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Tsai

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(54) **METHOD AND MODULE FOR REGULATING COLOR DISTRIBUTION**

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(51) **Int. Cl.**
G09G 3/34 (2006.01)

(52) **U.S. Cl.** **345/88**; 345/590; 345/591; 382/167

(58) **Field of Classification Search** 345/1.9, 345/88, 204, 590, 600, 604, 690; 382/166, 382/167

See application file for complete search history.

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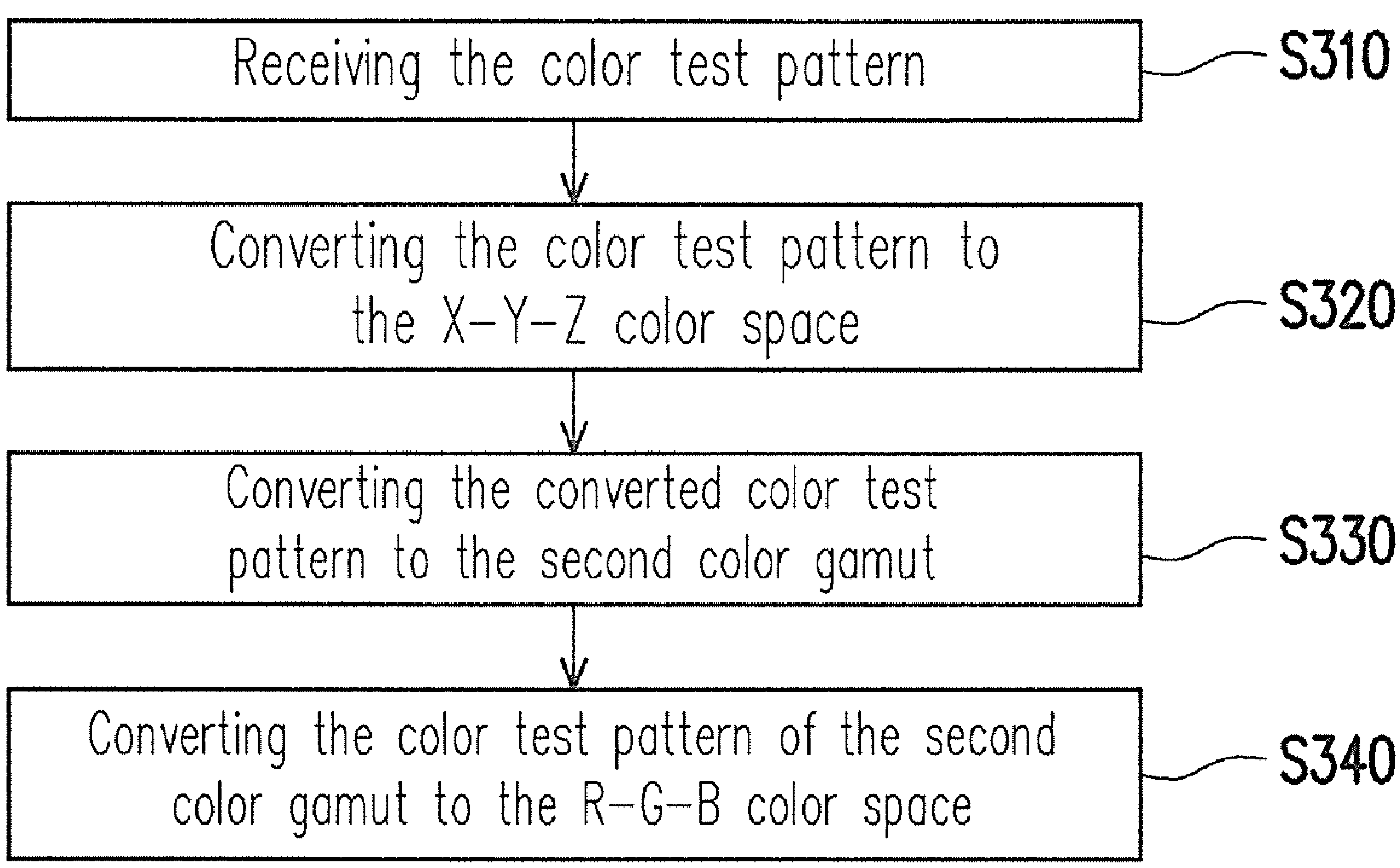
(57) **ABSTRACT**

The invention relates to a method and module for regulating color distribution. In this method, a reference point in a first gamut and a second reference point in a second gamut are found, and then the first gamut is converted to the second gamut based on the first and second reference point.

16 Claims, 11 Drawing Sheets



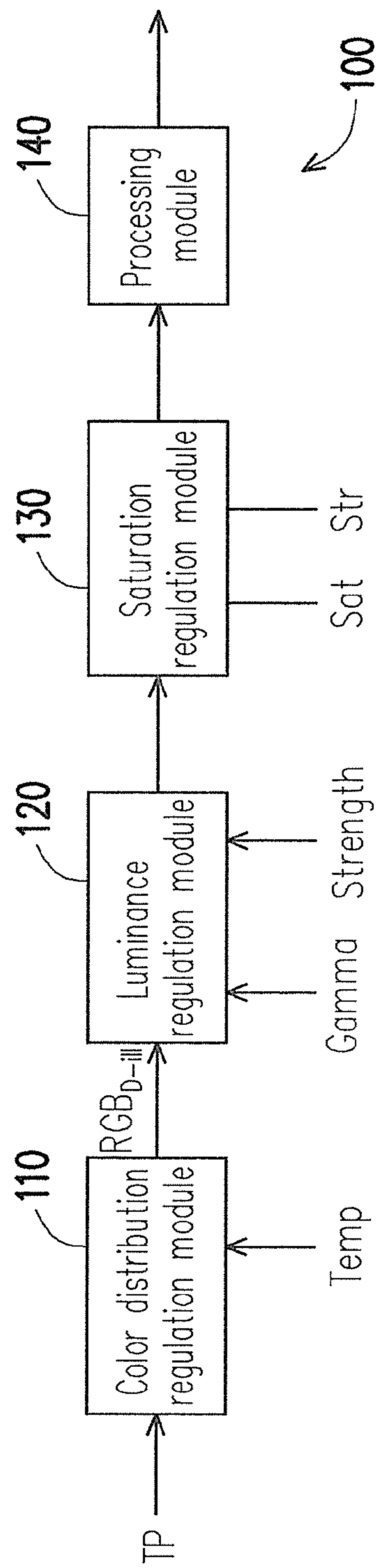

TP
Color distribution regulation module
110
Temp
RGB_D-ill
Luminance regulation module
120
Gamma
Strength
Saturation regulation module
130
Sat
Str
Processing module
140
100

FIG. 1

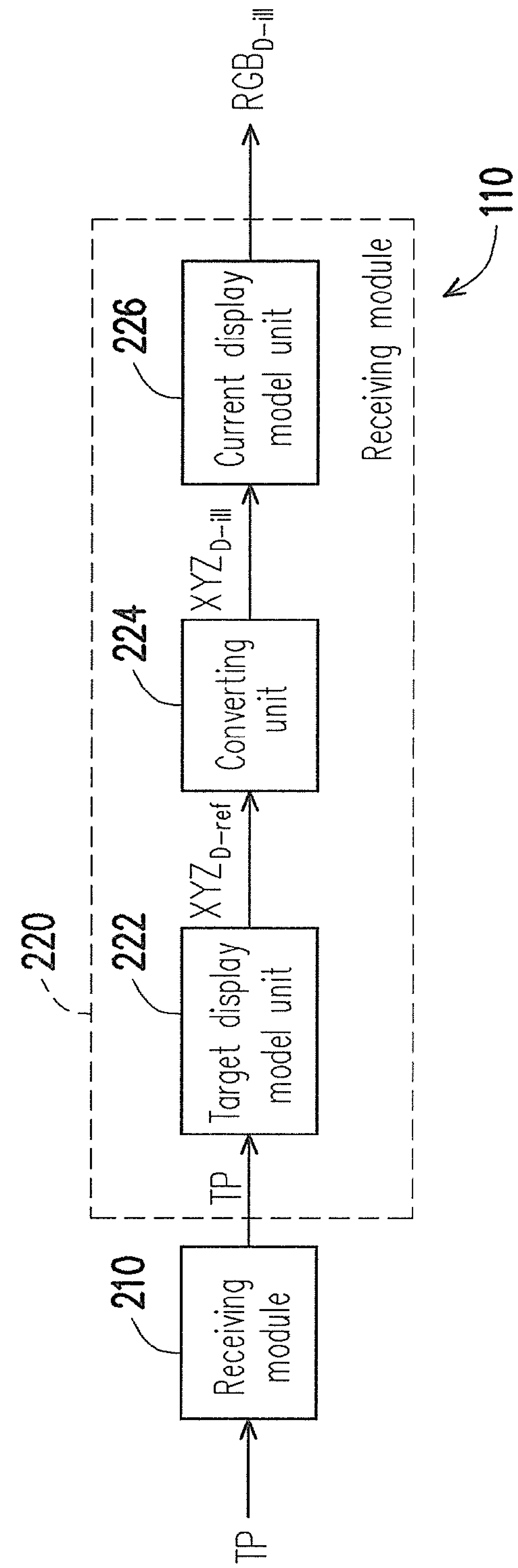

TP
Receiving module
210
TP
Target display model unit
222
220
XYZ_D-ref
Converting unit
224
XYZ_D-ill
Current display model unit
226
RGB_D-ill
Receiving module
110

FIG. 2

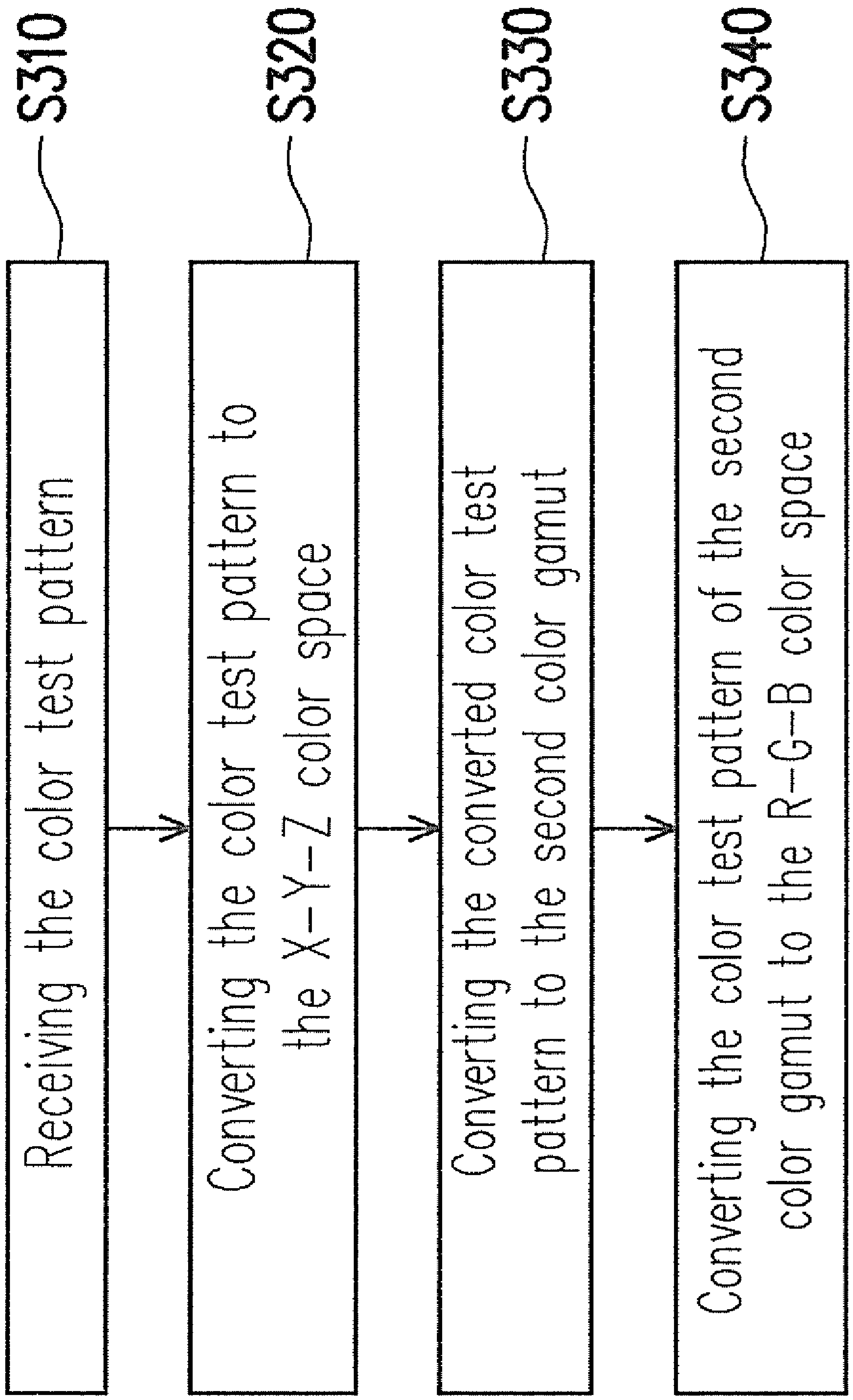

S310
Receiving the color test pattern
S320
Converting the color test pattern to the X-Y-Z color space
S330
Converting the converted color test pattern to the second color gamut
S340
Converting the color test pattern of the second color gamut to the R-G-B color space

