SOLID STATE IMAGING DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2015-177514; filed on September 9, 2015; the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a solid state imaging device.

BACKGROUND

Pixel-based noise caused by a pixel, and circuit-based noise caused by a circuit are known as main noise affecting imaging of a solid state imaging device. The pixel-based noise includes fixed pattern noise which is generated in a specified pixel due to a dark current of the pixel, and random noise which is generated at random in each pixel due to electric noise at the time of reading a signal. In the pixel-based noise, random noise which is generated as random roughness of the entire image is dominant. The circuit-based noise is generated as a fixed pattern of a vertical line or a horizontal line.

Recently, in order to adjust balance of the generated amount of a random noise that is the pixel-based noise and fixed pattern noise that is the circuit-based noise, a technology of adding random noise to a pixel signal is known. It is preferable that a solid state imaging device adjusts the amount of noise, and thereby image quality can be efficiently increased.

An example of related art includes JP-A-2014-143497.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a solid state imaging device according to an embodiment.

FIG. 2 is a block diagram of a camera system including the solid state imaging device illustrated in FIG. 1.

FIG. 3 is a block diagram of a noise supplement circuit illustrated in FIG. 1.

FIG. 4 is a graph illustrating an operation of a level limitation circuit illustrated in FIG. 3.

FIG. 5 is a graph illustrating a distribution of a signal level in a case in which the level limitation circuit illustrated in FIG. 3 does not limit an supplement signal.

FIG. 6 is a graph illustrating another distribution of a signal level in a case in which the level limitation circuit illustrated in FIG. 3 limit the supplement signal.

DETAILED DESCRIPTION

[0005]An exemplary embodiment provides a solid state imaging device which can improve image quality by adjusting the amount of noise.

[0006]In general, according to one embodiment, a solid state imaging device includes a pixel region, an output circuit, an addition circuit, and a limitation circuit. The pixel region includes a pixel. The pixel region outputs a pixel signal in accordance with a light amount incident on the pixel. The output circuit outputs an supplement signal whose output level is changed depending on a random number. The addition circuit adds the supplement signal to the pixel signal. The limitation circuit limits the supplement signal that is added to the pixel signal by the addition circuit according to an output level of the supplement signal.

[0008]A solid state imaging device according to the present embodiment will be hereinafter described with reference to the accompanying drawings. The invention is not limited to the embodiment.

Embodiment

[0009]FIG. 1 is a block diagram of a solid state imaging device according to an embodiment. FIG. 2 is a block diagram of a camera system including the solid state imaging device 5 illustrated in FIG. 1. The camera system 1 is an electronic apparatus including a camera module 2, for example, a camera-equipped mobile terminal. The camera system 1 may be an electronic apparatus such as a digital camera.

[0010]The camera system 1 includes the camera module 2 and a post-stage processing unit 3. The camera module 2 includes an imaging optical system 4 and a solid state imaging device 5. The post-stage processing unit 3 includes an image signal process (ISP) 6, a recording unit 7, and a display unit 8.

[0011]The imaging optical system 4 receives light from a subject. The imaging optical system 4 includes an imaging lens (not illustrated) focuses a subject image. The solid state imaging device 5 images a subject image. The solid state imaging device 5 is a complementary metal oxide semiconductor (CMOS) image sensor. The solid state imaging device 5 may be a charge coupled device (CCD).

[0012]The ISP 6 performs signal processing on an image signal from the solid state imaging device 5. The ISP 6 performs various signal processing such as, demosaic processing, white balance adjustment, color matrix processing, or gamma correction. The recording unit 7 records an image which is obtained by signal processing performed by the ISP 6, in a recording medium or the like. The recording unit 7 outputs an image signal to the display unit 8 according to an operation of a user.

[0013]The display unit 8 displays an image according to an image signal from the ISP 6, or an image signal which is read from the recording unit 7. The display unit 8 is, for example, a liquid crystal display. The camera system 1 performs a feed-back control of the camera module 2, based on the data which is obtained by signal processing of the ISP 6.

