has been the provision of a display device which has a light output of a relatively high level. Certain expedients well known in the art are used to effect increased light output wherever possible. It is known in the art, for example, that the light output of the electroluminescent material may be increased by increasing the voltage to strengthen the electric field which energizes the electrons to thereby energize a greater number of electrons in each cycle. Such method, however, is of limited value in that the applied field cannot be increased beyond the strength of the insulating properties of the material between the electrodes. Another method of increasing light emission contemplates an increase in the frequency of fluctuation of the applied field so that the electrons of the material are excited more often. In the use of such method, the brightness or light output of a cell increases with the frequency.

In that the conductor electrodes of an electroluminescent display cell are normally of a relatively large area and are spaced reasonably close together with only a thin layer of electroluminescent material therebetween, it is apparent that the capacity of a cell of this type is extremely high. The high capacity of the device produces a loading for the source which is dependent upon the frequency of the applied signal, the loading being extremely large for the high frequencies of operation which are used in effecting the optimum performance of solid-state lighting panels. The large capacity loading, in turn, reduces the efficiency of the conversion of the electrical power to light. There is a need for an inexpensive high frequency source, therefore, which is operative to energize solid-state panels in a more efficient manner, and it is an object of the present invention to provide a new and novel apparatus of such type, and particularly to provide an apparatus which generates a high frequency voltage signal for a capacitive load without excessively loading the electrical power source for the device.

A feature of the present invention is the manner in which a novel generator device provides a voltage output which may be varied by changing the capacitance of a variable capacitor member while yet maintaining the total charge present on the surfaces or plates of the capacitor member at a substantially constant value.

The novel generator means basically comprises a variable capacitor having at least a pair of capacitor plates, means for coupling a direct current potential source to the capacitor surfaces, means for varying the capacitance of the variable capacitor, the variation of the capacitance producing a fluctuating potential difference between the capacitor surface, and means for coupling the fluctuating potential on the capacitor surfaces to the high capacitance load.

One preferred embodiment of the novel generator of the present invention comprises a variable capacitor device comprising a movable and a fixed semicircular plate, means for coupling a direct current potential to both capacitor plates, an electric motor which is coupled to drive the movable plate in such a manner as to change the effective area between the plates of the capacitor device in a cyclical manner, and means for coupling the changing potential to a high capacitance load.

In a capacitor device $Q=CV$, where V is the voltage between a pair of capacitor plates, Q is the total charge on the plates and C is the capacitance of the device.

It is apparent therefore that a variation of the effective area of the capacitor plates to change the capacitance of the device while holding the total charge Q constant will effect a variation of the voltage V between the plates. Such variation is coupled over associated output terminals on the plates to a high capacitance load, such as a solid-state lighting panel, and the voltage coupled to such a load from the plates will be a fluctuating signal which does not load the electrical power generating means. One preferred embodiment of the present invention includes means for effecting one fluctuation cycle for every revolution of the movable capacitor plate, and a second preferred embodiment effects a plurality of such cycles during each revolution of the movable capacitor plates. Since the generator varies the voltage by changing the capacity in each of the embodiments, the voltage of the phosphor is raised and lowered without changing the charge, and a comparatively small amount of power is required to energize a high capacitive load at a high frequency rate.

These and other objects and features of the present invention will become apparent with reference to the following description, claims, and drawings in which:

Figure 1 is a partial schematic, partial perspective drawing of one basic embodiment of a solid state lighting arrangement including the novel generating means;

Figure 2 is a front view of the plates of one preferred embodiment of a variable capacitor for use with the signal generating means;

Figures 3*a*–3*c* are perspective views of parts of the capacitor plates of the embodiment of Figure 2 showing various relative positions attained by such plates during a normal cycle of operation; and

Figure 4 is a front view of a second preferred embodiment of the plates of the variable capacitor.

With reference to Figure 1, there is shown thereat a basic embodiment of the high-frequency voltage generator means **10** of the present invention in which motor means are used to change the capacitance of a variable capacitor member in a cyclic manner. The signal generator means **10** there shown basically comprises a variable capacitor having a fixed capacitor surface or plate **12** and a movable capacitor surface or plate **14**, and an electric motor **16** having a motor output shaft **20** coupled to the movable plate **14** to effect the rotation thereof relative to fixed plate **12** with energization of the motor **16**.

