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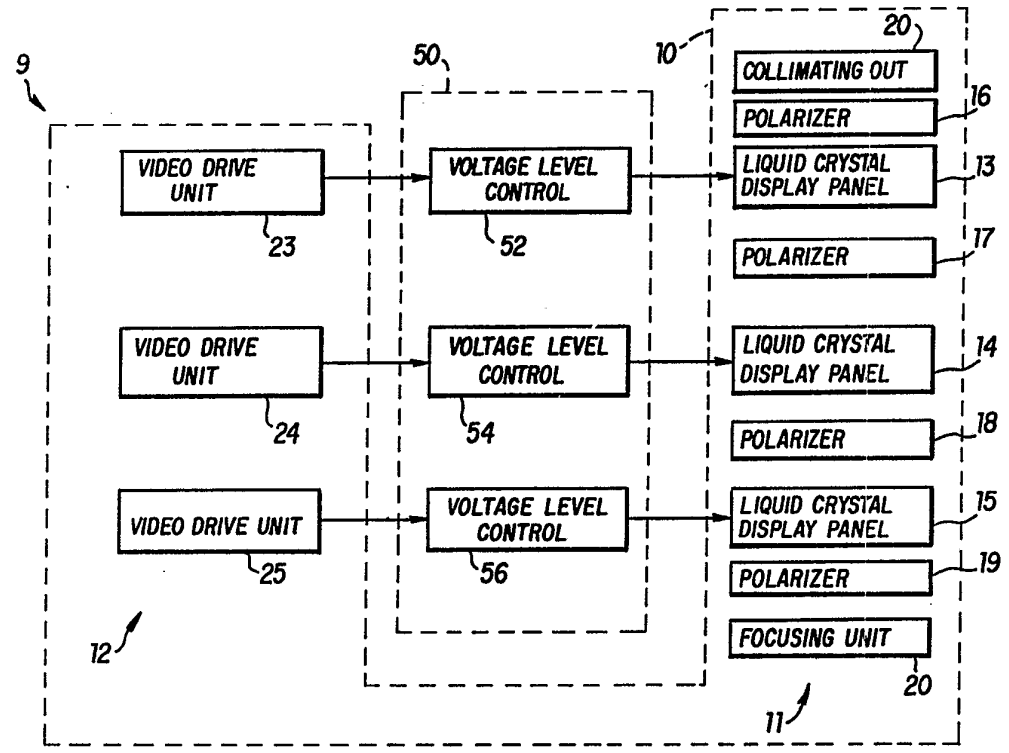

(57) Abstract

A new display panel system (9), includes a stacked display panel (11), and drive units therefor. The drive units (12), include a computer (38), for adjusting for the individual gamma characteristics of each one of the display panels (13, 14, 15), for color balancing purposes and for causing the luminance of each panel to be maximized, or at least greatly increased for each intensity level or shading of each color.

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Description

STACKED DISPLAY PANEL CONSTRUCTION AND METHOD OF MAKING SAME

Cross Referenced to Related Applications

This is a continuation-in-part of U.S. patent application Serial No. 07/506,429 filed April 9, 1990 entitled "STACKED DISPLAY PANEL CONSTRUCTION AND METHOD OF MAKING SAME" which is a continuation-in-part of U.S. patent application Serial No. 07/472,688 filed January 30, 1990, entitled "LIQUID CRYSTAL DISPLAY PANEL SYSTEM AND METHOD OF USING SAME", which is a continuation-in-part of U.S. patent application Serial No. 07/222,144 filed July 21, 1988 entitled "GRAY SCALE SYSTEM FOR VISUAL DISPLAYS". The foregoing patent applications are incorporated herein by reference.

Technical Field

The present invention relates, in general, to a stacked display panel system and a method of making it, in an improved manner. More particularly, the present invention relates to a stacked liquid crystal display panel system and method of making it, to improve the quality of the light images produced thereby.

Background Art

Large screen projection displays have been in demand for use in meetings, eduction, and for public announcement. Such systems are typically used in brightly lighted locations such as offices, airport lobbies and other public places. Thus, a bright screen with multicolored images is very important.

To satisfy the demand for such display systems, several types of liquid crystal display panel systems have been proposed. Such systems, however, have

typically been limited in the number of different colors produced, or have exhibited poor contrast ratios. Such limitations result from various factors. For example, the physical and electrical characteristics of the individual liquid crystal display panel assemblies for producing colors, typically vary in actual production.

In a stacked display panel construction, a series of display panels and associated polarizers or filters are arranged along an optical path. The relative luminance of the individual panels is also effected by the order in which the panel assemblies are disposed within a stacked arrangement; i.e., a panel disposed more closely to the light source generally exhibits greater light transmittance characteristics as compared to a panel which is disposed more remotely from the light source along the common optical path because of the induced heating by the light source.

Another problem with conventional liquid crystal display panel systems is that the light transmission characteristics of the individual panels in a stacked panel arrangement,also vary in actual production. Consequently, the contrast levels of a multiple number of panels arranged along an optical path, does not follow in a linear manner, thereby resulting in color distortion.

Not only do the abstract values differ from panel to panel in a stacked configuration where each panel is responsible for a portion of the visible color spectrum, but also the excitation or gamma curves (applied voltage versus relative luminance) for each panel vary widely in significant manners. Accordingly, even if the panels could somehow be matched at one intensity or shading level, it would be difficult, if not impossible, to cause

the contrast levels of the stacked panel arrangement to be balanced from one panel to the next, in a stacked panel arrangement.

Because typical liquid crystal display panel exhibits a hysteresis effect as a function of the applied voltage, different hues or shades of color can be produced by multiplexing the individual pixels or by applying incremented voltage steps between the excited and unexcited states of the panel. While such a technique may produce colors with multiple hues, it has been difficult, if not impossible, for such panel systems to produce a large number of different colors with multiple shading levels, because the relative luminance between the different colored panel assemblies varies to such a great extent.

For example, in U.S. Patent 4,416,514, there is disclosed a liquid crystal color filter, which includes a set of differently colored dichroic polarizers interposed with an equal number of voltage responsive twisted nematic liquid crystal cells, and a neutral polarizer. Each of the above described elements are arranged along an optical path in a predetermined manner for modifying the spectral content of visible light incident to the filter to produce any one of eight predetermined colors. Shades of the predetermined colors are achieved by varying the voltage applied to the individual liquid crystal cells.

While the above described patented system may produce a full colored display image, it was limited to only an eight color system, since it would be difficult, if not impossible, to balance the filter colors for different hues on a pixel by pixel basis, as the light

transmission characteristics of each of the liquid crystal display panels vary slightly, due to manufacturing inconsistencies between like panels and due to the physical and electrical characteristics of the panels. Thus, color balancing for the entire unit is generally unsatisfactory for some applications. More particularly, if the generating voltage levels are varied by same amount for each panel, each panel will have a different amount of relative luminance, thereby resulting in a distortion of the resulting colored image on a pixel by pixel image basis.

Summary of the Invention

Therefore, the principal object of the present invention is to provide a new and improved display panel system, and a method of making it, to produce improved light image characteristics, and yet be able to manufacture such a system according to modern mass production techniques.

Another object of the present invention is to provide such a new and improved display panel system, and a method of making it, wherein the system includes a stacked display panel construction, and wherein the display panel stages or assembles are balanced optically from assembly to assembly.

Briefly, the above and further objects are realized by providing a new and improved display panel system.

A new display panel system includes a stacked display panel and drive units therefor. The drive units include a computer for adjusting for the individual gamma characterics of each one of the display panels for color balancing purposes and for causing the luminance of each

panel to be maximized, or at least greatly increased for each intensity level or shading of each color.

Brief Description of Drawings

The above mentioned and other objects and features of this invention and the manner of attaining them will become apparent, and the invention itself will be best understood by reference to the following description of the embodiment of the invention in conjunction with the accompanying drawings, wherein:

FIG. 1 is a block diagram of a display panel system, which is constructed in accordance with the present invention;

FIG. 2 is a symbolic block circuit diagram of a voltage level control unit of the system of FIG. 1;

FIG. 3 is a diagrammatic and block diagram view of a display panel construction of the system of FIG. 1, illustrating it being used in a conventional overhead projector as controlled by a computer; and

FIGS. 4-10 are graphs useful in the understanding of the present invention.

Best Mode for Carrying Out the Invention

Referring now to Fig. 1, there is shown display panel system 9, which is constructed in accordance with the present invention, and which produces multicolored display images.

The display panel system 9 generally comprises a liquid crystal display panel assembly 10, which includes a liquid crystal display panel construction, shown generally at 11 and a video processing unit 12 which are more fully described in copending U.S. patent application Serial No. 07/506,429 filed concurrently herewith, and

foregoing mentioned U.S. patent application Serial No. 07/472,668 which are incorporated herein by reference.

The panel construction 11 includes a set of liquid crystal display panels 13, 14, and 15 which are disposed along a common optical path, which includes a collimating unit 20 and focusing unit 21 for directing light along the common optical path. The panel construction 11 also includes a set of spaced apart polarizers 16, 17, 18, and 19 which are also interleaved with, and optically aligned withthe display panels 13, 14, and 15 along the common optical path.