[0014]The solid state imaging device 5 includes a pixel region 11, a control circuit 12, a row scanning circuit 13, a column scanning circuit 14, a column processing circuit 15, and an imaging processing circuit 16. The pixel region 11 includes pixels which are arranged in a matrix. The pixel includes a photo diode which is an electro-optical conversion element. The electro-optical conversion element generates signal charges in accordance with an incident light amount. The pixel accumulates the signal charges which are generated according to the incident light amount. The pixel region 11 outputs the pixel signal in accordance with the incident light amount to the pixel.

[0015]The control circuit 12, the row scanning circuit 13, the column scanning circuit 14, the column processing circuit 15, and the imaging processing circuit 16 configure a peripheral circuit that is integrated in a chip in which the pixel region 11 is formed. Various data and blocks for driving the solid state imaging device 5 are supplied to the control circuit 12 through the imaging processing circuit 16 from the ISP 6 in the outside of the chip.

[0016]The control circuit 12 generates various pulse signals for controlling drive of a peripheral circuit portion, in response to a clock signal. The control circuit 12 supplies pulse signals indicating driving timing to each of the row scanning circuit 13, the column scanning circuit 14, the column processing circuit 15, and the imaging processing circuit 16.

[0017]The row scanning circuit 13 includes a shift register, an address decoder, or the like. The row scanning circuit 13 that is a pixel drive circuit supplies the pixels of the pixel region 11 with a drive signal. The control circuit 12 supplies the row scanning circuit 13 with a pulse signal in accordance with a vertical synchronization signal. The row scanning circuit 13 sequentially selects pixel rows from which pixel signals are read, according to the pulse signals from the control circuit 12. The row scanning circuit 13 performs read scanning by sequentially supplying read signals to each pixel in the selected pixel row. The read signals are drive signals for reading pixel signals generated according to an incident light amount, from the pixels.

[0018]The row scanning circuit 13 performs read scanning in accordance with supply of reset signals to each pixel, prior to supply of the read signals to each pixel. The reset signals are drive signals for discharging charges remaining in an electro-optical conversion element. Each pixel accumulate signal charges which are generated according to an incident light amount, during a period from when the reset signals are supplied until the read signals are supplied.

[0019]The drive signals are transmitted from the row scanning circuit 13 to each pixel through pixel drive lines 17. The pixel drive lines 17 are provided in each pixel row of the pixel region 11. The pixel rows are configured by pixels which are arranged in a row direction (horizontal direction).

[0020]The pixel signals are transmitted from each pixel to the column processing circuit 15 through vertical signal lines 18. The vertical signal lines 18 are provided in each pixel column of the pixel region 11. The pixel column is configured by the pixels which are arranged in a column direction (vertical direction).

[0021]The column processing circuit 15 performs processing on the pixel signals which are transmitted through the vertical signal lines 18, in unit circuits (not illustrated) which are provided in each pixel column. The column processing circuit 15 performs correlated double sampling (CDS) processing for reducing fixed pattern noise, with respect to the pixel signals. The column processing circuit 15 performs an AD conversion of converting a pixel signal that is an analog signal into a digital signal. The column processing circuit 15 may perform processing other than the CDS and AD conversion. The column processing circuit 15 retains the pixel signals which are obtained through the CDS and AD conversion, in each unit circuit.

[0022]The column scanning circuit 14 includes a shift register, an address decoder, and the like. The control circuit 12 supplies the column scanning circuit 14 with a pulse signal in accordance with a horizontal synchronization signal. The column scanning circuit 14 sequentially selects the pixel columns from which the pixel signals are output, according to the pulse signal from the control circuit 12. The column processing circuit 15 sequentially outputs retained in each unit circuit, according to select scanning performed by the column scanning circuit 14.

