

Aug. 11, 1964

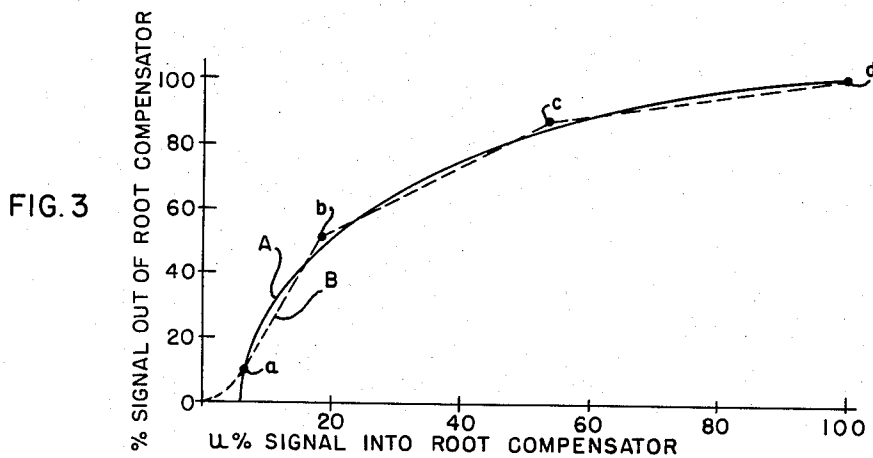
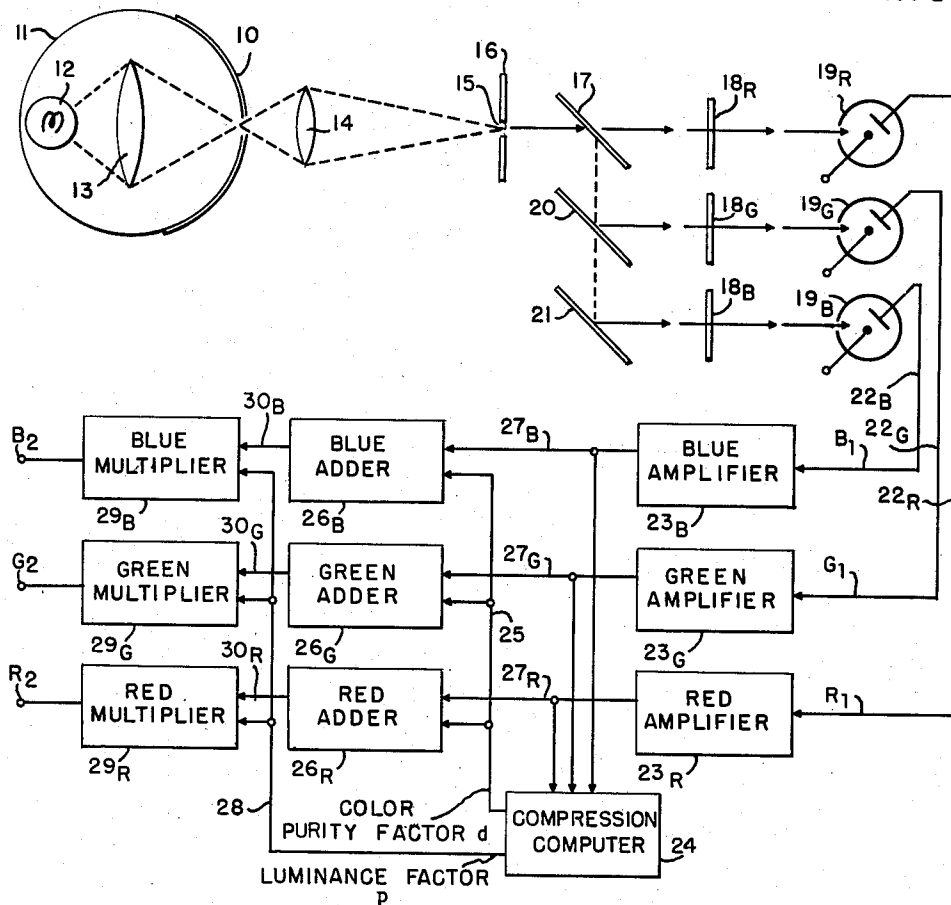
M. FARBER ETAL