The gamma curve adjustment system 10 generally comprises a linearization network 50 having a set of voltage level control circuits 52, 54, and 56 connected to the respective ones of the display panels 13, 14, and 15, for adjusting the initial direct current voltage applied to each one of the respective liquid crystal display panels to utilize substantially the full gamma curve characteristic for each respective panels, as will be explained hereinafter in greater detail. The linearization network 50 also tracks or follows the respective gamma curves characteristic for each one of the panels 13, 14, and 15, to permit the contrast level of the panel assembly 11 to be adjusted, without color distortion as will be explained hereinafter in greater detail.

Each of the voltage level control circuits 52, 54, and 56 is coupled between the individual liquid crystal display panels 13, 14, and 15 respectively, and a set of associated video drive units 23, 24, and 25 respectively. The drive units 23, 24, and 25 form part of the video processing unit 12. Each of the video drive units 23,

24, and 25 are also coupled to their respective liquid crystal display panels 13, 14, and 15 by suitable means (not shown), and are more fully described in the foregoing mentioned copending U.S. patent application Serial No. 07/472,668.

Each one of the liquid crystal display panels is used for a different color, and exhibits a different relative luminance as a function of the voltage applied to the respective liquid crystal display panels, such as panels 13, 14, and 15.

FIGS. 4, 5, and 6 show three typical gamma curves 28, 30, and 32 for panels 13, 14, and 15 respectively. As each of these curves is substantially identical in form, only gamma curve 28 will be described hereinafter in greater detail. In operation, the individual voltage level control circuits 52, 54, and 56 are adjusted to provide an initial direct current reference voltage (V_{ref}) for their respective liquid crystal display panels 13, 14, and 15, to enable a maximum amount, if not a high percentage of relative luminance to be produced by each of the panels 13, 14, and 15. Thus, according to the present invention, the assembly 10 enables a high percentage, if not a maximum percentage, of luminance to be achieved for each level of color intensity displayed for each pixel.

Considering now the linearization network 50 in greater detail with reference to FIGS. 1 and 2, each of the voltage level control circuits 52, 54, and 56 are similar to one another, except as will be explained hereinafter in greater detail. Accordingly, with reference to FIG. 2, only control circuit 56 will now be described.

Considering now the voltage level control circuit 56 in greater detail with reference to FIG. 2, the voltage level control circuit 56 is responsive to digital signals supplied by a microprocessor 38 disposed within the video drive unit 25. As more fully explained in the foregoing mentioned pending patent applictions, each one of the digital signals supplied by the microprocessor 38 is indicative of a given shading or color level for a displayable pixel forming part of the image produced by the panel assembly 10. More particularly, the voltage level control circuit 56 supplies a selected operating voltage level to the panel 15, which,m in turn, enables each displayable pixel to be displayed with a maximum, if not a relative high percentage of relative luminance for helpting to contrast one shading level from another.

In order to convert the digital signals supplied by the microprocessor 38 into an operating voltage level to maximize contrasting shading levels, the voltage level control circuit 56 includes a digital to analog converter 58 for converting digital signals from the computer 38, into analog voltage levels indicative of the different panel operating voltage levels for each color intensity level, to maximize, or at least to increase greatly the luminance of contrasting shading levels.

The voltage level control circuit 56 also includes a differential amplifier 60 for amplifying the analog voltage signal supplied by digital to analog converter 58 into an appropriate operating voltage level for the panel 15. In this regard, the control circuit 56 also includes a feedback gain control arrangement 62 for determining the amount of gain for the input signal to the amplifier 60.

In order to adjust the direct current reference voltage V_{ref} on lead 86 for panel 15, relative to the various operating voltage levels for the panel, the voltage level control circuit 56 also includes a direct current voltage offset arrangement 70.

Considering now the digital to analog converter 58 in greater detail with reference to FIG. 2, the digital to analog converter 58 tend to maximize the number of discrete operating voltage levels between the threshold voltage level V_T and the saturation voltage level V_{SAT}. The digital to analog converter 58 is also selected to have discrete voltage level steps or increments, which are balanced with the voltage increment levels produced by the digital to analog converters in each of the other control circuits 52 and 54. It should, therefore, be understood that the digital to analog converters of each one of the control circuits perform similar functions but will necessarily have different voltage increment step capabilities to compensate for the individual operating characteristics of their corresponding display panels 13, 14, and 15 respectively.

Considering now the feedback gain arrangement 62 in greater detail with reference to FIG. 2, the feedback gain arrangement includes two current limiting resistors 67 and 72 which are selected to cause the differential amplifier 60 to amplify the output voltage from the digital to analog converter 58, to an appropriate voltage. In this regard, like the digital to analog converters, the resistance values of the resistors in the other feedback gain arrangements for control circuits 52 and 54, may be different than the resistance values of

resistors 67 and 72, although they perform a similar function.

As best seen in FIG. 2, the resistor 72 connects the output of the digital to analog converter at 81 to the negative or inverting input 82 of the differential amplifier 60. The negative or inverting input 82 of the amplifier 60 is also coupled through resistor 67 via conductors 83 and 84 to an output 85 of the amplifier 60. Resistor 72 is a 5 kohm resistor while resistor 67 is a 10 kohm resistor.

Considering now the differential amplifier 60 in greater detail with reference to FIG. 2, the output 85 of the amplifier 60 is connected to the liquid crystal display panel 15 to provide a selected operating voltage for attempting to maximize contrasting shading or color levels, so that each pixel energized at one level will be easily distinguished from every other pixel energized at different shading levels of the same basic color.

In order to provide a differential voltage level reference as well as to provide a direct current voltage level reference for utilizing to the fullest extend possible the full gamma curve of the panel 15 to be utilized in response to changing shading or color levels, the noninverting or positive input of the amplifier 60 is coupled to the offset adjustment arrangement 70 by a conductor 86.

Considering now the offset adjustment arrangement 70 in greater detail with reference to FIG. 2, the offset arrangement 70 consist of a manually adjustable potentimeter 75 which has its wiper or tap connected to the noninverting input of amplifier 60 by the conductor 86.

The offset arrangement also includes a pair of voltage divider resistor 74 and 76 for providing the proper reference voltage to the amplifier 60 as a function of the resistance setting of potentimeter 75.

Resistor 74 is coupled to ground by conductor 90 and the potentimeter 75 by conductor 89. The resistor 76 is coupled to a negative voltage source (not shown) by conductor 87 and the opposite terminal of potentimeter 75 by conductor 88. Resistor 74 is a 1.5 Kohm resistor, resistor 76 is a 10 Kohm resistor and potentimeter 75 is a 2.0 Kohm potentimeter.

Considering now the operation of the system 9 in greater detail with reference to the gamma curves illustrated in FIGS. _____ to _____. The gamma curve 28 illustrates the relative luminance of panel 13 as a function of the voltage applied by the voltage level control circuit 52 to the panel 13.

The gamma curve 28 is developed by positioning the liquid crystal display panel assembly 10 on an overhead projector 40 and focusing the light output of the system 10 into the projection lense of the overhead projector 40 to display an image (not shown) on a viewing screen or surface 43. The light source of the overhead projector 30 directs light into the collimating unit 20 for collimating the light. The system 10 is then electrically activated so that each panel (and all the associated displayable pixels within the panels) 13, 14, and 15 is placed in a saturated state by their associate voltage level control circuits 52, 54, and 56 respective, thus, enabling the panel construction 11 to pass noncolored light or light exhibiting the maximum relative luminance. This maximum relative luminance has an

associated direct current reference or saturation voltage (V_{SAT}) which is measured by a user and record to form part of the gamma curve 28.

A processor program 100 is then activated by a user to cause the microprocessor 30 to generate a test pattern for displaying on the screen 43. The test pattern consists of three sets of discrete shading or color level setting, one set for each respective panel. Each set is substantially identical so only one will be described hereinafter.

Depending upon the type of computer that is driving the system 9, various shades of colors will be available. For example, a computer 35 (FIG. 3) is capable of producing at least 8 different shades of color where each shade is represented by a discrete digital code. These discrete colors are capable of being combined either in graphic or text form by the computer 35 to produce a display image which may be displayed on the screen of an associated video monitor; such as monitor 36 or on the viewing screen 43. Ideally the shading or contrast levels in the displayed images should be substantially the same as between the image displayed on the monitor 36 and the image displayed on the screen 43. The processor program 100 enables the system 9 to be adjusted so that the full gamma curve 28 can be utilized so the system 9 can produce a full spectrum with colors.

As each level of shading or color is sequentially displayed on the screen 42, a user manually adjusted the reference potentimeter, such as potentimeter 75, to vary the direct current voltage applied to the panel 13 and using a photometer 45 measures the relative luminance

with calibraated red, blue and photic filters of the panel 13 as a function of the applied voltage.

The program 100 generates a test pattern of 8 discrete shading or color levels and causes the drive units to generate signals for producing on a screen by screen basis each individual discrete level within the 8 discrete levels. The program code for program 100 is assembled in 870451 assembly language and is attached to this application as appendix A and represents the actual relative luminance of the panel 13 for each of the individual 8 shading or color levels as measured by a user.

To obtain each plotted point, the selected level is displayed and then using the photometer the relative red, green, or blue luminance of the screen 43 is measured as the potentimeter 75 is varied between V_T and V_{SAT}. Whenever the relative luminance for the displayed level is distinguished from the next lower level, the measured relative luminance is recorded.

As the test pattern starts with maximum color level (level 0), this represents the darkest shade and the relative luminance will be a function of the threshold voltage (VT). This relative luminance level is also recorded as a function of the applied voltage to form another part of the gamma curve.

