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Yamane et al.

[11] 3,801,864

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[54] **DISPLAY DEVICE**

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Feb. 25, 1972 Japan 47-18946

[52] **U.S. Cl.** ..... **315/169 TV**, 178/7.3 D, 313/108 B, 313/109.5, 315/169 R

[51] **Int. Cl.** **H04n 3/16**, H05b 37/00

[58] **Field of Search** .... 178/7.3 D, 7.5 D; 313/108 B, 109.5; 315/169 R, 169 TV

[56] **References Cited**

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Assistant Examiner—Lawrence J. Dahl
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[57] **ABSTRACT**

A display device comprising means for forming a discharge space including a plurality of discharge electrodes constituting an electron source, a plurality of first control grids arranged in parallel for controlling the electron beam generated from the discharge space, a plurality of second control grids arranged in parallel with each other and at right angles to said first control grids, means for accelerating the electron beam controlled by said first and second control grids, a phosphor illuminated by the impingement thereupon of the accelerated electron beam, means for applying to said second control grids pulse voltages in sequence, means for applying a pulse voltage to said discharge electrodes to effect a discharge only in the space corresponding to the control grid to which the pulse voltage is applied, and means for applying a pulse-width-modulated voltage to said first control grids.

1 Claim, 3 Drawing Figures

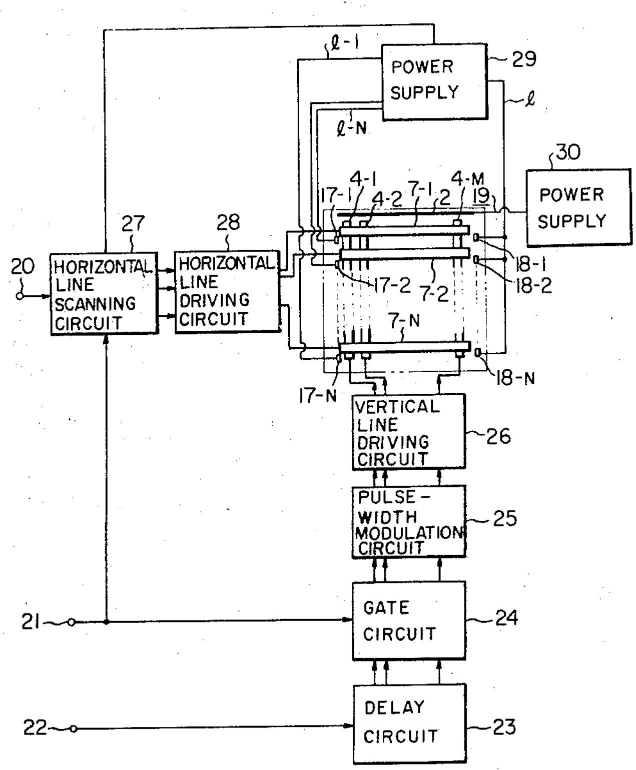


FIG. 1

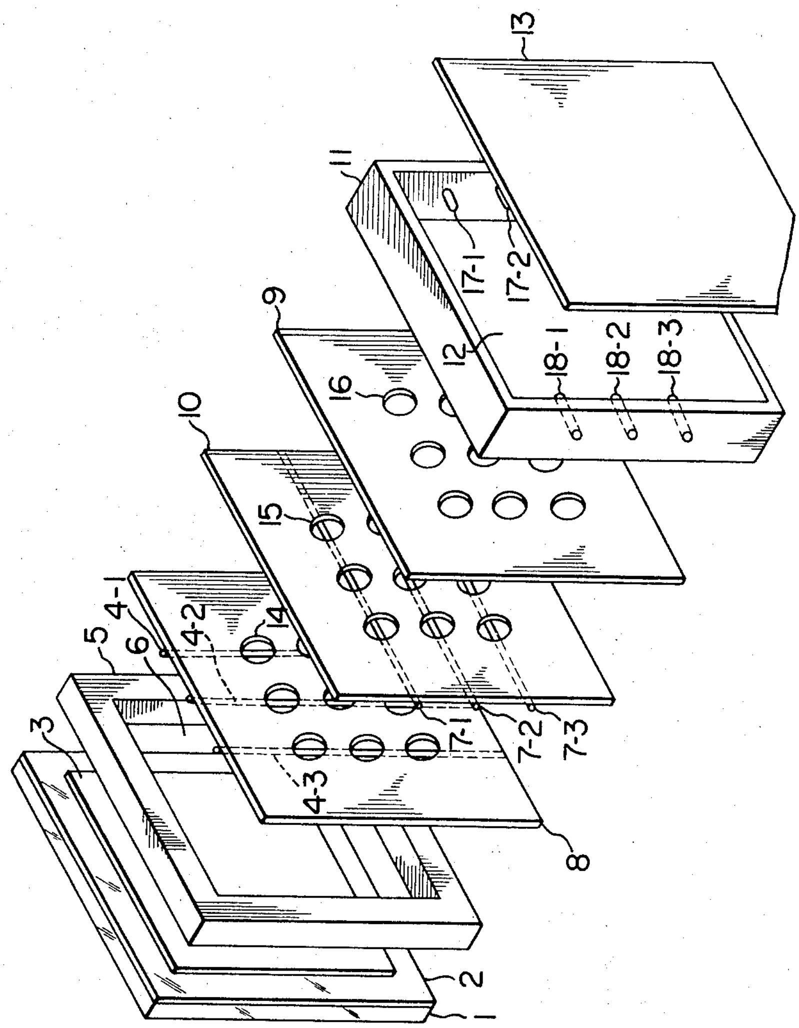


FIG. 2

