

Video signal-processing apparatus, system and method

5 FIELD OF THE INVENTION

The invention relates to a video signal-processing apparatus for processing a video signal that represents displayable images.

The invention also relates to a system comprising a video signal-processing apparatus.

10 The invention further relates to a method of controlling the emission of light emitted by a first illumination unit and a second illumination unit.

The invention further relates to an electronic circuit for use in a video signal-processing apparatus.

15 BACKGROUND OF THE INVENTION

A display apparatus known from the document EP-1379082-A1 has illumination units for providing a background light at its left-hand side and its right-hand side. The purpose of the background light is to illuminate, for example, the wall of a room extending away from the left side of the display apparatus and from the right side of the display
20 apparatus. The illumination units produce colored light, and the color and brightness (or intensity) can be controlled by a control means such that a user has the impression that the displayed picture extends beyond the displaying surface of the display apparatus. This feature is commercialized under the synonym “ambient light”, also known as “ambilight”.

The color of the light produced by the illumination units can be designed for
25 control in accordance with an average characteristic of a video signal, for example, the average color of an image represented by the video signal, which image is displayed on the displaying means.

The illumination units, which are known from the prior art described in the above document and employ LED technology, are fully controlled on the basis of the video signal.
30 While the illumination unit preferably employs LEDs, other light sources may be used.

The known apparatus has the drawback that, during the operating life of the apparatus, the light sources in the illumination unit will degrade and produce light having a lower intensity than their original intensity. The degradation taking place in any one of the illumination units creates a problem, causing the color of the light produced by the affected

illumination unit to be shifted or changed from its original color. As a result, it introduces a color mismatch problem between the illumination units. Due to the human physiology, this creates the following impression for a user of the apparatus. Human vision adapts to white in the viewing environment. Therefore, an image viewed in isolation, such as an image
5 displayed in a dark room, creates its own white reference, and a viewer will be quite tolerant of errors in the white point. However, if the same image is viewed in the presence of an external white reference or a second image, then differences in the white point can be objectionable. Hence the difference in color caused by any one degrading component or light source (e.g. LED) in any one of the illumination units will result in a different white point for
10 the affected illumination unit and thereby become objectionable to the viewer.

OBJECT AND SUMMARY OF THE INVENTION

The present invention is based on the recognition that the end user may require to operate the apparatus wherein the color of the light emitted by illumination units needs to be
15 set in such a manner that it fits the color of the ambience. For example, a certain color of the wall may need a certain color of light emitted by the illumination units that is different from the default color set by the factory. Therefore, an apparatus that permits personalization by the end user is needed in order to allow better control of the apparatus to be implemented.

It is a first object of the invention to provide an apparatus of the type described in
20 the opening paragraph, which is able to produce light of a color that can fit the color of the ambience different from the default state, and for conditions in which light sources in the illumination unit or units are degraded.

The apparatus having the features defined in claim 1 achieves this first object.

The provision of the characteristic features of the apparatus of the invention
25 creates the advantages that the color of the light, which has been emitted by the first illumination unit and has degraded, can be adjusted independently of the second illumination unit. In this way, the color of the light emitted by the first illumination unit can be made to match with the color of the light emitted by the second illumination unit.

It is advantageous if the product has the measures defined in claim 2 for
30 providing feedback means that are capable of producing a feedback signal, such as an On-Screen-Display (OSD) menu, or an audible signal like a beep, so as to support the viewer in adjusting the color of the light emitted by the illumination units. Such a feedback signal provides an indication of the level or position of the achieved color adjustment, as the viewer changes the color of the light produced by a certain component (i.e. light source) in the

degraded illumination units.

It is advantageous if the product has the measures defined in claim 3 for providing a color reference signal for display as displayable images by a displaying means. The viewer can use such displayable images as a reference for supporting the adjustment of the color of the light emitted by the illumination units.

It is advantageous if the product has the measures defined in claim 4 for adjusting the light intensity of at least one light source, such that a group of light sources in respective illumination units jointly produces light of a color in a spectral range and the color of the light emitted by the respective illumination units can be easily adjusted.

The second object of the invention is achieved by a system having the features defined in claim 5.

The provision of the characteristic features of the system of the invention creates the advantage that, at the viewer's wish, the effect of the light produced by the illumination units can be experienced at a position remote from the video signal-processing apparatus.

Other solutions of the invention as defined in claim 6 provide the advantage that the system, such as a DVD player and other devices without a display monitor, can be connected to a remote display monitor, thus giving the viewer the freedom to position the display monitor as well as the illumination units at any location remote from the video signal-processing apparatus and enjoy a different experience of ambient lighting that is not provided in an apparatus (or a system) with a display monitor and illumination units integrated in a single casing.

The third object of the invention is achieved by the method of controlling a color of light emitted by a first illumination unit and a second illumination unit, realized by performing the steps of the method as defined in claims 7 to 9. Accordingly, the advantages as mentioned in connection with the video signal-processing apparatus and the system according to the invention also apply to the method according to the invention.

The fourth object of the invention is achieved by the method of controlling a color of light emitted by a first illumination unit and a second illumination unit in accordance with a video signal by means of an electronic circuit as defined in claim 10.

The provision of the characteristic features of the electronic circuit creates the advantage that bulk-manufacture of a product becomes easier when the electronic circuit is incorporated and enabled to perform the method of the invention, which allows the realization of the functions needed for adjusting the color of the light emitted by the illumination units as mentioned in the preceding paragraph.

These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

5 The invention will be described in greater detail hereinafter, by way of non-limiting example, with reference to the embodiments shown in the drawings.

Fig. 1 is a block diagram of a first embodiment of a video signal-processing apparatus according to the present invention.

10 Fig. 2 is a block diagram of a second embodiment of a video signal-processing apparatus according to the present invention.

Fig. 3 is a flow chart illustrating the steps of a method for controlling a color of light emitted by the illumination units according to the present invention.

Figs. 4 to 6 schematically show possible adjustments of color components according to the invention.

