Sept. 2, 1969 J. E. HIGBEE ET AL 3,465,200
CATHODE RAY TUBE SYSTEM INCLUDING MEANS FOR VARYING BEAM INTENSITY
Filed Jan. 23, 1967 2 Sheets-Sheet 1

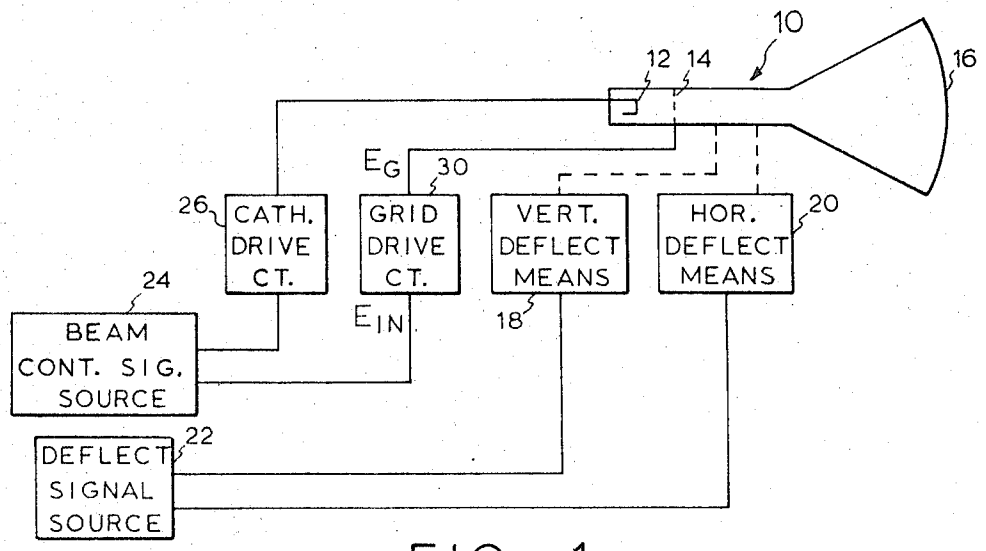
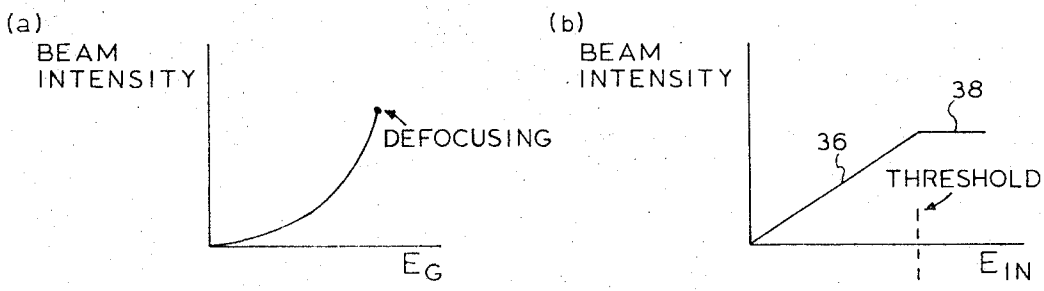