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APPARATUS FOR THE COMPRESSION OF COLOR IMAGES

Filed March 1, 1960

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

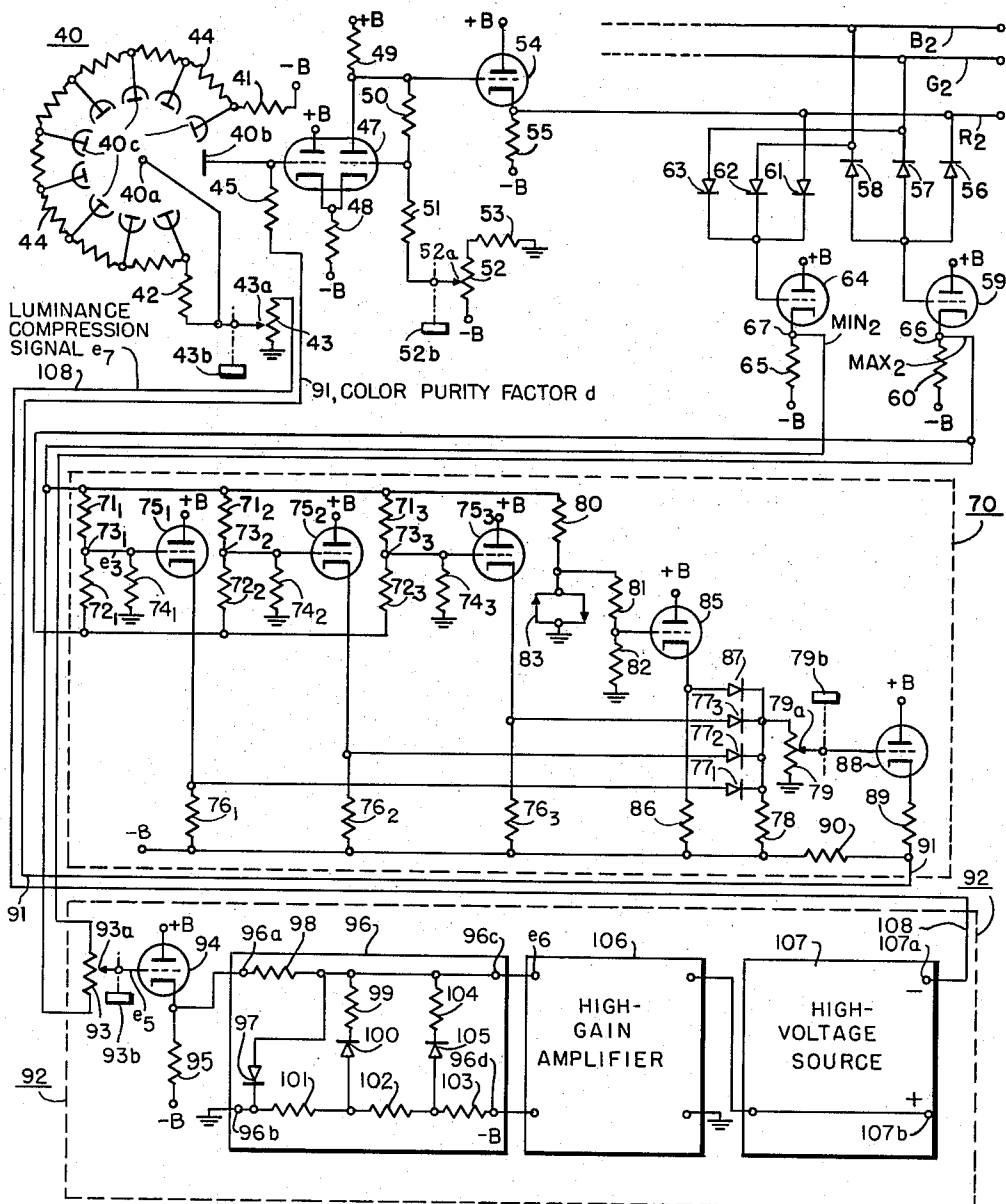


FIG.2

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## APPARATUS FOR THE COMPRESSION OF COLOR IMAGES

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18 Claims. (Cl. 178—5.2)

This invention relates to an apparatus for the compression of color images and, while it is of general application, it is particularly suitable for compressing the purity or saturation and the luminance or brightness of a color image represented on a film transparency or photographic print for reproduction by another medium, for example, by letterpress, gravure and lithographic printing, etc., which has ranges of purity and luminance different from the original copy. The term "compression" is used herein in the algebraic sense to denote either an increase (decompression) or a decrease in the range of the characteristic in question.

In the reproduction of images by photographic processes, compression of one or more characteristics of the reproduced image is usually effected by appropriate selection of the gamma of one or more of the reproduction processes. It can be shown that with this type of logarithmic compression, compression of the purity and luminance results in a shift in the dominant wavelength, with the exception of six particular dominant wavelengths, and such a shift is, of course, undesirable.

The present invention is particularly applicable to the process of producing color-separation printing plates or members for reproduction by printing processes employing, for example, a photoelectric engraving machine of the type described and claimed in Patent Re. 23,914, issued December 21, 1954, to John A. Boyajean, Jr., and will be specifically described in such an application. Usually, in such a process, the reproduction of the image is accomplished by printing with ink on paper. Such a printing process has narrower ranges of color purity and luminance than the film transparency or the photographic print from which the printing plate is produced. Therefore, it is desirable to compress the ranges of color purity and luminance in the process of preparing the color-separation printing plates.

The present invention, therefore, is directed to an apparatus for the compression of color images by means of which the purity and luminance of a reproduced image can be compressed without shifting the dominant wavelength or hue of the reproduced image. The invention is based upon a fundamental principle of colorimetry that the multiplication of each of the tristimulus components of any color signal by a constant effects a compression of the luminance of the signal, while the addition of a constant to each of such tristimulus components effects a compression of the purity of the signal, both without shifting the dominant wavelength. This is true irrespective of which objective system of tristimulus coordinates is used, that is, whether an R, G, B system, or the luminance, dominant wavelength and purity (C.I.E.) system or any linear transformation of the latter.

It is an object of the present invention, therefore, to provide a new and improved apparatus for the compression of the color purity or the luminance, or both, of a reproduced or reproducible color image without affecting the dominant wavelength.

In accordance with the invention, there is provided a system for compressing the color purity of a set of multistimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising circuit means for translating each of the multi-

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stimulus signals, circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of the multistimulus signals, and means for simultaneously adding the derived signal to each of the multistimulus signals to develop a new set of multistimulus-representative signals with compressed color purity.

Further in accordance with the invention, there is provided a system for compressing the luminance of a set of multistimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising circuit means for translating each of the multistimulus signals, circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of the multistimulus signals, and means for simultaneously multiplying each of the multistimulus signals by the derived signal to develop a new set of multistimulus-representative signals with compressed luminance.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, while its scope will be pointed out in the appended claims.

Referring now to the drawings:

FIG. 1 is a schematic line diagram of a system for the compression of the purity and luminance of a color image embodying the invention;

FIG. 2 is a circuit diagram of one of the color-translating channels of the system of FIG. 1; while

FIG. 3 represents characteristic curves of one of the components of the circuit of FIG. 2.

Before describing the specific apparatus and method of carrying out the invention, it is believed that it would be helpful to give an explanation of the underlying principles and a brief mathematical explanation of the derivation of the basic relationships that should be satisfied in achieving a desired compression of the color purity or luminance, or both, of a reproduced color image or of the color signal components suitable for the reproduction of such an image.

The International Commission on Illumination (C.I.E.) has specified a set of tristimulus primaries or coordinates, designated X, Y, Z, each of which can be expressed in terms of a set of R, G, B primaries. In this system, the luminance of any given color is represented by the Y component, while the chromaticity may be expressed by the coordinate x, y of the projection of the color point on the X, Y plane, in which the coordinates x, y have the values:

$$\left. \begin{aligned} x &= \frac{X}{X+Y+Z} \\ y &= \frac{Y}{X+Y+Z} \end{aligned} \right\} \quad (1)$$

The conventional color scanner includes three photocell pickups which develop from an image being scanned the tristimulus signals R, G, B. In terms of the C.I.E. coordinates, these signals are represented as follows:

$$\left. \begin{aligned} X &= a_x R + b_x G + c_x B \\ Y &= a_y R + b_y G + c_y B \\ Z &= a_z R + b_z G + c_z B \end{aligned} \right\} \quad (2)$$

where  $a_x, b_x, \dots, c_z$  are constants.

For a reference white, the scanner is set so that the components R, G, B have unity value. Therefore, the C.I.E. coordinates for reference white become:

$$\left. \begin{aligned} X_w &= a_x + b_x + c_x \\ Y_w &= a_y + b_y + c_y \\ Z_w &= a_z + b_z + c_z \end{aligned} \right\} \quad (3)$$

Now, if the original illumination of the image is uniformly changed to  $p$  percent of its original value, then the components of the modified signal  $X_p$ ,  $Y_p$ ,  $Z_p$  are represented by multiplying the right-hand terms of Equations 2 by the term  $p$ . It is noted that, while the luminance component  $Y$  has changed by the factor  $p$ , if the new values of  $X$ ,  $Y$ , and  $Z$  are substituted in Equations 1, the factor  $p$  cancels out and the chromaticity  $x_p$ ,  $y_p$  remains constant. It is clear that the same result follows if, instead of changing the original illumination, the values of the primary  $R$ ,  $G$ ,  $B$  signals developed from an image are multiplied by the factor  $p$ . That is, if each of the primary  $R$ ,  $G$ ,  $B$  signals is multiplied by the same factor  $p$ , the luminance of the image reproduced by such signals is changed but the chromaticity of each point in the image remains constant.