DESCRIPTION OF EMBODIMENTS

15 In the first embodiment shown in Fig. 1, a video signal-processing apparatus 10 comprises control means 11A, 11B, which are designed to produce control signals for controlling two illumination units 17A, 17B, and adjustment means 12 for adjusting the color
20 of the light emitted by at least one illumination unit 17A, 17B. The adjustment means 12 comprise an adjusting stage 18, which is designed to receive control commands from a remote control unit 19, and two matrix processing units 13A, 13B, each being coupled to respective driving means 14A, 14B, which are designed to drive the illumination units 17A, 17B in order to produce light. The video signal-processing apparatus 10 further comprises
25 feedback means 15 for indicating the color adjustment level.

The video signal-processing apparatus 10 further comprises displaying means (not shown in Fig. 1) coupled to the apparatus 10. The displaying means are provided for displaying an image, which is represented by a video signal VS received from a broadcasting station, or from a legacy device, such as a DVD player, or other sources.

30 In a variant of the first embodiment, the video signal-processing apparatus 10 may comprise a color reference source 16, which is designed to be selected and to provide an image intended for display by the displaying means. Said image is used as a color reference during adjustment of the color of the light emitted by the illumination units 17A, 17B.

In the present invention described hereinafter, the video signal-processing apparatus 10 forms part of a television apparatus and only the essential elements relevant to this invention will be described.

In the present invention, the control means 11A, 11B are designed to receive the video signal VS from the video signal-processing circuit (not shown in Fig. 1), wherein the output signals of said control means 11A, 11B are the control signals. In the present case, each control signal is in fact a group of three individual control signals as indicated by three lines extending from the respective control means 11A, 11B to the corresponding matrix processing units 13A, 13B in the adjustment means 12. Each individual control signal representing average red, green and blue color components of the image is collectively represented by the video signal VS. For this reason, the first group of individual control signals is denoted as CAV-1 and represents a first average video signal, and the second group of individual control signals is denoted as CAV-2 and represents a second average video signal. Said groups of individual control signals CAV-1, CAV-2 are coupled in a corresponding manner to an input of a first matrix processing unit 13A and to another input of a second matrix processing unit 13B, respectively. In accordance with a variant of the embodiment, each of the two groups of individual control signals can be combined to a single control signal, which comprises all the information provided by the individual control signal of the two groups of individual control signals as explained above.

In the present case, the illumination units 17A, 17B are designed to be controlled in dependence on the video signal VS. The average color of an image represented by the video signal VS therefore causes a corresponding color, which is derived from the superimposing the colors of light produced collectively by light sources R, G, B in each illumination unit 17A, 17B. In the present case, the apparatus 10 is designed in such a way that the left-hand illumination unit 11A emits a color of light corresponding to the average color of the image, or picture, displayed on the left-hand part of the display screen, while the color of the light emitted by the right-hand illumination unit 17B depends on an average color of a part of the image, or picture, displayed on the right-hand part of the display screen.

In addition to receiving the corresponding average video signals CAV-1, CAV-2, the two matrix processing units 13A, 13B are also designed to receive their corresponding group of control signals CSR-1, CSG-1, CSB-1; CSR-2, CSG-2, CSB-2, respectively, from the adjusting stage 18. Each matrix processing unit 13A, 13B is designed to provide the corresponding group of drive signals DSR1, DSG1, DSB1; DSR2, DSG2, DSB2 to its corresponding driving means 14A, 14B, respectively. The interaction between the

corresponding average video signals CAV-1, CAV-2 and the corresponding groups of control signals CSR-1, CSG-1, CSB-1; CSR-2, CSG-2, CSB-2, respectively, will be described in detail hereinafter, and the operational aspects of the matrix processing units 13A, 13B will be further described in other paragraphs of this disclosure.

5 The first matrix processing unit 13A is designed to receive a first group of control signals CSR-1, CSG-1, CSB-1 from the adjusting stage 18, wherein each control signal of said group of control signals CSR-1, CSG-1, CSB-1 corresponds to a color of a light source, namely red, green and blue, respectively. Said first matrix processing unit 13A is further designed to combine said first group of control signals CSR-1, CSG-1, CSB-1 and the
10 first average video signal CAV-1 to provide a group of drive signals DSR1, DSG1, DSB1 for the first driving means 14A, which will cause the first illumination unit 17A to emit the light of a desired color. The first illumination unit 17A is composed of light sources R, G, B that produce the three colors, red, green and blue, respectively, wherein the proportional combination of light emitted by the light sources R, G and B will provide the desired color of
15 light. The composition of light will not be described in detail, as it is known to the person skilled in the art.

 In analogy with the design of the first matrix processing unit 13A, the second matrix processing unit 13B is arranged to receive a second group of control signals CSR-2, CSG-2, CSB-2 from the adjusting stage 18, which is also designed to adjust the color of the
20 light emitted from the second illumination unit 17B. Said second matrix processing unit 13B combines said second group of control signals CSR-2, CSG-2, CSB-2 and the second average video signal CAV-2 to provide another group of drive signals DSR2, DSG2, DSB2 for the second driving means 14B, which will cause the second illumination unit 17B to emit light of the desired color. The second illumination unit 17B is also composed of light sources R, G
25 and B that produce red, green and blue light, respectively, wherein their proportional combination will provide the desired color of light emitted by the second illumination unit 17B.

 Apart from providing the two groups of control signals CSR-1, CSG-1, CSB-1; CSR-2, CSG-2, CSB-2 for the two corresponding matrix processing units 13A, 13B, the
30 adjusting stage 18 also supplies an indication signal IS to the feedback means 15. The indication signal IS indicatively communicates the adjustment of the color level. The feedback means 15 are designed to produce a feedback signal (not shown in Fig. 1), based on receiving said indication signal IS. Said feedback signal represents a user-understandable feedback regarding the level of color adjustment provided by the adjusting stage 18. In the

present case, the feedback signal is visualized by displaying a feedback image represented by said feedback signal, and this is realized with the aid of an On-Screen Display (OSD) or a graphical user interface (GUI). The feedback image can be displayed in the form of a sliding bar for each corresponding light source in the illumination units 17A, 17B.