FIG. 1



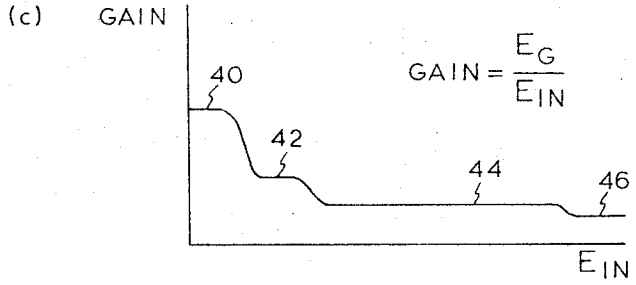


FIG. 2

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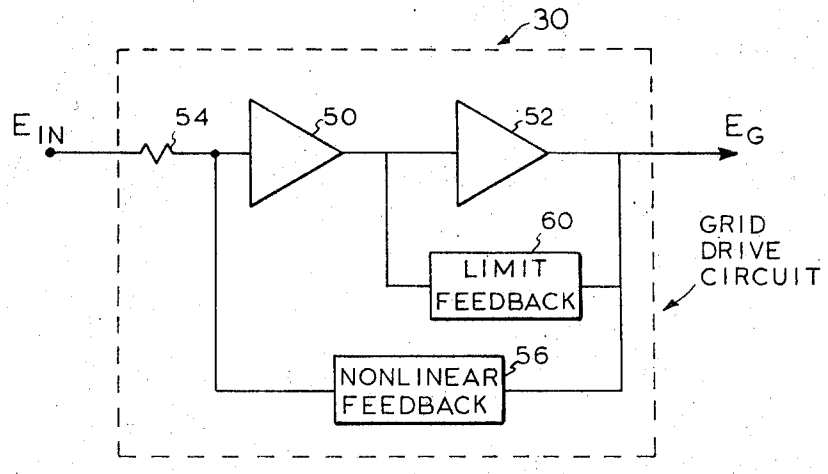


FIG. 3

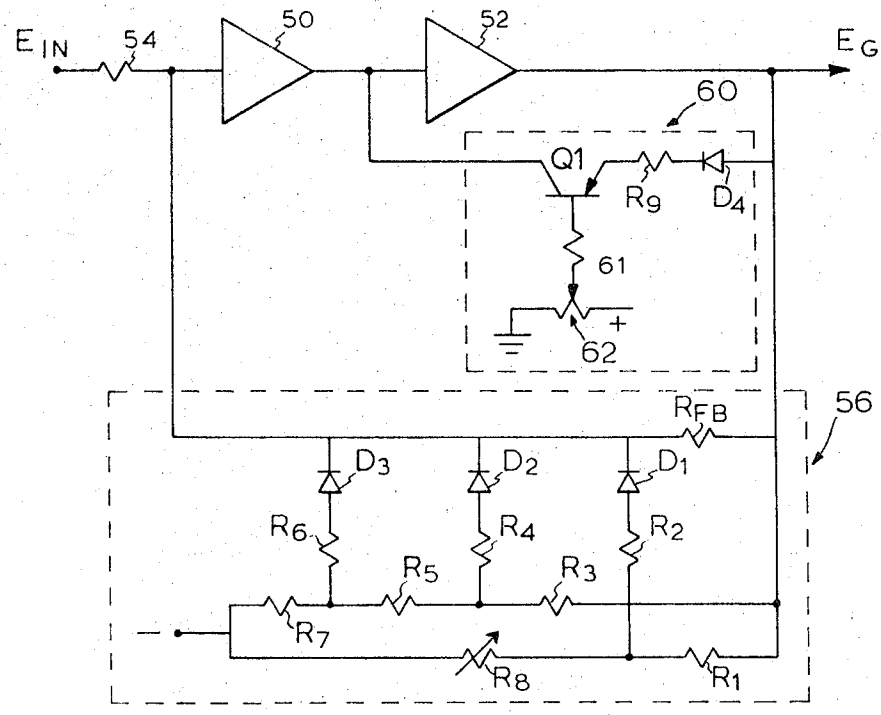


FIG. 4

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CATHODE RAY TUBE SYSTEM INCLUDING MEANS FOR VARYING BEAM INTENSITY

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U.S. Cl. 315—30 8 Claims

ABSTRACT OF THE DISCLOSURE

Circuit apparatus useful in a cathode ray tube display system for facilitating accurate control of beam intensity thus enabling intensity variations resulting from variations in beam velocity to be compensated for. The nonlinearity of the beam intensity versus control voltage characteristic typical of most cathode ray tubes is compensated for by incorporating a nonlinear feedback path in the amplifier producing the control voltage in response to an input voltage. Additionally, the amplifier incorporates a limiting feedback path to prevent the grid voltage from increasing beyond a certain threshold level at which defocussing occurs.