The dominant wavelength  $A$  (analogous to hue) of any color is determined by the intersection of a line through the points  $x$ ,  $y$  and reference white ( $x_w$ ,  $y_w$ ) and this line may be determined in terms of its slope:

$$\frac{y - y_w}{x - x_w} \quad (4)$$

Thus, if the value of the Expression 4 can be maintained constant with variation in the primary  $R$ ,  $G$ ,  $B$  signals, the resulting color image will maintain the same dominant wavelengths and the same spectral match.

Assume that to each of the primary signals of a given color  $R_1$ ,  $G_1$ ,  $B_1$  is added a constant  $d$  to form a color represented by  $R_2$ ,  $G_2$ ,  $B_2$ , then:

$$\left. \begin{aligned} R_2 &= R_1 + d \\ G_2 &= G_1 + d \\ B_2 &= B_1 + d \end{aligned} \right\} \quad (5)$$

From Equations 2 and 5;

$$\left. \begin{aligned} X_2 &= a_x(R_1 + d) + b_x(G_1 + d) + c_x(B_1 + d) \\ Y_2 &= a_y(R_1 + d) + b_y(G_1 + d) + c_y(B_1 + d) \end{aligned} \right\} \quad (6)$$

and

$$\left. \begin{aligned} X_2 &= X_1 + dX_w \\ Y_2 &= Y_1 + dY_w \end{aligned} \right\} \quad (7)$$

From this, by substitution, it can be shown that:

$$\frac{y_2 - y_w}{x_2 - x_w} = \frac{y_1 - y_w}{x_1 - x_w} \quad (8)$$

Stated in words, if a constant factor  $d$  is added to each of the primary signals  $R_1$ ,  $G_1$ ,  $B_1$  of a given color, the luminance and purity of the color are changed but the dominant wavelength remains constant. Since, as stated above, the multiplication of each of the primary signals  $R$ ,  $G$ ,  $B$  by a constant factor  $p$  does not alter the chromaticity  $x$ ,  $y$  of a given color, such an operation also does not alter the dominant wavelength or hue, which is determined by the chromaticity factor  $x$ ,  $y$ .

If the multiplying factor  $p$  and the additive factor  $d$  are functions of the primary  $R$ ,  $G$ ,  $B$  signals, the luminance and purity can be compressed as desired without affecting the dominant wavelength.

Referring now to FIG. 1 of the drawings, there is represented schematically a system embodying the principles described above for compressing the color purity and luminance of a set of multistimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby. In a preferred form of the invention, the input signals are tristimulus-representative signals and the invention will be specifically described in such an environment.

This system includes an optical apparatus for scanning a color copy 10. While the optical scanning apparatus may be of any well known type, there is shown schematically, by way of example, an optical apparatus of

the type described and claimed in U.S. Letters Patent No. 2,843,664 to R. E. Olin, dated, July 15, 1958, where the copy 10 is in the form of a transparency. Briefly, the optical apparatus includes a transparent drum 11 on which the copy 10 is mounted and within which is a source of illumination 12 and a lens 13 for focusing the light from the source 12 to a point on the surface of the copy 10. Disposed to pick up the illumination of successive points of the copy 10 is an objective lens 14 which focuses the light on an aperture 15 of an aperture plate 16. The light passing through the aperture 15 is directed to a partially silvered mirror 17, a portion of the light passing through the mirror to a red filter 18<sub>R</sub>, thence to a red-channel photocell 19<sub>R</sub>. Similarly, a portion of the light from the aperture 15 is reflected by the mirror 17 to a second partially silvered mirror 20, a portion of the light thereon being reflected to a green filter 18<sub>G</sub> and thence to a green-channel photocell 19<sub>G</sub>. Finally, the portion of the light passing through the mirror 20 is directed to a third fully silvered mirror 21 which directs the light to a blue filter 18<sub>B</sub> and a blue-channel photocell 19<sub>B</sub>. The signals developed by the photocells 19<sub>R</sub>, 19<sub>G</sub>, and 19<sub>B</sub> constitute the tristimulus input signals  $R_1$ ,  $G_1$ , and  $B_1$  of the compression system of the invention.

The compression system of the invention includes circuit means for translating each of the tristimulus signals. Each of these circuit means includes one of the photocell devices 19<sub>R</sub>, 19<sub>G</sub>, and 19<sub>B</sub> included in the signal-translating circuits 22<sub>R</sub>, 22<sub>G</sub>, and 22<sub>B</sub>, respectively, and each having one or more sensitivity controlling electrodes as described hereinafter. Each of the signal-translating circuits also includes a signal repeater, such as the red, green, and blue amplifiers 23<sub>R</sub>, 23<sub>G</sub>, and 23<sub>B</sub>, respectively, each having an input circuit coupled to its respective phototube.

The compression system of the invention further includes circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of the tristimulus signals. This circuit means may be in the form of a compression computer 24 coupled to the amplifiers 23<sub>R</sub>, 23<sub>G</sub>, 23<sub>B</sub> and circuit means for adding the derived signal to each of the tristimulus signals. This derived signal, which may be termed the color purity factor, is applied over a channel 25 to red, green, and blue adder circuits 26<sub>R</sub>, 26<sub>G</sub>, and 26<sub>B</sub>, respectively, to which are also applied the amplified tristimulus signals  $R_1$ ,  $G_1$ , and  $B_1$  over the channels 27<sub>R</sub>, 27<sub>G</sub>, and 27<sub>B</sub>, respectively. The computer 24 is also effective to derive a second signal, which may be termed the luminance factor, and the system includes means for simultaneously multiplying each of the tristimulus signals by the luminance factor to develop a new set of tristimulus-representative signals with compressed luminance. This luminance factor derived by the computer 24 is applied over the channel 28 to red, green, and blue multipliers 29<sub>R</sub>, 29<sub>G</sub>, and 29<sub>B</sub>, respectively, to which are also applied the output signals of the units 26<sub>R</sub>, 26<sub>G</sub>, and 26<sub>B</sub> over the channels 30<sub>R</sub>, 30<sub>G</sub>, and 30<sub>B</sub>, respectively.

As explained above, if a given signal, such as the color purity factor  $d$  derived by the unit 24, is added to each of the tristimulus signals  $R_1$ ,  $G_1$ ,  $B_1$ , there is developed a new set of tristimulus signals  $R_2$ ,  $G_2$ ,  $B_2$  having a compressed color purity but the same dominant wavelengths. Again, as explained above, if each of the input tristimulus signals  $R_1$ ,  $G_1$ ,  $B_1$  is multiplied by the same factor, such as the luminance factor  $p$  developed by the computer 24, there will be developed a new set of tristimulus signals  $R_2$ ,  $G_2$ ,  $B_2$  with a compressed luminance scale but with the same dominant wavelengths. These two operations may be performed simultaneously without interaction between them. Hence, the output tristimulus signals  $R_2$ ,  $G_2$ ,  $B_2$  may be used for reproduction of the color copy 10 with compressed purity and luminance ranges.