5 Said feedback image is used as a support to the viewer for adjusting the color level of the corresponding light sources R, G, B in the selected illumination unit 17A or 17B. This is done by the viewer, who has to make a selection of one illumination unit, e.g. the left-hand illumination unit 17A, as a target illumination unit for adjusting the color level of at least one of the light sources R, G, B in said illumination unit 17A, independent of the other
10 illumination unit 17B, or vice versa.

 In this example, the viewer can carry out the aforesaid adjustment on the target illumination unit, i.e. the left-hand illumination unit 17A, without making a comparison with a color reference. Alternatively, the viewer may use the other illumination unit 17B as a first
15 color reference, wherein the color of the light emitted by said target illumination unit 17A is adjusted to a color point, or white point, which is comparable with the color of the light emitted by said other illumination unit 17B.

 In a variant of the first embodiment of the invention, the adjusting stage 18 can be designed to supply a color reference control signal CS to a color reference source 16 so that a second color reference can be produced for display on the displaying means (not shown
20 in Fig. 1) in order to provide a second color reference to the viewer, or user, during adjustment of the color of the light emitted by any one of the illumination units 17A, 17B selected by said user. The second color reference may be an image of a uniform color (e.g. white color) wherein the light emitted has a selected color point, or white point, when displayed on said displaying means.

25 While the illumination units 17A, 17B preferably employ LEDs of the three colors, namely red, green and blue, as light sources R, G, B, other light sources may be used in alternative embodiments. For example, the light sources may be CCFL fluorescent lamps that collectively produce light with a color point, or white point, which is determined by the mix of blue, red and green phosphor components. This will not be described in detail as it is
30 known to the person skilled in the art.

 In operation, when the television apparatus first leaves the factory, the matrix processing units 13A, 13B are in a default state, or virgin state. This means that the two groups of control signals CSR-1, CSG-1, CSB-1; CSR-2, CSG-2, CSB-2 from the adjusting stage 18 each supplies a zero value, or certain default levels, when the viewer operating the

television apparatus has not activated any adjustment of the color level of the light emitted by any one of the illumination units 17A, 17B. The illumination units 17A, 17B are factory-adjusted in such a way that the light sources R, G, B of each illumination unit 17A, 17B collectively emit white light that has a certain desired or default color point, which is comparable with the color point of a reference white image generated by an external color reference source during display on the displaying means. Details on the factory adjustment will not be further described as they are known to the person skilled in the art.

During the operating life of the television apparatus, the color of the light emitted by any one of the illumination units 17A, 17B may change or shift from the levels that were adjusted in accordance with the default factory settings. This may cause the viewer to feel uncomfortable with the difference in the color of the light emitted by the affected illumination unit or units, i.e. the left-hand illumination unit 17A, and/or the right-hand illumination unit 17B. Such a change or shift of the color of the light emitted by the illumination units 17A, 17B can be caused by the phosphors of the light source (e.g. LED) getting less efficient over time, as well as by other effects in the light source that are responsible for a reduction of the light emitted from any one of the light sources during their lifetime. When this takes place, the viewer may wish to match the color of the light emitted by the two illumination units 17A, 17B, and this can be realized by activating the adjusting stage 18 of the adjustment means 12, using the remote control unit 19.

In order to adjust the color of the light emitted by the affected illumination unit, e.g. the left-hand illumination unit 17A, the viewer may call up a graphic user interface (GUI), or a OSD menu, by activating the adjusting stage 18 with the remote control unit 19 and then select, for example, said left-hand illumination unit 17A as the target illumination unit to be adjusted. The GUI, which is the feedback image, will then be displayed on the displaying means. Said GUI is displayed in the form of sliding bars. Each sliding bar corresponds to one of the colors (i.e. red, green or blue) of the light sources R, G, B in the illumination unit 17A. If the viewer wishes to adjust the color level of the red light source R, the remote control unit 19 is activated to cause the position of the corresponding sliding bar to change in a manner corresponding to an indication showing an increase or decrease of the red color level. Similarly, the remote control unit 19 can be activated to cause the other individual sliding bars to change in a manner corresponding to an indication showing an increase or decrease of the green or blue color level.

In the following elucidation, it is assumed that the red light source R has degraded during the operating life of the television apparatus and, as such, said red light

source R is responsible for a reduction of the light emitted from the affected illumination unit 17A. The effect on the color of the light emitted by said affected illumination unit 17A is that it becomes more greenish or more bluish in color, or in other words, the color of the light emitted by the affected illumination unit 17A is less reddish.

5 To adjust and compensate the reduction of the red component of the color of the light emitted by the light sources R, G, B in the affected illumination unit 17A, some options for adjusting the color of the light emitted by the light sources R, G, B in the illumination unit or units will be described hereinafter. The viewer can choose to adjust the affected illumination unit, e.g. the left-hand illumination unit 17A, to a desired color point or white
10 point of the light emitted from said target illumination unit 17A. In the example used herein, the viewer may need to adjust the color level of the red light source R so as to compensate for the reduction of the red color component of the light emitted by the target illumination unit 17A. The adjustment to the red light source R on the left-hand illumination unit 17A is shown in Fig. 4, which is denoted by the letter "R" and a double-headed arrow on the side labeled
15 LHS (left-hand side).

If the adjustment of the level of the red color component is not achievable due to insufficient room for further adjustment of said red light source R, the apparatus 10 is designed to allow the viewer to restore the original level of the red color component with the aid of the remote control unit 19 and then choose other options from the GUI so as to adjust
20 the other color components (i.e. green G and/or blue B) for achieving the desired color point, or white point, of light emitted collectively by the light sources R, G, B of the target illumination unit 17A. The adjustment of the green light source G, and/or the blue light source B, on the left-hand illumination unit 17A is also shown in Fig. 4, which is denoted by the letter "G" or "B", respectively, and a double-headed arrow on the side labeled LHS (left-
25 hand side). The viewer may also adjust all the light sources (i.e. red, green and blue light sources) collectively to achieve the desired color point, or white point, of light emitted by the target illumination unit 17A, as shown in Fig. 4. The activities described herein may be carried out on the target illumination unit 17A alone, by the viewer without relying on the use of a color reference.