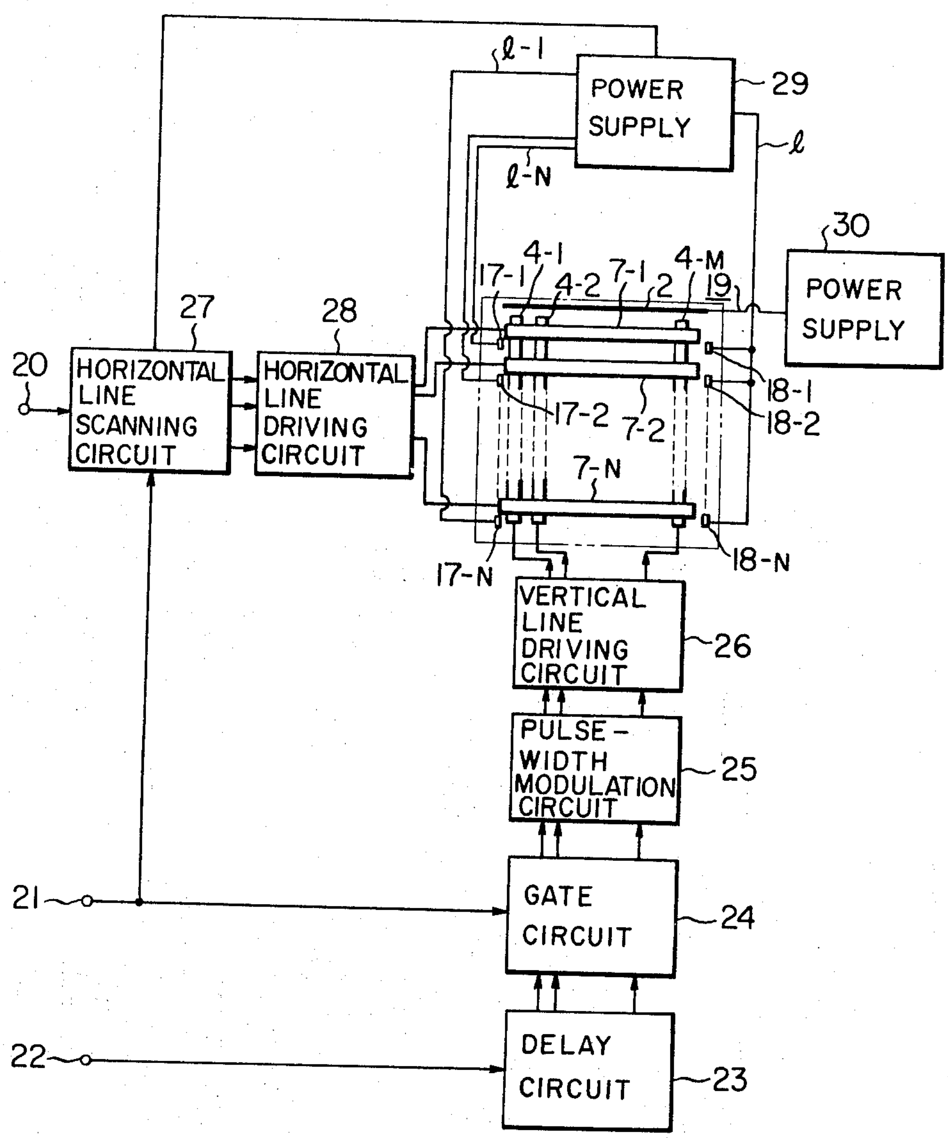
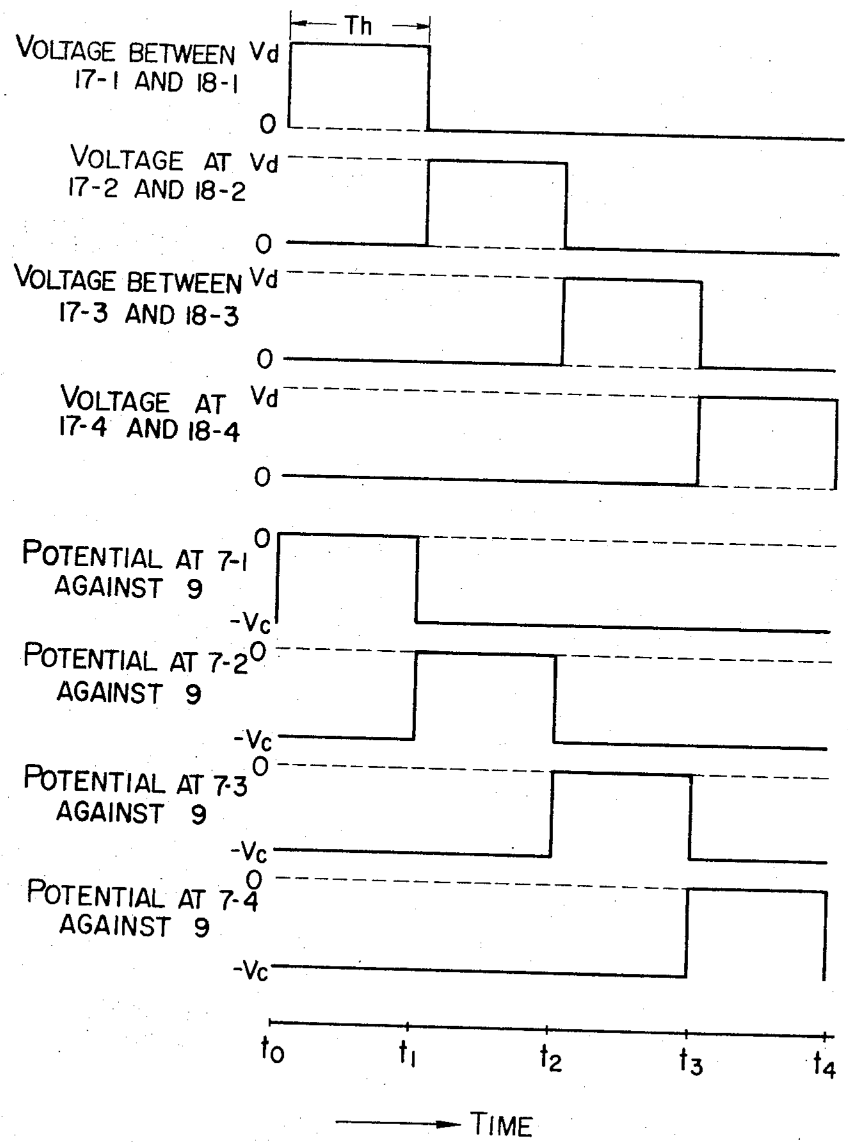

POWER SUPPLY
29
ℓ-1
ℓ
ℓ-N
30
POWER SUPPLY
4-1
4-M
17-1
4-2
7-1
2
19
27
28
20
HORIZONTAL LINE SCANNING CIRCUIT
HORIZONTAL LINE DRIVING CIRCUIT
18-1
17-2
7-2
18-2
7-N
17-N
18-N
VERTICAL LINE DRIVING CIRCUIT
26
PULSE-WIDTH MODULATION CIRCUIT
25
21
GATE CIRCUIT
24
22
DELAY CIRCUIT
23

FIG. 3


Th
VOLTAGE BETWEEN 17-1 AND 18-1
Vd
0
VOLTAGE AT 17-2 AND 18-2
Vd
0
VOLTAGE BETWEEN 17-3 AND 18-3
Vd
0
VOLTAGE AT 17-4 AND 18-4
Vd
0
POTENTIAL AT 7-1 AGAINST 9
0
-Vc
POTENTIAL AT 7-2 AGAINST 9
0
-Vc
POTENTIAL AT 7-3 AGAINST 9
0
-Vc
POTENTIAL AT 7-4 AGAINST 9
0
-Vc
t0
t1
t2
t3
t4
TIME

DISPLAY DEVICE

The present invention relates to a display device for use in a television or the like or more in particular to a display device using gaseous discharge as an electron source.