In the color compression system of FIG. 1, the color

purity factor  $d$  is added to each of the tristimulus signals at a point in the signal-translating channel following that at which the compression computer is connected; similarly, the luminance factor  $p$  is applied as a multiplier to each of the tristimulus signals at a point also following the compression computer. However, a satisfactory multiplier or modulator, linear over a wide range of signals, is relatively costly. In addition, it is subject to drift or residual signals which limit its useful dynamic range. In addition, it is desirable to use a photomultiplier as the phototube because of its high gain, but such a device produces a certain amount of electrical noise (shot noise) which, in the system of FIG. 1, is amplified in the following amplifier stages included in the color compression circuits described. When the scanner aperture is small, illumination of a copy with low reflectance or transmittance requires high gains to reach suitable signal levels, so that thermal noise amplification also becomes a problem. Furthermore, when the color purity factor  $d$  is added to the tristimulus signals following the computer, a certain number of impedance isolation stages is required and some additional amplification of the compression factor may be desirable. Therefore, there is a considerable economy, as well as other advantages, if the adding and multiplying operations on the tristimulus signals are performed ahead of the main signal amplifiers, such as the amplifiers 23<sub>R</sub>, 23<sub>G</sub>, 23<sub>B</sub> of FIG. 1, whereby these units also serve to amplify or regenerate the factors  $d$  and  $p$  as well as the tristimulus signals and the necessity of additional impedance isolating amplifiers is obviated. Furthermore, in the modified system just described, the above-mentioned limitations of the multiplier may be eliminated or greatly reduced by using photocells of the photomultiplier type and applying the luminance factor  $p$  to their sensitivity-controlling electrodes to control the gains of the photomultipliers, at the same time providing the required impedance isolation.

Furthermore, in performing the luminance and purity compression operations described generally with reference to the system of FIG. 1, it becomes necessary to determine the proper functional relation between the luminance-compression factor  $p$  and the unmodified primary signals  $R$ ,  $G$ ,  $B$  and the purity-compression factor  $d$  and such signals in accordance with the relative luminance and color-purity ranges of the original copy, such as a film transparency, and the reproduced image, such as a letterpress print. It has been determined empirically that when there is no purity compression, the luminance-compressed signals should approximate the  $m$ th root of the uncompressed signals, where  $m$  is a constant of the order of, but usually greater than, unit and is determined by the relative luminance ranges of the original copy and those of the medium by which the color image is reproduced. Also, when there is no luminance compression, it has been determined empirically that the purity-compressed signals should approximate the  $n$ th root of the uncompressed signals, where  $n$  is a constant usually about 2 and is determined by the relative color-purity ranges of the original copy and the medium by which the color image is reproduced. For best results, the compression factors  $m$  and  $n$  should depend upon both the maximum and minimum values, that is, the gamuts, of the primary signals  $R$ ,  $G$ ,  $B$ .

From the foregoing considerations, the relation between maximum modified signal ( $\text{Max}_2$ ) and the original maximum signal ( $\text{Max}_1$ ) and between the minimum modified signal ( $\text{Min}_2$ ) and the minimum original signal ( $\text{Min}_1$ ) may be expressed as follows:

$$\left. \begin{aligned} (\text{Max}_2) &= (\text{Max}_1)^{\frac{1}{n+m}} = (\text{Max}_1)^{\frac{1}{n}} (\text{Max}_2)^{-\frac{m}{n}} \\ (\text{Min}_2) &= (\text{Min}_1)^{\frac{1}{n+m}} = (\text{Min}_1)^{\frac{1}{n}} (\text{Min}_2)^{-\frac{m}{n}} \end{aligned} \right\} \quad (9)$$

In other words, considering the primary signal  $R$ , the

modified signal  $R_2$  in terms of the original signal  $R_1$  may be expressed as:

$$\left. \begin{aligned} R_2 &= pR_1 + d = R_1^{\frac{1}{n}} R_2^{-\frac{m}{n}} \\ G_2 &= pG_1 + d = G_1^{\frac{1}{n}} G_2^{-\frac{m}{n}} \\ B_2 &= pB_1 + d = B_1^{\frac{1}{n}} B_2^{-\frac{m}{n}} \end{aligned} \right\} \quad (10)$$

Computers for deriving the  $m$ th roots and the  $n$ th roots of the tristimulus signals over wide ranges of values are undesirably complex. In addition, rather than provide separate computers for each of the tristimulus signal channels, it has been found that satisfactory results can be obtained by providing a single  $p$ -factor computer and a single  $d$ -factor computer, each responsive jointly to the simultaneous maximum and minimum instantaneous values of the three tristimulus signals. Such maximum modified and unmodified signals may be represented as  $\text{Max}_2$  and  $\text{Max}_1$ , respectively, and the minimum modified and unmodified signals by  $\text{Min}_2$  and  $\text{Min}_1$ , respectively. Formulae for approximating these root functions and appropriate for solution by relatively simple computers have been derived by a combination of graphic and analytical methods. One satisfactory solution of Equations 10 gives the following approximations for the multiplying factor  $p$  and the additive factor  $d$ :

$$p = \frac{1}{n \left[ \frac{1}{n^p} \text{Max}_2 + \left( 1 - \frac{1}{n^p} \right) \text{Min}_2 \right]^{\frac{1}{p}}} \quad (11)$$

where

$$P = \frac{1}{m+n-1}$$

$$d = 2^{\frac{n-1}{n}} \cdot \frac{\text{Min}_2 \cdot \text{Max}_2}{\text{Min}_2 + \text{Max}_2} \quad (12)$$

The additive factor  $d$  may be rather closely approximated for simpler instrumentation as:

$$d = 2^{\frac{n-1}{n}} \left\{ \text{Minimum of } \left[ \frac{Y}{1+Y}, \frac{Y+K_1^2 X}{(1+K_1)^2}, \frac{Y+K_2^2 X}{(1+K_2)^2}, \frac{Y+K_3^2 X}{(1+K_3)^2} \dots \right] \right\} \quad (13)$$

where

$$\begin{aligned} Y &= \text{Min}_2 \\ X &= \text{Max}_2 \end{aligned}$$

and where  $K_1$ ,  $K_2$ ,  $K_3$ , etc. are constants less than unity chosen for closeness to approximation of Equation 12.