30 If the viewer has changed the various levels of the color of the light emitted by the light sources R, G, B, such that the color of light produced collectively shows undesirable results, the feedback image is designed to provide an option for the viewer to select and restore the levels to the factory default settings, using the remote control unit 19.

The adjustment means 12 can also be designed to adjust the color of the light emitted by each of the at least two illumination units 17A, 17B, independent of one another. For example, the viewer may like to have different colors of light collectively emitted by light sources R, G, B of each of the at least two illumination units 17A, 17B deviating from the default color settings, rather than for the purpose of compensating the degraded light source R, G, B. This may be carried out to offset the ambience effects, which are produced by the color of the wall or by other reasons, so as to suit the viewer's wishes. Therefore, the viewer may shift the color of the light emitted by the light sources R, G, B of one or more illumination units 17A, 17B, such that said illumination unit or units is or are made to produce different colors of light emitted by the light sources R, G, B. Fig. 5 shows an example of an adjustment made on only the red color component of the light emitted by the left-hand illumination unit 17A, while adjustment of the right-hand illumination unit 17B is carried out with various combinations of adjustments made for the green component, or the blue component, or the green and the blue components, or the red, green and blue components of the light emitted by the light sources R, G, B of said right-hand illumination unit 17B. Likewise as in the case of the first embodiment, the feedback image is designed to provide an option for the viewer to select and restore the factory default settings, using the remote control unit 19, for example, when the viewer needs to relocate the position of the TV apparatus. It should be noted that other combinations of adjusting the color of the light emitted by the light sources R, G, B of the left-hand illumination unit 17A, which are not shown on the side labeled LHS in Fig. 5, can be made together with different combinations of adjusting the color of the light emitted by the light sources R, G, B of the right-hand illumination unit 17B.

In another variant of the first embodiment, the viewer can use the other illumination unit 17B as a first color reference. In this case, the light sources R, G, B in the reference illumination unit 17B are maintained at their default levels. This situation is shown in Fig. 4 in which the right-hand side RHS shows no indication of adjustment that is denoted by a double-headed arrow, unlike what is shown on the left-hand side LHS with the double-headed arrows for denoting adjustment. In the example used in the present disclosure, the viewer only needs to adjust the level of the color of the red light source R to compensate for the reduction of the red color component of the light emitted by the target illumination unit 17A in accordance with the approach as described in the preceding paragraphs. The adjustment for compensating the color level of the degraded light source R is completed when the color point of the light emitted by the target illumination unit 17A is comparable

with the color point, or white point, of the light emitted by the first color reference, which is the reference illumination unit 17B.

When the red light source R of the target illumination unit 17A is adjusted, the adjusting stage 18 is designed to supply a new combination of a first group of control signals CSR-1, CSG-1, CSB-1 to the first matrix processing unit 13A as shown in Figure 1. In said first matrix processing unit 13A, the first group of control signals CSR-1, CSG-1, CSB-1 is combined with the first average video signal CAV-1 and this process can be carried out by a computer program performing the mathematical computation in accordance with a matrix equation. Said computer program is embedded in the microprocessor, or microcomputer. The results are a modified group of drive signals DSR1, DSG1, DSB1 that are supplied by the first matrix processing unit 13A to the first driving means 14A, which change the color level of the red, green or blue component of light emitted by the light sources R, G, B in accordance with the adjustment made by the viewer with the aid of the remote control unit 19.

In the variant of the first embodiment, a second color reference is used during adjustment of the color level of the light emitted by light sources R, G, B of the illumination units 17A, 17B. This offers the advantage that the viewer can choose to adjust two illumination units 17A, 17B independently of each other, so that said illumination units 17A, 17B can be made to match the color point or white point of the light emitted by the second color reference. For this variant, the viewer uses the remote control unit 19 to activate the adjusting stage 18. This will cause the adjusting stage 18 to supply a color reference control signal CS so as to switch on the color reference source 16 to produce the second color reference for display on the displaying means. The viewer then has the option to select one of the two illumination units 17A, 17B at a time as the target illumination unit for adjustment. This means that the viewer can select the first target illumination unit to be adjusted, e.g. the left-hand illumination unit 17A, and then the second target illumination unit to be adjusted, e.g. the right-hand illumination unit 17B, or vice versa. Fig. 6 shows some of the various combinations that can be made to adjust the level of color emitted by the left-hand illumination unit 17A and/or the right-hand illumination unit 17B to match the color of light emitted by the second color reference, which is displayed by the displaying means.

When the adjustment of intensity of light emitted by any one or both of the illumination units 17A, 17B is performed to compensate for the increase or reduction of color level caused by any of the degraded light sources R, G, B, the process of adjusting the target

illumination unit 17A that was described in the preceding paragraphs can also be applied to each of the selected target illumination units 17A, 17B.

The following paragraphs describe the interrelation of the color components of light emitted by the light sources R, G, B of the illumination units 17A, 17B and the corresponding color components of the video signal VS, as well as the effect or influence of the adjusting stage 18 introduced by the viewer. Such interrelationship is expressed in terms of mathematical formula. The light sources R, G, B in each illumination unit 17A, 17B are designed to emit light output based on the mathematical relations described hereinafter. The light output components, i.e. the red, green and blue components, are represented by the output components R_{out} , G_{out} , and B_{out} , and they are transformed from the input drive signals R_{in} , G_{in} , and B_{in} , respectively, in accordance with weightings applied to said input drive signals. These weightings are expressed in the form of a three-by-three matrix M. Hence, the mathematical formula relating to the output components and input drive signals is given by:

$$\begin{pmatrix} R_{out} \\ G_{out} \\ B_{out} \end{pmatrix} = \begin{bmatrix} A_{rr} & A_{gr} & A_{br} \\ A_{rg} & A_{gg} & A_{bg} \\ A_{rb} & A_{gb} & A_{bb} \end{bmatrix} \cdot \begin{bmatrix} R_{IN} \\ G_{IN} \\ B_{IN} \end{bmatrix} \quad \text{or} \quad \begin{pmatrix} R_{out} \\ G_{out} \\ B_{out} \end{pmatrix} = M \cdot \begin{pmatrix} R_{in} \\ G_{in} \\ B_{in} \end{pmatrix},$$

wherein M is

$$\begin{pmatrix} A_{rr} & A_{gr} & A_{br} \\ A_{rg} & A_{gg} & A_{bg} \\ A_{rb} & A_{gb} & A_{bb} \end{pmatrix}$$