[0023]The imaging processing circuit 16 performs processing on the pixel signals from the column processing circuit 15. The imaging processing circuit 16 includes a black level adjustment circuit 19 and a noise supplement circuit 20. The black level adjustment circuit 19 adjusts a black level of the pixel signal. The black level is a signal level which uses the time when a level of brightness is represented as gradation, as a reference, and is a signal level which represents the lowest gradation.

[0024]The noise supplement circuit 20 adds random noise components to the pixel signal which is adjusted by the black level adjustment circuit 19. For example, if random noise that is pixel-based noise and horizontal line noise that is circuit-based noise are generally generated on a screen at 15 to 1 ratio, both the noises become less noticeable visually. The noise supplement circuit 20 adds the random noise component to the pixel signal, thereby adjusting a balance of the generated amount of the pixel-based noise and the circuit-based noise. If the pixel-based noise is generated, a level of the pixel signal becomes a level different from a level in accordance with light incident on the pixel. The noise supplement circuit 20 adds the random noise components to the pixel signal, thereby generating a pixel signal with a level different from a level in accordance with light incident on the pixel, in the same manner as the random noise that is a pixel-based noise.

[0025]The imaging processing circuit 16 may be configured in various types to perform signal processing, in addition to the black level adjustment circuit 19 and the noise supplement circuit 20. The imaging processing circuit 16 may have a configuration for flaw correction, gamma correction, noise reduction processing, lens shading correction, white balance adjustment, distortion correction, resolution reconstruction, or the like.

[0026]The solid state imaging device 5 outputs a RAW image signal that is a signal through signal processing performed by the imaging processing circuit 16 to the outside of the chip. The camera system 1 may perform the signal processing which is performed by the solid state imaging device 5 according to the present embodiment, in a circuit other than a peripheral circuit portion of a chip which is the same as the pixel region 11. The signal processing may be performed by, for example, the ISP 6 of the post-stage processing unit 3, instead of the peripheral circuit portion. The camera system 1 may perform the signal processing which is performed by the peripheral circuit portion, in both the peripheral circuit and the ISP 6. The peripheral circuit and the ISP 6 may perform signal processing other than the signal processing described in the present embodiment.

[0027]Fig. 3 is a block diagram of the noise supplement circuit 20 illustrated in FIG. 1. The noise supplement circuit 20 includes a noise generation circuit 21, a level limitation circuit 22, an adder 23, a supplement control circuit 24, a selector 25, and registers 26 and 27. The noise generation circuit 21, the level limitation circuit 22, the adder 23, the supplement control circuit 24, and the selector 25 are configured by appropriately combining various logic circuits.

[0028]The noise generation circuit 21 is an output circuit which outputs a supplement signal that is obtained by adding random noise components to a pixel signal. The noise generation circuit 21 generates random numbers with a normal distribution. The noise generation circuit 21 changes an output level of the supplement signal according to the generated random number.

[0029]The level limitation circuit 22 makes supplement signals with an output level of a predetermined range pass through, and blocks supplement signals with an output level other than the predetermined range, among the supplement signals which are output from the noise generation circuit 21. The level limitation circuit 22 is a limitation circuit which limits the supplement signal that is added to a pixel signal by the adder 23 according to an output level of the supplement signal.

[0030]The adder 23 is an addition circuit which adds the supplement signal to the pixel signal that is input to the noise supplement circuit 20. The adder 23 outputs a noise supplement signal to which random noise components are added by supplement of the supplement signal. The noise supplement signal is an supplement addition signal which is a pixel signal to which the supplement signal is added.

[0031]The selector 25 is a select circuit which selects one of the pixel signal that is input to the noise supplement circuit 20 and the noise supplement signal from the adder 23, in response to a control signal from the supplement control circuit 24. The supplement control circuit 24 generates a control signal which is supplied to the selector 25. The noise supplement circuit 20 outputs a signal which is selected by the selector 25.