Ideally, to provide the greatest contrast between levels 0 and level 7, levels 0 to 7 should be equally spaced apart on the gamma curve 28 between V_T and V_{SAT}. The gamma curve in FIG. 3 part of the gamma curve as a function of the applied voltage that permitted the maximum luminance for the displayed level to be distinguished from the next lowest level.

The above disclosed process is repeated until all 8 levels of shading have been recorded to produce the gamma curve 28. The process is then repeated for the other panels to produce the other gamma curves 30 and 32. It should be noted that when recording the relative luminance level of the panels 13, 14, and 15, blue, red, and green filters (not shown) are used in the photometer 34 for recording the relative luminance as a function of applied voltage.

As best seen in FIG. 4 with respect to the individual shading levels of the blue panel 13, certain of the shading levels 0-3 were not distinguished from relative luminance at the threshold voltage level. Moreover, the upper shading level 7 was not disposed near the saturation voltage level. Thus, the full gamma curve is not utilized.

Referring now to FIG. 2, the digital signals generated by the microprocessor 38 correspond to the discrete shading levels. Accordingly, after determining the gamma curve response of the panels 13, 14, and 15, the microprocessor 38 is programmed by the user via a direct current voltage default program 200 to adjust the operating voltage to utilize the full gamma curve. More particularly, for example, with reference to the blue panel, an offset of 18 levels is established to better use the gamma curve 28. Thus when a level 1 shading signal is received by the microprocessor 38 from the computer 35, the microprocessor which convey the level 1 shading signal into a psuedo level signal indicative of level 19 so that the output voltage of amplifier 60 will correspond to a level 19 applied voltage as opposed to the actual level 1 signal. In this manner,

microprocessor 38 generates a series of pseudo signal that increment and decriment the applied voltage to maximum relative luminance between the discrete shading or color levels. FIGS. 7-9 illustrate the respective gamma curve 28A, 30A, and 32A and the relative luminance for the discrete shading levels when the microprocessor 38 has been programmed to offset the digital signals as described above.

Considering now the gamma curves 28A, 30A, and 32A in greater detail with reference to FIG. 10, it will be noted that when the three gamma curves are superimposed on the same graph that they have substantially different discrete level shifts over the full 8 discrete levels. For example, the relative luminance of the red panel varies between 5.5 cd/m^2 and 19.7 cd/m^2, as the applied voltage varies between -17.5 volts (V_T) and -20.5 volts (V_{SAT}).

Comparing the green panel between threshold voltage of -17.5 volts and the saturation voltage of -21.5 volts, the relative luminance varied between 5.0 cd/m^2 and 10.5 cd/m^2.

From the foregoing, it should be clear that the step voltage changes vary substantial between different panels. To compensate for these differences, each of the d/a converters associated with the voltage level control circuits, such as d/a converter 58 have different step voltage responses that are selected to balance the color contrast between the panels 13, 14, and 15.

In order to enable a user to achieve the contrast balance, the user may press a selected function key on a keyboard or utilize other equivalent means such as a

remote control infrared transmitter coupled to the microprocessor 38 by an infrared link.

Attached hereto as Appendix A is a source code listing of a firmware computer program stored in the microprocessor 38 for controlling the operation of the system 9. At pages 21, 43 through 49 of the appended Appendix A, there is disclosed the source code for controlling the tracking operation.

Therefore, the system 9 enables eight optimum operating levels for each one of the three color stages. In this regard, when the computer 35 calls for a given duty cycle level of color intensity to be generated by a given panel as explained in the foregoing patent applications, the microprocessor 38 provides a direct current bias signal for the given panel to bias the operation of the panel at the top of the luminance curve, so that when the computer 38 calls for a given intensity level, that designated level is optimized, since the intensity level voltage supplied to the panel is off-set by the d.c. bias voltage from the amplifier 60, thereby providing an optimized image display. The optimized image display is one where the luminance is of a sufficiently high relative value, and the contrast is also of a sufficiently high value. This voltage values corresponding the given bias level for a given computer 35 and a given panel are stored in the gamma curve look-up table found in the firmware to cause the amplifier 60 to generate the desired bias voltage level, for the top portion of the gamma curve. The contrast consideration takes into account that a manual contrast input (not shown) for the system 9 provides only a single decrement or increment, and yet the firmware determines three

corresponding decremental or incremental changes in the voltage levels for the three different color panels of the system 9.

Therefore, it has been discovered that by determining a single d.c. biasing offset voltage for each panel for a given type of computer 35, such as a Mac II personal computer, the multiplexed duty cycle color intensity levels supplied to a given panel, as explained in the foregoing patent applications, is optimized automatically by causing the desired distribution of operating points along the gamma curves as shown in FIGS. 7-9 for the eight given color intensity levels for determination of the off-set d.c. voltage is selected in the manner as described in the appended Appendix B. The off-set bias voltage for given panels and given computers are stored in the look up table in the firmware of Appendix A.

While particular embodiments of the present invention have been disclosed, it is to be understood that various different modifications are possible and are contemplated within the true spirit and scope of the appended claims. There is no intention, therefore, of limitations to the exact abstract or disclosure herein presented.

What is claimed is:

Claims

1. A gamma curve adjustment system for a stacked liquid crystal display panel construction comprising:

a display panel construction having at least one twisted nematic liquid crystal display panel having a plurality of electrically operable pixels for displaying multiple levels of color shades; and

direct current voltage level control means for varying the direct current voltage applied to said panel to maximize the relative luminance of each displayable pixel; and

said electrically operable pixels being electrically turned on and off independently of said direct current voltage control means.

2. A gamma curve adjustment system according to claim 1 wherein said direct current voltage level control means includes:

a microprocessor responsive digital to analog converter for generating analog signals indicative of the direct current voltages to be applied to said panel for each electrically operable pixel to maximize the relative luminance of said pixels; and

a differential amplifier responsive to said analog signals for generating said direct current voltages for said liquid crystal display panels.

3. A method for maximizing the relative luminance of electrically operable pixels in a stacked liquid crystal display panel construction, comprising:

generating a plurality of test patterns, each individual test pattern consisting of a plurality of pixels each pixel having the same color shading level;

adjusting the applied direct current voltage for each panel in the panel construction until the panel construction in response to a first test pattern for maximum luminance produces noncolored light;

measuring the applied direct current voltage for each panel at its saturated voltage level;

adjusting the applied direct current voltage for each panel in the panel construction in response to eight test pattern for maximum luminance at a maximum shaded colored light;

measuring the applied direct current voltage for each panel at its threshold voltage level;

adjusting the applied direct current voltage for one selected panel construction until the panel construction in respond to a second test pattern for determining maximum luminance between said saturated voltage level and said voltage level;

measuring the maximum relative luminance for said second test pattern and the applied voltage causing said panel to produce said maximum luminance;

recording the maximum relative luminance for said selected panel as a function of the applied voltage producing said maximum relative luminance in response to said second test pattern;

changing the test patterns sequentially;

measuring the maximum relative luminance for each sequential test pattern and the applied voltage causing said panel to produce said maximum luminance;

recording the maximum relative luminance for said selected panel as a function of applied voltage for producing said maximum relative luminance in response to each sequential test pattern;

selecting another panel in the system and repeating said adjusting, measuring and recording steps until gamma curves have been plotted for each respective panel in said panel construction; and

adjusting the direct current voltage applied to each panel to maximize the number of discrete color or shading levels between said saturation voltage and said threshold voltage, said adjustment being determined by the first shading level distinguishable from the shading level at said threshold voltage level.

AMENDED CLAIMS

[received by the International Bureau on 28 August 1991 (28.08.91); original claims 1-3 replaced by amended claims 1-16 (5 pages)]

1. A system for adjusting the luminance level of a visual display arrangement, comprising:

at least two twisted nematic liquid crystal display panels each having a plurality of electrically operable pixel elements for displaying multiple shading levels of a color image;

said panels having total twist angles of substantially greater than 90 degrees and being associated with polarizers which cooperate with said panels for permitting selected portions of the visible light spectrum to pass to form said color image;

direct current voltage control means for biasing said panels with direct current bias voltages to maximize substantially the luminance of each pixel image when said pixel elements are fully energized;

means for generating select voltages to energize selectively said plurality of electrically operable pixel elements, said select voltages in combination with said bias voltages causing selected pixel elements to be fully energized;

contrast adjustment means for balancing substantially the color contrast of the previously luminance adjusted panels, said contrast adjustment means causing the direct current bias voltages of the panels to be adjusted by substantially different offset direct current bias voltages to optimize substantially the color contrast of said panels.

2. A system according to claim 1 wherein said contrast adjustment means includes:

digital to analog converter means for generating analog signals indicative of the direct current voltages to be applied to said panels to

substantially optimize the color contrast of said panels; and

differential amplifier means responsive to said analog signals for generating said direct current voltages for said liquid crystal display panels.