Said three-by-three matrix M comprises the product of weightings applied in accordance with the Commission Internationale de L'Eclairage (CIE) definition/standards and the weightings introduced by the viewer when the adjusting stage 18 of the present invention is activated. For example, R_{out} consists of the following weighted components of the input drive signal, namely, $A_{rr} * R_{in}$; $A_{gr} * G_{in}$; and $A_{br} * B_{in}$. The weightings A_{rr} , A_{gr} , and A_{br} are products of corresponding weightings defined in accordance with the CIE definition and the corresponding weightings introduced by the viewer when activating the adjusting stage 18, which are applied to the red, green and blue input drive signals, i.e. R_{in} , G_{in} and B_{in} , respectively.

The input drive signals R_{in} , G_{in} , and B_{in} are derived from the video signal VS, wherein its RGB values define a particular set of primaries transformed from CIE XYZ defined by another three-by-three matrix transformation. These transformations involve tri-

stimulus values, which are sets of three linear-light components that conform to the CIE color matching functions. CIE XYZ is a special case of tri-stimulus values. In XYZ, any color is represented by a positive set of values. The RGB values of the video signal VS are transformed from CIE XYZ (with a particular white point, e.g. D65) in accordance with another mathematical formula:

$$\begin{pmatrix} R_{in} \\ G_{in} \\ B_{in} \end{pmatrix} = \mathbf{a} \cdot \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

wherein $\mathbf{a}$ is a matrix with values of weightings in accordance with CIE, representing

$$\begin{pmatrix} \mathbf{a}_{11} & \mathbf{a}_{12} & \mathbf{a}_{13} \\ \mathbf{a}_{21} & \mathbf{a}_{22} & \mathbf{a}_{23} \\ \mathbf{a}_{31} & \mathbf{a}_{32} & \mathbf{a}_{33} \end{pmatrix}$$

As defined in the preceding paragraph, the three-by-three matrix M is made up of the CIE weightings, which is denoted by matrix $\mathbf{a}$, and the viewer-influenced weightings are denoted by matrix $\mathbf{u}$, wherein said matrix $\mathbf{u}$ is a viewer-influenced matrix representing

$$\begin{pmatrix} \mathbf{u}_{rr} & \mathbf{u}_{gr} & \mathbf{u}_{br} \\ \mathbf{u}_{rg} & \mathbf{u}_{gg} & \mathbf{u}_{bg} \\ \mathbf{u}_{rb} & \mathbf{u}_{gb} & \mathbf{u}_{bb} \end{pmatrix}$$

Hence, matrix M is defined as a product of matrix $\mathbf{u}$ and matrix $\mathbf{a}$.

That is, $M = \mathbf{u} \cdot \mathbf{a}$

$$\text{which is, } M = \begin{pmatrix} \mathbf{u}_{rr} & \mathbf{u}_{gr} & \mathbf{u}_{br} \\ \mathbf{u}_{rg} & \mathbf{u}_{gg} & \mathbf{u}_{bg} \\ \mathbf{u}_{rb} & \mathbf{u}_{gb} & \mathbf{u}_{bb} \end{pmatrix} \cdot \begin{pmatrix} \mathbf{a}_{11} & \mathbf{a}_{12} & \mathbf{a}_{13} \\ \mathbf{a}_{21} & \mathbf{a}_{22} & \mathbf{a}_{23} \\ \mathbf{a}_{31} & \mathbf{a}_{32} & \mathbf{a}_{33} \end{pmatrix}$$

In other words, the relation between the corresponding components of light output, i.e. R_{out} , G_{out} , and B_{out} representing the red, green and blue color components of light emitted by the light sources R, G, B in the illumination units 17A, 17B, and the input drive signals R_{in} , G_{in} , and B_{in} , respectively, can be expressed in terms of matrices comprising the

U-matrix and the **a**-matrix as follows:

$$\begin{aligned}
 & \begin{pmatrix} R_{out} \\ G_{out} \\ B_{out} \end{pmatrix} = M \cdot \begin{pmatrix} R_{in} \\ G_{in} \\ B_{in} \end{pmatrix} \quad \text{or} \\
 & \begin{pmatrix} R_{out} \\ G_{out} \\ B_{out} \end{pmatrix} = \begin{pmatrix} A_{rr} & A_{gr} & A_{br} \\ A_{rg} & A_{gg} & A_{bg} \\ A_{rb} & A_{gb} & A_{bb} \end{pmatrix} \cdot \begin{pmatrix} R_{in} \\ G_{in} \\ B_{in} \end{pmatrix} \\
 & = \begin{pmatrix} \mathbf{u}_{rr} & \mathbf{u}_{gr} & \mathbf{u}_{br} \\ \mathbf{u}_{rg} & \mathbf{u}_{gg} & \mathbf{u}_{bg} \\ \mathbf{u}_{rb} & \mathbf{u}_{gb} & \mathbf{u}_{bb} \end{pmatrix} \cdot \begin{pmatrix} \mathbf{a}_{11} & \mathbf{a}_{12} & \mathbf{a}_{13} \\ \mathbf{a}_{21} & \mathbf{a}_{22} & \mathbf{a}_{23} \\ \mathbf{a}_{31} & \mathbf{a}_{32} & \mathbf{a}_{33} \end{pmatrix} \cdot \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}
 \end{aligned}$$

