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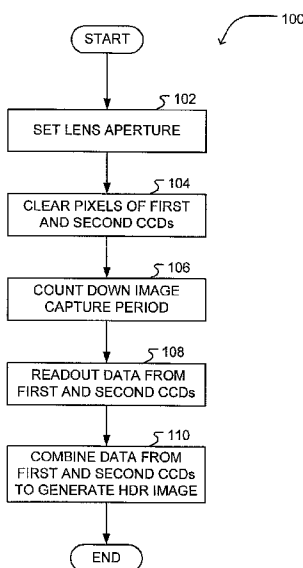
(43) International Publication Date  
19 June 2008 (19.06.2008)

PCT

(10) International Publication Number  
**WO 2008/073991 A2**

- (51) International Patent Classification:  
*H04N 5/235* (2006.01)
  - (21) International Application Number:  
PCT/US2007/087301
  - (22) International Filing Date:  
12 December 2007 (12.12.2007)
  - (25) Filing Language: English
  - (26) Publication Language: English
  - (30) Priority Data:  
11/609,837 12 December 2006 (12.12.2006) US
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  - (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
  - (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published:**  
— without international search report and to be republished upon receipt of that report

(54) Title: HDR CAMERA WITH MULTIPLE SENSORS



(57) Abstract: An electronic camera comprises two or more image sensor arrays. At least one of the image sensor arrays has a high dynamic range. The camera also comprises a shutter for selectively allowing light to reach the two or more image sensor arrays, readout circuitry for selectively reading out pixel data from the image sensor arrays, and a controller configured to control the shutter and the readout circuitry. The controller comprises a processor and a memory having computer-readable code embodied therein which, when executed by the processor, causes the controller to open the shutter for an image capture period to allow the two or more image sensor arrays to capture pixel data, and, read out pixel data from the two or more image sensor arrays.

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## HDR CAMERA WITH MULTIPLE SENSORS

### Technical Field

5 [0001] The invention relates to electronic cameras, and particularly to methods and electronic camera apparatus for capturing multiple exposures. The invention has application in capturing high dynamic range images.

### Background

10 [0002] Real world scenes can have contrast ratios of 50,000:1 between the brightness of the brightest highlights and the darkest shadows. Many conventional image formats and image rendering devices (such as digital projectors, computer monitors, and the like) are only capable of reproducing contrast ratios of a few hundred to one. In such file formats it is not uncommon for pixel brightness values to be specified using one 8-bit  
15 number per colour.

[0003] High dynamic range (“HDR”) image formats permit recording contrast ratios that are significantly greater than those of conventional 8-bit image formats. For example, some HDR formats use 16 or 32 bits per  
20 colour to represent different levels of brightness.

[0004] One way to obtain image data for high dynamic range images is to acquire multiple images with conventional imaging equipment at different exposure levels. This technique is described, for example, in  
25 Debevec et al. *Recovering High Dynamic Range Radiance Maps from Photographs*, Proceedings of SIGGRAPH 97, Computer Graphics Proceedings, Annual Conference Series, pp. 369-378 (August 1997, Los Angeles, California), Addison Wesley, Edited by Turner Whitted. ISBN 0-89791-896-7, which is hereby incorporated herein by reference.

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**[0005]** A problem is that the multiple images need to be aligned with one another. This makes it necessary to use a tripod in most cases. Further, setting a camera to take multiple images appropriate for combination into an HDR image requires significant knowledge regarding the appropriate combination of exposures to use for each of the images.

**[0006]** HDR images are becoming mainstream. There is a need for methods and apparatus for easily acquiring HDR images.

10 Summary of the Invention

**[0007]** This invention provides methods and apparatus for acquiring multiple exposures in electronic cameras. The methods and apparatus may be applied to acquiring images that can be combined to yield an HDR image. Apparatus according to some embodiments of the invention may  
15 comprise an electronic camera having multiple image sensors.

**[0008]** One aspect of the invention provides an electronic camera comprising two or more image sensor arrays. At least one of the image sensor arrays has a high dynamic range. The camera also comprises a  
20 shutter for selectively allowing light to reach the two or more image sensor arrays, readout circuitry for selectively reading out pixel data from the image sensor arrays, and, a controller configured to control the shutter and the readout circuitry. The controller comprises a processor and a memory having computer-readable code embodied therein which, when executed by  
25 the processor, causes the controller to open the shutter for an image capture period to allow the two or more image sensor arrays to capture pixel data, and, read out pixel data from the two or more image sensor arrays.

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**[0009]** Another aspect of the invention provides a method for producing high dynamic range image data in an electronic camera comprising two or more image sensor arrays, at least one of the image sensor arrays having a high dynamic range. The method comprises  
5 allowing light to reach the two or more image sensor arrays for an image capture period, reading out pixel data captured by the two or more image sensor arrays during the image capture period, and, combining the pixel data read out from the two or more image sensor arrays to produce high dynamic range image data.

