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(54) **CIRCUIT APPARATUS AND DISPLAY SYSTEM**

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G09G 3/34 (2006.01)

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CPC ***G09G 3/2055*** (2013.01); ***G09G 3/3426*** (2013.01); *G09G 2320/0242* (2013.01); *G09G 2360/16* (2013.01); *G09G 2380/10* (2013.01)

(58) **Field of Classification Search**
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See application file for complete search history.

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(57) **ABSTRACT**

A color information extraction section extracts color information from image information. A luminance information extraction section extracts luminance information for controlling the luminance of a backlight based on the color information. A dithering section adds bits for dithering to the lower bit side of the luminance information and outputs the luminance information after the addition to a display apparatus as output luminance information. An image color correction section corrects the color of the image information based on the color information and outputs the corrected image information to the display apparatus as output image information. An upper bit comparison section compares upper bits of the luminance information, upper bits of the output luminance information, and upper bits of the output image information with each other.

14 Claims, 13 Drawing Sheets

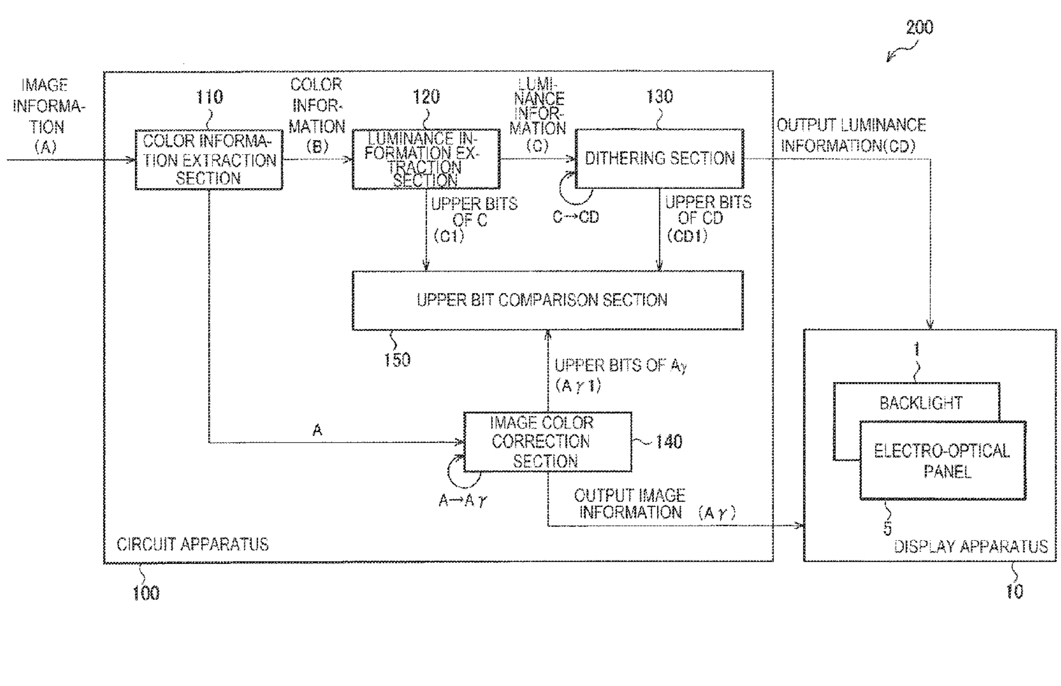

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FIG. 1

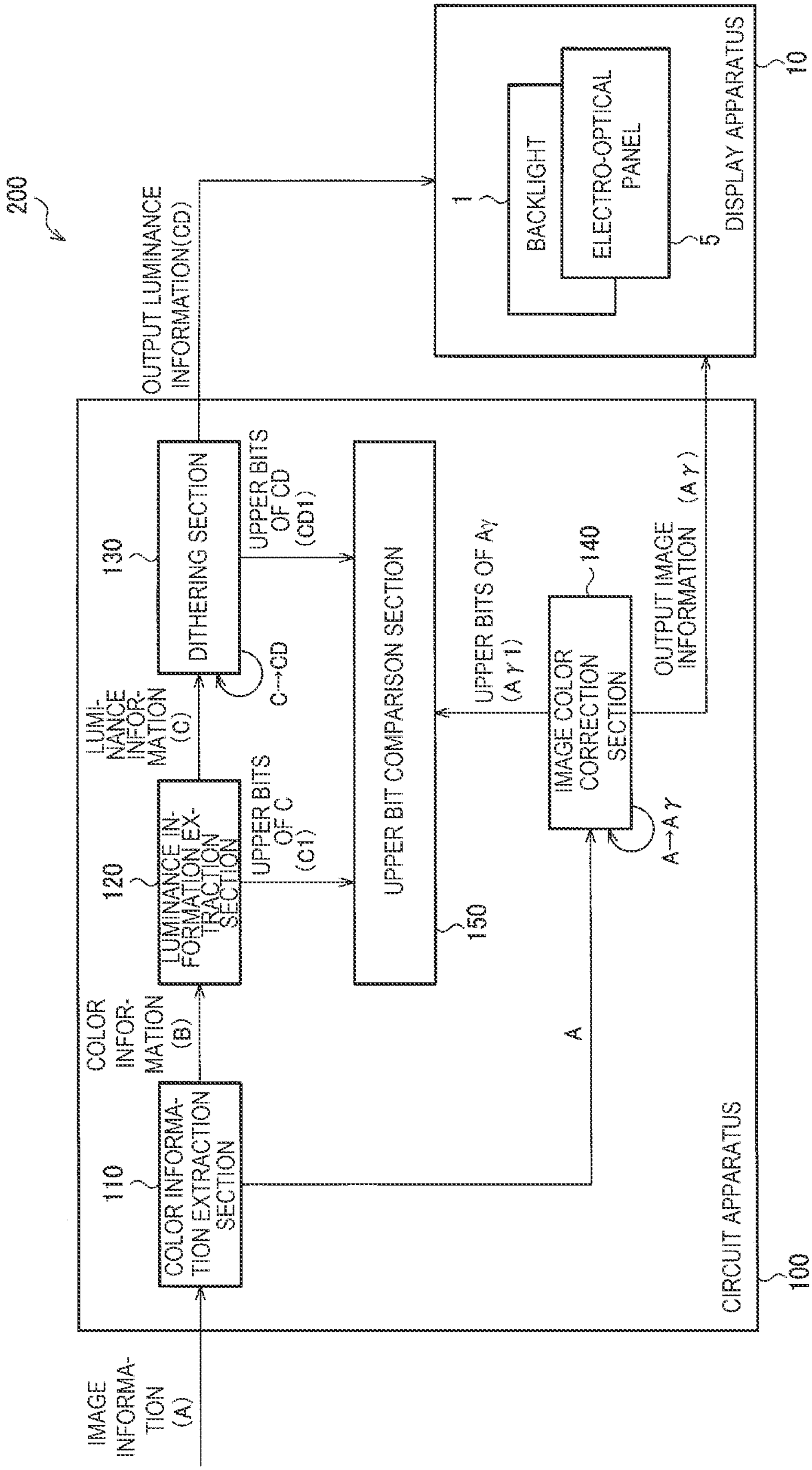

200
IMAGE INFORMATION (A)
COLOR INFORMATION EXTRACTION SECTION
110
COLOR INFORMATION (B)
LUMINANCE INFORMATION EXTRACTION SECTION
120
LUMINANCE INFORMATION (C)
DITHERING SECTION
130
C→CD
UPPER BITS OF C (C1)
UPPER BITS OF CD (CD1)
UPPER BIT COMPARISON SECTION
150
A
IMAGE COLOR CORRECTION SECTION
140
A→Aγ
UPPER BITS OF Aγ (Aγ1)
OUTPUT IMAGE INFORMATION (Aγ)
CIRCUIT APPARATUS
100
OUTPUT LUMINANCE INFORMATION (CD)
BACKLIGHT
1
ELECTRO-OPTICAL PANEL
5
DISPLAY APPARATUS
10

FIG. 2

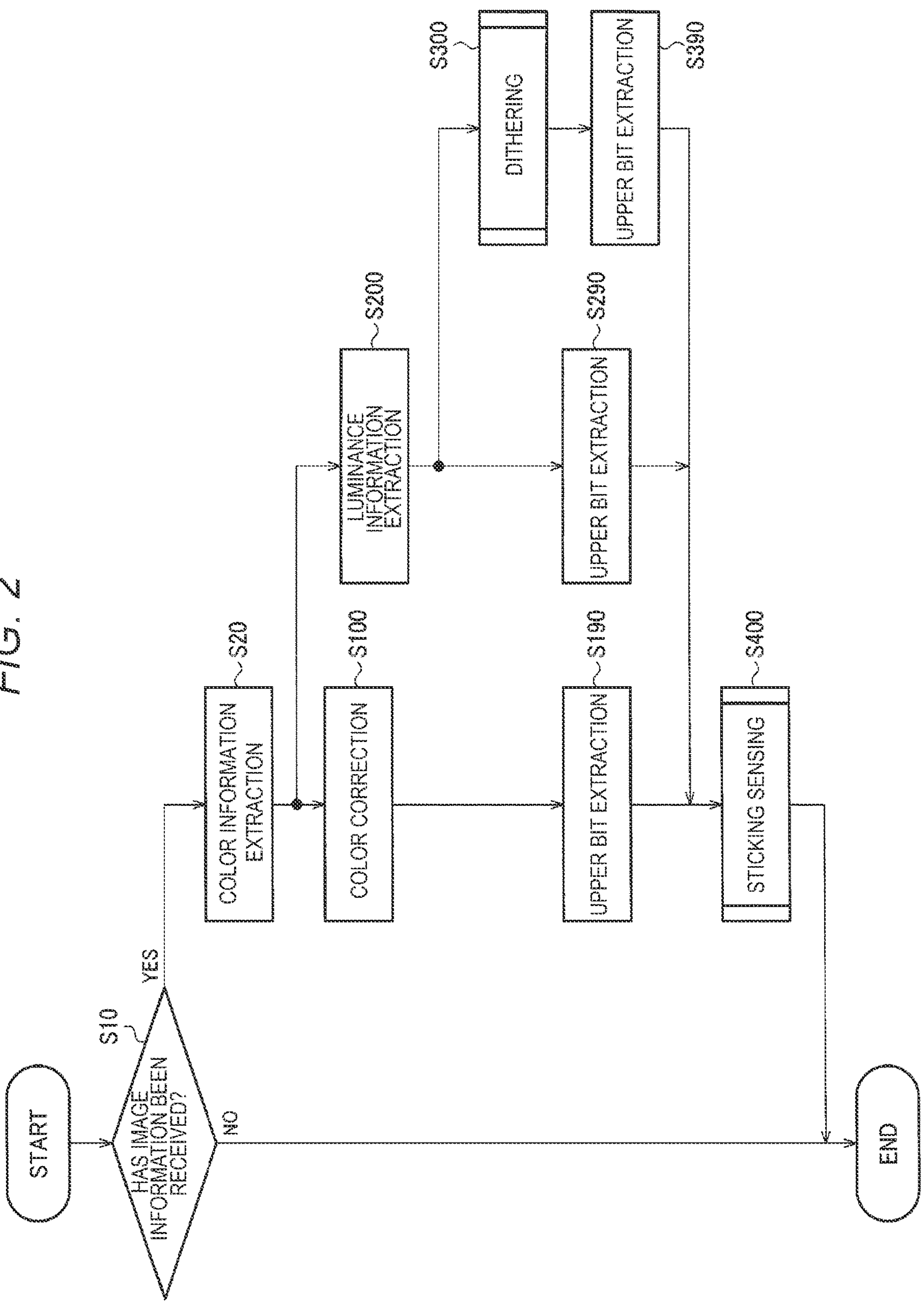

START
S10
HAS IMAGE INFORMATION BEEN RECEIVED?
YES
NO
S20
COLOR INFORMATION EXTRACTION
S100
COLOR CORRECTION
S190
UPPER BIT EXTRACTION
S200
LUMINANCE INFORMATION EXTRACTION
S290
UPPER BIT EXTRACTION
S300
DITHERING
S390
UPPER BIT EXTRACTION
S400
STICKING SENSING
END

FIG. 3

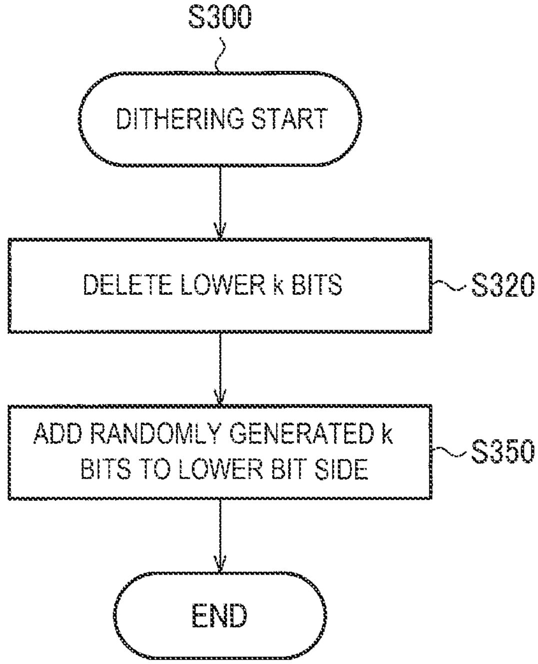

S300
DITHERING START
DELETE LOWER k BITS
S320
ADD RANDOMLY GENERATED k BITS TO LOWER BIT SIDE
S350
END

FIG. 4

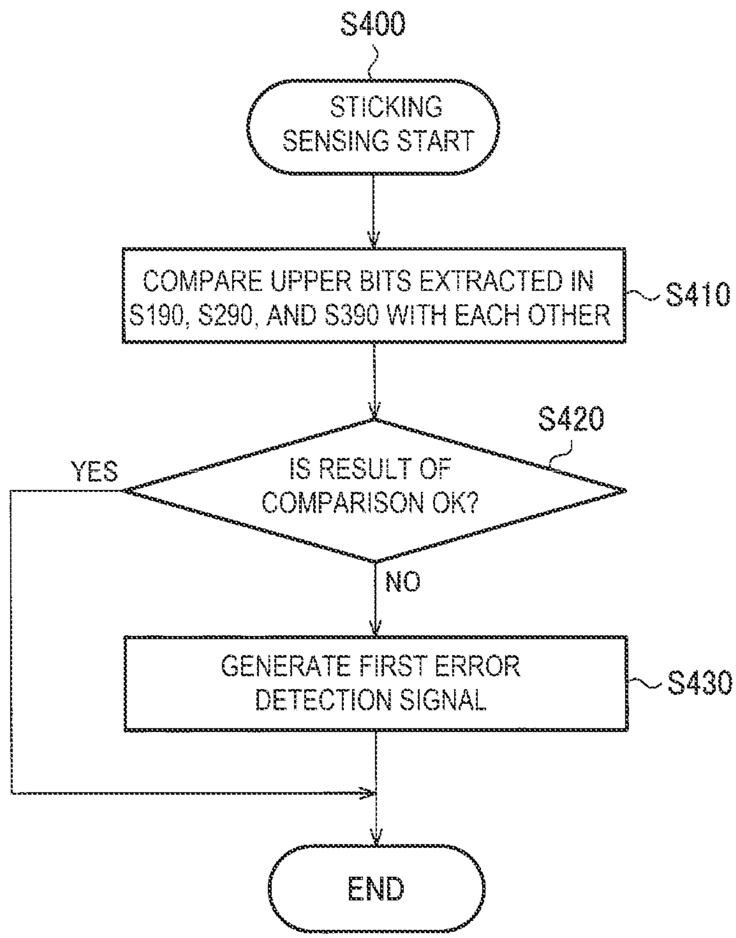

S400
STICKING SENSING START
COMPARE UPPER BITS EXTRACTED IN S190, S290, AND S390 WITH EACH OTHER
S410
S420
IS RESULT OF COMPARISON OK?
YES
NO
GENERATE FIRST ERROR DETECTION SIGNAL
S430
END