The invention herein described was made in the course of or under a contract or subcontract thereunder, with Department of the Air Force, Rome Air Development Center.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates generally to cathode ray tube (CRT) display systems and more particularly to means for use therein for facilitating the accurate control of beam intensity.

In certain sophisticated display systems, CRT's are called upon to display a variety of significantly different elements or symbols all drawn in constant time irrespective of size. For example, in such a system the CRT may be called upon to describe both a small circle (e.g., ¼ inch diameter), and a large circle (e.g., 6 inch diameter) in a single display pattern. If the two circles are drawn in the same amount of time, it should, of course, be apparent that the beam velocity must be much greater to describe the large circle than to describe the small circle. It should also be apparent that if the beam is moved with a greater velocity, it will appear less intense to an observer. In order to prevent this intensity variation, prior art systems have incorporated beam intensity control means responsive to beam velocity. It is found, however, prior art intensity control means are inadequate to provide accurate intensity control over a wide dynamic range because of the nonlinearities typically found in CRT's.

SUMMARY OF THE INVENTION

The present invention is directed to a system enabling CRT beam intensity to be controlled extremely accurately over a wide dynamic range.

Briefly, in accordance with one aspect of the present invention, means are provided for introducing nonlinearities between an input signal and an output control electrode (e.g., grid) signal to compensate for nonlinearities in the relationship of beam intensity to the control signal.

In the preferred embodiment of the present invention, the nonlinearities are introduced by an amplifier to which the input signal is applied. A nonlinear feedback path is employed whose impedance changes as the level of the input signal changes. Variations in the feedback impedance, of course, vary the closed loop gain of the amplifier.

Therefore, by proper selection of circuit components, beam intensity can be made to be a substantially linear function of the input signal.

Briefly, a further aspect of the present invention is based on the recognition that beam defocussing or blooming may occur as the control or grid signal exceeds a certain threshold level, and that by automatically limiting the grid signal variation this defocussing can be prevented.

Thus, in accordance with a further aspect of the preferred embodiment of the invention, an additional amplifier feedback path is provided which reduces the amplifier gain after the amplifier output signal exceeds a certain threshold level.

DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a block diagram of a CRT display system which incorporates the present invention;

FIG. 2(*a*) illustrates a typical CRT characteristic;

FIG. 2(*b*) illustrates an ideal CRT characteristic;

FIG. 2(*c*) illustrates a gain characteristic provided by an embodiment of the present invention;

FIG. 3 is a block diagram of the grid drive circuit of FIG. 1 in accordance with the present invention; and

FIG. 4 is a schematic circuit diagram of the grid drive circuit of FIG. 3.

Attention is now called to FIG. 1 which illustrates a CRT display system which can incorporate the teachings of the present invention. More particularly, the system of FIG. 1 utilizes a CRT **10** having an electron gun including a beam producing electrode or cathode **12** and a control electrode or grid **14**. Although other electrodes such as an anode would also be incorporated within the tube **10**, such other electrodes are not illustrated herein inasmuch as they do not bear upon the present invention. The cathode ray tube **10** also includes a face **16** coated with an illuminable material such as phosphor. In the normal operation of the tube **10**, an electron beam is provided by the cathode **12** and impinges upon the face **16** to develop a light spot.

The position of the beam with respect to the face **16** is controlled by a vertical deflection means **18** and a horizontal deflection means **20** which are responsive to signals provided by a deflection signal source **22**. It will be appreciated that by applying appropriate deflection signals to the means **18** and **20**, the beam can be caused to describe any desired pattern on the CRT face **16**.

The beam provided by cathode **12** can be selectively blanked and unblanked in response to signals provided by the beam control signal source **24** to the cathode drive circuit **26** whose output terminal is coupled to the cathode **12**. Thus, for example, the beam can be unblanked by establishing a large accelerating potential gradient between the cathode **12** and the anode (not shown). As an example, assume that the beam is unblanked by applying a +60 volt potential to the cathode **12**. On the other hand, the beam can be blanked by raising the potential applied to the cathode **12** to +100 volts, for example, to thus reduce the accelerating potential gradient.