In one embodiment of the invention, satisfactory results have been achieved by assigning values to the constants as follows:

$$\begin{aligned} K_1 &= 1 \\ K_2 &= \frac{2}{3} \\ K_3 &= \frac{3}{4} \end{aligned}$$

A modified color-compression system in which the tristimulus signals are operated upon by the color-purity factor  $d$  and the luminance factor  $p$  in advance of the compression computer, as describe above, and which includes instrumentation for solving Equations 11 and 13 above is represented schematically in FIG. 2. In the system of FIG. 2, for the sake of simplicity, the optical system is omitted, the input of the system being taken as the photosensitive devices such as the photocells 19<sub>R</sub>, 19<sub>G</sub>, 19<sub>B</sub> of FIG. 1. Also, for the sake of simplicity, only the red signal-translating channel is shown in its entirety, the other channels being duplicates thereof.

Referring now specifically to FIG. 2 of the drawings, there is represented a color-compression system comprising a photomultiplier device in each of the signal-translating channels, although only the photomultiplier 40 in the

red signal-translating channel is shown. The device 40 includes a photocathode 40a, an anode or collector electrode 40b, and a plurality of sensitivity-controlling electrodes or dynodes 40c. The dynodes 40c are connected to be energized from a voltage divider comprising a resistor 41, a resistor 42, a resistor 43, and a dynode resistor string comprising a plurality of resistors 44, all of these resistors being connected in series between a source -B and a manually adjustable contact 43a on resistor 43, one terminal of which is grounded.

The output signal of the photomultiplier 40 is developed across a load resistor 45 connected in the circuit of anode 40b. This signal is applied to the control electrode of a signal repeater such as a two-stage cathode-coupled amplifier comprising a twin-triode tube 47 having a common cathode resistor 48 returned to -B. The anode of the first section of the tube 47 is connected directly to +B, while the anode of the second section is connected to +B through a load resistor 49. The sources +B, -B may have any suitable values at various portions of the system or they may have uniform values of, for example, +150 volts for +B and -150 volts for -B. The resistor 49 also comprises a portion of a voltage-dividing circuit including resistors 50, 51, and 52 connected between +B and -B, the latter being provided with a tap 52a adjustable by the knob 52b. The junction of resistors 50 and 51 is connected to the control electrode of the right-hand section of tube 47 for providing a desired feedback and, by setting of tap 52a, for determining the zero setting of the amplifier system. Appropriate unidirectional bias for the control electrode of the right-hand section of tube 47 is provided by a zero-adjustment voltage divider comprising resistor 52 and a resistor 53 connected in series between -B and ground. The signal appearing across the load resistor 49 is applied to the control electrode of a signal repeater such as an amplifier tube 54 connected as a cathode-follower with its anode connected directly to +B and its cathode-load resistor 55 being returned to -B.

The color-compression system of FIG. 2 also comprises circuit means for deriving a signal responsive jointly to the simultaneous maximum and minimum instantaneous values of the tristimulus signals. This circuit means is coupled to the signal repeater 54 and to similar repeaters in the green and blue channels and thus, indirectly, to the photomultipliers in the respective channels. Specifically, this circuit means includes a plurality of unidirectionally conductive devices, such as semiconductor diodes 56, 57, and 58, having their cathodes individually connected to the signal repeaters, such as the repeater 54, of the signal-translating channels  $R_2$ ,  $G_2$ ,  $B_2$ . Since the signals on the channels  $R_2$ ,  $G_2$ ,  $B_2$  increase negatively with increases in illumination of their respective associated photomultipliers, the diodes 56, 57, and 58 selectively respond to the tristimulus signal of maximum instantaneous value. To this end, the anodes of the devices 56, 57, and 58 are connected together and to the control electrode of a signal-repeater tube 59 connected as a cathode-follower amplifier, that is, with its anode connected directly to +B and its cathode connected to -B through a load resistor 60. The signal-deriving circuit means further includes a plurality of oppositely poled unidirectionally conductive devices, such as semiconductor diodes 61, 62, and 63, having their anodes individually connected to the signal repeaters, such as the repeater 54, of the signal-translating channels  $R_2$ ,  $G_2$ ,  $B_2$  so as to be selectively responsive to the tristimulus signal of minimum instantaneous value. To this end, the cathodes of the devices 61, 62, and 63 are connected together and to the control electrode of a signal repeater such as an amplifier tube 64 connected as a cathode-follower, that is, with its anode connected directly to +B and its cathode connected to -B through a load resistor 65. With these connections, there is developed across the load resistor 60 a signal  $e_1$  representative of the maximum in-

stantaneous value of the output signals  $R_2$ ,  $G_2$ ,  $B_2$  and there is developed across the load resistor 65 a signal  $e_2$  representative of the minimum instantaneous value of these signals.

The color-compression system of the invention further comprises computer means for simultaneously developing the color-purity factor  $d$  and the luminance-compression factor  $p$  from the signal derived from the maximum and minimum instantaneous tristimulus signal values and adding the color-purity factor  $d$  to each of the tristimulus signals at points in the signal-translating channels preceding the signal-deriving means to develop a new set of tristimulus-representative signals with compressed color purity. Specifically, the circuit means for developing the color-purity factor  $d$  comprises means for developing from the derived signals  $e_1$  and  $e_2$ , a signal approximating the  $n$ th root thereof, where  $n$  is a constant of the order of, but usually greater than, unity. As analyzed above, the  $n$ th root of the derived signals  $e_1$ ,  $e_2$  may be approximated by the solution of Equation 13. The system of FIG. 2 includes a  $d$ -factor computer 70 for solving this equation. The computer 70 includes a resistance network comprising the resistors 71<sub>1</sub> and 72<sub>1</sub> connected in series between the terminals 66, 67 and having a junction 73<sub>1</sub> connected to ground through a resistor 74<sub>1</sub> and also connected to the control electrode of a signal repeater such as a cathode-follower amplifier tube 75<sub>1</sub> having a cathode-load resistor 76<sub>1</sub>. It can be shown that, if the voltages at the terminals 66, 67 are  $e_1$ ,  $e_2$ , respectively, the voltage  $e_3$  at junction 73<sub>1</sub> is represented by the relation:

$$e_3 = \frac{\left(\frac{1}{R72}\right)e_1 + \left(\frac{1}{R71}\right)e_2}{\left(\frac{1}{R72}\right) + \left(\frac{1}{R71}\right) + \left(\frac{1}{R74}\right)} \quad (14)$$

It is noted that this expression is of the form of the second term within the brackets of Equation 13. Thus, if resistor 71<sub>1</sub> is given a value of one unit, resistor 72<sub>1</sub> a value of  $1/K_1^2$  units, and resistor 74<sub>1</sub> a value of  $1/2K_1$  units, the signal  $e_3$  at the junction 73<sub>1</sub> applied to the amplifier 75<sub>1</sub> is representative of the second term within the brackets of Equation 13.