FIG. 5

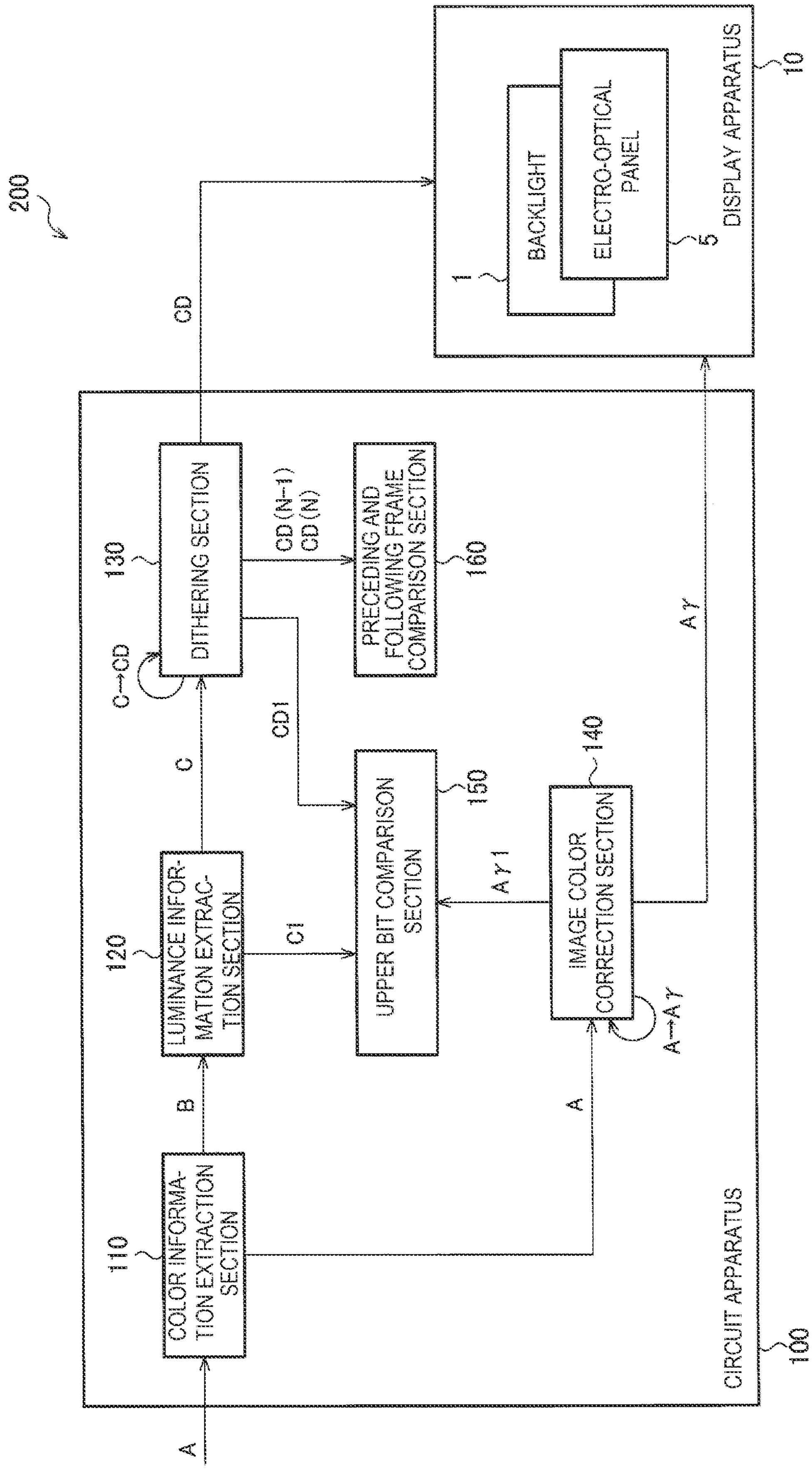

200
A
COLOR INFORMATION EXTRACTION SECTION
110
B
LUMINANCE INFORMATION EXTRACTION SECTION
120
C
C1
DITHERING SECTION
130
C→CD
CD1
CD (N−1)
CD (N)
PRECEDING AND FOLLOWING FRAME COMPARISON SECTION
160
UPPER BIT COMPARISON SECTION
150
A
Aγ1
IMAGE COLOR CORRECTION SECTION
140
A→Aγ
Aγ
CIRCUIT APPARATUS
100
CD
BACKLIGHT
1
ELECTRO-OPTICAL PANEL
5
DISPLAY APPARATUS
10

FIG. 6

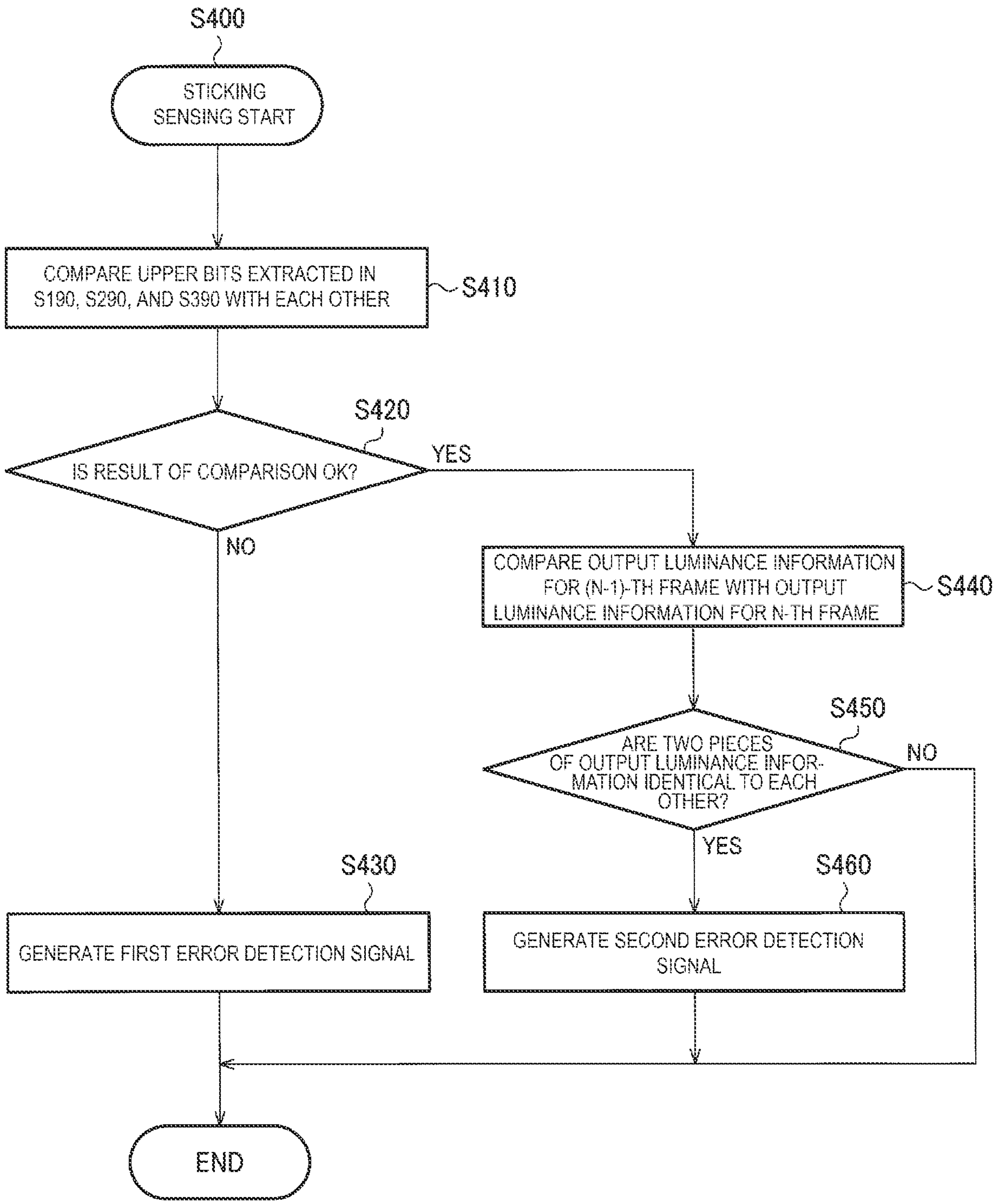
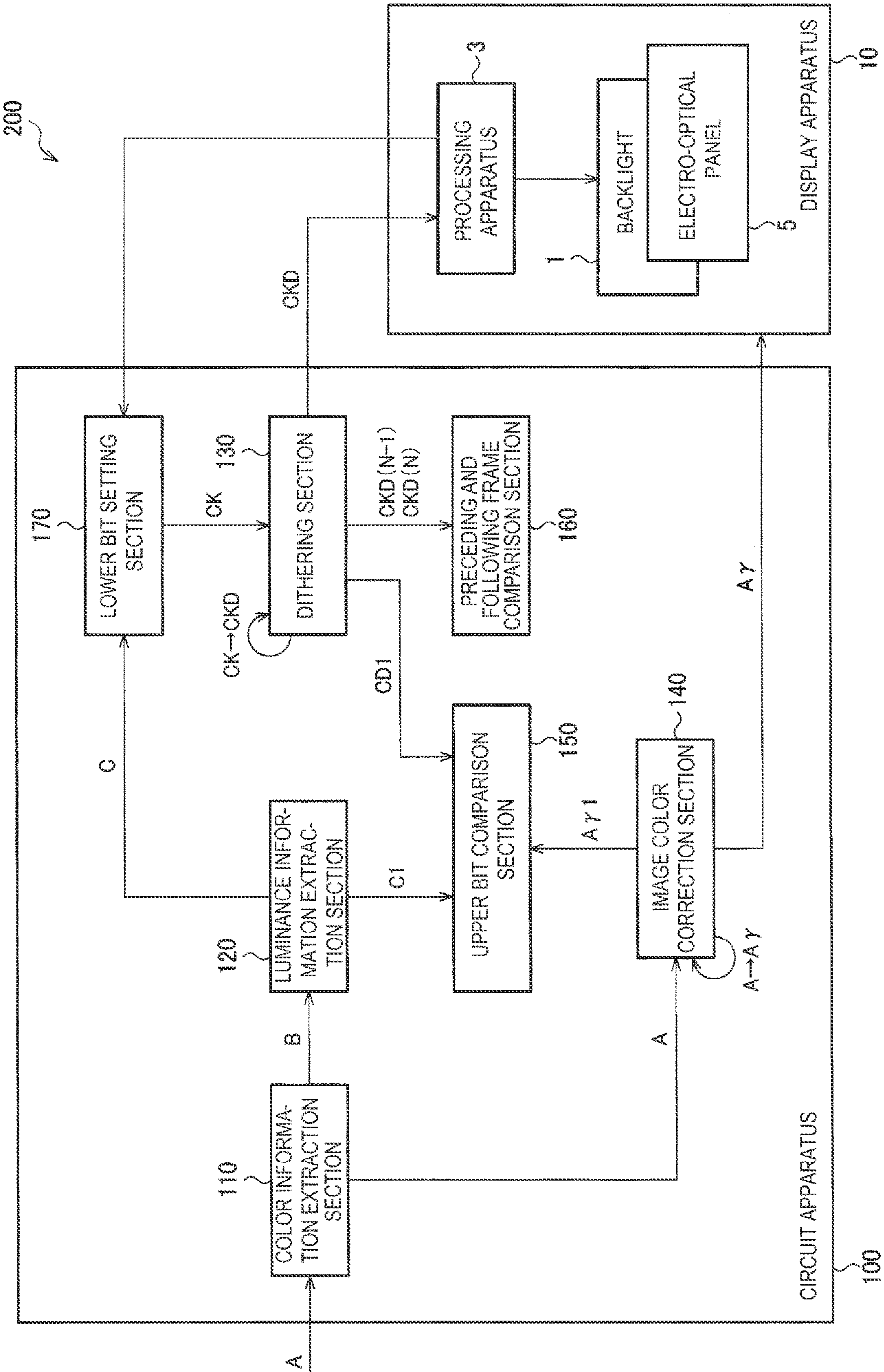

S400
STICKING SENSING START
COMPARE UPPER BITS EXTRACTED IN S190, S290, AND S390 WITH EACH OTHER
S410
S420
IS RESULT OF COMPARISON OK?
YES
NO
COMPARE OUTPUT LUMINANCE INFORMATION FOR (N-1)-TH FRAME WITH OUTPUT LUMINANCE INFORMATION FOR N-TH FRAME
S440
S450
ARE TWO PIECES OF OUTPUT LUMINANCE INFORMATION IDENTICAL TO EACH OTHER?
NO
YES
S430
S460
GENERATE FIRST ERROR DETECTION SIGNAL
GENERATE SECOND ERROR DETECTION SIGNAL
END

FIG. 7



200
DISPLAY APPARATUS
10
PROCESSING APPARATUS
3
BACKLIGHT
1
ELECTRO-OPTICAL PANEL
5
CKD
CIRCUIT APPARATUS
100
LOWER BIT SETTING SECTION
170
CK
DITHERING SECTION
130
CK→CKD
CKD (N−1)
CKD (N)
PRECEDING AND FOLLOWING FRAME COMPARISON SECTION
160
CD1
C
LUMINANCE INFORMATION EXTRACTION SECTION
120
C1
UPPER BIT COMPARISON SECTION
150
Aγ1
IMAGE COLOR CORRECTION SECTION
140
A→Aγ
Aγ
COLOR INFORMATION EXTRACTION SECTION
110
B
A
A

