Aug. 14, 1962 P. H. GLEICHAUF 3,049,641

HIGH TRANSCONDUCTANCE CATHODE RAY TUBE

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FIG.1.

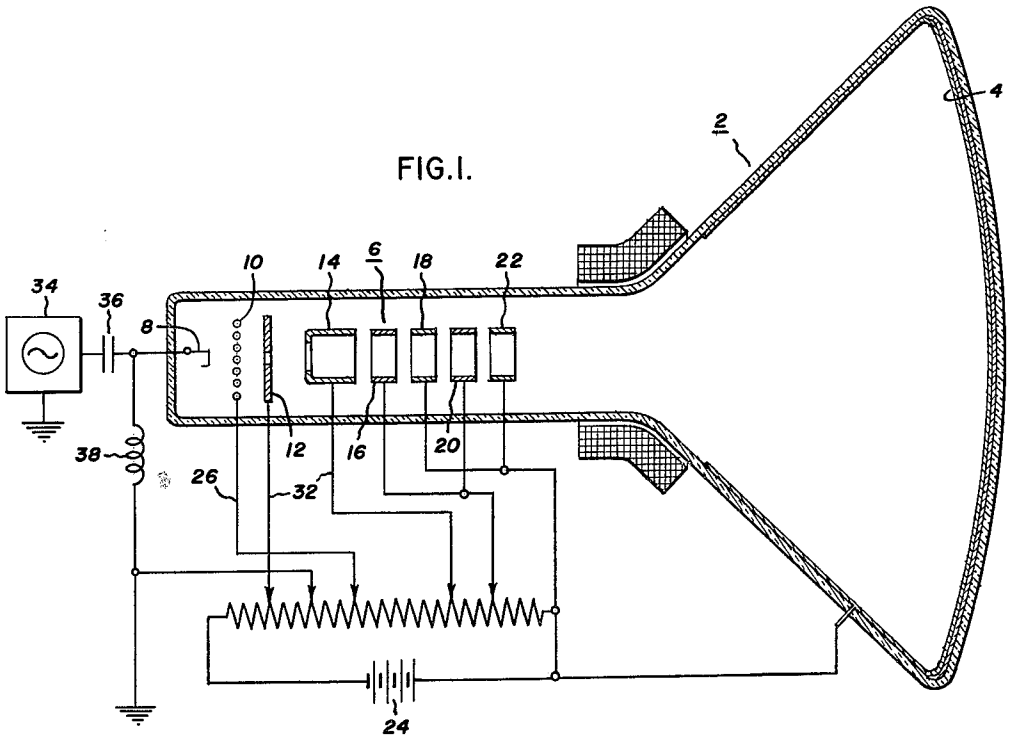
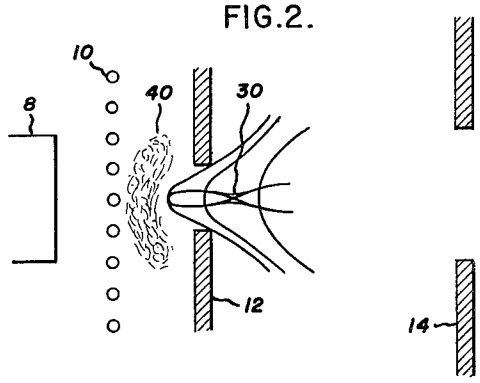


FIG.2.



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FIG.3.

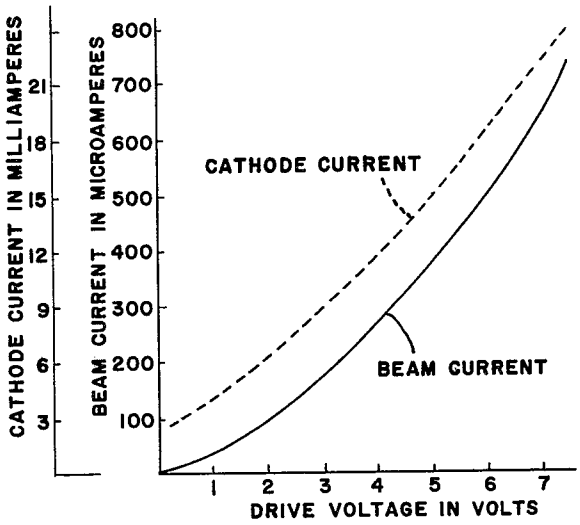


FIG.4.