[0032]The first field plate electrode 26 is a storage element which retains level information on a range of an output level of the supplement signal. The level information is registered in the register 26 when the solid state imaging device 5 is manufactured. The level information which is stored in the first register 26 may be changed depending on a setting operation to the camera system 1, an imaging mode, or the like. The level limitation circuit 22 determines passing-through or blocking of the supplement signal from the noise generation circuit 21, based on the level information registered in the first register 26.

[0033]The second register 27 is a storage element which retains number information on the number of pixels in which random noise components are added to the pixel signal. The number information is registered in the second register 27 when the solid state imaging device 5 is manufactured. The level information which is stored in the second register 27 may be changed depending on a setting operation to the camera system 1, an imaging mode, or the like.

[0034]The supplement control circuit 24 generates a control signal for selecting noise supplement signals of the number which is set in advance per frame, based on the number information registered in the second register 27. The supplement control circuit 24 generates a random number. A control signal is generated to change at random the timing when the noise supplement signal is selected, according to the generated random number.

[0035]The selector 25 selects the noise supplement signal corresponding to the number which is set in advance per frame at timing in accordance with the random number, in response to the control signal from the supplement control circuit 24. The storage element included in the noise supplement circuit 20 is not limited to the first register 26 and the second register 27, and may be a memory. As a result, the noise aupplement circuit 20 can provide random noise of the number which is set in advance to an image by changing a position at random for each frame.

[0036]FIG. 4 illustrates an operation of the level limitation circuit 22 illustrated in FIG. 3. A curved line illustrated in FIG. 4 is a graph representing a distribution of an output level of the supplement signal which is output from the noise generation circuit 21. A horizontal axis of the graph denotes an output level. A vertical axis denotes frequency. The level distribution of the supplement signal is modeled by a normal distribution. The noise generation circuit 21 outputs the supplement signal which changes at random in the normal distribution.

[0037]An output level “0” illustrated in FIG. 4 represents a reference level of the supplement signal which is output from the noise generation circuit 21. The more the output level is separated from “0” on a positive side, the higher the output level is compared to a reference level, and the more the output level is separated from “0” on a negative side, the lower the output level is compared to the reference level. According to the graph of FIG. 4, the noise generation circuit 21 outputs the supplement signal with the reference level at the highest frequency. The more the supplement signal is separated from the reference level on a high level side and a low level side, the lower the frequency of the supplement signal is.

[0038]The level limitation circuit 22 outputs the supplement signal with an output level from +A1 to +A2, and the supplement signal with an output level from –A1 to –A2, among the supplement signals from the noise generation circuit 21, to the adder 23. The level limitation circuit 22 blocks a supplement signal with an output level other than a level range of +A1 to +A2 and –A1 to –A2. In this example, the level limitation circuit 22 limits the supplement signal which is output to the adder 23, to the supplement signal in which an absolute value of the output level is greater than or equal to A1 and is less than or equal to A2.

[0039]The first register 26 retains the values of A1 and A2 as, for example, level information on a level range of the supplement signal. The level limitation circuit 22 determines whether or not the output level of the supplement signal from the noise generation circuit 21 is included in a level range from +A1 to +A2 and from –A1 to –A2, based on the values of A1 and A2 which are registered in advance in the first register 26.

[0040]Te first register 26 may retain at least A1 as the level information. The level limitation circuit 22 blocks the supplement signal in which an absolute value of the output level is less than A1, and thereby the supplement signal which is output to the adder 23 may be limited. The level limitation circuit 22 may output the supplement signal in which the absolute value of the output level exceeds A1 that is a predetermined threshold, to the adder 23.

[0041]Subsequently, supplement of random noise components which is performed by the noise supplement circuit 20 will be described by comparing a case in which the level limitation circuit 22 limits the supplement signal, with a case in which the level limitation circuit 22 does not limit the supplement signal. FIG. 5 illustrates a distribution of the signal level in a case in which the level limitation circuit 22 illustrated in FIG. 3 does not limit the addition signal. FIG. 6 illustrates another distribution of the signal level in a case in which the level limitation circuit 22 illustrated in FIG. 3 limits the addition signal.

