

9604478-9
IPOS GpyMETHOD OF AND CIRCUIT FOR DRIVING
CATHODELUMINESCENCE TYPE LIGHTING DEVICEBACKGROUND OF THE INVENTION

The present invention relates to a method of and an
5 apparatus for driving lighting devices utilizing
cathodeluminescence. More particularly, the invention is
directed to a method of and a circuit for driving a lighting
device suitable for use as a light source for an image input
apparatus such as an image scanner, a digital copying machine,
10 or a facsimile machine, or as a large display such as an
outdoor television-type display.

In lieu of conventional light sources such as fluorescent
lamps and line halogen lamps used as a line light source in an
image input apparatus or the like, a light source utilizing
15 cathodeluminescence, such as disclosed in Japanese Patent
Unexamined Publication No. 73970/1981, has been proposed as a
light source having low power consumption.

Figure 1 is a sectional view of a conventional
cathodeluminescence type light source. The construction of the
20 conventional light source will be described with reference to
Figure 1.

Reference numeral 10 designates a glass tube that is
evacuated to a predetermined degree of vacuum. Along the
length of the glass tube 10 extends a cathode 12. Reference



numeral 14 designates a glass substrate, a front surface of which is coated with a phosphor 16. An anode 18 is deposited on the phosphor 16. The anode 18 is made of an aluminum thin film that serves as a metal backing. A grid 20, which is a control electrode, is interposed between the cathode 12 and the anode 18, and is made of a metal plate having slits 11 of a length of about 0.3 to 1 mm. Commonly used as the phosphor materials are those including zinc sulfide (ZnS) as a base material, such as ZnS with copper (Cu) and aluminum (Al). The light-emitting efficiency of these phosphor materials is high.

A high voltage of about 8 kV is applied to the anode 18 of the light-emitting tube by an ordinary power supply E2, whereas a voltage V4 on the order of several volts is applied to the grid 20 by a power supply E4.

A driving method will be described next. Japanese Patent Unexamined Publication No. 3740/1978 discloses a method of driving the cathodeluminescence type light source. Figure 2 is a timing chart for driving such light source. CTLon designates a lighting signal input to a cathode drive circuit (not shown). Cathode drive signals Ek1 and Ek2, which are output signals generated from the cathode drive circuit, are applied to the terminals K1 and K2 of the cathode 12 of the light-emitting tube shown in Figure 1. The generation of the lighting signal CTLon is repeated with a cycle time t_0 based on a turning-off period t_{off} and a lighting period t_{on} .



During the turning-off period t_{off} , the voltages of the cathode drive signals E_{k1} and E_{k2} are V_2 and V_1 , respectively. The voltages V_2 and V_1 are higher than the voltage V_4 applied to the grid 20. When the voltages V_2 and V_1 are applied to the terminals K_1 and K_2 of the cathode 12, a difference in voltage $\Delta V = V_2 - V_1$ is supplied to the cathode 12 to cause the surface of the cathode to easily release thermoelectrons 24 (described later) by Joule heating.

However, since the voltages V_2 and V_1 applied to the terminals K_1 and K_2 of the cathode 12 are higher than the voltage V_4 applied to the grid 20, there is no emission of thermoelectrons 24 from the cathode 12.

During the lighting period t_{on} , the voltages of the cathode drive signals E_{k1} and E_{k2} both are 0 V. Since the voltage of the cathode 12 is lower than the voltage V_4 applied to the grid 20, the cathode 12 is heated by remaining heat, releasing thermoelectrons 24.

The thermoelectrons 24 pass through the slits 11 of the grid 20 and collide against the anode 18, to which the high voltage is applied. The thermoelectrons 24, having passed through the anode 18 formed of a thin film, collide against the phosphor 16, causing cathodeluminescence to occur.

The rate at which thermoelectrons are emitted from the surface of the cathode 12 depends on the surface temperature of the cathode 12. When a thermoelectron emitting substance



called an emitter material (not shown) is coated on the surface of the cathode 12, thermoelectrons are usually emitted therefrom at an adequate rate at surface temperatures of 500 to 700°. However, if the temperature is too high, evaporation of the emitter material is promoted, reducing the rate of emission of thermoelectrons. As a result, the amount of light emitted from the light source is impaired drastically. On the other hand, if the temperature is too low, the emission of thermoelectrons is not sufficient. To overcome this problem, three points, namely, the conduction voltage, the cathode resistance, and the conduction duty cycle at the time of operation (i.e., the ratio of the off period t_{off} to the lighting cycle t_0 in Figure 2) relevant to heating the cathode must be properly selected before driving the cathode.

However, in a lighting device used for an image input apparatus or the like, the integrated value of an amount of light stored in a CCD of a photoelectric transducer of the apparatus be made adjustable by making the lighting period t_{on} of the lighting device variable to increase the accuracy of the output signal from the CCD. However, if the lighting period t_{on} is varied in the conventional drive circuit, the off period t_{off} must also be varied (assuming the lighting cycle time t_0 is fixed). That is, the conduction duty cycle must be varied, which puts the surface temperature of the cathode 12 out of proper range, thus shortening the life of the light-



emitting tube.

The invention has been made in view of such problems. Accordingly, an object of the present invention is to provide a method and apparatus for driving a cathodeluminescence type lighting device that can adjust the lighting period variably and maintain a long life of the lighting device. This object is solved by the method of independent claim 1 and the apparatus of independent claim 4. Further advantageous features, aspects and details of the invention are evident from the dependent claims, the description and the drawings. The claims are intended to be understood as a first non-limiting approach of defining the invention in general terms.

The invention provides a method of and a circuit for driving a lighting device suitable for use as a light source for an image input apparatus such as an image scanner, a digital copying machine, or a facsimile machine, or as a large display such as an outdoor television-type display.

A driving method provided by a specific aspect of the invention repeats, at a predetermined lighting cycle, the steps of: heating a cathode of the lighting device by electric conduction to the cathode; emitting light by causing the cathode to release electrons without conduction to the cathode; and reposing without causing the cathode to release electrons with no conduction to the cathode. At least the period of the light-emitting step and the period of the reposing step are variable.

According to a further specific aspect of the invention, a driving circuit is provided which includes: a first control



section for controlling a potential of a first terminal of the cathode; and a second control section for controlling a potential of a second terminal of the cathode. The first control section and the second control section operate during a lighting period, a heating period, and a dummy period. The lighting period, the heating period, and the dummy period are repeated at a predetermined lighting cycle and are successively generated. The first control section

This Sheet Has Been Replaced



controls the potential of the first terminal to a potential lower than a potential of the control grid during the lighting period, and controls the potential of the first terminal to a potential higher than the potential of the control grid during the periods other than the lighting period. The second control section controls the potential of the second terminal to a potential higher than the potential of the control grid and different from the potential of the first terminal during the heating period, and controls the potential of the second terminal to a potential equal to the potential of the first terminal during the periods other than the heating period.

According to a specific aspect, the invention is characterized as having the heating period, the lighting period, and the reposing period in a single lighting cycle. When the lighting period is adjusted variably, the heating period can be maintained constant by varying the reposing period in accordance with the adjustment of the lighting period. Therefore, even if the lighting period is adjusted, the temperature of the cathode can be maintained within a proper range, thereby contributing to extending the service life of the light-emitting tube.

Figure 1 is a sectional view showing the construction of a conventional light source utilizing cathodeluminescence;

Figure 2 is a timing chart of a cathode drive circuit in



the conventional light source;

Figure 3 is a perspective view showing an example of a light-emitting tube to which a drive circuit of the invention is applied;

Figure 4 is a diagram showing in block form an exemplary drive circuit of the invention for the light-emitting tube shown in Figure 3, together with a schematic sectional view of the light-emitting tube;

Figure 5 is a timing chart illustrating the operation of a cathode drive circuit within the drive circuit of Figure 4;

Figure 6 is a circuit diagram showing an example of the cathode drive circuit performing the operation of Figure 5;

Figure 7 is a circuit diagram showing another example of the cathode drive circuit within the drive circuit of Figure 4;

Figure 8 is a timing chart illustrating the operation of the cathode drive circuit of Figure 7;

Figure 9 is a perspective view showing a light-emitting tube 110 of a lighting device for a color image input apparatus to which a drive circuit of the invention is applied;

Figure 10 is a sectional view taken along a line A-A' of Figure 9;

Figure 11 is a partially enlarged view showing a grid electrode 104 and separators 106-BB, 106-BR, 106-RC, and 106-GC in Figure 9;

Figure 12 is a partially enlarged view showing the grid



electrode 104 and inverted C-shaped separators 161-B, 161-R, and 161-G, which can be applied to the light-emitting tube of Figure 9;

Figure 13 is a diagram showing in block form an example of a drive circuit of the invention for the light-emitting tube 110 together with a partial sectional view of the light-emitting tube 110;

Figure 14 is a circuit diagram of a red light-emitting circuit 166-R within the cathode drive circuit 166 of Figure 13; and

Figure 15 is a timing chart illustrative of an operation of the cathode drive circuit 166.

Preferred embodiments of the invention will hereunder be described in detail with reference to the drawings.

Figure 3 is a perspective view showing an example of a cathodeluminescence type lighting tube to which a drive circuit of the invention is applied. A phosphor 16 for cathodeluminescence is coated on the inner surface of a front plate 28 of the light-emitting tube 26 in quantities of 0.1 to 100 mg/cm², most preferably 4 mg/cm², along the length of the light-emitting tube 26. The phosphor 16 is covered with an anode 30 made from aluminum, the anode being formed by vacuum



evaporation in thicknesses of 0.1 to 0.4 μm .

A back electrode 34 extends on the inner surface of a back plate 32 of the light-emitting tube 26 along the length of the back plate 32. The back electrode 34 is made from aluminum by vacuum evaporation or the like. Immediately above the back electrode 34 is a wire-like cathode 36. The cathode 36 is a tungsten thin wire 50 to 100 μm in diameter. An emitter material (not shown) is coated on the surface of the cathode 36. A grid 40 made of a metal plate that has a plurality of apertures 42 formed by blanking, electroforming or the like, is arranged at such a position as to shield the anode 30 from the cathode 36. The anode 30, the grid 40, the cathode 36, and the back electrode 34 are electrically driven to conduct by a drive circuit 44 (described later) via a terminal that extends externally from the light-emitting tube. Reference numeral 46 designates an evacuating tube that evacuates the light-emitting tube to a pressure of about 100 to 0.1 mPa. The light-emitting tube is thereafter sealed by melting the evacuating tube 46 by heating with a gas burner.

Figure 4 shows in block form an example of a drive circuit of the invention for the light-emitting tube 26 shown in Figure 3, together with a schematic sectional view of the light-emitting tube 26.

The drive circuit 44 includes three dc constant voltage power supplies E2 to E4 and a cathode drive circuit 48 for



lighting control.

A high voltage on the order of 8 kV is applied to the anode 30 by the power supply E2. A voltage V4 on the order of several volts is applied to the grid 40 by the power supply E4. An appropriate voltage is applied to the back electrode 34 by the power supply E3. Such voltages are applied to maximize the amount of thermoelectrons emitted by the cathode 36. Both terminals K1 and K2 of the cathode 36 are connected to the cathode drive circuit 48.

Figure 5 is a timing chart illustrating the operation of the cathode drive circuit 48. CTLon and CTLh designate signals input to a lighting signal input terminal Con and a heating signal input terminal Ch, respectively. Reference characters Ek1 and Ek2 designate drive voltage signals supplied to the terminals K1 and K2, respectively.

During a period t_h (heating period), the cathode drive voltage signal Ek1 is a predetermined voltage V3 (e.g., 23 V), and the other cathode drive voltage signal Ek2 is a predetermined voltage V1 (e.g., 8 V). Then, a difference in voltage $\Delta V = V3 - V1$ is produced between the terminals K1 and K2 of the cathode 36, enabling the surface of the cathode 36 to easily emit thermoelectrons 24 by Joule heating.

However, since the voltages V3 and V1 respectively applied to the terminals K1 and K2 of the cathode 36 are higher than the potential V4 applied to the grid 40, no thermoelectrons 24



are emitted from the cathode 36.

Then, during a period t_{on} (lighting period), which is between the moment at which the lighting signal CTLon rises from 0 V to 5 V and the moment at which the lighting signal CTLon drops to 0 V again, both cathode drive voltage signals Ek1 and Ek2 are 0 V, which makes the voltage at the cathode 36 lower than the applied voltage V4. As a result, the thermoelectrons 24 are released from the cathode 36 heated by the remaining heat. The thermoelectrons 24 pass through the apertures 42 of the grid 40 and collide against the anode 30 to which a high voltage has been applied. Further, the thermoelectrons 24 having passed through the anode 30 made of a thin film then collide against the phosphor 16 to produce cathodeluminescence.

Lastly, during a period t_d (dummy period), the lighting signal CTLon and the heating signal CTLh are both at 0 V. As a result, the voltage of both cathode drive signals Ek1 and Ek2 is V1. Since there is no difference in voltage between both terminals of the cathode 36, the cathode 36 is not heated in a manner similar to the lighting period t_{on} . Further, since the voltage V1 applied to the terminals K1 and K2 of the cathode 36 is higher than the voltage V4 applied to the grid 40, no thermoelectrons 24 are emitted from the cathode 36.

In this timing chart, to variably adjust the lighting period t_{on} , the cycle time t_0 and the heating period t_h are



fixed, whereas the lighting period t_{on} is varied within the range of $t_0 - t_1$. Accordingly, only the luminous duty cycle can be varied with the heating duty cycle maintained constant.

Figure 6 shows an exemplary circuit of the cathode drive circuit 48 shown in Figure 5.

This cathode drive circuit 48 has two operational amplifiers OP1 and OP2, to which the dc voltage V1 is applied by a power supply E8 as a supply voltage. A threshold voltage V0 (e.g., 1.5 V) is applied to both inverting input terminals (-).

One of the operational amplifiers OP1 has a non-inverting input terminal (+) connected to the signal input terminal Con so that the lighting signal CTLon can be received thereby, and the output terminal thereof is connected to the control gates of two complementary transistors Tr1 and Tr2 through a set of dividing resistors R2 and R3 and through a set of dividing resistors R5 and R4, respectively. The output terminals of the complementary transistors Tr1 and Tr2 are connected to the cathode terminal K2.

The other operational amplifier OP2 has a non-inverting input terminal (+) connected to the signal input terminal Ch so that the heating signal CTLh can be received thereby, and the output terminal thereof connected to the base of a switching transistor Tr4 through a resistor R8. The emitter of the switching transistor Tr4 is grounded, and the collector thereof



is connected to the control gate of the transistor Tr3 through a resistor R6. The voltage V3 which is a voltage combination of the voltage V1 of the power supply E8 with a voltage of the power supply E5 is applied to the control gate of the transistor Tr3 through a resistor R7. The voltage V3 is also applied to the source of the transistor Tr3. The drain of the transistor Tr3 is connected to the other cathode terminal K1.

The operation of the circuit will be described below. An operation during the heating period t_h will be described first.

When the heating signal CTLh has risen to 5 V from 0 V, the output voltage of the operational amplifier OP2 rises to V1 from 0 V, which causes the transistor Tr4 to turn on and the potential of a node of the resistors R7 and R6 to become almost 0 V. Then, since the transistor Tr3 turns on, the voltage V3 is applied to the terminal K1 of the cathode 36.

During this heating period t_h , the output voltage of the operational amplifier OP1 is 0 V. As a result, the transistor Tr1 turns off, whereas the transistor Tr2 turns on, which causes the power supply E8 to apply the voltage V1 to the terminal K2 of the cathode 36.

As the voltages V3 and V1 are then applied to the terminals K1 and K2 of the cathode 36, the cathode 36 is heated with current passing therethrough.

The operation of the circuit during the lighting period t_{∞}



will be described next.

When the lighting signal CTLon has risen to 5 V from 0 V, the output voltage of the operational amplifier OP1 becomes V1. Since this causes the transistor Tr1 to turn on and the transistor Tr2 to turn off, the voltage at the terminal K2 of the cathode 36 is almost 0 V.

Since the heating signal CTLh is at 0 V in this instance, the output voltage of the operational amplifier OP2 is 0 V, leaving the transistor Tr4 turned off. As a result, the transistor Tr3 is turned off, which opens the current loop flowing through the cathode 36. Consequently, the terminal K1 of the cathode 36 is at 0 V, which is equal to the potential at the terminal K2.

The operation of the circuit during the dummy period (t_d) will be described.

When the lighting signal CTLon has dropped to 0 V from 5 V, the output voltage of the operational amplifier OP1 drops to 0 V. Then, the transistor Tr1 is turned off, and the transistor Tr2 turns on, causing the voltage at the terminal K2 of the cathode 36 to become the voltage V1 of the power supply E8.

Since the heating signal CTLh is at 0 V at this time, similar to the lighting period t_{on} , the current loop flowing through the cathode 36 is open. As a result, the potential at the terminal K1 of the cathode 36 is V1, which is equal to the



potential at the terminal K2.

In the drive circuit shown in Figures 5 and 6, the heating duty cycle of the cathode 36 is t_h/t_0 . Thus, if the lighting cycle t_0 and the heating period t_h are kept constant at all times, then the heating duty cycle is constant, thereby keeping the surface temperature of the cathode within a predetermined range. The lighting period t_{on} can be variably adjusted independently of the heating period t_h by using the dummy period t_d .

The variable range of the lighting period t_{on} is between 0 and $t_0 - t_h$. Therefore, the variable range of the lighting period t_{on} can be increased by increasing the voltage V3 of the cathode drive signal Ek1 during the heating period t_h shown in Figure 5 as much as possible, so that the heating duty cycle can be decreased, i.e., the period t_h can be shortened as much as the voltage V3 is increased.

Figure 7 shows another exemplary circuit that can be used as the cathode drive circuit 48 of Figure 4, and Figure 8 is a timing chart showing an operation thereof.

The circuit shown in Figure 7 is advantageous in that the construction thereof is simpler than the circuit shown in Figure 6.

Further, the operation shown in Figure 8 has a feature that the lighting period t_{on} comes first and that the heating period t_h starts in response to the end of the lighting period



t_{on}. More specifically, the lighting signal CTLon is generated at an independent timing, whereas the heating signal CTLh is generated at a timing dependent on the lighting signal CTLon. One of the advantages in this system is that when the lighting device is used as a light source of an image input apparatus, the image reading period can be easily synchronized with the lighting period. The reason is that the lighting signal CTLon can be generated in direct synchronism with a pulse signal that is generated by the image input apparatus and synchronized with the reading period. In contrast thereto, in the operation shown in Figure 5, the lighting signal CTLon is generated at a timing dependent on the heating signal CTLh causing the lighting signal CTLon to rise upon dropping of the heating signal CTLh. Therefore, the lighting signal CTLon cannot be generated in direct synchronism with the pulse signal from the image input apparatus.

The circuit illustrated in Figure 7 will be described below.

A transistor Tr11 receives the lighting signal CTLon on the base thereof through a resistor R11. The emitter thereof is grounded, and the collector thereof is connected to a dc constant voltage supply (e.g., 24 V $\pm$ 10%) through a resistor R12 and to the base of a transistor Tr12. The transistor Tr12 is connected to the above-mentioned dc constant voltage supply; the emitter thereof is connected to the terminal K2 of the



cathode and grounded through a resistor R13. Between the base of the transistor Tr12 and ground is connected a zener diode ZD1 whose zener voltage is, e.g., 25.8 V and whose function is to clamp variations in the dc voltage supply on the high side of the nominal voltage.

A transistor Tr13 receives the heating signal CTLh on the base thereof through a resistor R14. The emitter thereof is grounded, and the collector is connected to the base of a transistor Tr14 through a zener diode ZD2 whose zener voltage is, e.g., 7.4 V and which is connected in the forward direction. The transistor Tr14 has a resistor R15 interposed between the emitter and the base thereof, with the emitter connected to the terminal K1 of the cathode and the collector grounded.

The operation of the circuit will be described with reference to Figures 7 and 8.

As shown in Figure 8, upon initiation of the lighting cycle t_0 , the lighting signal CTLon rises to 5 V from 0 V and drops to 0 V after a predetermined lighting period t_m . In response to the drop of the lighting signal CTLon, the heating signal CTLh rises to 5 V from 0 V and drops to 0 V after a predetermined heating period t_h .

Referring to Figure 7, upon rising of the lighting signal CTLon at the start of the lighting period t_m , the transistor Tr11 turns on and the transistor Tr12 turns off. As a result,



the terminal K2 of the cathode 36 is grounded to be at 0 V, as shown in Figure 8.

Since the heating signal CTLh is at 0 V at this time, the transistor Tr13 is turned off, which means that the transistor Tr14 is turned off as well. Therefore, the current loop flowing through the cathode 36 is open. As a result, the potential at the cathode terminal K1 becomes 0 V, which is equal to the potential at the other terminal K2.

In this way, the voltage of each of the terminals K1 and K2 of the cathode 36 is 0 V, that is, lower than the grid voltage V4 during the lighting period t_{on} , so that electrons are emitted from the already-heated cathode 36 and collide against the phosphor of the anode after being accelerated by the grid. As a result, the emission of light starts.

At the end of the lighting period t_{on} , the lighting signal CTLon drops, and simultaneously therewith the heating signal CTLh rises. When the lighting signal CTLon drops, the transistor Tr11 turns off, which causes the transistor Tr12 to turn on. As a result, the potential of the cathode terminal K2 connected to the emitter of the transistor Tr12 becomes almost 23 V (V3), which is obtained by subtracting the voltage drop of the transistor Tr12 from the power supply voltage (24 V).

Further, since the transistor Tr13 turns on and the transistor Tr14 turns on at the rising of the heating signal CTLh, the potential of the cathode terminal K1 becomes almost



8 V (V1), which is obtained by adding a base-emitter voltage of the transistor Tr13 to the zener voltage 7.4 V.

In this way, the voltage of one terminal K2 of the cathode 36 is 23 V (V3) and that of the other terminal K1 is 8 V (V1) during the heating period t_h , which causes current to flow through the cathode 36 to heat the cathode 36. However, since the potential V3 of the cathode 36 is higher than the potential V4 of the grid, no electrons are emitted.

At the end of the heating period t_h , the heating signal CTLh drops. As a result, both transistors Tr13 and Tr14 turn off, which in turn opens the current loop passing through the cathode 36. Since the voltage of the cathode terminal K2 is 23 V (V3) at this time, which is equal to that during the heating period, the voltage of the terminal K1 becomes 23 V (V3) as well. Therefore, no current flows through the cathode 36, which means that the cathode 36 is not heated. In addition, since the potential V3 of the cathode 36 is higher than the potential V4 at the grid, there is no emission of light.

The above describes the embodiments applied to the lighting device shown in Figure 3 for the emission of light of a single color.

Embodiments of the invention to be applied to a lighting device for the emission of light of three colors, which can be used for a color image input apparatus, will be described next.

Figure 9 is a perspective view of an example of a light-



emitting tube 110 used as a lighting device for a color image input apparatus to which the invention can be applied.

Figure 10 is a sectional view taken along a line A-A' in Figure 9, and Figure 11 is a partially enlarged view showing a grid electrode 104 and separators 106-BB, 106-BR, 106-RG, and 106-GG in Figure 9.

The construction of the light-emitting tube 110 will be described below. Red, green, and blue cathodes 101-R, 101-G, and 101-B extend between the grid electrode 104 and a back electrode 105 (both described later) while being supported by cathode support members 108-R, 108-G, and 108-B on both ends thereof, respectively. The cathodes 101-R, 101-G, and 101-B are thin tungsten wires 10 to 50 μ m in diameter. The surface of each cathode is coated with an electron emitting substance (not shown) such as barium oxide or the like. The function of the coating is to improve electron emitting efficiency.

The grid electrode 104 is located between the cathodes 101-R, 101-G, 101-B and an anode 102 by bending a plate in trapezoidal form, the plate being electrically conductive such as stainless steel, brass, or aluminum, as well as nonmagnetic. As shown in Figure 10, the grid electrode 104 is fixed by clamping with glass side plates 171, 172 and a bottom plate 173. As shown in Figure 11, the grid electrode 104 has four separators 106-BB, 106-BR, 106-RG, 106-GG for partitioning the cathodes. The separators are fixed at a plurality of fixing



points 160. These separators are electrically conductive with the grid electrode 104. Further, on a side of the grid electrode 104 which is opposite to the anode are a plurality of net-like or slit-shaped apertures 145-R, 145-G, 145-B for allowing electrons to pass therethrough, the electrons being generated by the cathodes 101-R, 101-G, 101-B.

Each separator 106 flexes between the fixing points 160 when thermally expanded by heat radiated from the cathode. This causes an inconsistent amount of light. It is desirable to increase the number of fixing points 160 to suppress the flexing as much as possible. Further, it is desirable to bend the upper edge part, the lower edge part, or both of each separator 106 in L form so that the separator 106 becomes hard to flex. Otherwise, as shown in Figure 12, inverted C-shaped separators 161-B, 161-R, and 161-G may be used.

The back electrode 105 is formed between the cathodes 101-R, 101-G, and 101-B and the glass bottom plate 173. The back electrode 105 is made of carbon paste.

Phosphors of three kinds, namely, a green-emitting phosphor 103-G, a red-emitting phosphor 103-R, and a blue-emitting phosphor 103-B, are sequentially coated on the inner surface of a transparent glass plate 107 by means of screen printing or the like. The phosphors used here are those capable of emitting light by cathodeluminescence, such as yttrium oxysulfide (Y_2O_3S) with europium (Eu) or samarium (Sm)



as the red-emitting phosphor, zinc sulfide (ZnS) with copper (Cu) and aluminum (Al) as the green-emitting phosphor, zinc sulfide (ZnS) with silver (Ag) and chlorine (Cl) as the blue-emitting phosphor, and the like.

The anode 102 is formed by depositing a 1 to 10 μm thick layer of aluminum on the inner surface of the phosphor-coated transparent glass plate 107 by means of vacuum evaporation or the like.

Lastly, the surfaces of the glass parts in contact and the interface of the leads externally extending from the light-emitting tube 110 from each electrode are closed with low-melting point glass or the like, put in a high-temperature vessel at 500 to 600° to be fused so that a container 177 including the transparent plate 107, the glass plates 171, 172, 173, 174, and 175 shown in Figure 9 is formed. Then, when the container 177 is evacuated to a range of 100 to 0.1 mPa by an evacuating tube 176, the container 177 is sealed to maintain the evacuated condition therewithin.

The three-color light-emitting tube 110, when used as a light source for a color image input apparatus, injects light in three colors to a single direction from a substantially single light source. As a result, even if an original having steps or irregularities on the surface is input, excellent color reproduction free from color mismatching can be obtained.

Figure 13 shows in block form a drive circuit of the



invention for independently producing emissions of light from the phosphors 103-R, 103-G, and 103-B for the respective colors of such light-emitting tube 110.

A drive circuit 167 shown in Figure 13 includes three dc constant voltage power supplies and a cathode drive circuit 166. The respective cathodes 101-R, 101-G, and 101-B are connected to the cathode drive circuit 166 at both terminals K1-R, K2-R, K1-G, K2-G, K1-B, and K2-B.

Figure 14 is a circuit diagram of the cathode drive circuit 166. A circuit 166-R in Figure 14 drives the cathode 101-R for the red color. Two other circuits (of the same construction) are arranged in parallel to drive the cathode 101-G for the green color and the cathode 101-B for the blue color. The three cathodes 101-R, 101-G, and 101-B are driven independently by these three circuits.

The circuit shown in Figure 14 is the same as the cathode drive circuit 48 for the single color light-emitting tube shown in Figure 6. A lighting signal input terminal Con-R and a heating signal input terminal Ch-R receive a lighting signal CTL-R and a heating signal CTL-Rh for red (see Figure 15), respectively. The cathode terminals K1-R and K2-R are connected to the cathode 101-R for red.

Figure 15 is a timing chart showing the operation of the cathode drive circuit 166.

As shown in Figure 15, the drive signals CTL-Rh, CTL-R for



the red color, the drive signals CTL-Gh, CTL-G for the green color, and the drive signals CTL-Bh, CTL-B for the blue color are generated 120° out of phase with one another. The operation of each color is the same as the operation shown in Figure 5.

The three-color light-emitting tube can, of course, be driven by the three circuits, the construction of each of which is the same as that shown in Figure 7. In such a case, the operation shown in Figure 8 is performed per color. The operations of the three colors are 120° out of phase with one another.

While the preferred embodiments of the invention have been described above, the invention is not limited to them, but may be embodied in various other modes.

As described in the foregoing, the invention according to a specific aspect is characterized as arranging a dummy period in which no heating or lighting is effected during a lighting cycle and making the dummy period and the lighting period variable. Therefore, even if the lighting period is variably adjusted, the heating duty cycle can be maintained constant, thereby allowing the life of the lighting device to be increased.

This Sheet Has Been Replaced





CLAIMS

1. A method of driving a cathodeluminescence type lighting device, comprising the steps of:

5

heating a cathode of said cathodeluminescence type lighting device by electric conduction;

10

emitting light by causing the cathode to release electrons absent conduction to the cathode once said cathode is heated; and

15

reposing said cathode during a period when said cathode is not heated and said release of said electrons is terminated;

20

wherein said heating, light-emitting, said reposing steps are repeated at predetermined lighting cycles, and

at least a period of said light-emitting step and a period of said reposing step are variable.

25

2. The method according to claim 1, wherein a ratio of a period of said heating step to the lighting cycle is maintained constant.

30

3. The method according to claim 1 or 2, further comprising the step of controlling timings of said heating step, said light-emitting step, and said reposing step, said step of controlling timings determining a timing of said light-emitting step independently of the timings of said heating step and of said reposing step and the timings of said heating step and of said reposing step dependent on the timing of said light-emitting step.

35





4. An apparatus, especially for carrying out the method of any one of the preceding claims, for driving a cathodeluminescence type lighting device (26;110) having a control grid (40;104) arranged between a cathode (36;101) and an anode (30;102), said apparatus comprising:

a first control section for controlling a potential of a first terminal of said cathode (36;101) and

a second control section for controlling a potential of a second terminal of said cathode (36;101);

said first control section and said second control section operating during a lighting period (t_{on}), a heating period (t_h), and a dummy period (t_d), respectively, wherein said lighting period, said heating period, and said dummy period are repeated at predetermined lighting cycles and are successively generated;

said first control section controlling the potential of the first terminal to a potential lower than a potential of said control grid (40;104) during said lighting period, and controlling the potential of the first terminal to a potential higher than the potential of said control grid (40;104) during periods other than said lighting period; and

said second control section controlling the potential of the second terminal to a potential higher than the potential of said control grid (40;104) and different from the potential of the first terminal during said heating period, and controlling the potential of the





second terminal to a potential equal to the potential of the first terminal during periods other than said heating period.

5
10 5. The apparatus according to claim 4, wherein said second control section opens a current loop passing through said cathode (36;101) during periods other than said heating period so that the potential of the second terminal becomes equal to the potential of the first terminal.

15 6. The apparatus according to claim 4 or 5, wherein said second control section controls the potential of the second terminal to a potential higher than the potential of the first terminal during said heating period (t_h).

20 7. The apparatus according to any one of claims 4 to 6, wherein said second control section controls the potential of the second terminal to a potential lower than the potential of the first terminal during said heating period (t_h).

25 8. The apparatus according to any one of claims 4 to 7, wherein

30 said first control section operates in response to a lighting signal indicating said lighting period;

said second control section operates in response to a heating signal indicating said heating period;

35 said apparatus further comprising:



THIS SHEET HAS BEEN
REPLACED

This Sheet Has Been Replaced



4

5 a signal generating section for generating said lighting
signal and said heating signal, said signal generating
section determining a timing for generating said lighting
signal independently of said heating signal and a timing
for generating said heating signal dependent on said
lighting signal.

10



* C L M S *

ABSTRACT

A lighting device emits light by releasing electrons to an anode from a Joule-heated cathode and causes the electrons to collide against a phosphor on the anode side. A method of driving the lighting device repeats, at a predetermined lighting cycle, a heating period (t_h) in which the cathode is heated by conduction, a lighting period (t_{on}) in which the cathode is caused only to release electrons without conduction so that light is emitted, and a dummy period (t_d) in which no conduction or emission of light occurs at the cathode. To variably adjust the lighting period (t_{on}), adjustments are absorbed by the dummy period (t_d) to maintain the heating period (t_h) constant at all times. With respect to the timing control of each period, the lighting period (t_{on}) is controlled at a timing independent of the heating period (t_h), whereas the heating period (t_h) is controlled at a timing dependent on the lighting period (t_{on}). This is preferred to facilitate the timing control of the lighting period (t_{on}).