Fixed terminal **24** is attached to capacitor plate **12** and wiper terminal **26** is supported in contacting relation with shaft **20** which supports capacitor plate **14**. Conductors **27**, **L1** connected to terminals **24**, **26** couple the electrical output of the capacitor plates **12**, **14** over conductor pair **28** to terminals **T32**, **T34** of capacitive load **30**.

The capacitive load, in the disclosed embodiment, comprises a solid-state lighting panel **30** including a pair of conductor electrodes **32**, **34**, which have a layer of electroluminescent material **33** sandwiched therebetween in the manner of known electroluminescent cells. Terminals T32 and T34 attached to the plate members **32**, **34** couple the output of the generating device **10** to the solid state conductor electrodes **32**, **34** respectively. Other forms of cells may, of course, be used in such arrangement, the more basic species of the drawings being illustrated to simplify the disclosure of the invention.

Capacitor plates **12**, **14** are coupled over conductors L1, L2 to an energizing source **18**, which may be a 110 volt, 60 cycle A.C. or D.C. source, as desired. In the event that the energizing source is a conventional 110 v., 60 cycle, A.C. source, a rectifier network such as the illustrated network **19** including diode **21**, capacitor **23** and resistor **25** are connected between the plates **12**, **14** and conductors L1, L2 to effect the provision of the desired D.C. signal to the capacitor plates **12**, **14**. Manifestly if a D.C. source is available, rectifier network **19** is not required, and conductors **L1** and **L2** will be coupled over resistor **25** (or a suitable inductance member) to terminals **24**, **26**.

The electric motor **16** may be of any standard type in most applications, and may comprise a high speed motor in applications which require a higher frequency signal. If the load requires constant frequency energization, a constant speed motor should be utilized. In that a 110 volt, 60 cycle A.C. source is normally available, an A.C. motor is normally used in the system. However, a D.C. motor may be used whenever D.C. energy is available. The operating speed and size of the motor **16** may be selected to provide an output signal of a value consistent with the requirements of the load **30**. A ⅛ H.P. motor, for example, may be sufficiently large to energize a load **30** which comprises a smaller size electroluminescent cell such as disclosed herein. In operation, motor **16** is connected over conductors **L1**, **L2** to the available power source (not shown) and motor shaft **20** operates to rotate the attached capacitor plate **14** relative to the fixed condenser plate **12**.

Referring to Figure 3, the method of varying the capacity of the signal generating means **10** of Figure 1 to attain the desired output signal is shown in detail. As is well known in the art, the value of the capacitance C of a pair of capacitor plates is directly proportional to the area of the electrical field between the plates, and a field of such type is electrostatically generated only between two plates which are of a conductive material and which are in juxtaposed position relative to each other. It is apparent, therefore, that the capacitance C of a pair of plates, such as **12**, **14** of the signal generator means 10 at any time is dependent upon the dimensions of the coextensive or effective areas of the conductive segments **12**, **14** at such time. With reference to Figure 3*a* the capacitance C of the plates **12**, **14** is at a maximum value (C max.) when the conductive portions **12**, **14** of the plates are in the relative juxtaposed position thereshown. Rotation of the movable plate **14** to cause an angular displacement of 90° of the movable plate **14** relative to the fixed plate **12**, illustrated in Figure 3*b*, reduces the area of the conducting segments **12**, **14** which is in juxtaposed relation to approximately one-half of the relative juxtaposed area which exists when in the position of Figure 3*a*. The capacitance C of capacitor **10** is accordingly reduced by a proportional value. Further rotation of the movable plate **14** to effect an angular displacement of 180° of the movable plate **14** from its original position (as illustrated in Figure 3*a*) results in a minimum juxtaposed area. The capacitance is, of course, also of a minimum value (C min.) when the plates are in such relative position. Further rotation of the movable member **14** serves to increase the value of both the juxtaposed area and the capacitance of the plates toward the maximum value. Manifestly, complete rotation of the movable plate **14** causes the capacitance C of the variable capacitor **10** to fluctuate in a sinusoidal manner between a maximum and minimum value.

Since $V=Q/C$, where V is the voltage between the plates and Q is the total charge on them, if Q is held constant, any fluctuation in the capacitance C induces a proportional but inverted fluctuation in the voltage V. The sinusoidal fluctuation in the capacitance C of the signal generator means **10** induced by the rotation of the movable plate **14** therefore induces a sinusoidal fluctuation in the voltage V which appears at terminals **24**, **26**. The voltage fluctuation is 180° out of phase with the capacitance fluctuation, and varies between $Q/C_{\text{min.}}$ and $Q/C_{\text{max.}}$ in a sinusoidal manner. The variable voltage as coupled to the panel **30** effects the excitation thereof to provide an increased light output by reason of the increased frequency of potential variation.