Similarly, additional cathode-follower networks are connected between the terminals 66, 67 for representing the third and fourth terms within the brackets of Equation 13, these networks being similar to those just described and the elements thereof being identified by the same reference numerals with subscripts "2" and "3," respectively, and the resistance elements thereof having values related to  $K_2$  and  $K_3$  in the same manner. The signals developed across the cathode-load resistors 76<sub>1</sub>, 76<sub>2</sub>, and 76<sub>3</sub> are connected to the anodes of unidirectionally conductive devices, such as the semiconductor diodes 77<sub>1</sub>, 77<sub>2</sub>, and 77<sub>3</sub>, respectively, while the cathodes of these devices are connected together and returned to the source -B through a resistor 78 and are also returned to ground through a potentiometer 79 having a tap 79a manually adjustable by a knob 79b.

The minimum instantaneous value of the tristimulus signals appearing at the terminal 67 is also applied to a network comprising resistors 80, 81, and 82 connected in series to ground. In parallel with the resistors 81 and 82 is connected a varistor 83 which may comprise silicon carbide commercially available under the name "Thyrite." The junction of the resistors 81, 82 is connected to the control electrode of a signal repeater such as a cathode-follower amplifier tube 85 having a cathode-load resistor 86. By graphical or empirical methods, resistors 80, 81, and 82 and varistor 83 can be chosen so that, if the minimum signal  $e_1$  is applied to such network, the signal  $e_4$  appearing at the junction of resistors 81 and 82 can be represented by the relation:

$$e_4 \approx \frac{e_1}{1 + e_1} \quad (15)$$

It is noted that the preceding expression is of the form of the first term within the brackets of Equation 13.

The output signal of amplifier 85 appearing across its load resistor 86 is applied to the cathode of a unidirectionally conductive device, such as the semiconductor diode 87, the anode of which is connected in common with the anodes of devices 77<sub>1</sub>, 77<sub>2</sub>, and 77<sub>3</sub>. Thus, there is developed across resistor 79 a signal which has the most positive value (or the least algebraic negative value) of the signals across the resistors 76<sub>1</sub>, 76<sub>2</sub>, 76<sub>3</sub>, and 86 and which is thus representative of the minimum of the several terms within the brackets of Equation 13.

The potentiometer 79 may be in the form of a tapered potentiometer proportioned so that, if its tap 79a is adjusted by its knob 79b to a position or setting corresponding to the value  $n$ , the signal at the tap 79a will be that portion of the minimum signal passed by the several amplifiers represented by the factor  $n-1/n$ . This factor is representative of the multiplying factor outside of the braces of Equation 13 and the resultant signal at tap 79a is thus representative of the color-purity factor  $d$ . The potentiometer 79, instead of being tapered, may be designed with a linear characteristic and adjusted manually by the knob 79b in accordance with an  $n-1/n$  calibration chart.

The color-compression system of the invention further comprises means for simultaneously adding the developed color-purity factor or signal  $d$  to the input circuits of the R, G, and B signal repeaters. To this end, the signal at the tap 79a is applied to the control electrode of a signal repeater such as a cathode-follower vacuum-tube amplifier 88 having cathode-load resistors 89 and 90 in series returned to the source -B. The amplified (actually attenuated) color-purity signal developed at the junction of resistors 89, 90 is applied by way of a conductor 91 and the photomultiplier anode-load resistor 45 to the control electrode of the left-hand section of amplifier 47 in the red signal-translating channel, where it is added to or combined with the signal developed by the photomultiplier 40. The color-purity signal developed at the junction of resistors 89, 90 is attenuated to allow for the gain of amplifier 47, while at the same time the proper operating bias for the photomultiplier anode and the control electrode of the left-hand section of amplifier 47 is developed across resistor 90. It will be understood that this same signal is similarly applied to the corresponding signal amplifiers in the green and blue signal-translating channels.

The color-compression system of the invention further comprises means for simultaneously multiplying each of the tristimulus signals by a derived signal, specifically, the luminance-compression factor  $p$ , to develop a new net of tristimulus-representative signals with compressed luminance. The computer means for developing the luminance-compression factor  $p$  includes means for developing from the derived signals, a signal approximating the  $P$ th root thereof, where  $P$  is a constant of the order of unity. The system also includes means for simultaneously applying such developed signal to the photomultiplier electrodes to control the gains thereof.

Specifically, the system of FIG. 2 includes a  $p$ -factor computer 92 for solving Equation 11. This computer includes a potentiometer 93 connected between the terminals 66, 67 and having a tap 93a manually adjustable by a knob 93b. The potentiometer 93 may be tapered so that, if the tap 93a is adjusted to a position or setting representative of the value  $n$ , or may have a linear characteristic and adjustment made according to an  $n_1^P-n^P$  calibration chart, the signal  $e_5$  at the tap 93a is represented by the relationship:

$$e_5 = \frac{1}{n^P} e_1 + \left(1 - \frac{1}{n^P}\right) e_2 \quad (16)$$

Alternatively, the potentiometer 93 may have a linear characteristic and the contact 93a may be adjusted man-

ually in accordance with a  $(n_1^P-n^P)$  calibration chart. Since signal  $e_1$  represents  $(\text{Max}_2)$  and signal  $e_2$  represents  $(\text{Min}_2)$ , the foregoing expression is the same as that within the brackets of the denominator of Equation 11 and, if substituted therein, gives:

$$p = \frac{1}{n e_5^P} = \frac{1}{n} e_5^{-P} \quad (17)$$

That is, each of the tristimulus input signals should be multiplied to the  $-P$  power of the signal  $e_5$ .

The signal  $e_5$  at tap 93a is fed into a cathode-follower amplifier tube 94 having a cathode load resistor 95 returned to -B. The signal  $e_6$  across the load resistor 95 is applied to the luminance root compensator 96. However, the luminance compression is effected by controlling the potentials of the dynodes of the photomultipliers, such as the device 40, by way of a voltage divider 43 returned to ground. The photomultiplier 40 has a gain characteristic which is a power function  $r$  of the total dynode voltage. Therefore, the root compensator 96 must take into consideration not only the exponent  $-P$  of the signal  $e_5$ , but also the exponent  $r$  of the photomultiplier characteristic.

In determining the transfer characteristic of the root compensator 96, the analysis is simplified by the assumption that the image being translated is a neutral grey so that the signal  $\mu$  impressed on the amplifier 94 is expressed by the relation:

$$\mu = \text{Max}_2 = \text{Min}_2 \quad (18)$$

Under this assumption Equation 16 becomes simply:

$$e_5 = \mu \quad (19)$$

The gain of the photomultiplier is represented by the relation:

$$G = \left( \frac{E_k - V E_s}{E_k - E_s} \right)^r \quad (20)$$

where

$E_k$ =dynode voltage when exposed to minimum luminance.  
 $E_s$ =dynode swing voltage so that the total dynode voltage when exposed to maximum luminance is  $E_k - E_s$ .

$V$ =nonlinear transfer characteristic of root compensator.  
 $r$ =exponent representing the relationship between the photomultiplier gain and the dynode voltage change.