A well known conventional display device comprises a vacuum housing in which are arranged grid wires, a phosphor and a cathode for electron emission. In such a conventional device, the cathode is such that it is impossible to emit electrons uniformly over a wide area, resulting in an unsatisfactory display of images.

One possible approach to such a problem of the conventional device is to produce electrons over a wide area by the use of gaseous discharge. The use of the gaseous discharge is deemed to enable a large current to be obtained over a wider area than in the thermionic emission of electrons and enable response time to be improved.

Even if the discharge is always effected over the whole area of a predetermined discharge space, only a small percentage of the released electrons is used for display of an image, resulting in a low efficiency.

Accordingly, it is an object of the present invention to provide a display device which is capable of displaying an image with a high efficiency by efficiently using the electrons released by the gaseous discharge.

In order to achieve the above-mentioned object, the present invention is characterized by the fact that a control voltage is applied to a line at a time and a discharge voltage in synchronism with the control voltage is applied to that discharge electrode for effecting a discharge only in the portion of the discharge space corresponding to the control grid to which the control voltage is applied.

The above and other objects, features and advantages will be made apparently by the detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagram showing the construction of the display device according to the present invention;

FIG. 2 is a block diagram showing an embodiment of the present invention; and

FIG. 3 is a diagram of waveforms for explaining the operation of the embodiment of FIG. 2.

Referring to FIG. 1 showing the construction of the display device according to the invention employing a gaseous discharge for electron source, reference numeral **1** shows a transparent insulating plate of glass or the like, numeral **2** a transparent conductive film of NESA film (trade mark) or the like laid on the surface of the transparent insulating plate **1**, numeral **3** a phosphor layer applied on the transparent conductive layer **2**, numeral **4**, including numerals **4–1**, **4–2** and **4–3**, first control grids arranged in parallel with each other on a plane almost in parallel with the phosphor layer **3**, numeral **5** a first insulating frame, numeral **6** an accelerating space formed in the first insulating frame **5**, numeral **7**, including the numerals **7–1**, **7–2** and **7–3**, second control grids arranged in parallel with each other at right angles to the first control grids **4**, numeral **8** a first insulating separator inserted between the first control grids **4** and the second control grids **7**, numeral **9** a conductive shielding plate, numeral **10** a second insulating separator inserted between the second control grids **7** and the conductive shielding plate **9**, numeral **11** a second insulating plate, numeral **12** a discharge space formed in the second insulating frame **11**, numeral **13** an insulating plate, and numerals **14**, **15** and **16** apertures bored in those points of the first and second insulating separators and the conductive shielding plate where the control grids intersect each other. By way of explanation, the apertures and areas surrounding them will be referred to as a control space. Reference numerals **17** and **18**, including numerals **17–1**, **17–2**, **17–3**, **18–1**, **18–2** and **18–3**, show discharge electrodes for releasing electrons in the discharge space **12**. The accelerating space **6**, the discharge space **12** and the control space are hermetically sealed, each containing inert gas, silver vapor or mixed gas thereof.

In the device with the above-described construction, a voltage is applied between the discharge electrodes **17** and **18** thereby to effect gaseous discharge in the discharge space **12**. The electrons released by the gaseous discharge are passed by diffusion to the control space through the apertures bored in the conductive shielding plate **9**. In the process, if a bias voltage which is negative with respect to the conductive shielding plate **9** is applied to the second control grids **7**, the electrons are attracted back to the conductive shielding plate **9**. In this case, application to a specified grid, say, the grid **7–1** among the control grids **7** of a voltage which is positive or zero with respect to the negative bias voltage (such negative or zero voltage is hereinafter referred to as a control voltage) causes the electron beam to pass through only those apertures **15** in the insulating plate **10** which correspond to the control grid **7–1.** When the control voltage is applied only to a specified one of the first control grids **4**, electrons are accelerated to pass into the accelerating space through only those apertures of the insulating plate **8** involving the first and second control grids to which the control voltage is applied. Those electrons are accelerated in the accelerating space by the high voltage **12** applied to the transparent conductive film **2** and impinge upon the phosphor with high energy thereby to illuminate it. Accordingly, it is possible to display a television image due to an image signal by employing a signal corresponding to an image signal such as pulse-width modulated signal as the control voltage applied to either the first grids or second grids.