This Sheet Has Been Replaced



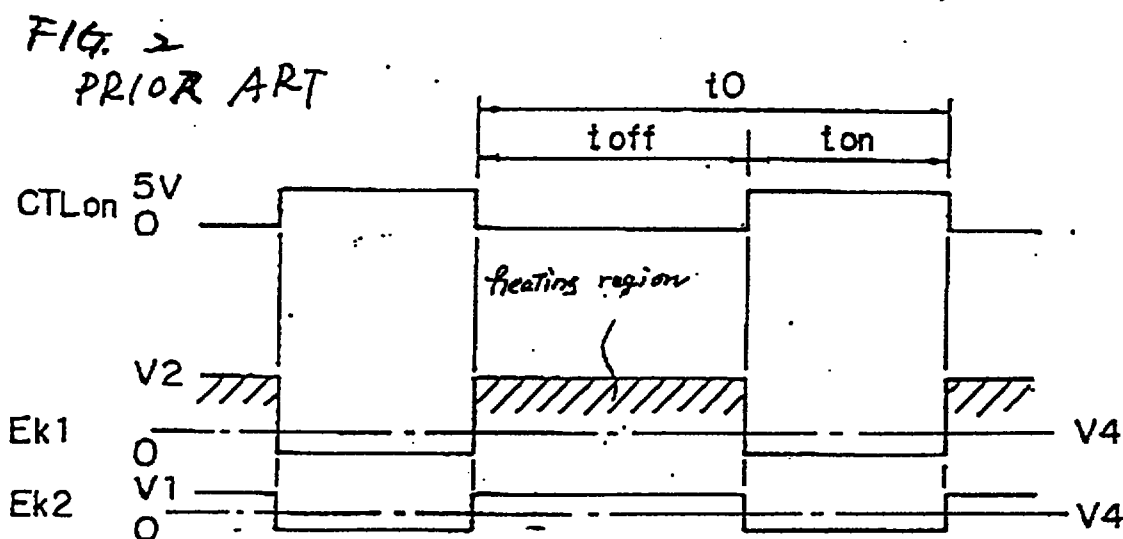
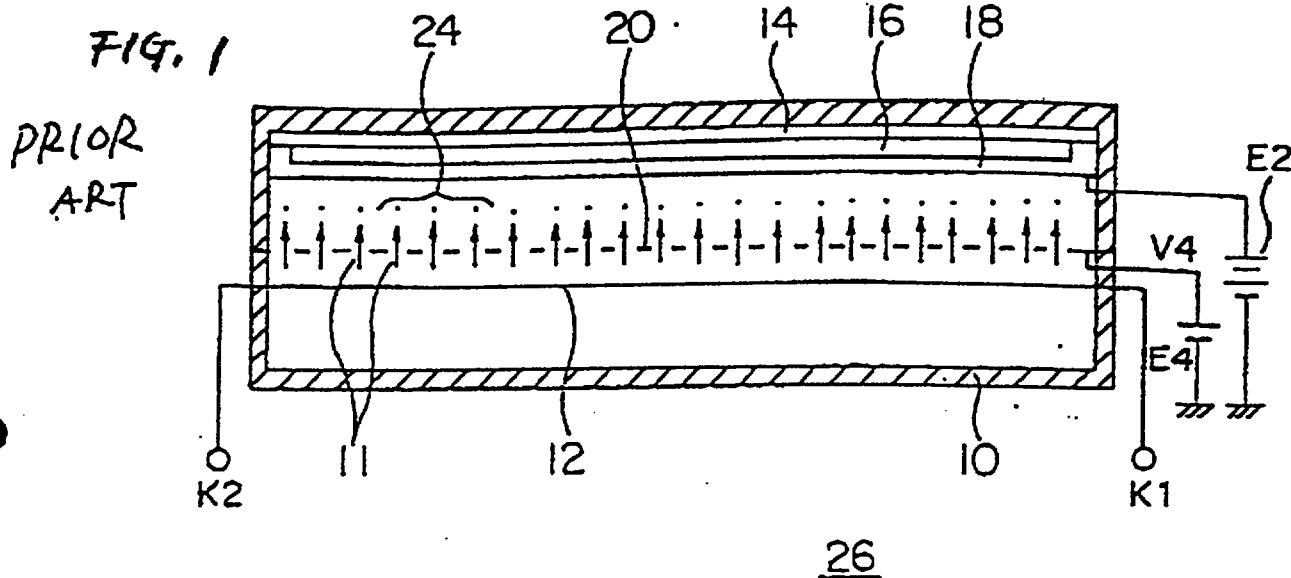
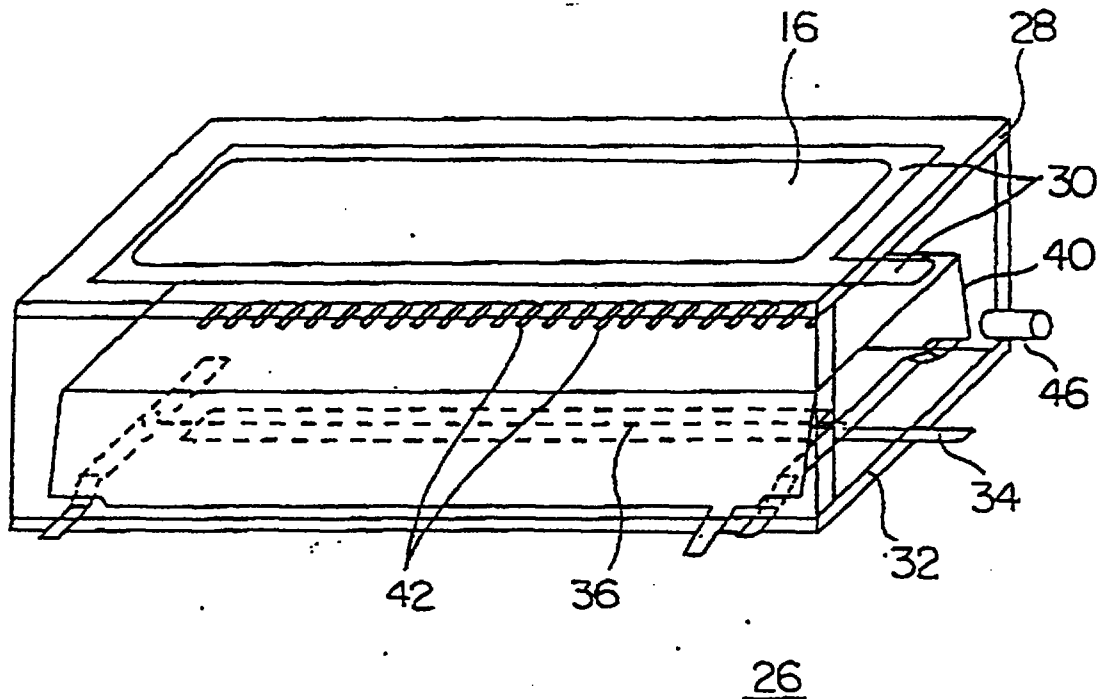


FIG. 3



3/12

FIG. 4

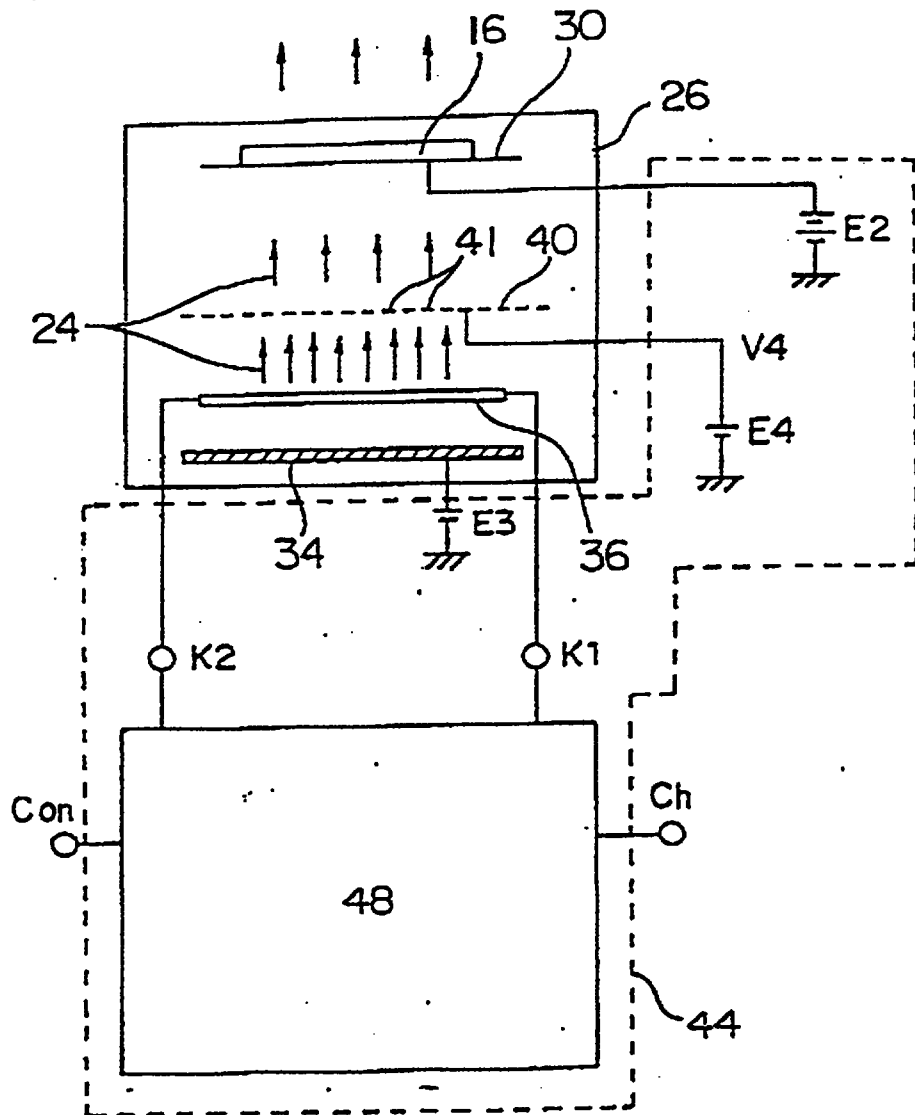


FIG. 5

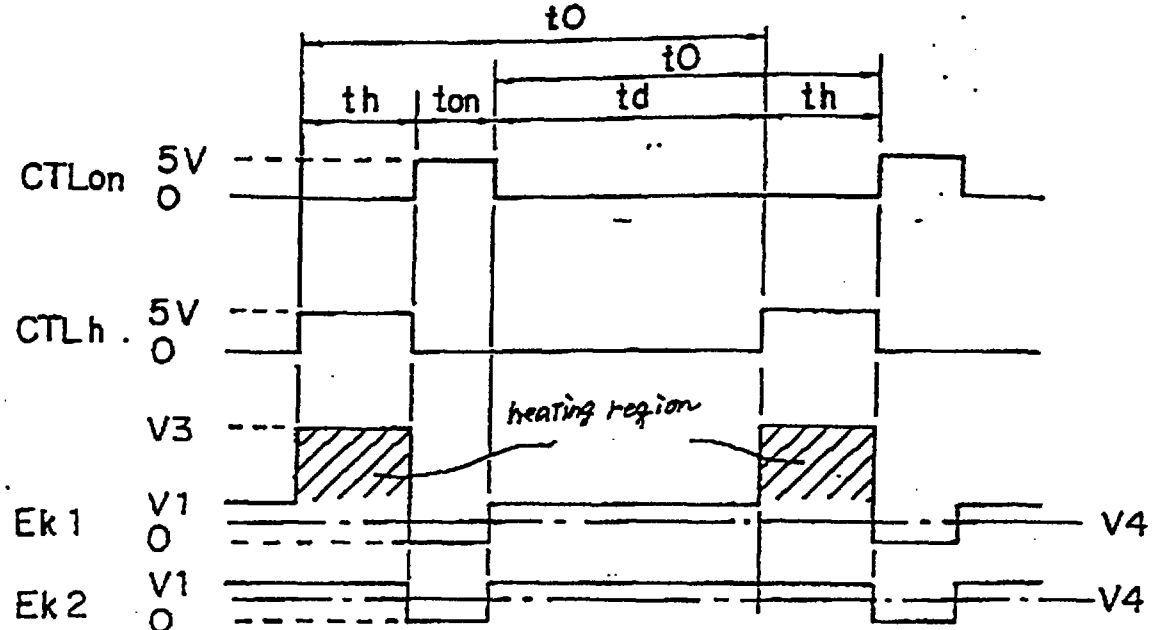
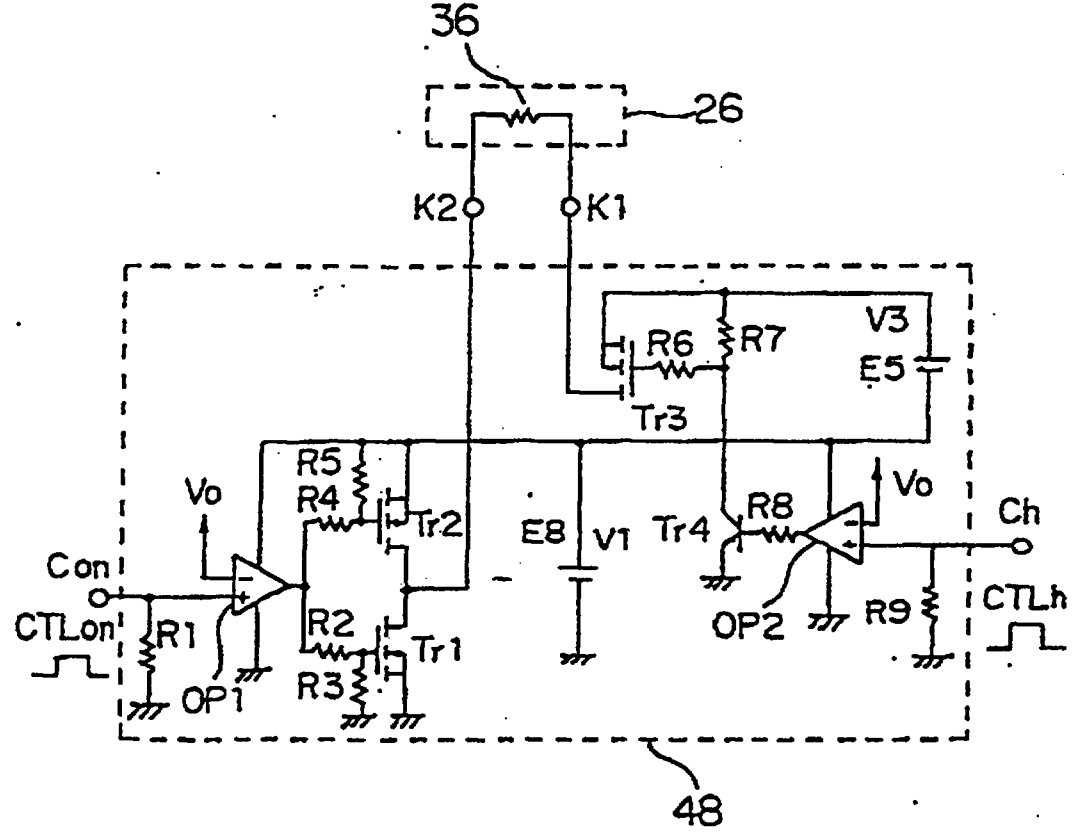


FIG. 6



5/12

FIG. 7

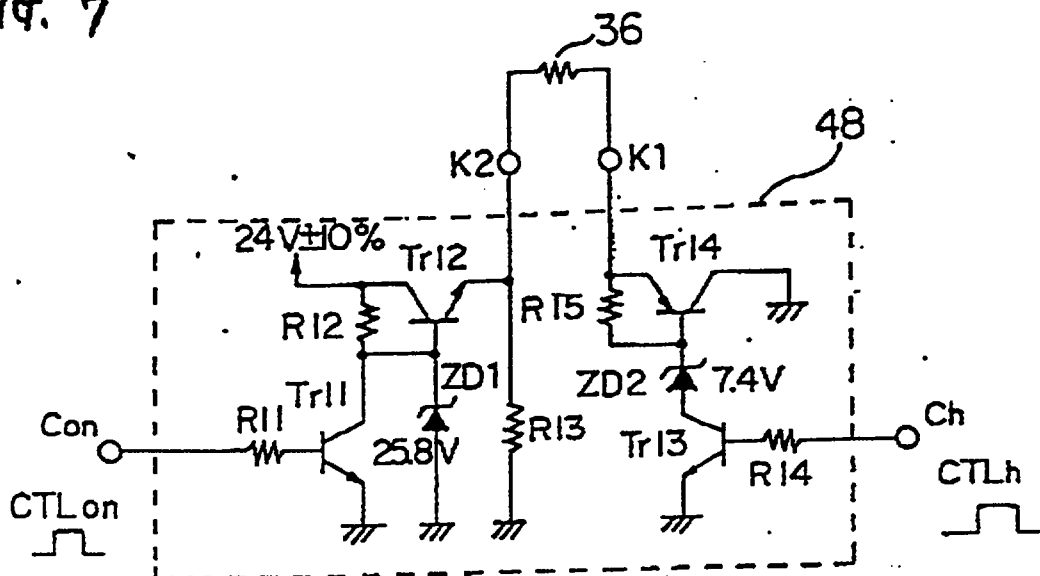
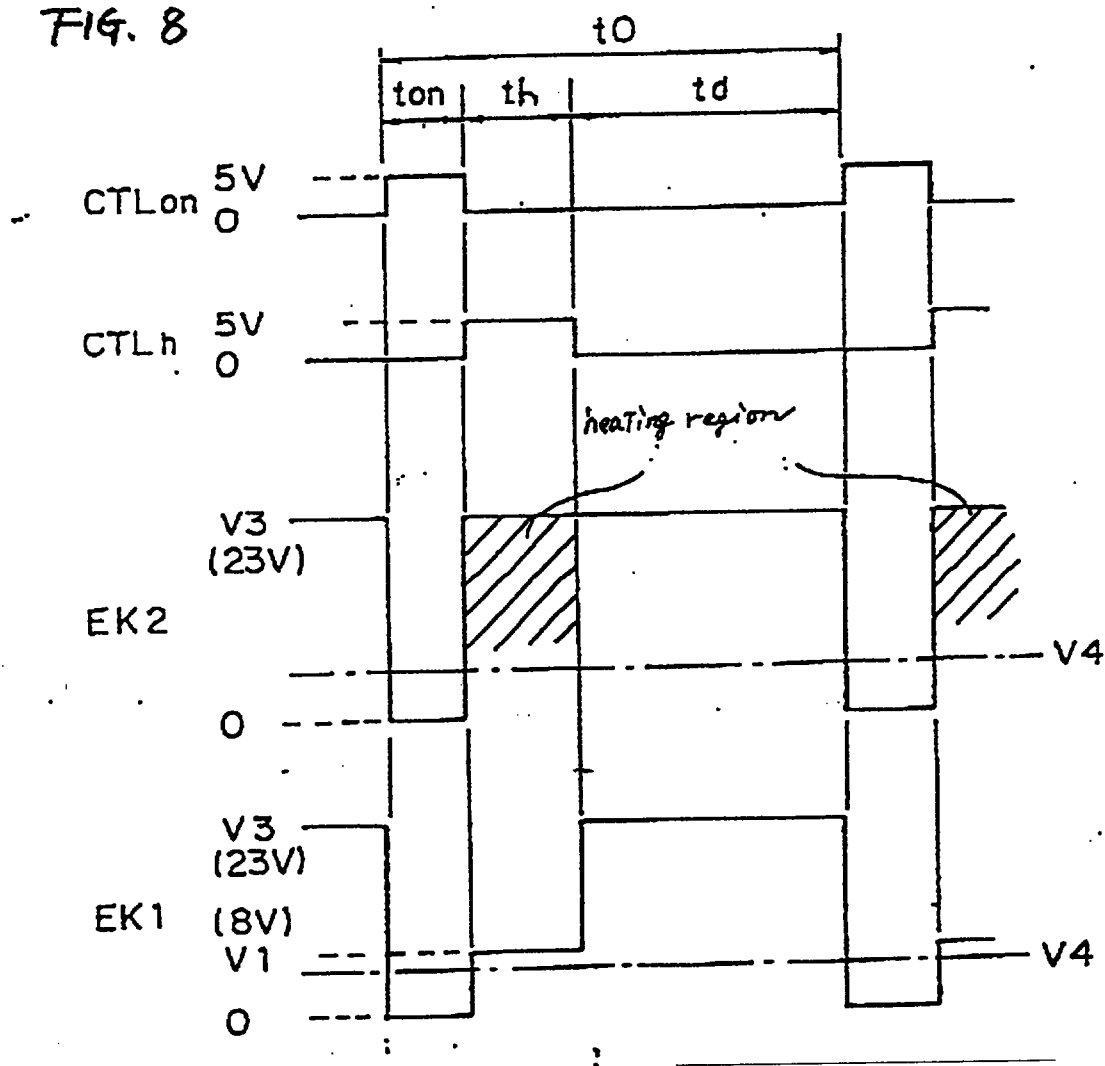


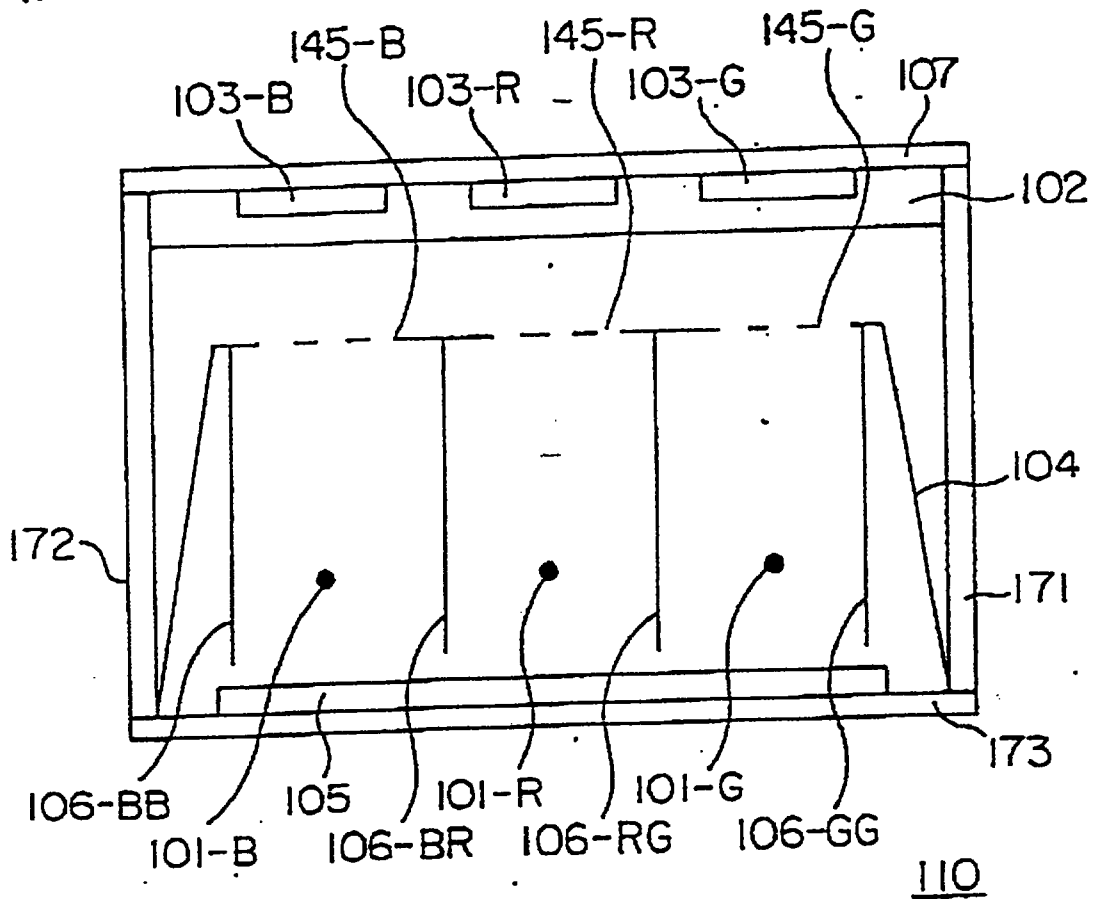
FIG. 8



$$.6 / 12$$


7/12

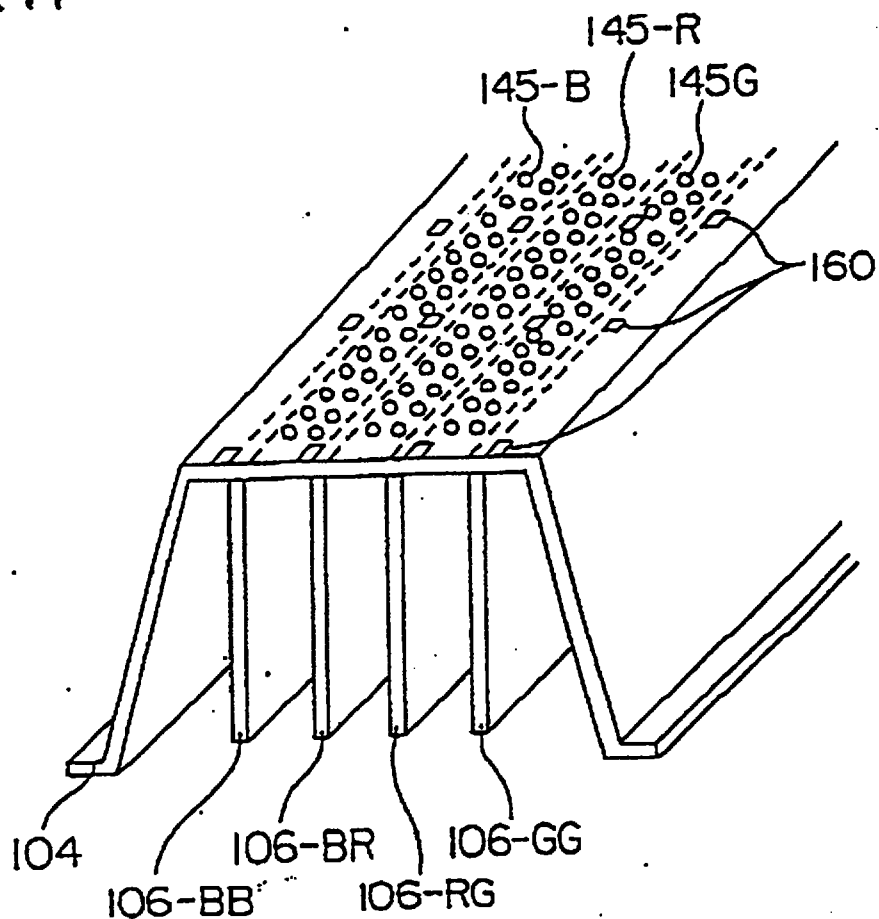
FIG. 10



THIS SHEET HAS BEEN
REPLACED

8/12

FIG. 11



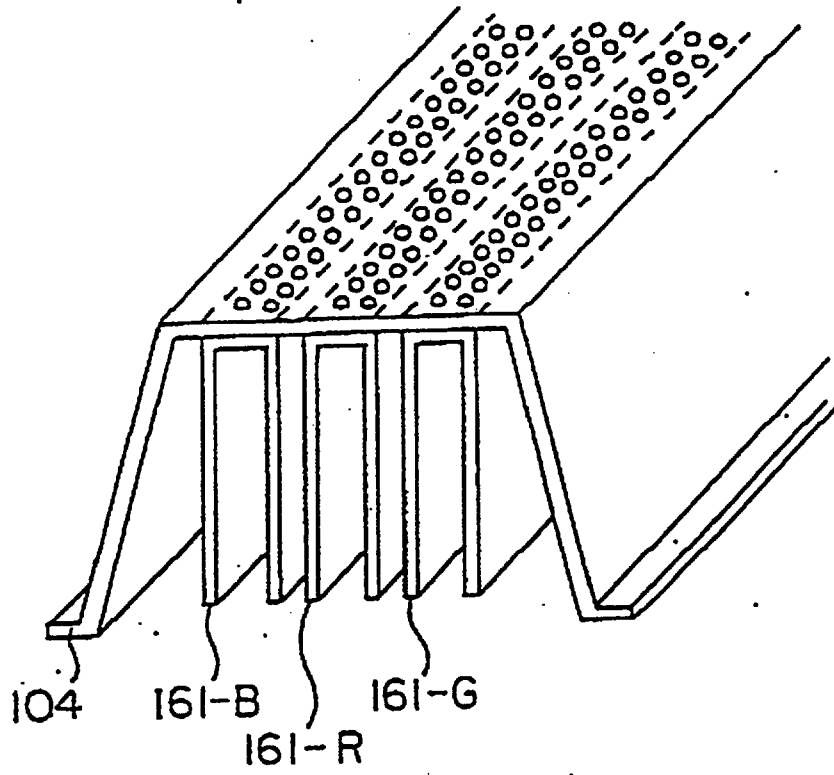
This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

9/12

FIG. 12

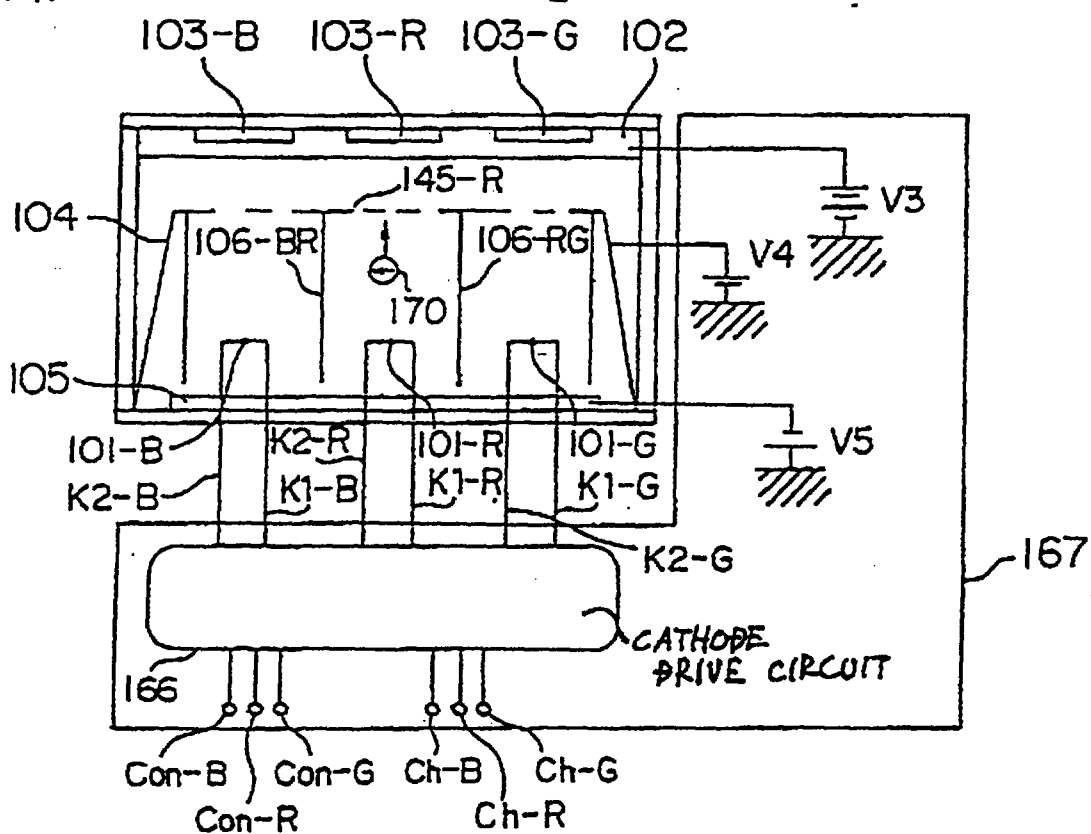


This Sheet Has Been Replaced



$$\frac{10}{12}$$

FIG. 13



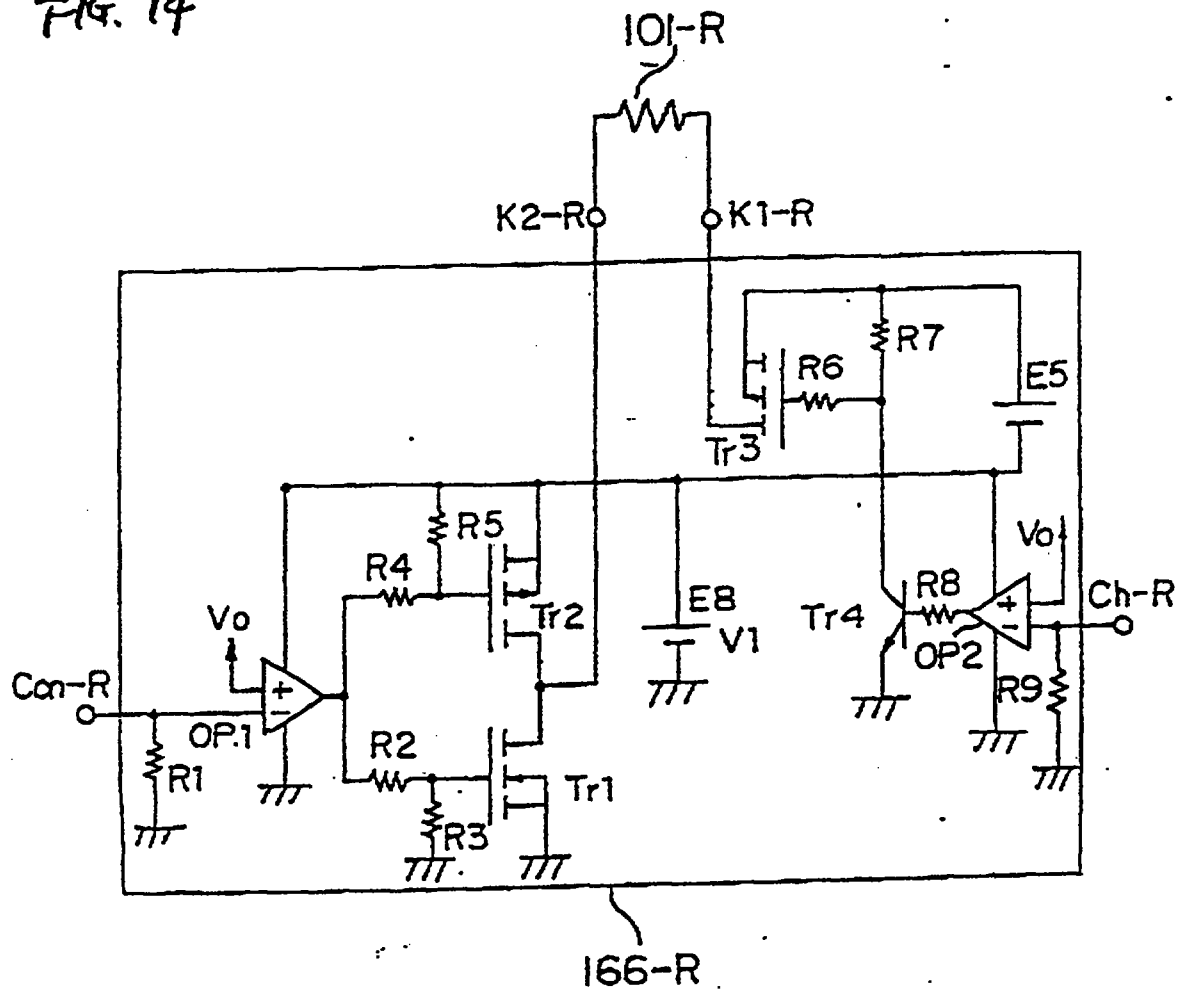
This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

11/12

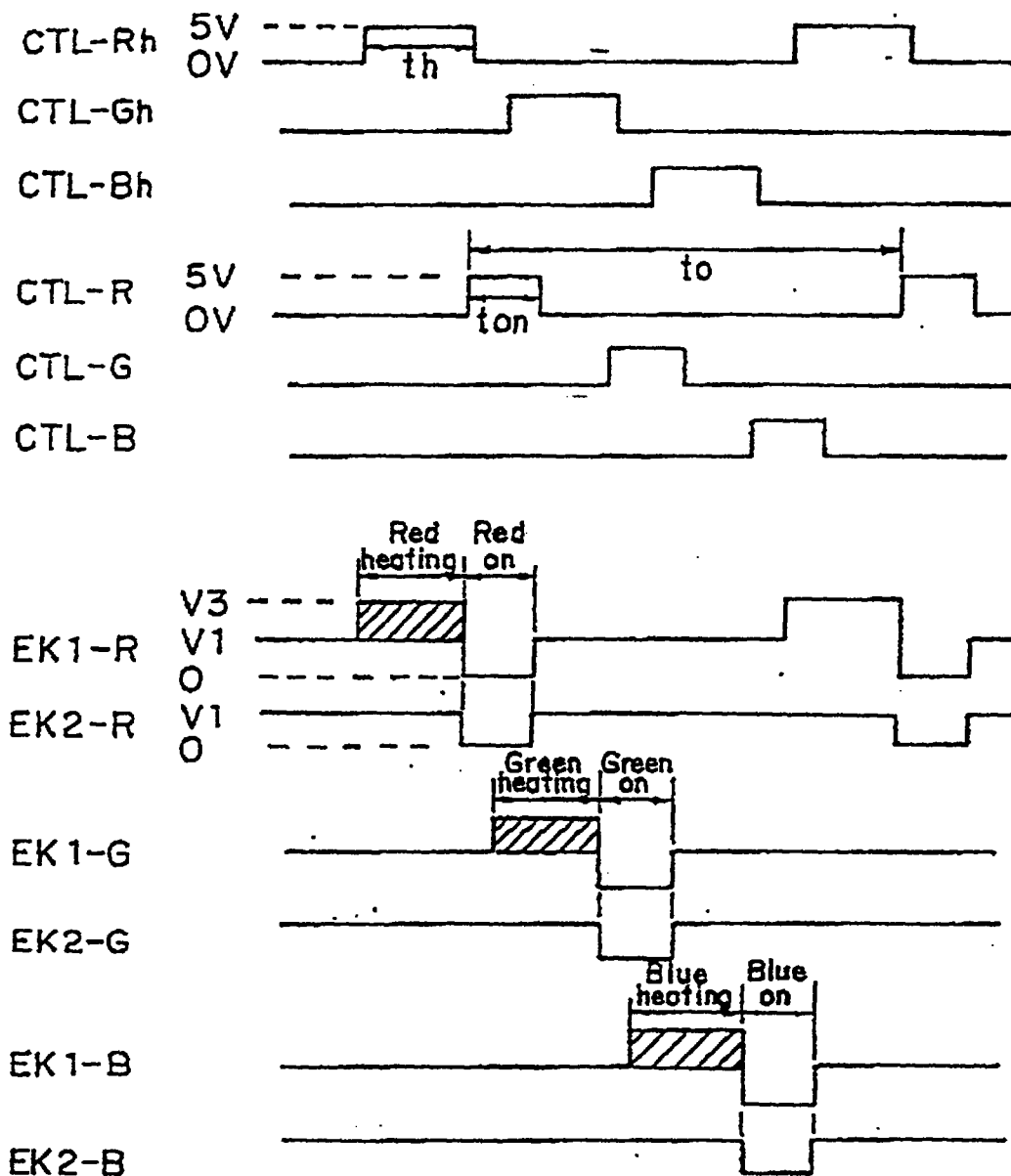
FIG. 19



This Sheet Has Been Replaced



FIG. 15



22 APR

960447B-9
IP05 COPY

REPLACEMENT SHEET

22 APR 1996

THIS SHEET HAS BEEN
REPLACED

**METHOD OF AND CIRCUIT FOR DRIVING
CATHODELUMINESCENCE TYPE LIGHTING DEVICE**

The present invention relates to a method of and an apparatus for driving lighting devices utilizing cathodeluminescence.