The relationship of the modified signal  $\mu$  to the unmodified signal  $\mu_0$  with constant dynode voltage is:

$$\mu = \mu_0^{\frac{1}{P}} \quad (21)$$

and the photomultiplier 40 must establish the relation:

$$\mu = \mu_0 \cdot G \quad (22)$$

Combining Equations 21 and 22 gives:

$$G = \mu^{(1-P)} \quad (23)$$

Substituting Equation 20 in Equation 23, letting

$$\frac{E_s}{E_k} = S$$

and solving for  $V$  gives:

$$V = \frac{1 - (1-S)\mu^{\frac{1-P}{r}}}{S} \quad (24)$$

Assuming that the luminance exponent  $P=2.5$ , the exponent  $r=6$ , and the swing voltage is sufficient to make  $S=0.5$ , then:

$$V = 2 \left( 1 - 0.5\mu^{\frac{1}{4}} \right) \quad (25)$$

Equation 25 is plotted as solid-line curve A of FIG. 3. Dashed-line curve B of FIG. 3 represents the transfer

characteristic of the root compensator 96 which, it is seen, closely approximates curve A. Specifically, the portion O-a of curve B is provided by a unilaterally conductive device 97 connected across the terminals 96a, 96b of the compensator 96 through a dropping resistor 98. The device 97 may be a germanium diode poled in the nonconductive direction and having a back resistance of the order of 2 megohms. Following the diode 97 is a shunt path including a resistor 99 in series with a diode 100 poled in a conductive direction and returned to a point on a voltage divider comprising resistors 101, 102, and 103 connected in series from -B to ground so as to provide a negative bias on the anode of the diode 100. The shunting action of the diode 100 in conjunction with the series resistors 98, 99 is effective to develop the portion a-b of the transfer characteristic of curve B. Again, following the diode 100 is a second shunt path including a series resistor 104 in series with a diode 105 returned to a point on the voltage divider so that the anode of the diode 105 is suitably negatively biased. The diodes 100 and 105 may also be germanium diodes.

In the operation of the root compensator, the diode 97, due to its back resistance, develops the portion O-a of curve B. Thereafter, the diodes 100 and 105 remain nonconductive until the signal reaches a value equal to the bias on the diode 100 and the portion a-b of the characteristic is developed. At the point b, the diode 100 becomes conductive and further increases in the applied negative signal are partially shunted through its path so that the portion b-c is developed. When the applied signal increases negatively to a value equal to the bias on the diode 105 corresponding to the point c, that diode becomes conductive and further shunts the applied signal so that the portion c-d of the characteristic is developed.

The signal  $e_7$  appearing at the output terminals 96c, 96d is applied to a high-gain amplifier 106, the output terminals of which are connected in series with a high voltage source 107, so that the voltage appearing at the output terminals 107a, 107b of the latter unit is the resultant of the output signal of the amplifier 106 and the normal high voltage of the source 107. This resultant signal is applied by way of conductor 108 to the upper terminal of potentiometer 43 returned to ground and providing the exciting voltage for the dynodes of the photomultiplier 40.

It is believed that the operation of the color-compression system of the invention will be clear from the foregoing description and theoretical analysis. In brief, referring to FIG. 2, the image to be reproduced is scanned and the light from successive elements is focused on the photomultiplier 40 and similar units in the green and blue channels, for example, by the optical system represented in FIG. 1. The photomultiplier 40 and similar units develop electrical signals representative of the red, green, and blue primary components which are translated, by way of the amplifiers 47 and 54 and similar amplifiers in the other channels, to the signal-output channels  $R_2$ ,  $G_2$ , and  $B_2$ . The operator will adjust the zero-setting potentiometer 52 in each of the channels to obtain proper color balance for reproducing the black portions of the particular object, and the dynode supply potentiometer 43 for the white portions. The maximum instantaneous value of the signals on these channels is selected by the diodes 56, 57, 58 and applied to the cathode-follower amplifier 59, while simultaneously the minimum instantaneous value of these signals is selected by the diodes 61, 62, 63 and applied to the cathode-follower amplifier 64.

The source -B, to which the load resistors 60, 65 are returned, is effectively at ground for video-frequency signals so that the maximum instantaneous signal  $Max_2$  appears at the terminal 66 and the minimum instantaneous signal  $Min_2$ , at the terminal 67. The resultant signal between terminals 66, 67 is impressed across the voltage divider comprising resistors 71<sub>1</sub> and 72<sub>1</sub> in series, which,

with the resistor 74<sub>1</sub>, are proportioned so that the signal  $e_3$  at the terminal 73<sub>1</sub> is represented by Equation 14 and also by the second term within the brackets of Equation 13. Similarly, at the terminals 73<sub>2</sub> and 73<sub>3</sub> of the similar following networks, there are developed signals representative of the third and fourth terms within the brackets of Equation 13.

Simultaneously, the signal  $Min_2$  is applied to the network 80-83 which develops at the junction of resistors 81, 82 a signal representative of Equation 17, which is also the first term within the braces of Equation 13. The network comprising the load resistors 76<sub>1</sub>, 76<sub>2</sub>, 76<sub>3</sub>, and 86 and the diodes 77<sub>1</sub>, 77<sub>2</sub>, 77<sub>3</sub>, and 87 selects the minimum instantaneous value of these four signals and impresses it upon the potentiometer 79, the tap 79a of which is adjusted in accordance with the relation  $(n-1)/n$ , which is the term outside of the braces of Equation 13.

Therefore, the signal at the tap 79a applied to the cathode-follower amplifier 88 is representative of the color-purity compression factor  $d$  defined by Equation 13. This signal, after amplification, is applied by way of conductor 91 and resistor 45 to the control electrode of the left-hand section of adding amplifier 47, wherein it is added to the video signal developed by the photomultiplier 40. This same signal representative of the color-purity compression factor  $d$  is, of course, similarly added to the outputs of the photomultipliers in the green and blue channels. As explained above, the addition of this same signal to each of the red, green, and blue tristimulus signals effects a compression of the color purity of the signals in the channels  $R_2$ ,  $G_2$ ,  $B_2$  without shifting the dominant wavelength of any image reproduced by these signals.