3. A method for maximizing the relative luminance of electrically operable pixels in a stacked liquid crystal display panel construction, comprising:

generating a plurality of test patterns, each individual test pattern consisting of a plurality of pixels each pixel having the same color shading level;

adjusting the applied direct current voltage for each panel in the panel construction until the panel construction in response to a first test pattern for maximum luminance produces noncolored light;

measuring the applied direct current voltage for each panel at its saturated voltage level;

adjusting the applied direct current voltage for each panel in the panel construction in response to eight test patterns for maximum luminance at a maximum shaded colored light;

measuring the applied direct current voltage for each panel at its threshold voltage level;

adjusting the applied direct current voltage for one selected panel construction until the panel construction in response to a second test pattern for determining maximum luminance between said saturated voltage level and said voltage level;

measuring the maximum relative luminance for said second test pattern and the applied voltage causing said panel to produce said maximum luminance;

recording the maximum relative luminance for said selected panel as a function of the applied voltage

producing said maximum relative luminance in response to said second test pattern;

changing the test patterns sequentially;

measuring the maximum relative luminance for each sequential test pattern and the applied voltage causing said panel to produce said maximum luminance;

recording the maximum relative luminance for said selected panel as a function of applied voltage for producing said maximum relative luminance in response to each sequential test pattern;

selecting another panel in the system and repeating said adjusting, measuring and recording steps until gamma curves have been plotted for each respective panel in said panel construction; and

adjusting the direct current voltage applied to each panel to maximize the number of discrete color or shading levels between said saturation voltage and said threshold voltage, said adjustment being determined by the first shading level distinguishable from the shading level at said threshold voltage level.

4. A display system according to claim 1, wherein said liquid crystal display panels are a nematic liquid crystal display panels.

5. A display system according to claim 4, wherein said nematic liquid crystal display panels are twisted nematic liquid crystal display panels.

6. A display system according to claim 4, wherein said nematic liquid crystal display panels are highly twisted nematic liquid crystal display panels.

7. A display system according to claim 4, wherein said nematic liquid crystal display panels are supertwisted nematic liquid crystal display panels.

8. A method for displaying color images, comprising:

using a liquid crystal display panels having a plurality of electrically operable pixel elements for displaying color images;

interleaving said panels with polarizers that cooperate with said panels for passing selected portions of the visible light spectrum to form a given color image;

using direct current voltage level control means for biasing said panels with a direct current reference voltage;

biasing said panels with direct current voltages to maximize substantially the luminance of the color image when said pixel elements are fully energized;

selectively said pixel elements, said selected voltages in combination with said bias voltages causing selected pixel elements to be fully energized;

balancing the color contrast of said panel by causing the direct current voltages to be adjusted by substantially different offset direct current voltages to optimize substantially the color contrast of said panels.

9. A display system according to claim 7, wherein said liquid crystal display panels in cooperation with the associated polarizers passes non-colored light and colored light, said colored light being substantially in the yellow color spectrum of visible light.

10. A display system according to claim 7, wherein one of said liquid crystal display panels in cooperation with its associated polarizers passes non-colored light and colored light, said colored light being substantially in the magenta color spectrum of visible light.

11. A display system according to claim 7, wherein one of said liquid crystal display panels in cooperation with its associated polarizers passes non-colored light and colored light, said colored light being substantially in the cyan color spectrum of visible light.

12. A display system according to claim 7, wherein one of said liquid crystal display panel in cooperation with its associated polarizers passes colored light, said colored light being substantially in the red color spectrum of visible light.

13. A display system according to claim 7, wherein one of said liquid crystal display panel in cooperation with its associated polarizers passes colored light, said colored light being substantially in the green color spectrum of visible light.

14. A display system according to claim 7, wherein one of said liquid crystal display panel passes colored light, said colored light being substantially in the blue color spectrum of visible light.

15. A system according to claim 1, wherein said liquid crystal panels are active matrix liquid crystal display panels.

16. A display system according to claim 1, wherein said direct current voltage level control means is manually adjustable between a substantially maximum amount of relative luminance when said panels are energized and a substantially minimum amount of relative luminance when said panels are de-energized.

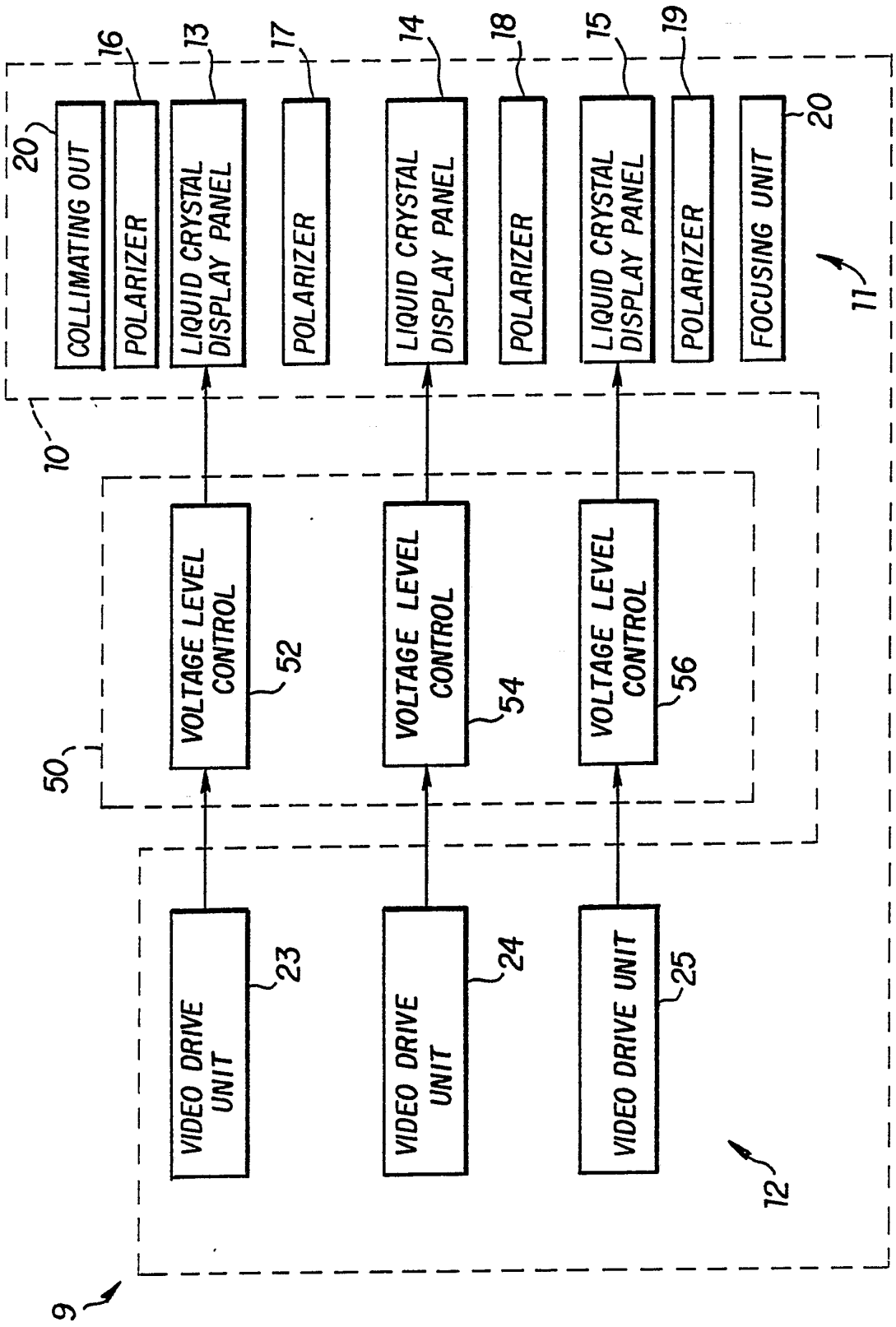
COLLIMATING OUT
POLARIZER
LIQUID CRYSTAL DISPLAY PANEL
POLARIZER
LIQUID CRYSTAL DISPLAY PANEL
POLARIZER
LIQUID CRYSTAL DISPLAY PANEL
POLARIZER
FOCUSING UNIT
VOLTAGE LEVEL CONTROL
VOLTAGE LEVEL CONTROL
VOLTAGE LEVEL CONTROL
VIDEO DRIVE UNIT
VIDEO DRIVE UNIT
VIDEO DRIVE UNIT
9
10
11
12
13
14
15
16
17
18
19
20
23
24
25
50
52
54
56