It is apparent from the foregoing description that the capacitive load and the novel generating means in effect comprise two condensers connected in parallel, and as a result the voltage fluctuations energize the load without loss of energy except for small losses due to system resistance and leakage, and dielectric heating. The power coupled to the signal generator system is provided to supply the losses of the system and the energy required to excite the phosphor material.

In the illustrated embodiment of Figure 1, the capacitance is varied by rotating a movable one of the pair of condenser plates **12, 14**. In other possible embodiments which are within the scope of the invention, and which modifications will be obvious to persons skilled in the art, the capacitance C may be increased by changing the dielectric constant of an insulating media disposed between the plates **12, 14**. Photocapacitive devices and other devices using ionized gas may be used to provide control in a similar manner.

The capacitor plates **12, 14** may be of any one of a number of different constructions, including the configuration shown in Figure 1. In one preferred embodiment, such as shown in Figure 2, the plates are preferably made a part of a member which is circular in cross-section so that high speed rotation may be effected without experiencing possible vibration problems due to an unbalanced load. As there shown the first circular member **40** (which is the fixed member of the pair of members) includes a first semicircle segment **12′** of a conducting material and a second semicircle segment **13′** of a non-conducting material. The second cooperating member **41**, which is the movable member of the pair of members, is of a similar structure, and includes a conducting semicircle segment **14′** and a non-conducting semicircle segment **15′**. It is apparent that as the movable member **41** is rotated, the conductive portions **12′, 14′** of the two members **40, 41** will operate as capacitor plates, and the changing effective capacitive area will cause a fluctuating potential to be coupled over terminals **24, 26** to the load **30**. Ostensibly, the fixed member **40** does not require the insulated portion **13′** for operation, such structure being used basically for the purpose of conformance of parts.

The frequency of the induced voltage fluctuations may be further increased without resorting to an increase of motor speed by using capacitor plates **12″, 14″** of the configuration shown in Figure 4. Such structure comprises a first fixed circular member **42** having a plurality of wedge-shaped conducting segments **12″** and a plurality of non-conducting wedge-shaped segments **13″** disposed in adjacent alternate sequence relative to each other. The movable circular member **43** comprises a similar arrangement of wedge-shaped conductive members **14″** and non-conductive members **15″**. As illustrated in Figure 4, each plate has eight conductive and eight non-conductive segments. The capacitance C of each of the capacitor plates **14″** will therefore fluctuate between a maximum and a minimum value a related number of times during each complete rotation of the movable plate **43** relative to fixed plate **42**. Ostensibly an increase in the number of segments **12″, 13″** increases the frequency of fluctuation in the output signal by a correspondingly higher value.

It is further apparent that the non-conductive segments **13″, 15″** in the device of Figure 4 may be cut out sections rather than solid insulator segments, and the device will be operative in the same manner.

One method of providing a plurality of conducting segments **12″, 14″** on the plates **42, 43** comprises the steps of etching parts of the surface of a disc of a non-conducting material, such as aluminum oxide, by a photo-engraving method, and then filling or coating those parts of the surface which have been etched by an electroplating method. Other similar methods of manufacturing will be immediately apparent to parties skilled in the art.

Conclusion

The improved generating means of the present invention provides an improved energizing signal for a high capacitance load **30**, such as solid-state lighting panel, in an extremely economical and reliable manner. Since only a constant total charge is required of the power sources, the output signals are produced without effecting extreme loading of that power source. Further, in certain embodiments, frequencies of the order of 20,000 c.p.s. may be readily provided by an inexpensive unit which is energized by a conventional D.C. or A.C. 60 cycle, 110 volt power signal source.

The maximum capacitance of the capacitor plates **12, 14** may be of any desired value and may be controlled by varying the size of the plates **12, 14** and the spacing therebetween. In all cases, for maximum effect, the capacitance of the capacitor plates **12, 14** should be greater than the capacitance of the load to permit a greater proportion of the total capacitance of the variable capacitor **10** to fluctuate during the rotation of the movable plate **14**.

It is apparent that the segments **41, 43** of the capacitor plates **12, 14** do not have to be shaped as shown, but may be of other shapes to permit use in applications in which a sine wave output is not desired. Suitable distortion of the waveform of the signal output may likewise be accomplished in an obvious manner. Whereas the output of the present arrangement has been disclosed as comprising a fluctuating D.C. voltage under certain load applications, it may be desirable to include capacitive coupling between the generator and the load to provide an A.C. output voltage, and such modification is considered to be clearly within the scope of the teaching of the present invention.