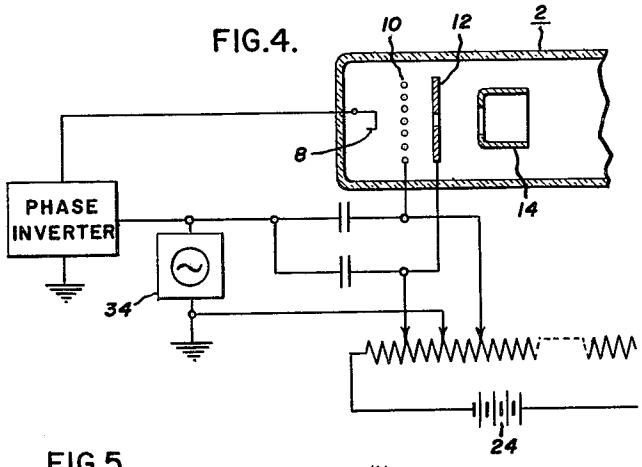
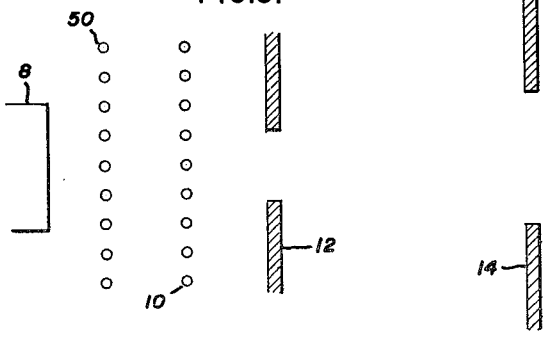


FIG.5.



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HIGH TRANSCONDUCTANCE CATHODE RAY TUBE

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6 Claims. (Cl. 315—30)

This invention relates to cathode ray tubes, and more particularly to cathode ray tube electron beam generating apparatus providing high transconductance and especially suitable for use with low amplitude electron beam intensity modulation signals, as in transistorized television receivers.

Various attempts have been made in the prior art to increase the transconductance of electron guns for television picture tubes. Control grids of the mesh type, having a multiplicity of small apertures instead of a single large aperture, have been tried, for example. But such grids generally require very close spacing to the cathode, and correspondingly close spacing of the first anode to the mesh control grid, in order to obtain a satisfactory field intensity at the cathode. Such close spacings are objectionable both from an electrical and a mechanical standpoint.

Other attempts to achieve high transconductance have been made, but as far as I am aware no solution to this problem has yet been developed which is of acceptable structural simplicity yet affords satisfactory performance, particularly as respects obtaining adequate resolution at all current levels and avoiding objectionably close spacing of electrodes.

A principal object of the present invention, therefore, is to provide improved cathode ray tube electron beam generating apparatus capable of providing modulation of electron beam currents over a desired range from cutoff to desired maximum screen brighness with a control or drive signal having a small amplitude of the order of a few volts, while maintaining desirably small electron beam spot size at the luminescent screen for good picture signal resolution.

Another object is to provide an improved high transconductance electron beam generating apparatus affording desirably small electron beam spot size for high image resolution, and having a desirably large depth of focus, with minimum cathode loading.

Another object is to provide an improved electron gun particularly suitable for use with low amplitude beam current modulation signals, and in which the requirement of prior art electron guns for extremely close spacing of electrodes is avoided.

These and other objects of the present invention will be apparent from the following description taken in conjunction with the accompanying drawing, wherein

FIG. 1 is a view, partly in axial section and partly schematic, of a cathode ray tube electron beam generating apparatus constructed according to my invention;

FIG. 2 is an enlarged schematic view of a portion of the apparatus shown in FIG. 1;

FIG. 3 is a graph showing certain operating characteristics of an apparatus constructed according to the invention;

FIG. 4 is a fragmentary view of an alternative embodiment;

FIG. 5 is a fragmentary view of another alternative embodiment.

Briefly according to one aspect of the present invention I provide high transconductance cathode ray tube electron beam generating apparatus in which a positively biased foraminate space charge grid is located between a cathode and a first anode for separate control of modulation, and a first negatively biased crossover-forming grid is located between the space charge grid and first anode for separate electron optical purposes, and both the space charge grid and crossoverforming grid are simultaneously modulated with respect to the cathode according to a beam intensity modulation signal.

Turning to the drawing, FIG. 1 shows electron beam generating means constructed according to the invention, and including a cathode ray tube having an envelope **2**, screen **4**, and an electron gun **6**. The electron gun **6** includes, arranged in succession along the electron beam axis in the neck of the tube, an indirectly heated cathode **8**, space charge grid **10**, first or crossover-forming grid **12**, first anode **14** and a suitable conventional focusing means shown by way of example as focusing electrodes **16**, **18**, **20**, and **22**. Suitable electrode bias potentials are provided by a power supply, shown schematically at **24**. The potentials of the various electrodes are described hereafter with respect to that of the cathode, and the cathode may be at direct current ground as shown.