FIG. 3

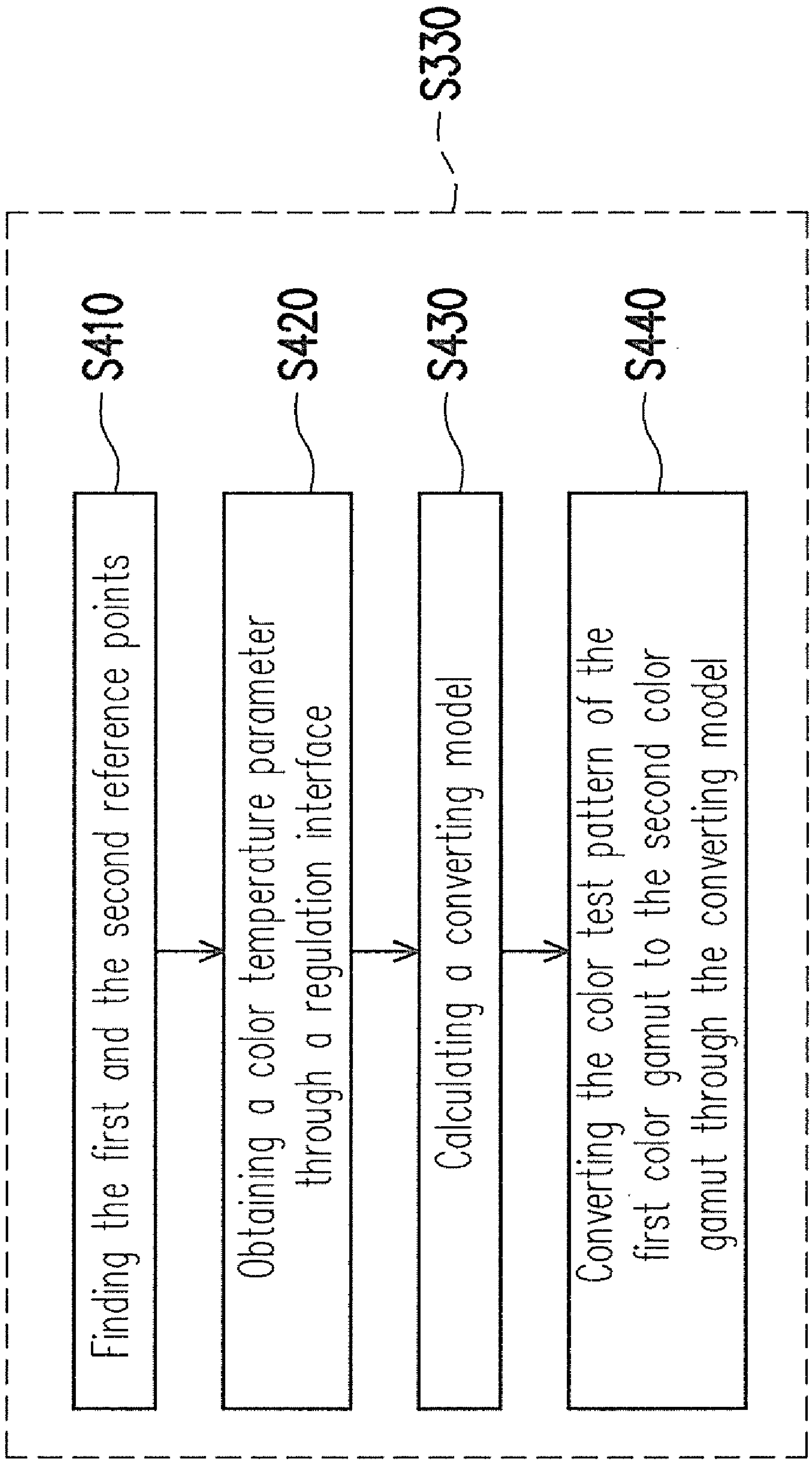

S330
S410
Finding the first and the second reference points
S420
Obtaining a color temperature parameter through a regulation interface
S430
Calculating a converting model
S440
Converting the color test pattern of the first color gamut to the second color gamut through the converting model

FIG. 4

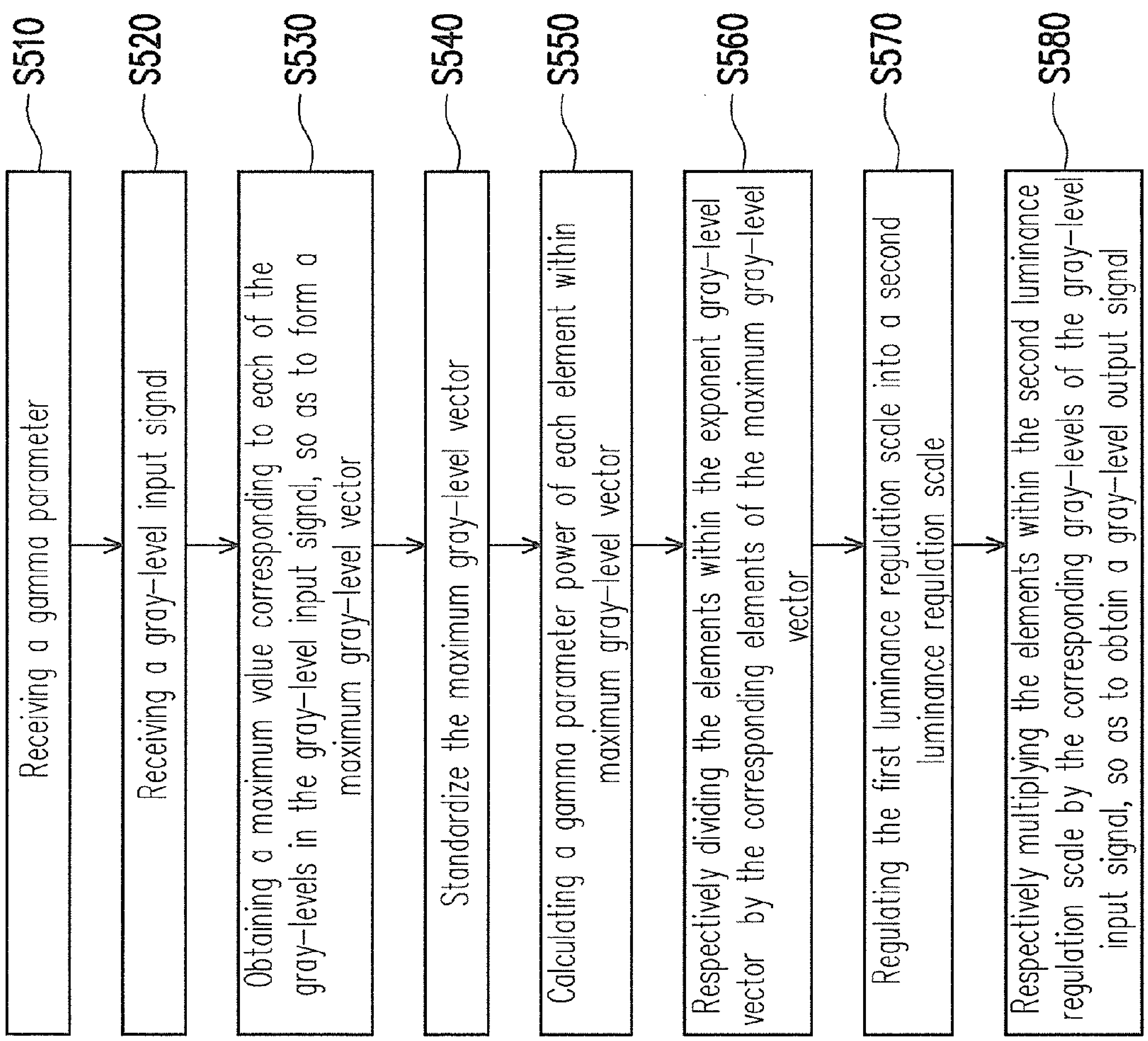

S510
Receiving a gamma parameter
S520
Receiving a gray-level input signal
S530
Obtaining a maximum value corresponding to each of the gray-levels in the gray-level input signal, so as to form a maximum gray-level vector
S540
Standardize the maximum gray-level vector
S550
Calculating a gamma parameter power of each element within maximum gray-level vector
S560
Respectively dividing the elements within the exponent gray-level vector by the corresponding elements of the maximum gray-level vector
S570
Regulating the first luminance regulation scale into a second luminance regulation scale
S580
Respectively multiplying the elements within the second luminance regulation scale by the corresponding gray-levels of the gray-level input signal, so as to obtain a gray-level output signal