FIG. 8

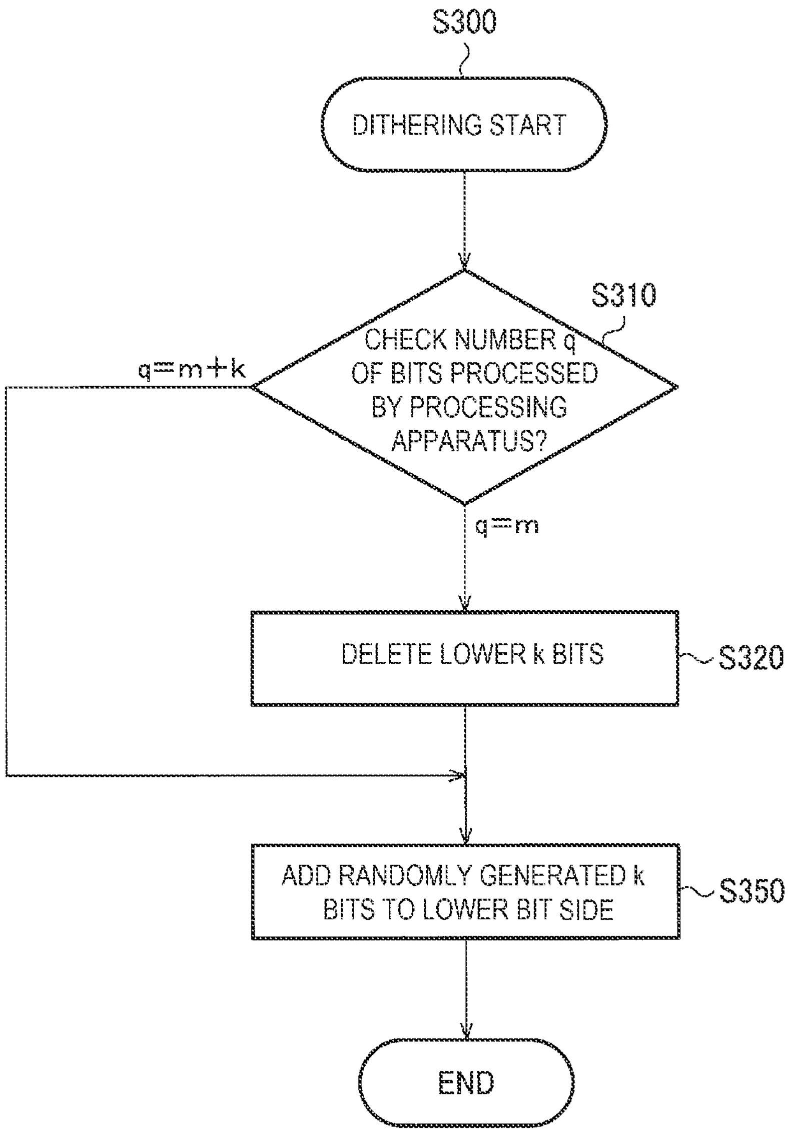

S300
DITHERING START
S310
CHECK NUMBER q OF BITS PROCESSED BY PROCESSING APPARATUS?
q=m+k
q=m
DELETE LOWER k BITS
S320
ADD RANDOMLY GENERATED k BITS TO LOWER BIT SIDE
S350
END

FIG. 9

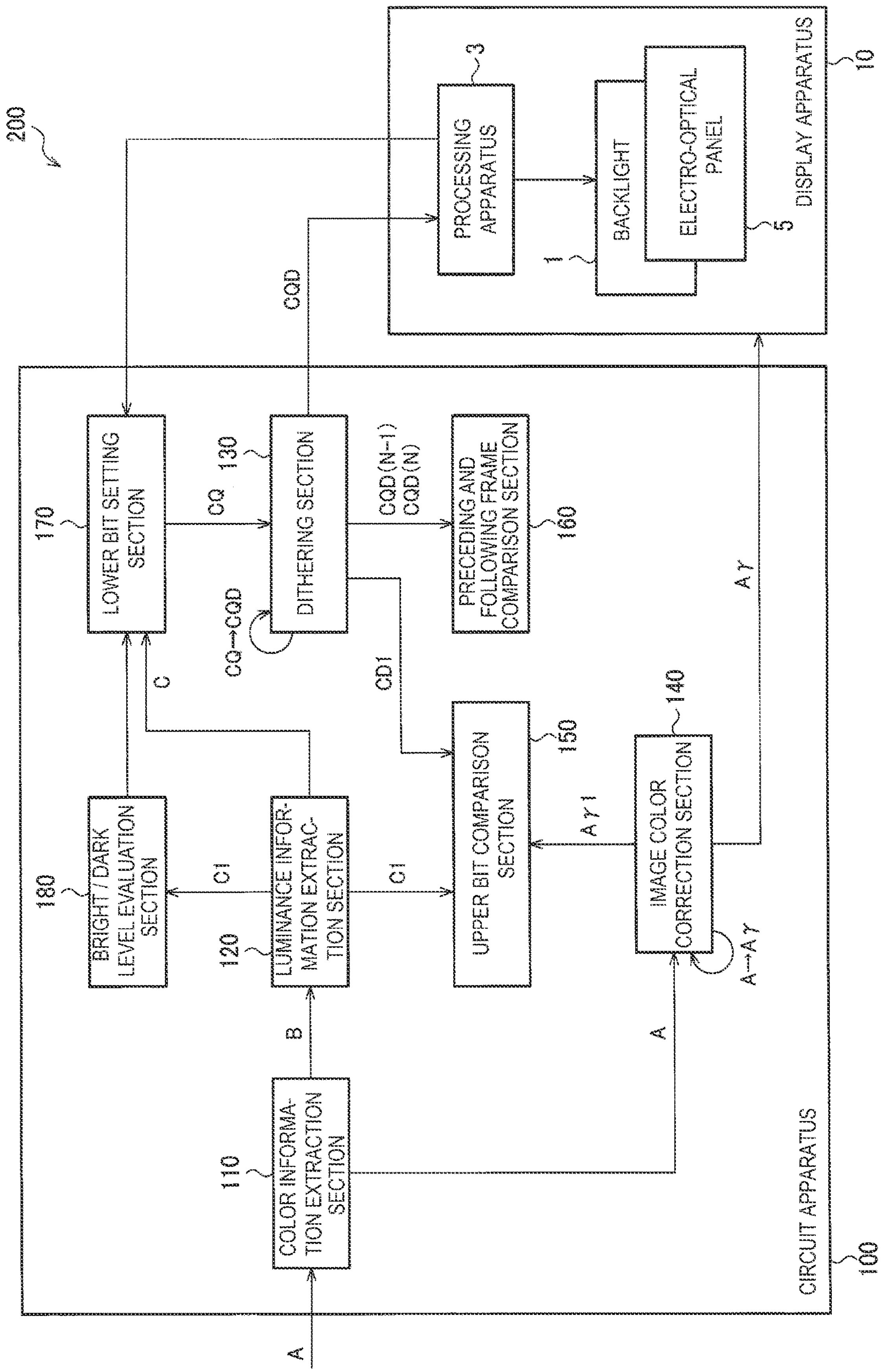

200
PROCESSING APPARATUS
3
BACKLIGHT
1
ELECTRO-OPTICAL PANEL
5
DISPLAY APPARATUS
10
CQD
LOWER BIT SETTING SECTION
170
CQ
DITHERING SECTION
130
CQ→CQD
CQD (N−1)
CQD (N)
PRECEDING AND FOLLOWING FRAME COMPARISON SECTION
160
C
CD1
BRIGHT / DARK LEVEL EVALUATION SECTION
180
LUMINANCE INFORMATION EXTRACTION SECTION
120
C1
UPPER BIT COMPARISON SECTION
150
Aγ1
IMAGE COLOR CORRECTION SECTION
140
A→Aγ
Aγ
B
A
COLOR INFORMATION EXTRACTION SECTION
110
CIRCUIT APPARATUS
100

FIG. 10

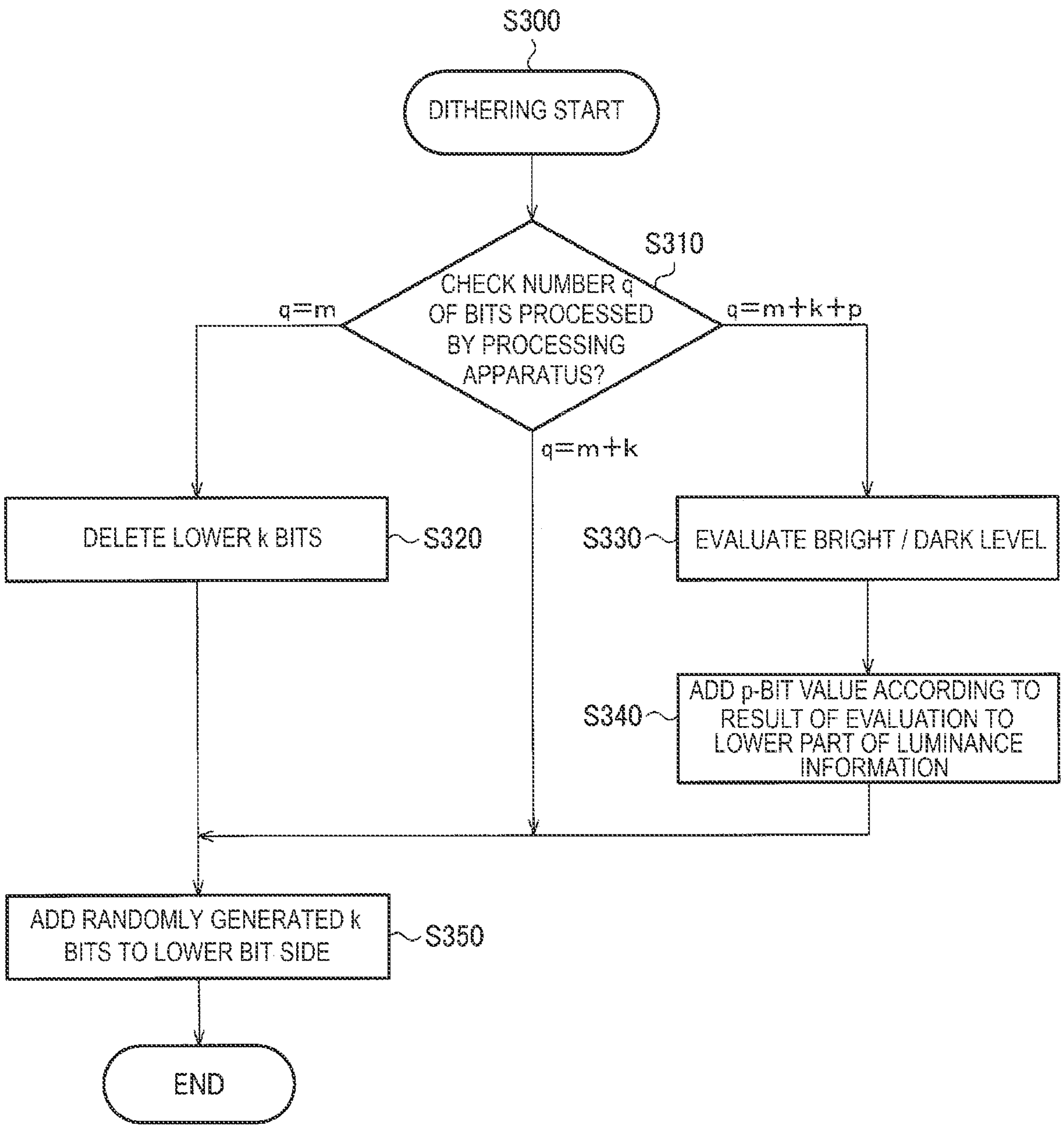

S300
DITHERING START
S310
CHECK NUMBER q OF BITS PROCESSED BY PROCESSING APPARATUS?
q=m
q=m+k+p
q=m+k
DELETE LOWER k BITS
S320
S330
EVALUATE BRIGHT / DARK LEVEL
S340
ADD p-BIT VALUE ACCORDING TO RESULT OF EVALUATION TO LOWER PART OF LUMINANCE INFORMATION
ADD RANDOMLY GENERATED k BITS TO LOWER BIT SIDE
S350
END

FIG. 11

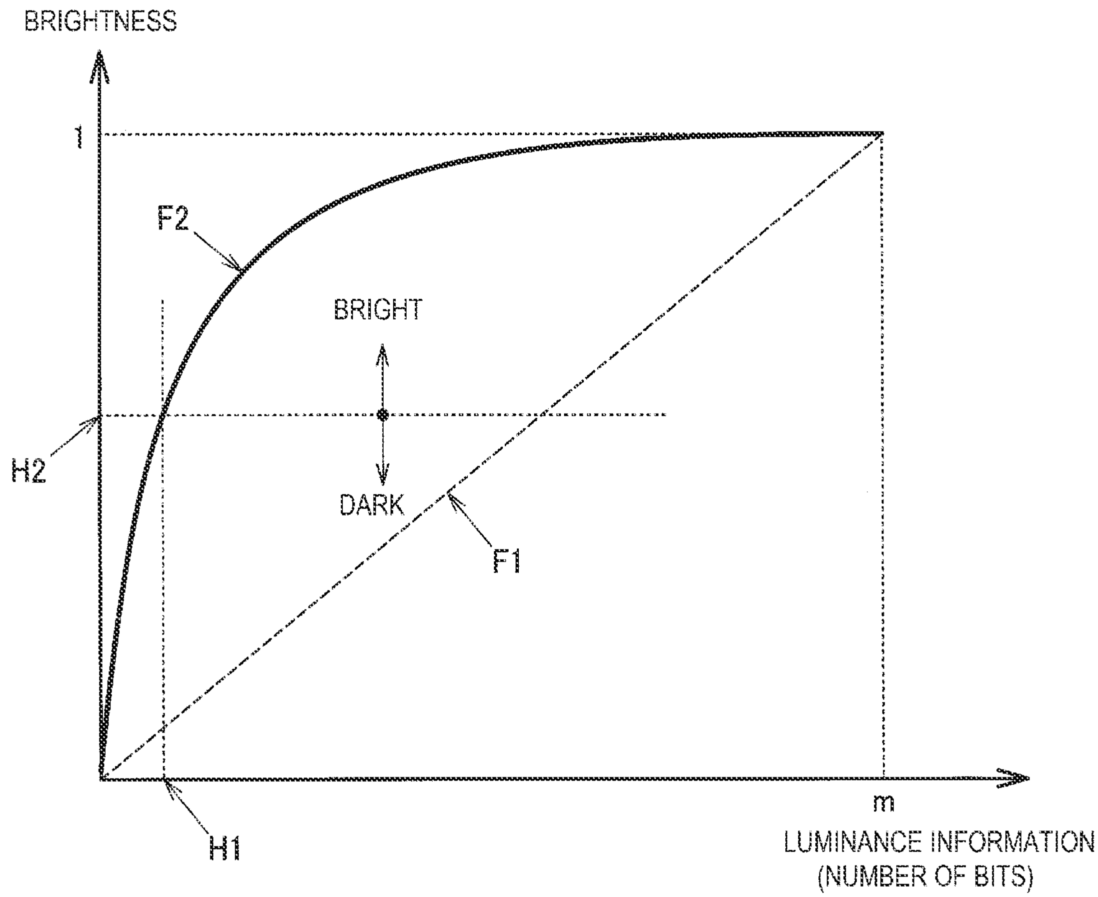

BRIGHTNESS
1
F2
BRIGHT
H2
DARK
F1
H1
m
LUMINANCE INFORMATION
(NUMBER OF BITS)