The space charge grid **10** consists of a planar conductive foraminate member, such as a wire mesh and which is here shown for example as a fine wire grille. The grid **10** is disposed normal to the tube neck axis, and is connected through lead **26** to a direct current bias potential of a few volts, for example less than ten volts and preferably below five volts, positive with respect to the cathode. The relatively small size of the openings in the grid **10** minimizes penetration toward the cathode of fields from more remote grids, yet the total current which can be drawn through the grid **10** is high because of the large number of openings in it.

The apertured grid **12** is a planar conductor disposed transverse to the electron beam axis. The grid **12** has mainly electron optical functions, and serves to form the crossover of the electron beam, as shown at **30** in FIG. 2. The grid **12** is connected through lead **32** to a source of negative direct current bias, usually greater in absolute value than that of grid **10**, and which may be for example 15 to 30 volts below cathode potential.

A suitable source of electron beam intensity modulation signals, which source may be for example the video signal detector stage of a television receiver, is shown at **34**.

The operation of the electron gun of FIG. 1 may best be understood in connection with the enlarged schematic view of FIG. 2. According to the invention both the first grid **12** and the space charge grid **10** are modulated relative to the cathode, in accordance with beam intensity modulation signals. This may be accomplished for example by applying the electron beam intensity modulation signal to the cathode through a suitable coupling capacitor **36**. A suitable inductor **38** isolates the modulation signals on the cathode from ground.

Part of the modulated stream of electrons from the cathode is injected into the space between the space charge grid **10** and the first grid **12** and there forms a cloud of electrons which serves as a virtual cathode, as shown at **40** in FIG. 2. The field produced between the first grid **12** and first anode **14** penetrates through the aperture of the first grid **12** and draws electrons from the virtual cathode **40** to form the electron beam. The relatively large number of openings in the foraminate space charge grid contributes to the formation of a virtual cathode **40** which is both well defined along the electron gun axis and is well spread out transverse to the gun axis. The virtual cathode complements the shape of the adjacent field equipotentials in such a way as to produce, with the opening in grid **12** and the presence of the first anode **14**, a strong immersion lens which minimizes the electron beam transverse dimension, at the crossover **30**, for good resolution.

Such apparatus has the advantage that the functions of modulation and electron-optical focusing are separated,

providing high transconductance without sacrifice of resolution. The transconductance is high because it is substantially that of the diode formed by the cathode 8 and space charge grid 10, only slightly reduced by the negative bias of grid 12 applied for electron-optical purposes. Also transconductance is further increased because the virtual cathode moves toward the aperture of grid 12 as modulation voltage amplitude increases.

The negative bias of the grid 12 also has the advantage of preventing destruction of the virtual cathode 40 by the positive field penetration through the aperture in the first grid as the electron flow supplying the virtual cathode is diminished when the beam intensity modulating signal calls for beam current cutoff. The simultaneous modulation of the space charge grid 10 and first grid 12 has the further advantage of minimizing the tendency of the negative bias on the first grid 12 to reduce the transconductance of the electron gun. This is accomplished because the simultaneous modulation of the first grid 12 and space charge grid 10 makes the first grid 12 most negative, and thereby affords greatest protection to the virtual cathode 40, when the space charge grid 10 is most negative and the supply of electrons to the virtual cathode 40 is least. Conversely, the first grid 12 is made most positive only when the space charge grid 10 is made most positive and can provide the most abundant supply of electrons to the virtual cathode 40.

An electron gun as shown in FIG. 1 has been built having a cathode-space charge grid spacing at assembly of about .004 inch, a first grid-space charge grid spacing at assembly of about .004 inch, a first grid aperture of about .030 inch, and a cathode diameter of about .125 inch. The space charge grid consisted of .0004 inch diameter wire wound on a supporting frame with a pitch of 825 turns per inch. The spacing of the virtual cathode from the first grid varied during modulation from about .002 inch to .0026 inch. This gun produced a peak cathode current of about 20 milliamperes with a cathode loading of about 200 milliamperes/cm.^{2}, and at 14,000 volts screen potential and 1600 volts first anode potential electron beam current cutoff was achieved with space charge grid potential of +2.5 volts and first grid potential of —17.5 volts. With cathode drive as shown, 7 volts was sufficient to modulate the beam from cutoff to a beam current of about 700 microamperes, with resolution and brightness comparable to conventional picture tubes requiring drive voltage of 70 volts or so. A graph of electron beam current at the luminescent screen, versus drive voltage, for this gun is shown in FIG. 3.