FIG. 5

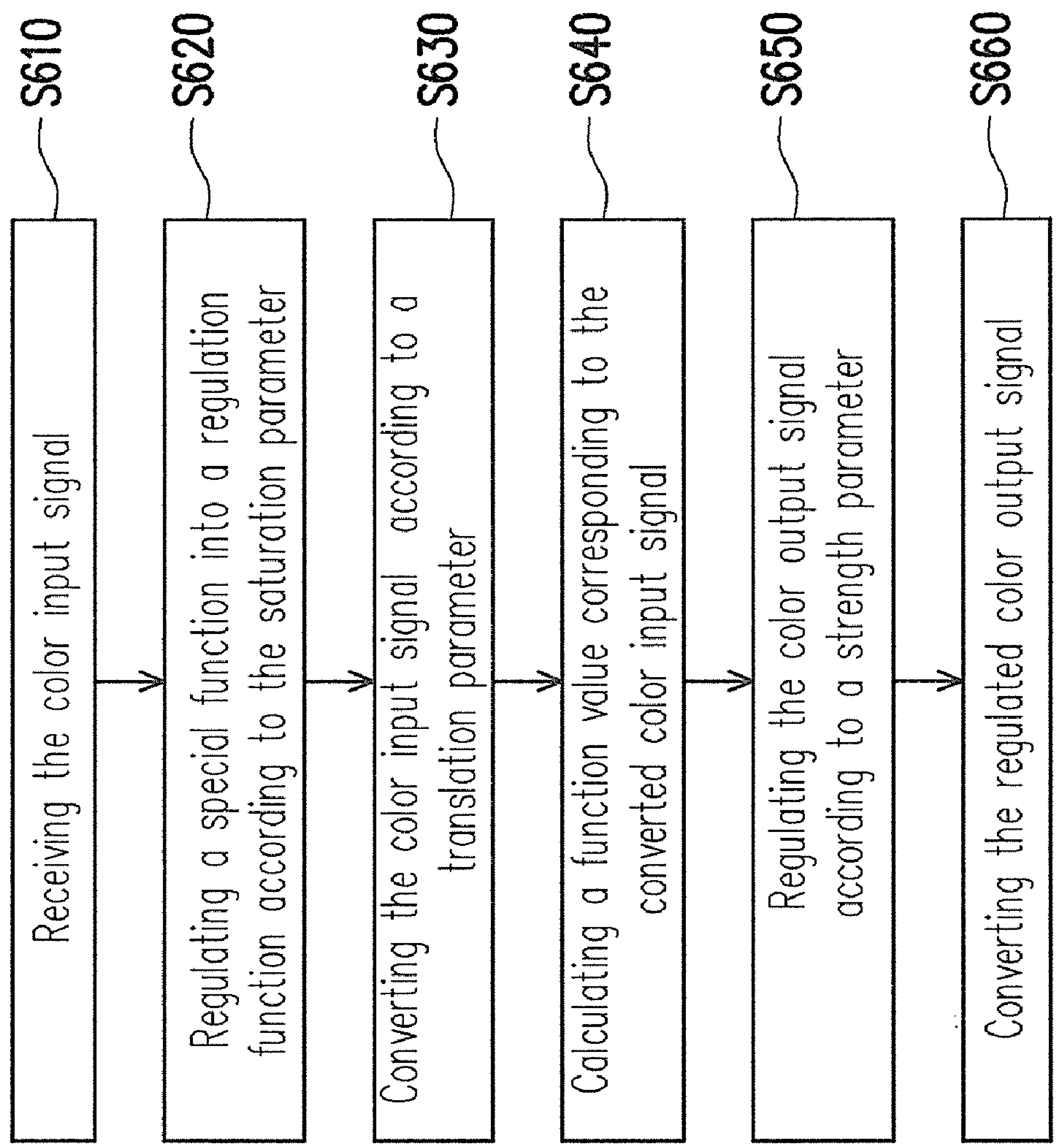

S610
Receiving the color input signal
S620
Regulating a special function into a regulation function according to the saturation parameter
S630
Converting the color input signal according to a translation parameter
S640
Calculating a function value corresponding to the converted color input signal
S650
Regulating the color output signal according to a strength parameter
S660
Converting the regulated color output signal