Typically, in the operation of the tube **10**, the beam will be moved with considerably different velocities in generating a display. This is so because in many systems each symbol or line is drawn in constant time regardless of the size of the symbol or line. Thus, if a short vector and a long vector are described in the same amount of time, it is apparent that the beam must be moved with a greater velocity to describe the long vector. When the beam moves with a greater velocity, the light intensity developed thereby decreases. In other words, beam intensity is roughly inversely proportional to beam velocity. In order to compensate for these intensity variations and thus enable all information to be displayed with near uniform intensity, some prior art systems have provided means for varying the intensity as a function of beam

velocity. Beam intensity can be controlled by controlling the potential applied to the grid **14**, for example. Thus, as the potential E_G provided by drive circuit **30** to the grid **14** is increased toward the potential of the cathode **12**, the beam intensity will increase. However, as is illustrated by FIG. 2(*a*), the beam intensity versus grid potential characteristic of a CRT is typically nonlinear. That is, at low grid potentials when there is a large negative potential gradient from the cathode **12** to the grid **14** the beam intensity varies by only a small increment in response to a unit change of the grid voltage E_G.

However, as the grid potential increases and the negative gradient from the cathode to the grid decreases, small changes in grid voltage E_G will cause much larger changes in the beam intensity. Furthermore, as the grid voltage approaches the cathode voltage the CRT will typically defocus seriously.

It would, of course, be ideal for the beam intensity to vary substantially linearly as a function of the input signal E_{IN}, provided by the control signal source **24** to the drive circuit **30**, as is illustrated by linear portion **36** of FIG. 2(*b*). Additionally, it is desirable to limit the beam intensity, as shown at **38** in FIG. 2(*b*), to prevent defocussing after the input voltage exceeds a certain threshold level.

In accordance with the present invention, the grid drive circuit **30** is designated to introduce nonlinearities in the characteristic relating the grid signal E_G to the input signal E_{IN}. In accordance with a prefered embodiment of the invention, th gain (E_G/E_{IN}) of the drive circuit **30** is varied as the level of the input signal E_{IN} increases. Thus, from a consideration of FIG. 2(*a*), it should be apparent that a greater amount of gain is required for low levels of E_G with decreasing gain required as signal E_G increases. Thus, the preferred embodiment of the invention as illustrated in FIGS. 3 and 4 provides for different gain levels which decrease as the signal E_{IN} increases. More particularly, at a low level of signal E_{IN} a relatively high gain **40** is exhibited by the drive circuit **30**. As the level of signal E_{IN} increases, the gain is successively decreased to level **42**, level **44**, and level **46**. It will, of course, be appreciated that the gain characteristic illustrated in FIG. 2(*c*) is exemplary only and that the gain characteristic should be selected to approximate the linear portion **36** of the ideal characteristic of FIG. 2(*b*). It should further be appreciated that it is not at all necessary to actually achieve the ideal characteristic of FIG. 2(*b*) inasmuch as small amounts of beam intensity variation will be barely noticed by a system user and in any event will not significantly detract from the clarity or esthetic character of the display.

Attention is now called to FIG. 3 which illustrates a block diagram of the grid drive circuit **30** of FIG. 1 which includes means for both introducing nonlinearities to linearize the relationship between beam intensity and input signal E_{IN} and means for limiting the beam intensity as the signal E_{IN} exceeds a threshold level. Briefly, the drive circuit **30** is preferably comprised of two or more amplification stages **50** and **52**. The signal E_{IN} is applied through impedance **54** to the input terminal of amplifier **50**. The output terminal of amplifier **50** is coupled to the input terminal of amplifier **52**. The grid signal E_G is provided on the output terminal of amplifier **52**.

In order to introduce the nonlinearities previously discussed, a nonlinear feedback path **56** is connected between the output terminal of amplifier **52** and the input terminal of amplifier **50**. The impedance of the nonlinear feedback path **56** varies as the input signal E_{IN} varies to thus vary the gain exhibited to an input signal as illustrated by FIG. 2(*c*).