At the same time, the resultant signal between the terminals 66 and 67 is applied across the potentiometer 93, the tap 93a of which is adjusted in accordance with the function  $1/n^P$  so that the signal  $e_5$  at the tap 93a applied to the control electrode of the cathode-follower amplifier 94 is representative of Equation 16. The signal  $e_5$  amplified by tube 94 appears across the load resistor 95, from which it is applied to the root compensator 96. As explained above, the unit 96 translates the signal  $e_5$  in accordance with characteristic curve B of FIG. 3, which is a close approximation of characteristic curve A representative of Equation 25. The root compensator 96 thus takes into account the exponents  $P$  and  $r$ , so that the signal  $e_6$  at the output of the unit 96 has the proper characteristic for "swinging" the high voltage of source 107. To that end, the signal output of unit 106 is connected in series with the normal output terminals of unit 107 and the resultant signal  $e_7$  is applied by way of conductor 108 and the adjustable potentiometer 43 to the dynode string of photomultiplier 40 to control the gain of that unit. The signal output of photomultiplier 40 for constant dynode voltage is thus modulated or multiplied by the signal  $e_7$ , taking into account the dynode voltage-gain characteristic of the photomultiplier 40. The ratio of the modified signal  $R_2$  now developed by that unit to the unmodified signal  $R_1$  (at constant dynode voltage) is represented by the luminance-compression factor  $p$  of Equation 11. This same luminance-compression signal is, of course, similarly applied to the photomultipliers in the green and blue channels. As explained above, such a multiplication of the tristimulus primary signals  $R_1$ ,  $G_1$ ,  $B_1$  by the same luminance-compression factor  $p$  results in compression of the luminance of an image reproduced by the signals on the channels  $R_2$ ,  $G_2$ ,  $B_2$  without shifting the dominant wavelength of the reproduced color image.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and

modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A system for compressing the color purity of a set of multistimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said multistimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of said multistimulus signals; and means for simultaneously adding said derived signal to each of said multistimulus signals to develop a new set of multistimulus-representative signals with compressed color purity.
2. A system for compressing the color purity of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of said tristimulus signals; and means for simultaneously adding said derived signal to each of said tristimulus signals to develop a new set of tristimulus-representative signals with compressed color purity.
3. A system for compressing the color purity of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous maximum and minimum instantaneous values of said tristimulus signals; and means for simultaneously adding said derived signal to each of said tristimulus signals to develop a new set of tristimulus-representative signals with compressed color purity.
4. A system for compressing the color purity of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby; comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal selectively responsive to both the tristimulus signal of maximum instantaneous value and the tristimulus signal of minimum instantaneous value; and means for simultaneously adding said derived signal to each of said tristimulus signals to develop a new set of tristimulus-representative signals with compressed color purity.
5. A system for compressing the color purity of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; a circuit comprising a plurality of unidirectionally conductive devices in parallel for selecting the tristimulus signal of maximum instantaneous value; a circuit comprising a plurality of oppositely poled unidirectionally conductive devices in parallel for selecting the tristimulus signal of minimum instantaneous value; circuit means for deriving a signal responsive jointly to said selected signals; and means for simultaneously adding said derived signal to each of said tristimulus signals to develop a new set of tristimulus-representative signals with compressed color purity.
6. A system for compressing the color purity of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of said tristimulus signals; means for modifying said derived signal and utilizing said modified signal to produce approximately the  $m$ th root of each of said tristimulus signals, where  $m$  is a constant; and means for simultaneously adding said modified signal to each of said tristimulus signals to develop a new set of tristimulus-representative signals with compressed color purity.
7. A system for compressing the color purity of a set

of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of said tristimulus signals; means for modifying said derived signal and utilizing said modified signal to produce approximately the  $m$ th root of each of said tristimulus signals, where  $m$  is a constant having a value of the order of unity; and means for simultaneously adding said modified signal to each of said tristimulus signals to develop a new set of tristimulus-representative signals with compressed color purity.

8. A system for compressing the color purity of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of said tristimulus signals; and means for simultaneously adding said derived signal to each of said tristimulus signals at points in said signal-translating circuit means preceding said signal-deriving circuit means to develop a new set of tristimulus-representative signals with compressed color purity.

9. A system for compressing the color purity of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; a signal repeater included in each of said signal-translating circuit means and having an input circuit; circuit means coupled to said signal repeaters for deriving a signal responsive jointly to the simultaneous instantaneous values of said tristimulus signals; and means for simultaneously adding said derived signal to the input circuits of said signal repeaters to develop a new set of tristimulus-representative signals with compressed color purity.

10. A system for compressing the luminance of a set of multistimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said multistimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of said multistimulus signals; and means for simultaneously multiplying each of said multistimulus signals by said derived signal to develop a new set of multistimulus-representative signals with compressed luminance.

11. A system for compressing the luminance of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous maximum and minimum instantaneous values of said tristimulus signals; and means for simultaneously multiplying each of said tristimulus signals by said derived signal to develop a new set of tristimulus-representative signals with compressed luminance.

12. A system for compressing the luminance of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal selectively responsive to both the tristimulus signal of maximum instantaneous value and the tristimulus signal of minimum instantaneous value; and means for simultaneously multiplying each of said tristimulus signals by said derived signal to develop a new set of tristimulus-representative signals with compressed luminance.

13. A system for compressing the luminance of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said

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tristimulus signals; a circuit comprising a plurality of unidirectionally conductive devices in parallel for selecting the tristimulus signal of maximum instantaneous value; a circuit comprising a plurality of oppositely poled unidirectionally conductive devices in parallel for selecting the tristimulus signal of minimum instantaneous value; circuit means for deriving a signal responsive jointly to said selected signals; and means for simultaneously multiplying each of said tristimulus signals by said derived signal to develop a new set of tristimulus-representative signals with compressed luminance.

14. A system for compressing the luminance of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of said tristimulus signals; means for modifying said derived signal and utilizing said modified signal to produce approximately the  $n$ th root of each of said tristimulus signals, where  $n$  is a constant; and means for simultaneously multiplying each of said tristimulus signals by said modified signal to develop a new set of tristimulus-representative signals with compressed luminance.

15. A system for compressing the luminance of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of said tristimulus signals; means for modifying said derived signal and utilizing said modified signal to produce approximately the  $n$ th root of each of said tristimulus signals, where  $n$  is a constant having a value of the order of 2; and means for simultaneously multiplying each of said tristimulus signals by said modified signal to develop a new set of tristimulus-representative signals with compressed luminance.

16. A system for compressing the luminance of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby,

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comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of said tristimulus signals; and means for simultaneously multiplying each of said tristimulus signals by said derived signal at points in said signal-translating circuit means preceding said signal-deriving circuit means to develop a new set of tristimulus-representative signals with compressed luminance.

17. A system for compressing the luminance of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; a photomultiplier device included in each of said signal-translating circuit means and having one or more sensitivity-controlling electrodes; circuit means coupled to said photomultiplier devices for deriving a signal responsive jointly to the simultaneous instantaneous values of said tristimulus signals; and means for simultaneously applying said derived signal to said electrodes of said photomultiplier devices to control the gains thereof, thereby to develop a new set of tristimulus-representative signals with compressed luminance.

18. A system for compressing the color purity and luminance of a set of tristimulus-representative signals without affecting the dominant wavelengths of the image reproduced thereby, comprising: circuit means for translating each of said tristimulus signals; circuit means for deriving a signal responsive jointly to the simultaneous instantaneous values of said tristimulus signals; means for simultaneously adding said derived signal to each of said tristimulus signals; and means for simultaneously multiplying each of said tristimulus signals by said derived signal, thereby to develop a new set of tristimulus-representative signals with compressed color purity and luminance.

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