FIG. 6

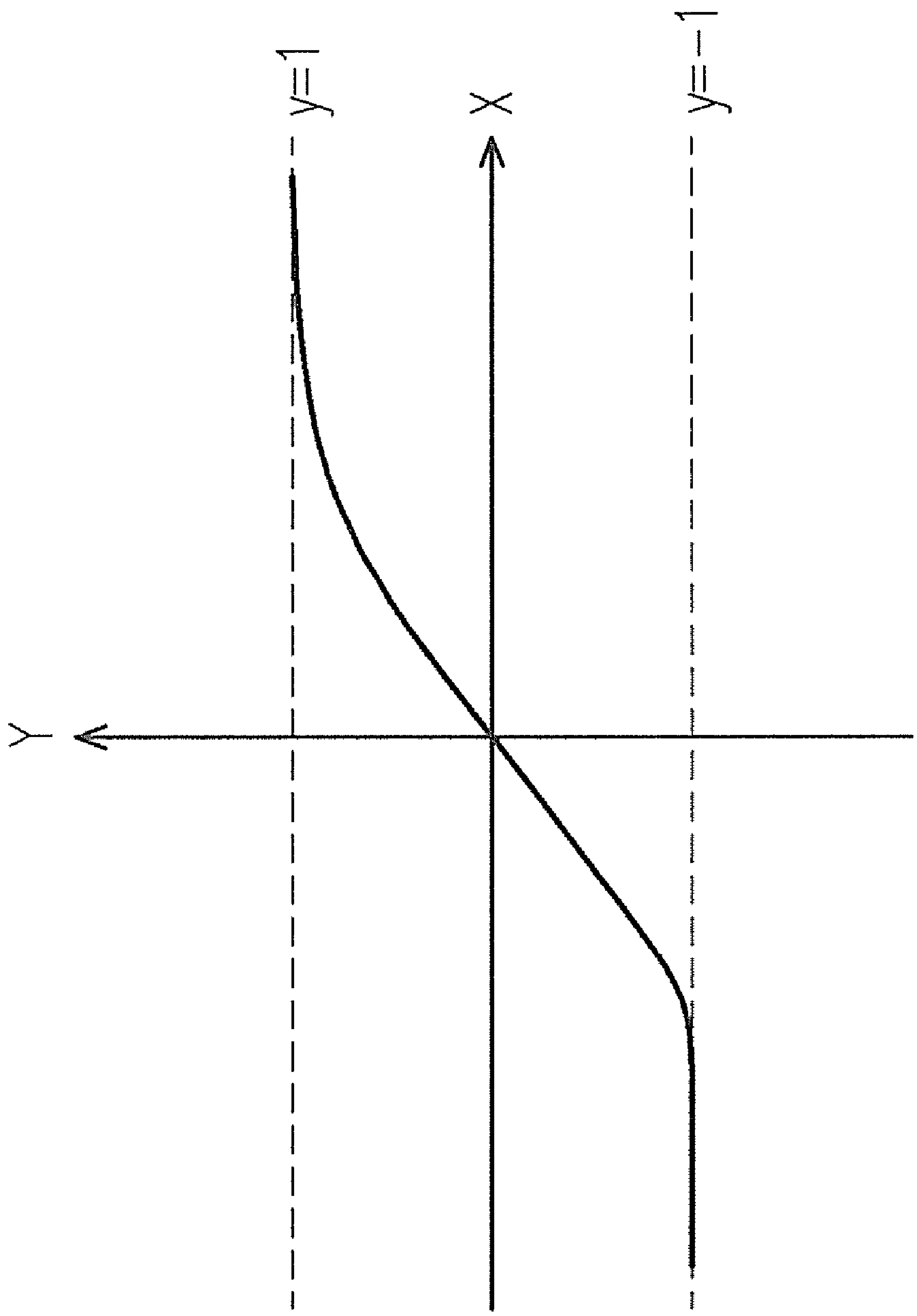


FIG. 7

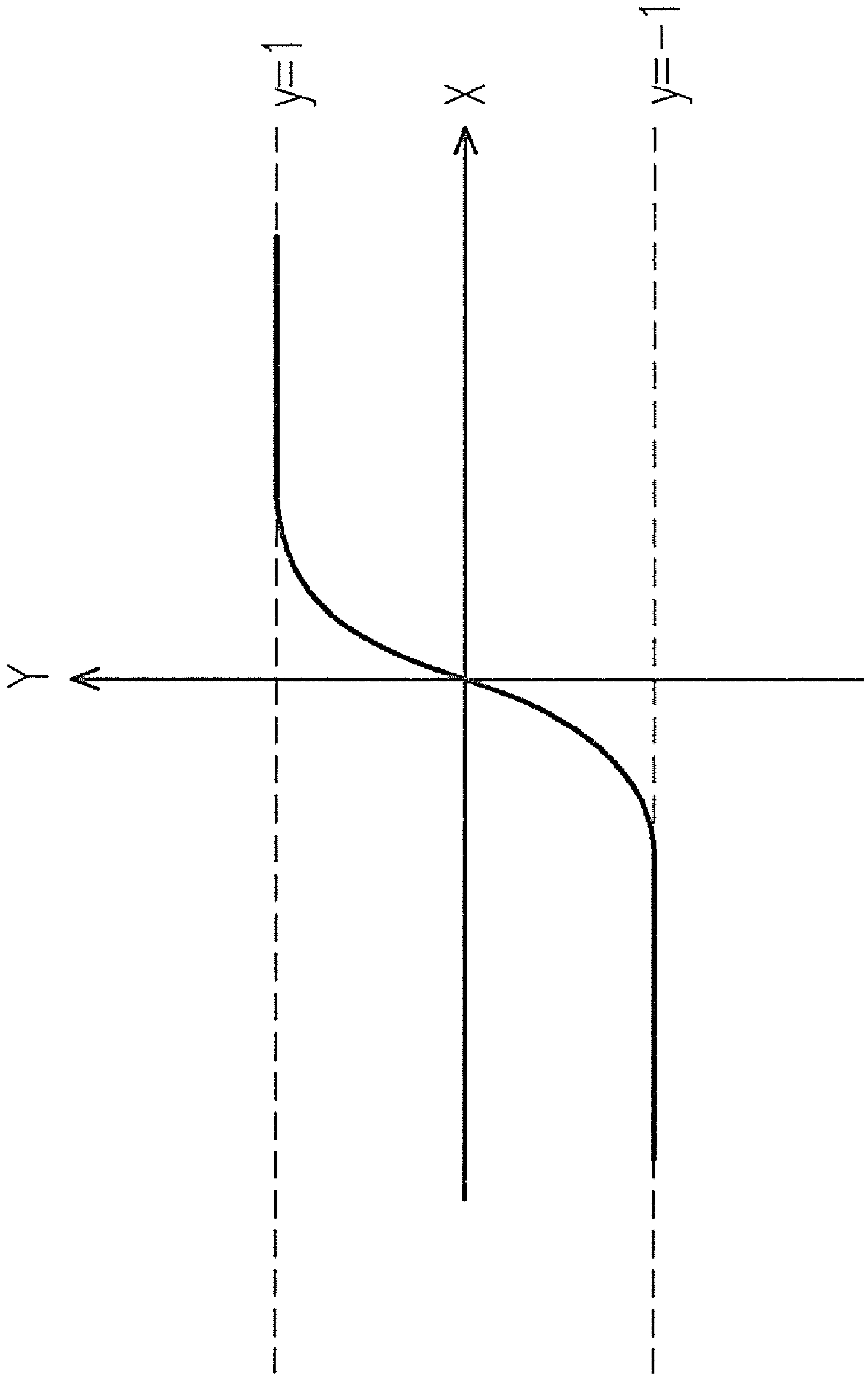


FIG. 8

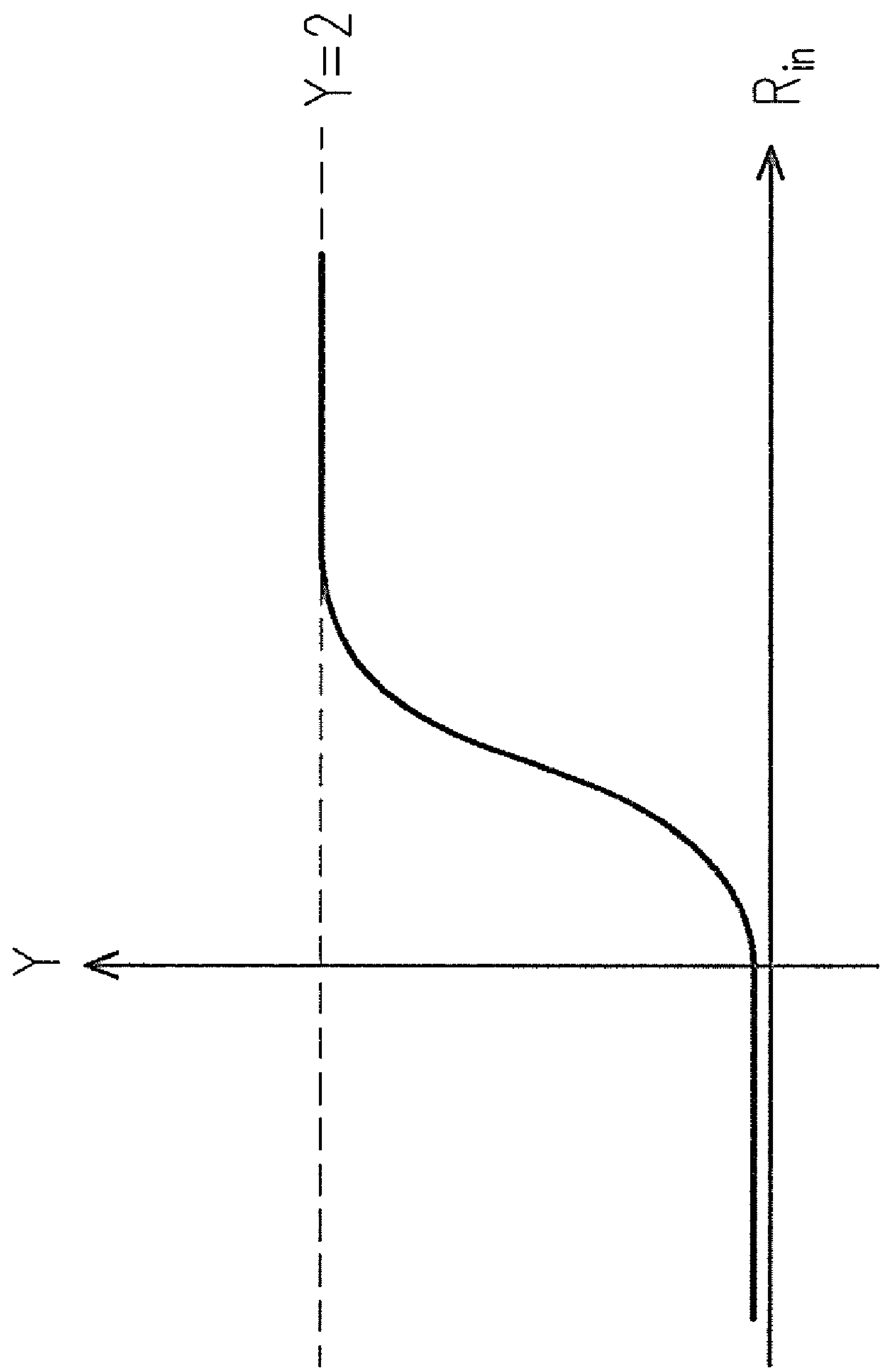


FIG. 9

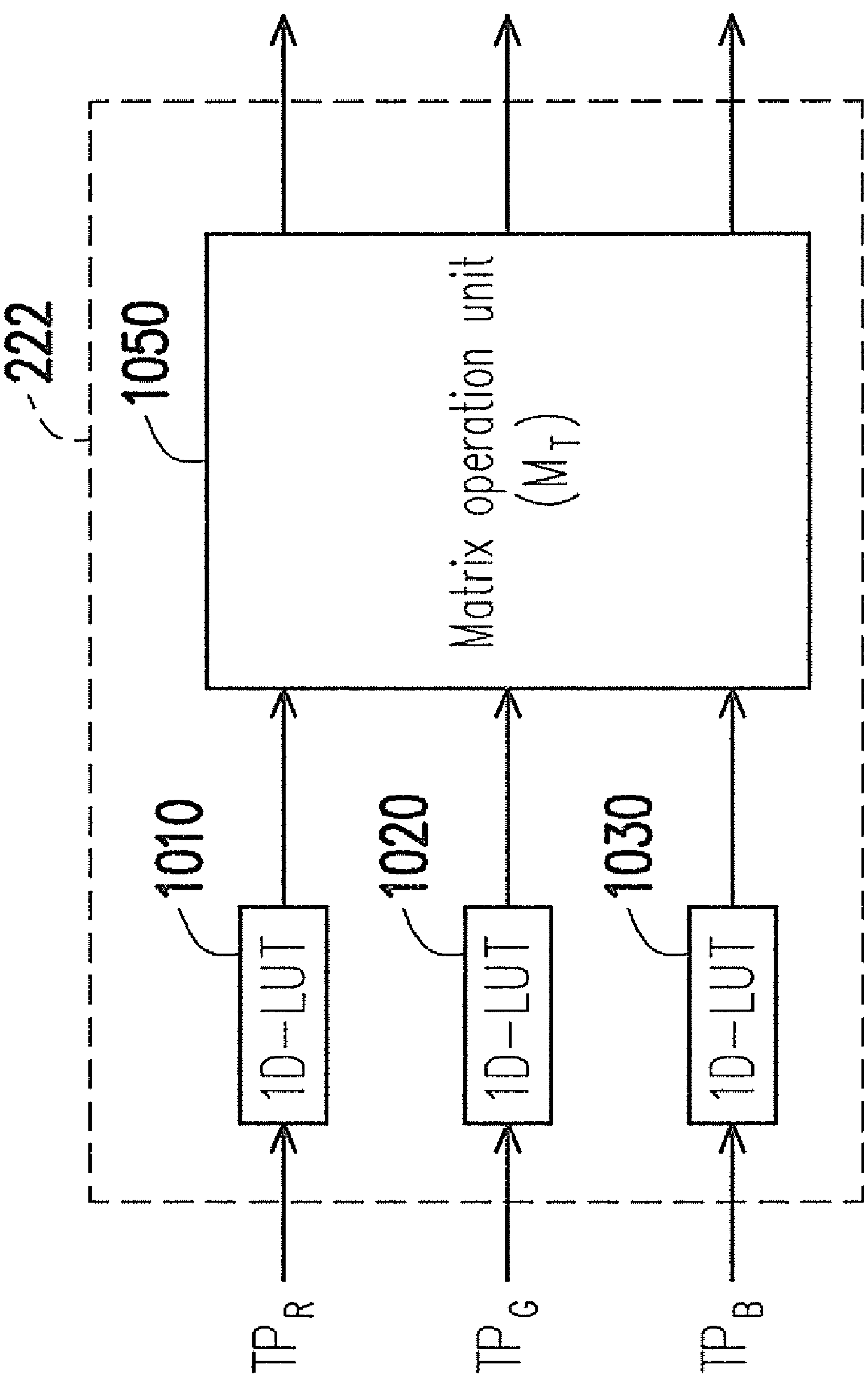

222
1050
Matrix operation unit
(M_T)
1010
1020
1030
1D-LUT
1D-LUT
1D-LUT
TP_R
TP_G
TP_B

FIG. 10

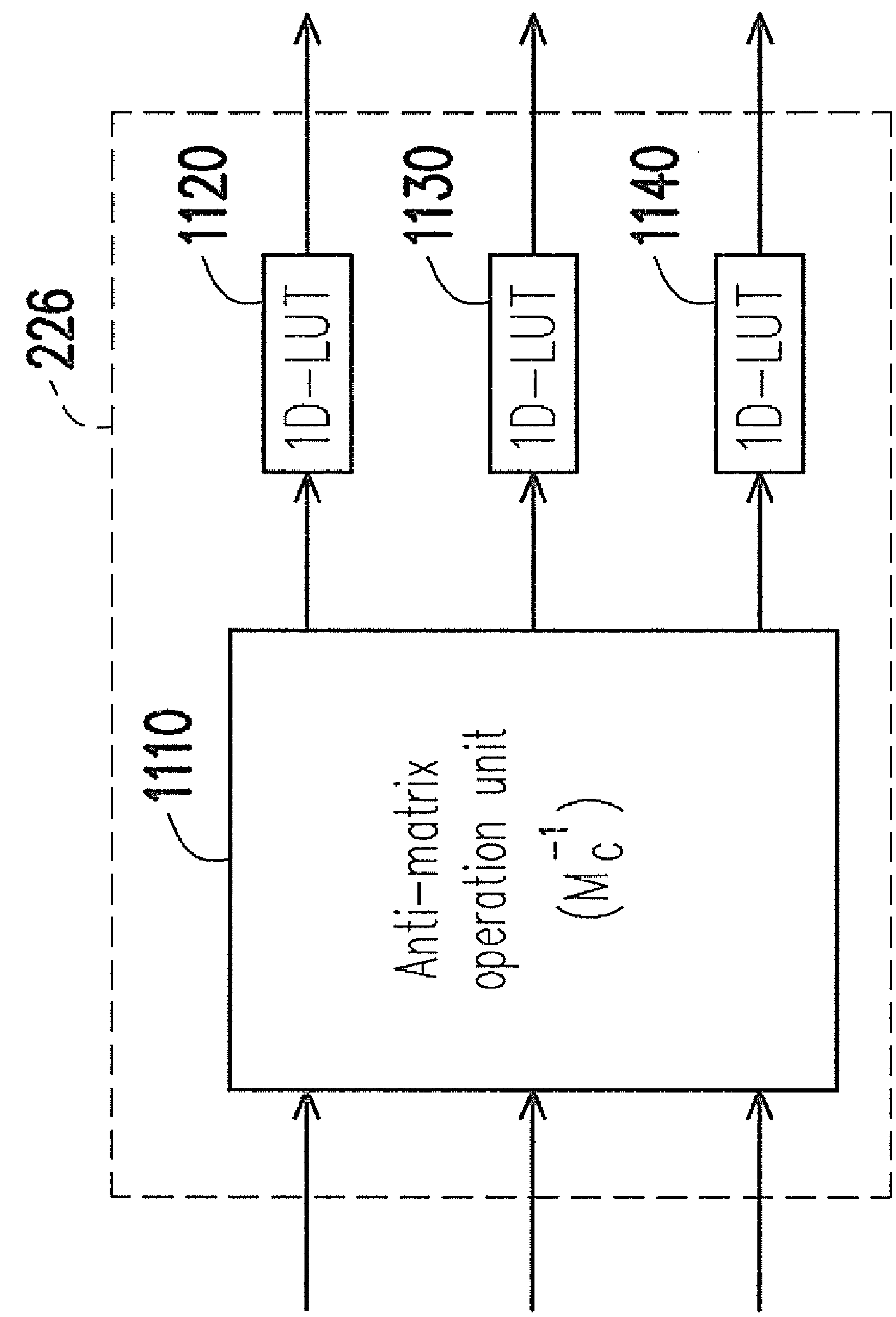

226
1120
1130
1140
1D-LUT
1D-LUT
1D-LUT
1110
Anti-matrix operation unit
(M_c^{-1})