In order to limit beam intensity as shown by the portion **38** of FIG. 2(*b*), a limit feedback path **60** is provided between the output and input terminals of amplifier **52**. The limit feedback path **60** is normally open. However, when the output signal provided by amplifier **52** tries to exceed an established threshold level, the feedback path **60** is closed to thus reduce the closed loop gain of the amplifier **52** to a very small value. Thus, the output signal E_G provided by amplifier **52** will be maintained at the threshold level, thereby preventing the beam defocussing previously mentioned.

Attention is now called to FIG. 4 which illustrates the grid drive circuit **30** of FIG. 3 in greater detail. More particularly, as can be seen from FIG. 4, the nonlinear feedback path **56** is comprised of a feedback resistor R_{FB} connected between the output of amplifier **52** and the input of amplifier **50**. A plurality of circuit paths are connected in parallel with the feedback resistor R_{FB}. Each of these parallel paths includes a diode which is normally back biased but which becomes forward biased as the input signal E_{IN} increases to thus gradually insert resistance in parallel with the resistor R_{FB} to thus reduce gain. It will be recalled that the closed loop gain of an amplifier having a feedback loop coupled from its output to its input is approximately equal to the ratio between the effective feedback resistance and the input resistance, herein resistor **54**. Thus, if the feedback resistance can be reduced by gradually introducing resistance in parallel with resistor R_{FB}, the gain can be correspondingly reduced.

More particularly, a first path in parallel with the feedback resistance R_{FB} is comprised of resistor R_1 connected in series with resistor R_2 and a switch, preferably a diode D_1. A second path in parallel with feedback resistor R_{FB} includes resistor R_3 connected in series with resistor R_4 and diode D_2. A third parallel path is comprised of previously mentioned resistor R_3 connected in series with resistors R_5, R_6, and diode D_3.

Resistor R_7 connects the junction between resistors R_5 and R_6 to a source of negative potential. A variable resistor R_8 similarly connects the junction between resistors R_1 and R_2 to the source of negative potential.

In the operation of the feedback path **56** for low levels of input signal E_{IN}, each of the diodes D_1, D_2, and D_3 will be back biased so that the feedback resistance will be defined solely by the resistor R_{FB}. Thus, the gain of the drive circuit of FIG. 4 will be defined by the ratio between the value of resistor R_{FB} and the value of input resistor **54**. As the level of the input signal E_{IN} increases, the output signal E_G also increases, thus increasing the potential at the junction between resistor R_1 and variable resistor R_8. When the level of E_G increases sufficiently, diode D_1 will be forward biased to thus insert resistors R_1 and R_2 in parallel with feedback resistor R_{FB} to accordingly lower the effective feedback resistance and correspondingly lower the closed loop gain. It will be appreciated that the level of signal E_G required to forward bias the diode D_1 depends upon the setting of variable resistor R_8. As the input signal level increases further, the diode D_2 and subsequently the diode D_3 will become forward biased to thereby introduce additional resistance in parallel with the feedback resistor R_{FB} to further lower the effective feedback resistance and the closed loop gain.

Accordingly, it should now be appreciated that the gain level **40** represented in FIG. 2(*c*) is established when all the diodes D_1, D_2, and D_3 are back biased. When diode D_1 becomes forward biased, the closed loop gain decreases to the level **42** and as diodes D_2 and D_3 become successively forward biased the gain decreases further to level **44** and subsequently to level **46**.

The limit feedback path **60** includes a diode D_4 connected in series with a resistor R_9 to the emitter of PNP transistor **Q1**. The collector of the transistor **Q1** is connected to the input terminal of amplifier **52**. The base of transistor **Q1** is connected to the tap **61** of a potentiometer **62** connected between ground and a source of positive potential.

