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AUTOFOCUS CONTROL APPARATUS, IMAGE PICKUP APPARATUS, AUTOFOCUS CONTROL METHOD, AND STORAGE MEDIUM

Abstract

An autofocus control apparatus includes a processor configured to control a focus drive unit configured to drive a focus lens unit that is at least a part of an imaging optical system based on contrast information obtained from an image sensor that includes a plurality of photoelectric converters arranged on a two-dimensional plane, each of the plurality of photoelectric converters including a light receiver configured to convert light incident from the imaging optical system into a voltage pulse, and a counter configured to count the number of the voltage pulses. The processor is configured to cause the focus drive unit to reciprocate the focus lens unit while continuing exposure of the image sensor, and control the focus drive unit based on the contrast information of each of a plurality of images generated from the number of pulses of the voltage pulses generated within an exposure period of the exposure.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a Continuation of International Patent Application No. PCT/JP2023/035930, filed on Oct. 2, 2023, which claims the benefit of Japanese Patent Application No. 2022-180703, filed on Nov. 11, 2022, each of which is hereby incorporated by reference herein in their entirety.

BACKGROUND
Technical Field
[0002] The present disclosure relates to an autofocus control apparatus.
Description of Related Art
[0003] In autofocus (AF) using contrast information, a direction in which to move the focus lens unit is determined by reciprocating a focus lens unit within a small range. Unlike the active method that irradiate an object with auxiliary light, this contrast detecting method can advantageously perform focusing without causing the object, such as an animal, to notice the photographer. However, since the contrast of the image is used, the focusing speed is lower than that in the method using triangulation. In addition, conventional cameras equipped with a CMOS or CCD have difficulty in acquiring a contrast difference in dark places, and the focusing accuracy is not high.
[0004] Japanese Patent Laid-Open No. 2003-262788 discloses an AF control apparatus that attempts to increase a focus control speed by changing a frame rate of a photoelectric converter according to the object luminance.
SUMMARY
[0005] An autofocus control apparatus according to one aspect of the disclosure includes a processor configured to control a focus drive unit configured to drive a focus lens unit that is at least a part of an imaging optical system based on contrast information obtained from an image sensor that includes a plurality of photoelectric converters arranged on a two-dimensional plane, each of the plurality of photoelectric converters including a light receiver configured to convert light incident from the imaging optical system into a voltage pulse, and a counter configured to count the number of the voltage pulses. The processor is configured to cause the focus drive unit to reciprocate the focus lens unit while continuing exposure of the image sensor, and control the focus drive unit based on the contrast information of each of a plurality of images generated from the number of pulses of the voltage pulses generated within an exposure period of the exposure. An image pickup apparatus having the above autofocus control apparatus also constitutes another aspect of the disclosure. An autofocus control method corresponding to the above autofocus control apparatus also constitutes another aspect of the disclosure. A storage medium storing a program that causes a computer to execute the above autofocus control method also constitutes another aspect of the disclosure.
[0006] Further features of various embodiments of the disclosure will become apparent from the following description of embodiments with reference to the attached drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a block diagram illustrating the configuration of an image pickup apparatus in which the conventional AF control apparatus is used.

[0008] FIG. **2** is a block diagram illustrating the configuration of an image pickup apparatus in which an AF control apparatus according to each embodiment is used.

[0009] FIG. **3**A is a circuit diagram illustrating the configuration of an imaging pixel in each embodiment.

[0010] FIG. **3**B explains the operation principle of an image sensor in each embodiment.

[0011] FIG. **4** is a flowchart illustrating an operation of the conventional image pickup apparatus.

[0012] FIG. **5** is a flowchart illustrating an operation of the image pickup apparatus according to each embodiment.

[0013] FIG. **6** is a timing chart illustrating the conventional contrast AF operation.

[0014] FIG. **7** is a timing chart illustrating a contrast AF operation according to a first embodiment.