FIG. 11

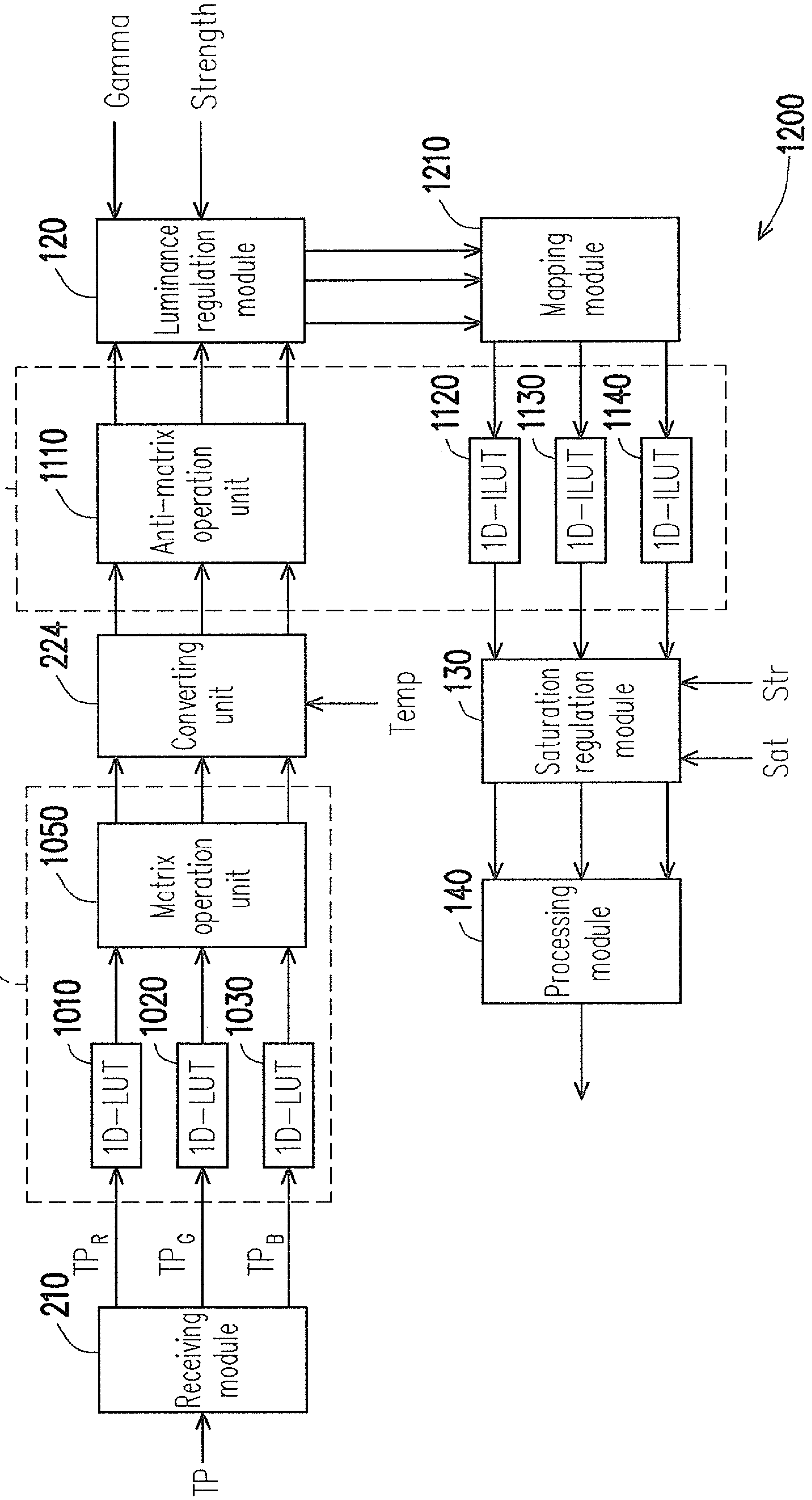

Gamma
Strength
1200
120
Luminance regulation module
1210
Mapping module
226
1110
Anti-matrix operation unit
1120
1130
1140
1D-ILUT
1D-ILUT
1D-ILUT
224
Converting unit
Temp
130
Saturation regulation module
Sat
Str
222
1050
Matrix operation unit
140
Processing module
1010
1020
1030
1D-LUT
1D-LUT
1D-LUT
210
TP_R
TP_G
TP_B
Receiving module
TP

FIG. 12

METHOD AND MODULE FOR REGULATING COLOR DISTRIBUTION

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority benefit of Taiwan application serial no. 97138958, filed on Oct. 9, 2008. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of specification.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a color compensation technique. More particularly, the invention relates to a color compensation technique considering a color characteristic of a display device itself.

2. Description of the Related Art

In high-tech-developed modern society, electronic products are widely used in people's daily life, and people more and more depend on electronic products such as televisions and game apparatuses used for entertainment and computers used for working. Regardless of a working requirement or an entertainment requirement, display devices such as the televisions, projectors and liquid crystal displays (LCD) are indispensable.

Since color types actually displayed by different display devices are different, and in a color image technology domain, a so-called "color gamut" refers to a quantity of the color types that can be actually displayed by a color image display device. Therefore, different display devices have their unique color gamut ranges respectively.

To achieve a better color hue for a display device having poor color performance, conventionally, an extra hardware device (for example, a color enrichment chip or a color corrector, etc.) is generally required to improve the color hue of a video signal output from a graphics card or a graphics chip, such leads to a hardware cost increasing. If the extra hardware device is not utilized, according to the conventional technique, a central processing unit (CPU) of a computer is required to perform a color enrichment software, however such that a calculation burden of the CPU is increased. Moreover, in the conventional technique, a color characteristic or the color gamut range of the display device itself is not taken into consideration. Therefore, when the output video signal of the graphics card or the graphics chip is displayed on the display device, the color enrichment effect is actually not fully achieved.

Moreover, in order to has a comfortable visual effect, the graphics chip or the graphics card generally has an internal regulating function to adjust color distribution such as including image luminance, saturation and color temperature, etc. thereof according to actual requirements. Taking the graphics card for example, an application program is generally applied therein, so that the user can regulate the image luminance, the saturation and the color temperature, etc. via a regulation interface provided by the application program.

In the graphics card or the graphics chip, the image luminance, the saturation and the color temperature, etc. that determined by the user are set in gamma ramps. The graphics card or the graphics chip can regulate an output color distribution according to the gamma ramps. However, the gamma ramps have a relative relation between input color distribution and output color distribution, so that when the user regulates the image luminance, the saturation and the color temperature, etc. via the regulation interface, the input/output relative relation of the gamma ramps has to be recalculated. Therefore, when the user makes an adjustment, an image delay or image flickering phenomenon may occur once a calculation speed of the computer or the graphics card is excessively slow.

BRIEF SUMMARY OF THE INVENTION

The invention provides a method and module for regulating color distribution by converting a color gamut via reference points.

The invention provides a color distribution regulation method includes: providing a first color gamut and a second color gamut; finding a first reference point in the first color gamut; finding a second reference point in the second color gamut; and converting the first color gamut to the second color gamut based on the first reference point and the second reference point.

In an embodiment of the present invention, the color distribution regulation method further includes: obtaining a color temperature parameter via a regulation interface, and finding a third reference point in a third color gamut according to the color temperature parameter

In an embodiment of the present invention, the first, second and third color gamuts belong to a first color space. The step of converting the first color gamut to the second color gamut of the color distribution regulation method further includes: calculating a converting model according to positions of the first, second and third reference points in the first color space; and converting the first color gamut to the second color gamut via the converting model.

In an embodiment of the present invention, the step of converting the first color gamut to the second color gamut includes: converting the first color gamut to the third color gamut based on the first reference point and the third reference point; and converting the third color gamut to the second color gamut based on the third reference point and the second reference point.

In an embodiment of the present invention, the first color space is represented by X-Y-Z coordinates. The position of the first reference point in the first color space is represented by (T_WP_x, T_WP_Y, T_WP_z). The position of the second reference point in the first color space is represented by (C_WP_x, C_WP_Y, C_WP_z). The position of the third reference point in the first color space is represented by (U_WP_x, U_WP_Y, U_WP_z). The converting model is represented by M_{CA}, and a value of the converting model is $\underline{M_{CA}}=K_\alpha \underline{M_A} \underline{\underline{K_\beta^D}} \underline{M_A^{-1}}$, wherein

$$K_\alpha = \frac{T\_WP_Y}{C\_WP_Y}, \underline{\underline{K_\beta^D}}$$

represents a diagonal matrix,

$$\underline{\underline{K_\beta^D}} = \mathrm{diag}\left(\frac{U\_WP_x}{D\_WP_x}, \frac{U\_WP_Y}{D\_WP_Y}, \frac{U\_WP_z}{D\_WP_z}\right),$$

(D_WP_x, D_WP_Y, D_WP_z) represents a position of an environmental light source reference point in the first color gamut, M_A represents a reference coordinates converting matrix, −1 represents an anti-matrix operation, and diag(.) represents a diagonal matrix with elements on the diagonal of the diagonal matrix being sequentially formed by internal vectors.

In an embodiment of the present invention, the first reference point is a white point in the first color gamut, the second reference point is a white point in the second color gamut, and the third reference point is a white point in the third color gamut. The first color gamut is a color gamut of a target display. The color distribution regulation method further includes: providing a color test pattern, wherein the color test pattern belongs to a second color space; providing the target display model; and converting the color test pattern to be in the first color space by the target display model to distribute the color test pattern to the first color gamut in the first color space.

In an embodiment of the present invention, the color test pattern is a L×N matrix represented by TP, the target display model is a N×N matrix represented by M_T, the step of converting the color test pattern to be in the first color space includes performing a matrix multiplication operation to multiply the color test pattern TP by the target display model M_T to obtain the color test pattern distributed to the first color gamut in the first color space, wherein the obtained color test pattern is represented by $XYZ_{D\text{-}ref}$, the value of the obtained color test pattern is $XYZ_{D\text{-}ref}=M_T TP$.

In an embodiment of the present invention, the step of converting the first color gamut to the second color gamut includes converting the color test pattern distributed to the first color gamut to be in the second color gamut via the converting model, wherein the converted color test pattern is distributed to the second color gamut in the first color space.

In an embodiment of the present invention, the converting model is a N×N matrix represented by M_{CA}, and the color test pattern distributed to the first color gamut in the first color space is represented by $XYZ_{D\text{-}ref}$. The step of converting the color test pattern of the first color gamut to be distributed to the second color gamut includes: performing a matrix multiplication operation to multiply the color test pattern $XYZ_{D\text{-}ref}$ in the first color gamut by the converting model M_{CA} to obtain the color test pattern distributed to the second color gamut, wherein the obtained color test pattern is represented by $XYZ_{D\text{-}ill}$, the value of the obtained color test pattern is $XYZ_{D\text{-}ill}=M_{CA}\times XYZ_{D\text{-}ref}$.

In an embodiment of the present invention, the second color gamut is a color gamut of a current display. The color distribution regulation method further includes steps after the step of converting the first color gamut to the second color gamut: providing the current display model; and converting the color test pattern distributed to the second color gamut in the first color space to be in the second color gamut in the second color space by the current display model to distribute the color test pattern to the second color gamut in the second color space.

In an embodiment of the present invention, the current display model is a N×N matrix represented by M_C, and the color test pattern distributed to the second color gamut in the first color space is represented by $XYZ_{D\text{-}ill}$. The step of converting the color test pattern distributed to the second color gamut in the first color space to be in the second color gamut in the second color space includes: performing a matrix multiplication operation to multiply the color test pattern $XYZ_{D\text{-}ill}$ distributed to the second color gamut by the anti-matrix of the current display model M_C to obtain the color test pattern distributed to the second color gamut in the second color space, wherein the obtained color test pattern is represented by $RGB_{D\text{-}ill}$, the value of the obtained color test pattern is $RGB_{D\text{-}ill}=M_C^{-1}\times XYZ_{D\text{-}ill}$.

In an embodiment of the present invention, the color distribution regulation method further includes obtaining a gamma ramps by calculation according to the color test pattern distributed in the second color gamut of the second color space.

The invention provides a color distribution regulation module. The color distribution regulation module includes a receiving module for receiving a color test pattern; and a converting module storing a first color gamut and a second color gamut, wherein the converting module is used for converting the color test pattern to be in the first color gamut, and converting the color test pattern distributed to the first color gamut to be in the second color gamut based on a first reference point in the first color gamut and a second reference point in the second color gamut.

In an embodiment of the present invention, the color distribution regulation module further includes a regulation interface for receiving a color temperature parameter, wherein the converting module finds a third reference point in a third color gamut according to the color temperature parameter.

In an embodiment of the present invention, the first color gamut is a color gamut of a target display, the second color gamut is a color gamut of a current display. The converting module includes: a target display model unit comprising a target display model and converting the color test pattern to be in a first color space via the target display model to distribute the color test pattern to the first color gamut in the first color space; a converting unit converting the color test pattern distributed to the first color gamut to be in the third color gamut based on the first reference point and the third reference point, and then converting the color test pattern distributed to the third color gamut to be in the second color gamut based on the second reference point and the third reference point; and a current display model unit comprising a current display model and converting the color test pattern distributed to the second color gamut in the first color space to be in the second color space by the current display model to distribute the color test pattern to the second color gamut in the second color space.