While what is described is regarded to be a preferred embodiment of the invention, it will be apparent that variations, rearrangements, modifications and changes may be made therein without departing from the scope of the present invention as defined by the appended claims.

What is claimed is:

1. A generator apparatus for energizing high capacitance loads comprising a solid state lighting panel including a first and a second conductor plate, an electroluminescent material disposed between and in intermediate contact with said first and second conductor plates, and an input terminal on each of said conductor plates; a variable capacitor device including at least a first and a second plate member supported for movement relative to each other, each of said members having at least one conducting and one nonconducting section, means for coupling a direct current potential to the conductive portions of said capacitor plate members including means for coupling the device to an alternating current source, and rectifier means for deriving a direct current potential therefrom for energizing the conductive sections of said plate members; motor means connected to said alternating current source operative to provide cyclical relative movement between the conductive sections of said members to cyclically vary the coextensive area of the two plate members, and output means for coupling the resultant sinusoidal variation of potential which occurs between the conductive sections of said members to the terminal members on the first and second conductor plates of the high capacitance load.

2. A display device for providing a controlled light output comprising in combination: a generator apparatus comprising a variable capacitor device including first and second capacitor surfaces, and means for cyclically varying the capacitance of said device; means coupled to said generator apparatus for applying a difference of potential between said surfaces to produce a fluctuating potential difference therebetween in response to said cyclical capacitance variation; a high capacitance load comprising a solid-state lighting panel including first and second conductor electrodes, and a layer of electroluminescent ma-

terial disposed intermediate said conductor electrodes; and means, coupled between said load and said surfaces, for coupling said fluctuating potential difference to said high capacitance load to thereby energize the electroluminescent material of said panel in the provision of a controlled light output therefrom.

3. A display device for providing a controlled light output comprising in combination: a generator apparatus comprising a variable capacitor device including first and second capacitor surfaces mounted in spaced adjacent relation, and means for cyclically varying the effective capacitive area of said capacitor surfaces; means coupled to said generator apparatus for applying a difference of potential between said surfaces to produce a fluctuating potential difference therebetween in response to said cyclical capacitive area variation; a high capacitance load comprising a solid-state lighting panel including first and second conductor electrodes, and a layer of electroluminescent material disposed intermediate said conductor electrodes; and means, coupled between said load and said surfaces, for coupling said fluctuating potential difference to said high capacitance load to thereby energize the electroluminescent material of said panel in the provision of a controlled light output therefrom.

4. A display device for providing a controlled light output comprising in combination: a generator apparatus comprising a variable capacitor device including a first capacitor plate which is fixedly positioned and a second capacitor plate supported for movement relative to said first plate, and means for rotating said second plate relative to said first plate to thereby cyclically vary the coextensive area of said plates and thus cyclically vary the capacitance of said device; means coupled to said generator apparatus for applying a difference of potential between said plates to produce a fluctuating potential difference therebetween in response to said cyclical capacitance variation; a high capacitance load comprising a solid-state lighting panel including first and second conductor electrodes, and a layer of electroluminescent material disposed intermediate said conductor electrodes; and means, coupled between said load and said plates, for coupling said fluctuating potential difference to said high capacitance load to thereby energize the electroluminescent material of said panel whereby said generator apparatus and said load in effect comprise two capacitors connected in parallel, and said fluctuating potential difference energizes said load with only negligible energy losses.

5. The combination of claim 4 in which one of said plates includes an electrically conductive section and an electrically non-conductive section, and the other of said plates includes a plurality of electrically conductive sections and a plurality of electrically non-conductive sections, each successive pair of conductive sections being separated by a non-conductive section.

6. A display device for providing a controlled light output comprising in combination: a generator apparatus comprising a variable capacitor device, and means for cyclically varying the capacitance of said capacitor device; means coupled to said generator apparatus for applying a difference of potential across said capacitor device to produce a fluctuating potential difference thereacross in response to said cyclical capacitance variation; a high capacitance load comprising a lighting panel including a first and second spaced electrode, and a light-emitting media disposed therebetween; and means for coupling said fluctuating potential difference on said surfaces to the electrodes of said high capacitance load to thereby energize the light-emitting media of said panel in the provision of a controlled light output therefrom.

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