[0015] FIG. **8** is a timing chart illustrating a contrast AF operation according to a second embodiment.

DETAILED DESCRIPTION

[0016] In the following, the term "unit" may refer to a software context, a hardware context, or a combination of software and hardware contexts. In the software context, the term "unit" refers to a functionality, an application, a software module, a function, a routine, a set of instructions, or a program that can be executed by a programmable processor such as a microprocessor, a central processing unit (CPU), or a specially designed programmable device or controller. A memory contains instructions or programs that, when executed by the CPU, cause the CPU to perform operations corresponding to units or functions. In the hardware context, the term "unit" refers to a hardware element, a circuit, an assembly, a physical structure, a system, a module, or a subsystem. Depending on the specific embodiment, the term "unit" may include mechanical, optical, or electrical components, or any combination of them. The term "unit" may include active (e.g., transistors) or passive (e.g., capacitor) components. The term "unit" may include semiconductor devices having a substrate and other layers of materials having various concentrations of conductivity. It may include a CPU or a programmable processor that can execute a program stored in a memory to perform specified functions. The term "unit" may include logic elements (e.g., AND, OR) implemented by transistor circuits or any other switching circuits. In the combination of software and hardware contexts, the term "unit" or "circuit" refers to any combination of the software and hardware contexts as described above. In addition, the term "element," "assembly," "component," or "device" may also refer to "circuit" with or without integration with packaging materials.

[0017] Referring now to the accompanying drawings, a detailed description will be given of embodiments according to the disclosure. Corresponding elements in respective figures will be designated by the same reference numerals, and a duplicate description thereof will be omitted.

[0018] FIG. **1** is a block diagram illustrating the configuration of the conventional image pickup apparatus **1**. The image pickup apparatus **1** includes an imaging optical system **100**, an image sensor **101**, an A/D converter **102**, an image processing unit **103**, a memory **104**, a focus drive unit **106**, a control unit **107**, a contrast determining unit **108**, a recording medium **109**, an operation unit **110**, and a display unit **111**. The image processing unit **103**, the memory **104**, the control unit **107**, and the contrast determining unit **108** constitute an AF control apparatus **10**.

[0019] The focus drive unit **106** performs focusing for the imaging optical system **100** by driving a focus lens unit, which is at least a part of the imaging optical system **100**, in the optical axis direction. The image sensor **101** acquires an optical image of an object formed by the imaging optical system **100**. The conventional image sensor **101** includes, for example, a CMOS sensor or a CCD sensor. The A/D converter **102** converts the optical image acquired by the image sensor **101** into digital data. The converted digital data is processed by the image processing unit **103** and stored in the memory **104**. The contrast determining unit **108** determines a drive direction of the focus lens unit using the digital data that has been processed by the image processing unit **103** and stored in the memory **104**. The control unit **107** controls the focus drive unit **106** based on the result of the contrast determining unit **108** and moves the focus lens unit.

[0020] This prior art acquires a plurality of images for AF determination, and determines the contrast at the contrast determining unit **108**. The images for focus determination are acquired by reading analog data from the image sensor **101** and then converting the analog data into digital data at the A/D converter **102**. At this time, the image sensor **101** once stops exposure. Therefore, in order to acquire the next image for focus determination, the image sensor **101** is to start exposure again. Therefore, in order to determine the contrast by comparing contrast values (contrast information) and drive the focus lens unit, a time is required for the A/D conversion of multiple pieces of data and re-exposure.

[0021] The control unit **107** controls the overall operation of the image pickup apparatus **1**. The control unit **107** includes a CPU (at least one processor) and executes a program for controlling each component in the image pickup apparatus **1**. The control unit **107** also controls the focus drive unit **106** using the result of the correlation calculation output from the image processing unit **103** to perform focusing for the imaging optical system **100**. The operation unit **110** is an operation member for the shutter operation and exposure control operation of the image pickup apparatus **1**. The display unit **111** displays captured still images and moving images. The display unit **111** also displays a menu screen and the like. The recording medium **109** is a removable recording medium for recording still image data and moving image data.