In an embodiment of the present invention, the color distribution regulation module further includes a processing module obtaining a gamma ramps by calculation according to the color test pattern distributed to the second color gamut.

The invention regulates a color distribution and a color temperature by converting color gamuts based on reference points in the color gamuts.

In order to make the aforementioned and other objects, features and advantages of the present invention comprehensible, a preferred embodiment accompanied with figures is described in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

FIG. **1** is a system block diagram illustrating a color regulation system according to an embodiment of the present invention;

FIG. **2** is a block diagram illustrating a color distribution regulation module **110** of a color regulation system **100**;

FIG. **3** is a flowchart illustrating a color distribution regulation method according to an embodiment of the present invention;

FIG. **4** is a flowchart illustrating sub steps of a step S**330**;

FIG. **5** is a flowchart illustrating a luminance regulation method according to an embodiment of the present invention;

FIG. **6** is a flowchart illustrating a saturation regulation method according to an embodiment of the present invention;

FIG. **7** is a diagram of a special function;

FIG. **8** is a diagram of a regulating function;

FIG. **9** is a diagram of a regulating function after translation;

FIG. **10** is a system block diagram illustrating a target display model unit **222**;

FIG. **11** is a system block diagram illustrating a current display model unit **226**; and

FIG. **12** is a block diagram illustrating a color regulation system according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

FIG. **1** is a system block diagram illustrating a color regulation system according to an embodiment of the present invention. Referring to FIG. **1**, the color regulation system **100** includes a color distribution regulation module **110**, a luminance regulation module **120**, a saturation regulation module **130** and a processing module **140**. To achieve a better color regulating effect, a color test pattern is applied to the embodiment. The color distribution regulation module **110** regulates a color distribution and a color temperature of the color test pattern, and the luminance regulation module **120** regulates a luminance of the color test pattern, and then the saturation regulation module **130** regulates a saturation degree of the color test pattern. Finally, the processing module **140** obtains gamma ramps by calculation according to the regulated color test pattern.

However, those skilled in the art should understand that during the aforementioned regulating processes, operations of the color distribution regulation module **110**, the luminance regulation module **120** and the saturation regulation module **130** are not sequential, and if only a part of color features is required to be regulated, only one of or two of the color distribution regulation module **110**, the luminance regulation module **120** and the saturation regulation module **130** is applied.

FIG. **2** is a block diagram illustrating the color distribution regulation module **110** of the color regulation system **100**. Referring to FIG. **2**, the color distribution regulation module **110** includes a receiving module **210** and a converting module **220**. The converting module **220** includes a target display model unit **222**, a converting unit **224** and a current display model unit **226**. In the embodiment, the color distribution regulation module **110**, for example, executes a color distribution regulation method, which is shown as a flowchart of FIG. **3**. In the following content, regulations of the color distribution and the color temperature are described in coordination with the color distribution regulation method.

Referring to FIG. **2** and FIG. **3**, first, the receiving module **210** receives the color test pattern (step S**310**), wherein the color test pattern can be randomly generated by a computer or a graphics card, or can be pre-stored in the computer. For simplicity's sake, the received color test pattern is represented by $\underline{\underline{TP}}$, assuming the color test pattern belongs to a R-G-B color space, and the color test pattern $\underline{\underline{TP}}$ respectively contains L gray-levels corresponding to the RGB three coordinates directions, so that the color test pattern $\underline{\underline{TP}}$ can be represented by a matrix:

$$\underline{\underline{TP}} = \begin{bmatrix} r_0 & g_0 & b_0 \\ r_1 & g_1 & b_1 \\ \vdots & \vdots & \vdots \\ r_{L-1} & g_{L-1} & b_{L-1} \end{bmatrix}_{L\times 3}.$$

In the present embodiment, a value of L is, for example, 256. To clarify the following mathematic equations, if a mathematic symbol represents a matrix, double bottom lines are added to the symbol, for example, $\underline{\underline{TP}}$. If the mathematic symbol represents a vector, a single bottom line is added to the symbol, and if the mathematic symbol represents a scalar, none bottom line is added to the symbol.

Next, the target display model unit **222** applies a target display model to convert the color test pattern $\underline{\underline{TP}}$ to a X-Y-Z color space (step S**320**), so that the color test pattern $\underline{\underline{TP}}$ is distributed to a first color gamut, wherein the first color gamut is, for example, a color gamut of a color distribution of a target display. In other words, the color test pattern $\underline{\underline{TP}}$ converted by the target display model unit **222** is distributed to the color gamut of the color distribution of the target display in the X-Y-Z color space. In the present embodiment, the target display is, for example, a display having a better color performance, and the target display model is, for example, a N×N matrix represented by $\underline{\underline{M_T}}$, wherein N is a dimension of the color space, and in the present embodiment, a value of N is 3. The color test pattern $\underline{\underline{TP}}$ converted by the target display model unit **222** is represented by $\underline{\underline{XYZ_{D\text{-}ref}}}$, and a value thereof is $\underline{\underline{XYZ_{D\text{-}ref}}}=\underline{\underline{M_T}}\,\underline{\underline{TP}}$.

Next, the converting unit **224** converts the converted color test pattern $\underline{\underline{XYZ_{D\text{-}ref}}}$ to a second color gamut within the X-Y-Z color space via a converting model (step S**330**), wherein the second color gamut is, for example, a color gamut of a color distribution of a current display, and the current display is a currently driven display. The step S**330** further includes a plurality of sub steps, which are shown as FIG. **4**.

Referring to FIG. **4**, first, a first and a second reference points are respectively found from the color gamuts (step S**410**). The first reference point is, for example, a white point in the first color gamut, and is represented by (T_WP_X, T_WP_Y, T_WP_Z) in the X-Y-Z color space. The second reference point is, for example, a white point in the second color gamut, and is represented by (C_WP_X, C_WP_Y, C_W_Z) in the X-Y-Z color space. Next, a color temperature parameter (referred to as Temp) is obtained via a regulation interface (Step S**420**), wherein the regulation interface is, for example, an operation interface of a user, and the user can regulate a desired color temperature via the operation interface. Next, a third reference point in a third color gamut is found according to the color temperature parameter Temp. The third color gamut is, for example, the desired color distribution, and the third reference point is, for example, a white point in the third color gamut, and is represented by (U_WP_X, U_WP_Y, U_WP_Z) in the X-Y-Z color space. Moreover, an environmental light source reference point in the first color gamut, the second color gamut and the third color gamut is, for example, a D50 white point, and is represented by (D_WP_X, D_WP_Y, D_WP_Z) in the X-Y-Z color space.

Next, a converting model is calculated according to positions of the first, the second and the third reference points in the first color space (step S430). In the present embodiment, the converting model can be mathematically represented by a matrix M_{CA}, and a value thereof is $M_{CA}=K_\alpha M_A K_\beta^D M_A^{-1}$ . . . (1), wherein K_α is, for example, a scaling coefficient, and a value thereof is

$$K_\alpha = \frac{T\_WP_Y}{C\_WP_Y};\ \underline{\underline{K_\beta^D}}$$

is a diagonal matrix, and a value thereof is

$$\underline{\underline{K_\beta^D}} = \mathrm{diag}\left(\frac{U\_WP_x}{D\_WP_x}, \frac{U\_WP_Y}{D\_WP_Y}, \frac{U\_WP_z}{D\_WP_z}\right);$$

−1 represents an anti-matrix operation; diag(.) represents a diagonal matrix with elements on the diagonal thereof being sequentially formed by internal vectors, and M_A is a 3×3 reference coordinates converting matrix. Moreover, according to the mathematic equation (1), the converting model M_{CA} is, for example, a 3×3 matrix.

After the converting model M_{CA} is obtained, the color test pattern $XYZ_{D\text{-}ref}$ of the first color gamut is converted to the second color gamut via the converting model M_{CA} (step S440), so that the color test pattern is distributed to the second color gamut. The color test pattern converted to the second color gamut is represented by $XYZ_{D\text{-}ill}$, and a value thereof is $XYZ_{D\text{-}ill}=M_{CA}XYZ_{D\text{-}ref}$ . . . (2). A physical meaning of the mathematic equations (1) and (2) is that the color test pattern $XYZ_{D\text{-}ref}$ of the first color gamut is first converted to the desired third color gamut based on the first reference point and the third reference point, and then the color test pattern of the third color gamut is converted to the second color gamut based on the third reference point and the second reference point.

Referring to FIG. **3** again, finally, the current display model unit **226** receives the color test pattern $XYZ_{D\text{-}ill}$ converted to the second color gamut, and converts the color test pattern of the second color gamut to the R-G-B color space according to the current display model (step S**340**), so as to distribute the color test pattern to the second color gamut in the R-G-B color space.

In the present embodiment, the current display is the currently driven display, and the current display model is, for example, a N×N matrix represented by M_C, wherein N is a dimension of the color space. In the present embodiment, a value of N is 3. The color test pattern $XYZ_{D\text{-}ill}$ converted by the current display model unit **226** is represented by $RGB_{D\text{-}ill}$, and a value thereof is $RGB_{D\text{-}ill}=M_C^{-1}\times XYZ_{D\text{-}ill}$. In the present embodiment, the color test pattern $RGB_{D\text{-}ill}$ distributed in the second color gamut of the R-G-B color space is input to the luminance regulation module **120**. According to the aforementioned mathematic equations, it is known that the color test pattern $\underline{RGB_{D\text{-}ill}}$ is, for example, a 256×3 matrix.

According to the aforementioned operations of the color distribution regulation module, during the color gamut conversion, not only the third color gamut obtained according to the color temperature parameter regulated by the user is referenced, but also the second color gamut of the current display is also referenced. Therefore, during regulation of the color features, the characteristic of the current display is also taken into consideration, so that after the regulation, color enrichment of the displayed image is more obvious.

Referring to FIG. **1** again, the luminance regulation module **120**, for example, executes a luminance regulation method, and a flowchart thereof is shown in FIG. **5**. In the following content, regulation of the color luminance is described in coordination with the luminance regulating method. First, the luminance regulation module **120** receives a gamma parameter (step S**510**), and the gamma parameter is, for example, obtained via a regulation interface. In other words, the gamma parameter is a parameter that can be regulated by the user. Next, the luminance regulation module **120** receives a gray-level input signal (step S**520**), wherein the gray-level input signal is obtained from the color test pattern $RGB_{D\text{-}ill}$ converted by the color distribution regulation module **110**.

According to the operation of the color distribution regulation module **110**, the gray-level input signal $RGB_{D\text{-}ill}$ belongs to the R-G-B color space, and respectively has L gray-levels in the RGB coordinates directions. In the present embodiment, a value of L is 256. Therefore, the gray-level input signal $\underline{RGB_{D\text{-}ill}}$ is a 256×3 matrix that can be represented by

$$\underline{\underline{RGB_{D\text{-}ill}}} = \begin{bmatrix} R_{in\_0} & G_{in\_0} & B_{in\_0} \\ R_{in\_1} & G_{in\_1} & B_{in\_1} \\ \vdots & \vdots & \vdots \\ R_{in\_255} & G_{in\_255} & B_{in\_255} \end{bmatrix}_{256\times 3}.$$

Next, after the gray-level input signal is received, the luminance regulation module **120** obtains a maximum value corresponding to each of the gray-levels in the gray-level input signal $RGB_{D\text{-}ill}$, so as to form a maximum gray-level vector (step S**530**). According to the above mathematic equation of $RGB_{D\text{-}ill}$, the luminance regulation module **120** obtains the maximum value of the elements in each row of the gray-level input signal $RGB_{D\text{-}ill}$. Namely, the each of the elements within the maximum gray-level vector is formed by the maximum value of the elements in each row of the gray-level input signal $RGB_{D\text{-}ill}$. In the present embodiment, the maximum gray-level vector is, for example, represented by $V_{max}=[V_{max\_0}\ V_{max\_1} \ldots V_{max\_255}]$, wherein element values are $V_{max\_0}=\max\{R_{in\_0},G_{in\_0},B_{in\_0}\}$, $V_{max\_1}=\max\{R_{in\_1}, G_{in\_1},B_{in\_1}\}, \ldots, V_{max\_255}=\max\{R_{in\_255},G_{in\_255},B_{in\_255}\}$, and max{.} represents obtaining a maximum value.