In lieu of conventional light sources such as fluorescent lamps and line halogen lamps used as a line light source in an image input apparatus or the like, a light source utilizing cathodeluminescence, such as disclosed in Japanese Patent Unexamined Publication No. 73970/1981, has been proposed as a light source having low power consumption.

Figure 1 is a sectional view of a conventional cathodeluminescence type light source. The construction of the conventional light source will be described with reference to Figure 1.

Reference numeral 10 designates a glass tube that is evacuated to a predetermined degree of vacuum. Along the length of the glass tube 10 extends a cathode 12. Reference

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

numeral 14 designates a glass substrate, a front surface of which is coated with a phosphor 16. An anode 18 is deposited on the phosphor 16. The anode 18 is made of an aluminum thin film that serves as a metal backing. A grid 20, which is a control electrode, is interposed between the cathode 12 and the anode 18, and is made of a metal plate having slits 11 of a length of about 0.3 to 1 mm. Commonly used as the phosphor materials are those including zinc sulfide (ZnS) as a base material, such as ZnS with copper (Cu) and aluminum (Al). The light-emitting efficiency of these phosphor materials is high.

A high voltage of about 8 kV is applied to the anode 18 of the light-emitting tube by an ordinary power supply E2, whereas a voltage V4 on the order of several volts is applied to the grid 20 by a power supply E4.

A driving method will be described next. Japanese Patent Unexamined Publication No. 3740/1978 discloses a method of driving the cathodeluminescence type light source. Figure 2 is a timing chart for driving such light source. CTLon designates a lighting signal input to a cathode drive circuit (not shown). Cathode drive signals Ek1 and Ek2, which are output signals generated from the cathode drive circuit, are applied to the terminals K1 and K2 of the cathode 12 of the light-emitting tube shown in Figure 1. The generation of the lighting signal CTLon is repeated with a cycle time t_0 based on a turning-off period t_{off} and a lighting period t_{on} .



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

During the turning-off period t_{off} , the voltages of the cathode drive signals E_{k1} and E_{k2} are V_2 and V_1 , respectively. The voltages V_2 and V_1 are higher than the voltage V_4 applied to the grid 20. When the voltages V_2 and V_1 are applied to the terminals K_1 and K_2 of the cathode 12, a difference in voltage $\Delta V = V_2 - V_1$ is supplied to the cathode 12 to cause the surface of the cathode to easily release thermoelectrons 24 (described later) by Joule heating.

However, since the voltages V_2 and V_1 applied to the terminals K_1 and K_2 of the cathode 12 are higher than the voltage V_4 applied to the grid 20, there is no emission of thermoelectrons 24 from the cathode 12.

During the lighting period t_{on} , the voltages of the cathode drive signals E_{k1} and E_{k2} both are 0 V. Since the voltage of the cathode 12 is lower than the voltage V_4 applied to the grid 20, the cathode 12 is heated by remaining heat, releasing thermoelectrons 24.

The thermoelectrons 24 pass through the slits 11 of the grid 20 and collide against the anode 18, to which the high voltage is applied. The thermoelectrons 24, having passed through the anode 18 formed of a thin film, collide against the phosphor 16, causing cathodeluminescence to occur.

The rate at which thermoelectrons are emitted from the surface of the cathode 12 depends on the surface temperature of the cathode 12. When a thermoelectron emitting substance



22 APR 1996

called an emitter material (not shown) is coated on the surface of the cathode 12, thermoelectrons are usually emitted therefrom at an adequate rate at surface temperatures of 500 to 700°. However, if the temperature is too high, evaporation of the emitter material is promoted, reducing the rate of emission of thermoelectrons. As a result, the amount of light emitted from the light source is impaired drastically. On the other hand, if the temperature is too low, the emission of thermoelectrons is not sufficient. To overcome this problem, three points, namely, the conduction voltage, the cathode resistance, and the conduction duty cycle at the time of operation (i.e., the ratio of the off period t_{off} to the lighting cycle t_0 in Figure 2) relevant to heating the cathode must be properly selected before driving the cathode.

However, in a lighting device used for an image input apparatus or the like, the integrated value of an amount of light stored in a CCD of a photoelectric transducer of the apparatus be made adjustable by making the lighting period t_{on} of the lighting device variable to increase the accuracy of the output signal from the CCD. However, if the lighting period t_{on} is varied in the conventional drive circuit, the off period t_{off} must also be varied (assuming the lighting cycle time t_0 is fixed). That is, the conduction duty cycle must be varied, which puts the surface temperature of the cathode 12 out of proper range, thus shortening the life of the light-



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

emitting tube.

The invention has been made in view of such problems. Accordingly, an object of the present invention is to provide a method and apparatus for driving a cathodeluminescence type lighting device that can adjust the lighting period variably and maintain a long life of the lighting device. This object is solved by the method of independent claim 1 and the apparatus of independent claim 4. Further advantageous features, aspects and details of the invention are evident from the dependent claims, the description and the drawings. The claims are intended to be understood as a first non-limiting approach of defining the invention in general terms.

The invention provides a method of and a circuit for driving a lighting device suitable for use as a light source for an image input apparatus such as an image scanner, a digital copying machine, or a facsimile machine, or as a large display such as an outdoor television-type display.

A driving method provided by a specific aspect of the invention repeats, at a predetermined lighting cycle, the steps of: heating a cathode of the lighting device by electric conduction to the cathode; emitting light by causing the cathode to release electrons without conduction to the cathode; and reposing without causing the cathode to release electrons with no conduction to the cathode. At least the period of the light-emitting step and the period of the reposing step are variable.

According to a further specific aspect of the invention, a driving circuit is provided which includes: a first control



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

section for controlling a potential of a first terminal of the cathode; and a second control section for controlling a potential of a second terminal of the cathode. The first control section and the second control section operate during a lighting period, a heating period, and a dummy period. The lighting period, the heating period, and the dummy period are repeated at a predetermined lighting cycle and are successively generated. The first control section



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

controls the potential of the first terminal to a potential lower than a potential of the control grid during the lighting period, and controls the potential of the first terminal to a potential higher than the potential of the control grid during the periods other than the lighting period. The second control section controls the potential of the second terminal to a potential higher than the potential of the control grid and different from the potential of the first terminal during the heating period, and controls the potential of the second terminal to a potential equal to the potential of the first terminal during the periods other than the heating period.

According to a specific aspect, the invention is characterized as having the heating period, the lighting period, and the reposing period in a single lighting cycle. When the lighting period is adjusted variably, the heating period can be maintained constant by varying the reposing period in accordance with the adjustment of the lighting period. Therefore, even if the lighting period is adjusted, the temperature of the cathode can be maintained within a proper range, thereby contributing to extending the service life of the light-emitting tube.

Figure 1 is a sectional view showing the construction of a conventional light source utilizing cathodeluminescence;

Figure 2 is a timing chart of a cathode drive circuit in

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

the conventional light source;

Figure 3 is a perspective view showing an example of a light-emitting tube to which a drive circuit of the invention is applied;

Figure 4 is a diagram showing in block form an exemplary drive circuit of the invention for the light-emitting tube shown in Figure 3, together with a schematic sectional view of the light-emitting tube;

Figure 5 is a timing chart illustrating the operation of a cathode drive circuit within the drive circuit of Figure 4;

Figure 6 is a circuit diagram showing an example of the cathode drive circuit performing the operation of Figure 5;

Figure 7 is a circuit diagram showing another example of the cathode drive circuit within the drive circuit of Figure 4;

Figure 8 is a timing chart illustrating the operation of the cathode drive circuit of Figure 7;

Figure 9 is a perspective view showing a light-emitting tube 110 of a lighting device for a color image input apparatus to which a drive circuit of the invention is applied;

Figure 10 is a sectional view taken along a line A-A' of Figure 9;

Figure 11 is a partially enlarged view showing a grid electrode 104 and separators 106-BB, 106-BR, 106-RC, and 106-GC in Figure 9;

Figure 12 is a partially enlarged view showing the grid



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

electrode 104 and inverted C-shaped separators 161-B, 161-R, and 161-G, which can be applied to the light-emitting tube of Figure 9;

Figure 13 is a diagram showing in block form an example of a drive circuit of the invention for the light-emitting tube 110 together with a partial sectional view of the light-emitting tube 110;

Figure 14 is a circuit diagram of a red light-emitting circuit 166-R within the cathode drive circuit 166 of Figure 13; and

Figure 15 is a timing chart illustrative of an operation of the cathode drive circuit 166.

Preferred embodiments of the invention will hereunder be described in detail with reference to the drawings.

Figure 3 is a perspective view showing an example of a cathodeluminescence type lighting tube to which a drive circuit of the invention is applied. A phosphor 16 for cathodeluminescence is coated on the inner surface of a front plate 28 of the light-emitting tube 26 in quantities of 0.1 to 100 mg/cm², most preferably 4 mg/cm², along the length of the light-emitting tube 26. The phosphor 16 is covered with an anode 30 made from aluminum, the anode being formed by vacuum



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

evaporation in thicknesses of 0.1 to 0.4 μm .

A back electrode 34 extends on the inner surface of a back plate 32 of the light-emitting tube 26 along the length of the back plate 32. The back electrode 34 is made from aluminum by vacuum evaporation or the like. Immediately above the back electrode 34 is a wire-like cathode 36. The cathode 36 is a tungsten thin wire 50 to 100 μm in diameter. An emitter material (not shown) is coated on the surface of the cathode 36. A grid 40 made of a metal plate that has a plurality of apertures 42 formed by blanking, electroforming or the like, is arranged at such a position as to shield the anode 30 from the cathode 36. The anode 30, the grid 40, the cathode 36, and the back electrode 34 are electrically driven to conduct by a drive circuit 44 (described later) via a terminal that extends externally from the light-emitting tube. Reference numeral 46 designates an evacuating tube that evacuates the light-emitting tube to a pressure of about 100 to 0.1 mPa. The light-emitting tube is thereafter sealed by melting the evacuating tube 46 by heating with a gas burner.

Figure 4 shows in block form an example of a drive circuit of the invention for the light-emitting tube 26 shown in Figure 3, together with a schematic sectional view of the light-emitting tube 26.

The drive circuit 44 includes three dc constant voltage power supplies E2 to E4 and a cathode drive circuit 48 for



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

lighting control.

A high voltage on the order of 8 kV is applied to the anode 30 by the power supply E2. A voltage V4 on the order of several volts is applied to the grid 40 by the power supply E4. An appropriate voltage is applied to the back electrode 34 by the power supply E3. Such voltages are applied to maximize the amount of thermoelectrons emitted by the cathode 36. Both terminals K1 and K2 of the cathode 36 are connected to the cathode drive circuit 48.

Figure 5 is a timing chart illustrating the operation of the cathode drive circuit 48. CTLon and CTLh designate signals input to a lighting signal input terminal Con and a heating signal input terminal Ch, respectively. Reference characters Ek1 and Ek2 designate drive voltage signals supplied to the terminals K1 and K2, respectively.

During a period t_h (heating period), the cathode drive voltage signal Ek1 is a predetermined voltage V3 (e.g., 23 V), and the other cathode drive voltage signal Ek2 is a predetermined voltage V1 (e.g., 8 V). Then, a difference in voltage $\Delta V = V3 - V1$ is produced between the terminals K1 and K2 of the cathode 36, enabling the surface of the cathode 36 to easily emit thermoelectrons 24 by Joule heating.

However, since the voltages V3 and V1 respectively applied to the terminals K1 and K2 of the cathode 36 are higher than the potential V4 applied to the grid 40, no thermoelectrons 24



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

are emitted from the cathode 36.

Then, during a period t_m (lighting period), which is between the moment at which the lighting signal CTLon rises from 0 V to 5 V and the moment at which the lighting signal CTLon drops to 0 V again, both cathode drive voltage signals Ek1 and Ek2 are 0 V, which makes the voltage at the cathode 36 lower than the applied voltage V4. As a result, the thermoelectrons 24 are released from the cathode 36 heated by the remaining heat. The thermoelectrons 24 pass through the apertures 42 of the grid 40 and collide against the anode 30 to which a high voltage has been applied. Further, the thermoelectrons 24 having passed through the anode 30 made of a thin film then collide against the phosphor 16 to produce cathodeluminescence.

Lastly, during a period t_d (dummy period), the lighting signal CTLon and the heating signal CTLh are both at 0 V. As a result, the voltage of both cathode drive signals Ek1 and Ek2 is V1. Since there is no difference in voltage between both terminals of the cathode 36, the cathode 36 is not heated in a manner similar to the lighting period t_m . Further, since the voltage V1 applied to the terminals K1 and K2 of the cathode 36 is higher than the voltage V4 applied to the grid 40, no thermoelectrons 24 are emitted from the cathode 36.

In this timing chart, to variably adjust the lighting period t_m , the cycle time t_c and the heating period t_h are



22 APR 1996

fixed, whereas the lighting period t_{on} is varied within the range of $t_0 - t_1$. Accordingly, only the luminous duty cycle can be varied with the heating duty cycle maintained constant.

Figure 6 shows an exemplary circuit of the cathode drive circuit 48 shown in Figure 5.

This cathode drive circuit 48 has two operational amplifiers OP1 and OP2, to which the dc voltage V1 is applied by a power supply E8 as a supply voltage. A threshold voltage V0 (e.g., 1.5 V) is applied to both inverting input terminals (-).

One of the operational amplifiers OP1 has a non-inverting input terminal (+) connected to the signal input terminal Con so that the lighting signal CTLon can be received thereby, and the output terminal thereof is connected to the control gates of two complementary transistors Tr1 and Tr2 through a set of dividing resistors R2 and R3 and through a set of dividing resistors R5 and R4, respectively. The output terminals of the complementary transistors Tr1 and Tr2 are connected to the cathode terminal K2.

The other operational amplifier OP2 has a non-inverting input terminal (+) connected to the signal input terminal Ch so that the heating signal CTLh can be received thereby, and the output terminal thereof connected to the base of a switching transistor Tr4 through a resistor R8. The emitter of the switching transistor Tr4 is grounded, and the collector thereof



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

is connected to the control gate of the transistor Tr3 through a resistor R6. The voltage V3 which is a voltage combination of the voltage V1 of the power supply E8 with a voltage of the power supply E5 is applied to the control gate of the transistor Tr3 through a resistor R7. The voltage V3 is also applied to the source of the transistor Tr3. The drain of the transistor Tr3 is connected to the other cathode terminal K1.

The operation of the circuit will be described below. An operation during the heating period t_h will be described first.

When the heating signal CTLh has risen to 5 V from 0 V, the output voltage of the operational amplifier OP2 rises to V1 from 0 V, which causes the transistor Tr4 to turn on and the potential of a node of the resistors R7 and R6 to become almost 0 V. Then, since the transistor Tr3 turns on, the voltage V3 is applied to the terminal K1 of the cathode 36.

During this heating period t_h , the output voltage of the operational amplifier OP1 is 0 V. As a result, the transistor Tr1 turns off, whereas the transistor Tr2 turns on, which causes the power supply E8 to apply the voltage V1 to the terminal K2 of the cathode 36.

As the voltages V3 and V1 are then applied to the terminals K1 and K2 of the cathode 36, the cathode 36 is heated with current passing therethrough.

The operation of the circuit during the lighting period t_m



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

will be described next.

When the lighting signal $CTLon$ has risen to 5 V from 0 V, the output voltage of the operational amplifier OP1 becomes V_1 . Since this causes the transistor Tr1 to turn on and the transistor Tr2 to turn off, the voltage at the terminal K2 of the cathode 36 is almost 0 V.

Since the heating signal $CTLh$ is at 0 V in this instance, the output voltage of the operational amplifier OP2 is 0 V, leaving the transistor Tr4 turned off. As a result, the transistor Tr3 is turned off, which opens the current loop flowing through the cathode 36. Consequently, the terminal K1 of the cathode 36 is at 0 V, which is equal to the potential at the terminal K2.

The operation of the circuit during the dummy period (t_d) will be described.

When the lighting signal $CTLon$ has dropped to 0 V from 5 V, the output voltage of the operational amplifier OP1 drops to 0 V. Then, the transistor Tr1 is turned off, and the transistor Tr2 turns on, causing the voltage at the terminal K2 of the cathode 36 to become the voltage V_1 of the power supply E8.

Since the heating signal $CTLh$ is at 0 V at this time, similar to the lighting period t_{on} , the current loop flowing through the cathode 36 is open. As a result, the potential at the terminal K1 of the cathode 36 is V_1 , which is equal to the



22 APR 1996

potential at the terminal K2.

In the drive circuit shown in Figures 5 and 6, the heating duty cycle of the cathode 36 is t_h/t_0 . Thus, if the lighting cycle t_0 and the heating period t_h are kept constant at all times, then the heating duty cycle is constant, thereby keeping the surface temperature of the cathode within a predetermined range. The lighting period t_m can be variably adjusted independently of the heating period t_h by using the dummy period t_d .

The variable range of the lighting period t_m is between 0 and $t_0 - t_h$. Therefore, the variable range of the lighting period t_m can be increased by increasing the voltage V3 of the cathode drive signal Ek1 during the heating period t_h shown in Figure 3 as much as possible, so that the heating duty cycle can be decreased, i.e., the period t_h can be shortened as much as the voltage V3 is increased.

Figure 7 shows another exemplary circuit that can be used as the cathode drive circuit 48 of Figure 4, and Figure 8 is a timing chart showing an operation thereof.

The circuit shown in Figure 7 is advantageous in that the construction thereof is simpler than the circuit shown in Figure 6.

Further, the operation shown in Figure 8 has a feature that the lighting period t_m comes first and that the heating period t_h starts in response to the end of the lighting period



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

t_m . More specifically, the lighting signal CTLon is generated at an independent timing, whereas the heating signal CTLh is generated at a timing dependent on the lighting signal CTLon. One of the advantages in this system is that when the lighting device is used as a light source of an image input apparatus, the image reading period can be easily synchronized with the lighting period. The reason is that the lighting signal CTLon can be generated in direct synchronism with a pulse signal that is generated by the image input apparatus and synchronized with the reading period. In contrast thereto, in the operation shown in Figure 5, the lighting signal CTLon is generated at a timing dependent on the heating signal CTLh causing the lighting signal CTLon to rise upon dropping of the heating signal CTLh. Therefore, the lighting signal CTLon cannot be generated in direct synchronism with the pulse signal from the image input apparatus.

The circuit illustrated in Figure 7 will be described below.

A transistor Tr11 receives the lighting signal CTLon on the base thereof through a resistor R11. The emitter thereof is grounded, and the collector thereof is connected to a dc constant voltage supply (e.g., $24\text{ V} \pm 10\%$) through a resistor R12 and to the base of a transistor Tr12. The transistor Tr12 is connected to the above-mentioned dc constant voltage supply; the emitter thereof is connected to the terminal K2 of the



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

cathode and grounded through a resistor R13. Between the base of the transistor Tr12 and ground is connected a zener diode ZD1 whose zener voltage is, e.g., 25.8 V and whose function is to clamp variations in the dc voltage supply on the high side of the nominal voltage.

A transistor Tr13 receives the heating signal CTLh on the base thereof through a resistor R14. The emitter thereof is grounded, and the collector is connected to the base of a transistor Tr14 through a zener diode ZD2 whose zener voltage is, e.g., 7.4 V and which is connected in the forward direction. The transistor Tr14 has a resistor R15 interposed between the emitter and the base thereof, with the emitter connected to the terminal K1 of the cathode and the collector grounded.

The operation of the circuit will be described with reference to Figures 7 and 8.

As shown in Figure 8, upon initiation of the lighting cycle t_0 , the lighting signal CTLon rises to 5 V from 0 V and drops to 0 V after a predetermined lighting period t_{on} . In response to the drop of the lighting signal CTLon, the heating signal CTLh rises to 5 V from 0 V and drops to 0 V after a predetermined heating period t_h .

Referring to Figure 7, upon rising of the lighting signal CTLon at the start of the lighting period t_{on} , the transistor Tr11 turns on and the transistor Tr12 turns off. As a result,



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

the terminal K2 of the cathode 36 is grounded to be at 0 V, as shown in Figure 8.

Since the heating signal CTLh is at 0 V at this time, the transistor Tr13 is turned off, which means that the transistor Tr14 is turned off as well. Therefore, the current loop flowing through the cathode 36 is open. As a result, the potential at the cathode terminal K1 becomes 0 V, which is equal to the potential at the other terminal K2.

In this way, the voltage of each of the terminals K1 and K2 of the cathode 36 is 0 V, that is, lower than the grid voltage V4 during the lighting period t_{on} , so that electrons are emitted from the already-heated cathode 36 and collide against the phosphor of the anode after being accelerated by the grid. As a result, the emission of light starts.

At the end of the lighting period t_{on} , the lighting signal CTLon drops, and simultaneously therewith the heating signal CTLh rises. When the lighting signal CTLon drops, the transistor Tr11 turns off, which causes the transistor Tr12 to turn on. As a result, the potential of the cathode terminal K2 connected to the emitter of the transistor Tr12 becomes almost 23 V (V3), which is obtained by subtracting the voltage drop of the transistor Tr12 from the power supply voltage (24 V).

Further, since the transistor Tr13 turns on and the transistor Tr14 turns on at the rising of the heating signal CTLh, the potential of the cathode terminal K1 becomes almost



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

8 V (V1), which is obtained by adding a base-emitter voltage of the transistor Tr13 to the zener voltage 7.4 V.

In this way, the voltage of one terminal K2 of the cathode 36 is 23 V (V3) and that of the other terminal K1 is 8 V (V1) during the heating period t_h , which causes current to flow through the cathode 36 to heat the cathode 36. However, since the potential V3 of the cathode 36 is higher than the potential V4 of the grid, no electrons are emitted.

At the end of the heating period t_h , the heating signal CTLh drops. As a result, both transistors Tr13 and Tr14 turn off, which in turn opens the current loop passing through the cathode 36. Since the voltage of the cathode terminal K2 is 23 V (V3) at this time, which is equal to that during the heating period, the voltage of the terminal K1 becomes 23 V (V3) as well. Therefore, no current flows through the cathode 36, which means that the cathode 36 is not heated. In addition, since the potential V3 of the cathode 36 is higher than the potential V4 at the grid, there is no emission of light.

The above describes the embodiments applied to the lighting device shown in Figure 3 for the emission of light of a single color.

Embodiments of the invention to be applied to a lighting device for the emission of light of three colors, which can be used for a color image input apparatus, will be described next.

Figure 9 is a perspective view of an example of a light-

This Sheet Has Been Replaced



22 APR 1996

emitting tube 110 used as a lighting device for a color image input apparatus to which the invention can be applied.

Figure 10 is a sectional view taken along a line A-A' in Figure 9, and Figure 11 is a partially enlarged view showing a grid electrode 104 and separators 106-BB, 106-BR, 106-RG, and 106-GG in Figure 9.

The construction of the light-emitting tube 110 will be described below. Red, green, and blue cathodes 101-R, 101-G, and 101-B extend between the grid electrode 104 and a back electrode 105 (both described later) while being supported by cathode support members 108-R, 108-G, and 108-B on both ends thereof, respectively. The cathodes 101-R, 101-G, and 101-B are thin tungsten wires 10 to 50 μ m in diameter. The surface of each cathode is coated with an electron emitting substance (not shown) such as barium oxide or the like. The function of the coating is to improve electron emitting efficiency.

The grid electrode 104 is located between the cathodes 101-R, 101-G, 101-B and an anode 102 by bending a plate in trapezoidal form, the plate being electrically conductive such as stainless steel, brass, or aluminum, as well as nonmagnetic. As shown in Figure 10, the grid electrode 104 is fixed by clamping with glass side plates 171, 172 and a bottom plate 173. As shown in Figure 11, the grid electrode 104 has four separators 106-BB, 106-BR, 106-RG, 106-GG for partitioning the cathodes. The separators are fixed at a plurality of fixing



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

points 160. These separators are electrically conductive with the grid electrode 104. Further, on a side of the grid electrode 104 which is opposite to the anode are a plurality of net-like or slit-shaped apertures 145-R, 145-G, 145-B for allowing electrons to pass therethrough, the electrons being generated by the cathodes 101-R, 101-G, 101-B.

Each separator 106 flexes between the fixing points 160 when thermally expanded by heat radiated from the cathode. This causes an inconsistent amount of light. It is desirable to increase the number of fixing points 160 to suppress the flexing as much as possible. Further, it is desirable to bend the upper edge part, the lower edge part, or both of each separator 106 in L form so that the separator 106 becomes hard to flex. Otherwise, as shown in Figure 12, inverted C-shaped separators 161-B, 161-R, and 161-G may be used.

The back electrode 105 is formed between the cathodes 101-R, 101-G, and 101-B and the glass bottom plate 173. The back electrode 105 is made of carbon paste.

Phosphors of three kinds, namely, a green-emitting phosphor 103-G, a red-emitting phosphor 103-R, and a blue-emitting phosphor 103-B, are sequentially coated on the inner surface of a transparent glass plate 107 by means of screen printing or the like. The phosphors used here are those capable of emitting light by cathodeluminescence, such as yttrium oxysulfide (Y_2O_3S) with europium (Eu) or samarium (Sm)



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

as the red-emitting phosphor, zinc sulfide (ZnS) with copper (Cu) and aluminum (Al) as the green-emitting phosphor, zinc sulfide (ZnS) with silver (Ag) and chlorine (Cl) as the blue-emitting phosphor, and the like.

The anode 102 is formed by depositing a 1 to 10 μm thick layer of aluminum on the inner surface of the phosphor-coated transparent glass plate 107 by means of vacuum evaporation or the like.

Lastly, the surfaces of the glass parts in contact and the interface of the leads externally extending from the light-emitting tube 110 from each electrode are closed with low-melting point glass or the like, put in a high-temperature vessel at 500 to 600° to be fused so that a container 177 including the transparent plate 107, the glass plates 171, 172, 173, 174, and 175 shown in Figure 9 is formed. Then, when the container 177 is evacuated to a range of 100 to 0.1 mPa by an evacuating tube 176, the container 177 is sealed to maintain the evacuated condition therewithin.

The three-color light-emitting tube 110, when used as a light source for a color image input apparatus, injects light in three colors to a single direction from a substantially single light source. As a result, even if an original having steps or irregularities on the surface is input, excellent color reproduction free from color mismatching can be obtained.

Figure 13 shows in block form a drive circuit of the



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

invention for independently producing emissions of light from the phosphors 103-R, 103-G, and 103-B for the respective colors of such light-emitting tube 110.

A drive circuit 167 shown in Figure 13 includes three dc constant voltage power supplies and a cathode drive circuit 166. The respective cathodes 101-R, 101-G, and 101-B are connected to the cathode drive circuit 166 at both terminals K1-R, K2-R, K1-G, K2-G, K1-B, and K2-B.

Figure 14 is a circuit diagram of the cathode drive circuit 166. A circuit 166-R in Figure 14 drives the cathode 101-R for the red color. Two other circuits (of the same construction) are arranged in parallel to drive the cathode 101-G for the green color and the cathode 101-B for the blue color. The three cathodes 101-R, 101-G, and 101-B are driven independently by these three circuits.

The circuit shown in Figure 14 is the same as the cathode drive circuit 48 for the single color light-emitting tube shown in Figure 6. A lighting signal input terminal Con-R and a heating signal input terminal Ch-R receive a lighting signal CTL-R and a heating signal CTL-Rh for red (see Figure 15), respectively. The cathode terminals K1-R and K2-R are connected to the cathode 101-R for red.

Figure 15 is a timing chart showing the operation of the cathode drive circuit 166.

As shown in Figure 15, the drive signals CTL-Rh, CTL-R for



22 APR 1996

the red color, the drive signals CTL-Gh, CTL-G for the green color, and the drive signals CTL-Bh, CTL-B for the blue color are generated 120° out of phase with one another. The operation of each color is the same as the operation shown in Figure 5.

The three-color light-emitting tube can, of course, be driven by the three circuits, the construction of each of which is the same as that shown in Figure 7. In such a case, the operation shown in Figure 8 is performed per color. The operations of the three colors are 120° out of phase with one another.

While the preferred embodiments of the invention have been described above, the invention is not limited to them, but may be embodied in various other modes.

As described in the foregoing, the invention according to a specific aspect is characterized as arranging a dummy period in which no heating or lighting is effected during a lighting cycle and making the dummy period and the lighting period variable. Therefore, even if the lighting period is variably adjusted, the heating duty cycle can be maintained constant, thereby allowing the life of the lighting device to be increased.

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

This Sheet Has Been Replaced



CLAIMS

1. A method of driving a cathodeluminescence type lighting device, comprising the steps of:

heating a cathode of said cathodeluminescence type lighting device by electric conduction;

emitting light by causing the cathode to release electrons absent conduction to the cathode once said cathode is heated; and

reposing said cathode during a period when said cathode is not heated and said release of said electrons is terminated;

wherein said heating, light-emitting, said reposing steps are repeated at predetermined lighting cycles, and

at least a period of said light-emitting step and a period of said reposing step are variable.

2. The method according to claim 1, wherein a ratio of a period of said heating step to the lighting cycle is maintained constant.

3. The method according to claim 1 or 2, further comprising the step of controlling timings of said heating step, said light-emitting step, and said reposing step, said step of controlling timings determining a timing of said light-emitting step independently of the timings of said heating step and of said reposing step and the timings of said heating step and of said reposing step dependent on the timing of said light-emitting step.



* C L M S *

22 APR 1996

This Sheet Has Been Replaced



4. An apparatus, especially for carrying out the method of any one of the preceding claims, for driving a cathodeluminescence type lighting device (26;110) having a control grid (40;104) arranged between a cathode (36;101) and an anode (30;102), said apparatus comprising:

a first control section for controlling a potential of a first terminal of said cathode (36;101) and

a second control section for controlling a potential of a second terminal of said cathode (36;101);

said first control section and said second control section operating during a lighting period (t_{on}), a heating period (t_h), and a dummy period (t_d), respectively, wherein said lighting period, said heating period, and said dummy period are repeated at predetermined lighting cycles and are successively generated;

said first control section controlling the potential of the first terminal to a potential lower than a potential of said control grid (40;104) during said lighting period, and controlling the potential of the first terminal to a potential higher than the potential of said control grid (40;104) during periods other than said lighting period; and

said second control section controlling the potential of the second terminal to a potential higher than the potential of said control grid (40;104) and different from the potential of the first terminal during said heating period, and controlling the potential of the





22 APR 1996

second terminal to a potential equal to the potential of the first terminal during periods other than said heating period.