When the TV apparatus is shipped out of the factory and the viewer has not activated the adjusting stage 18 with the remote control unit 19, the matrix **U** will contain weightings that are at default settings (or factory settings). The matrix **U** will therefore have the following weightings:

$$\begin{pmatrix} \mathbf{u}_{rr} & \mathbf{u}_{gr} & \mathbf{u}_{br} \\ \mathbf{u}_{rg} & \mathbf{u}_{gg} & \mathbf{u}_{bg} \\ \mathbf{u}_{rb} & \mathbf{u}_{gb} & \mathbf{u}_{bb} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

At default setting of the light output components, which are represented by the output components R_{out} , G_{out} , and B_{out} , this can be illustrated by the following mathematical formula:

$$\begin{aligned}
 & \begin{pmatrix} R_{out} \\ G_{out} \\ B_{out} \end{pmatrix} = \begin{pmatrix} \mathbf{u}_{rr} & \mathbf{u}_{gr} & \mathbf{u}_{br} \\ \mathbf{u}_{rg} & \mathbf{u}_{gg} & \mathbf{u}_{bg} \\ \mathbf{u}_{rb} & \mathbf{u}_{gb} & \mathbf{u}_{bb} \end{pmatrix} \cdot \begin{pmatrix} \mathbf{a}_{11} & \mathbf{a}_{12} & \mathbf{a}_{13} \\ \mathbf{a}_{21} & \mathbf{a}_{22} & \mathbf{a}_{23} \\ \mathbf{a}_{31} & \mathbf{a}_{32} & \mathbf{a}_{33} \end{pmatrix} \cdot \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \\
 & = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} \mathbf{a}_{11} & \mathbf{a}_{12} & \mathbf{a}_{13} \\ \mathbf{a}_{21} & \mathbf{a}_{22} & \mathbf{a}_{23} \\ \mathbf{a}_{31} & \mathbf{a}_{32} & \mathbf{a}_{33} \end{pmatrix} \cdot \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}
 \end{aligned}$$

Hence, when the TV apparatus is in operation and the viewer has not activated the adjusting stage 18, the light output components R_{out} , G_{out} , and B_{out} will be represented by the mathematical relation that is applicable to a situation in which it is “without the advantageous effects of the invention”, and is given by:

$$\begin{pmatrix} R_{out} \\ G_{out} \\ B_{out} \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \cdot \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

$$= \begin{pmatrix} R_{in} \\ G_{in} \\ B_{in} \end{pmatrix}$$

In other words, the output components R_{out} , G_{out} , and B_{out} are the same as the input drive signals R_{in} , G_{in} and B_{in} , wherein said input drive signals comprise components in accordance with the CIE XYZ tri-stimulus values or standards, which is without any influence of the viewer-influenced matrix u .

It should be noted that, although the weightings in the matrix u described in the present disclosure are expressed in the form of zeros and ones, these weightings may have certain values when the apparatus 10 is aligned in the factory.

The operation of the preferred embodiment as shown in Fig. 1 will be described in the following paragraphs in conjunction with the flow chart 100 shown in Fig. 3. Only the main steps relevant to the present invention will be described and, where necessary, intermediate steps are briefly addressed.

The method according to the invention starts at step 200. When the viewer presses the key on the remote control unit 19 to select the option of adjusting the color of the light emitted by the target illumination unit, e.g. illumination unit 17A, so as to match the color point or white point of the color reference, e.g. the first color reference, namely, the other illumination unit 17B, or the second color reference displayed on the displaying means, which is shown in step 201, the video signal-processing apparatus 10 will prompt the viewer

to select a color reference option from the feedback means 15 displayed by the displaying means, which is shown in step 202.

If the viewer does not make a selection after a pre-determined duration has expired or lapsed, the apparatus 10 will return to its normal operating mode, which is indicated by step 203.

If the viewer selects a color reference within the pre-determined duration, the method continues in step 204, in which the apparatus 10 checks whether the viewer has selected the option of using an illumination unit 17A, 17B as the color reference. If the viewer selects the option of using illumination units 17A, 17B as a color reference, as indicated in step 205, the apparatus 10 will prompt the viewer to select one of the at least two illumination units 17A, 17B as a first color reference, e.g. the left-hand illumination unit 17A. The selected illumination unit 17A then emits a fixed color as the first color reference, e.g. a white color reference of a pre-determined color point or color temperature is emitted by said selected illumination unit 17A. The other illumination unit 17B (i.e. the right-hand illumination unit) becomes the target illumination unit and it will be enabled in such a way that it is subjected to adjustment with respect to the color of the light emitted by it, which is indicated in step 206 and will be explained in more detail in the following paragraphs. As a consequence of this adjustment, the second illumination unit 17B will produce light of a color that matches the color of the first color reference, i.e. in the above example the left illumination unit 17A, which emits light of the color that is representative of the first color reference.

If the selection made by the viewer in step 204 is to make use of the displaying means for producing the second color reference, then the method branches to step 207 in which the apparatus 10 selects the displaying means for producing the second color reference. In step 208, in accordance with this selection, the apparatus 10 stops reproducing any video content and starts displaying a picture or a uniform raster having a color that is representative of the second color reference, which is supplied by the color reference source 16, for example, a white screen of a pre-determined color point, or color temperature. In step 209 of the method, the apparatus 10 will also prompt the viewer to select one of the at least two illumination units 17A, 17B as the target illumination unit that needs to be adjusted. For example, the viewer may select the right illumination unit 17B as the target illumination unit. This selected illumination unit 17B (i.e. the right-hand illumination unit) is then subjected to adjustment with respect to the color of the light emitted by it, which is indicated in step 206 and will be explained in more detail in the following paragraphs.

When one of the at least two illumination units 17A, 17B has been selected as the target illumination unit to be subjected to adjustment with respect to the color of the light emitted by it, the feedback means 15 produce a visual user interface in the form of a OSD menu, or a graphical user interface (GUI), which is displayed by the displaying means of apparatus 10, as indicated in step 210. In the present case, a sliding bar provides an indication of the color adjustment level for the respective light sources R, G, B of the illumination unit 17B, so that the viewer can adjust each light source R, G, B for deriving a color that is emitted by the target illumination unit 17B and matches the first color reference or second color reference, as indicated in step 211.