FIG. 1

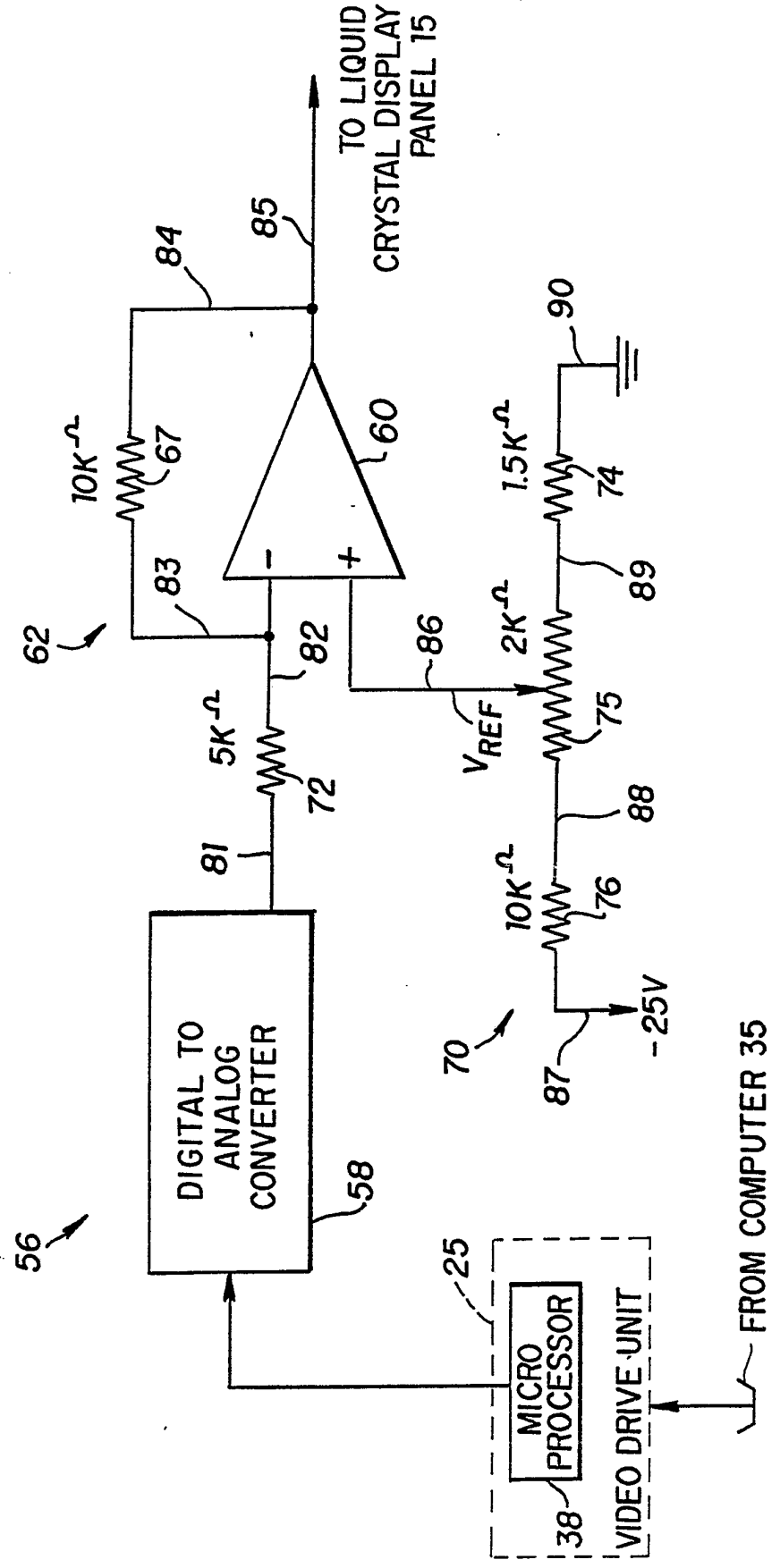
TO LIQUID CRYSTAL DISPLAY PANEL 15
85
84
90
10K Ω
67
60
1.5K Ω
74
62
83
82
89
86
2K Ω
5K Ω
72
V_{REF}
75
81
88
10K Ω
76
DIGITAL TO ANALOG CONVERTER
58
70
-25V
87
56
25
MICRO PROCESSOR
38
VIDEO DRIVE UNIT
FROM COMPUTER 35

FIG. 2

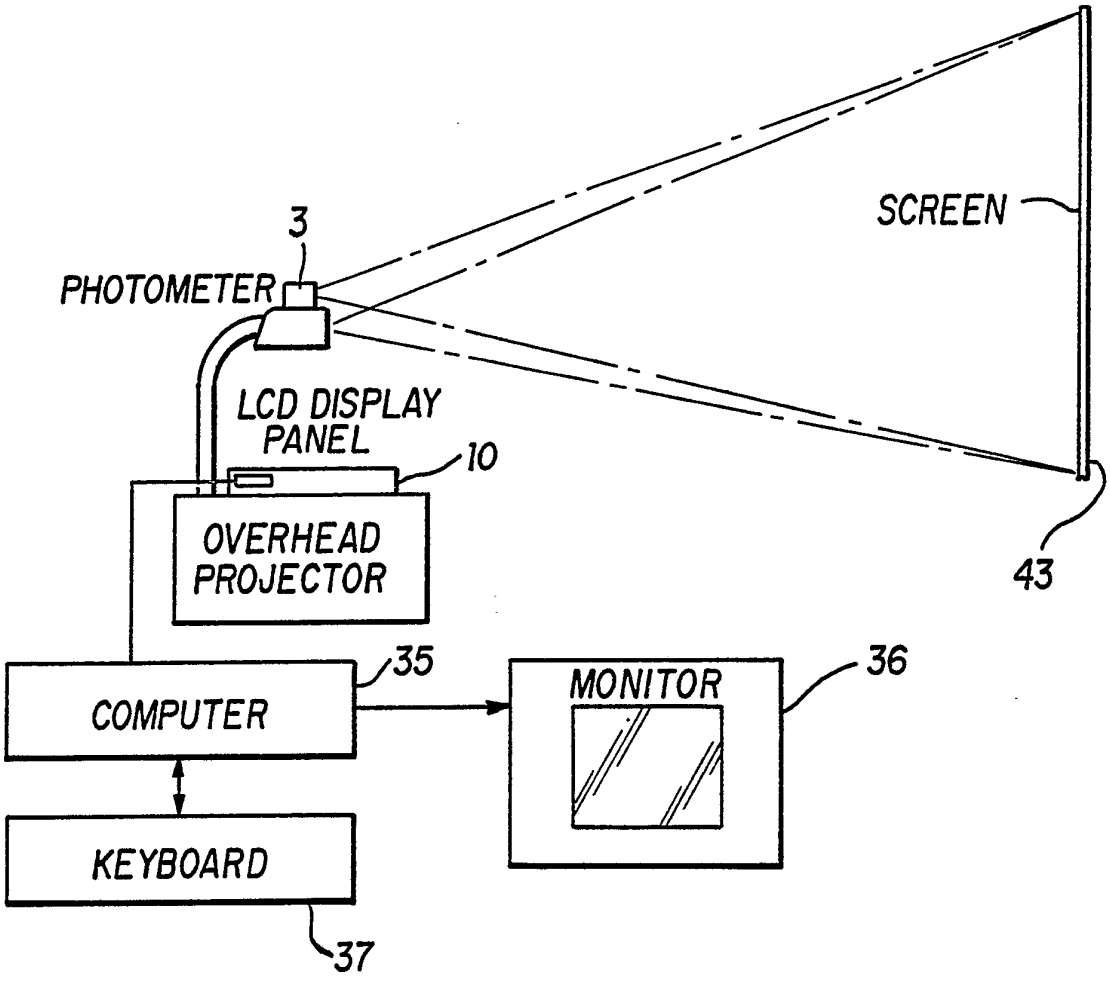
SCREEN
3
PHOTOMETER
LCD DISPLAY PANEL
10
OVERHEAD PROJECTOR
43
35
COMPUTER
MONITOR
36
KEYBOARD
37

FIG. 3

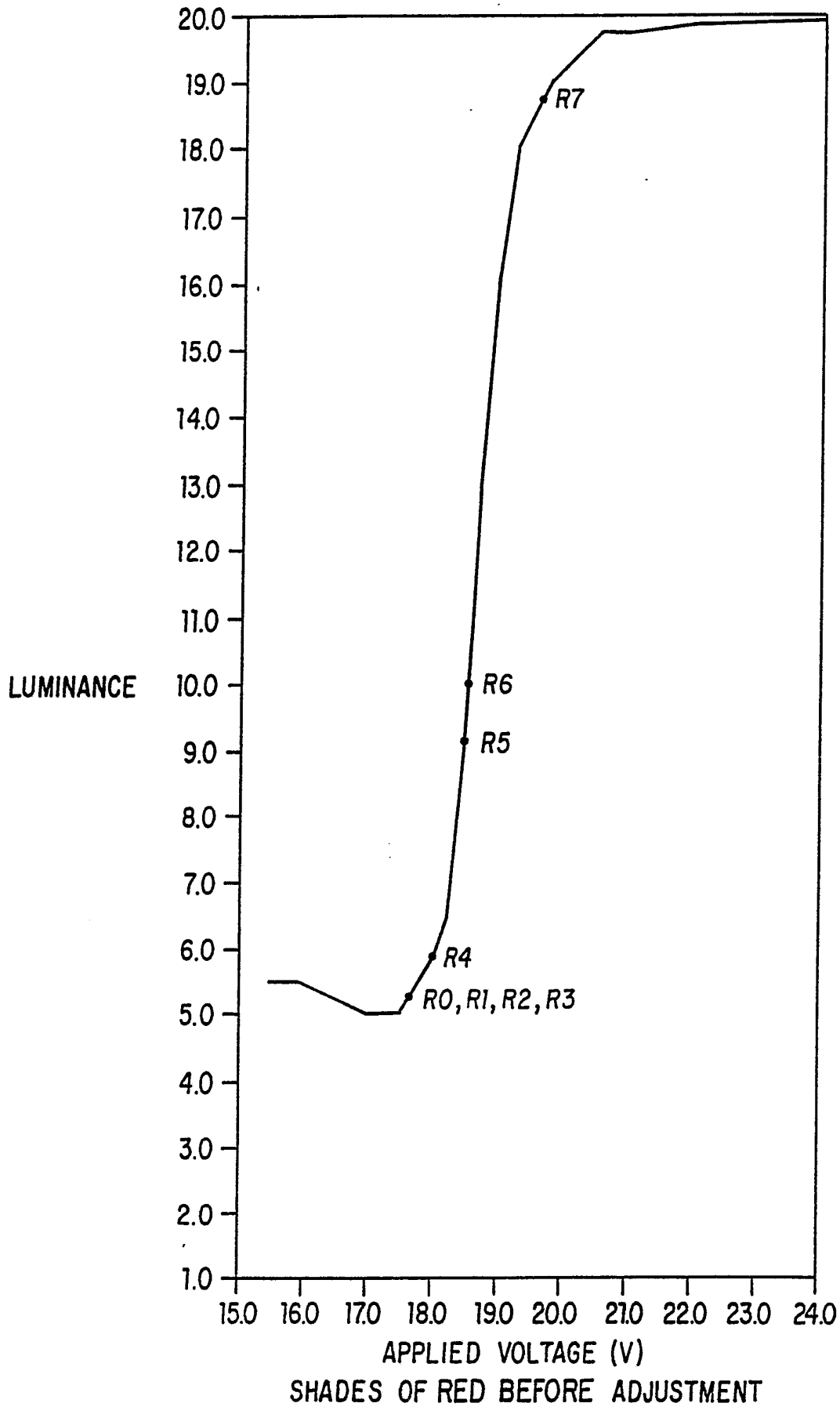
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
LUMINANCE
R7
R6
R5
R4
R0, R1, R2, R3
15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0
APPLIED VOLTAGE (V)
SHADES OF RED BEFORE ADJUSTMENT