Next, the luminance regulation module **120** standardizes the maximum gray-level vector V_{max} (step S**540**), and the standardized maximum gray-level vector

$$\underline{V_{max}} \text{ is } \underline{V_{max}} = \left[\ \frac{V_{max\_0}}{S}\ \ \frac{V_{max\_1}}{S}\ \ \ldots\ \ \frac{V_{max\_L-1}}{S}\ \right].$$

Wherein, S is a standardized parameter, and a value thereof is the maximum value in the elements of the maximum gray-level vector before the standardization. In other words, $S=\max\{V_{max\_0}\ V_{max\_1}, \ldots, V_{max\_255}\}$. According to the above mathematic equation, each of the element values in the standardized maximum gray-level vector $\underline{V_{max}}$ is between

0-1. For simplicity's sake, the standardized maximum gray-level vector $\underline{\overline{V}_{max}}$ is represented by $[\overline{V}_{max\_0}\ \overline{V}_{max\_1}\ \ldots\ \overline{V}_{max\_255}]$.

Next, the luminance regulation module **120** calculates a gamma parameter power of each element within the standardized maximum gray-level vector $\underline{\overline{V}_{max}}$ (step S**550**), so as to obtain an exponent gray-level vector. Wherein, the gamma parameter is the parameter received in the step S**510**, and is represented by Gamma. The exponent gray-level vector is represented by $\underline{\overline{V}_{max}}^{Gamma}$, and a value thereof is $\underline{\overline{V}_{max}}^{Gamma}=[(\overline{V}_{max\_0})^{Gamma}\ (\overline{V}_{max\_1})^{Gamma}\ \ldots\ (\overline{V}_{max\_255})^{Gamma}]$.

Next, the luminance regulation module **120** respectively divides the elements within the exponent gray-level vector $\underline{\overline{V}_{max}}^{Gamma}$ max by the corresponding elements of the maximum gray-level vector $\underline{V_{max}}$, so as to obtain a first luminance regulation factor (step S**560**). Wherein, the first luminance regulation factor is represented by $\underline{M}$, and a value thereof is

$$\underline{M}=\left[\frac{(\overline{V}_{max\_0})^{Gamma}}{V_{max\_0}}\ \ \frac{(\overline{V}_{max\_1})^{Gamma}}{V_{max\_1}}\ \ \ldots\ \ \frac{(\overline{V}_{max\_255})^{Gamma}}{V_{max\_255}}\right].$$

Next, the luminance regulation module **120** regulates the first luminance regulation factor $\underline{M}$ into a second luminance regulation factor according to a strength parameter (step S**570**). Wherein, the strength parameter is a parameter obtained via the aforementioned regulation interface, and is represented by Strength, and a value thereof is between 0-1. The second luminance regulation factor is represented by $\underline{\alpha}=[\alpha_0\ \alpha_1\ \ldots\ \alpha_{255}]$, and a value thereof is $\underline{\alpha}=(1-\text{Strength})+\underline{M}\times\text{Strength}$. In other words, each of the elements in the second luminance regulation factor $\underline{\alpha}$ is

$$\alpha_i=(1-\text{Strength})+\left(\frac{(\overline{V}_{max\_i})^{Gamma}}{V_{max\_i}}\right)\times\text{Strength},$$

wherein i is an integer between 0-255.

In the present embodiment, the strength parameter Strength is used for fine-tuning the luminance parameter, so that the luminance regulated by the luminance regulation module **120** is not only influenced by the gamma parameter Gamma. In other words, a regulation factor of the luminance regulated by the gamma parameter Gamma can be reduced by the strength parameter Strength. If Strength=1, the luminance regulation factors $\underline{M}$ and $\underline{\alpha}$ are the same, and the regulation factor of the luminance regulated by the gamma parameter Gamma is not reduced. If Strength=0, the second luminance regulation factor $\underline{\alpha}=0$, and now the luminance is totally not influenced by the gamma parameter Gamma. Namely, the luminance regulation module **120** does not regulate the luminance of the gray-level input signal $RGB_{D\text{-}ill}$.

Finally, after the second luminance regulation factor $\underline{\alpha}$ is obtained, the luminance regulation module **120** respectively multiplies the elements within the second luminance regulation factor $\underline{\alpha}$ by the corresponding gray-levels of the gray-level input signal, so as to obtain a gray-level output signal (step S**580**). In detail, regarding the R coordinates direction in the color space, a set of the gray-levels of the gray-level input signal $\overline{RGB_{D\text{-}ill}}$ in the R coordinates direction is represented by $\{R_{in\_0}, R_{in\_1}, \ldots, R_{in\_255}\}$ and a set of the gray-levels of the gray-level output signal in the R coordinates direction is represented by $\{R_{out\_0}, R_{out\_1}, \ldots, R_{out\_255}\}$, wherein $R_{out\_0}=\alpha_0\times R_{in\_0}$, $R_{out\_1}=\alpha_1\times R_{in\_1}$, . . . , $R_{out\_255}=\alpha_{255}\times R_{in\_255}$. Similarly, in the step S**580**, sets of the gray-levels of the gray-level output signal in the G and B coordinates direction are respectively represented by $\{G_{out\_0}, G_{out\_1}, \ldots, G_{out\_255}\}$ and $\{B_{out\_0}, B_{out\_1}, \ldots, B_{out\_255}\}$, wherein $G_{out\_i}=\alpha_i\times G_{in\_i}$, $B_{out\_i}=\alpha_i\times B_{in\_i}$, and i is an integer between 0-255. The luminance regulation module **120** outputs the calculated gray-level output signal to the saturation regulation module **130**.

Referring to FIG. **1** again, the saturation regulation module **130** for example, performs a saturation regulation method, and a flowchart thereof is shown in FIG. **6**. In the following content, regulation of the color saturation is described in coordination with the saturation regulation method. First, the saturation regulation module **130** receives a color input signal (step S**610**). In the present embodiment, the color input signal received by the saturation regulation module **130** is, for example, the gray-level output signal output by the luminance regulation module **120**. Therefore, according to the aforementioned operation of the luminance regulation module **120**, it is known that the gray-level output signal contains the RGB three coordinates directions and has a plurality of gray-levels (including $\{R_{out\_0}, R_{out\_1}, \ldots, R_{out\_255}\}$, $\{G_{out\_0}, G_{out\_1}, \ldots, G_{out\_255}\}$ and $\{B_{out\_0}, B_{out\_1}, \ldots, B_{out\_255}\}$) in each of the coordinates directions.

Since the saturation regulations performed by the saturation regulation module **130** for each of the gray-levels in the coordinates direction are similar, any gray-level in the R coordinates direction is taken as an example, and is represented by R_{in}. In other words, in the following embodiment, assuming the color input signal is R_{in}, and the saturation regulation module **130** only performs the saturation regulation to the color input signal R_{in}.

Next, the saturation regulation module **130** receives a saturation parameter (referred to as Sat), and regulates a special function into a regulating function according to the saturation parameter (step S**620**). Wherein, the special function is, for example, a one-to-one and onto function, and is represented by Y=F(X). For simplicity's sake, the special function is, for example, a hyperbolic tangent function of a hyperbolic function, which is represented by Y=tan h(X), and a function figure thereof is shown in FIG. **7**. The saturation parameter Sat is, for example, obtained via the aforementioned regulation interface, so that the user can regulates the color saturation through the saturation parameter Sat.

In the step S**620**, the saturation regulation module **130** regulates a curvature of the function Y tan h(X) according to the saturation parameter Sat, and the adjusted regulating function is, for example, represented by Y=tan h[$(S_2\times\text{Sat}+1)\cdot X$], wherein S_2 is a predetermined parameter. Here, if a product of the predetermined parameter S_2 and the saturation parameter Sat is a positive number, the curvature of the regulation parameter is then greater than that of the original special function, and the function figure of the regulating function is shown in FIG. **8**.

Next the saturation regulation module **130** converts the color input signal R_{in} into r_{in} according to a translation parameter (step S**630**). Wherein, the translation parameter is represented by D, the converted color input signal is represented by r_{in}, and a relation of r_{in} and R_{in} is $r_{in}=(R_{in}-D)/D$, wherein D is a positive number. In the present embodiment, the color input signal R_{in} serves as a definition domain of the regulating function, and the step of converting the color input signal R_{in} into r_{in} is, for example, to perform coordinate conversion and translation to the regulating function. Therefore, if the regulating function is represented by Y=tan h[$(S_2\times Sat+1)\cdot R_{in}$], a function figure thereof is shown in FIG. **9**.

Next, the saturation regulation module **130** calculates a function value corresponding to the converted color input signal r_{in} (step S**640**), and outputs the function value corresponding to the r_{in} as a color output signal. Wherein, the color output signal is represented by h_r, and a value thereof is $h_r=S_r\times\tan h[(S_2\times Sat+1)\cdot r_{in}]$, wherein S_r is a scaling parameter used for linearly amplifying or reducing the function value corresponding to r_{in}, so that the value of the color output signal h_r can be within a designed range.

Next, the saturation regulation module **130** regulates the color output signal h_r into r_{out} according to a strength parameter (step S**650**). Wherein, the strength parameter is a parameter obtained via the aforementioned regulation interface, and is represented by Str, and a value thereof is between 0-1. The regulated color output signal h_r is represented by r_{out} and a value thereof is $r_{out}=(1-Str)\times r_{in}+Str\times h_r$. The strength parameter Str is similar to the strength parameter Strength of the luminance regulation module **120**, and is used for further fine-tuning the saturation parameter, so that the luminance regulated by the saturation regulation module **130** is not only influenced by the saturation parameter Sat.

Finally, the saturation regulation module **130** converts the regulated color output signal r_{out} into R_{out} (step S**660**). Wherein, R_{out} represents the converted color output signal, and a relation of r_{out} and R_{out} is $R_{out}=r_{out}\times D+D$, wherein D is the translation parameter utilized in the step S**630**. Since in the step S**630**, coordinates conversion and coordinates translation have been performed by the saturation regulation module **130**, after the color output signal r_{out} is calculated, the saturation regulation module **130** should restore the coordinates according to the original translation parameter D in the step S**660**, so as to obtain an actual value of the color output signal R_{out}.

Moreover, though any gray-level in the R coordinates direction is taken as an example, since saturation degree regulations of a plurality of the gray-levels ($\{R_{out\_0}, R_{out\_1}, \ldots, R_{out\_255}\}$, $\{G_{out\_0}, G_{out\_1}, \ldots, G_{out\_255}\}$ and $\{B_{out\_0}, B_{out\_1}, \ldots, B_{out\_255}\}$) in each of the coordinates directions are similar, a corresponding color output signal R_{out} can be found from each of the gray-levels in the RGB three coordinates directions. It should be noted that since value ranges of the input gray-levels for the coordinates directions are different, or the saturation degrees to be regulated are different, the scaling parameter S_r, the translation parameter D or the predetermined parameter S_2 can be varied according to different coordinates directions.