As soon as the viewer completes the adjustment of the selected target illumination unit, e.g. the right-hand illumination unit 17B, he indicates to the apparatus 10 to proceed to the next step (not shown in Fig. 3), using the remote control unit 19. Depending on the viewer's selection of the color reference in step 204, the apparatus 10 will check and operate the next step 212. When the viewer has selected the use of a second color reference in step 204, the apparatus 10 will prompt the viewer to select the next target illumination unit (e.g. illumination unit 17A) to be adjusted, as indicated in step 213. The steps for adjusting this newly selected target illumination unit, which are described in the preceding paragraphs with reference to steps 206 and 210 to 212, will then be repeated.

When the viewer has indicated to the apparatus 10 that adjustment of the selected target illumination unit in step 212 has been completed, or when the apparatus 10 detects that, in said step, the viewer has completed adjustment of the color emitted by the target illumination unit 17A, 17B, which was selected from the option of using one of the illumination units 17A, 17B as the first color reference in step 204, the visual user interface, which was displayed by the displaying means, will then disappear from the display screen of the displaying means, as indicated in step 214. This can be done by using the remote control unit 19. Accordingly, the apparatus 10 will then return to its normal operation state, as shown in step 203, and the color of the light emitted by illumination units 17A, 17B will be in accordance with the adjustment carried out in conformity with the viewer's wishes. Hence, the method according to the invention is finalized in step 215.

It should be noted that said visual user interface may be designed to disappear after a pre-determined duration when the apparatus 10 detects no activity initiated by the viewer. In this case, all adjustments made to adjust the color level for the respective light sources R, G, B of the target illumination unit 17A, 17B are reset to an original state, or to the last status before selection of the target illumination 17B, i.e. the original state before step

201 is selected. After the visual user interface has disappeared from the display screen, the apparatus 10 will return to its normal TV operation state, as indicated in step 203, and the method according to the invention is then terminated in step 215.

For illustrating the step of adjusting the light emitted by the target illumination unit 17B so as to match the first color reference or the second color reference, as indicated in step 211, it is assumed here by way of example that the target illumination unit 17B emits light of a reddish white color when it is compared with the first color reference (i.e. light of the white color reference emitted from the illumination unit 17A), or when it is compared with the light produced with the aid of the second color reference, which is generated by the color reference source 16, i.e. light of the white color reference, which is displayed by the displaying means. The reddish white color light emitted by the target illumination unit 17B may be caused by degradation of the green light source G and/or the blue light source B through the operating life of the apparatus 10. For the sake of simplicity, the description herein is limited to only one degraded light source, e.g. the green light source G. In such a situation, the viewer may carry out the aforesaid method according to the invention, as shown in Fig. 3. Using the visual user interface activated in step 210, the viewer can navigate the corresponding sliding bar that is displayed for the green light source G, as in this example, so that the intensity of light produced by said green light source G is increased to a level such that in combination or superposition with the other remaining light sources, namely the red light source R and the blue light source B. The collective effect of the light emitted by the light sources R, G, B results in light emitted by the target illumination unit 17B having the color of light which matches the color of the light produced with the aid of the selected color reference source, which is the light of the desired white color reference emitted from the first color reference (i.e. illumination unit 17A), or the second color reference displayed by the displaying means.

When adjustment of the target illumination unit 17B is completed in the given example, the color level set for the adjusted light source (i.e. the green light source G in the above example) is stored in the memory of a microcontroller as a value or a "flag". Further detailed explanation will not be given herein, as this is known to the person skilled in the art. The information from said flag is then used by the adjustment means 12 of Fig. 1 or Fig. 2 to supply the corresponding control signal (i.e. the green control signal CSG-2) of the second group of control signals CSR-2, CSG-2, CSB-2 to the corresponding matrix processing unit 13A, 13B, which is the second matrix processing unit 13B in this example and supplies the drive signals DSR2, DSG2, DSB2 to the second driving means 14B. Hence, said flag causes

the corresponding second average video signal CAV-2 to be modified and provide an increased drive level in the green drive signal DSG2. This in turn causes the drive signal to the green light source G in the right-hand illumination unit 17B to produce a higher intensity of light so as to compensate for the reduced intensity caused by the degradation of the green light source G. In this manner, the collective light emitted by the light sources R, G, B in the target illumination unit 17B is made to match the white color of the light emitted by the other illumination unit 17A, which is made the first color reference, or the white color of light displayed by the second color reference by the displaying means.

It should be noted that the aforesaid steps can be applied for reasons other than for compensating the shift or change in the color of light emitted by illumination units 17A, 17B as caused by any one of the degraded light sources R, G, B.

A second embodiment of the invention is shown in Fig. 2. In Fig 2, all components, which are identical to those in Fig. 1 are denoted by the same reference numerals and will not be further described. In this embodiment, a video signal-processing apparatus 10 comprises control means 11A, 11B, which, in contrast to the embodiment shown in Fig. 1, are designed to produce the average video signals CAV-1, CAV-2 that correspondingly control two illumination units 17A, 17B, which are communicatively connectable to the video signal-processing apparatus 10. Said control means 11A, 11B are designed to control said two illumination units 17A, 17B via the adjustment means 12, which is designed to adjust the color of the light emitted by at least one illumination unit 17A, 17B.

The adjustment means 12 comprise an adjusting stage 18, which is designed to receive control commands from a remote control unit 19, and two matrix processing units 13A, 13B, each being coupled to respective driving means 14A, 14B, which are designed to drive the illumination units 17A, 17B in order to produce light. The video signal-processing apparatus 10 further comprises feedback means 15 for indicating the color adjustment level.