5
10 5. The apparatus according to claim 4, wherein said second control section opens a current loop passing through said cathode (36;101) during periods other than said heating period so that the potential of the second terminal becomes equal to the potential of the first terminal.

15 6. The apparatus according to claim 4 or 5, wherein said second control section controls the potential of the second terminal to a potential higher than the potential of the first terminal during said heating period (t_h).

20 7. The apparatus according to any one of claims 4 to 6, wherein said second control section controls the potential of the second terminal to a potential lower than the potential of the first terminal during said heating period (t_h).

25 8. The apparatus according to any one of claims 4 to 7, wherein

30 said first control section operates in response to a lighting signal indicating said lighting period;

said second control section operates in response to a heating signal indicating said heating period;

35 said apparatus further comprising:



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

4

5 a signal generating section for generating said lighting
signal and said heating signal, said signal generating
section determining a timing for generating said lighting
signal independently of said heating signal and a timing
for generating said heating signal dependent on said
lighting signal.

10

This Sheet Has Been Replaced



* C L M S *

THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

7

ABSTRACT

5 A lighting device emits light by releasing electrons to an anode from a Joule-heated cathode and causes the electrons to collide against a phosphor on the anode side. A method of driving the lighting device repeats, at a predetermined lighting cycle, a heating period (t_h) in which the cathode is heated by conduction, a lighting period (t_{on}) in which the cathode is caused only to release electrons without conduction so that light is emitted, and a dummy period (t_d) in which no conduction or emission of light occurs at the cathode. To variably adjust the lighting period (t_{on}), adjustments are absorbed by the dummy period (t_d) to maintain the heating period (t_h) constant at all times. With respect to the timing control of each period, the lighting period (t_{on}) is controlled at a timing independent of the heating period (t_h), whereas the heating period (t_h) is controlled at a timing dependent on the lighting period (t_{on}). This is preferred to facilitate the timing control of the lighting period (t_{on}).

15

This Sheet Has Been Replaced



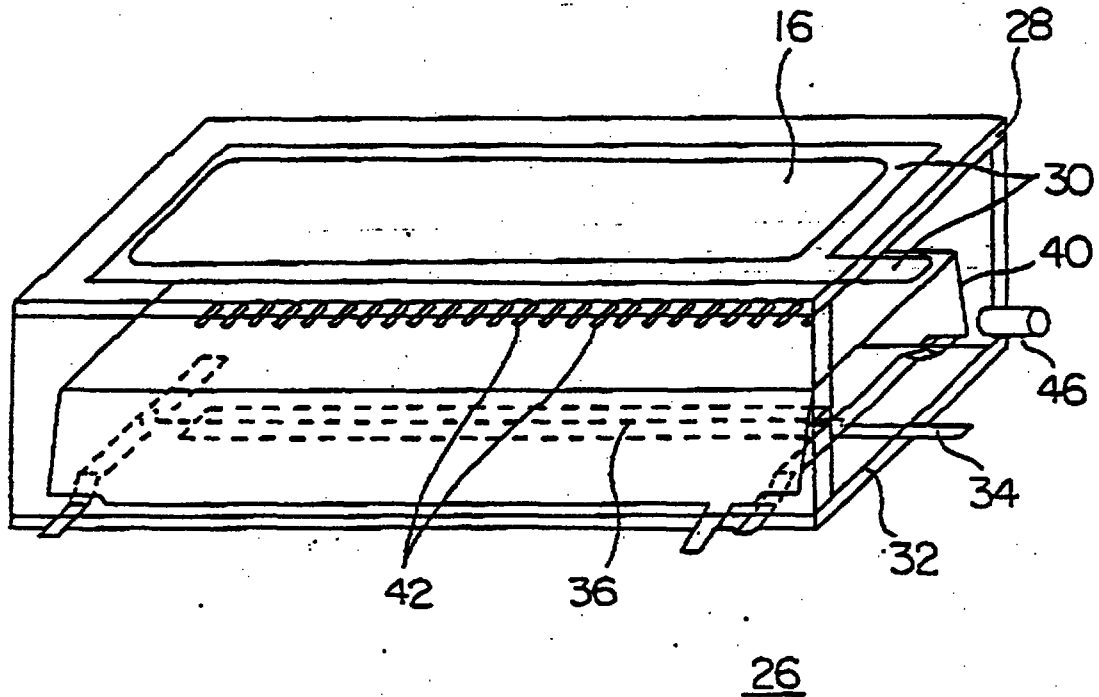
THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

2/12

FIG. 3



This Sheet Has Been Replaced



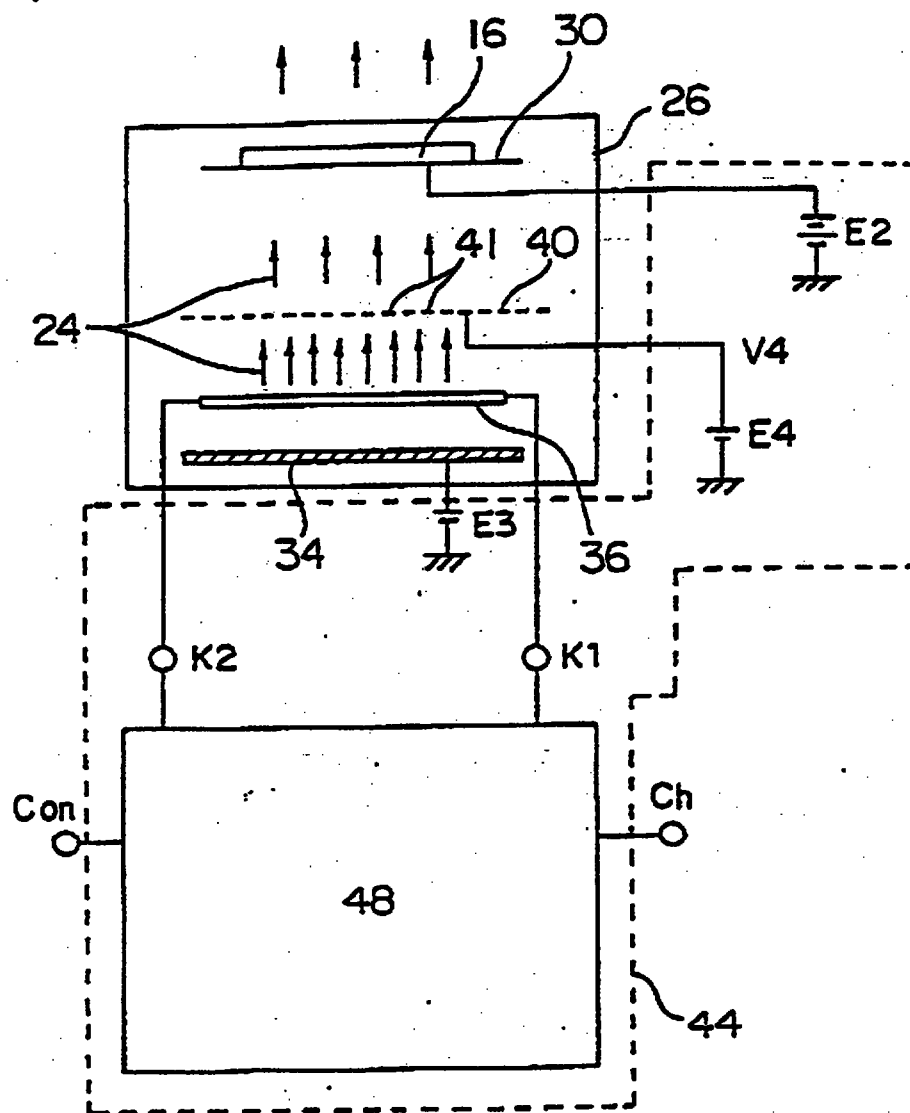
THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

3/12

FIG. 4



This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

4/12

FIG. 5

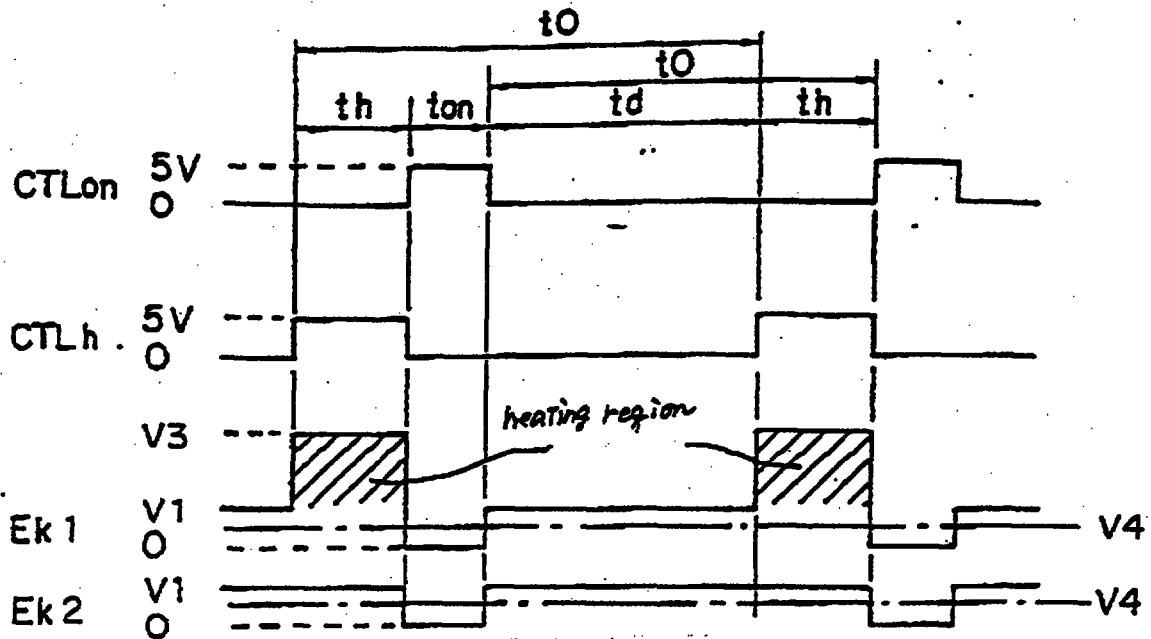
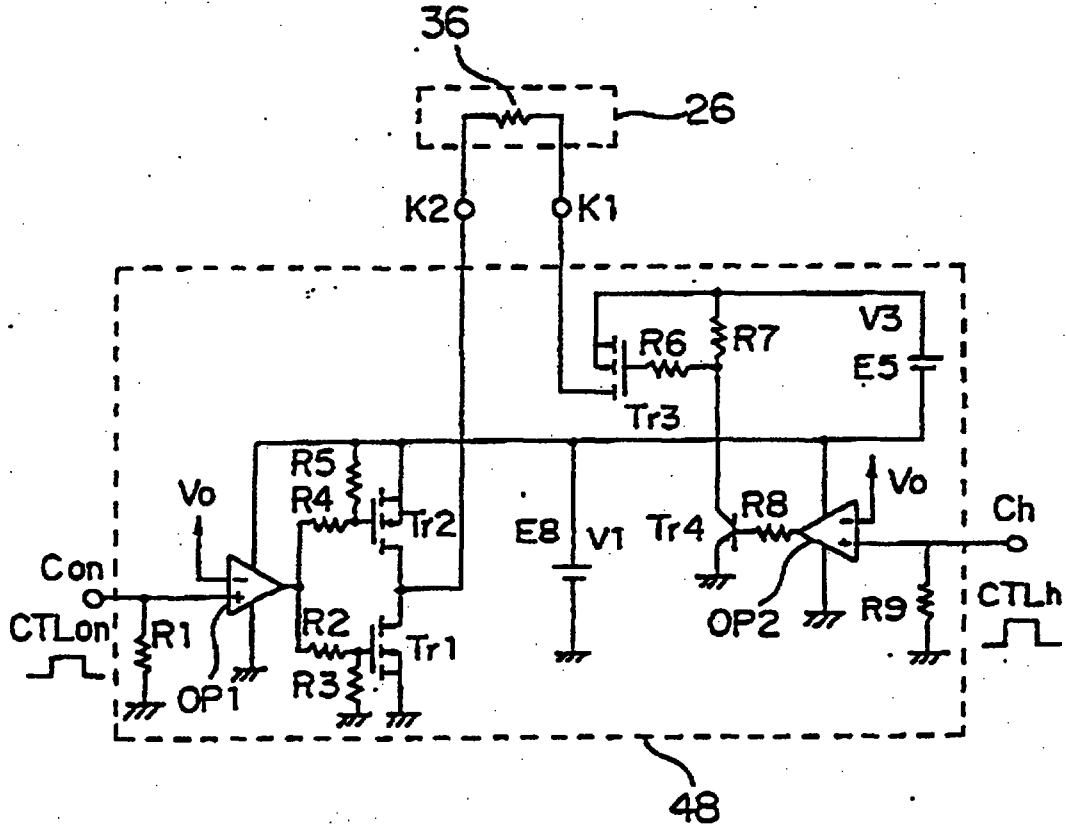


FIG. 6



This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

5/12

FIG. 7

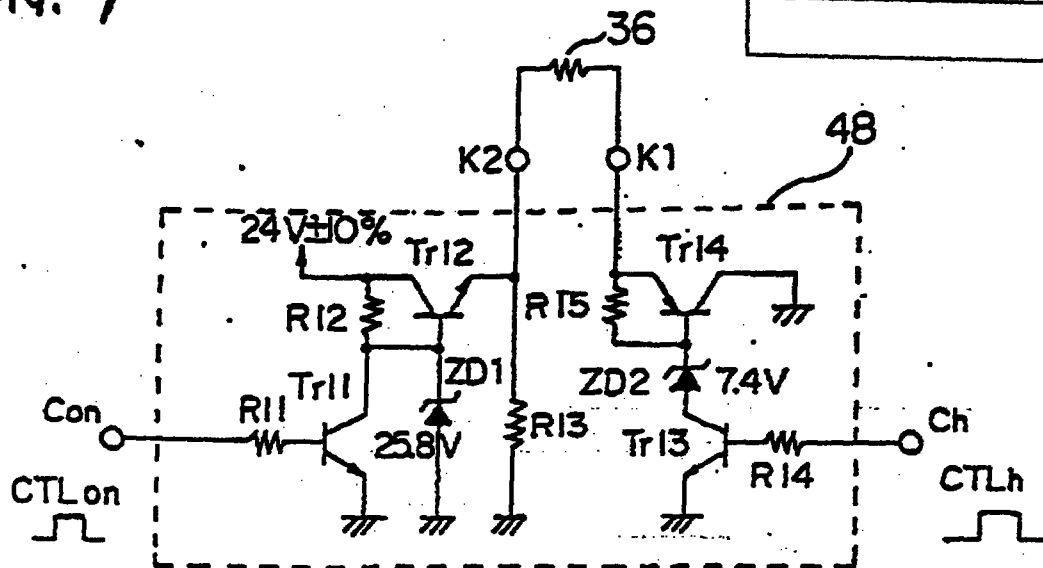
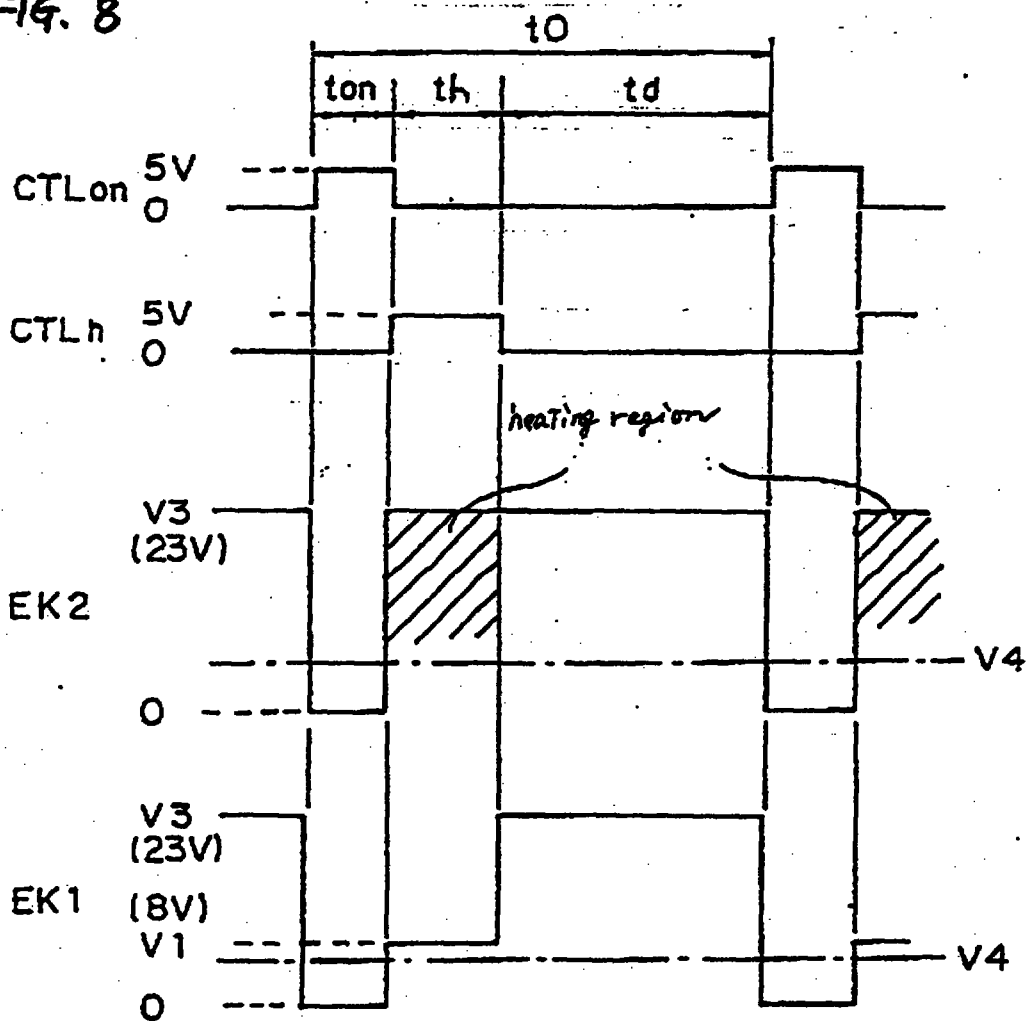


FIG. 8



This Sheet Has Been Replaced



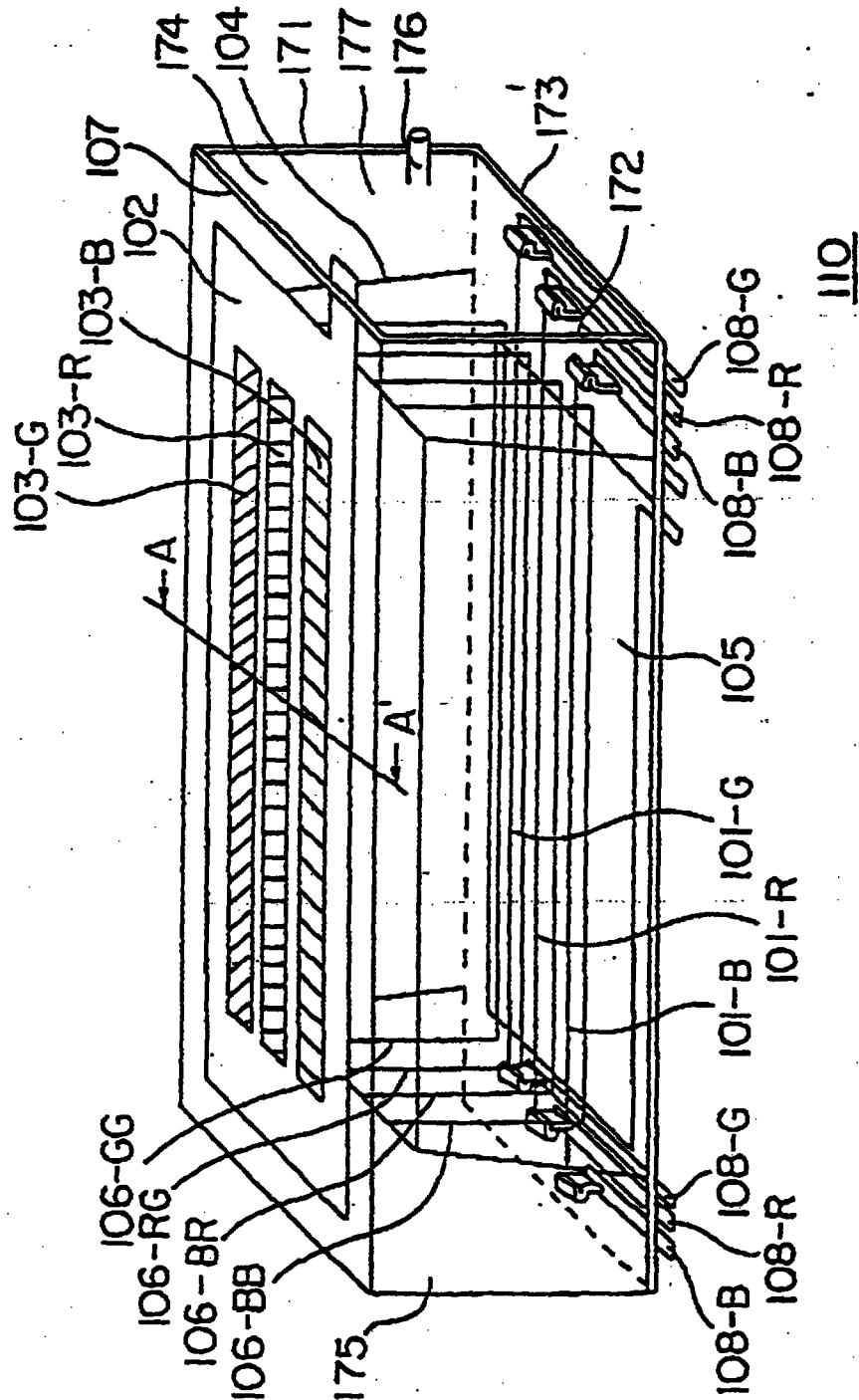
THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

6/12

FIG. 9



This Sheet Has Been Replaced



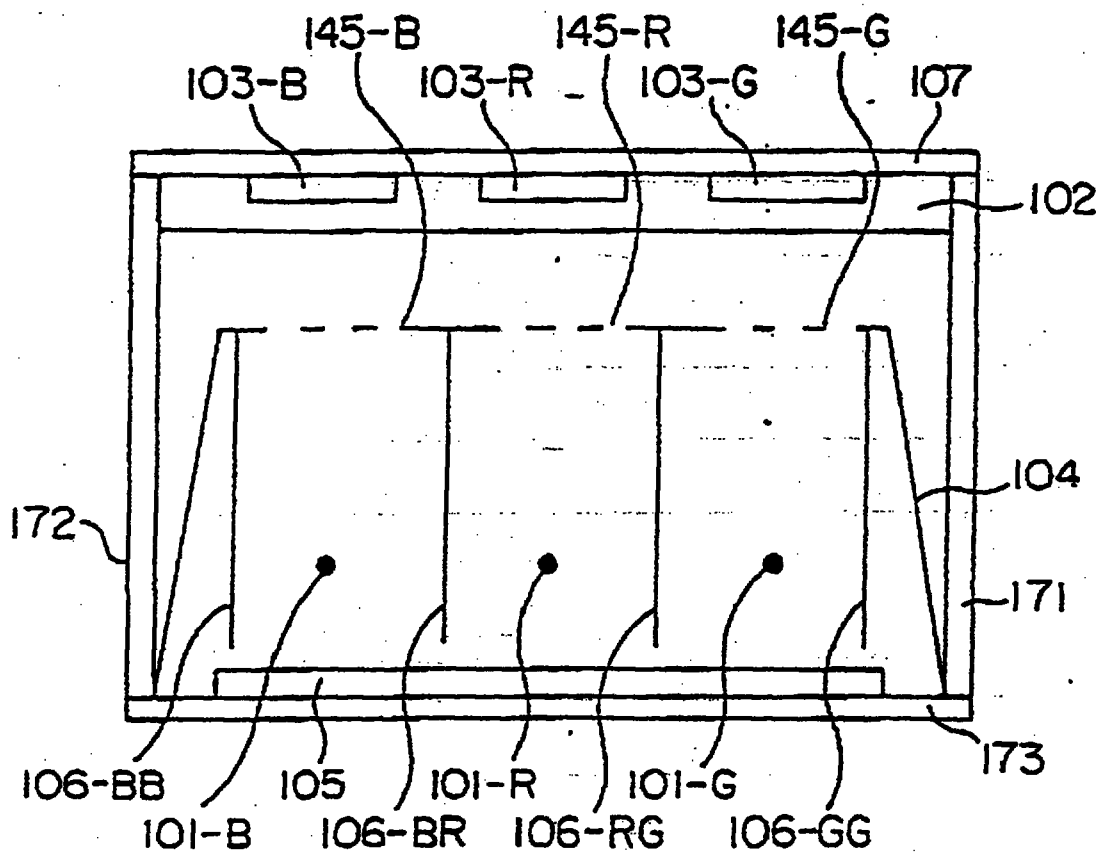
THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

7/12

FIG. 10



This Sheet Has Been Replaced



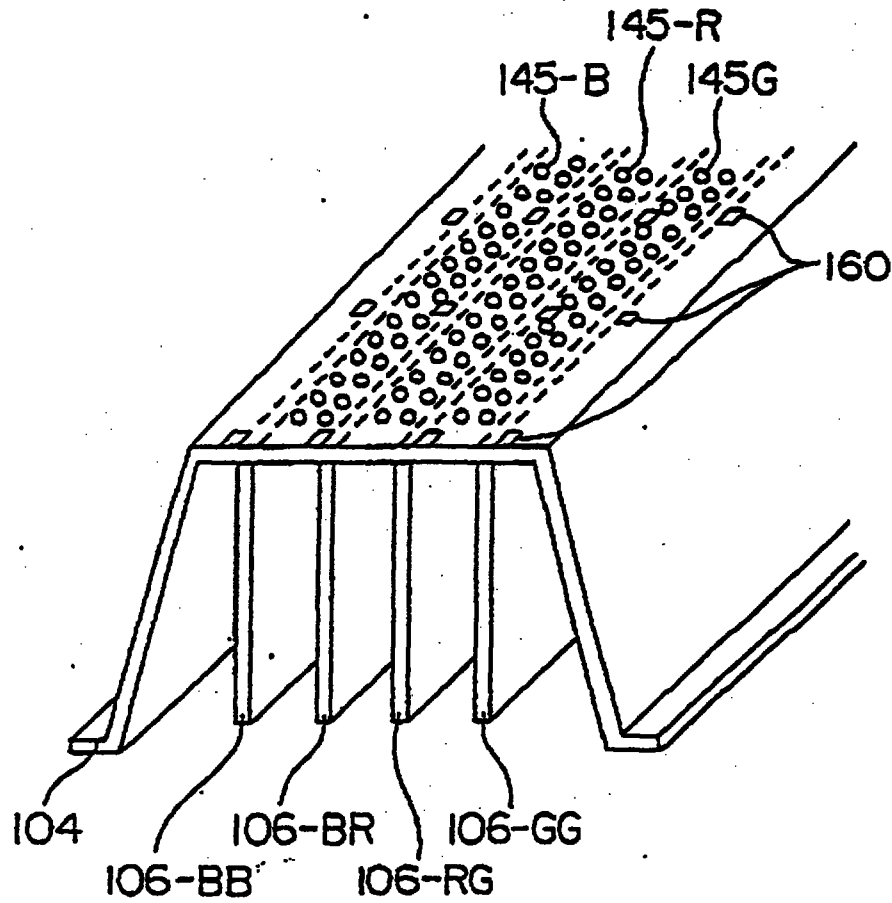
THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

8/12

FIG. 11



This Sheet Has Been Replaced

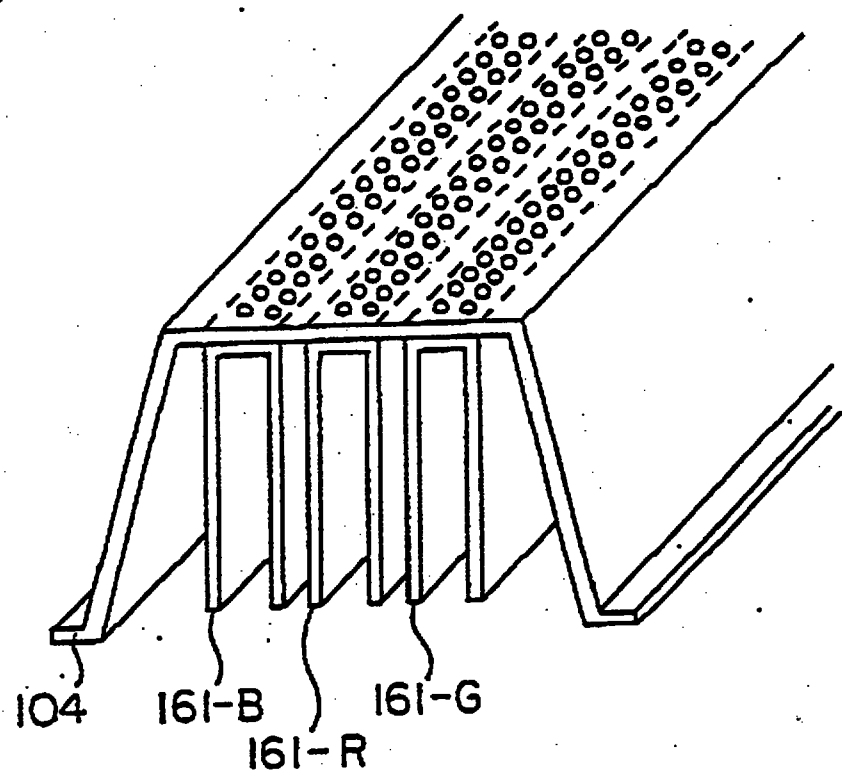


THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET
22 APR 1996

9/12

FIG. 12



This Sheet Has Been Replaced



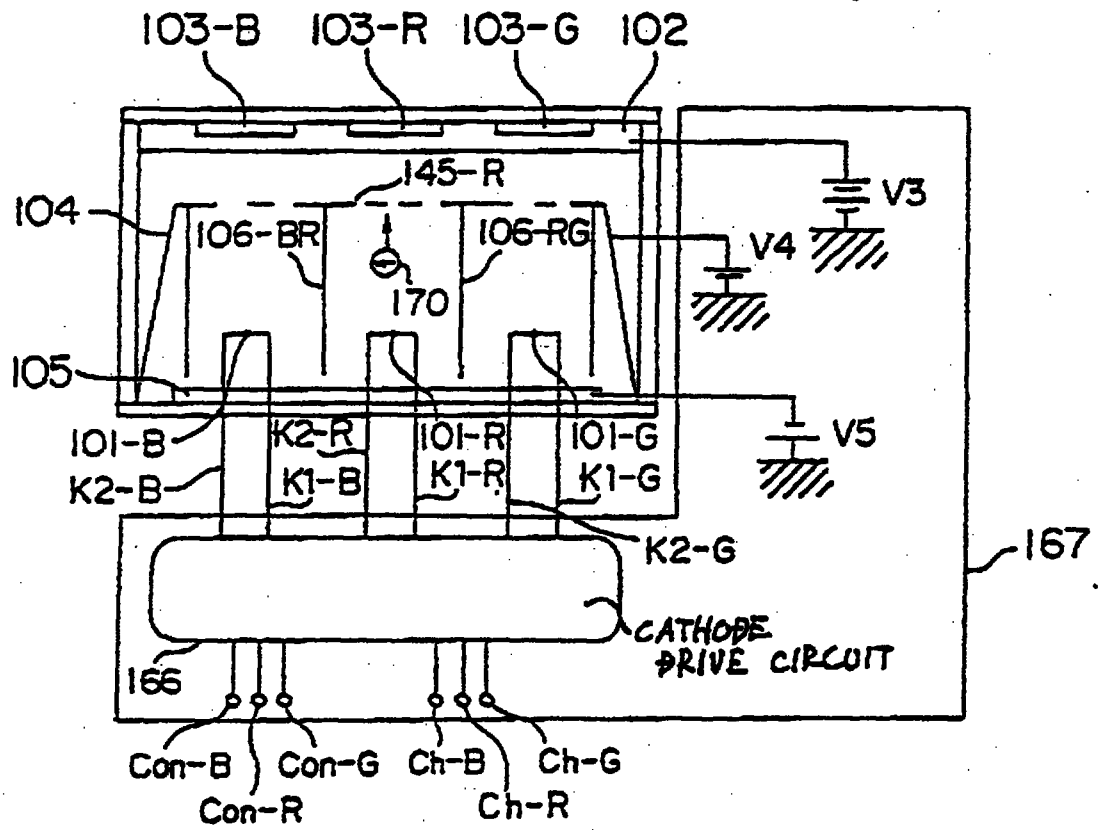
THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