According to the aforementioned operations of the saturation modulation module **130**, it is known that in the present embodiment, an input/output relation is obtained according to the relative relation of the definition domain and the value domain of the special function. In other words, during regulation of the color saturation, the saturation degree of the color output signal can be directly regulated by just regulating the special function, and finding the input/output relation by looking up a table is unnecessary. Moreover, in the present embodiment, the special function is the hyperbolic tangent function, though those skilled in the art should understand that the special function can also be a hyperbolic cosine function, a hyperbolic sine function or other types of function.

Referring to FIG. **1** again, after the color test pattern TP is regulated by the color distribution regulation module **110**, the luminance regulation module **120** and the saturation regulation module **130**, the color temperature, the luminance and the saturation thereof are all regulated according to the parameters set by the user. Finally, the processing module **140** calculates the gamma ramps according to the regulated color test pattern (i.e. the color output signal R_{out} corresponding to each of the gray-levels, that is output by the saturation modulation module). After the processing module **140** obtains the gamma ramps, the gamma ramps can be stored in a graphics card or a graphics chip of a computer system, so that the graphics card can regulate a signal output to a display device according to the obtained gamma ramps. In other words, images displayed by the display device may have a better color hue without executing a color enrichment software by the computer system.

The target display model unit **222** of the color distribution regulation module **110** converts the color test pattern TP from the R-G-B color space to the X-Y-Z color space. Regarding a current image processing technique, the target display model unit **222** includes a plurality of one dimension look-up tables (1D-LUT) **1010-1030** and a matrix calculation unit **1050** shown as FIG. **10**. The aforementioned color test pattern TP is grouped into data TP_R of the R coordinates direction, data TP_G of the G coordinates direction and data TP_B of the B coordinates direction. The matrix calculation unit **1050** includes a target display model, for example, the aforementioned matrix M_T. Data corresponding to the data TP_R, TP_G and TP_B of the three coordinates directions of the color test pattern are respectively found by the 1-D LUTs **1010-1030**, and the data output from the 1-D LUTs **1010-1030** is multiplied by the matrix M_T via the matrix calculation unit **1050**, so as to be converted to the X-Y-Z color space.

Similarly, the current display model unit **226** includes an anti-matrix operation unit **1110** and a plurality of one dimension inversion look-up tables (1D-ILUT) **1120-1140** shown in FIG. **11**. The color test pattern $XYZ_{D\text{-}ref}$ is grouped into data $X_{D\text{-}ref}$ of the X coordinates direction, data $Y_{D\text{-}ref}$ of the G coordinates direction and data $Z_{D\text{-}ref}$ of the B coordinates direction. The anti-matrix operation unit **1110** includes a current display model, for example, the aforementioned matrix M_C. After the data $X_{D\text{-}ref}$, $Y_{D\text{-}ref}$ and $Z_{D\text{-}ref}$ of the three coordinates directions of the color test pattern are multiplied by the anti-matrix M_C^{-1} of the matrix M_C via the anti-matrix operation unit **1110**, the data is converted to the R-G-B color space. Then, the corresponding data are found by the 1D-ILUTs **1120-1140**.

According to the above embodiment, according to FIGS. **1-2** and FIGS. **10-11**, the color regulation system can be illustrated in FIG. **12**. Referring to FIG. **12**, the color regulation system **1200** includes a receiving module **210**, a target display model unit **222**, a converting unit **224**, a current display model unit **226**, a luminance regulation module **120**, a mapping module **1210**, a saturation regulation module **130** and a processing module **140**. The components within the color regulation system **1200** are similar to that shown in FIGS. **1-2** and FIGS. **10-11**, while the color regulation system **1200** further includes a mapping module **1210**, which is used for evenly distributing the output of the luminance regulation module **120** to a predetermined range.

In the above embodiment, though the processing module **140** obtains the gamma ramps by calculating the color test pattern regulated by the aforementioned units, those skilled in the art should understand that the spirit of the present invention lies in how to regulate the color features of the display device, and is not limited to the case that the gamma ramps is obtained based on calculation.

In summary, the present invention has at least the following advantages:

1. During regulation of the color features, a characteristic of the current display itself is taken into consideration, so that the display device can maintain a maximum color gamut range under different color temperature parameters. Therefore, after the regulations of the color features are accomplished, the color enrichment effect can be achieved.

2. Since the gamma ramps obtained based on the color regulation can be applied to the current graphics card or the graphics chip, so that the color hue of the display device can be improved without an extra hardware cost of the computer system. Moreover, the graphics card can also directly regulate the signal output to the display device according to the obtained gamma ramps, so that increase of a calculation burden of the CPU can be avoided.

3. The input/output relation is obtained according to the relative relation of the definition domain and the value domain of the special function. In other words, during regulation of the color saturation, the saturation degree of the color output signal can be directly regulated by just regulating the curvature of the special function, and finding the input/output relation by looking up a table is unnecessary.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

What is claimed is:

1. A color distribution regulation method, comprising:

providing a first color gamut and a second color gamut in a first color space;

finding a first reference point in the first color gamut;

finding a second reference point in the second color gamut; and

converting the first color gamut to the second color gamut according to the first reference point and the second reference point, wherein the step of converting the first color gamut to the second color gamut comprises:

calculating a converting model according to positions of the first reference point, the second reference point and a third reference point in the first color space, wherein the third reference point is distributed in a third color gamut of the first color space; and

converting the first color gamut to the second color gamut via the converting model.

2. The color distribution regulation method according to claim **1**, further comprising:

obtaining a color temperature parameter via a regulation interface; and

finding the third reference point in the third color gamut according to the color temperature parameter.

3. The color distribution regulation method according to claim **1**, wherein the step of converting the first color gamut to the second color gamut via the converting model comprises:

converting the first color gamut to the third color gamut based on the first reference point and the third reference point; and

converting the third color gamut to the second color gamut based on the third reference point and the second reference point.

4. The color distribution regulation method according to claim **3**, wherein the first color space is represented by X-Y-Z coordinates, the position of the first reference point in the first color space is represented by (T_WP_x, T_WP_Y, T_WP_z) the position of the second reference point in the first color space is represented by (C_W_x, C_WP_Y, C_WP_z), the position of the third reference point in the first color space is represented by (U_WP_x, U_WP_Y, U_WP_z), the converting model is represented by M_{CA}, and a value of the converting model is $\underline{M_{CA}}=K_\alpha \underline{M_A K_\beta^D M_A^{-1}}$, wherein

$$K_\alpha = \frac{T\_WP_Y}{C\_WP_Y}, \underline{\underline{K_\beta^D}}$$

represents a diagonal matrix,

$$\underline{\underline{K_\beta^D}} = \mathrm{diag}\left(\frac{U\_WP_x}{D\_WP_x}, \frac{U\_WP_Y}{D\_WP_Y}, \frac{U\_WP_z}{D\_WP_z}\right),$$

(D_WP_x, D_WP_Y, D_WP_z) represents a position of an environmental light source reference point in the first color gamut, M_A represents a reference coordinates converting matrix, −1 represents an anti-matrix operation, and diag(.) represents a diagonal matrix with elements on the diagonal of the diagonal matrix being sequentially formed by internal vectors.

5. The color distribution regulation method according to claim **4**, wherein the first reference point is a white point in the first color gamut, the second reference point is a white point in the second color gamut, and the third reference point is a white point in the third color gamut.

6. The color distribution regulation method according to claim **1**, wherein the first color gamut is a color gamut of a target display, and the color distribution regulation method further comprises:

providing a color test pattern, wherein the color test pattern belongs to a second color space;

providing a target display model; and

converting the color test pattern to be in the first color space by the target display model to distribute the color test pattern to the first color gamut in the first color space.

7. The color distribution regulation method according to claim **6**, wherein the color test pattern is a L×N matrix represented by TP, the target display model is a N×N matrix represented by M_T, the step of converting the color test pattern to be in the first color space comprises:

performing a matrix multiplication operation to multiply the color test pattern TP by the target display model M_T to obtain the color test pattern distributed to the first color gamut in the first color space, wherein the obtained color test pattern is represented by $XYZ_{D\text{-}ref}$, the value of the obtained color test pattern is $XYZ_{D\text{-}ref}=M_T TP$.

8. The color distribution regulation method according to claim **6**, wherein the step of converting the first color gamut to the second color gamut comprises:

converting the color test pattern distributed to the first color gamut to be in the second color gamut via the converting model, wherein the converted color test pattern is distributed to the second color gamut in the first color space.

9. The color distribution regulation method according to claim **8**, wherein the converting model is a N×N matrix represented by M_{CA}, the color test pattern distributed to the first color gamut in the first color space is represented by $XYZ_{D\text{-}ref}$, and the step of converting the color test pattern of the first color gamut to be in the second color gamut comprises:

performing a matrix multiplication operation to multiply the color test pattern $XYZ_{D\text{-}ref}$ in the first color gamut by the converting model M_{CA} to obtain the color test pattern distributed to the second color gamut, wherein the obtained color test pattern is represented by $XYZ_{D\text{-}ill}$, the value of the obtained color test pattern is $\overline{XYZ_{D\text{-}ill}} = M_{CA} \times XYZ_{D\text{-}ref}$.

10. The color distribution regulation method according to claim **8**, wherein the second color gamut is a color gamut of a current display, and after the step of converting the first color gamut to the second color gamut, the color distribution regulation method further comprises:

providing the current display model; and

converting the color test pattern distributed to the second color gamut in the first color space to be in the second color gamut in the second color space by the current display model to distribute the color test pattern to the second color gamut in the second color space.

11. The color distribution regulation method according to claim **10**, wherein the current display model is a N×N matrix represented by M_C, the color test pattern distributed to the second color gamut in the first color space is represented by $XYZ_{D\text{-}ill}$, and the step of converting the color test pattern distributed to the second color gamut in the first color space to be in the second color gamut in the second color space comprises:

performing a matrix multiplication operation to multiply the color test pattern $XYZ_{D\text{-}ill}$ distributed to the second color gamut by the anti-matrix of the current display model M_C to obtain the color test pattern distributed to the second color gamut in the second color space, wherein the obtained color test pattern is represented by $RGB_{D\text{-}ill}$, the value of the obtained color test pattern is $\overline{RGB_{D\text{-}ill}} = M_C^{-1} \times XYZ_{D\text{-}ill}$.

12. The color distribution regulation method according to claim **10**, further comprising:

obtaining a gamma ramps by calculation according to the color test pattern distributed to the second color gamut in the second color space.

13. A color distribution regulation module, comprising:

a receiving module for receiving a color test pattern; and

a converting module storing a first color gamut and a second color gamut in a first color space, wherein the converting module calculates a converting model according to a position of a first reference point in the first color gamut, a position of a second reference point in the second color gamut and a position of a third reference point in a third color gamut of the first color space, and the converting module converts the color test pattern distributed to the first color gamut to be in the second color gamut via the converting model.

14. The color distribution regulation module according to claim **13**, further comprising:

a regulation interface for receiving a color temperature parameter,

wherein the converting module finds a the third reference point in a the third color gamut according to the color temperature parameter.

15. The color distribution regulation module according to claim **13**, wherein the first color gamut is a color gamut of a target display, the second color gamut is a color gamut of a current display, and the converting module comprises:

a target display model unit comprising a target display model and converting the color test pattern to be in the first color space via the target display model to distribute the color test pattern to the first color gamut in the first color space;

a converting unit converting the color test pattern distributed to the first color gamut to be in the third color gamut based on the first reference point and the third reference point, and then converting the color test pattern distributed to the third color gamut to be in the second color gamut based on the second reference point and the third reference point; and

a current display model unit comprising a current display model and converting the color test pattern distributed to the second color gamut in the first color space to be in a second color space by the current display model to distribute the color test pattern to the second color gamut in the second color space.

16. The color distribution regulation module according to claim **15**, further comprising:

a processing module obtaining a gamma ramps by calculation according to the color test pattern distributed to the second color gamut.

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