In this way of generating electrons by gaseous discharge, differing from the conventional method in which the thermionic emission is used with the cathode as an electron source, electrons are obtained uniformly from over a wide area, thereby making it possible to produce a large current. Further, the use of the gaseous discharge permits the response character to be improved remarkably.

In this connection, the continuous discharge in the whole discharge area in the discharge space results in only a small part of the released electrons being consumed in the display operation, wasting much of the power for reduced efficiency.

This problem is obviated in the following-described embodiment of which the block diagram is illustrated in FIG. 2. In this embodiment, an image is displayed by the pulse-width modulation in which the image signal corresponding to the image to be displayed is represented by a pulse width equivalent to the level of the image signal. In the drawing, the reference numeral **19** generally shows the display device according to the invention as shown in FIG. 1 which includes the discharge electrodes **17** and **18**, the first control grids **4** and the second control grids **7**. Each of the discharge electrodes **17** is independent of each other, while the other electrodes **18** are connected with each other. Reference numeral **20** shows an input terminal for vertical synchronizing signals, numeral **21** an input terminal for horizontal synchronizing signals, numeral **22** an input terminal for image signals, and numeral **23** a delay circuit or line with a delay time equal to the horizontal scanning period or the period required for generation of the horizontal synchronizing signal. The delay circuit **23** has output terminals in the number of M corresponding to the grids **4–1, 4–2, 4–3, . . . 4-M**. Reference numeral **25** shows a pulse width modulation circuit containing an analog memory, numeral **26** a vertical line driving circuit driven by the output of the pulse width modulation circuit **25**, numeral **27** a horizontal line scanning circuit driven by the horizontal synchronizing signal which is provided with output terminals in the number of N corresponding to the second control grids **7–1, 7–2, 7–3, . . . 7**–N, numeral **28** a horizontal line driving circuit with its input signal provided by the scanning pulse from the horizontal line scanning circuit, numeral **29** a power supply for generating discharge voltages in sequence at the N output terminals periodically in synchronism with the horizontal synchronizing signal, and numeral **30** another power supply for applying a high voltage to the transparent conductive film **2**. Some of the outputs of the discharge power supply **29** are applied to the independent discharge electrodes **17–1, 17–2, . . . 17**–L, while the other outputs thereof are applied to the commonly-connected discharge electrodes **18–1, 18–2, . . . 18**–L.

After the passage of a period equal to the horizontal scanning period following the application of a video signal to the input terminal **22** of the delay circuit **23**, the video signal for one horizontal scanning period is distributed over the delay circuit. Under this condition, application of a horizontal synchronizing signal to the gate circuit **24** through the terminal **21** causes each of the gates to conduct, so that a signal appearing at each of the output terminals of the delay circuit **23** is applied to each input terminal of the pulse width modulation circuit **25** are converted into M signals of the same amplitude but with widths different according to their levels, which pulses are amplified by the vertical line driving circuits **25** and applied to the first control grids **4–1, 4–2, . . . 4**–M. On the other hand, the vertical synchronizing signal obtained through the terminal **20** and the horizontal synchronizing signal produced through the terminal **21** drive the horizontal line scanning circuit **27**, whereupon the output terminals thereof in the number of N corresponding to the second grids **7–1, 7–2, . . . 7**–N produce sequential scanning pulses at an interval approximate to the horizontal scanning period. The scanning pulses are amplified by the horizontal line driving circuit **28** and applied to the second control grids **7–1, 7–2, . . . 7**–N in sequence.