10/12

FIG. 13



This Sheet Has Been Replaced



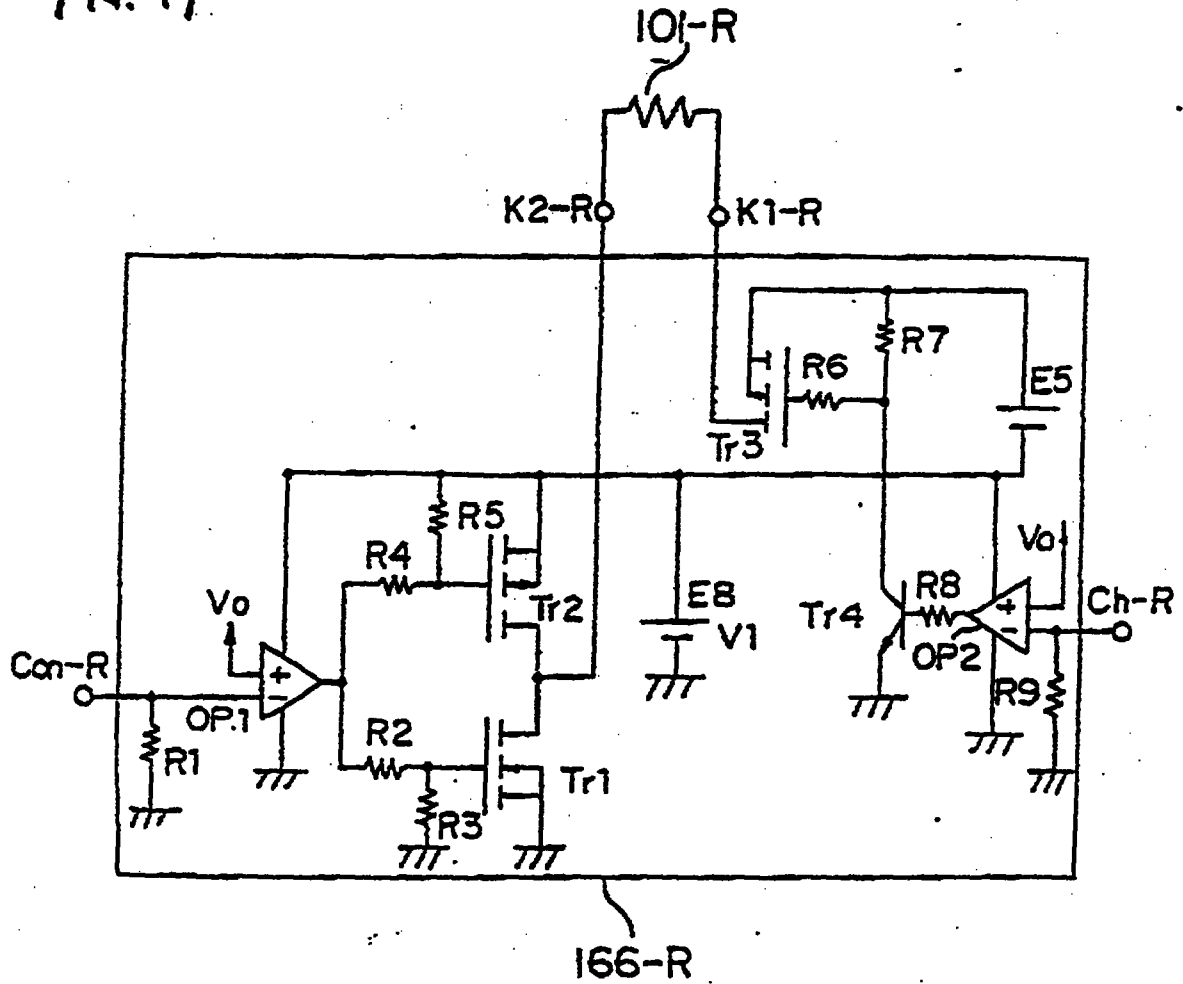
THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

22 APR 1996

11/12

FIG. 19



This Sheet Has Been Replaced

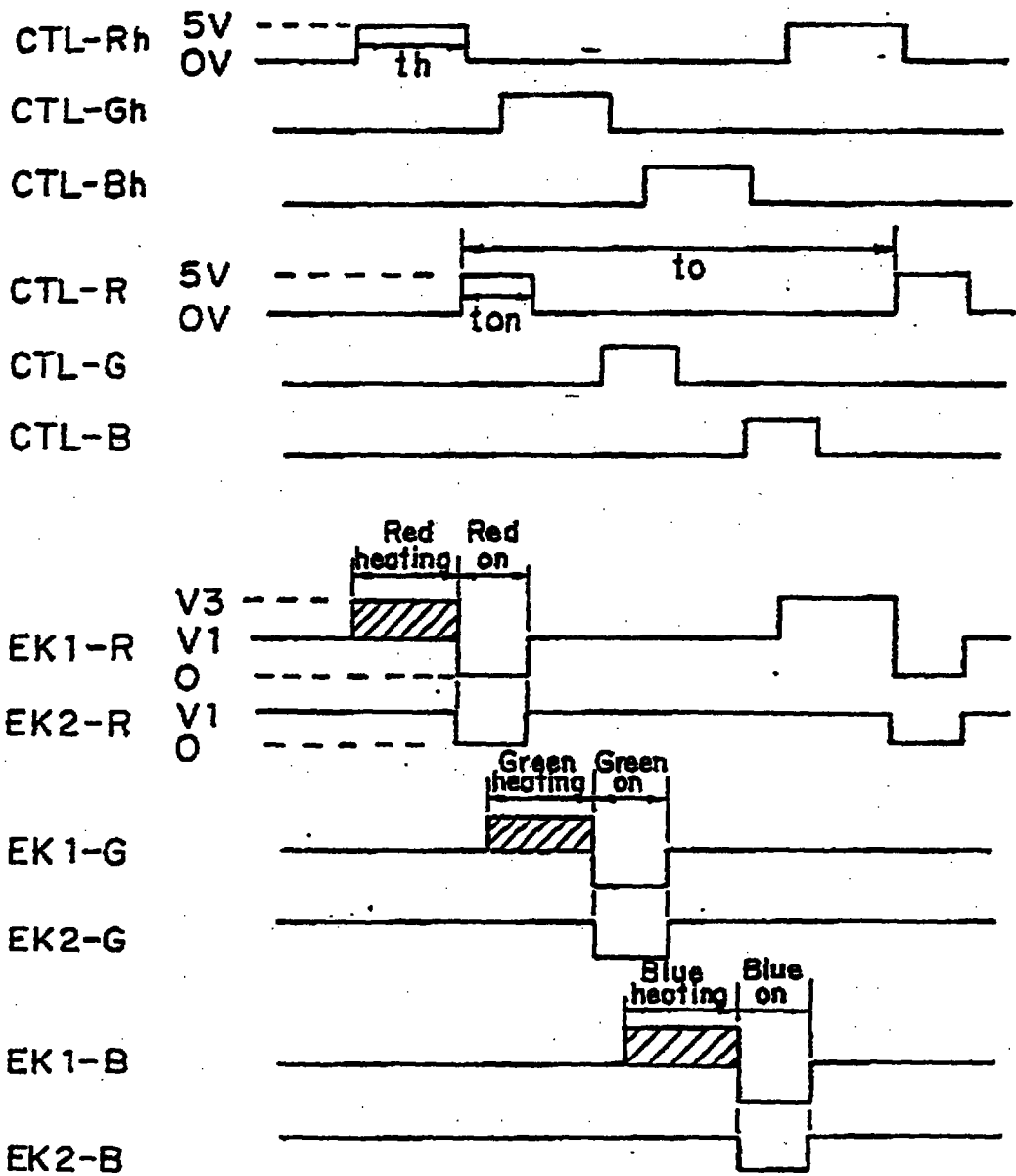


THIS SHEET HAS BEEN REPLACED

REPLACEMENT SHEET
22 APR 1996

12/12

FIG. 15



This Sheet Has Been Replaced



9604478-9
IP05 copy

REPLACEMENT SHEET

19 OCT 1996

1

METHOD OF AND CIRCUIT FOR DRIVING
CATHODELUMINESCENCE TYPE LIGHTING DEVICE

THIS SHEET HAS BEEN
REPLACED

BACKGROUND OF THE INVENTION

The present invention relates to a method of and an apparatus for driving lighting devices utilizing cathodeluminescence. More particularly, the invention is directed to a method of and a circuit for driving a lighting device suitable for use as a light source for an image input apparatus such as an image scanner, a digital copying machine, or a facsimile machine, or as a large display such as an outdoor television-type display.

In lieu of conventional light sources such as fluorescent lamps and line halogen lamps used as a line light source in an image input apparatus or the like, a light source utilizing cathodeluminescence, such as disclosed in Japanese Patent Unexamined Publication No. 73970/1981, has been proposed as a light source having low power consumption.

Figure 1 is a sectional view of a conventional cathodeluminescence type light source. The construction of the conventional light source will be described with reference to Figure 1.

Reference numeral 10 designates a glass tube that is evacuated to a predetermined degree of vacuum. Along the length of the glass tube 10 extends a cathode 12. Reference

This Sheet Has Been Replaced.



19 OCT 1996

numeral 14 designates a glass substrate, a front surface of which is coated with a phosphor 16. An anode 18 is deposited on the phosphor 16. The anode 18 is made of an aluminum thin film that serves as a metal backing. A grid 20, which is a control electrode, is interposed between the cathode 12 and the anode 18, and is made of a metal plate having slits 11 of a length of about 0.3 to 1 mm. Commonly used as the phosphor materials are those including zinc sulfide (ZnS) as a base material, such as ZnS with copper (Cu) and aluminum (Al). The light-emitting efficiency of these phosphor materials is high.

A high voltage of about 8 kV is applied to the anode 18 of the light-emitting tube by an ordinary power supply E2, whereas a voltage V4 on the order of several volts is applied to the grid 20 by a power supply E4.

A driving method will be described next. Japanese Patent Unexamined Publication No. 3740/1978 discloses a method of driving the cathodeluminescence type light source. Figure 2 is a timing chart for driving such light source. CTLon designates a lighting signal input to a cathode drive circuit (not shown). Cathode drive signals Ek1 and Ek2, which are output signals generated from the cathode drive circuit, are applied to the terminals K1 and K2 of the cathode 12 of the light-emitting tube shown in Figure 1. The generation of the lighting signal CTLon is repeated with a cycle time t_0 based on a turning-off period t_{off} and a lighting period t_{on} .



19 OCT 1996

During the turning-off period t_{off} , the voltages of the cathode drive signals E_{k1} and E_{k2} are V_2 and V_1 , respectively. The voltages V_2 and V_1 are higher than the voltage V_4 applied to the grid 20. When the voltages V_2 and V_1 are applied to the terminals K_1 and K_2 of the cathode 12, a difference in voltage $\Delta V = V_2 - V_1$ is supplied to the cathode 12 to cause the surface of the cathode to easily release thermoelectrons 24 (described later) by Joule heating.

However, since the voltages V_2 and V_1 applied to the terminals K_1 and K_2 of the cathode 12 are higher than the voltage V_4 applied to the grid 20, there is no emission of thermoelectrons 24 from the cathode 12.

During the lighting period t_{on} , the voltages of the cathode drive signals E_{k1} and E_{k2} both are 0 V. Since the voltage of the cathode 12 is lower than the voltage V_4 applied to the grid 20, the cathode 12 is heated by remaining heat, releasing thermoelectrons 24.

The thermoelectrons 24 pass through the slits 11 of the grid 20 and collide against the anode 18, to which the high voltage is applied. The thermoelectrons 24, having passed through the anode 18 formed of a thin film, collide against the phosphor 16, causing cathodeluminescence to occur.

The rate at which thermoelectrons are emitted from the surface of the cathode 12 depends on the surface temperature of the cathode 12. When a thermoelectron emitting substance



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

4

called an emitter material (not shown) is coated on the surface of the cathode 12, thermoelectrons are usually emitted therefrom at an adequate rate at surface temperatures of 500 to 700°. However, if the temperature is too high, evaporation of the emitter material is promoted, reducing the rate of emission of thermoelectrons. As a result, the amount of light emitted from the light source is impaired drastically. On the other hand, if the temperature is too low, the emission of thermoelectrons is not sufficient. To overcome this problem, three points, namely, the conduction voltage, the cathode resistance, and the conduction duty cycle at the time of operation (i.e., the ratio of the off period t_{off} to the lighting cycle t_0 in Figure 2) relevant to heating the cathode must be properly selected before driving the cathode.

However, in a lighting device used for an image input apparatus or the like, the integrated value of an amount of light stored in a CCD of a photoelectric transducer of the apparatus be made adjustable by making the lighting period t_{on} of the lighting device variable to increase the accuracy of the output signal from the CCD. However, if the lighting period t_{on} is varied in the conventional drive circuit, the off period t_{off} must also be varied (assuming the lighting cycle time t_0 is fixed). That is, the conduction duty cycle must be varied, which puts the surface temperature of the cathode 12 out of proper range, thus shortening the life of the light-

This Sheet Has Been Replaced



19 OCT 1996

emitting tube.

SUMMARY OF THE INVENTION

The invention has been made in view of such problems. Accordingly, an object of the present invention is to provide a method for driving a cathodeluminescence type lighting device that can adjust the lighting period variably and maintain a long life of the lighting device.

A driving method provided by the invention repeats, at a predetermined lighting cycle, the steps of: heating a cathode of the lighting device by electric conduction to the cathode; emitting light by causing the cathode to release electrons without conduction to the cathode; and reposing without causing the cathode to release electrons with no conduction to the cathode. At least the period of the light-emitting step and the period of the reposing step are variable.

Further, a driving circuit provided by the invention includes: a first control section for controlling a potential of a first terminal of the cathode; and a second control section for controlling a potential of a second terminal of the cathode. The first control section and the second control section operate during a lighting period, a heating period, and a dummy period. The lighting period, the heating period, and the dummy period are repeated at a predetermined lighting cycle and are successively generated. The first control section



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

6

controls the potential of the first terminal to a potential lower than a potential of the control grid during the lighting period, and controls the potential of the first terminal to a potential higher than the potential of the control grid during the periods other than the lighting period. The second control section controls the potential of the second terminal to a potential higher than the potential of the control grid and different from the potential of the first terminal during the heating period, and controls the potential of the second terminal to a potential equal to the potential of the first terminal during the periods other than the heating period.

The invention is characterized as having the heating period, the lighting period, and the reposing period in a single lighting cycle. When the lighting period is adjusted variably, the heating period can be maintained constant by varying the reposing period in accordance with the adjustment of the lighting period. Therefore, even if the lighting period is adjusted, the temperature of the cathode can be maintained within a proper range, thereby contributing to extending the service life of the light-emitting tube.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a sectional view showing the construction of a conventional light source utilizing cathodeluminescence;

Figure 2 is a timing chart of a cathode drive circuit in

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET
19 OCT 1996

7

the conventional light source;

Figure 3 is a perspective view showing an example of a light-emitting tube to which a drive circuit of the invention is applied;

Figure 4 is a diagram showing in block form an exemplary drive circuit of the invention for the light-emitting tube shown in Figure 3, together with a schematic sectional view of the light-emitting tube;

Figure 5 is a timing chart illustrating the operation of a cathode drive circuit within the drive circuit of Figure 4;

Figure 6 is a circuit diagram showing an example of the cathode drive circuit performing the operation of Figure 5;

Figure 7 is a circuit diagram showing another example of the cathode drive circuit within the drive circuit of Figure 4;

Figure 8 is a timing chart illustrating the operation of the cathode drive circuit of Figure 7;

Figure 9 is a perspective view showing a light-emitting tube 110 of a lighting device for a color image input apparatus to which a drive circuit of the invention is applied;

Figure 10 is a sectional view taken along a line A-A' of Figure 9;

Figure 11 is a partially enlarged view showing a grid electrode 104 and separators 106-BB, 106-BR, 106-RG, and 106-GG in Figure 9;

Figure 12 is a partially enlarged view showing the grid

This Sheet Has Been Replaced



19 OCT 1996

electrode 104 and inverted C-shaped separators 161-B, 161-R, and 161-G, which can be applied to the light-emitting tube of Figure 9;

Figure 13 is a diagram-showing in block form an example of a drive circuit of the invention for the light-emitting tube 110 together with a partial sectional view of the light-emitting tube 110;

Figure 14 is a circuit diagram of a red light-emitting circuit 166-R within the cathode drive circuit 166 of Figure 13; and

Figure 15 is a timing chart illustrative of an operation of the cathode drive circuit 166.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the invention will hereunder be described in detail with reference to the drawings.

Figure 3 is a perspective view showing an example of a cathodeluminescence type lighting tube to which a drive circuit of the invention is applied. A phosphor 16 for cathodeluminescence is coated on the inner surface of a front plate 28 of the light-emitting tube 26 in quantities of 0.1 to 100 mg/cm², most preferably 4 mg/cm², along the length of the light-emitting tube 26. The phosphor 16 is covered with an anode 30 made from aluminum, the anode being formed by vacuum



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1976

9

evaporation in thicknesses of 0.1 to 0.4 μm .

A back electrode 34 extends on the inner surface of a back plate 32 of the light-emitting tube 26 along the length of the back plate 32. The back electrode 34 is made from aluminum by vacuum evaporation or the like. Immediately above the back electrode 34 is a wire-like cathode 36. The cathode 36 is a tungsten thin wire 50 to 100 μm in diameter. An emitter material (not shown) is coated on the surface of the cathode 36. A grid 40 made of a metal plate that has a plurality of apertures 42 formed by blanking, electroforming or the like, is arranged at such a position as to shield the anode 30 from the cathode 36. The anode 30, the grid 40, the cathode 36, and the back electrode 34 are electrically driven to conduct by a drive circuit 44 (described later) via a terminal that extends externally from the light-emitting tube. Reference numeral 46 designates an evacuating tube that evacuates the light-emitting tube to a pressure of about 100 to 0.1 mPa. The light-emitting tube is thereafter sealed by melting the evacuating tube 46 by heating with a gas burner.

Figure 4 shows in block form an example of a drive circuit of the invention for the light-emitting tube 26 shown in Figure 3, together with a schematic sectional view of the light-emitting tube 26.

A drive circuit 44 includes three dc constant voltage power supplies E2 to E4 and a cathode drive circuit 48 for

This Sheet Has Been Replaced



19 OCT 1996

lighting control.

A high voltage on the order of 8 kV is applied to the anode 30 by the power supply E2. A voltage V4 on the order of several volts is applied to the grid 40 by the power supply E4. An appropriate voltage is applied to the back electrode 34 by the power supply E3. Such voltages are applied to maximize the amount of thermoelectrons emitted by the cathode 36. Both terminals K1 and K2 of the cathode 36 are connected to the cathode drive circuit 48.

Figure 5 is a timing chart illustrating the operation of the cathode drive circuit 48. CTLon and CTLh designate signals input to a lighting signal input terminal Con and a heating signal input terminal Ch, respectively. Reference characters Ek1 and Ek2 designate drive voltage signals supplied to the terminals K1 and K2, respectively.

During a period t_h (heating period), the cathode drive voltage signal Ek1 is a predetermined voltage V3 (e.g., 23 V), and the other cathode drive voltage signal Ek2 is a predetermined voltage V1 (e.g., 8 V). Then, a difference in voltage $\Delta V = V3 - V1$ is produced between the terminals K1 and K2 of the cathode 36, enabling the surface of the cathode 36 to easily emit thermoelectrons 24 by Joule heating.

However, since the voltages V3 and V1 respectively applied to the terminals K1 and K2 of the cathode 36 are higher than the potential V4 applied to the grid 40, no thermoelectrons 24



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

11

are emitted from the cathode 36.

Then, during a period t_{on} (lighting period), which is between the moment at which the lighting signal CTL_{on} rises from 0 V to 5 V and the moment at which the lighting signal CTL_{on} drops to 0 V again, both cathode drive voltage signals Ek_1 and Ek_2 are 0 V, which makes the voltage at the cathode 36 lower than the applied voltage V_4 . As a result, the thermoelectrons 24 are released from the cathode 36 heated by the remaining heat. The thermoelectrons 24 pass through the apertures 42 of the grid 40 and collide against the anode 30 to which a high voltage has been applied. Further, the thermoelectrons 24 having passed through the anode 30 made of a thin film then collide against the phosphor 16 to produce cathodeluminescence.

Lastly, during a period t_d (dummy period), the lighting signal CTL_{on} and the heating signal CTL_h are both at 0 V. As a result, the voltage of both cathode drive signals Ek_1 and Ek_2 is V_1 . Since there is no difference in voltage between both terminals of the cathode 36, the cathode 36 is not heated in a manner similar to the lighting period t_{on} . Further, since the voltage V_1 applied to the terminals K_1 and K_2 of the cathode 36 is higher than the voltage V_4 applied to the grid 40, no thermoelectrons 24 are emitted from the cathode 36.

In this timing chart, to variably adjust the lighting period t_{on} , the cycle time t_0 and the heating period t_h are

This Sheet Has Been Replaced



19 OCT 1996

fixed, whereas the lighting period t_{on} is varied within the range of $t_0 - t_h$. Accordingly, only the luminous duty cycle can be varied with the heating duty cycle maintained constant.

Figure 6 shows an exemplary circuit of the cathode drive circuit 48 shown in Figure 5.

This cathode drive circuit 48 has two operational amplifiers OP1 and OP2, to which the dc voltage V1 is applied by a power supply E8 as a supply voltage. A threshold voltage V0 (e.g., 1.5 V) is applied to both inverting input terminals (-).

One of the operational amplifiers OP1 has a non-inverting input terminal (+) connected to the signal input terminal Con so that the lighting signal CTLon can be received thereby, and the output terminal thereof is connected to the control gates of two complementary transistors Tr1 and Tr2 through a set of dividing resistors R2 and R3 and through a set of dividing resistors R5 and R4, respectively. The output terminals of the complementary transistors Tr1 and Tr2 are connected to the cathode terminal K2.

The other operational amplifier OP2 has a non-inverting input terminal (+) connected to the signal input terminal Ch so that the heating signal CTLh can be received thereby, and the output terminal thereof connected to the base of a switching transistor Tr4 through a resistor R8. The emitter of the switching transistor Tr4 is grounded, and the collector thereof



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

13

is connected to the control gate of the transistor Tr3 through a resistor R6. The voltage V3 which is a voltage combination of the voltage V1 of the power supply E8 with a voltage of the power supply E5 is applied to the control gate of the transistor Tr3 through a resistor R7. The voltage V3 is also applied to the source of the transistor Tr3. The drain of the transistor Tr3 is connected to the other cathode terminal K1.

The operation of the circuit will be described below. An operation during the heating period t_h will be described first.

When the heating signal CTLh has risen to 5 V from 0 V, the output voltage of the operational amplifier OP2 rises to V1 from 0 V, which causes the transistor Tr4 to turn on and the potential of a node of the resistors R7 and R6 to become almost 0 V. Then, since the transistor Tr3 turns on, the voltage V3 is applied to the terminal K1 of the cathode 36.

During this heating period t_h , the output voltage of the operational amplifier OP1 is 0 V. As a result, the transistor Tr1 turns off, whereas the transistor Tr2 turns on, which causes the power supply E8 to apply the voltage V1 to the terminal K2 of the cathode 36.

As the voltages V3 and V1 are then applied to the terminals K1 and K2 of the cathode 36, the cathode 36 is heated with current passing therethrough.

The operation of the circuit during the lighting period t_{on}

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

14

will be described next.

When the lighting signal CTLon has risen to 5 V from 0 V, the output voltage of the operational amplifier OP1 becomes V1. Since this causes the transistor Tr1 to turn on and the transistor Tr2 to turn off, the voltage at the terminal K2 of the cathode 36 is almost 0 V.

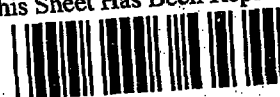
Since the heating signal CTLh is at 0 V in this instance, the output voltage of the operational amplifier OP2 is 0 V, leaving the transistor Tr4 turned off. As a result, the transistor Tr3 is turned off, which opens the current loop flowing through the cathode 36. Consequently, the terminal K1 of the cathode 36 is at 0 V, which is equal to the potential at the terminal K2.

The operation of the circuit during the dummy period (t_d) will be described.

When the lighting signal CTLon has dropped to 0 V from 5 V, the output voltage of the operational amplifier OP1 drops to 0 V. Then, the transistor Tr1 is turned off, and the transistor Tr2 turns on, causing the voltage at the terminal K2 of the cathode 36 to become the voltage V1 of the power supply E8.

Since the heating signal CTLh is at 0 V at this time, similar to the lighting period t_{on} , the current loop flowing through the cathode 36 is open. As a result, the potential at the terminal K1 of the cathode 36 is V1, which is equal to the

This Sheet Has Been Replaced



19 OCT 1996

potential at the terminal K2.

In the drive circuit shown in Figures 5 and 6, the heating duty cycle of the cathode 36 is t_h/t_0 . Thus, if the lighting cycle t_0 and the heating period t_h are kept constant at all times, then the heating duty cycle is constant, thereby keeping the surface temperature of the cathode within a predetermined range. The lighting period t_{on} can be variably adjusted independently of the heating period t_h by using the dummy period t_d .

The variable range of the lighting period t_{on} is between 0 and $t_0 - t_h$. Therefore, the variable range of the lighting period t_{on} can be increased by increasing the voltage V3 of the cathode drive signal Ek1 during the heating period t_h shown in Figure 5 as much as possible, so that the heating duty cycle can be decreased, i.e., the period t_h can be shortened as much as the voltage V3 is increased.

Figure 7 shows another exemplary circuit that can be used as the cathode drive circuit 48 of Figure 4, and Figure 8 is a timing chart showing an operation thereof.

The circuit shown in Figure 7 is advantageous in that the construction thereof is simpler than the circuit shown in Figure 6.

Further, the operation shown in Figure 8 has a feature that the lighting period t_{on} comes first and that the heating period t_h starts in response to the end of the lighting period



19 OCT 1996

t_{on}. More specifically, the lighting signal CTLon is generated at an independent timing, whereas the heating signal CTLh is generated at a timing dependent on the lighting signal CTLon. One of the advantages in this system is that when the lighting device is used as a light source of an image input apparatus, the image reading period can be easily synchronized with the lighting period. The reason is that the lighting signal CTLon can be generated in direct synchronism with a pulse signal that is generated by the image input apparatus and synchronized with the reading period. In contrast thereto, in the operation shown in Figure 5, the lighting signal CTLon is generated at a timing dependent on the heating signal CTLh causing the lighting signal CTLon to rise upon dropping of the heating signal CTLh. Therefore, the lighting signal CTLon cannot be generated in direct synchronism with the pulse signal from the image input apparatus.

The circuit illustrated in Figure 7 will be described below.

A transistor Tr11 receives the lighting signal CTLon on the base thereof through a resistor R11. The emitter thereof is grounded, and the collector thereof is connected to a dc constant voltage supply (e.g., 24 V $\pm$ 10%) through a resistor R12 and to the base of a transistor Tr12. The transistor Tr12 is connected to the above-mentioned dc constant voltage supply; the emitter thereof is connected to the terminal K2 of the



19 OCT 1996

cathode and grounded through a resistor R13. Between the base of the transistor Tr12 and ground is connected a zener diode ZD1 whose zener voltage is, e.g., 25.8 V and whose function is to clamp variations in the dc voltage supply on the high side of the nominal voltage.

A transistor Tr13 receives the heating signal CTLh on the base thereof through a resistor R14. The emitter thereof is grounded, and the collector is connected to the base of a transistor Tr14 through a zener diode ZD2 whose zener voltage is, e.g., 7.4 V and which is connected in the forward direction. The transistor Tr14 has a resistor R15 interposed between the emitter and the base thereof, with the emitter connected to the terminal K1 of the cathode and the collector grounded.

The operation of the circuit will be described with reference to Figures 7 and 8.

As shown in Figure 8, upon initiation of the lighting cycle t_0 , the lighting signal CTLon rises to 5 V from 0 V and drops to 0 V after a predetermined lighting period t_{on} . In response to the drop of the lighting signal CTLon, the heating signal CTLh rises to 5 V from 0 V and drops to 0 V after a predetermined heating period t_h .

Referring to Figure 7, upon rising of the lighting signal CTLon at the start of the lighting period t_{on} , the transistor Tr11 turns on and the transistor Tr12 turns off. As a result,



19 OCT 1996

the terminal K2 of the cathode 36 is grounded to be at 0 V, as shown in Figure 8.

Since the heating signal CTLh is at 0 V at this time, the transistor Tr13 is turned off, which means that the transistor Tr14 is turned off as well. Therefore, the current loop flowing through the cathode 36 is open. As a result, the potential at the cathode terminal K1 becomes 0 V, which is equal to the potential at the other terminal K2.

In this way, the voltage of each of the terminals K1 and K2 of the cathode 36 is 0 V, that is, lower than the grid voltage V4 during the lighting period t_{on} , so that electrons are emitted from the already-heated cathode 36 and collide against the phosphor of the anode after being accelerated by the grid. As a result, the emission of light starts.

At the end of the lighting period t_{on} , the lighting signal CTLon drops, and simultaneously therewith the heating signal CTLh rises. When the lighting signal CTLon drops, the transistor Tr11 turns off, which causes the transistor Tr12 to turn on. As a result, the potential of the cathode terminal K2 connected to the emitter of the transistor Tr12 becomes almost 23 V (V3), which is obtained by subtracting the voltage drop of the transistor Tr12 from the power supply voltage (24 V)

Further, since the transistor Tr13 turns on and the transistor Tr14 turns on at the rising of the heating signal CTLh, the potential of the cathode terminal K1 becomes almost



19 OCT 1996

8 V (V1), which is obtained by adding a base-emitter voltage of the transistor Tr13 to the zener voltage 7.4 V.

In this way, the voltage of one terminal K2 of the cathode 36 is 23 V (V3) and that of the other terminal K1 is 8 V (V1) during the heating period t_h , which causes current to flow through the cathode 36 to heat the cathode 36. However, since the potential V3 of the cathode 36 is higher than the potential V4 of the grid, no electrons are emitted.

At the end of the heating period t_h , the heating signal CTLh drops. As a result, both transistors Tr13 and Tr14 turn off, which in turn opens the current loop passing through the cathode 36. Since the voltage of the cathode terminal K2 is 23 V (V3) at this time, which is equal to that during the heating period, the voltage of the terminal K1 becomes 23 V (V3) as well. Therefore, no current flows through the cathode 36, which means that the cathode 36 is not heated. In addition, since the potential V3 of the cathode 36 is higher than the potential V4 at the grid, there is no emission of light.

The above describes the embodiments applied to the lighting device shown in Figure 3 for the emission of light of a single color.

Embodiments of the invention to be applied to a lighting device for the emission of light of three colors, which can be used for a color image input apparatus, will be described next.

Figure 9 is a perspective view of an example of a light-



19 OCT 1996

emitting tube 110 used as a lighting device for a color image input apparatus to which the invention can be applied.

Figure 10 is a sectional view taken along a line A-A' in Figure 9, and Figure 11 is a partially enlarged view showing a grid electrode 104 and separators 106-BB, 106-BR, 106-RG, and 106-GG in Figure 9.

The construction of the light-emitting tube 110 will be described below. Red, green, and blue cathodes 101-R, 101-G, and 101-B extend between the grid electrode 104 and a back electrode 105 (both described later) while being supported by cathode support members 108-R, 108-G, and 108-B on both ends thereof, respectively. The cathodes 101-R, 101-G, and 101-B are thin tungsten wires 10 to 50 μm in diameter. The surface of each cathode is coated with an electron emitting substance (not shown) such as barium oxide or the like. The function of the coating is to improve electron emitting efficiency.

The grid electrode 104 is located between the cathodes 101-R, 101-G, 101-B and an anode 102 by bending a plate in trapezoidal form, the plate being electrically conductive such as stainless steel, brass, or aluminum, as well as nonmagnetic. As shown in Figure 10, the grid electrode 104 is fixed by clamping with glass side plates 171, 172 and a bottom plate 173. As shown in Figure 11, the grid electrode 104 has four separators 106-BB, 106-BR, 106-RG, 106-GG for partitioning the cathodes. The separators are fixed at a plurality of fixing



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

21

points 160. These separators are electrically conductive with the grid electrode 104. Further, on a side of the grid electrode 104 which is opposite to the anode are a plurality of net-like or slit-shaped apertures 145-R, 145-G, 145-B for allowing electrons to pass therethrough, the electrons being generated by the cathodes 101-R, 101-G, 101-B.

Each separator 106 flexes between the fixing points 160 when thermally expanded by heat radiated from the cathode. This causes an inconsistent amount of light. It is desirable to increase the number of fixing points 160 to suppress the flexing as much as possible. Further, it is desirable to bend the upper edge part, the lower edge part, or both of each separator 106 in L form so that the separator 106 becomes hard to flex. Otherwise, as shown in Figure 12, inverted C-shaped separators 161-B, 161-R, and 161-G may be used.

The back electrode 105 is formed between the cathodes 101-R, 101-G, and 101-B and the glass bottom plate 173. The back electrode 105 is made of carbon paste.

Phosphors of three kinds, namely, a green-emitting phosphor 103-G, a red-emitting phosphor 103-R, and a blue-emitting phosphor 103-B, are sequentially coated on the inner surface of a transparent glass plate 107 by means of screen printing or the like. The phosphors used here are those capable of emitting light by cathodeluminescence, such as yttrium oxysulfide (Y_2O_3S) with europium (Eu) or samarium (Sm)

This Sheet Has Been Replaced



19 OCT 1996

as the red-emitting phosphor, zinc sulfide (ZnS) with copper (Cu) and aluminum (Al) as the green-emitting phosphor, zinc sulfide (ZnS) with silver (Ag) and chlorine (Cl) as the blue-emitting phosphor, and the like.

The anode 102 is formed by depositing a 1 to 10 μm thick layer of aluminum on the inner surface of the phosphor-coated transparent glass plate 107 by means of vacuum evaporation or the like.

Lastly, the surfaces of the glass parts in contact and the interface of the leads externally extending from the light-emitting tube 110 from each electrode are closed with low-melting point glass or the like, put in a high-temperature vessel at 500 to 600° to be fused so that a container 177 including the transparent plate 107, the glass plates 171, 172, 173, 174, and 175 shown in Figure 9 is formed. Then, when the container 177 is evacuated to a range of 100 to 0.1 mPa by an evacuating tube 176, the container 177 is sealed to maintain the evacuated condition therewithin.

The three-color light-emitting tube 110, when used as a light source for a color image input apparatus, injects light in three colors to a single direction from a substantially single light source. As a result, even if an original having steps or irregularities on the surface is input, excellent color reproduction free from color mismatching can be obtained.

Figure 13 shows in block form a drive circuit of the



19 OCT 1996

invention for independently producing emissions of light from the phosphors 103-R, 103-G, and 103-B for the respective colors of such light-emitting tube 110.

A drive circuit 167 shown in Figure 13 includes three dc constant voltage power supplies and a cathode drive circuit 166. The respective cathodes 101-R, 101-G, and 101-B are connected to the cathode drive circuit 166 at both terminals K1-R, K2-R, K1-G, K2-G, K1-B, and K2-B.

Figure 14 is a circuit diagram of the cathode drive circuit 166. A circuit 166-R in Figure 14 drives the cathode 101-R for the red color. Two other circuits (of the same construction) are arranged in parallel to drive the cathode 101-G for the green color and the cathode 101-B for the blue color. The three cathodes 101-R, 101G, and 101-B are driven independently by these three circuits.