[0042]FIG. 5 and FIG. 6 illustrate distributions of the levels of the pixel signals when brightness information of the lowest gradation is captured on the entire screen. It is assumed that data with regard to the pixel signals from the entire valid pixels which are arranged in the pixel region 11 is included in the distributions. The valid pixel is a pixel that is configured to receive light from a subject. A horizontal axis of the graph denotes a level of a signal. A vertical axis of the graph denotes frequency.

[0043]D0 illustrated in FIG. 5 is a graph which represents a distribution of levels of the pixel signals before the supplement signal with the random noise components is added. The distribution of the levels of the pixel signals is normally modeled by a normal distribution. L0 is a black level reference value, and is a central value of the normal distribution. The black level reference value is a target value of black level adjustment of the black level adjustment circuit 19, and is, for example, 64 LSB. Even though each pixel is collectively driven such that the level of the pixel signal becomes the black level reference value with respect to brightness information of the lowest gradation, a difference between the levels of the pixel signals can occur in each pixel due to a slight change which is generated in signal outputs for each pixel.

[0044]If the level limitation circuit 22 does not limit the supplement signal, the noise supplement circuit 20 adds the random noise components whose levels are changed depending on random numbers, to the pixel signals regardless of the levels. The noise supplement circuit 20 outputs the noise supplement signal to which the random noise components are added, and the pixel signal to which the random noise components are not added, with respect to the pixel signal which forms the distribution of D0. D1 is a graph which represents a distribution of a level in relation to the pixel signal and the noise supplement signal that are output from the noise supplement circuit 20.

[0045]Since the supplement signals with entire levels which are output from the noise generation circuit 21 are added to the pixel signals, the levels of the noise supplement signals are distributed in a wider level range, compared to a range before the supplement signal is added. Since the noise supplement signal is output, D1 is a normal distribution which is more widely spread compared to D0. The central value of the normal distribution becomes L0 as it is. Since the distribution population parameters of D1 and D0 are the same, the wider the distribution of D1 becomes at a wide output level range, the lower the frequency of L0 of the distribution of D1 is, compared to the frequency of L0 of the distribution of D0.

[0046]According to the distribution of D1, the noise supplement signal appears in a relatively high frequency at a level close to the black level reference value. Since the random noise with a level close to the peak before the random noise components are added appears in a high frequency, many particles of noise are seen in portions with the same color, and the random noise is easily noticed. Even though the number of random noises is adjusted such that the random noise and fixed pattern noise have a good balance, image quality is degraded due to an increase of noticeable random noise. For this reason, effects of image quality improvement which is obtained by adding the noise components for balance adjustment of the noise, can decrease.

[0047]Meanwhile, if the supplement signal is limited, the noise supplement circuit 20 adds the supplement signal with an output level of a predetermined range, among the supplement signals which are input from the noise generation circuit 21, to the pixel signal. D2 illustrated in FIG. 6 represents a distribution of with regard to the pixel signal and the noise supplement signal which are output from the noise supplement circuit 20. D0 illustrated in FIG. 6 is the same as D0 illustrated in FIG. 5. In addition, D1 illustrated in FIG. 5 is illustrated in FIG. 6 as a reference.

[0048]The supplement signal which is input to the adder 23 is limited to the supplement signal with an output level in a level range from +A1 to +A2 and from –A1 to –A2, as illustrated in FIG. 4. Mountain portions occur in which frequencies are respectively high in a hem portion on a high level side and a hem portion on a low level side, in D2. Since the supplement signal with an output level in the level range from –A1 to +A1 is not added to the pixel signal, a central portion including L0 in D2 maintains approximately the same normal distribution as D0. The frequency of L0 of the distribution of D2 is lower than that of L0 of the distribution of D0.