Discharge pulse voltages are produced from the power supply in synchronism with the scanning pulses applied sequentially to the second control grids **7–1, 7–2, 7–3, . . . 7**–N or the horizontal synchronizing signal for driving the horizontal scanning circuit. The discharge pulse voltages are applied to the discharge electrodes **17** and **18**. In view of the fact that the discharge electrodes **17–1, 17–2, . . . 17**–N are connected to the output terminals of the power supply **29** independently of each other through the lines *l*–**1**, *l*–**2**, . . . *l*–N, while the discharge electrodes **18–1, 18–2, . . . 18**–N are connected commonly to the output terminal of the power supply **29** through the line *l*, the application of each scanning pulse causes a discharge voltage to be applied to that discharge electrode corresponding to the control grid to which the scanning pulse is applied. Therefore, each time the scanning pulse is generated, a discharge voltage is supplied in sequence from the discharge power supply through the lines *l*–**1**, *l*–**2**, . . . *l*–N, with the result that the discharge voltage and the scanning pulses which are control voltages applied to the second grids **7–1, 7–2, . . . 7**–N assume the phase relationship as shown in FIG. **4**.

It will be apparent from this diagram that during the period from t_0 to t_1 the control voltage is applied only to the grid **7–1** and the potential thereof is zero while the potentials of the grids **7–2, 7–3, . . . 7**–N with respect to the conductive shielding plate **9** are negative and take the value of $-V_c$. As a result, it is only those electrons diffused by way of those of the apertures **16** bored in the conductive shielding plate **9** which correspond to the grid **7–1** that are capable of entering the control space. Also, during this period, the discharge voltage is applied to the discharge electrodes **17–1** and **18–1** respectively through the lead wires *l*–**1** and *l*, and therefore a discharge occurs and plasma exists only in that portion of the discharge space which corresponds to the grid **7–1**.

The control voltage is applied only to the grid **7–2** and the discharge voltage applied only to to the discharge electrodes **17–2** and **18–2** during the period from t_1 to t_2. In like manner, not only the control voltage but the discharge voltage are applied in sequence in the subsequent processes.

In this way, during the application of the control voltage, discharge occurs only in that portion of the discharge space corresponding to the control grid to which the control voltage is applied, whereby electrons generated by the discharge are efficiently used and waste of electric power in the discharge space **12** is eliminated.

Even though the embodiment of FIG. **1** involves three grids and three discharge electrodes, it is needless to say that it is possible to manufacture a display device with n grids and n discharge electrodes with the same advantages. Further, an AC instead of DC voltage may be employed as the discharge voltage.

In the case where the width of the plasma generated by the discharge in the discharge space is larger than the interval between the control grids, a set of discharge electrodes may be usually provided for a plurality of the control grids in the number of, say, m. In such a case, it is also needless to say that is suffices to apply the discharge voltage to the same set of discharge electrodes during the scanning of the m control grids.

It will be understood from the above description that according to the present invention the use of electric discharge as a source of electrons permits uniform brightness to be achieved over the whole area of the display face of the display device, greatly contributing to an improved efficiency.

What we claim is:

1. A display device comprising a first insulating member for forming a discharge space for effecting gaseous discharge, said first insulating member being provided with a plurality of discharge electrodes as a source of electrons, a second insulating member for hermetically sealing said discharge space, a conductive member provided with a plurality of small apertures through which an electron beam from said discharge space is adapted to be passed, a third insulating member for forming an accelerating space for accelerating the electron beam passing through said plurality of small apertures, a transparent insulating member for hermetically sealing said accelerating space, first and second control grids interposed between said conductive member and said third insulating member for controlling the entrance of said electron beam into said accelerating space, said control grids intersecting each other at the positions corresponding to said small apertures, an insulating separator provided with a plurality of small apertures at the positions corresponding to those of said small apertures in said conductive member in such a manner that said first and second control grids in certain spaced relationship intersect, a phosphor formed on said transparent insulating member, a transparent electrode formed intermediate said transparent insulating member and said phosphor for causing an electron beam from said accelerating space to impinge upon said phosphor, means for supplying sequential control pulses to said plurality of second control grids, a power supply for generating a discharge voltage in synchronism with said control pulse applied to said second control grids, means connected with said power supply for applying said discharge voltage only to the discharge electrode in the portion of said discharge space corresponding to said second control grids to which said control pulse is applied, means for applying to said first plurality of control grids a signal which is pulse-modulated from a predetermined display signal in accordance with the level of each pulse of said display signal, and means for applying a high voltage to said transparent electrode for accelerating the electron beam in said accelerating space, whereby a gaseous discharge occurring in that portion of said discharge space which corresponds to said second control grid to which said control voltage is applied.

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