The circuit shown in Figure 14 is the same as the cathode drive circuit for the single color light-emitting tube shown in Figure 6. A lighting signal input terminal Con-R and a heating signal input terminal Ch-R receive a lighting signal CTL-R and a heating signal CTL-Rh for red (see Figure 15), respectively. The cathode terminals K1-R and K2-R are connected to the cathode 101-R for red.

Figure 15 is a timing chart showing the operation of the cathode drive circuit 166.

As shown in Figure 15, the drive signals CTL-Rh, CTL-R for

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

24

the red color, the drive signals CTL-Gh, CTL-G for the green color, and the drive signals CTL-Bh, CTL-B for the blue color are generated 120° out of phase with one another. The operation of each color is the same as the operation shown in Figure 5.

The three-color light-emitting tube can, of course, be driven by the three circuits, the construction of each of which is the same as that shown in Figure 7. In such a case, the operation shown in Figure 8 is performed per color. The operations of the three colors are 120° out of phase with one another.

While the preferred embodiments of the invention have been described above, the invention is not limited to them, but may be embodied in various other modes.

As described in the foregoing, the invention is characterized as arranging a dummy period in which no heating or lighting is effected during a lighting cycle and making the dummy period and the lighting period variable. Therefore, even if the lighting period is variably adjusted, the heating duty cycle can be maintained constant, thereby allowing the life of the lighting device to be increased.

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1981

This Sheet Has Been Replaced



25

CLAIMS

What is claimed is:

1. A method of driving a cathodeluminescence type lighting device, comprising the steps of:

heating a cathode of said cathodeluminescence type lighting device by electric conduction;

emitting light by causing the cathode to release electrons absent conduction to the cathode once said cathode is heated; and

reposing said cathode during a period when said cathode is not heated and said release of said electrons is terminated;

wherein said heating, light-emitting, and reposing steps are repeated at predetermined lighting cycles, and

at least a period of said light-emitting step and a period of said reposing step are variable.

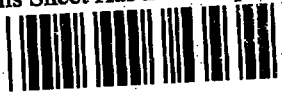
2. The method according to claim 1, wherein a ratio of a period of said heating step to the lighting cycle is maintained constant.

3. The method according to claim 1, further comprising the step of controlling timings of said heating step, said light-emitting step, and said reposing step, said step of



* C L M S *

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

26

controlling timings determining a timing of said light-emitting step independently of the timings of said heating step and of said reposing step and the timings of said heating step and of said reposing step dependent on the timing of said light-emitting step.

4. An apparatus for driving a cathodeluminescence type lighting device having a control grid arranged between a cathode and an anode, said apparatus comprising:

a first control section for controlling a potential of a first terminal of said cathode; and

a second control section for controlling a potential of a second terminal of said cathode;

said first control section and said second control section operating during a lighting period, a heating period, and a dummy period, respectively, wherein said lighting period, said heating period, and said dummy period are repeated at predetermined lighting cycles and are successively generated;

said first control section controlling the potential of the first terminal to a potential lower than a potential of said control grid during said lighting period, and controlling the potential of the first terminal to a potential higher than the potential of said control grid during periods other than said lighting period; and



* C L M S *

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

27

said second control section controlling the potential of the second terminal to a potential higher than the potential of said control grid and different from the potential of the first terminal during said heating period, and controlling the potential of the second terminal to a potential equal to the potential of the first terminal during periods other than said heating period.

5. The apparatus according to claim 4, wherein said second control section opens a current loop passing through said cathode during periods other than said heating period so that the potential of the second terminal becomes equal to the potential of the first terminal.

6. The apparatus according to claim 4, wherein said second control section controls the potential of the second terminal to a potential higher than the potential of the first terminal during said heating period.

7. The apparatus according to claim 4, wherein said second control section controls the potential of the second terminal to a potential lower than the potential of the first terminal during said heating period.

8. The apparatus according to claim 4, wherein



* C L M S *

THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

28

said first control section operates in response to a lighting signal indicating said lighting period;

said second control section operates in response to a heating signal indicating said heating period;

said apparatus further comprising:

a signal generating section for generating said lighting signal and said heating signal, said signal generating section determining a timing for generating said lighting signal independently of said heating signal and a timing for generating said heating signal dependent on said lighting signal.



This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

29

METHOD OF AND CIRCUIT FOR DRIVING
CATHODELUMINESCENCE TYPE LIGHTING DEVICE

ABSTRACT OF THE DISCLOSURE

A lighting device emits light by releasing electrons to an anode from a Joule-heated cathode and causes the electrons to collide against a phosphor on the anode side. A method of driving the lighting device repeats, at a predetermined lighting cycle, a heating period (t_h) in which the cathode is heated by conduction, a lighting period (t_{on}) in which the cathode is caused only to release electrons without conduction so that light is emitted, and a dummy period (t_d) in which no conduction or emission of light occurs at the cathode. To variably adjust the lighting period (t_{on}), adjustments are absorbed by the dummy period (t_d) to maintain the heating period (t_h) constant at all times. With respect to the timing control of each period, the lighting period (t_{on}) is controlled at a timing independent of the heating period (t_h), whereas the heating period (t_h) is controlled at a timing dependent on the lighting period (t_{on}). This is preferred to facilitate the timing control of the lighting period (t_{on}).

FIGURE 5

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

1

FIG. 1 PRIOR ART

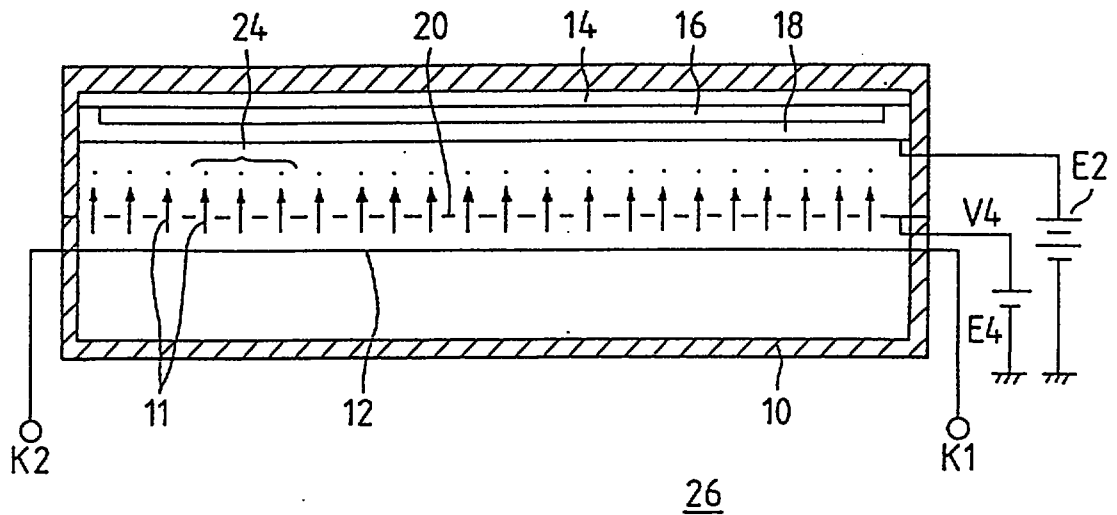
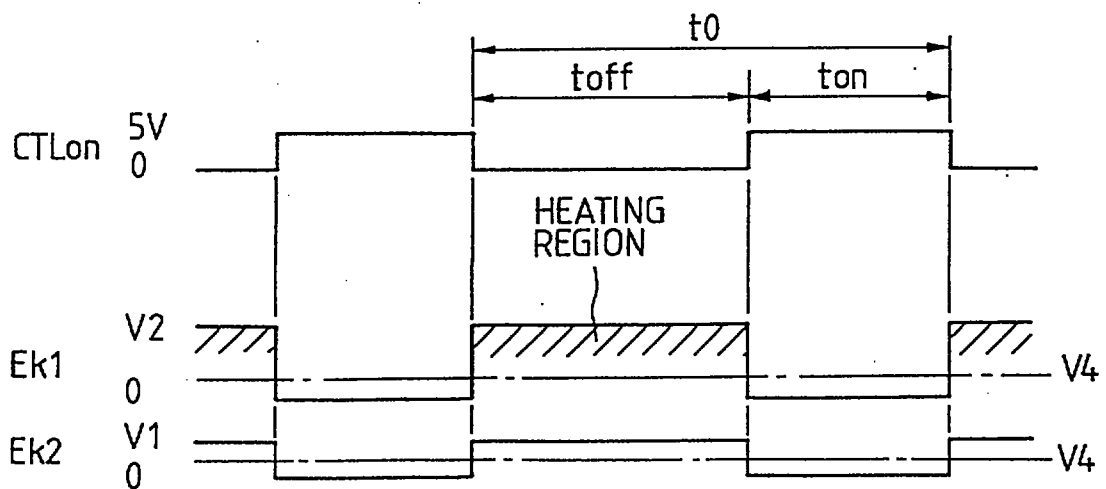


FIG. 2 PRIOR ART



This Sheet Has Been Replaced



19 OCT 1996

2

FIG. 3

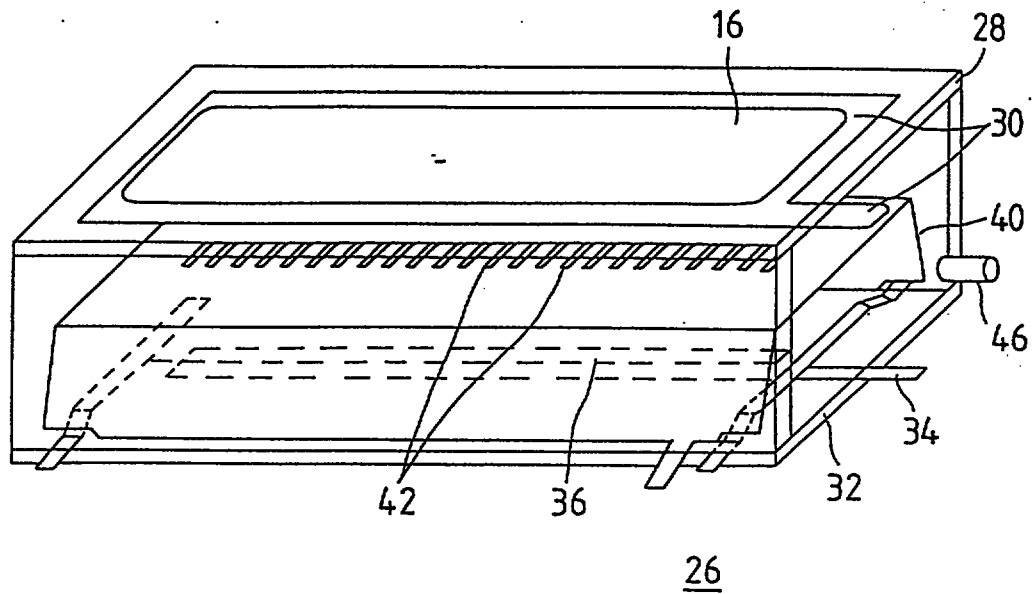
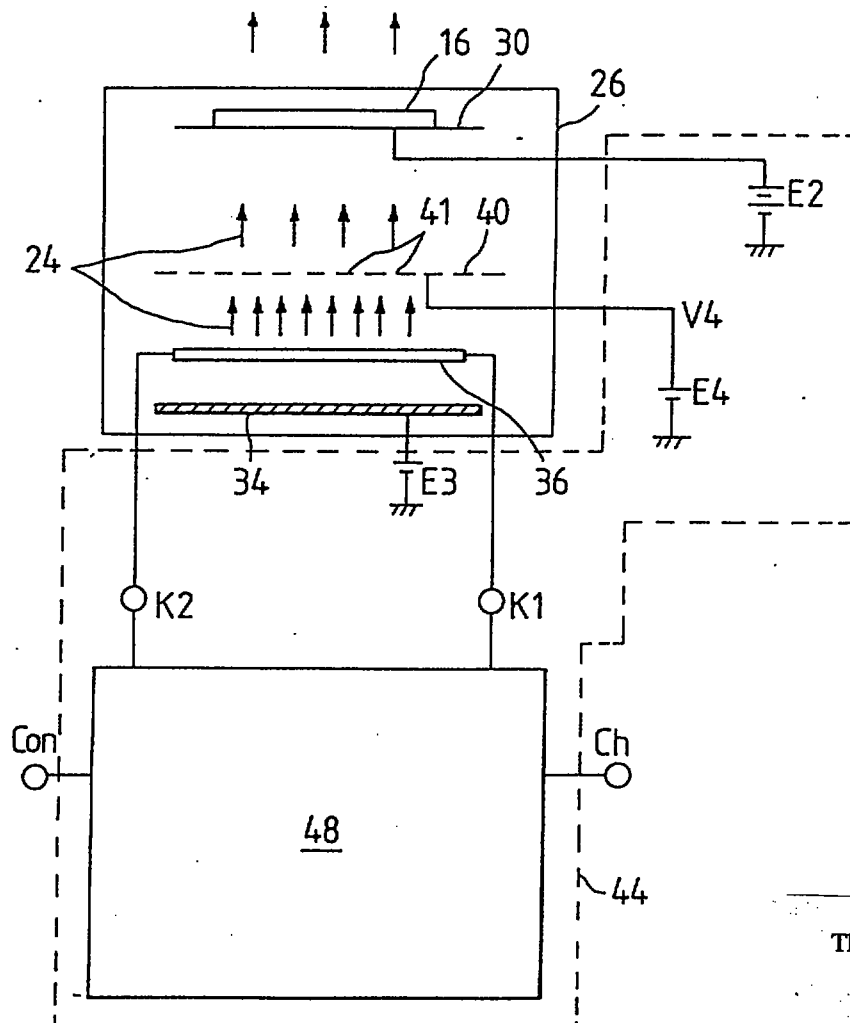


FIG. 4



19 OCT 1996

FIG. 5

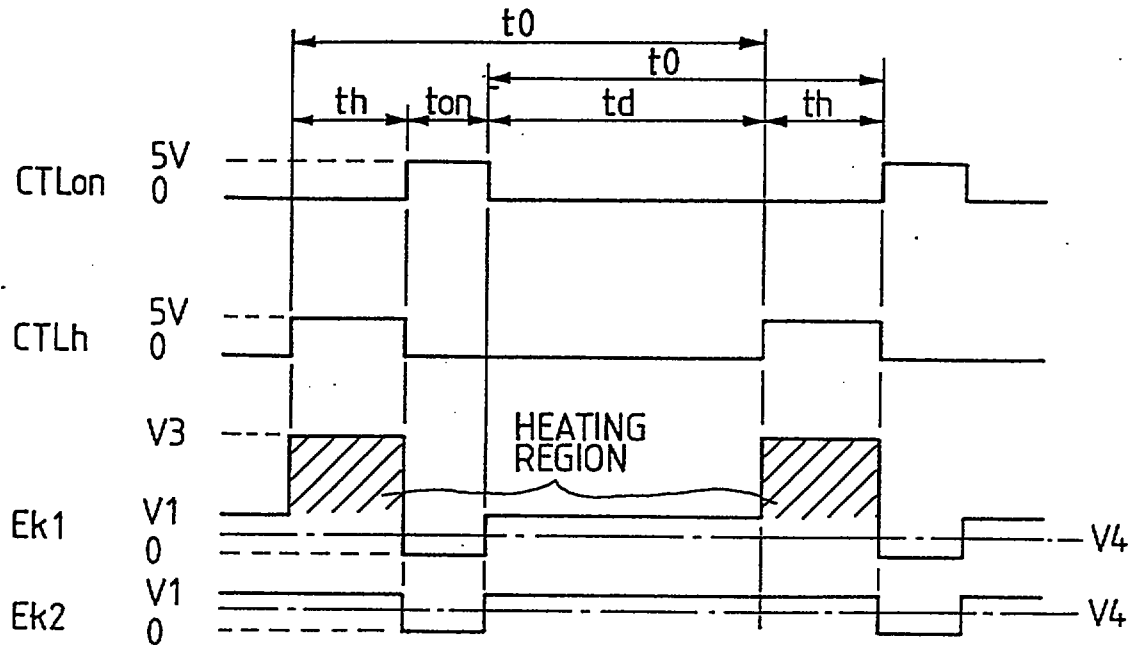
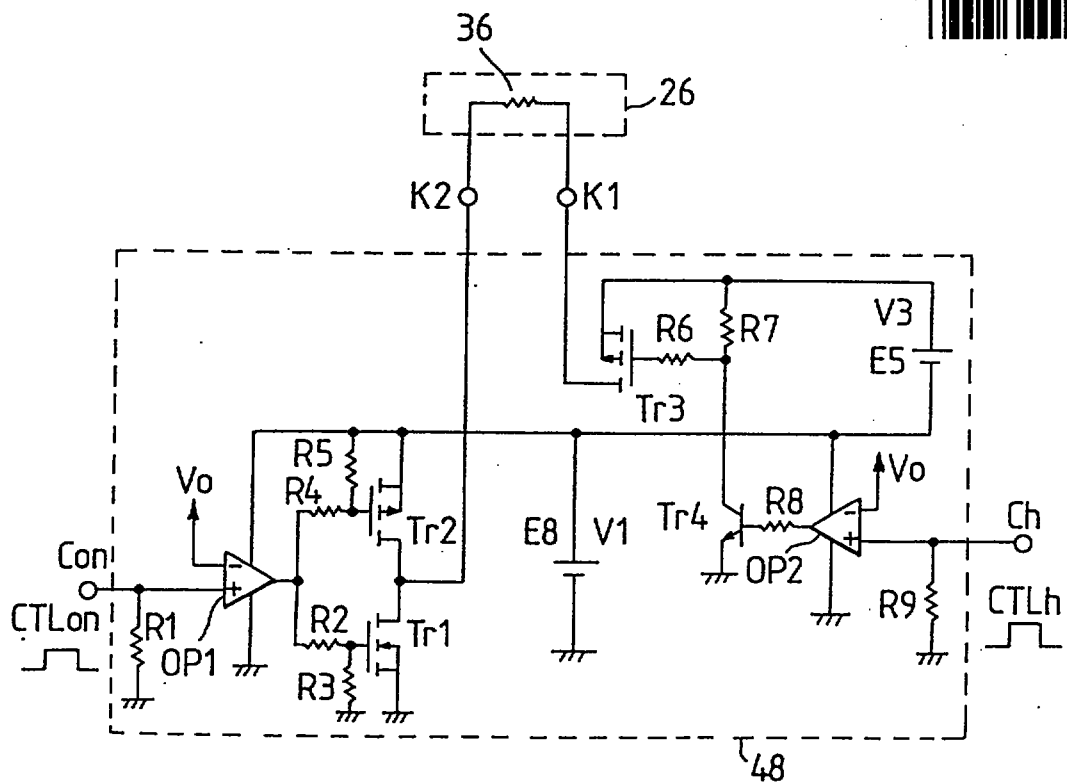


FIG. 6

This Sheet Has Been Replaced

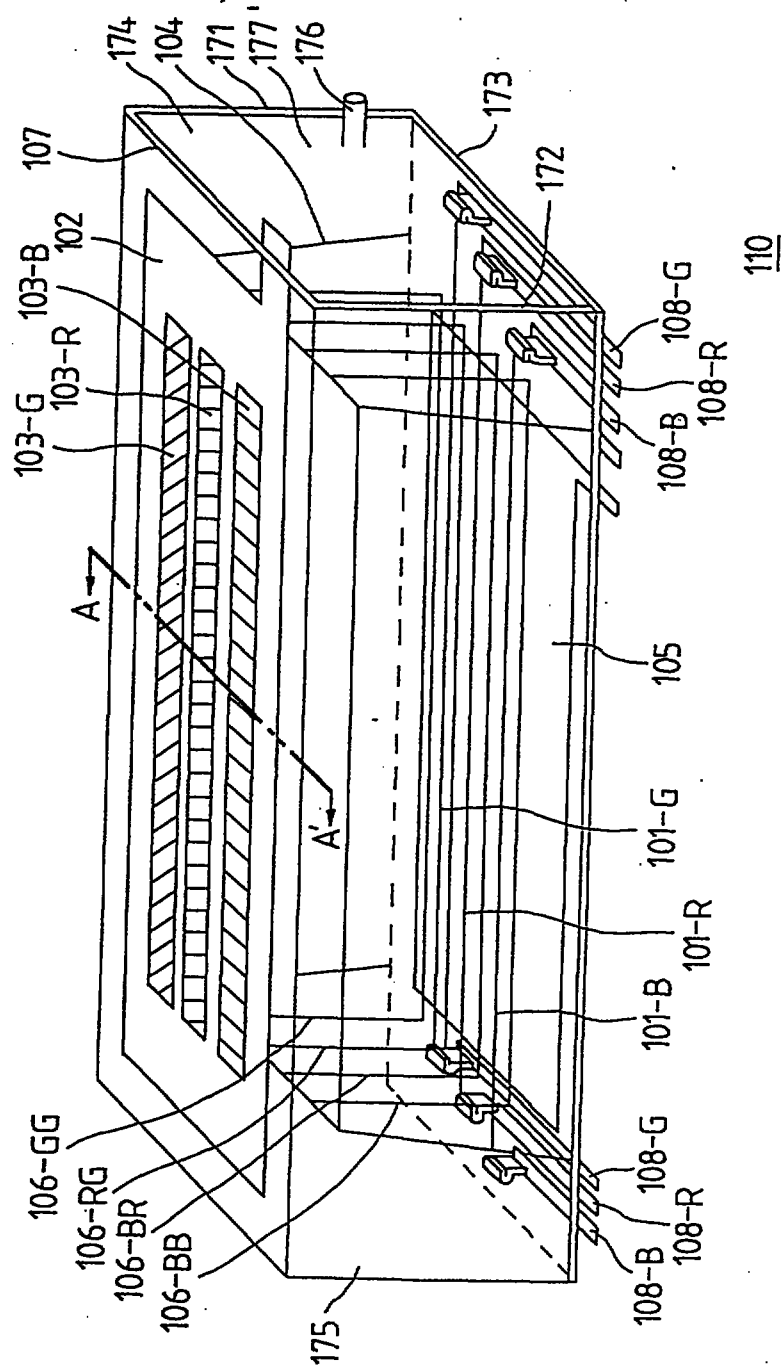


THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET
19 OCT 1996

5

FIG. 9



This Sheet Has Been Replaced



19 OCT 1996

6

FIG. 10

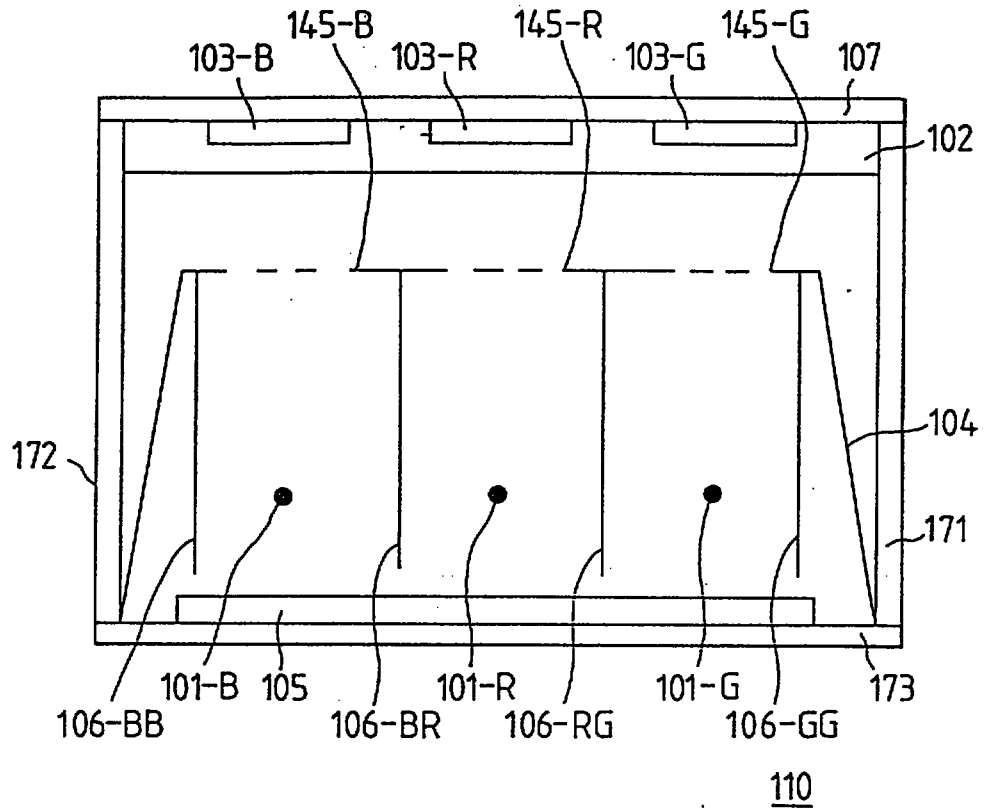
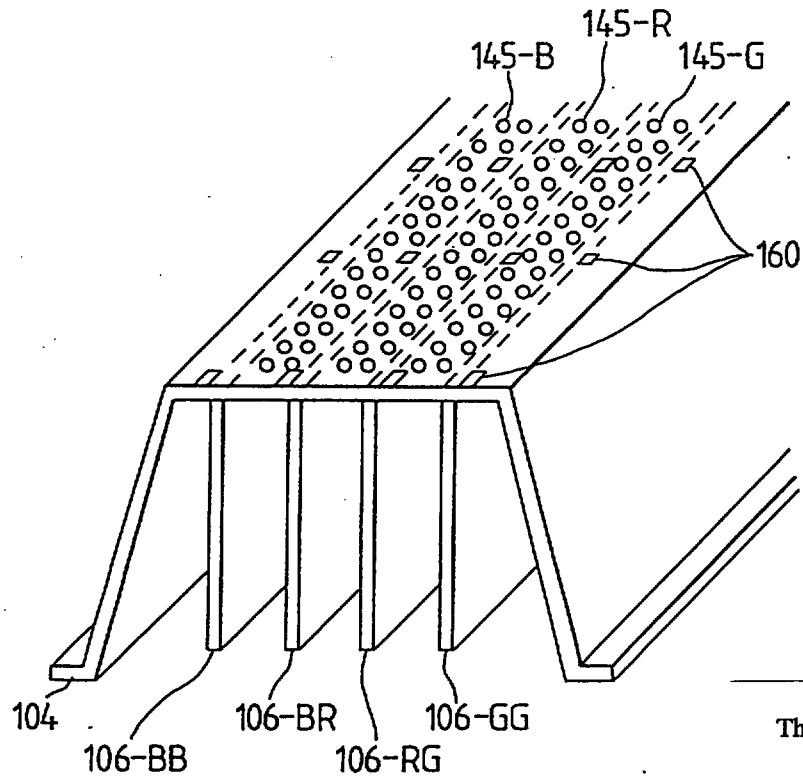


FIG. 11



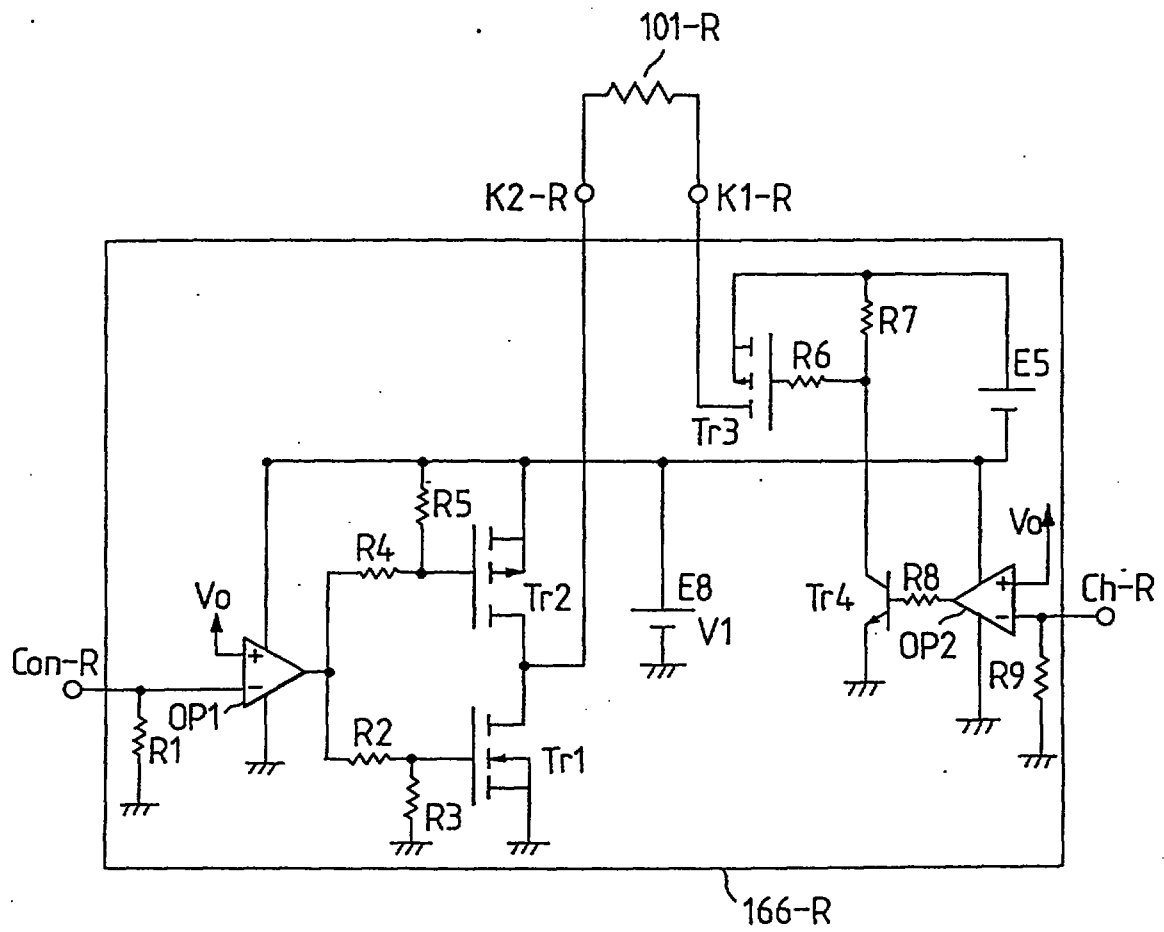
THIS SHEET HAS BEEN
REPLACED

REPLACEMENT SHEET

19 OCT 1996

8

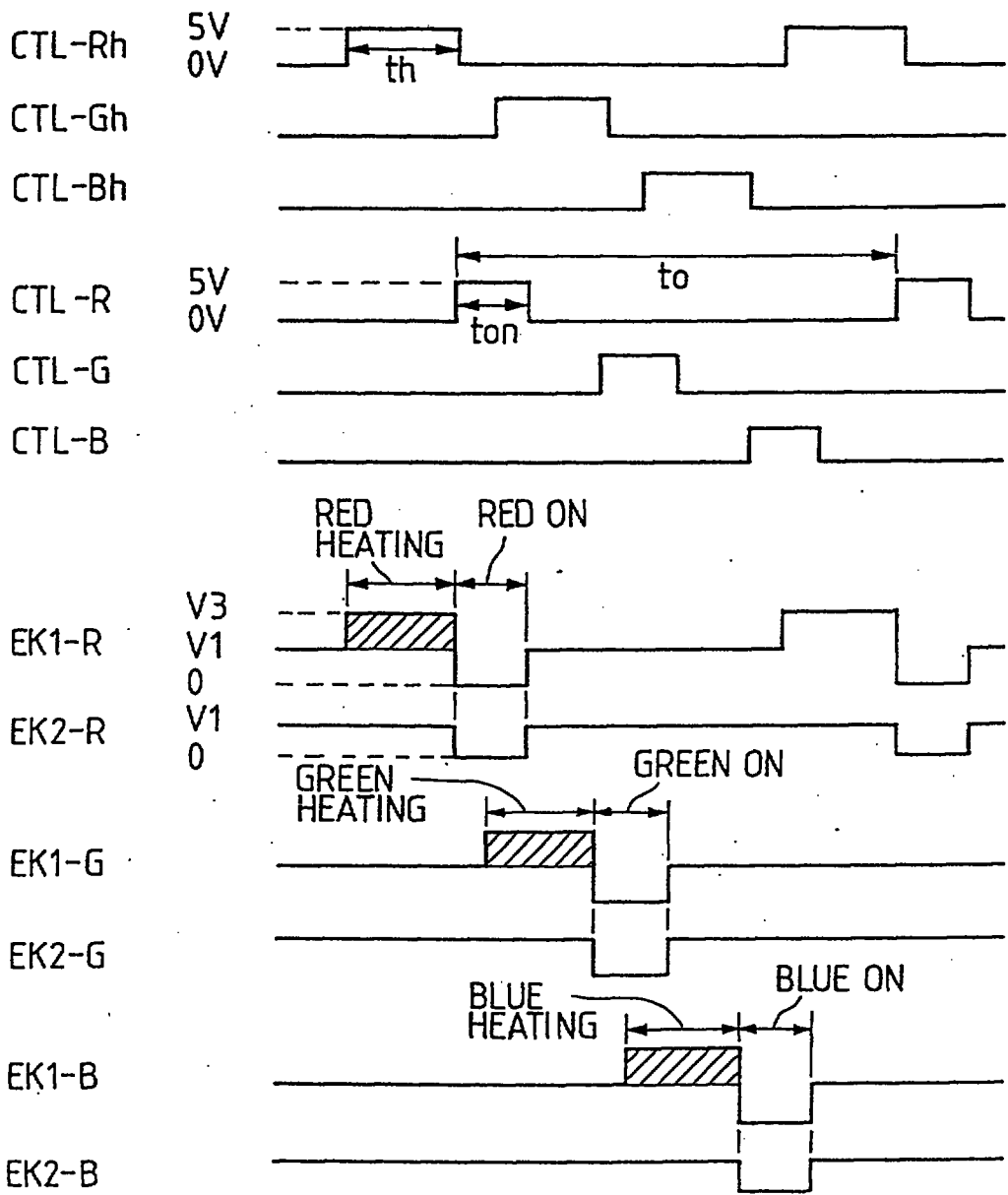
FIG. 14



This Sheet Has Been Replaced



FIG. 15



0-814300



20 JAN 1998

- 1 -

METHOD OF AND CIRCUIT FOR DRIVING CATHODELUMINESCENCE TYPE LIGHTING DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to a method of and an apparatus for driving lighting devices utilizing cathodeluminescence. More particularly, the invention is directed to a method of and a circuit for driving a lighting device suitable for use as a light source for an image input apparatus such as an image scanner, a digital copying machine, or a facsimile machine, or for a large display such as an outdoor television-type display.