FIG. 4

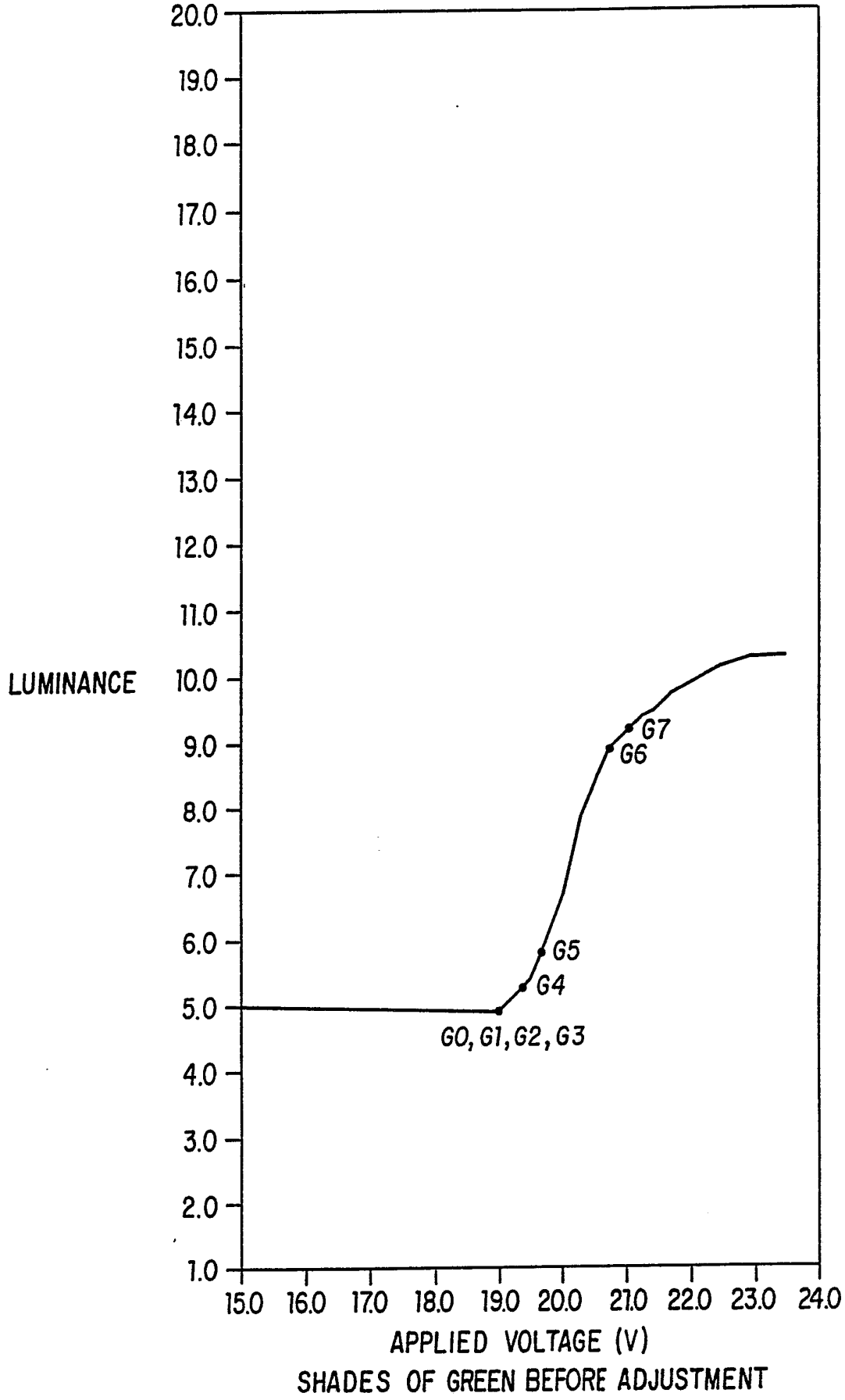
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
LUMINANCE
G7
G6
G5
G4
G0, G1, G2, G3
15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0
APPLIED VOLTAGE (V)
SHADES OF GREEN BEFORE ADJUSTMENT

FIG. 5

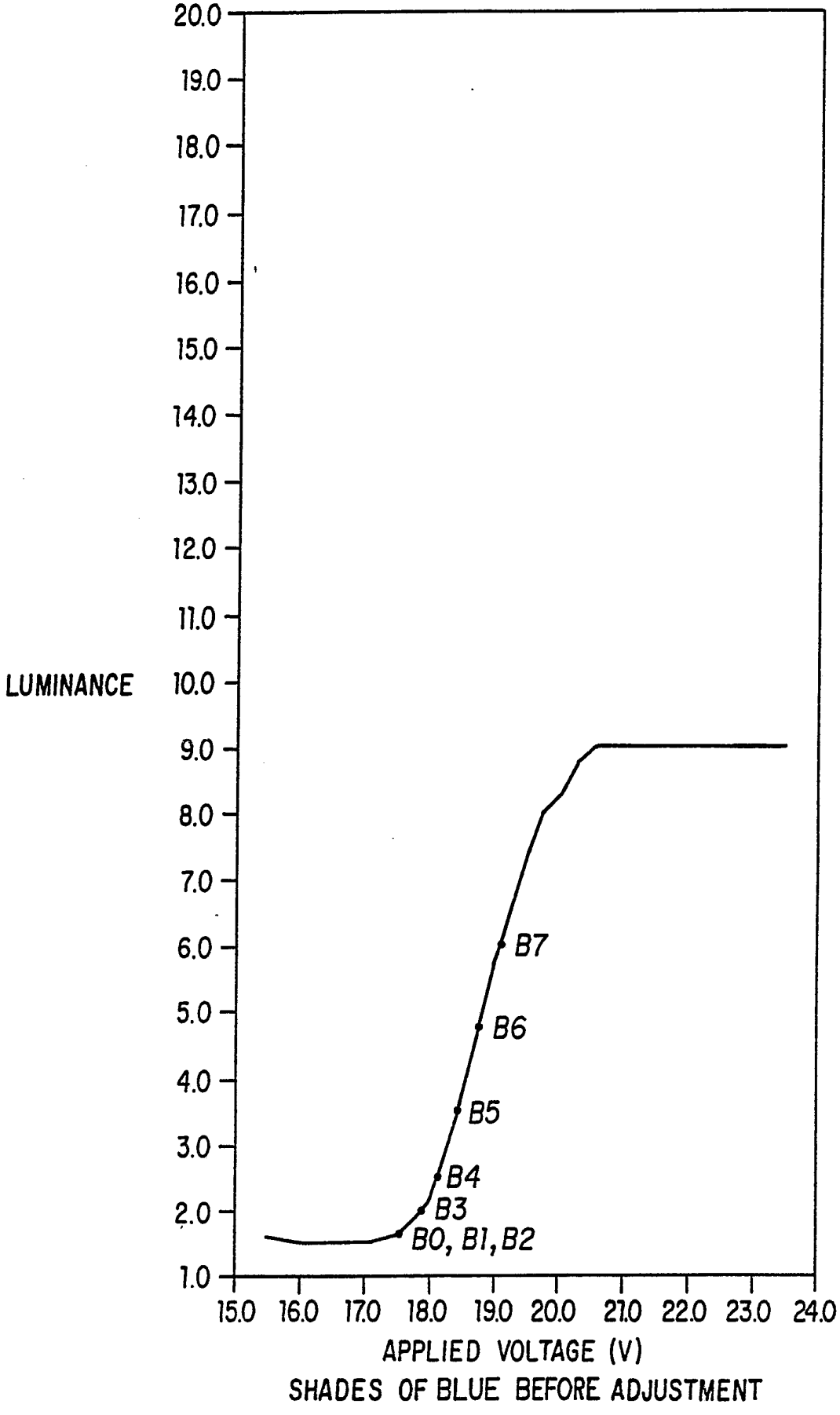
LUMINANCE
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
B7
B6
B5
B4
B3
B0, B1, B2
15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0
APPLIED VOLTAGE (V)
SHADES OF BLUE BEFORE ADJUSTMENT