Further in accordance with the invention, as shown in FIG. 4 the drive voltage requirements can be further reduced by application of the beam intensity modulation signal in push-pull relation, by impressing it in on the cathode and in opposite phase on both the space charge grid 10 and first grid 12.

Another alternative embodiment is shown in FIG. 5 in which an additional modulation grid 50 is interposed between the space charge grid and the cathode. With this embodiment the modulation signal is applied to grid 50 instead of the space charge grid 10. The grid 50 is also biased negatively and thus avoids drawing grid current and thereby minimizes loading of the modulation signal source 34.

It will be appreciated by those skilled in the art that the invention may be carried out in various ways and may take various forms and embodiments other than those illustrative embodiments heretofore described. It is to be understood that the scope of the invention is not limited by the details of the foregoing description, but will be defined in the following claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Cathode ray tube electron beam generating apparatus comprising a cathode, a first anode forming an opening for passage of the electron beam therethrough, a space charge grid transversely disposed between the cathode and first anode, means for biasing the space charge grid positive with respect to the cathode, a crossover-forming grid comprising a planar conductive member having a single central aperture transversely disposed between the first anode and the space charge grid, means for biasing the crossover-forming grid negative with respect to the cathode, and means for varying the degree of positiveness of the space charge grid relative to the cathode in accordance with an electron beam intensity modulation signal.

2. Cathode ray tube electron beam generating apparatus comprising a cathode, a first anode forming an opening for passage of the electron beam therethrough, a foraminate space charge electrode transversely disposed between the cathode and first anode, means for providing a direct current bias on the space charge electrode positive with respect to the cathode, a crossover-forming grid comprising a planar conductive member transversely disposed between the first anode and the space charge electrode and having a central aperture, means for providing a negative direct current bias on the crossover-forming grid, and means for simultaneously varying the potentials of both the space charge electrode and the crossover-forming grid relative to the cathode in accordance with an electron beam intensity modulation signal.

3. Cathode ray tube electron beam generating apparatus comprising a cathode, a first anode, a foraminate grid between the cathode and first anode, means for providing a direct current bias on the foraminate grid of less than 10 volts positive with respect to the cathode, a crossover-forming grid comprising a planar conductive member transversely disposed between the first anode and the foraminate grid and having a single central aperture through which the electron beam is adapted to pass, means for providing a direct current bias on the crossover-forming grid of negative polarity and sufficient amplitude to cut-off electron flow through said aperture, and means for simultaneously varying the potential of both the foraminate grid and crossover-forming grid relative to the cathode in accordance with a beam intensity modulation signal.

4. Cathode ray tube electron beam generating apparatus comprising a cathode, a centrally apertured first anode, a foraminate space charge grid between the cathode and first anode, a crossover-forming grid comprising a sheet metal plate between the first anode and the foraminate grid and having a single central aperture through which the electron beam is adapted to pass, means for providing a direct current bias on the foraminate grid of positive polarity with respect to the cathode to form a virtual cathode between the foraminate grid and crossover-forming grid, means for providing a direct current bias on the crossover-forming grid of negative polarity with respect to the cathode and larger than the positive bias on the space charge grid, and means for simultaneously varying the potential of both the foraminate grid and crossover-forming grid relative to the cathode in accordance with a beam intensity modulation signal.

5. Cathode ray tube electron beam generating apparatus comprising a cathode, a first anode, a foraminate grid transversely disposed between the first anode and the cathode, means for providing a direct current bias on the foraminate grid of less than 10 volts positive with respect to the cathode, a crossover-forming grid comprising a planar conductive member transversely disposed between the first anode and the foraminate grid and having a single central aperture through which the electron beam is adapted to pass, means for providing a direct current bias on the crossover-forming grid of negative polarity with respect to the cathode and larger than the positive bias on the space charge grid, and means for applying an electron beam intensity modulation signal in push-pull relation to the cathode on the one hand and to both the

foraminate grid and crossover-forming grid on the other hand.

6. Cathode ray tube electron beam generating apparatus comprising a cathode, a first anode forming an opening for passage of the electron beam therethrough, a foraminate space charge grid between the cathode and first anode, means for biasing the space charge grid positive with respect to the cathode, a crossover-forming grid comprising a planar conductive member transversely disposed between the first anode and the space charge grid and having a single central aperture, means for biasing the crossover-forming grid negative with respect to the cathode, a modulation grid between the space charge grid and cathode, means for biasing the modulation grid negative relative to the cathode, and means for simultaneously modulating both the modulation grid and the crossover-forming grid relative to the cathode in accordance with an electron beam intensity modulation signal.

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