FIG. 12

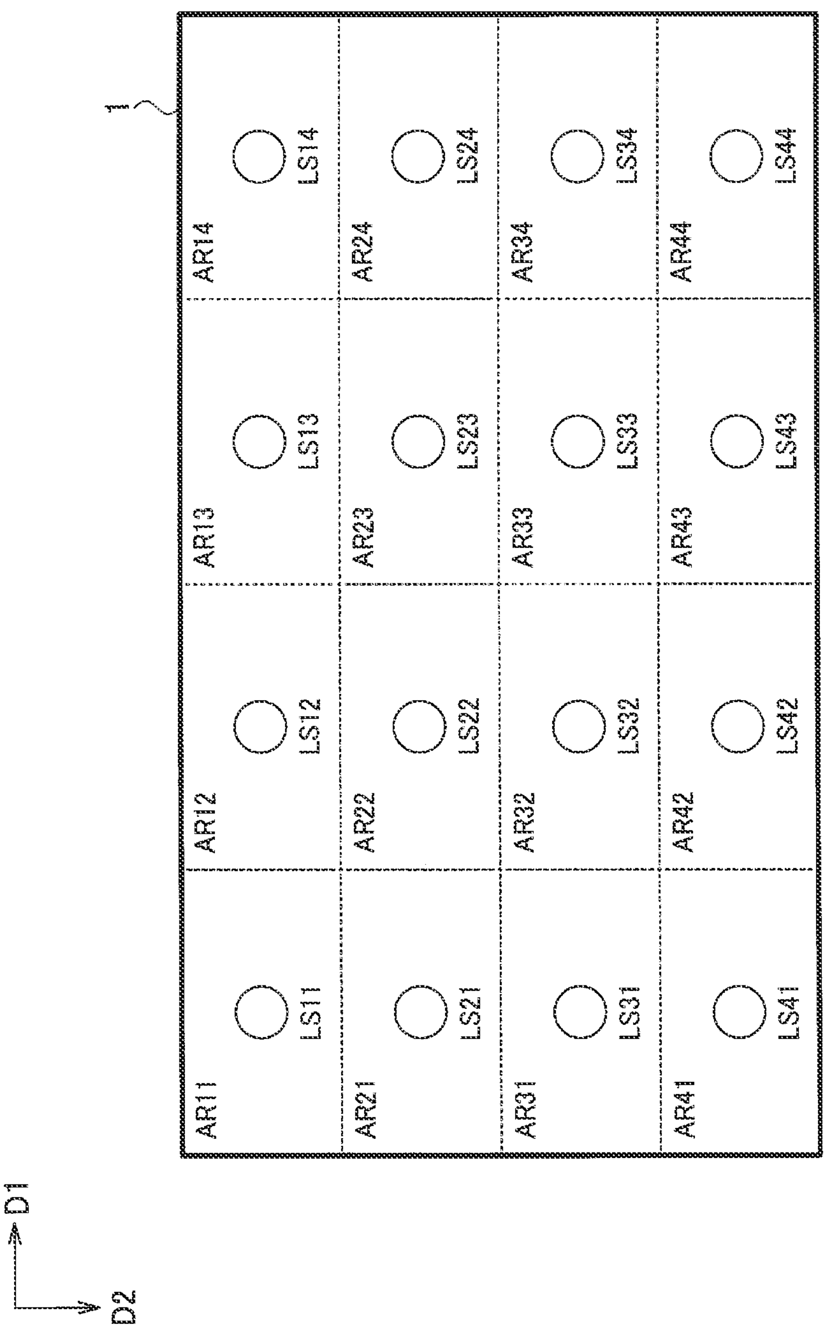

1
AR11
LS11
AR12
LS12
AR13
LS13
AR14
LS14
AR21
LS21
AR22
LS22
AR23
LS23
AR24
LS24
AR31
LS31
AR32
LS32
AR33
LS33
AR34
LS34
AR41
LS41
AR42
LS42
AR43
LS43
AR44
LS44
D1
D2

FIG. 13

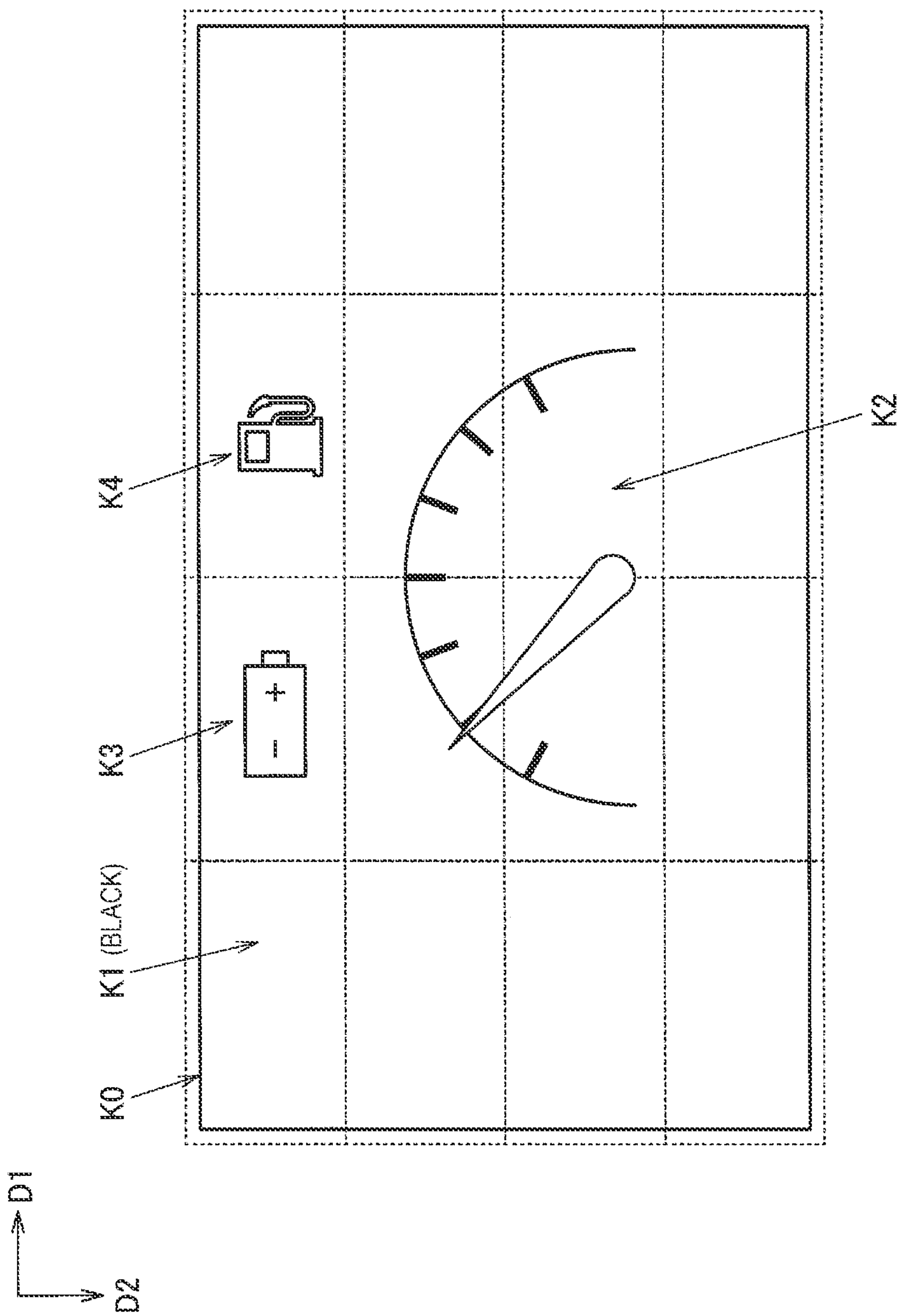
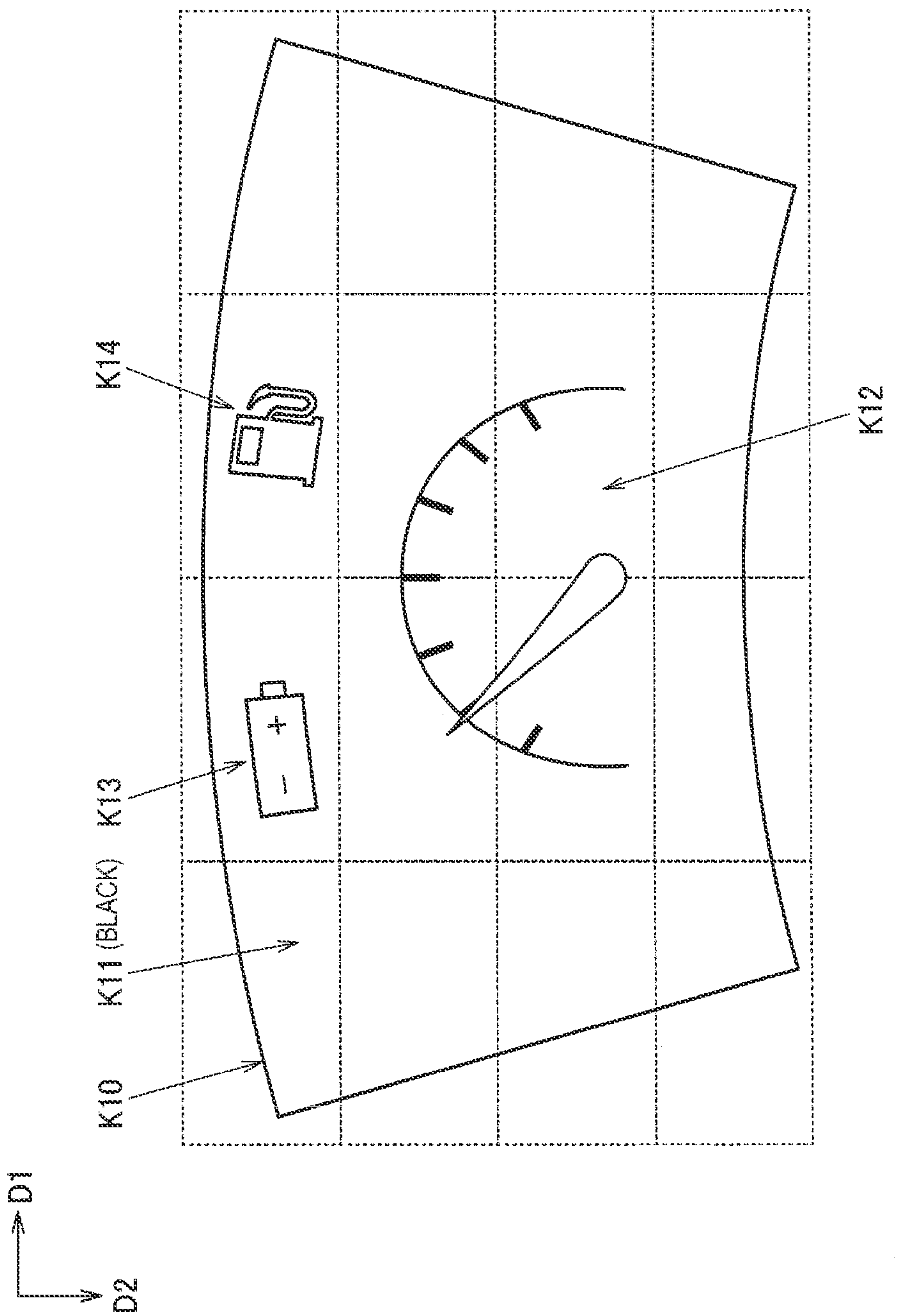


FIG. 14



CIRCUIT APPARATUS AND DISPLAY SYSTEM

The present application is based on, and claims priority from JP Application Serial Number 2022-140563, filed Sep. 5, 2022, the disclosure of which is hereby incorporated by reference herein in its entirety.

BACKGROUND

1. Technical Field

The present disclosure relates to a circuit apparatus, a display system, and the like.

2. Related Art

There has been a known display apparatus including a light source, such as an LED. JP-A-2009-016104 discloses a method for controlling the light source with a drive signal formed of (n+m) bits, the upper n bits and the lower m bits providing different control contents.

JP-A-2009-016104 is an example of the related art.

There has, however, been no proposed method for checking whether data on controlling the light source of the display apparatus is correctly transmitted and received by comparing the upper bits of the light source control signal with the upper bits of image information.

SUMMARY

An aspect of the present disclosure relates to a circuit apparatus that controls a display apparatus including a backlight and an electro-optical panel, the circuit apparatus including a color information extraction section that extracts color information from image information, a luminance information extraction section that extracts luminance information for controlling luminance of the backlight based on the color information, a dithering section that adds bits for dithering to a lower bit side of the luminance information and outputs the luminance information after the addition to the display apparatus as output luminance information, an image color correction section that corrects a color of the image information and outputs the corrected image information as output image information to the display apparatus, and an upper bit comparison section that compares upper bits of the luminance information, upper bits of the output luminance information, and upper bits of the output image information with each other.

Another aspect of the present disclosure relates to a display system including the circuit apparatus and the display apparatus described above.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** describes an example of the configurations of a display control system and a circuit apparatus.

FIG. **2** is a flowchart for describing an example of processes carried out in the present embodiment.

FIG. **3** is a flowchart for describing an example of dithering.

FIG. **4** is a flowchart for describing an example of sticking sensing.

FIG. **5** describes another example of the configurations of the display control system and the circuit apparatus.

FIG. **6** is a flowchart for describing another example of the sticking sensing.

FIG. **7** describes another example of the configurations of the display control system and the circuit apparatus.

FIG. **8** is a flowchart for describing another example of the dithering.

FIG. **9** describes another example of the configurations of the display control system and the circuit apparatus.

FIG. **10** is a flowchart for describing another example of the dithering.