In lieu of conventional light sources such as fluorescent lamps and line halogen lamps used as a line light source in an image input apparatus or the like, a light source utilizing cathodeluminescence, such as disclosed in Japanese Patent Unexamined Publication No. 73970/1981, has been proposed as a light source having low power consumption.

FIG. 1 is a sectional view of a conventional cathodeluminescence type light source. The construction of the conventional light source will be described with reference to FIG. 1.

Reference numeral 10 designates a glass tube that is evacuated to a predetermined degree of vacuum. Along the length of the glass tube 10 extends a cathode 12. Reference numeral 14 designates a glass substrate, a front surface of which is coated with a phosphor 16. An anode 18 is deposited on the phosphor 16. The anode 18 is made of an aluminum thin film that serves as a metal backing. A grid 20, which is a control electrode, is interposed between the cathode 12 and the anode 18, and is made of a metal plate having slits 11 of a length of about 0.3 to 1 mm. Commonly used as the phosphor materials are those including zinc sulfide (ZnS) as a base material, such as ZnS with copper (Cu) and aluminum (Al). The light-emitting efficiency of these phosphor materials is high.

A high voltage of about 8 kV is applied to the anode 18 of the light-emitting tube by an ordinary power supply E2, whereas a voltage V4 on the order of several volts is applied to the grid 20 by a power supply E4.

A driving method will be described next. Japanese Patent Unexamined Publication No. 3740/1978 discloses a method of driving the cathodeluminescence type light source. FIG. 2 is a timing chart for driving such light source. CT1 on designates a lighting signal input to a cathode drive circuit

20 JAN 1998

- 2 -

(not shown). Cathode drive signals E_{k1} and E_{k2} , which are output signals generated from the cathode drive circuit, are applied to the terminals K1 and K2 of the cathode 12 of the light-emitting tube shown in FIG. 1. The generation of the lighting signal CTLon is repeated with a cycle time t_0 based on a turning-off period t_{off} and a lighting period t_{on} .

During the turning-off period t_{off} , the voltages of the cathode drive signals E_{k1} and E_{k2} are V_2 and V_1 , respectively. The voltages V_2 and V_1 are higher than the voltage V_4 applied to the grid 20. When the voltages V_2 and V_1 are applied to the terminals K1 and K2 of the cathode 12, a difference in voltage $\Delta V = V_2 - V_1$ is supplied to the cathode 12 to cause the surface of the cathode to easily release thermoelectrons 24 (described later) by Joule heating.

However, since the voltages V_2 and V_1 applied to the terminals K1 and K2 of the cathode 12 are higher than the voltage V_4 applied to the grid 20, there is no emission of thermoelectrons 24 from the cathode 12.

During the lighting period t_{on} , the voltages of the cathode drive signals E_{k1} and E_{k2} both are 0 V. Since the voltage of the cathode 12 is lower than the voltage V_4 applied to the grid 20, the cathode 12 is heated by remaining heat, releasing thermoelectrons 24.

The thermoelectrons 24 pass through the slits 11 of the grid 20 and collide against the anode 18, to which the high voltage is applied. The thermoelectrons 24, having passed through the anode 18 formed of a thin film, collide against the phosphor 16, causing cathodeluminescence to occur.

The rate at which thermoelectrons are emitted from the surface of the cathode 12 depends on the surface temperature of the cathode 12. When a thermoelectron emitting substance called an emitter material (not shown) is coated on the surface of the cathode 12, thermoelectrons are usually emitted therefrom at an adequate rate at surface temperatures of 500° to 700°. However, if the temperature is too high, evaporation of the emitter material is promoted, reducing the rate of emission of thermoelectrons. As a result, the amount of light emitted from the light source is impaired drastically. On the other hand, if the temperature is too low, the emission of thermoelectrons is not sufficient. To overcome this problem, three points, namely, the conduction voltage, the cathode resistance, and the conduction duty cycle at the time of operation (i.e., the ratio of the off period t_{off} to the lighting cycle t_0 in FIG. 2) relevant to heating the cathode must be properly selected before driving the cathode.

20 JAN 1998

- 3 -

However, in a lighting device used for an image input apparatus or the like, the integrated value of an amount of light stored in a CCD of a photoelectric transducer of the apparatus is made adjustable by making the lighting period t_{on} of the lighting device variable to increase the accuracy of the output signal from the CCD. However, if the lighting period t_{on} is varied in the conventional drive circuit, the off period t_{off} must also be varied (assuming the lighting cycle time t_0 is fixed). That is, the conduction duty cycle must be varied, which puts the surface temperature of the cathode 12 out of proper range, thus shortening the life of the light-emitting tube.

SUMMARY OF THE INVENTION

The invention has been made in view of such problems. Accordingly, an object of the present invention is to provide a method for driving a cathodeluminescence type lighting device that can adjust the lighting period variably and maintain a long life of the lighting device.

A driving method provided by the invention repeats, at a predetermined lighting cycle, the steps of: heating a cathode of the lighting device by electric conduction to the cathode; emitting light by causing the cathode to release electrons without conduction to the cathode; and reposing without causing the cathode to release electrons with no conduction to the cathode. At least the period of the light-emitting step and the period of the reposing step are variable.

Further, a driving circuit provided by the invention includes: a first control section for controlling a potential of a first terminal of the cathode; and a second control section for controlling a potential of a second terminal of the cathode. The first control section and the second control section operate during a lighting period, a heating period, and a dummy period. The lighting period, the heating period, and the dummy period are repeated at a predetermined lighting cycle and are successively generated. The first control section controls the potential of the first terminal to a potential lower than a potential of the control grid during the lighting period, and controls the potential of the first terminal to a potential higher than the potential of the control grid during the periods other than the lighting period. The second control section controls the potential of the second terminal to a potential higher than the potential of the control grid and different from the potential of the first terminal during the heating period, and controls the potential of the second terminal to a potential equal to the potential of the

20 JAN 1998

- 4 -

first terminal during the periods other than the heating period.

The invention is characterized as having the heating period, the lighting period, and the reposing period in a single lighting cycle. When the lighting period is adjusted variably, the heating period can be maintained constant by varying the reposing period in accordance with the adjustment of the lighting period. Therefore, even if the lighting period is adjusted, the temperature of the cathode can be maintained within a proper range, thereby contributing to extending the service life of the light-emitting tube.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view showing the construction of a conventional light source utilizing cathodeluminescence;

FIG. 2 is a timing chart of a cathode drive circuit in the conventional light source;

FIG. 3 is a perspective view showing an example of a light-emitting tube to which a drive circuit of the invention is applied;

FIG. 4 is a diagram showing in block form an exemplary drive circuit of the invention for the light-emitting tube shown in FIG. 3, together with a schematic sectional view of the light-emitting tube;

FIG. 5 is a timing chart illustrating the operation of a cathode drive circuit within the drive circuit of FIG. 4;

FIG. 6 is a circuit diagram showing an example of the cathode drive circuit performing the operation of FIG. 5;

FIG. 7 is a circuit diagram showing another example of the cathode drive circuit within the drive circuit of FIG. 4;

FIG. 8 is a timing chart illustrating the operation of the cathode drive circuit of FIG. 7;

FIG. 9 is a perspective view showing a light-emitting tube 110 of a lighting device for a color image input apparatus to which a drive circuit of the invention is applied;

FIG. 10 is a sectional view taken along a line A—A' of FIG. 9;

FIG. 11 is a partially enlarged view showing a grid electrode 104 and separators 106-BB, 106-BR, 106-RG, and 106-GG in FIG. 9;

FIG. 12 is a partially enlarged view showing the grid electrode 104 and inverted C-shaped separators 161-B,

20 JAN 1998

- 5 -

161-R, and 161-G, which can be applied to the light-emitting tube of FIG. 9;

FIG. 13 is a diagram showing in block form an example of a drive circuit of the invention for the light-emitting tube 110 together with a partial sectional view of the light-emitting tube 110;

FIG. 14 is a circuit diagram of a red light-emitting circuit 166-R within the cathode drive circuit 166 of FIG. 13; and

FIG. 15 is a timing chart illustrative of an operation of the cathode drive circuit 166.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the invention will hereunder be described in detail with reference to the drawings.

FIG. 3 is a perspective view showing an example of a cathodeluminescence type lighting tube to which a drive circuit of the invention is applied. A phosphor 16 for cathodeluminescence is coated on the inner surface of a front plate 28 of the light-emitting tube 26 in quantities of 0.1 to 100 mg/cm², most preferably 4 mg/cm², along the length of the light-emitting tube 26. The phosphor 16 is covered with an anode 30 made from aluminum, the anode being formed by vacuum evaporation in thicknesses of 0.1 to 0.4 μ m.

A back electrode 34 extends on the inner surface of a back plate 32 of the light-emitting tube 26 along the length of the back plate 32. The back electrode 34 is made from aluminum by vacuum evaporation or the like. Immediately above the back electrode 34 is a wire-like cathode 36. The cathode 36 is a tungsten thin wire 50 to 100 μ m in diameter. An emitter material (not shown) is coated on the surface of the cathode 36. A grid 40 made of a metal plate that has a plurality of apertures 42 formed by blanking, electroforming or the like, is arranged at such a position as to shield the anode 30 from the cathode 36. The anode 30, the grid 40, the cathode 36, and the back electrode 34 are electrically driven to conduct by a drive circuit 44 (described later) via a terminal that extends externally from the light-emitting tube. Reference numeral 46 designates an evacuating tube that evacuates the light-emitting tube to a pressure of about 100 to 0.1 mPa. The light-emitting tube is thereafter sealed by melting the evacuating tube 46 by heating with a gas burner.

FIG. 4 shows in block form an example of a drive circuit of the invention for the light-emitting tube 26 shown in FIG. 3, together with a schematic sectional view of the light-emitting tube 26.

20 JAN 1998

- 6 -

A drive circuit 44 includes three dc constant voltage power supplies E2 to E4 and a cathode drive circuit 48 for lighting control.

A high voltage on the order of 8 kV is applied to the anode 30 by the power supply E2. A voltage V4 on the order of several volts is applied to the grid 40 by the power supply E4. An appropriate voltage is applied to the back electrode 34 by the power supply E3. Such voltages are applied to maximize the amount of thermoelectrons emitted by the cathode 36. Both terminals K1 and K2 of the cathode 36 are connected to the cathode drive circuit 48.

FIG. 5 is a timing chart illustrating the operation of the cathode drive circuit 48. CTLon and CTLh designate signals input to a lighting signal input terminal Con and a heating signal input terminal Ch, respectively. Reference characters Ek1 and Ek2 designate drive voltage signals supplied to the terminals K1 and K2, respectively.

During a period t_h (heating period), the cathode drive voltage signal Ek1 is a predetermined voltage V3 (e.g., 23 V), and the other cathode drive voltage signal Ek2 is a predetermined voltage V1 (e.g., 8 V). Then, a difference in voltage $\Delta V = V3 - V1$ is produced between the terminals K1 and K2 of the cathode 36, enabling the surface of the cathode 36 to easily emit thermoelectrons 24 by Joule heating.

However, since the voltages V3 and V1 respectively applied to the terminals K1 and K2 of the cathode 36 are higher than the potential V4 applied to the grid 40, no thermoelectrons 24 are emitted from the cathode 36.

Then, during a period t_{on} (lighting period), which is between the moment at which the lighting signal CTLon rises from 0 V to 5 V and the moment at which the lighting signal CTLon drops to 0 V again, both cathode drive voltage signals Ek1 and Ek2 are 0 V, which makes the voltage at the cathode 36 lower than the applied voltage V4. As a result, the thermoelectrons 24 are released from the cathode 36 heated by the remaining heat. The thermoelectrons 24 pass through the apertures 42 of the grid 40 and collide against the anode 30 to which a high voltage has been applied. Further, the thermoelectrons 24 having passed through the anode 30 made of a thin film then collide against the phosphor 16 to produce cathodeluminescence.

Lastly, during a period t_d (dummy period), the lighting signal CTLon and the heating signal CTLh are both at 0 V. As a result, the voltage of both cathode drive signals Ek1 and Ek2 is V1. Since there is no difference in voltage between both terminals of the cathode 36, the cathode 36 is not heated in a manner similar to the lighting period t_{on} . Further, since

20 JAN 1998

- 7 -

the voltage V_1 applied to the terminals K1 and K2 of the cathode 36 is higher than the voltage V_4 applied to the grid 40, no thermoelectrons 24 are emitted from the cathode 36.

In this timing chart, to variably adjust the lighting period t_{on} , the cycle time t_0 and the heating period t_h are fixed, whereas the lighting period t_{on} is varied within the range of $t_0 - t_h$. Accordingly, only the luminous duty cycle can be varied with the heating duty cycle maintained constant.

FIG. 6 shows an exemplary circuit of the cathode drive circuit 48 shown in FIG. 5.

This cathode drive circuit 48 has two operational amplifiers OP1 and OP2, to which the dc voltage V_1 is applied by a power supply E8 as a supply voltage. A threshold voltage V_0 (e.g., 1.5 V) is applied to both inverting input terminals (-).

One of the operational amplifiers OP1 has a non-inverting input terminal (+) connected to the signal input terminal Con so that the lighting signal CTLon can be received thereby, and the output terminal thereof is connected to the control gates of two complementary transistors Tr1 and Tr2 through a set of dividing resistors R2 and R3 and through a set of dividing resistors R5 and R4, respectively. The output terminals of the complementary transistors Tr1 and Tr2 are connected to the cathode terminal K2.

The other operational amplifier OP2 has a non-inverting input terminal (+) connected to the signal input terminal Ch so that the heating signal CTLh can be received thereby, and the output terminal thereof connected to the base of a switching transistor Tr4 through a resistor R8. The emitter of the switching transistor Tr4 is grounded, and the collector thereof is connected to the control gate of the transistor Tr3 through a resistor R6. The voltage V_3 which is a voltage combination of the voltage V_1 of the power supply E8 with a voltage of the power supply E5 is applied to the control gate of the transistor Tr3 through a resistor R7. The voltage V_3 is also applied to the source of the transistor Tr3. The drain of the transistor Tr3 is connected to the other cathode terminal K1.

The operation of the circuit will be described below. An operation during the heating period t_h will be described first.

When the heating signal CTLh has risen to 5 V from 0 V, the output voltage of the operational amplifier OP2 rises to V_1 from 0 V, which causes the transistor Tr4 to turn on and the potential of a node of the resistors R7 and R6 to become almost 0 V. Then, since the transistor Tr3 turns on, the voltage V_3 is applied to the terminal K1 of the cathode 36.

20 JAN 1998

- 8 -

During this heating period t_h , the output voltage of the operational amplifier OP1 is 0 V. As a result, the transistor Tr1 turns off, whereas the transistor Tr2 turns on, which causes the power supply E8 to apply the voltage V1 to the terminal K2 of the cathode 36.

As the voltages V3 and V1 are then applied to the terminals K1 and K2 of the cathode 36, the cathode 36 is heated with current passing therethrough.

The operation of the circuit during the lighting period t_{on} will be described next.

When the lighting signal CTLon has risen to 5 V from 0 V, the output voltage of the operational amplifier OP1 becomes V1. Since this causes the transistor Tr1 to turn on and the transistor Tr2 to turn off, the voltage at the terminal K2 of the cathode 36 is almost 0 V.

Since the heating signal CTLh is at 0 V in this instance, the output voltage of the operational amplifier OP2 is 0 V, leaving the transistor Tr4 turned off. As a result, the transistor Tr3 is turned off, which opens the current loop flowing through the cathode 36. Consequently, the terminal K1 of the cathode 36 is at 0 V, which is equal to the potential at the terminal K2.

The operation of the circuit during the dummy period (t_d) will be described.

When the lighting signal CTLon has dropped to 0 V from 5 V, the output voltage of the operational amplifier OP1 drops to 0 V. Then, the transistor Tr1 is turned off, and the transistor Tr2 turns on, causing the voltage at the terminal K2 of the cathode 36 to become the voltage V1 of the power supply E8.

Since the heating signal CTLh is at 0 V at this time, similar to the lighting period t_{on} , the current loop flowing through the cathode 36 is open. As a result, the potential at the terminal K1 of the cathode 36 is V1, which is equal to the potential at the terminal K2.

In the drive circuit shown in FIGS. 5 and 6, the heating duty cycle of the cathode 36 is t_h/t_0 . Thus, if the lighting cycle t_0 and the heating period t_h are kept constant at all times, then the heating duty cycle is constant, thereby keeping the surface temperature of the cathode within a predetermined range. The lighting period t_{on} can be variably adjusted independently of the heating period t_h by using the dummy period t_d .

The variable range of the lighting period t_{on} is between 0 and $t_0/14 t_h$. Therefore, the variable range of the lighting period t_{on} can be increased by increasing the voltage V3 of

20 JAN 1998

- 9 -

the cathode drive signal E_{k1} during the heating period t_h shown in FIG. 5 as much as possible, so that the heating duty cycle can be decreased, i.e., the period t_h can be shortened as much as the voltage V_3 is increased.

FIG. 7 shows another exemplary circuit that can be used as the cathode drive circuit 48 of FIG. 4, and FIG. 8 is a timing chart showing an operation thereof.

The circuit shown in FIG. 7 is advantageous in that the construction thereof is simpler than the circuit shown in FIG. 6.

Further, the operation shown in FIG. 8 has a feature that the lighting period t_{on} comes first and that the heating period t_h starts in response to the end of the lighting period t_{on} . More specifically, the lighting signal CTL_{on} is generated at an independent timing, whereas the heating signal CTL_h is generated at a timing dependent on the lighting signal CTL_{on} . One of the advantages in this system is that when the lighting device is used as a light source of an image input apparatus, the image reading period can be easily synchronized with the lighting period. The reason is that the lighting signal CTL_{on} can be generated in direct synchronism with a pulse signal that is generated by the image input apparatus and synchronized with the reading period. In contrast thereto, in the operation shown in FIG. 5, the lighting signal CTL_{on} is generated at a timing dependent on the heating signal CTL_h causing the lighting signal CTL_{on} to rise upon dropping of the heating signal CTL_h . Therefore, the lighting signal CTL_{on} cannot be generated in direct synchronism with the pulse signal from the image input apparatus.

The circuit illustrated in FIG. 7 will be described below.

A transistor $Tr11$ receives the lighting signal CTL_{on} on the base thereof through a resistor $R11$. The emitter thereof is grounded, and the collector thereof is connected to a dc constant voltage supply (e.g., $24\text{ V} \pm 10\%$) through a resistor $R12$ and to the base of a transistor $Tr12$. The transistor $Tr12$ is connected to the above-mentioned dc constant voltage supply; the emitter thereof is connected to the terminal $K2$ of the cathode and grounded through a resistor $R13$. Between the base of the transistor $Tr12$ and ground is connected a zener diode $ZD1$ whose zener voltage is, e.g., 25.8 V and whose function is to clamp variations in the dc voltage supply on the high side of the nominal voltage.

A transistor $Tr13$ receives the heating signal CTL_h on the base thereof through a resistor $R14$. The emitter thereof is grounded, and the collector is connected to the base of a transistor $Tr14$ through a zener diode $ZD2$ whose zener voltage is, e.g., 7.4 V and which is connected in the forward direction. The transistor $Tr14$ has a resistor $R15$ interposed

20 JAN 1998

-10 -

between the emitter and the base thereof, with the emitter connected to the terminal K1 of the cathode and the collector grounded.

The operation of the circuit will be described with reference to FIGS. 7 and 8.

As shown in FIG. 8, upon initiation of the lighting cycle t_0 , the lighting signal CTLon rises to 5 V from 0 V and drops to 0 V after a predetermined lighting period t_{on} . In response to the drop of the lighting signal CTLon, the heating signal CTLh rises to 5 V from 0 V and drops to 0 V after a predetermined heating period t_h .

Referring to FIG. 7, upon rising of the lighting signal CTLon at the start of the lighting period t_{on} , the transistor Tr11 turns on and the transistor Tr12 turns off. As a result, the terminal K2 of the cathode 36 is grounded to be at 0 V, as shown in FIG. 8.

Since the heating signal CTLh is at 0 V at this time, the transistor Tr13 is turned off, which means that the transistor Tr14 is turned off as well. Therefore, the current loop flowing through the cathode 36 is open. As a result, the potential at the cathode terminal K1 becomes 0 V, which is equal to the potential at the other terminal K2.

In this way, the voltage of each of the terminals K1 and K2 of the cathode 36 is 0 V, that is, lower than the grid voltage V4 during the lighting period t_{on} , so that electrons are emitted from the already-heated cathode 36 and collide against the phosphor of the anode after being accelerated by the grid. As a result, the emission of light starts.

At the end of the lighting period t_{on} , the lighting signal CTLon drops, and simultaneously therewith the heating signal CTLh rises. When the lighting signal CTLon drops, the transistor Tr11 turns off, which causes the transistor Tr12 to turn on. As a result, the potential of the cathode terminal K2 connected to the emitter of the transistor Tr12 becomes almost 23 V (V3), which is obtained by subtracting the voltage drop of the transistor Tr12 from the power supply voltage (24 V).

Further, since the transistor Tr13 turns on and the transistor Tr14 turns on at the rising of the heating signal CTLh, the potential of the cathode terminal K1 becomes almost 8 V (V1), which is obtained by adding a base-emitter voltage of the transistor Tr13 to the zener voltage 7.4 V.

In this way, the voltage of one terminal K2 of the cathode 36 is 23 V (V3) and that of the other terminal K1 is 8 V (V1) during the heating period t_h , which causes current to flow through the cathode 36 to heat the cathode 36. However, since the potential V3 of the cathode 36 is higher than the

20 JAN 1998

- 11 -

potential V4 of the grid, no electrons are emitted.

At the end of the heating period t_h , the heating signal CTLh drops. As a result, both transistors Tr13 and Tr14 turn off, which in turn opens the current loop passing through the cathode 36. Since the voltage of the cathode terminal K2 is 23 V (V3) at this time, which is equal to that during the heating period, the voltage of the terminal K1 becomes 23 V (V3) as well. Therefore, no current flows through the cathode 36, which means that the cathode 36 is not heated. In addition, since the potential V3 of the cathode 36 is higher than the potential V4 at the grid, there is no emission of light.

The above describes the embodiments applied to the lighting device shown in FIG. 3 for the emission of light of a single color.

Embodiments of the invention to be applied to a lighting device for the emission of light of three colors, which can be used for a color image input apparatus, will be described next.

FIG. 9 is a perspective view of an example of a light-emitting tube 110 used as a lighting device for a color image input apparatus to which the invention can be applied.

FIG. 10 is a sectional view taken along a line A—A' in FIG. 9, and FIG. 11 is a partially enlarged view showing a grid electrode 104 and separators 106-BB, 106-BR, 106-RG, and 106-GG in FIG. 9.

The construction of the light-emitting tube 110 will be described below. Red, green, and blue cathodes 101-R, 101-G, and 101-B extend between the grid electrode 104 and a back electrode 105 (both described later) while being supported by cathode support members 108-R, 108-G, and 108-B on both ends thereof, respectively. The cathodes 101-R, 101-G, and 101-B are thin tungsten wires 10 to 50 μm in diameter. The surface of each cathode is coated with an electron emitting substance (not shown) such as barium oxide or the like. The function of the coating is to improve electron emitting efficiency.

The grid electrode 104 is located between the cathodes 101-R, 101-G, 101-B and an anode 102 by bending a plate in trapezoidal form, the plate being electrically conductive such as stainless steel, brass, or aluminum, as well as nonmagnetic. As shown in FIG. 10, the grid electrode 104 is fixed by clamping with glass side plates 171, 172 and a bottom plate 173. As shown in FIG. 11, the grid electrode 104 has four separators 106-BB, 106-BR, 106-RG, 106-GG for partitioning the cathodes. The separators are fixed at a plurality of fixing points 160. These separators are electrically conductive with the grid electrode 104. Further, on a

20 JAN 1998

- 12 -

side of the grid electrode 104 which is opposite to the anode are a plurality of net-like or slit-shaped apertures 145-R, 145-G, 145-B for allowing electrons to pass therethrough, the electrons being generated by the cathodes 101-R, 101-G, 101-B.

Each separator 106 flexes between the fixing points 160 when thermally expanded by heat radiated from the cathode. This causes an inconsistent amount of light. It is desirable to increase the number of fixing points 160 to suppress the flexing as much as possible. Further, it is desirable to bend the upper edge part, the lower edge part, or both of each separator 106 in L form so that the separator 106 becomes hard to flex. Otherwise, as shown in FIG. 12, inverted C-shaped separators 161-B, 161-R, and 161-G may be used.

The back electrode 105 is formed between the cathodes 101-R, 101-G, and 101-B and the glass bottom plate 173. The back electrode 105 is made of carbon paste.

Phosphors of three kinds, namely, a green-emitting phosphor 103-G, a red-emitting phosphor 103-R, and a blue-emitting phosphor 103-B, are sequentially coated on the inner surface of a transparent glass plate 107 by means of screen printing or the like. The phosphors used here are those capable of emitting light by cathodeluminescence, such as yttrium oxysulfide (Y_2O_3S) with europium (Eu) or samarium (Sm) as the red-emitting phosphor, zinc sulfide (ZnS) with copper (Cu) and aluminum (Al) as the green-emitting phosphor, zinc sulfide (ZnS) with silver (Ag) and chlorine (Cl) as the blue-emitting phosphor, and the like.

The anode 102 is formed by depositing a 1 to 10 μm thick layer of aluminum on the inner surface of the phosphor-coated transparent glass plate 107 by means of vacuum evaporation or the like.

Lastly, the surfaces of the glass parts in contact and the interface of the leads externally extending from the light-emitting tube 110 from each electrode are closed with low-melting point glass or the like, put in a high-temperature vessel at 500° to 600° to be fused so that a container 177 including the transparent plate 107, the glass plates 171, 172, 173, 174, and 175 shown in FIG. 9 is formed. Then, when the container 177 is evacuated to a range of 100 to 0.1 mPa by an evacuating tube 176, the container 177 is sealed to maintain the evacuated condition therewithin.

The three-color light-emitting tube 110, when used as a light source for a color image input apparatus, injects light in three colors to a single direction from a substantially single light source. As a result, even if an original having steps or irregularities on the surface is input, excellent color

20 JAN 1998

- 13 -

reproduction free from color mismatching can be obtained.

FIG. 13 shows in block form a drive circuit of the invention for independently producing emissions of light from the phosphors 103-R, 103-G, and 103-B for the respective colors of such light-emitting tube 110.

A drive circuit 167 shown in FIG. 13 includes three dc constant voltage power supplies and a cathode drive circuit 166. The respective cathodes 101-R, 101-G, and 101-B are connected to the cathode drive circuit 166 at both terminals K1-R, K2-R, K1-G, K2-G, K1-B, and K2-B.

FIG. 14 is a circuit diagram of the cathode drive circuit 166. A circuit 166-R in FIG. 14 drives the cathode 101-R for the red color. Two other circuits (of the same construction) are arranged in parallel to drive the cathode 101-G for the green color and the cathode 101-B for the blue color. The three cathodes 101-R, 101G, and 101-B are driven independently by these three circuits.

The circuit shown in FIG. 14 is the same as the cathode drive circuit for the single color light-emitting tube shown in FIG. 6. A lighting signal input terminal Con-R and a heating signal input terminal Ch-R receive a lighting signal CTL-R and a heating signal CTL-Rh for red (see FIG. 15), respectively. The cathode terminals K1-R and K2-R are connected to the cathode 101-R for red.

FIG. 15 is a timing chart showing the operation of the cathode drive circuit 166.

As shown in FIG. 15, the drive signals CTL-Rh, CTL-R for the red color, the drive signals CTL-Gh, CTL-G for the green color, and the drive signals CTL-Bh, CTL-B for the blue color are generated 120° out of phase with one another. The operation of each color is the same as the operation shown in FIG. 5.

The three-color light-emitting tube can, of course, be driven by the three circuits, the construction of each of which is the same as that shown in FIG. 7. In such a case, the operation shown in FIG. 8 is performed per color. The operations of the three colors are 120° out of phase with one another.

While the preferred embodiments of the invention have been described above, the invention is not limited to them, but may be embodied in various other modes.

As described in the foregoing, the invention is characterized as arranging a dummy period in which no heating or lighting is effected during a lighting cycle and making the dummy period and the lighting period variable. Therefore, even if the lighting period is variably adjusted, the heating duty cycle can be maintained constant, thereby allowing the life of the lighting device to be increased.

20 JAN 1998

- 14 -

What is claimed is:

1. A method of driving a cathodeluminescence lighting device, comprising the steps of:

heating a cathode of said cathodeluminescence lighting device by electric conduction;

emitting light by causing the cathode to release electrons absent conduction to the cathode once said cathode is heated; and

delaying initiation of said heating step in a subsequent lighting cycle for a period during which said cathode is not heated and said release of said electrons is terminated, wherein said lighting cycle includes said heating step, said light-emitting step, and said delaying step;

wherein said heating, light-emitting, and delaying steps are repeated at predetermined lighting cycles, and at least a period of said light-emitting step and a period of said delaying step are variable.

2. The method according to claim 1, wherein a ratio of a period of said heating step to the lighting cycle is maintained constant.

3. A method of driving a cathodeluminescence lighting device, comprising the steps of:

heating a cathode of said cathodeluminescence lighting device by electric conduction;

emitting light by causing the cathode to release electrons absent conduction to the cathode once said cathode is heated; and

delaying initiation of said heating step in a subsequent lighting cycle for a period during which said cathode is heated; and

delaying initiation of said heating step in a subsequent lighting cycle for a period during which said cathode is not heated and said release of said electrons is terminated, wherein said lighting cycle includes said heating step, said light-emitting step, and said delaying step;

wherein said heating, light-emitting, and delaying steps are repeated at predetermined lighting cycles, and

at least a period of said light-emitting step and a period of said delaying step are variable;

wherein said method further comprises the step of controlling timings of said heating step, said light-emitting step, and said delaying step, said step of controlling timings determining a timing of said light-emitting step independently of the timings of said heating step and of



* C L M S *

20 JAN 1998

- 15 -

said delaying step and the timings of said heating step and of said delaying step dependent on the timing of said light-emitting step.

4. An apparatus for driving a cathodeluminescence type lighting device having a control grid arranged between a cathode and an anode, said apparatus comprising:

a first control section for controlling a potential of a first terminal of said cathode; and

a second control section for controlling a potential of a second terminal of said cathode;

said first control section and said second control section operating during a lighting period, a heating period, and a dummy period, respectively, wherein said lighting period, said heating period, and said dummy period are repeated at predetermined lighting cycles and are successively generated;

said first control section controlling the potential of the first terminal to a potential lower than a potential of said control grid during said lighting period, and controlling the potential of the first terminal to a potential higher than the potential of said control grid during periods other than said lighting period; and

said second control section controlling the potential of the second terminal to a potential higher than the potential of said control grid and different from the potential of the first terminal during said heating period, and controlling the potential of the second terminal to a potential equal to the potential of the first terminal during periods other than said heating period.

5. The apparatus according to claim 4, wherein said second control section opens a current loop passing through said cathode during periods other than said heating period so that the potential of the second terminal becomes equal to the potential of the first terminal.

6. The apparatus according to claim 4, wherein said second control section controls the potential of the second terminal to a potential higher than the potential of the first terminal during said heating period.

7. The apparatus according to claim 4, wherein said second control section controls the potential of the second terminal to a potential lower than the potential of the first terminal during said heating period.

8. The apparatus according to claim 4, wherein

said first control section operates in response to a lighting signal indicating said lighting period;

said second control section operates in response to a heating signal indicating said heating period;



* C L M S *

20 JAN 1998

- 16 -

said apparatus further comprising:

a signal generating section for generating said lighting signal and said heating signal, said signal generating section determining a timing for generating said lighting signal independently of said heating signal and a timing for generating said heating signal dependent on said lighting signal.