[0022] FIG. **2** is a block diagram illustrating the configuration of the image pickup apparatus **2** according to each embodiment. The image pickup apparatus **2** includes an imaging optical system **200**, an image sensor **201**, a photon counter **202**, a memory **203**, an image generator **204**, an image-sensor control unit **205**, a focus drive unit **206**, a control unit **207**, a contrast determining unit **208**, a recording medium **209**, an operation unit **210**, and a display unit **211**. In each embodiment, the photon counter **202**, the memory **203**, the image generator (at least one processor) **204**, the control unit **207**, and the contrast determining unit (at least one processor) **208** constitute an AF control apparatus **20**.

[0023] The focus drive unit **206** performs focusing for the imaging optical system **200** by driving a focus lens unit, which is at least a part of the imaging optical system **200**, in the optical axis direction. The memory **203** and the photon counter **202** may be provided inside the image sensor **201**.

[0024] The image pickup apparatus **2** according to each embodiment is an image pickup apparatus in which a lens apparatus having the imaging optical system **200** and a camera body are integrated with each other, but each embodiment is not limited to this example. The image pickup apparatus **2** may be configured so that a lens apparatus (interchangeable lens) can be attached and detached. In this case, the focus drive unit **206** may be provided on the lens device side.

[0025] The image sensor **201** acquires an optical image of an object formed by the imaging optical system **200**. The photon counter **202** counts voltage pulses output from each pixel on the image sensor **201** each time one photon enters the pixel (this is called photon counting hereinafter). The number of counted photons (photon counts) is recorded in the memory **203** together with the time when the photon was counted. The image generator **204** generates an image using the voltage pulses output from the image sensor **201**. The image sensor **201** is controlled by the image-sensor control unit **205**. The image sensor **201** in each embodiment is a so-called photon counting type image sensor having pixels using the avalanche effect (multiplication). For example, each pixel is a Single Photon Avalanche Diode (SPAD) having an avalanche photodiode driven in a Geiger mode.

The image sensor **201** further includes a pixel array in which a plurality of pixels are arranged in a matrix (a two-dimensional plane in the row and column directions), and outputs image data from the pixels by sequentially scanning each row.

[0026] The control unit **207** controls the overall operation of the image pickup apparatus **2**. The control unit **207** includes a CPU (processor), and executes a program for controlling each component in the image pickup apparatus **2**. The contrast determining unit **208** calculates a contrast value (contrast information) for each image based on the image output from the image generator **204**. The control unit **207** controls the focus drive unit **206** based on the results of the contrast value for each image, and performs focusing for the imaging optical system **200**. The recording medium **209** is a removable recording medium for recording still image data and video data. The operation unit **210** is an operation member for the shutter operation and exposure control operation of the image pickup apparatus **2**. The display unit **211** displays captured still images and moving images. The display unit **211** also displays a menu screen and the like.

[0027] Referring now to FIG. **3**A, the configuration of the image sensor **201** will be described in detail. FIG. **3**A is a circuit diagram illustrating the configuration of an imaging pixel of the image sensor **201**. The imaging pixel circuit (photoelectric converter) **300** of each pixel of the image sensor **201** includes an avalanche photodiode (APD hereinafter) **301**, a quench resistor **302**, a waveform shaping circuit **303**, and a counter **304**. The APD **301** can amplify a signal charge amount excited by photons by several to a million times by using the avalanche multiplication phenomenon generated by a strong electric field induced in the pn junction of a semiconductor. The APD **301** can greatly amplify a weak light signal by utilizing the high gain of this avalanche multiplication phenomenon, improving the signal-to-noise ratio relative to the readout noise generated in the readout circuit, and achieving a luminance resolution at the single photon level.