The tap **61** of potentiometer **62** is utilized to establish a reference potential on the base of transistor **Q1**. As long

as the output signal E_G provided by the amplifier **52** is not greater than the potential applied to the base of transistor Q1, the diode D_4 will be back biased and the transistor Q1 will be held off. On the other hand, when the signal E_G increases to a level two diode drops greater than the potential established on the potentiometer tap **61**, the diode D_4 will become forward biased and turn the transistor Q1 on. The introduction of the low impedance feedback loop around amplifier **52** through transistor Q1 reduces the closed loop gain of the amplifier **52** to a very small value such that the level of signal E_G cannot rise much above the potential established by the potentiometer **62**.

It is pointed out that the feedback path **60** is connected around amplifier stage **52** rather than around both stages **50** and **52** primarily to assure stability. That is, inasmuch as the feedback through path **60** is around fewer stages than the principal signal loop through path **56**, it will introduce less phase shift and therefore will not tend to oscillate.

From the foregoing, it should be appreciated that a circuit apparatus has been disclosed herein for enabling beam intensity in a cathode ray tube to be controlled extremely accurately over a wide dynamic range. Accurate control is achieved by introducing nonlinearities in the grid electrode drive circuit which nonlinearities tend to linearize the relationship between beam intensity and input signal E_{IN}. Additionally, the disclosed circuit apparatus introduces limiting means for preventing the grid signal E_G from increasing beyond a certain level at which severe beam defocussing can occur.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In combination with a cathode ray tube having beam producing means and a control electrode, drive circuit means responsive to an input signal for providing a control signal to said control electrode for controlling the intensity of said beam, said cathode ray tube having a nonlinear characteristic relating beam intensity to control signal level, said drive circuit means including:

an amplifier having input and output terminals;

means for applying said input signal to said amplifier input terminal;

means coupled to said amplifier for nonlinearly varying the gain thereof as a function of input signal level to substantially linearize the characteristic relating beam intensity to input signal level;

means coupling the output terminal of said amplifier to said control electrode;

means including a normally open feedback path connected between said output terminal and said input terminal for limiting said control signal to a predetermined level; and

means for closing said normally open feedback path in response to said control signal reaching said predetermined level.

2. The combination of claim **1** wherein said normally open feedback path includes a transistor having an emitter, a collector, and a base;

means connecting said emitter and collector between said amplifier input and output terminals; and

means applying a variable potential to said base.

3. The combination of claim **1** wherein said means for varying gain includes a second feedback path including a feedback impedance coupling said amplifier output terminal to said amplifier input terminal; and

means for varying said feedback impedance as a function of input signal level.

4. The combination of claim **3** wherein said feedback impedance includes a fixed resistor; and wherein

said means for varying said feedback impedance includes a plurality of impedance paths connected in parallel with said feedback resistor;

a plurality of switch means, each connected in a different one of said paths; and

means for closing each of said switch means in response to a different level of control signal.

5. The combination of claim **4** wherein each of said switch means comprises a diode.

6. In combination with a cathode ray tube having beam producing means and a control electrode, drive circuit means responsive to an input signal for producing a control signal for application to said control electrode for controlling the intensity of said beam, said cathode ray tube having a nonlinear characteristic relating beam intensity to control signal level, said drive circuit means includng:

an amplifier having at least first and second stages, each stage having input and output terminals;

means for applying said input signal to said input terminal of said first stage;

means coupling said first stage output terminal to said second stage input terminal;

means coupling said second stage output terminal to said control electrode;

first feedback means coupled between said second stage output terminal and said first stage input terminal for nonlinearly varying the gain of said amplifier as a function of input signal level to substantially linearize the characteristic relating beam intensity to input signal level; and

second feedback means connected between said second stage output terminal and said second stage input terminal for limiting said control signal to a predetermined level.

7. The combination of claim **6** wherein said first feedback means includes a feedback impedance; and

means for varying said feedback means as a function of input signal level.

8. The combination of claim **6** wherein said second feedback means comprises a normally open feedback path including a transistor having an emitter, a collector, and a base;

means connecting said emitter and collector between said second stage output terminal and said second stage input terminal; and

means coupling a controllable potential source to said transistor base.

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