FIG. **11** describes the relationship between brightness and luminance information.

FIG. **12** describes how to divide a display region.

FIG. **13** describes an example of image information.

FIG. **14** describes an example of the image information having undergone distortion correction.

DESCRIPTION OF EMBODIMENTS

A preferable embodiment of the present disclosure will be described below in detail. It is not intended that the present embodiment described below unduly limits the contents described in the claims, and all configurations described in the present embodiment are not necessarily essential configuration requirements.

FIG. **1** shows an example of the configurations of a circuit apparatus **100** and a display system **200** according to the present embodiment. The display system **200** is a system that controls how a display apparatus **10** performs display operation and includes the circuit apparatus **100** and the display apparatus **10**. The display apparatus **10** is, for example, a cluster display or a head-up display for automotive applications, but not limited to those for automotive applications. For example, the following description will be made with reference to display operation for automotive applications, but the method according to the present embodiment is not limited to those for automotive applications. In the following description, a head-up display is referred to as an HUD.

The display apparatus **10** includes a backlight **1** and an electro-optical panel **5**. The backlight **1** is provided with a plurality of light sources. Specifically, the backlight **1** includes a plurality of light sources that are each achieved by an LED or any other component and are arranged in an array. The display apparatus **10** may include a light source driver that is not shown but drives the light sources of the backlight **1**, a display driver that is not shown but drives the electro-optical panel **5**, and other components. In variations that will be described later, the light source driver, which drives the light sources of the backlight **1**, may be called a processing apparatus **3**, the details of which will be described later. The display driver also includes a data driver that drives data lines of the electro-optical panel **5**, a scan driver that drives scan lines of the electro-optical panel **5**, a display controller, and other components. In the present embodiment, the light sources provided in the backlight **1** can be controlled with m-bit luminance information in the circuit apparatus **100**, more specifically, a case where m=8 bits (0 to 255) is presented by way of example.

The circuit apparatus **100** receives image information from a predetermined device that is not shown in FIG. **1** and outputs output luminance information, output image information, and other pieces of information based on the image information to the display apparatus **10** by using a method described below. The image information in the present embodiment is assumed to be raster data formed of m bits for each of RGB colors. That is, the number of bits for each of the colors in the image information and the number of bits in the luminance information are assumed to be the same m bits. However, the description does not preclude a case where the image information may be expressed in other formats, such as the CMYK format. For example, when the display system **200** is used in an automotive application, the predetermined device carries out the processes of sensing a variety of pieces of information on the vehicle and forming image information based on the sensed data. The variety of types of information on the vehicle may include speed information, information on warning lights and the amount of remaining fuel, and other pieces of information on the vehicle being driven, but not limited thereto, and may also include, for example, information on sensed vehicles or passersby in front of the vehicle. In this case, the predetermined device can be achieved, for example, by an SoC (System on Chip) having a graphics function.

Each portion that constitutes the display system **200** according to the present embodiment thus transmits and receives a variety of data and updates frames at a predetermined frame rate to achieve an animated display on the display apparatus **10**. Therefore, when the display system **200** is used, for example, in an automotive application, a user can grasp changes in the speed of the vehicle through video images on a meter of the vehicle. In the present embodiment, the order of generated frames may be expressed by N (N is integer greater than or equal to 2). Data for controlling the state in which the backlight **1** is turned on or off is also updated in correspondence with the frame update.

However, at least some of the portions that constitute the display system **200** may not, for example, accurately transmit and receive the data on the control of the luminance of the light sources of the backlight **1**, which may cause an event in which the information on the control of the state in which the backlight **1** is turned on or off is not updated, so that the data before the update may remain being transmitted and received. In the present embodiment, the event described above is called an event in which "the backlight **1** is stuck" or the like. The event may prevent the user from viewing the image that should be normally viewed on the display apparatus **10**. In the following description, "the backlight **1** is stuck" or the like is simply called "sticking". The present embodiment relates to a method for sensing the sticking.

It is assumed in the present embodiment that data transmitted to the electro-optical panel **5** be transmitted and received without any problems. In other words, it is assumed that there are no problems with the predetermined device described above, a color information extraction section **110**, an image color correction section **140**, an upper bit comparison section **150**, the display driver that is not shown, and other sections, and that the values of upper bits of the output image information, which will be described later, are always correct.

The circuit apparatus **100** includes the color information extraction section **110**, a luminance information extraction section **120**, a dithering section **130**, the image color correction section **140**, and the upper bit comparison section **150**. Although not shown in FIG. **1**, the circuit apparatus **100** can further include other components, which will be described later in detail.

The circuit apparatus **100** can be achieved, for example, by a processor. For example, each process in the present embodiment can be achieved by a processor that operates based on a program or other information and a memory that stores the program or other information. The processor may, for example, be achieved by individual hardware components for the functions of the portions that constitute the display system **200**, or a hardware component that integrally provides the functions of the portions. For example, the processor can include hardware, which can include at least one of a circuit that processes digital signals and a circuit that processes analog signals. For example, the processor can be formed of one or more circuit apparatuses or one or more circuit elements mounted on a circuit substrate. The processor may, for example, be a CPU (Central Processing Unit). Note that the processor is not limited to a CPU and can be a GPU (graphics processing unit), a DSP (digital signal processor), or any of a variety of other processors. The processor may instead be a hardware circuit formed of an ASIC. The processor may include an amplifier circuit, a filter circuit, and other circuits that process analog signals. The circuit apparatus **100** then reads and executes a sticking sensing program from the memory that is not shown in FIG. **1** to, for example, achieve the functions as the color information extraction section **110**, the luminance information extraction section **120**, the dithering section **130**, the image color correction section **140**, and the upper bit comparison section **150**. The functions of the color information extraction section **110**, the luminance information extraction section **120**, the dithering section **130**, the image color correction section **140**, and the upper bit comparison section **150** will be described later in the description with reference to FIG. **2**.

Processes carried out in the present embodiment will be described with reference to the flowchart of FIG. **2**. The procedure in FIG. **2** is performed in a predetermined cycle, for example, by timer interruption. The predetermined period is assumed to be shorter than the period based on the frame rate described above. The circuit apparatus **100** carries out the process of evaluating whether image information has been received (step S**10**). When the circuit apparatus **100** determines that no image information has been received (NO in step S**10**), the circuit apparatus **100** terminates the procedure. On the other hand, when the circuit apparatus **100** determines that image information has been received (YES in step S**10**), the circuit apparatus **100** performs color information extraction (step S**20**).

In the color information extraction (step S**20**), specifically, for example, the color information extraction section **110** extracts color information from the image information. For example, the color information extraction section **110** extracts R, G, and B grayscale values at a pixel located at predetermined coordinates in the image information received from the predetermined device, which is not shown in FIG. **1**, and transmits the extracted grayscale values to the luminance information extraction section **120** and the image color correction section **140**. The predetermined coordinates may be formed of a plurality of sets of predetermined coordinates, but it is assumed in the description for simplicity thereof that there is only one set of predetermined coordinates. In the following description, for example, the color information at a pixel where R, G, and B grayscale values are each 0 may be denoted, for example, as (R, G, B)=(0, 0, 0). The color information, the luminance information, the values of the upper bits, and other numerical values are hereinafter denoted by using the binary or decimal system as appropriate. Although not shown in the flowchart of FIG. **2**, the color information extraction section **110** also carries out the process of transmitting the received image information as is to the image color correction section **140**. In other words, the color information extraction section **110** transmits the R, G, and B grayscale values of all pixels contained in the image information to the image color correction section **140**.

The predetermined coordinates can be set as appropriate in correspondence with the coordinates at which a predetermined image is disposed. However, for example, when the predetermined image is a uniform background image, any coordinates may be set as the predetermined coordinates. For example, when the method according to the present embodiment is applied to each area AR, which will be described later, the predetermined coordinates may be set for each area AR.

For example, when a predetermined instrument including the display system **200** is operated, the predetermined device, which is not shown in FIG. **1**, generates an initial image that is an image in an initial state as the image information and transmits the generated image information to the circuit apparatus **100**. In the present embodiment, the initial image is assumed to be a dark uniform background image, for example, (R, G, B)=(0, 0, 0) is satisfied at all pixels that constitute the initial image. Thereafter, when the user desires to cause the predetermined instrument to notify new information at a predetermined timing, the predetermined device transmits a predetermined image corresponding to the new information to the circuit apparatus **100** as new image information. The predetermined image is displayed on the display apparatus **10** as a bright image clearly distinguishable from the initial image. Specifically, for example, at least one of the R, G, and B grayscale values of the predetermined image is so set that the value of the upper bits is greater than or equal to 1. The "value of the upper bits is greater than or equal to 1" refers, for example, to the state in which the upper bits are not 0000 when the number of upper bits is 4. The "value of the upper bits is 0", which will be described later refers, for example, to the state in which the upper bits are 0000 when the number of upper bits is 4. In the present embodiment, for convenience, a color expressed by upper bits having a value greater than or equal to 1 is called a "bright color", and a color expressed by upper bits having a value equal to 0 is called a "dark color". The upper bits will be described later in detail. To simplify the description, the predetermined image used herein is a uniform blue background image, and the R and G grayscale values of the predetermined image are 0. A case where the predetermined image is formed of different images on an area basis and a case where at least two of the R, G and B grayscale values of the predetermined image are not 0 will be described later. In the following figures, the image information may be denoted as A.

For example, when the blue grayscale value of the predetermined image is 11111010 (=250), the color information extraction section **110** transmits 11111010 (=250) as the color information to the luminance information extraction section **120**. When the image information is the image information on the initial image, the color information extraction section **110** transmits 00000000 (=0) as the color information to the luminance information extraction section **120**. In the following figures, the color information may be denoted as C.

After performing the color information extraction (step S**20**), the circuit apparatus **100** performs color correction (step S**100**) and luminance information extraction (step S**200**), and after performing the color correction (step S**100**), the circuit apparatus **100** performs upper bit extraction (step S**190**). That is, the memory that is not shown in FIG. **1** stores in advance coefficient information necessary for the color correction (step S**100**). For example, when the blue color of the predetermined image displayed on the display apparatus **10** seems to be insufficient, the coefficient information stored in the memory that is not shown compensates for the insufficient blue color. The same holds true for the other colors. In the image color correction (step S**100**), the image color correction section **140** selects the coefficient information corresponding to the received color information and multiplies the color information by the coefficient information for each pixel that constitutes the image information. When the image color correction section **140** receives the image information based on the initial image, the image color correction section **140** may omit step S**100** and use the image information based on the initial image as is as the output image information.

It is assumed in the present embodiment that the output image information is the image information after the image color correction section **140** performs the color correction (step S**100**). In the following description and illustration, the output image information may be denoted as Aγ.

The image color correction section **140** then transmits the output image information to the display apparatus **10**, and the display driver, which is not shown, display an image based on the output image information on the electro-optical panel **5**. The image color correction section **140** thus corrects the color of the image information and outputs the corrected image information as the output image information to the display apparatus **10**.

In the upper bit extraction (step S**190**), specifically, for example, the image color correction section **140** carries out the processes of extracting the color information at the predetermined coordinates described above in the output image information, extracting the values of the upper bits of the color information, and transmitting the values of the upper bits to the upper bit comparison section **150**. In the following description, the upper bits may be denoted as Aγ**1**.

The color information at the predetermined coordinates in the output image information in which the color has been corrected by the color correction (step S**100**) may differ from the color information at the predetermined coordinates in the initial image information, which does not matter. The reason for this is that when the image information is based on the "bright color", the output image information after the color correction (step S**100**) still has a "bright color". That is, performing the color correction (step S**100**) on image information in which the value of the upper bits is greater than or equal to 1 does not change the fact that the value of the upper bits is still greater than 1, and does not affect the result of sticking sensing (step S**400**), which will be described later.

Specifically, for example, when the blue grayscale value at the predetermined coordinates in the output predetermined image as a result of the color correction (step S**100**) performed on the predetermined image ranges from 240 (11110000) to 255 (11111111), the image color correction section **140** transmits 1111, which represent the upper 4 bits as the upper bits, as Aγ**1**. The 4 bits used herein are derived from m/2 bits when m=8 bits, and will be described later in detail. Similarly, when the grayscale scale value ranges from 224 to 239, 1110, which represent the upper 4 bits, is transmitted as Aγ**1**. That is, when the color correction (step S**100**) is performed on the predetermined image having a blue grayscale value of 250, the value in the color information on the color of the output predetermined image is no longer 250, and the value of Aγ**1** may vary depending on the result of the color correction, which does not matter because it is not expected that the value of Aγ**1** does not fall within the range from 16 to 255. It is, however, desirable that the grayscale value of the predetermined image is a highest possible value.

In the luminance information extraction (step S**200**), for example, the luminance information extraction section **120** extracts the luminance information for controlling the luminance of the backlight **1** based on the color information. More specifically, for example, when the luminance information extraction section **120** receives 11111010 as the color information from the color information extraction section **110** as described above, the luminance information extraction section **120** carries out the process of setting the luminance information on the luminance of the light sources of the backlight **1** at 11111010 and the process of transmitting the set luminance information to the dithering section **130**. When the color information transmitted to the image color correction section **140** is the color information based on the initial image, that is, when the color information is 00000000, the luminance information extraction section **120** carries out the process of setting the luminance information at 00000000. That is, when image information formed only of the initial image is transmitted, the user is practically looking at the electro-optical panel **5** with the backlight **1** turned off.

After performing the luminance information extraction (step S**200**), the circuit apparatus **100** performs the upper bit extraction (step S**290**) and dithering (step S**300**). The dithering (step S**300**) will be described later in detail with reference to FIG. **3**. In the upper bit extraction (step S**290**), for example, the luminance information extraction section **120** carries out the processes of extracting the upper bits of the luminance information set in step S**200** and transmitting the extracted upper bits to the upper bit comparison section **150**. More specifically, since the luminance information has been set at 11111010, the luminance information extraction section **120** carries out the process of transmitting 1111, which represent the upper 4 bits as the upper bits, to the upper bit comparison section **150**. The situation in which the 4 bits in the description are derived from m/2 bits when m=8 bits is the same as the situation in step S**190**. In the following description, the values of the upper bits may be denoted as C**1**. In the present embodiment, for convenience, light based on luminance information in which the value of the upper bits is greater than or equal to 1 is called "bright light", and light based on luminance information in which the value of the upper bits is 0 is called "dark light".

FIG. **3** is a flowchart for describing the dithering (step S**300**) in more detail. For example, the dithering section **130** carries out the processes of deleting k bits from the lower bits (step S**320**) and adding randomly generated k bits to the lower bits (step S**350**). The constant k is the number of bits for dithering, is an integer greater than or equal to 1, and is desirably small enough not to affect the result of the sticking sensing (step S**400**), which will be described later. For example, when the value of k is increased, there is a possibility of a change from the "bright light" to the "dark light" or from the "dark light" to the "bright light" due to the dithering (step S**300**), but in the present embodiment, k is assumed to be a numerical value that falls within a range within which there is no possibility of such a change. The constant k may be a value set in advance, or the value of the set k may be changed after the display system **200** is activated.