[0028] The APD **301** is connected to a reverse bias voltage VAPD via a quench resistor **302**, and generates charges by avalanche multiplication when a photon is incident. The generated charges are discharged via the quench resistor **302**. In other words, the generation of electric charges by avalanche multiplication and the discharge of electric charges through the quench resistor **302** are repeated according to the number of photons incident on the APD **301**. Based on the voltage on the cathode side of the APD **301**, in a case where no photons are incident, the voltage is approximately the same as the reverse bias voltage VAPD, and the voltage is reduced by the electric charges generated by the incidence of photons on the APD **301**.

[0029] The waveform shaping circuit **303** generates a voltage pulse by amplifying and detecting edges of the change in the voltage on the cathode side of the APD **301** caused by the generation and discharge of electric charges according to the incidence of photons. In each embodiment, the APD **301** corresponds to a light receiver configured to convert the light (light beam) incident from the exit pupil of the imaging optical system **200** into a voltage pulse based on the avalanche effect.

[0030] The counter **304** as a counter unit counts the number of voltage pulses (number of pulses) output by the waveform shaping circuit **303** for a predetermined time, and outputs the count result as a digital value to the photon counter **202** outside the pixel. In each embodiment, the counter **304** corresponds to a counter that counts the number of voltage pulses generated within the exposure time.

[0031] The count result, which is a digital value, is stored in the memory **203** via the photon counter **202**. Acquiring the count numbers from a plurality of imaging pixel circuits **300** in a predetermined area on the pixel array can generate an image for AF determination, an image for one frame, or a final image. Each embodiment does not require the A/D conversion in acquiring the image for AF determination. In acquiring a plurality of images for focus determination, the photon count number (pulse number) acquired from the image sensor **201** and photon count information (count information) including the acquisition time of the count number, which is time information associated with the count number, are stored in the memory **203**. Adding and subtracting the photon count number at an arbitrary timing while exposure is continued can provide an image for AF determination at an arbitrary timing during the exposure period. For example, calculating a difference between the count number at time t1 and the count number at time t2 (>t1) can provide an image for AF determination at a time corresponding to time t2. An image for AF determination at the time corresponding to time t3 (>t2) may be obtained by a difference between the count number at time t2 and the count number at time t3. Alternatively, the count number at time t2 may be added to or subtracted from a difference between the count number at time t1 and the count number at time t3 to obtain the image for AF determination at the time corresponding to time t3. Therefore, compared to the prior art, the time required for A/D conversion and the time required for re-acquiring the image for AF determination are not required, and each embodiment can achieve high-speed AF. In addition, using the SPAD can achieve highly accurate AF without irradiating active light even in dark places.

[0032] FIG. **3**B explains the operation principle of the image sensor **201** according to this embodiment. In FIG. **3**B, the horizontal axis represents time, and a relationship between the pulse waveform of the output voltage due to avalanche multiplication output from the APD **301** when a photon is incident and a threshold value Vth for determining the incidence of a photon is illustrated. FIG. **3**B illustrates the case where a potential capable of applying a reverse bias voltage exceeding the breakdown voltage is supplied to the APD **301**. For each of the photon A (time tA) and photon B (time tB) incident on the APD **301**, avalanche multiplication occurs to the extent that a pulse waveform that changes beyond the counter threshold value Vth is output, and each pulse is time-resolved. Hence, the incident photons can be counted over time.