FIG. 6

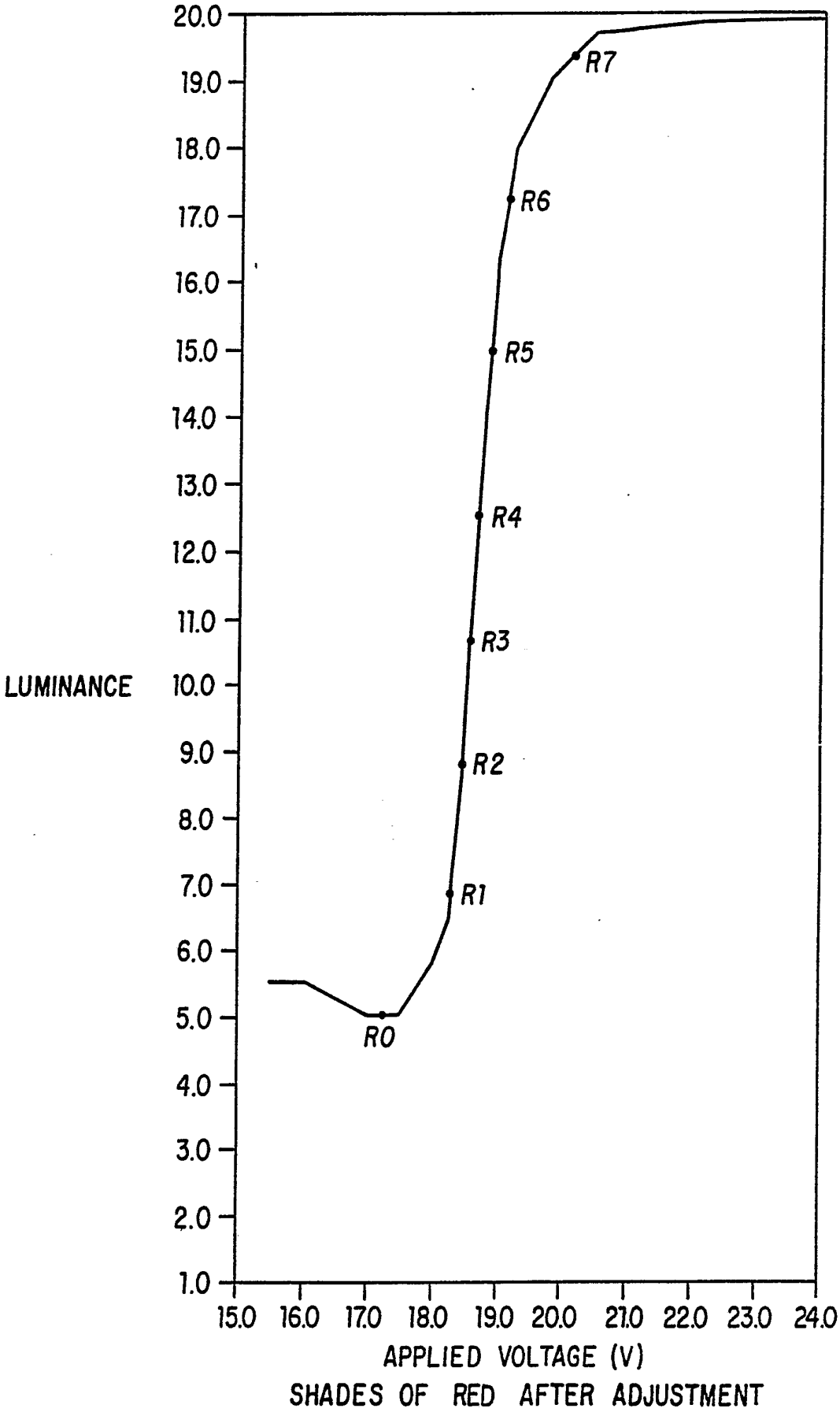
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
LUMINANCE
R7
R6
R5
R4
R3
R2
R1
R0
15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0
APPLIED VOLTAGE (V)
SHADES OF RED AFTER ADJUSTMENT

FIG. 7

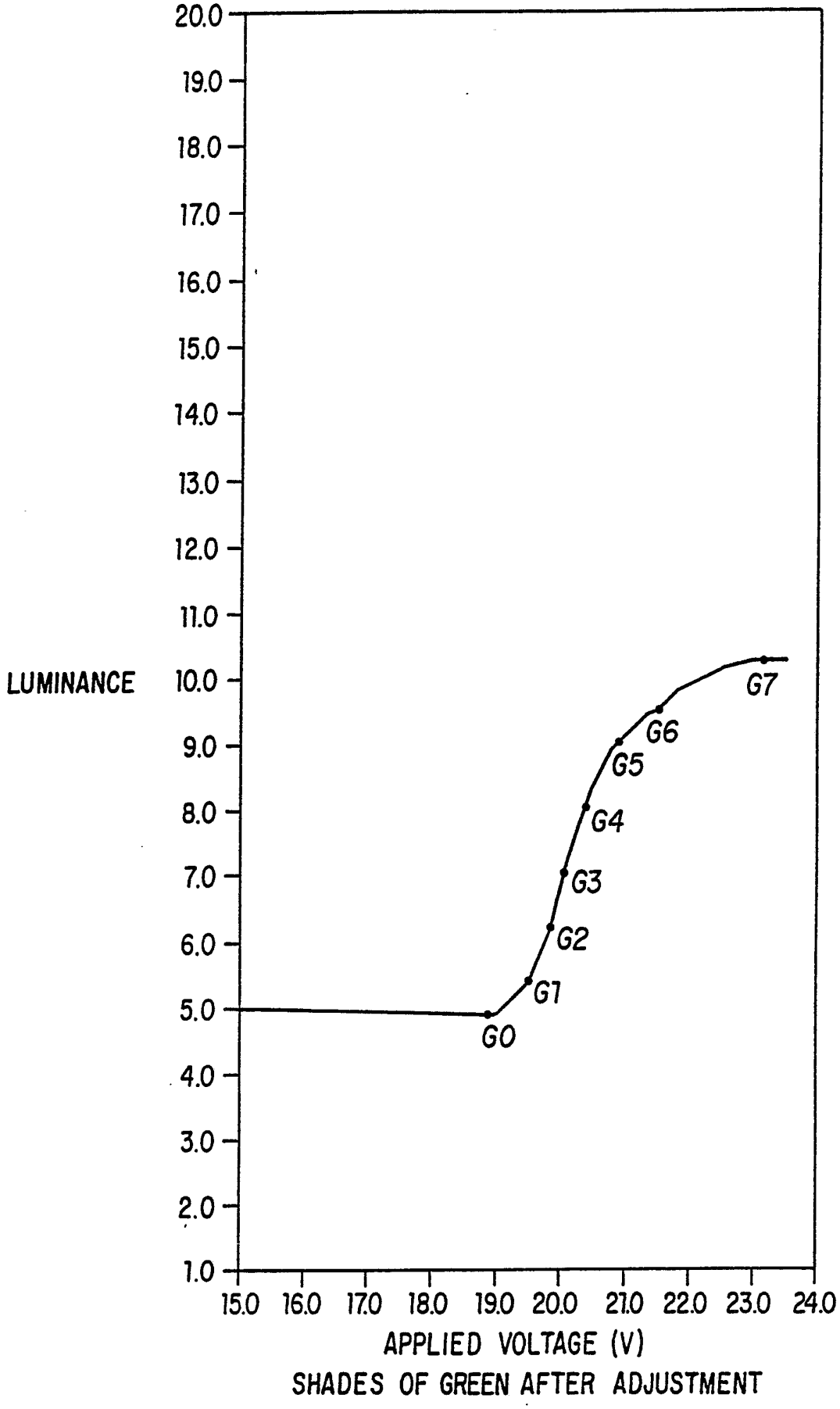
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
LUMINANCE
G0
G1
G2
G3
G4
G5
G6
G7
15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0
APPLIED VOLTAGE (V)
SHADES OF GREEN AFTER ADJUSTMENT