In contrast to the first embodiment shown in Fig.1, the coupling between the matrix processing units 13A, 13B and the corresponding driving means 14A, 14B, which drive the illumination units 17A and 17B, is not physically connected. Instead, the matrix processing units 13A, 13B are designed to be connected to transmitting means 21A, 21B, which are situated in the apparatus 10. Said transmitting means 21A, 21B are communicatively coupled to driving means 14A, 14B, which drive the illumination units 17A, 17B, by means of receiving means 22A, 22B. Said driving means 14A, 14B and the illumination units 17A, 17B are arranged to be located remote from said apparatus 10. The video signal-processing apparatus 10 further comprises displaying means (not shown in Fig.

1) coupled to the apparatus 10. The displaying means are provided to display an image that is represented by a video signal VS received from a broadcasting station or from a legacy device, such as a DVD player, or other sources.

5 In a variant of the second embodiment, the video signal-processing apparatus 10 may comprise a color reference source 16, which is designed to be selected and to provide an image intended for display by the displaying means. Said image is used as a second color reference during adjustment of the color of the light emitted by the illumination units 17A, 17B.

10 In the embodiment described hereinafter, the video signal-processing apparatus 10 is part of a television apparatus and only the essential elements relevant to this invention will be described.

The operating/functional modes will be further described hereinafter. In this second embodiment, the drive signals DSR1, DSG1, DSB1; DSR2, DSG2, DSB2 from the corresponding matrix processing units 13A, 13B are designed to be communicated by
15 corresponding transmitting means 21A, 21B situated in the apparatus 10, and receiving means 22A, 22B, which are correspondingly connected to the driving means 14A, 14B that drive the respective illumination units 17A, 17B, which are arranged to be located remote from said apparatus 10. Communication between the transmitting means 21A, 21B and the receiving means 22A, 22B at the remote location is realized by means of any communication
20 technology, which is well-known to the person skilled in the art. Such a communication technology includes but is not limited to Wi-Fi, infra-red, power-line connectivity (PLC) and other radio-frequency (RF) broadcasting techniques, and will not be further described.

In a third embodiment, the apparatus 10, in contrast to the second embodiment shown in Fig. 2, is designed to comprise displaying means, which are communicatively
25 connectable to said apparatus 10. Communication between the apparatus 10 and the displaying means is realized by means of any communication technology, which is well-known to the person skilled in the art. Such a communication technology includes but is not limited to Wi-Fi, infra-red, power-line connectivity (PLC) and other RF broadcasting techniques, and will not be further described.

30 The second and third embodiments are advantageous for application on video signal-processing apparatuses other than television apparatuses, e.g. DVD players, set top boxes, hard-disk recorders/players and the like.

Elements of various embodiments can be combined without departing from the scope of the invention.

Furthermore, the invention may be embodied with a smaller number of components than in the embodiments described hereinbefore, wherein one component carries out multiple functions. The invention may also be embodied with more elements than described hereinbefore, wherein functions carried out by one component in the embodiment are distributed among multiple components.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. Use of the article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention may be implemented by means of hardware comprising several distinct elements and/or by means of a suitably programmed processor. In the device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS

1. A video signal-processing apparatus (10) for processing a video signal (VS), which represents displayable images, and for providing a control signal (CAV-1, CAV-2) for controlling a color of light emitted by a first illumination unit (17A) and at least a second
5 illumination unit (17B), both illumination units (17A, 17B) being designed for emitting light of a color depending on the corresponding control signals (CAV-1, CAV-2), said video signal-processing apparatus (10) comprising:

control means (11A, 11B) designed for producing said control signal (CAV-1, CAV-2) for controlling the color of the light emitted by the illumination units (17A, 17B) in
10 accordance with the video signal (VS); and

adjustment means (12) for adjusting the color of the light emitted by the illumination units (17A, 17B), which adjustment means (12) are designed for adjusting at least one color component of the color of the light emitted by the first illumination unit (17A) independent of at least one color component of the color of the light emitted by the second illumination unit
15 (17B).

2. A video signal-processing apparatus (10) as claimed in claim 1, further comprising feedback means (15) that are designed for producing a feedback signal for representing a feedback regarding a level of color adjustment provided by the adjustment
20 means (12).

3. A video signal-processing apparatus (10) as claimed in claim 1 or 2, further comprising a color reference signal source (16) that is designed for producing a color reference signal, which color reference signal is intended to be utilized for adjusting the color
25 of the light emitted by the illumination units (17A, 17B).

4. A video signal-processing apparatus (10) as claimed in claim 1, wherein each illumination unit (17A, 17B) comprises at least two light sources, each of the light sources (R, G, B) is designed for producing light of an individual color with an
30 individual intensity, such that the light emitted by each illumination unit (17A, 17B)

represents a superposition of the light emitted by the light sources of the respective illumination unit (17A, 17B), and

wherein the adjustment means (12) are capable of adjusting the intensity of the light emitted by the light sources (R, G, B).

5

5. A system comprising a video signal-processing apparatus (10) as claimed in any one of claims 1 to 4, and the illumination units (17A, 17B), wherein the illumination units (17A, 17B) are designed to be communicatively connectable to the video signal-processing apparatus (10).

10

6. A system as claimed in claim 5, further comprising displaying means which are communicatively connectable to the video signal-processing apparatus (10).

7. A method of controlling the emission of light emitted by a first illumination unit (17A) and at least a second illumination unit (17B) in accordance with a video signal (VS), the method comprising the step of:

adjusting a color of the light emitted by the illumination units (17A, 17B), wherein at least one color component of the color of the light emitted by the first illumination unit (17A) is adjusted independently of at least one color component of the color of the light emitted by the second illumination unit (17B).

8. A method as claimed in claim 7, further comprising the step of producing a feedback signal for representing a color adjustment level.

9. A method as claimed in claim 8, further comprising the step of producing a color reference signal, which color reference signal is intended to be utilized for adjusting the color of the light emitted by the illumination unit (17A, 17B).

10. An electronic circuit suitable for use in the video signal-processing apparatus (10) as claimed in claims 1 to 6, which said circuit is designed to perform the steps of the method as claimed in any one of claims 7 to 9.