[0033] FIG. **4** illustrates a flowchart illustrating the operation from image acquisition to determining contrast and driving the focus lens unit in the conventional image pickup apparatus **1**. First, in step S**401**, the control unit **107** starts exposure of the image sensor **101** in order to acquire an image for AF determination. Thereafter, in step S**402**, the control unit **107** temporarily ends exposure of the image sensor **101** and minutely drives the focus lens unit to acquire the next image. In step S**403**, the control unit **107** causes the A/D converter **102** to read analog data from the image sensor **101**. In step S**404**, the control unit **107** causes the A/D converter **102** to convert the analog data into digital data. In step S**405**, the control unit **107** causes the image processing unit **103** to generate an image. In step S**406**, the control unit **107** stores the generated image in the memory **104**. In step S**407**, the control unit **107** causes the contrast determining unit **108** to calculate a contrast value from the image stored in the memory **104**. The operations from step S**401** to step S**407** are performed multiple times, and in step S**408**, the control unit **107** causes the contrast determining unit **108** to compare the contrast values from the plurality of images. In step S**409**, the control unit **107** controls the focus drive unit **106** to drive the focus lens unit in a direction that increases a contrast value.

[0034] FIG. **6** is a timing chart of the image pickup apparatus **1** of the conventional example. First, exposure is started to obtain an image for AF determination. Thereafter, exposure is once completed, analog data is read from the image sensor, an image for AF determination is generated by A/D conversion, and the contrast value of the image is calculated. Once exposure is completed, the focus lens unit is minutely driven, and when the reading of the first analog data is started, exposure is started again to obtain the next image for AF determination. This operation is repeated a plurality of times to calculate the contrast values of the plurality of images. By comparing the contrast values, the focus lens unit is driven in a direction that increases the contrast value. For live-view display on the screen and for capturing a unit frame of a moving image or a still image, exposure is performed for a predetermined exposure time after the focus lens unit is moved, and a final in-focus image is output.

[0035] FIG. **5** is a flowchart illustrating the contrast value determination and AF operation in the exposure time of a unit frame of the image pickup apparatus **2** according to this embodiment. First, in step S**501**, the control unit **207** starts exposure of the image sensor **201**. Then, in step S**502**, the control unit **207** causes the photon counter **202** to count the number of photons incident on each pixel, and records the counted number of photons together with the time in the memory **203**. In step S**503**, the control unit **207** causes the image generator **204** to generate an image for AF determination from the photon count information stored in the memory **203**, which includes the photon count number and the acquisition time of that count number. Here, the image generator **204** can generate an image for AF determination at an arbitrary timing during the exposure period by properly adding and subtracting the photon count information at an arbitrary timing. In step S**504**, the control unit **207** causes the contrast determining unit **208** to calculate a contrast value from the generated image for AF determination. In step S**505**, the control unit **207** controls the focus drive unit **206** to drive the focus lens unit in a direction that increases a contrast value. In step S**506**, the control unit **207** determines whether the time is within the exposure time of the unit frame, and in a case where it is within the exposure time of the unit frame, repeats the processing of steps S**501** to S**505**. In step S**507**, the control unit **207** ends the exposure of the image sensor **201**.

First Embodiment

[0036] FIG. **7** is a timing chart in a case where a moving image is captured with the image pickup apparatus **2** according to the first embodiment. The first embodiment premises that the moving image is captured while the focus lens unit is always driven back and forth in the optical axis direction to kept in focus on a predetermined object. First, exposure is started to obtain an image for one frame of the moving image. At the same time, photon counting is started to count the number of photons, and the count number of photons is recorded in the memory **203**. While the focus lens unit is driven back and forth (reciprocated), an image for AF determination is produced at an arbitrary timing based on the photon count, and the contrast value of the image is calculated. The focus lens unit is driven in the direction that increases the contrast value. Exposure continues during one frame of operation. After one frame of operation is completed, exposure ends once, the photon counter is reset, and exposure is started again to obtain the image of the next frame. As illustrated in FIG. **7**, the first embodiment can continuously obtain images for AF determination. Thereby, the object can be tracked at all times, and highly accurate moving image capturing can be achieved.