A method for generating random values is not limited to a specific method as long as the values of the k bits in the (N−1)-th frame differ from the values of the k bits in the N-th frame, and may be a method for generating random numbers or a method for repeatedly generating a fixed value. A method for regularly generating 00, 01, 10, and 11 with k=2 is presented below by way of example, but not limited thereto.

Specifically, for example, when k=2, the dithering section **130** deletes in step S**320** the lower two bits (=10) of 11111010 received from the luminance information extraction section **120** to set 111110.

Thereafter, in step S**350**, the dithering section **130** periodically generates 11111000, 11111001, 11111010, and 11111011, for example, by using the method described above. Although not shown in FIG. **3**, the dithering section **130** outputs the values generated in step S**350** to the display apparatus **10** as the output luminance information. In the following description, the output luminance information may be denoted as CD. In the present embodiment, the backlight **1** of the display apparatus **10** includes a plurality of light sources, and since the initial and predetermined images are uniform background images, it is assumed that one piece of output luminance information can control all the light sources of the backlight **1**. The case where image information varies for each of the areas AR will be described later. The dithering section **130** thus adds bits for dithering to the lower bit side of the luminance information and outputs the luminance information after the addition to the display apparatus **10** as the output luminance information.

When the dithering section **130** receives the luminance information based on the initial image, that is, 00000000, then 00000000, 00000001, 00000010, and 00000011 are periodically generated in steps S**320** and S**350**, and transmitted as the output luminance information to the display apparatus **10**. In this case, since only the grayscale values ranging from 0 to 3 with respect to the largest grayscale value 255 are output to the display apparatus **10**, the state in which the backlight **1** is not turned on in effect continues.

After performing the dithering (step S**300**), the circuit apparatus **100** performs the upper bit extraction (step S**390**). For example, when the upper bits extracted in steps S**190** and S**290** are 4 bits, the dithering section **130** carries out the process of transmitting 1111, which represent the values of the upper 4 bits of the output luminance information, to the upper bit comparison section **150** accordingly. In the following description, the values of the upper bits may be denoted as CD**1**.

The circuit apparatus **100** then performs the sticking sensing (step S**400**). FIG. **4** is a flowchart for describing the sticking sensing (step S**400**) in more detail. The circuit apparatus **100** carries out the process of comparing the upper bits extracted in steps S**190**, S**290**, and S**390** with each other (step S**410**). That is, the upper bit comparison section **150** compares the upper bits of the luminance information (C**1**), the upper bits of the output luminance information (CD**1**), and the upper bits of the output image information (Aγ**1**) with each other. More specifically, the result of the comparison is determined as OK (no problem) when the values of C**1**, CD**1**, and Aγ**1** are all greater than or equal to 1, or when the values of C**1**, CD**1**, and Aγ**1** are all 0, otherwise the result of the comparison is determined as NG (problematic).

The circuit apparatus **100** then carries out the process of evaluating whether the result of the comparison is problematic (step S**420**), and when the result of the comparison is determined to be OK (YES in step S**420**), the circuit apparatus **100** terminates the procedure.

For example, when the processes in FIG. **2** are carried out at a first timing at which only the initial image is displayed, the color information at the pixels that constitute the initial image is (R, G, B)=(0, 0, 0), so that the values of C**1**, CD**1**, and Aγ**1** are all 0. On the other hand, when the processes in FIG. **2** are carried out at a second timing at which the predetermined image is displayed in the example described above, the values of C**1**, CD**1**, and Aγ**1** are greater than or equal to 1. That is, the upper bit comparison section **150** determines the result of the evaluation in step S**420** to be YES when the values of C**1**, CD**1**, and Aγ**1** are all greater than or equal to 1 at the second timing. The circuit apparatus **100** thus determines that no sticking has occurred.

As described above, the circuit apparatus **100** according to the present embodiment controls the display apparatus **10** including the backlight **1** and the electro-optical panel **5**, and includes the color information extraction section **110**, the luminance information extraction section **120**, the dithering section **130**, the image color correction section **140**, and the upper bit comparison section **150**. The color information extraction section **110** extracts the color information from the image information. The luminance information extraction section **120** extracts the luminance information for controlling the luminance of the backlight **1** based on the color information. The dithering section **130** adds bits for dithering to the lower bit side of the luminance information and outputs the luminance information after the addition to the display apparatus **10** as the output luminance information. The image color correction section **140** corrects the color of the image information and outputs the corrected image information as the output image information to the display apparatus **10**. The upper bit comparison section **150** compares the upper bits of the luminance information, the upper bits of the output luminance information, and the upper bits of the output image information with each other.

The circuit apparatus **100** according to the present embodiment, which controls the display apparatus **10** including the backlight **1** and the electro-optical panel **5**, can thus be used with the display apparatus **10**. The circuit apparatus **100** further includes the color information extraction section **110**, the luminance information extraction section **120**, the dithering section **130**, and the image color correction section **140**, and can therefore extract the upper bits of the luminance information, the upper bits of the output luminance information, and the upper bits of the output image information. The circuit apparatus **100** still further includes the upper bit comparison section **150** and can therefore compare the upper bits of the luminance information, the upper bits of the output luminance information, and the upper bits of the output image information with each other. Whether the sticking has occurred can therefore be detected at an appropriate timing.

Specifically, assume, for example, that the luminance information extraction section **120** malfunctions at the first timing described above, so that the luminance information extraction section **120** does not update the luminance information and keeps transmitting the luminance information having the same value. In this case, the dithering section **130** transmits the output luminance information carrying the grayscale values ranging from 0 to 3 to the display apparatus **10**, so that the situation in which the light sources of the backlight **1** emit practically no light continues after the first timing, as described above. Therefore, even when the image information based on the predetermined image is transmitted from the predetermined device at the second timing, the user cannot view the predetermined image. In this regard, applying the method according to the present embodiment and executing step S**400** at the second timing allows the value of Aγ**1** to be greater than or equal to 1 and the values of C**1** and CD**1** to be 0. The upper bit comparison section **150** can thus determine that the result of the evaluation in step S**420** is NO, whereby the circuit apparatus **100** can carry out the process of determining that the sticking has occurred at the second timing.

Assume, for example, that the dithering section **130** malfunctions at the first timing, so that the dithering section **130** keeps transmitting output luminance information dithered for the same luminance information value. Similarly, also in this case, even when the image information based on the predetermined image is transmitted from the predetermined device at the second timing, the user cannot view the predetermined image. In this regard, applying the method according to the present embodiment and executing step S**400** at the second timing allows the values of Aγ**1** and C**1** to be greater than or equal to 1 and the value of CD**1** to be 0. The upper bit comparison section **150** thus determines the result of the evaluation in step S**420** to be NO, whereby the circuit apparatus **100** can carry out the process of determining that the sticking has occurred at the second timing.

The method according to the present embodiment may instead be achieved as a display system **200**. That is, the display system **200** according to the present embodiment includes the circuit apparatus **100** and the display apparatus **10** described above. The same effects as those described above can thus be provided.

The method according to the present embodiment is not limited to the method described above. For example, the upper bit comparison section **150** may carry out the process of generating a first error detection signal (step S**430**) after determining the result of the evaluation in step S**420** to be NO, as shown in FIG. **4**. The first error detection signal is specifically, for example, but not limited to, a signal for generating a predetermined audio alarm, a signal for turning on a predetermined lamp, or a reset signal, and any of a variety of other methods can be employed. As described above, in the circuit apparatus **100** according to the present embodiment, the upper bit comparison section **150** outputs the first error detection signal when the results of comparing the upper bits of the luminance information, the upper bits of the output luminance information, and the upper bits of the output image information show that they disagree with one another. The user can thus quickly recognize that the sticking has occurred. For example, when the sticking occurs at the second timing described above, the user who is looking at the display apparatus **10** can only recognize that the initial image continues to be displayed. In this regard, applying the method according to the present embodiment causes the first error signal to be output at the second timing, whereby the user can recognize that the sticking has occurred at the second timing. The user can thus quickly recognize that the sticking has occurred and take appropriate measures. Examples of the appropriate measures may include reactivating the display system **200**, stopping the entire apparatus including the display system **200**, and checking each piece of hardware and software that constitute the display system **200**.

The circuit apparatus **100** and the display system **200** according to the present embodiment may, for example, be configured as shown in FIG. **5**. FIG. **5** differs from FIG. **1** in that the configuration shown in FIG. **5** includes a preceding and following frame comparison section **160**. That is, the circuit apparatus **100** according to the present embodiment further includes the preceding and following frame comparison section **160**, which compares the output luminance information for the (N−1)-th frame with the output luminance information for the N-the frame, where N is an integer greater than or equal to 2. Whether the sticking has occurred can thus grasped on a frame update timing basis.

When the circuit apparatus **100** and the display system **200** are configured as in the example shown in FIG. **5**, the sticking sensing (step S**400**) may, for example, be performed by carrying out the processes shown in FIG. **6**. FIG. **6** differs from FIG. **4** in that FIG. **6** further includes steps S**440**, S**450**, and S**460**. In the following description, the configurations and processes that duplicate those in FIGS. **1** and **4** will be omitted as appropriate.

When the circuit apparatus **100** determines the result of the evaluation in step S**420** described above to be YES, the circuit apparatus **100** carries out the process of comparing the output luminance information for the (N−1)-th frame with the output luminance information for the N-th frame (step S**440**). In the following description and illustration, the output luminance information for the (N−1)-th frame may be denoted as CD(N−1), and the output luminance information for the N-th frame may be denoted as CD(N).

For example, the preceding and following frame comparison section **160** includes a buffer that stores data on CD(N−1) and data on CD(N), and after receiving the data on CD(N−1) and the data on CD(N) from the dithering section **130**, compares the data on CD (N−1) with the data on CD (N). Thereafter, when the circuit apparatus **100** determines that the data on CD(N−1) is identical to the data on CD(N) (YES in step S**450**), the circuit apparatus **100** carries out the process of generating a second error detection signal (step S**460**) and terminates the procedure. The second error detection signal is an error detection signal different from the first error detection signal described above. On the other hand, when the circuit apparatus **100** determines that the data on CD(N−1) is not identical to the data on CD(N) (NO in step S**450**), the circuit apparatus **100** terminates the procedure.

When the operation in step S**350** described above is functioning properly, the value of the output luminance information output from the dithering section **130** on a frame basis will not be continuously the same, as described above. That is, when the result of the evaluation in step S**440** is determined to be YES, the dithering is not functioning properly, indicating that the dithering section **130** is malfunctioning. As described above, in the circuit apparatus **100** according to the present embodiment, the preceding and following frame comparison section **160** outputs the second error detection signal when the output luminance information for the (N−1)-th frame is identical to the output luminance information for the N-th frame. The user can thus quickly grasp that the dithering is not functioning properly. The user can thus quickly grasp that the sticking has occurred in the circuit apparatus **100** and display system **200**.

Comparing the case where the functions of the display system **200** each work properly with the case where only the function of the dithering section **130** out of the functions of the display system **200** is not working shows that the only difference that occurs is that the same CD value is transmitted to the display apparatus **10**, so that substantially desired brightness continues to be displayed. When the processor performing the function of the dithering section **130** is malfunctioning, however, it is desirable to quickly take appropriate measures because the malfunction suggests that other functions may also not work separately.

Assume, for example, that the predetermined image is displayed at the second timing and the user recognizes the situation in which the predetermined image is continuously displayed, but the imaged displayed on the display apparatus **10** has become dark at a third timing after the second timing. In this case, which means that the displayed image has not been switched to the initial image but the backlight **1** has no longer emitted light, it thus can be determined that the sticking has occurred. In this case, for example, when both the first and second error detection signals described above are not output, the luminance information extraction section **120** and the dithering section **130** of the circuit apparatus **100** are functioning properly, so that the user can determine that a problem has occurred not in the circuit apparatus **100** but in the display apparatus **10**. As described above, applying the method according to the present embodiment allows quick determination of whether the defect has occurred in the circuit apparatus **100** or the display apparatus **10** when the sticking occurs.

The above description is based on the assumption that, for example, the R and G grayscale values are 0 as the color information on the color of the predetermined image, and the method according to the present embodiment is also applicable to a case where at least two of the R, G, and B grayscale values are not zero as the color information on the color of the predetermined image. In this case, step S**200** may be the process of extracting the grayscale value of a color component having the largest grayscale value out of the entire color components as the color information. For example, when color information of (R, G, B)=(250, 10, 10) is received as the image information formed of the predetermined image from the color information extraction section **110**, the largest grayscale value is 250, so that the luminance information may be set at 11111010 (=250). As described above, in the circuit apparatus **100** according to the present embodiment, the luminance information extraction section **120** extracts luminance information based on the color component having the highest luminance out of the plurality of color components in the color information. The luminance information for controlling the light sources of the display apparatus **10**, which displays image information for displaying colors including a plurality of color components, can thus be appropriately extracted.

Step S**190** in this case may be the process of extracting upper bits corresponding to the grayscale value of the color component having the largest grayscale value among the color components at the predetermined coordinates in the output image information as the result of the color correction (step S**100**) performed on the image information. Also in this case, for example, when the color of the color component having the largest grayscale value in the image information is a "bright color," the color of the color component having the largest grayscale value in the output image information is also considered to be a "bright color," so that the value of the upper bits output to the upper bit comparison section **150** is still greater than or equal to 1.

As described above, in the circuit apparatus **100** according to the present embodiment, the image color correction section **140** outputs the upper bits of the output image information to the upper bit comparison section **150** based on the color component having the largest value among the plurality of color components in the output image information. The upper bits of the output image information containing a plurality of color components can thus be appropriately extracted and transmitted to the upper bit comparison section **150**.

The above description is an example applicable to a case where the number of bits processed by the processing apparatus **3**, which is a light source driver that controls the backlight **1**, is equal to the number of bits of output luminance information, but the method according to the present embodiment is not necessarily applied thereto. For example, configuring the circuit apparatus **100** and the display system **200** as shown in FIG. **7** allows the method according to the present embodiment to be applicable to even a case where the number of bits processed by the processing apparatus **3**, which controls the backlight **1**, is greater than the number of bits of the output luminance information. The number of bits processed by the processing apparatus **3** is hereinafter denoted as q as appropriate. FIG. **7** differs from FIG. **3** in that the configuration shown in FIG. **7** further includes a lower bit setting section **170** and FIG. **7** shows the processing apparatus **3**. The lower bit setting section **170** can be achieved by the processor described above. The lower bit setting section **170** may be further provided in the circuit apparatus **100** shown in FIG. **1**. The number of bits processed by the processing apparatus **3** is determined as appropriate based, for example, on the number of bits that a CPU that constitutes the processing apparatus **3** can process in one clock, and the number of bits per unit in the communication between the processing apparatus **3** and the circuit apparatus **100**.