FIG. 8

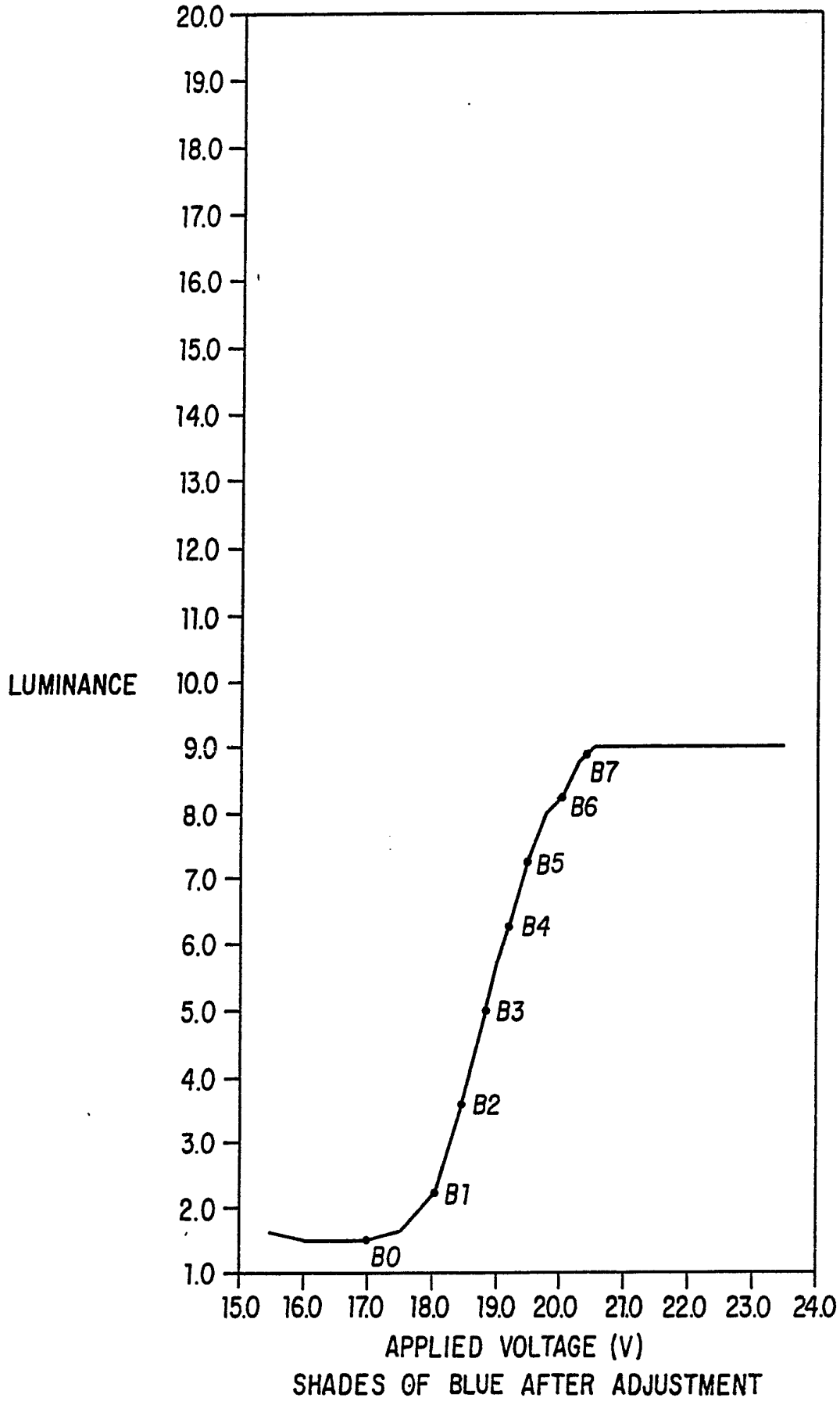
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
LUMINANCE
B0
B1
B2
B3
B4
B5
B6
B7
15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0
APPLIED VOLTAGE (V)
SHADES OF BLUE AFTER ADJUSTMENT

FIG. 9

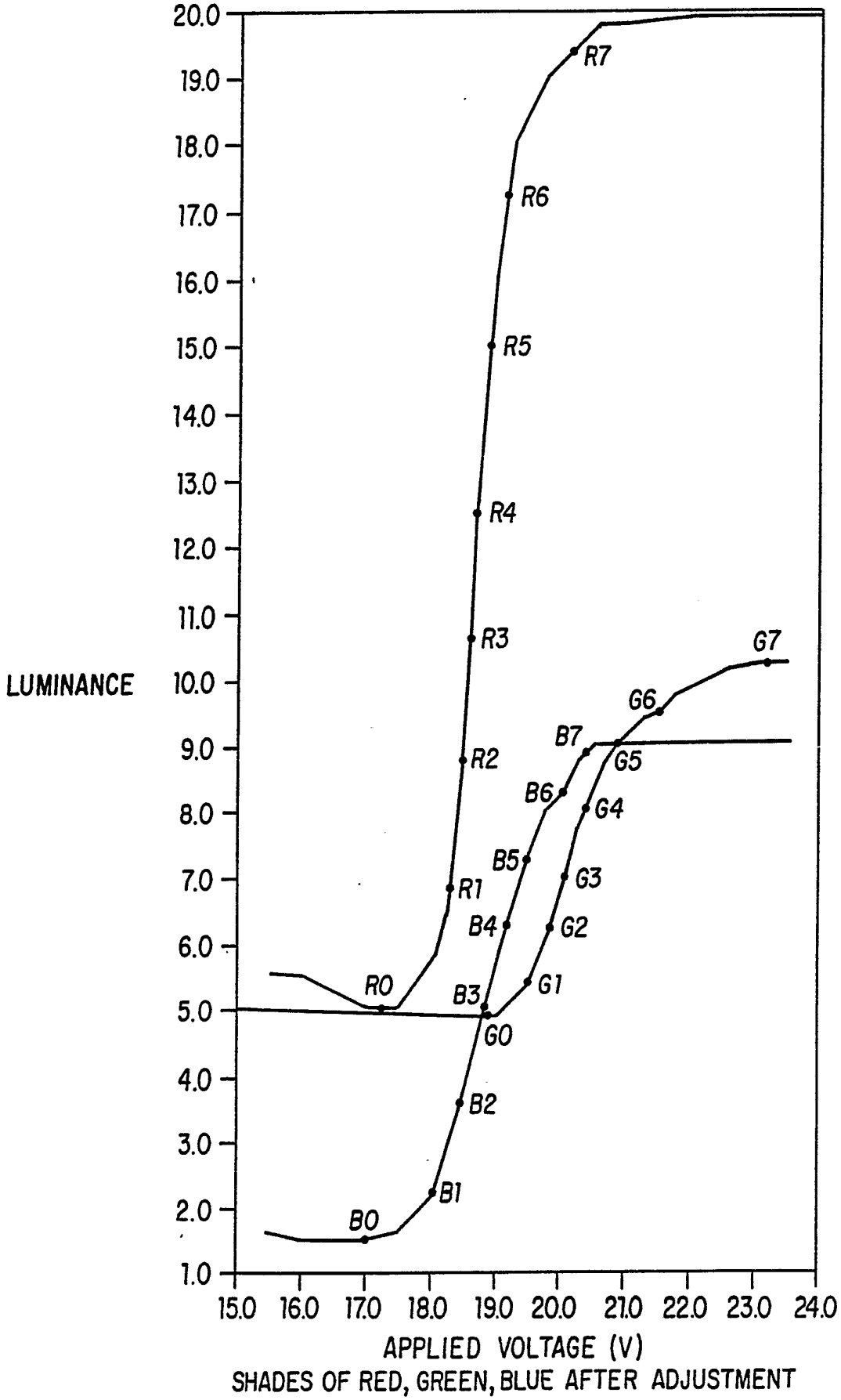
LUMINANCE
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
R7
R6
R5
R4
R3
R2
R1
R0
G7
G6
G5
G4
G3
G2
G1
G0
B7
B6
B5
B4
B3
B2
B1
B0
15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0
APPLIED VOLTAGE (V)
SHADES OF RED, GREEN, BLUE AFTER ADJUSTMENT

FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No PCT/US91/02387

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5) : H04N, 17/02, 17/00, 9/64, 5/57, 5/74; G02F,1/1335
U.S. CL: 358/1 10,139, 29, 168-169, 236; 350/335

II. FIELDS SEARCHED

Minimum Documentation Searched

Classification System	Classification Symbols
U.S.	340/784,793,811,812 350/332,335,336 358/10,29,31,32,59,60,139,164,168-170, 231,236

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched

III. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A,P	US,A 4,942,458 (MIYAJIMA et al) 17 July 1990, Col. 3, lines 9-16; col. 4, lines 43-47; col. 7, lines 31-40; col. 8, lines 1-2	1
A,P	US,A 4,921,334 (AKODES), 01 May 1990, Col. 3, line 62-68; col. 6, line 5-13	1,2
A	US,A 4,868,668 (TAVERNETTI), 19 September 1989, Col. 2, lines 52-61; col. 7, lines 2-22	1,2,3
A	US,A 4,838,655 (HUNAHATA et al) 13 June 1989, col. 3, lines 10-20; col. 4, lines 27-38	1

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
23 May 1991	12 JUL 1991
International Searching Authority	**Signature of Authorized Officer**
ISA/US	Andrea Rolumaus for Steve Saras

Form PCT/ISA/210 (second sheet) (May 1986)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, ** with indication, where appropriate, of the relevant passages **	Relevant to Claim No **
A	US,A 4,663,667 (SHENK) 05 May 1987, Col. 2, lines 49-52: col.2, Lines 61-65.	1,2
A	US,A 4,568,975 (HARSHBARGER) 04 Febtuary 1986; col. 3, lines 52-68; col. 4, lines 1-7; col. 7, lines 60-68; col. 8, lines 1-37.	3
A	US,A 4,523,232 (KAMEDA et al) 11 June 1985; col. 1, lines 55-68; col. 2, lines 1-23; col. 4, lines 17-24.	1,2,3

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1 ☐ Claim numbers because they relate to subject matter [1] not required to be searched by this Authority, namely:

2. ☐ Claim numbers . because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [1], specifically:

3. ☐ Claim numbers_____, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

I. Claims 1,2 drawn to a stacked liquid crystal display class 340/784

II. Claim 3 drawn to measurement of display contrast and luminance class 358/139

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application. Telephone Practice

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

International Application No.
PCT/US91/02387

ATTACHMENT TO CHAPTER I PCT TELEPHONE
MEMORANDUM FOR LACK OF UNITY OF INVENTION

Detailed Reasons For Holding Lack of Unity of Invention

Group I, claims 1-2, drawn to stacked liquid crystal display and D.C. voltage biasing, classified in Class 340, subclass 784. Group II, claim 3, drawn to measurement of display contract and luminance, classified in Class 358, testing. Group II has separate utility such as measurement of contrast and luminance of CRT, plasma, and LCD displays, etc.