Second Embodiment

[0037] FIG. **8** is a timing chart in a case where still images are captured by the image pickup apparatus **2** according to a second embodiment. The second embodiment presumes that AF control is started when the shutter button of the image pickup apparatus **2** is half-pressed by the user (S**1**), and then the shutter button is further pressed down to the full-press state (S**2**), and a still image is acquired. First, exposure starts at the same time as the shutter button of the image pickup apparatus **2** is half-pressed, photon counting is started to count the number of photons, and the photon count number is recorded in the memory **203**. While the focus lens unit is driven back and forth (reciprocated) in the optical axis direction, an image for AF determination is produced at an arbitrary timing based on the photon count number, and the contrast value of the image is calculated. The focus lens unit is driven in the direction that increases the contrast value, and finally, the focus lens unit is driven to a position where the contrast value is maximum. Then, when the shutter button is fully pressed (S**2**), exposure is performed for a predetermined exposure time from the photon count number stored in the memory **203**, and a still image that is a final in-focus image is generated. To generate a still image, the number of pulses of voltage pulses (photon count number) generated during the still-image exposure period, excluding an exposure period during which the images for AF determination were generated, is used. A still image may be generated by adding or subtracting an image produced based on the photon count number acquired during the still-image capturing exposure period. During this series of operations, exposure continues.

[0038] Each embodiment may satisfy the following inequality (1):

[00001] $0. < m / fT < 1.$ (1)

where m is an average number of incident photons per pixel on the image sensor **201**, and fT is a clock number of the image sensor **201**.

[0039] Inequality (1) defines the average number of incident photons per pixel m relative to the clock number fT.

[0040] A relationship between the count number n per pixel and the average number of incident photons per pixel m will now be described. The count number n per pixel is defined by the following expression using the average number of incident photons m and the clock number fT.

[00002] $n = \mathrm{fT} \times (1 - \mathrm{Exp}(-m / \mathrm{fT}))$

[0041] Here, the average number of incident photons per pixel m is defined by the following expression.

[00003] $m = S \times \mathrm{Lf} \times t\mathrm{Lf} = (R \times T / 4F \wedge 2) \times \mathrm{Le}$

[0042] Here, S is sensor sensitivity, Lf is sensor surface illuminance, t is an exposure time, R is object reflectance, T is lens transmittance, and F is an F-number (aperture value) of the lens. From inequality (1), the smaller the value of the average number of incident photons per pixel m relative to the clock number fT is, the more linearity can be satisfied.

[0043] In a case where the value becomes higher than the upper limit of inequality (1), a relationship between the number of incident photons m and the counted value will no longer be linear. In a case where the value becomes lower than the lower limit of inequality (1), the measurement error will increase due to the influence of noise components. The determination of linearity is not limited to the count of the number of photons, and the determination criteria may be set based on the object illuminance and the luminance value of the image.

[0044] Inequality (1) may be replaced with inequality (1a) below:

[00004] $0.01 < m / \mathrm{fT} < 0.8 \quad (1a)$

[0045] Inequality (1) may be replaced with inequality (1b) below:

[00005] $0.05 < m / \mathrm{fT} < 0.5 \quad (1b)$

OTHER EMBODIMENTS

[0046] Embodiment(s) of the disclosure can also be realized by a computer of a system or apparatus that reads out and executes computer-executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a ‘non-transitory computer-readable storage medium’) to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer-executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer-executable instructions. The computer-executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read-only memory (ROM), a storage of distributed computing systems, an optical disc (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)™), a flash memory device, a memory card, and the like.

[0047] While the disclosure has described example embodiments, it is to be understood that the disclosure is not limited to the example embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

[0048] Each embodiment can provide an AF control apparatus that can perform focus detection at a higher speed and with a higher degree of accuracy than the conventional method in performing AF using a contrast detection method.