In the exemplary configuration in FIG. **7**, the dithering (step S**300**) in FIG. **3** may be performed by carrying out the processes shown in FIG. **8**. The circuit apparatus **100** carries out the process of checking the number of bits processed by the processing apparatus **3** (step S**310**). Specifically, for example, the circuit apparatus **100** includes an interface that is not shown, and the lower bit setting section **170** receives, via the interface, information on the number of bits handled by the processing apparatus **3** from the processing apparatus **3**. When the interface receives, for example, data containing a packet "00" from the processing apparatus **3**, the interface analyzes the data, recognizes that the number of bits processed by the processing apparatus **3** is 8, and transmits information on the number of bits to the lower bit setting section **170**. Similarly, when the number of bits processed by the processing apparatus **3** is 10, the packet is set at "01"; when the number of bits processed by the processing apparatus **3** is 12, the packet is set at "10"; when the number of bits processed by the processing apparatus **3** is 16, the packet is set at "11"; and so on. The lower bit setting section **170** then carries out the process of comparing the number of bits (q) handled by the processing apparatus **3** with the number of bits (m) of the luminance information transmitted from the luminance information extraction section **120**.

Thereafter, for example, when the number of bits (q) processed by the processing apparatus **3** is equal to the number of bits of the luminance information (q=m), the circuit apparatus **100** executes step S**320**. Step S**320** in FIG. **8**, however, differs from step S**320** in FIG. **3** in terms of points below. Specifically, for example, when the number of bits processed by the processing apparatus **3** and the number of bits of the luminance information are 8, the lower bit setting section **170** carries out the processes of setting the number of bits k for dithering at a desired number, deleting the lower k bits from the grayscale values of the luminance information, and transmitting the luminance information after the deletion to the dithering section **130**. In FIG. **7**, the luminance information after the deletion is denoted as CK. When q=m, the value indicated by CK is the value as the result of the deletion of the lower k bits from the value of C.

The dithering section **130** then executes step S**350** and terminates the procedure. In FIG. **7**, the output luminance information to which the bits for dithering has been added is denoted as CKD. Step S**350** in FIG. **8**, when compared with step S**350** in FIG. **3**, has a common process content and process executer. On the other hand, step S**320** in FIG. **8** differs from step S**320** in FIG. **3** in terms of process executer, as described above. As described above, in the circuit apparatus **100** according to the present embodiment, when the number of bits of the luminance information is m (m is integer greater than or equal to 2) and the number of bits for dithering is k (k is integer greater than or equal to 1), and when the number of bits processed by the processing apparatus **3** is m, the lower bit setting section **170** outputs the luminance information from which the lower k bits have been deleted to the dithering section **130**. Luminance information formed of an appropriate amount of information can thus be transmitted to the dithering section **130** when the number of bits processed by the processing apparatus **3** is equal to the number of bits of the luminance information.

When it is considered reasonable that the number of bits processed by the processing apparatus **3** (q) is the sum of the number of bits of luminance information (m) and the number of bits for dithering (k) (q=m+k), the circuit apparatus **100** executes step S**350** without executing step S**320**. Specifically, assume, for example, that q=10 and m=8. In this case, when k=2, q=m+k is satisfied. When the luminance information is formed of 8 bits, the lower bit setting section **170** determines that q=m+k is satisfied because setting the number of bits for dithering at 2 is reasonable. A case where q=m+k is satisfied and k does not fall within the reasonable range will be described later. The lower bit setting section **170** then carries out the process of transmitting the luminance information transmitted from the luminance information extraction section **120** as is to the dithering section **130**. When q=m+k is satisfied, the value indicated by CK is equal to the value of C. As described above, in the circuit apparatus **100** according to the present embodiment, when the number of bits of the luminance information is m (m is integer greater than or equal to 2) and the number of bits for dithering is k (k is integer greater than or equal to 1), and when the number of bits processed by the processing apparatus **3** is m+k, the lower bit setting section **170** outputs the luminance information to the dithering section **130** without deleting the lower bits. Luminance information formed of an appropriate amount of information can thus be transmitted to the dithering section **130** when the number of bits processed by the processing apparatus **3** is handled as the sum of the number of bits of the luminance information and the number of bits for dithering.

For example, when the luminance information received by the dithering section **130** is 11111010, 10-bit values, 1111101000, 1111101001, 1111101010, and 1111101011, are periodically generated in step S**350** as the output image information indicated by CKD. The dithering section **130** then transmits the 10-bit output luminance information to the processing apparatus **3**. As described above, the circuit apparatus **100** according to the present embodiment further includes the lower bit setting section **170**. The lower bit setting section **170** carries out the process of setting the lower bits of the luminance information from the luminance information extraction section **120** in accordance with the number of bits processed by the processing apparatus **3**, which controls the backlight **1** based on the output luminance information, and outputs the set luminance information to the dithering section **130**. The sticking can thus be quickly detected when the number of bits processed by the processing apparatus **3** differs from the number of bits of the luminance information.

The number of upper bits extracted by the subsequent upper bit extraction (step S**390**) remains the same as the number of upper bits extracted in steps S**190** and S**290**, that is, 4, as described above, so that 1111 is transmitted as the upper 4 bits. In other words, the upper bits transmitted from the dithering section **130** to the upper bit comparison section **150** in the example in FIG. **7** are the values indicated by CD**1** as in FIGS. **1** and **3**.

The circuit apparatus **100** and display system **200** according to the present embodiment may, for example, be configured as shown in FIG. **9**. FIG. **9** differs from FIG. **7** in that the circuit apparatus **100** further includes a bright/dark level evaluation section **180**. When the circuit apparatus **100** and display system **200** are configured as shown by way of example in FIG. **9**, the dithering (step S**300**) may, for example, be performed by carrying out the processes shown in FIG. **10**. FIG. **10** differs from FIG. **8** in that the process in step S**310** bifurcates not only into the process in S**320** but into the processes in steps S**330** and S**340**. In the description with reference to FIGS. **9** and **10**, the portions that duplicate those in FIGS. **1** to **8** will be omitted as appropriate.

In step S**310**, when q cannot be expressed by q=m+k, but can be expressed by q=m+k+p (where p is integer greater than or equal to 1), the circuit apparatus **100** carries out the process of evaluating the bright/dark level (step S**330**) and the process of adding a p-bit value to the lower part of the luminance information in accordance with the result of the evaluation (step S**340**), and then carries out the step S**350** described above. Specifically, for example, when q=12 and m=8, then k=4 is employed to represent q by q=m+k. However, 4 bits as the number of bits for dithering are too large with respect to the luminance information formed of 8 bits, and are therefore not appropriate. It is therefore determined that q is reasonably expressed, for example, by q=m+k+p with k and p each set at 2.

The bright/dark level evaluation (step S**330**) evaluates whether the light based on the luminance information is the "bright light" or the "dark light. More specifically, the bright/dark level evaluation section **180** receives the upper m/2 bits of the luminance information, that is, the value of C**1** described above in FIG. **1** from the luminance information extraction section, evaluates whether the value of C**1** is greater than or equal to 1, and transmits the result to the lower bit setting section **170**.

The mechanism by which the bright/dark level can be evaluated from the upper m/2 bits will now be described with reference to the graph in FIG. **11**. When normalized brightness is expressed along the vertical axis, and the luminance information is expressed along the horizontal axis, the brightness of the light output from the light sources is proportional to the grayscale value, so that the relationship between the brightness and the luminance information is a linear relationship as indicated, for example, by F**1**. On the other hand, it is known from Weber-Fechner's law that the relationship between human brightness perception and the luminance information is expressed by a logarithmic function indicated by F**2**. In the graph of F**2**, let H**1** be the luminance information, and H**2** be the standard value of the human brightness perception for the luminance information of H**1**. For example, when the luminance information on the horizontal axis is 8 bits, and H**2**=0.5, H**1** is approximately around 4 bits. That is, when the value of the upper 4 bits of the luminance information, which is formed of 8 bits, is greater than or equal to 1, the value of the graph in FIG. **11** on the vertical axis is greater than 0.5. That is, under the assumption that light corresponding to value of the graph in FIG. **11** on the vertical axis being greater than 0.5 is the bright light and humans can recognize the light, humans can recognize that light based on luminance information in which the value of the upper 4 bits of the luminance information formed of 8 bits is greater than or equal to 1 is the "bright light". Similarly, for example, light based on luminance information in which the value of the upper 5 bits of the luminance information formed of 10 bits is greater than or equal to 1 can be perceived by humans as the bright light.

As described above, evaluating whether the value of the upper m/2 bits of the m-bit luminance information is greater than or equal to 1 or 0 allows determination of whether the light from the light sources based on the luminance information is the "bright light" or the "dark light. The method described above is also applicable to the number of upper bits in steps S**190** and S**290** having been described above with reference to FIG. **3**. The constant m may be an odd number in the present embodiment, but setting m at an even number makes the application of the method according to the present embodiment easier. That is, in the circuit apparatus **100** according to the present embodiment, the upper bits of the luminance information are the upper m/2 bits out of the m bits in a case where the number of bits of the luminance information is m (m is even number greater than or equal to 2). The range of the upper bits of the luminance information can thus be set appropriately. On the assumption that humans can recognize that light corresponding to value of the graph in FIG. **11** on the vertical axis being greater than 0.6 is the bright light, humans can recognize that light based on luminance information in which the value of the upper 3 bits of the luminance information formed of 8 bits is greater than or equal to 1 is the "bright light".

For example, when the luminance information evaluated in step S**330** is luminance information based on the "bright light", a value of 1 is added to each of the lower bits of the luminance information in step S**340**. For example, assume that q=12, m=8, k=2, and p=2, and that the lower bit setting section **170** receives information indicating that the light is the "bright light" from the bright/dark level evaluation section **180** and receives luminance information of 11111111 (=255) from the luminance information extraction section **120**. In this case, "11" is added to the luminance information, and the result of the addition is transmitted as 1111111111 (=1024) to the dithering section **130**. The fact that the luminance information is information on the "bright light" can thus be clarified.

On the other hand, for example, when the luminance information evaluated in step S**330** is luminance information based on the "dark light", the lower bit setting section **170** adds in step S**340** a value of 0 to each of the lower bits of the luminance information in step S**340**. For example, assume that q=12, m=8, k=2, and p=2, and that the lower bit setting section **170** receives information indicating that the light is the "dark light" from the bright/dark level evaluation section **180** and receives luminance information of 00000000 (=0) from the luminance information extraction section **120**. In this case, "00" is added to the luminance information to change it to 0000000000 (=0). The fact that the luminance information is information on the "dark light" can thus be clarified.

Thereafter, although not shown, the lower bit setting section **170** carries out the process of transmitting the luminance information with the p-bit value added to the lower part thereof to the dithering section **130**. In the example in FIG. **9**, the luminance information transmitted from the lower bit setting section **170** to the dithering section **130** is denoted as CQ. When q=m+k+p is satisfied, the value of CQ is a value to which the lower p bits of the luminance information indicated by C are added. The value of CQ is otherwise equal to the value of CK in FIG. **7**.

The circuit apparatus **100** then executes step S**350** and terminates the procedure. For example, the dithering section **130** having received the luminance information indicated by CQ adds 2 bits, which are bits for dithering, to the luminance information and transmits the resultant information as 12-bit output luminance information to the processing apparatus **3**.

In FIG. **9**, the output luminance information to which the bits for the dithering have been added is denoted as CQD. In the example in FIG. **9**, the upper bits transmitted to the upper bit comparison section **150** by the subsequent upper bit extraction (step S**390**) is the value indicated by CD**1**, as in FIG. **7**.

As described above, the circuit apparatus **100** according to the present embodiment further includes the bright/dark level evaluation section **180**, which evaluates whether the image information is on a bright or dark image based on the luminance information. When the number of bits of the luminance information is m (m is integer greater than or equal to 2), the number of bits for dithering is k (k is integer greater than or equal to 1), and the number of processed bits is m+k+p (p is integer greater than or equal to 1), the lower bit setting section **170** adds lower bits the number of which is p according to the result of the evaluation performed by the bright/dark level evaluation section **180** to the luminance information. Luminance information formed of an appropriate amount of information can thus be transmitted to the dithering section **130** when the number of bits processed by the processing apparatus **3** is greater than the sum of the number of bits of the luminance information and the number of bits for dithering.

The method according to the present embodiment is not limited to the method described above. For example, the display apparatus **10** may be divided into a plurality of areas AR, and the method according to the present embodiment may be applied to each of the divided areas AR. For example, in FIG. **12**, the backlight **1** includes a light source LS**11**, a light source LS**12**, a light source LS**13**, a light source LS**14**, a light source LS**21**, a light source LS**22**, a light source LS**23**, a light source LS**24**, a light source LS**31**, a light source LS**32**, a light source LS**33**, a light source LS**34**, a light source LS**41**, a light source LS**42**, a light source LS**43**, and a light source LS**44**. That is, the method according to the present embodiment may be applied to the display areas of the display apparatus **10** divided in correspondence with the arrangement of the light sources LS**11** to LS**44**. To simplify the description, the backlight **1**, the electro-optical panel **5**, and the display apparatus **10** are assumed to have the same area. The display area corresponding to the light source LS**11** is called an area AR**11**. That is, the display area of the display apparatus **10** can be divided into the area AR**11**, an area AR**12**, an area AR**13**, an area AR**14**, an area AR**21**, an area AR**22**, an area AR**23**, an area AR**24**, an area AR**31**, an area AR**32**, an area AR**33**, an area AR**34**, an area AR**41**, an area AR**42**, an area AR**43**, and an area AR**44**. It is assumed in FIG. **12** that 4 light sources are arranged along a direction D**1** on a row basis and 4 light sources are arranged along a direction D**2** on a column basis only by way of example. The areas AR are used by the circuit apparatus **100** to carry out the processes, and there is no boundary between the areas AR in a display image actually displayed on the electro-optical panel **5**. It is assumed in the present embodiment that the light intensity distribution of the light from the light sources is not considered.