* C L M S *

20 JAN 1998

- 1 -

FIG. 1 PRIOR ART

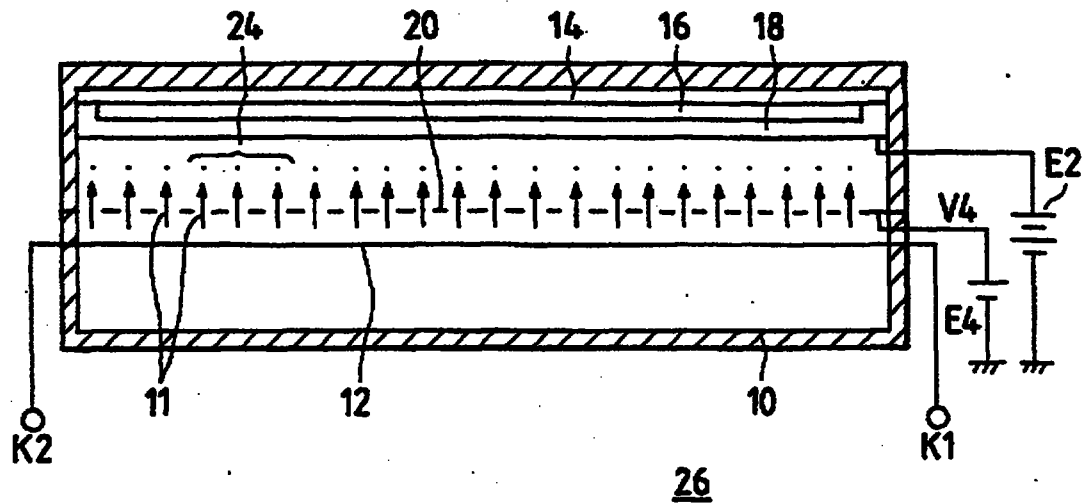
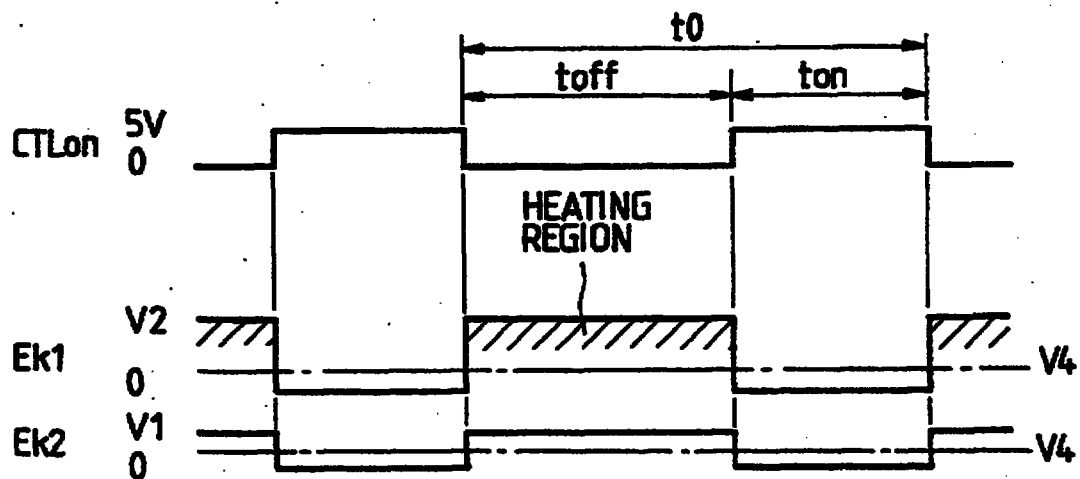


FIG. 2 PRIOR ART



20 JAN 1998

- 2 -

FIG. 3

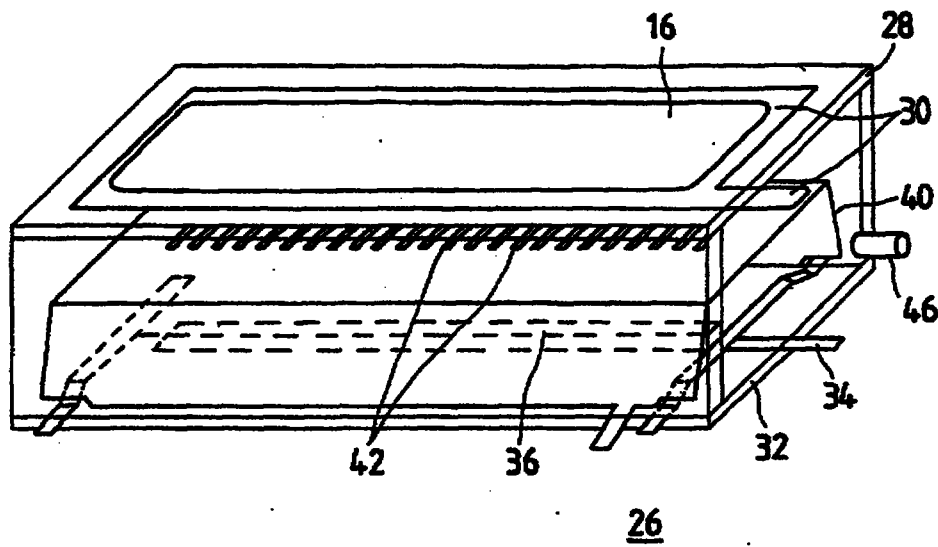
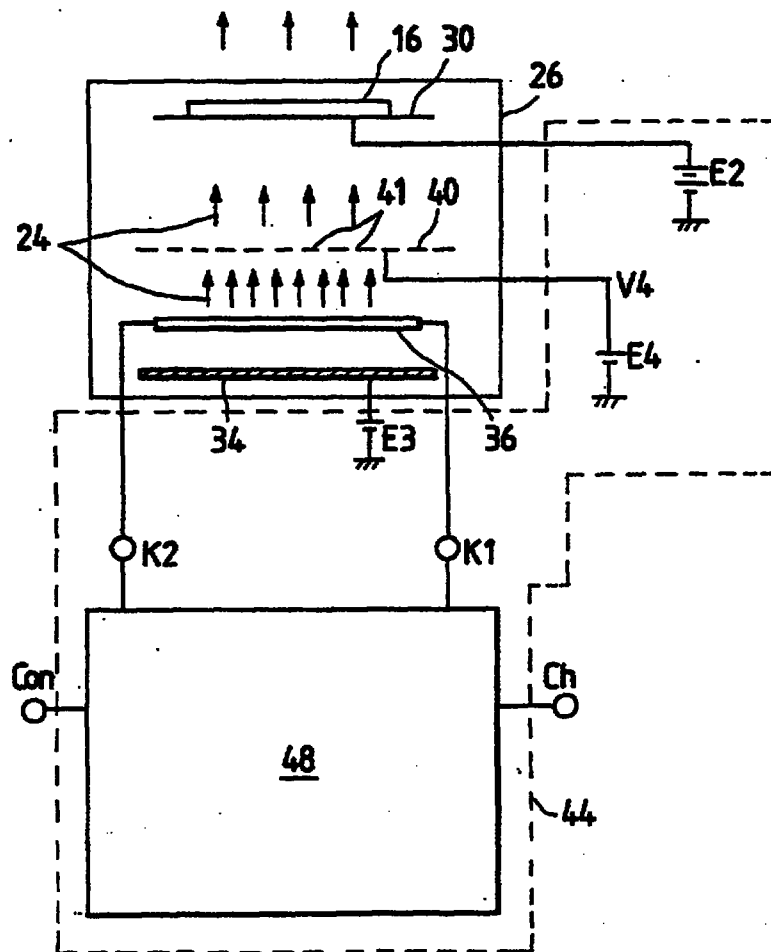


FIG. 4



20 JAN 1998

- 3 -

FIG. 5

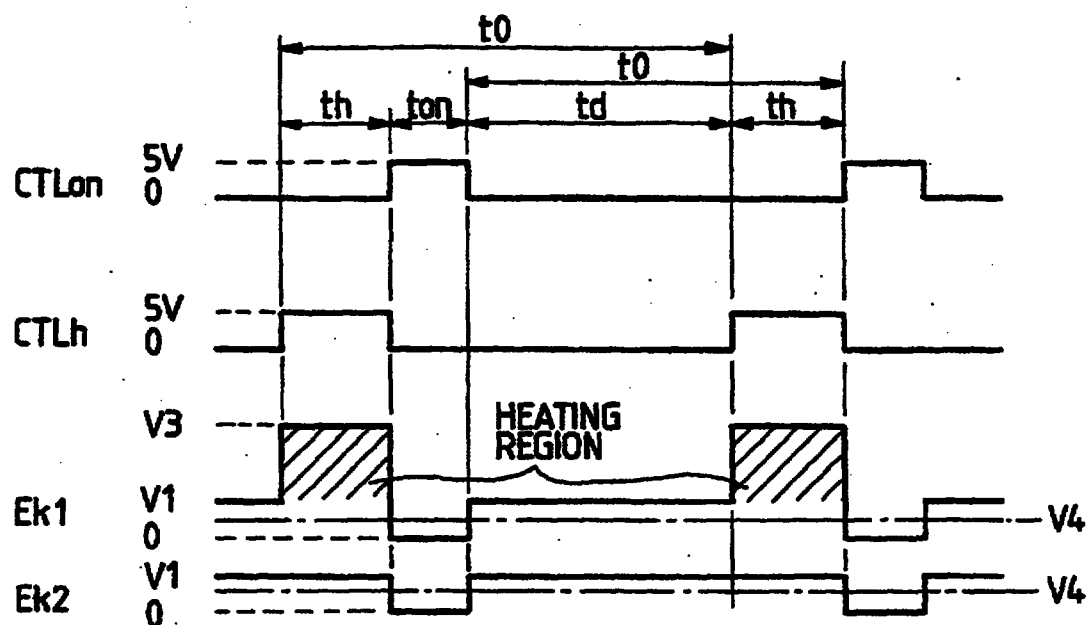
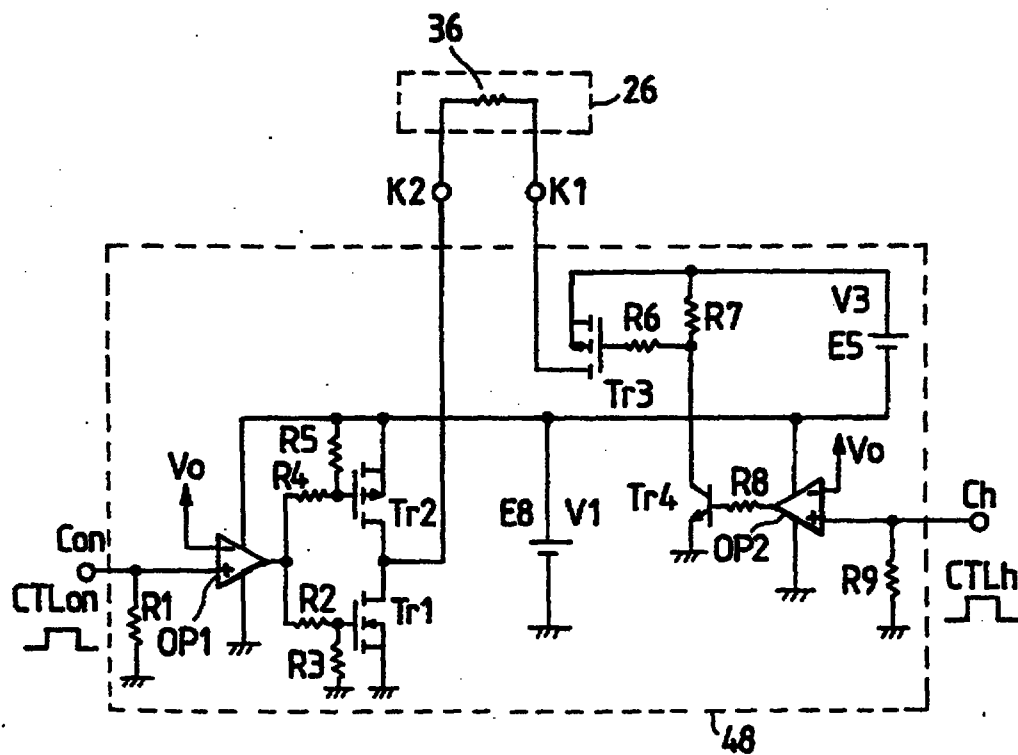


FIG. 6



20 JAN 1998

FIG. 7

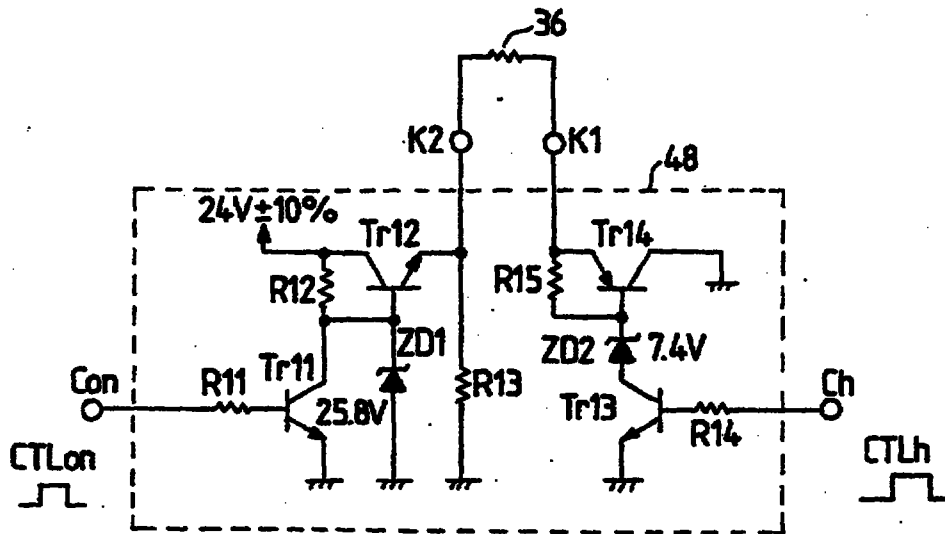
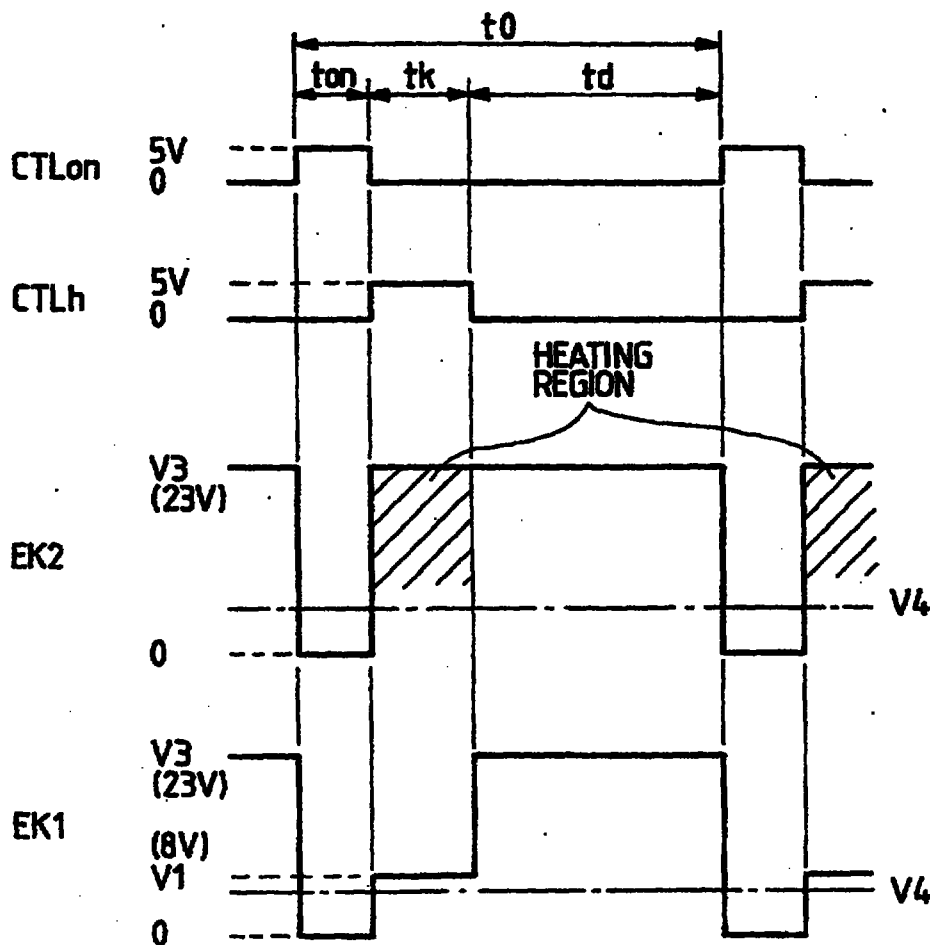
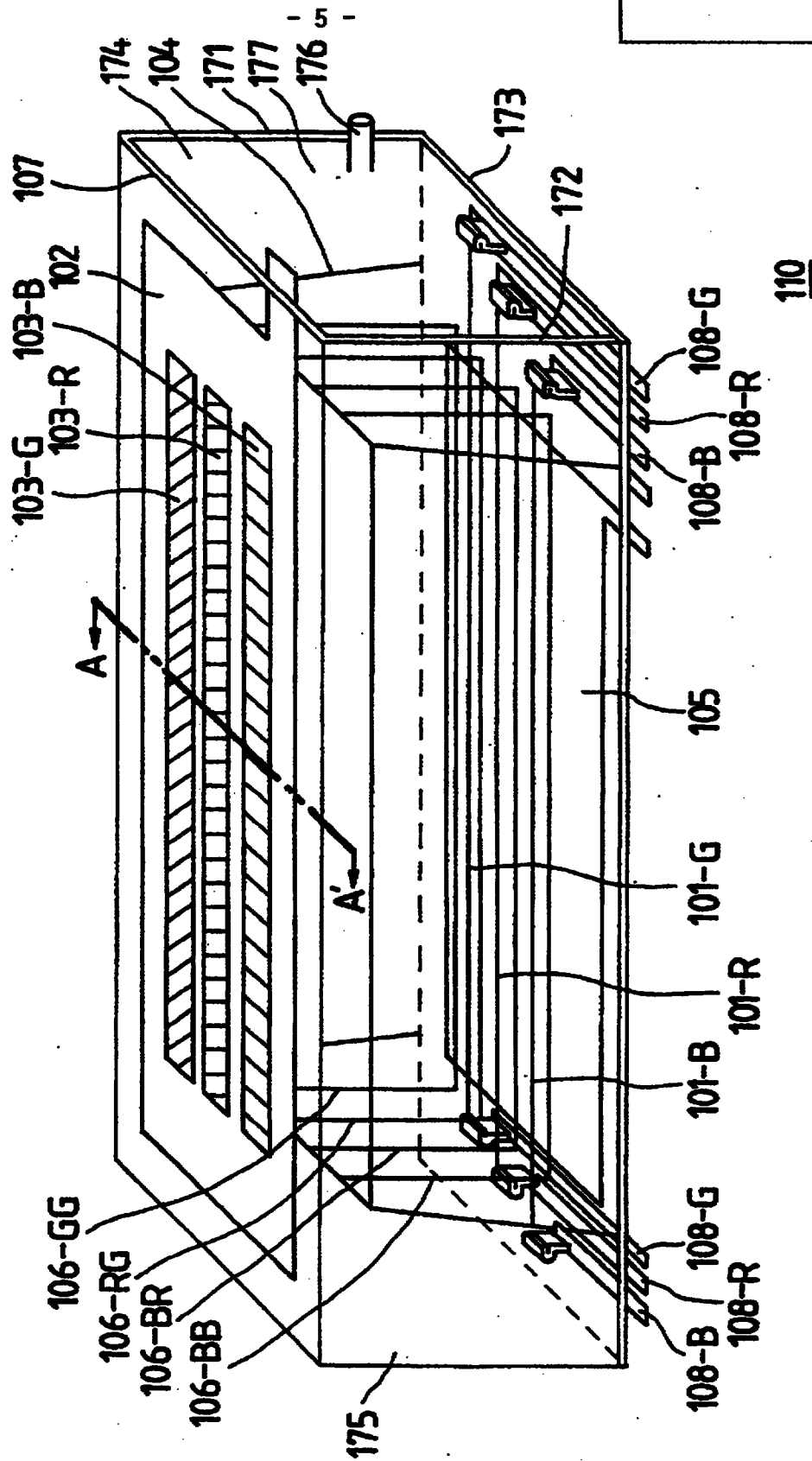


FIG. 8



20 JAN 1998

FIG. 9



20 JAN 1998

- 6 -

FIG. 10

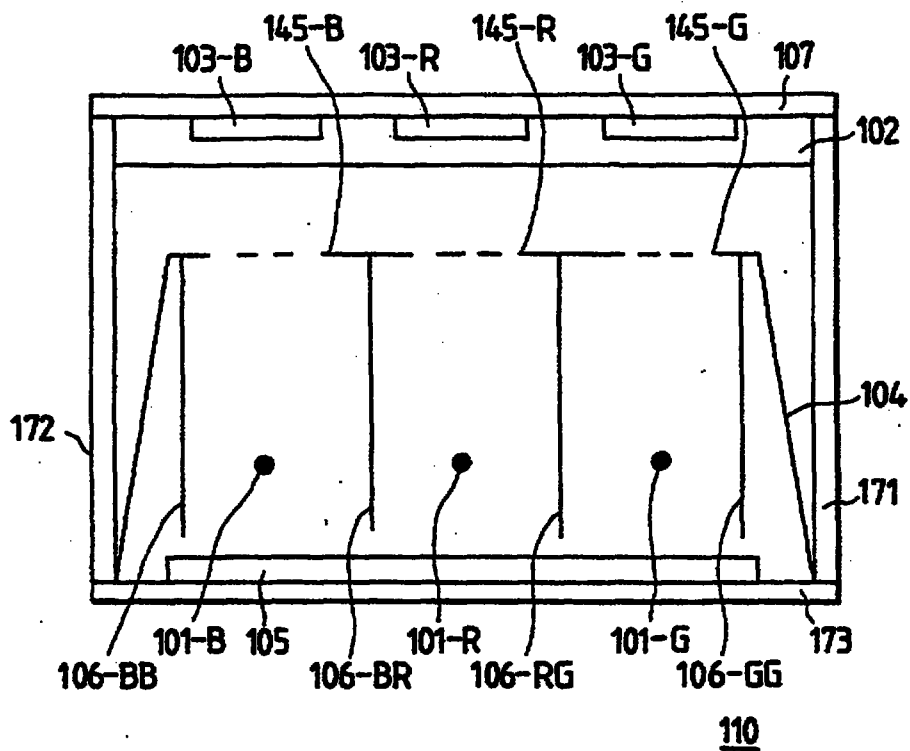
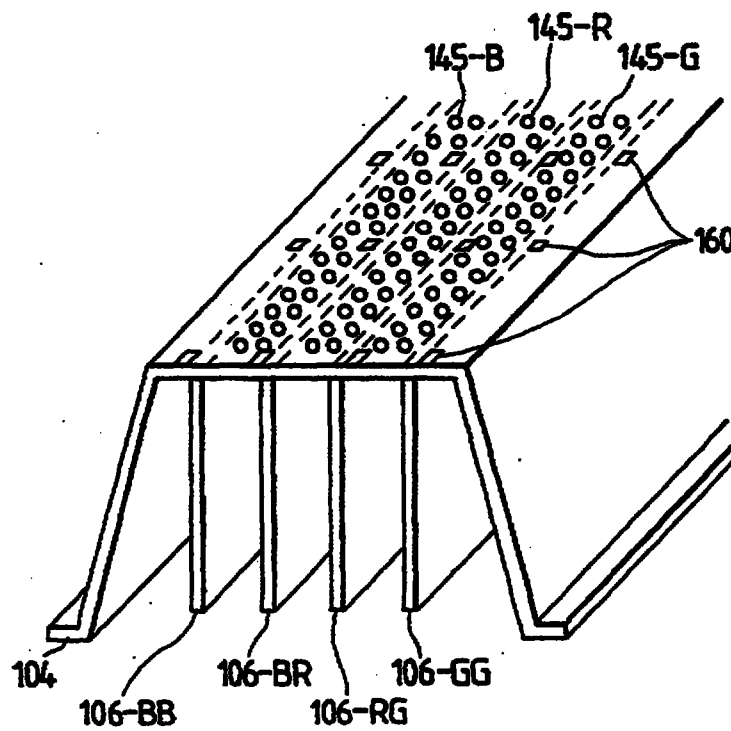


FIG. 11



20 JAN 1998

- 7 -
FIG. 12

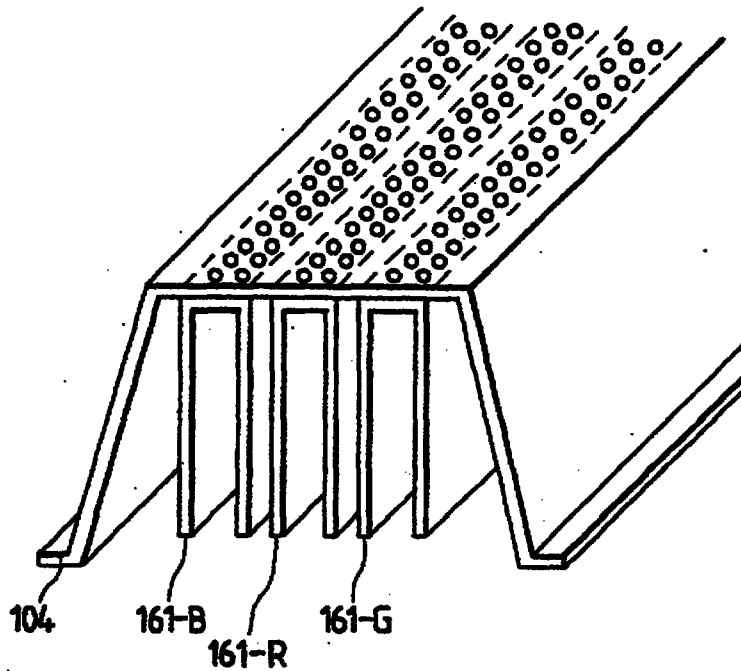
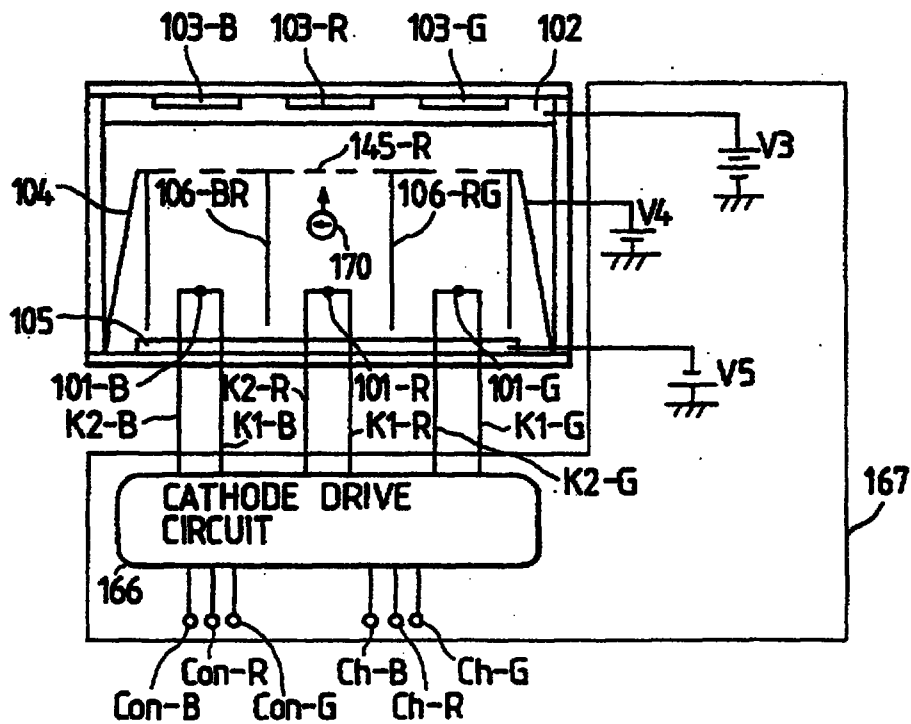


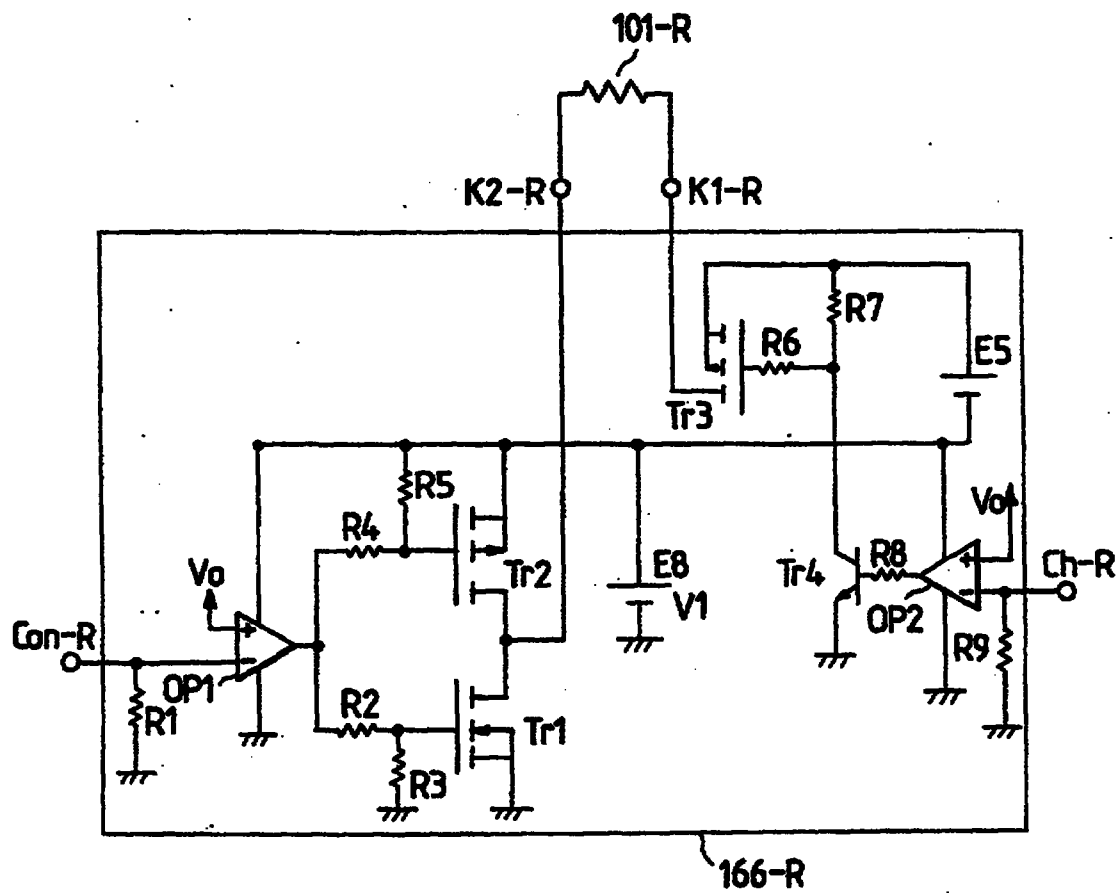
FIG. 13



20 JAN 1998

- 8 -

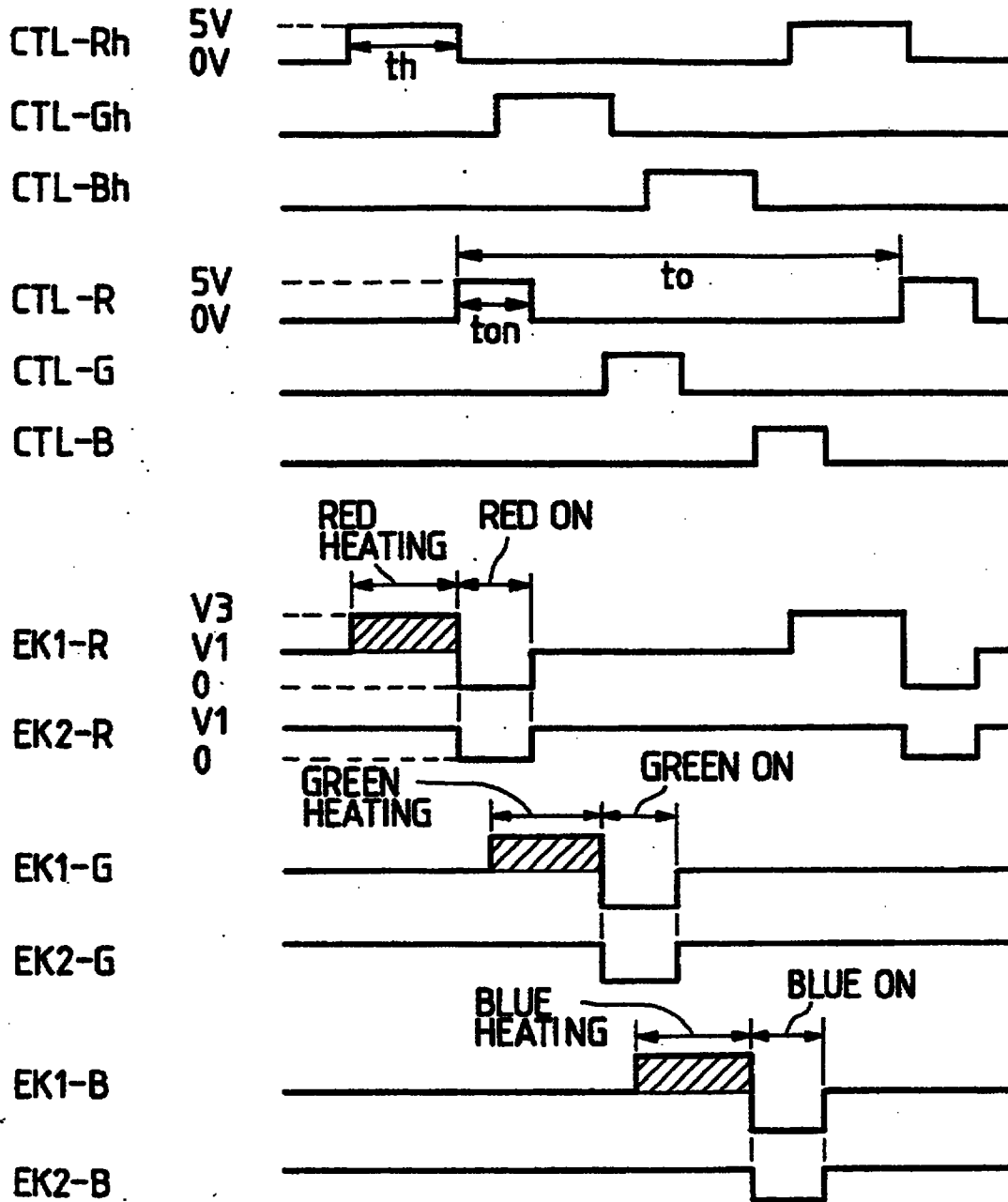
FIG. 14



20 JAN 1998

- 9 -

FIG. 15



9604478-9
IPOS copy

- 17 -

REPLACEMENT SHEET

24 FEB 1998

ABSTRACT

METHOD OF AND CIRCUIT FOR DRIVING CATHODELUMINESCENCE TYPE LIGHTING DEVICE

A lighting device emits light by releasing electrons to an anode from a Joule-heated cathode and causes the electrons to collide against a phosphor on the anode side. A method of driving the lighting device repeats, at a predetermined lighting cycle, a heating period (t_h) in which the cathode is heated by conduction, a lighting period (t_{on}) in which the cathode is caused only to release electrons without conduction so that light is emitted, and a dummy period (t_d) in which no conduction or emission of light occurs at the cathode. To variably adjust the lighting period (t_{on}), adjustments are absorbed by the dummy period (t_d) to maintain the heating period (t_h) constant at all times. With respect to the timing control of each period, the lighting period (t_{on}) is controlled at a timing independent of the heating period (t_h), whereas the heating period (t_h) is controlled at a timing dependent on the lighting period (t_{on}). This is preferred to facilitate the timing control of the lighting period (t_{on}).

FIGURE 4

FIGURE 5

24.02.98