Claims

1. An autofocus control apparatus comprising: at least one processor that executes instructions to control a focus drive unit configured to drive a focus lens unit that is at least a part of an imaging optical system based on contrast information obtained from an image sensor that includes a plurality of photoelectric converters arranged on a two-dimensional plane, each of the plurality of photoelectric converters including a light receiver configured to convert light incident from the imaging optical system into a voltage pulse, and a counter configured to count the number of the voltage pulses, wherein the at least one processor is configured to: cause the focus drive unit to reciprocate the focus lens unit while continuing exposure of the image sensor, and control the focus drive unit based on the contrast information of each of a plurality of images generated from the number of pulses of the voltage pulses generated within an exposure period of the exposure.
2. The autofocus control apparatus according to claim 1, wherein the light receiver is an avalanche photodiode that is provided in each pixel on the image sensor and driven in a Geiger mode.
3. The autofocus control apparatus according to claim 1, further comprising a memory storing the number of pulses of the voltage pulses generated within the exposure period of the exposure.
4. The autofocus control apparatus according to claim 1, wherein the at least one processor is configured to generate the plurality of images using the number of pulses of the voltage pulses generated within the exposure period of the exposure.
5. The autofocus control apparatus according to claim 4, wherein the at least one processor is configured to generate the plurality of images using count information including the number of pulses of the voltage pulses generated within the exposure period of the exposure and time information associated with the number of pulses.
6. The autofocus control apparatus according to claim 5, wherein the at least one processor is configured to generate the plurality of images by adding and subtracting the count information.
7. The autofocus control apparatus according to claim 4, wherein the at least one processor is configured to generate an in-focus image exposed for a predetermined exposure time using the number of pulses of the voltage pulses generated within the exposure period of the exposure.
8. The autofocus control apparatus according to claim 7, wherein the at least one processor is configured to generate the in-focus image exposed for the predetermined exposure time using the number of pulses of the voltage pulses generated within the exposure period of the exposure excluding an exposure period during which the plurality of images were generated.
9. The autofocus control apparatus according to claim 7, wherein the exposure period for generating each of the plurality of images is shorter than the predetermined exposure time for generating the in-focus image.
10. The autofocus control apparatus according to claim 4, wherein the at least one processor is configured to generate the plurality of images continuously.
11. The autofocus control apparatus according to claim 1, wherein the following inequality is satisfied:
$0.0<m/fT<1.0$ where m is an average number of incident photons per pixel on the image sensor, and fT is a clock number of the image sensor.
12. The autofocus control apparatus according to claim 1, wherein the plurality of images are images for focus determination.
13. The autofocus control apparatus according to claim 1, wherein the at least one processor is configured to performs focusing for the imaging optical system by controlling the focus drive unit.
14. The autofocus control apparatus according to claim 1, wherein the at least one processor is configured to calculate the contrast information of each of the plurality of images.

15. The autofocus control apparatus according to claim 1, wherein the light receiver converts the light incident from the imaging optical system into the voltage pulse based on an avalanche effect.
16. An image pickup apparatus comprising: an image sensor that includes a plurality of photoelectric converters arranged on a two-dimensional plane; and the autofocus control apparatus according to claim 1, wherein each of the photoelectric converters includes: a light receiver configured to convert light incident from an imaging optical system into a voltage pulse, and a counter configured to count the number of the voltage pulses.
17. The image pickup apparatus according to claim 16, further comprising the focus drive unit configured to drive the focus lens unit.
18. An autofocus control method comprising: controlling a focus drive unit configured to drive a focus lens unit that is at least a part of an imaging optical system based on contrast information obtained from an image sensor that includes a plurality of photoelectric converters arranged on a two-dimensional plane, each of the plurality of photoelectric converters including a light receiver configured to convert light incident from the imaging optical system into a voltage pulse, and a counter configured to count the number of the voltage pulses, wherein the controlling the focus drive unit includes: causing the focus drive unit to reciprocate the focus lens unit while continuing exposure of the image sensor, and controlling the focus drive unit based on the contrast information of each of a plurality of images generated from the number of pulses of the voltage pulses generated within an exposure period of the exposure.
19. A storage medium storing a program that causes a computer to execute the autofocus control method according to claim 18.