[0049]In the distribution of D2, the frequency of a level close to the black level reference value decreases compared to the distribution of D1. In addition, in the distribution of D2, the frequency of the random noise of a level separated from the peak before the random noise components are added increases, compared to the distribution of D1. The noise supplement circuit 20 lowers the frequency of the noise around a central value of the normal distribution, compared to a case in which the level limitation circuit 22 does not limit the supplement signal, and distributes the noise in a level range which becomes a hem portion of the normal distribution. As a result, particles of noise in portions with the same color are reduced, and the random noise is hardly noticed.

[0050]The noise supplement circuit 20 can adjust the number of random noises such that the random noise and fixed pattern noise have a good balance, and can reduce noticeable random noise. The solid state imaging device 5 can obtain effects of high image quality improvement by adding the noise components for balance adjustment of the noise.

[0051]According to the embodiment, the level limitation circuit 22 limits the supplement signal which is added to the pixel signal by the adder 23, according to the output level of the supplement signal. The solid state imaging device 5 lowers the frequency of the random noise of a level close to the peak before the random noise components are added, and thus the random noise is hardly noticed, and effect of high image quality improvement can be obtained. As a result, the solid state imaging device 5 can obtain effects of image quality improvement by adjusting the amount of noise.

[0052]While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

WHAT IS CLAIMED IS:

1. A solid state imaging device comprising:

a pixel region which includes a pixel and outputs a pixel signal in accordance with a light amount incident on the pixel;

an output circuit which outputs an supplement signal whose output level is changed depending on a random number;

an addition circuit which adds the supplement signal to the pixel signal; and

a limitation circuit which limits the supplement signal that is added to the pixel signal by the supplement circuit according to an output level of the supplement signal.

2. The device according to Claim 1, wherein the limitation circuit outputs an supplement signal with an output level exceeding a threshold, among the supplement signals from the output circuit, to the addition circuit.

3. The device according to Claim 1, wherein the limitation circuit outputs an supplement signal with an output level in a range which is set in advance, among the supplement signals from the output circuit, to the addition circuit.

4. The device according to any one of Claims 1 to 3, further comprising:

a select circuit which selects one of the pixel signal and an supplement addition signal that is a pixel signal to which the supplement signal is added by the addition circuit,

wherein the select circuit selects the supplement addition signal corresponding to the number which is set in advance per frame, at timing in accordance with a random number.

5. The device according to any one of Claims 1 to 4, wherein the output circuit changes the output level according to a random number having a normal distribution.

ABSTRACT

According to one embodiment, a solid state imaging device includes a pixel region, a noise generation circuit which is an output circuit, an adder which is an addition circuit, and a level limitation circuit which is a limitation circuit. The pixel region includes a pixel. The pixel region outputs a pixel signal in accordance with a light amount incident on the pixel. The output circuit outputs an supplement signal whose output level is changed depending on a random number. The addition circuit adds the supplement signal to the pixel signal. The limitation circuit limits the supplement signal that is added to the pixel signal by the addition circuit according to an output level of the supplement signal.

FIG. 1

5: SOLID STATE IMAGING DEVICE

13: ROW SCANNING CIRCUIT

11: PIXEL REGION

12: CONTROL CIRCUIT

15: COLUMN PROCESSING CIRCUIT

14: COLUMN SCANNING CIRCUIT

16: IMAGING PROCESSING CIRCUIT

19: BLACK LEVEL ADJUSTMENT CIRCUIT

20: NOISE SUPPLEMENT CIRCUIT

FIG. 2

1: CAMERA SYSTEM

2: CAMERA MODULE

4: IMAGING OPTICAL SYSTEM

5: SOLID STATE IMAGING DEVICE

3: POST-STAGE PROCESSING UNIT

7: RECORDING UNIT

8: DISPLAY UNIT

FIG. 3

20: NOISE SUPPLEMENT CIRCUIT

21: NOISE GENERATION CIRCUIT

22: LEVEL LIMITATION CIRCUIT

24: SUPPLEMENT CONTROL CIRCUIT