For example, when the display system **200** is used for automotive applications, the predetermined device outputs the image information shown in FIG. **13** to the circuit apparatus **100**. The regions indicated by the dotted lines in FIG. **13** correspond to the areas AR**11** to AR**44** in FIG. **12**. The image information is information at each pixel in the regions labeled with K**1**, which are within the solid line labeled with K**0**, and includes, for example, a meter image labeled with K**2** and warning light images labeled with K**3** and K**4**. For clarity of the display, the regions other than the images labeled with K**2**, K**3**, and K**4** are black images ((R, G, B)=(0, 0, 0)) as the initial image, although the regions are not colored. The image of the meter labeled with K**2** is assumed to be a white image ((R, G, B)=(255, 255, 255)). It is further assumed that the image of the warning light labeled with K**3** is a yellow image ((R, G, B)=(255, 255, 0)) and the image of the warning light labeled with K**4** is a red image ((R, G, B)=(255, 0, 0)).

For example, when the predetermined instrument including the display system **200** is activated, the predetermined device outputs image information on an image that is superimposition of the initial image and the meter image labeled with K**2** to the circuit apparatus **100**. The circuit apparatus then carries out the processes in FIG. **2** for each of the areas AR**11** to AR**44**. For example, since only the black initial image ((R, G, B)=(0, 0, 0)) is displayed in the area AR**11**, the luminance information is **0** as described above, and the output luminance information to which the bits for dithering based on **0** have been added is transmitted to the processing apparatus **3**. The light source LS**11** corresponding to the area AR**11** thus practically does not emit light. The same holds true for the areas AR**12**, AR**13**, AR**14**, AR**21**, AR**24**, AR**31**, AR**34**, AR**41**, AR**42**, AR**43**, and AR**44**. On the other hand, the areas AR**22**, AR**23**, AR**32**, and AR**33** contain the white ((R, G, B)=(255, 255, 255)) meter image, so that 255 is extracted as the color information in the color information extraction (step S**20**). As a result, the luminance information extracted by the luminance information extraction (step S**200**) becomes 255, and the output luminance information having undergone the dithering (step S**300**) based on the luminance information is transmitted to the display apparatus **10**. The light sources LS**22**, LS**23**, LS**32**, and LS**33** are thus turned on. As described above, in the circuit apparatus **100** according to the present embodiment, the luminance information extraction section **120** extracts the luminance information from the color information for each of the plurality of areas AR of the electro-optical panel **5**. The luminance information can thus be grasped for each of the areas AR, into which the display apparatus **10** is segmented.

In addition, the color correction (step S**100**) is performed on the image information in the areas AR**22**, AR**23**, AR**32**, and AR**33**. That is, the areas AR**22**, AR**23**, AR**32**, and AR**33** are so controlled that a white color tone is produced as the meter image. To check whether the sticking has occurred in the light sources LS**22**, LS**23**, LS**32**, and LS**33**, the value of Aγ**1** is output from the image color correction section **140** to the upper bit comparison section **150**. As described above, in the circuit apparatus **100** according to the present embodiment, the image color correction section **140** outputs the upper bits of the output image information to the upper bit comparison section **150** for each of the plurality of areas AR of the electro-optical panel **5**. The output image information can thus be grasped for each of the areas AR, into which the display apparatus **10** is segmented.

For example, when an event relating to the warning light labeled with K**3** is sensed, the predetermined device transmits image information to which the image labeled with K**3** has been added to the circuit apparatus **100**. As a result, in the area AR**12**, color information containing a bright color is extracted by the color information extraction (step S**20**), luminance information on the luminance of bright light is extracted by the luminance information extraction (step S**200**), and output luminance information based on the bright light is transmitted to the display apparatus **10** by the dithering (step S**300**). The light source LS**12** is thus turned on, and the user can clearly recognize the yellow warning light labeled with K3 in the area AR12. In the event of the sticking, even when the user cannot recognize the yellow warning light labeled with K3, the method according to the present embodiment allows the user to quickly recognize the event relating to the warning light. The user can thus quickly and appropriately take measured against the event relating to the warning light.

Similarly, when an event relating to the warning light labeled with K4 is sensed, the user can clearly recognize the red warning light labeled with K4 in the area AR13. In the event of the sticking, even when the user cannot recognize the red warning light labeled with K4, the method according to the present embodiment allows the user to quickly recognize the event relating to the warning light. The user can thus quickly and appropriately take measured against the event relating to the warning light.

The display system **200** according to the present embodiment can be implemented, for example, as a variation in which another configuration is added. For example, although not shown, the display system **200** may further include a distortion correction IC. In this case, the distortion-correction IC performs distortion correction on the image information generated by the predetermined device, and the image information having undergone the distortion correction is transmitted to the circuit apparatus **100**. In this case, the image information shown in FIG. **13** described above is transmitted, for example, as the image information shown in FIG. **14** to the circuit apparatus **100**. The outer shape of the image information labeled with K**0** is distorted, as labeled with K**10**. Similarly, the meter image labeled with K2 becomes the shape labeled with K**12**, the warning light image labeled with K3 becomes the shape labeled with K**13**, and the warning light image labeled with K4 becomes the shape labeled with K**14**. An HUD can thus be configured by combining, for example, a mirror, a transparent screen, and other components none of which is shown with each other, and an image having an appropriate shape can be projected on the transparent screen. The transparent screen is, for example, an automobile windshield.

In FIG. **14**, for example, the image labeled with K**12** is disposed in the areas AR**22**, AR**23**, AR**32**, and AR**33**, as the image labeled with K2 in FIG. **13** is. Similarly, the image labeled with K**13** is disposed in the area AR**12**, as the image labeled with K3 in FIG. **13** is. Similarly, the image indicated by K**14** is disposed in the area AR**13**, as the image indicated by K4 in FIG. **13** is. Changing the image information in FIG. **13** to that in FIG. **14** therefore does not change the area where whether the sticking has occurred needs to be checked. The distortion correction may, however, change the arrangement of the images, in which case the area that needs to be checked for the sticking is changed appropriately.

As described above, a circuit apparatus according to the present embodiment controls a display apparatus including a backlight and an electro-optical panel, and includes a color information extraction section, a luminance information extraction section, a dithering section, an image color correction section, and an upper bit comparison section. The color information extraction section extracts color information from image information. The luminance information extraction section extracts luminance information for controlling the luminance of the backlight based on the color information. The dithering section adds bits for dithering to the lower bit side of the luminance information and outputs the luminance information after the addition to the display apparatus as output luminance information. The image color correction section corrects the color of the image information and outputs the corrected image information as output image information to the display apparatus. The upper bit comparison section compares upper bits of the luminance information, the upper bits of the output luminance information, and the upper bits of the output image information with each other.

As described above, in the circuit apparatus according to the present embodiment, comparing the upper bits of the luminance information, the upper bits of the output luminance information, and the upper bits corresponding to the output image information with each other allows detection of whether the sticking has occurred at an appropriate timing.

In the present embodiment, the upper bit comparison section may output a first error detection signal when the results of the comparison between the upper bits of the luminance information, the upper bits of the output luminance information, and the upper bits of the output image information show that the three sets of upper bits disagree with one another.

The user can thus quickly recognize that the sticking has occurred.

The circuit apparatus according to the present embodiment may further include a preceding and following frame comparison section that compares the output luminance information for the (N−1)-th frame with the output luminance information for the N-th frame, where N is an integer greater than or equal to 2.

Whether the sticking has occurred can thus be grasped on a frame update timing basis.

In the present embodiment, the preceding and following frame comparison section may output a second error detection signal when the output luminance information for the (N−1)-th frame is identical to the output luminance information for the N-th frame.

The user can thus quickly grasp that the dithering is not functioning properly.

In the present embodiment, the luminance information extraction section may extract the luminance information based on a color component having highest luminance out of a plurality of color components in the color information.

Luminance information for controlling a light source of the display apparatus, which displays the image information for displaying colors including the plurality of color components, can thus be extracted appropriately.

In the present embodiment, the image color correction section may output the upper bits of the output image information to the upper bit comparison section based on the color component having the largest value among the plurality of color components in the output image information.

The image color correction section can thus appropriately extract the upper bits of the output image information containing the plurality of color components and transmit the extracted upper bits to the upper bit comparison section.

In the present embodiment, the luminance information extraction section may extract the luminance information from the color information for each of a plurality of areas of the electro-optical panel.

The luminance information can thus be grasped for each of the areas into which the display apparatus is segmented.

In the present embodiment, the image color correction section may output the upper bits of the output image information to the upper bit comparison section for each of the plurality of areas of the electro-optical panel.

The output image information can thus be grasped for each of the areas into which the display apparatus is segmented.

In the present embodiment, the upper bits of the luminance information may be upper m/2 bits out of m bits, where m is the number of bits of the luminance information (m is even number greater than or equal to 2).

The range of the upper bits of the luminance information can thus be set appropriately.

In the present embodiment, the circuit apparatus may further include a lower bit setting section that carries out the process of setting lower bits of the luminance information from the luminance information extraction section in accordance with the number of bits processed by a processing apparatus that controls the backlight based on the output luminance information, and outputs the set luminance information to the dithering section.

The sticking can thus be quickly detected when the number of bits processed by the processing apparatus differs from the number of bits of the luminance information.

In the present embodiment, when the number of bits processed by the processing apparatus is m, the lower bit setting section may output the luminance information from which lower k bits are deleted to the dithering section, where m represents the number of bits of the luminance information (m is integer greater than or equal to 2), and k represents the number of bits for dithering (k is integer greater than or equal to 1).

Luminance information formed of an appropriate amount of information can thus be transmitted to the dithering section when the number of bits processed by the processing apparatus is equal to the number of bits of the luminance information.

In the present embodiment, when the number of bits processed by the processing apparatus is m+k, the lower bit setting section may output the luminance information without deletion of the lower bits to the dithering section, where m represents the number of bits of the luminance information (m is integer greater than or equal to 2), and k represents the number of bits for dithering (k is integer greater than or equal to 1).

Luminance information formed of an appropriate amount of information can thus be transmitted to the dithering section when the number of bits processed by the processing apparatus is handled as the sum of the number of bits of the luminance information and the number of bits for dithering.

In the present embodiment, the circuit apparatus may further include a bright/dark level evaluation section that evaluates whether the image information is on a bright or dark image based on the luminance information. The lower bit setting section may add lower bits the number of which is p according to the result of the evaluation performed by the bright/dark level evaluation section to the luminance information, where m represents the number of bits of the luminance information (m is integer greater than or equal to 2), k represents the number of bits for dithering (k is integer greater than or equal to 1), and m+k+p represents the number of processed bits (p is integer greater than or equal to 1).

Luminance information formed of an appropriate amount of information can thus be transmitted to the dithering section when the number of bits processed by the processing apparatus is greater than the sum of the number of bits of the luminance information and the number of bits for dithering.

A display system according to the present embodiment includes the circuit apparatus and the display apparatus described above.

The present embodiment has been described above in detail, and a person skilled in the art will readily appreciate that a large number of variations are conceivable to the extent that they do not substantially depart from the novel items and effects of the present disclosure. Such variations are all therefore assumed to fall within the scope of the present disclosure. For example, a term described at least once in the specification or the drawings along with a different term having a broader meaning or the same meaning can be replaced with the different term anywhere in the specification or the drawings. Furthermore, all combinations of the present embodiment and the variations fall within the scope of the present disclosure. Moreover, the configuration, operation, and other factors of each of the circuit apparatus, the display system, and the like are not limited to those described in the present embodiment and can be changed in a variety of manners.

What is claimed is:

1. A circuit apparatus that controls a display apparatus including a backlight and an electro-optical panel, the circuit apparatus comprising:

a color information extraction section that extracts color information from image information;

a luminance information extraction section that extracts luminance information for controlling luminance of the backlight based on the color information;

a dithering section that adds bits for dithering to a lower bit side of the luminance information and outputs the luminance information after the addition to the display apparatus as output luminance information;

an image color correction section that corrects a color of the image information and outputs the corrected image information as output image information to the display apparatus; and

an upper bit comparison section that compares upper bits of the luminance information, upper bits of the output luminance information, and upper bits of the output image information with each other.

2. The circuit apparatus according to claim **1**,

wherein the upper bit comparison section outputs a first error detection signal when results of the comparison between the upper bits of the luminance information, the upper bits of the output luminance information, and the upper bits of the output image information show that the three sets of upper bits disagree with one another.

3. The circuit apparatus according to claim **1**, further comprising

a preceding and following frame comparison section that compares the output luminance information for an (N−1)-th frame with the output luminance information for an N-th frame, where N is an integer greater than or equal to 2.

4. The circuit apparatus according to claim **3**,

wherein the preceding and following frame comparison section outputs a second error detection signal when the output luminance information for the (N−1)-th frame is identical to the output luminance information for the N-th frame.

5. The circuit apparatus according to claim **1**,

wherein the luminance information extraction section extracts the luminance information based on a color component having highest luminance out of a plurality of color components in the color information.

6. The circuit apparatus according to claim **1**,

wherein the image color correction section outputs the upper bits of the output image information to the upper bit comparison section based on a color component having a largest value among a plurality of color components in the output image information.

7. The circuit apparatus according to claim 1,
wherein the luminance information extraction section extracts the luminance information from the color information for each of a plurality of areas of the electro-optical panel.

8. The circuit apparatus according to claim 1,
wherein the image color correction section outputs the upper bits of the output image information to the upper bit comparison section for each of a plurality of areas of the electro-optical panel.

9. The circuit apparatus according to claim 1,
wherein the upper bits of the luminance information are upper m/2 bits out of m bits, where m is a number of bits of the luminance information (m is even number greater than or equal to 2).

10. The circuit apparatus according to claim 1, further comprising
a lower bit setting section that carries out process of setting lower bits of the luminance information from the luminance information extraction section in accordance with a number of bits processed by a processing apparatus that controls the backlight based on the output luminance information, and outputs the set luminance information to the dithering section.

11. The circuit apparatus according to claim 10,
wherein when the number of bits processed by the processing apparatus is m, the lower bit setting section outputs the luminance information from which lower k bits are deleted to the dithering section, where m represents a number of bits of the luminance information (m is integer greater than or equal to 2), and k represents a number of bits for dithering (k is integer greater than or equal to 1).

12. The circuit apparatus according to claim 10,
wherein when the number of bits processed by the processing apparatus is m+k, the lower bit setting section outputs the luminance information without deletion of lower bits to the dithering section, where m represents a number of bits of the luminance information (m is integer greater than or equal to 2), and k represents a number of bits for dithering (k is integer greater than or equal to 1).

13. The circuit apparatus according to claim 10, further comprising
a bright/dark level evaluation section that evaluates whether the image information is on a bright or dark image based on the luminance information,
wherein the lower bit setting section adds lower bits a number of which is p according to a result of the evaluation performed by the bright/dark level evaluation section to the luminance information, where m represents a number of bits of the luminance information (m is integer greater than or equal to 2), k represents a number of bits for dithering (k is integer greater than or equal to 1), and m+k+p represents the number of bits processed by the processing apparatus (p is integer greater than or equal to 1).

14. A display system comprising:
the circuit apparatus according to claim 1; and
the display apparatus.

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