10

**[0010]** Other aspects of the invention and features of specific embodiments are described below.

#### Brief Description of Drawings

15 **[0011]** In drawings which illustrate non-limiting embodiments of the invention:

Figure 1 shows a sensor layout for an interline transfer CCD;

Figure 2 is a block diagram of an electronic camera according to one embodiment of the invention; and,

20 Figure 3 is a flowchart illustrating the steps in a method according to another embodiment of the invention.

#### Description

25 **[0012]** Throughout the following description, specific details are set forth in order to provide a more thorough understanding of the invention. However, the invention may be practiced without these particulars. In other instances, well known elements have not been shown or described in detail to avoid unnecessarily obscuring the invention. Accordingly, the

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specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

**[0013]** One aspect of the invention provides an electronic camera  
5 configured to capture multiple exposures of a single image. The multiple  
exposures may be used to create a high dynamic range (HDR) image.  
Methods for combining data from multiple exposures to yield a HDR  
image are known in the art. For example, some such methods are  
described in Mann, S. et al. *Being 'undigital' with digital cameras:*  
10 *Extending dynamic range by combining differently exposed pictures*, In  
Proc. IS&T 46th Annual Conference (May, 1995) pp. 422-428 which is  
hereby incorporated herein by reference and in the Debevec et al. article  
referred to above.

15 **[0014]** Electronic cameras typically have a shutter which can be  
opened to selectively allow light to reach a light sensitive chip or closed to  
block light from reaching the chip. When the shutter is open, a lens  
projects an image onto the chip. The shutter may comprise a mechanical  
shutter, for example.

20 **[0015]** The chip measures light intensity at a number of pixel  
locations. Values representing the intensity at each of the pixels can be  
read out and stored in a memory. Light sensitive chips also typically  
include means for selecting the amount of time the light sensitive elements  
25 collect light before the data stored therein is read out. Such means can act  
as an "electronic shutter". For example, many CCD chips include a  
control that triggers reading out of pixel data from light-sensitive pixels  
into vertical data registers that are shielded from light. The inventors have  
determined that providing an electronic camera with multiple CCD chips

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allows the camera to capture multiple exposures of a single image simultaneously.

**[0016]** Figure 1 shows a sensor layout for an interline transfer charge coupled device (“CCD”) **10** of the type used in many electronic cameras. **CCD 10** comprises a plurality of imaging regions **12** which comprise light sensitive elements, and storage regions which comprise vertical registers **14**. In the illustrated embodiment, imaging regions **12** alternate with vertical registers **14** in a horizontal direction. Imaging regions **12** each comprise a plurality of pixels **16**. Each pixel **16** comprises a sensor that stores charge. The amount of stored charge depends upon the number of photons detected by the sensor. As indicated by the arrows in Figure 1, after an image is exposed, pixel data characterizing the charges stored in pixels **16** are shifted to vertical registers **14**.

**[0017]** Vertical registers **14** (which are sometimes referred to as “column registers”) may be covered with an opaque mask layer (e.g. with strips of aluminum) to prevent incoming light from striking vertical registers **14**. Vertical registers **14** preserve the charges’ characteristics as the pixel data is shifted down vertical registers **14** into a horizontal register **18**. (The terms “vertical”, “horizontal” and “down” used in this description refer to the orientation of the elements shown in Figure 1, rather than to any particular physical orientation.) The pixel data is generally read out from horizontal register **18** to an analog-to-digital converter through one or more amplifiers and/or other signal conditioning circuits (not shown).

**[0018]** Figure 2 shows an electronic camera **20** equipped with first and second CCDs **10A** and **10B**. Each of CCDs **10A** and **10B** may be

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similar in structure to CCD **10** of Figure 1, but may have different characteristics. For example, first CCD **10A** may comprise a high resolution sensor having a normal dynamic range. Second CCD **10B** may comprise a low resolution sensor having a high dynamic range. In some  
5 embodiments, the resolution of first CCD **10A** may be, for example, 1920x1080 or higher. The resolution of second CCD **10B** may be as low as, for example, 1/4 the resolution of first CCD **10A** in each dimension. Also, in some embodiments, first CCD **10A** may comprise a color sensor, and second CCD **10B** may comprise a monochrome sensor.

10

**[0019]** Camera **20** comprises a mechanical shutter **22** for selectively allowing light from an image to reach CCDs **10A** and **10B**. When mechanical shutter **22** is open, the incoming light is focused by an optical system (not shown) onto CCDs **10A** and **10B**. A controller **24** controls the  
15 opening and closing of shutter **22** by means of a shutter control line **26**. Controller **24** also controls the clocking of vertical registers **14** and horizontal register **18** of CCDs **10A** and **10B** by means of CCD control lines **28A** and **28B**. Controller **24** may comprise, for example, a microprocessor running software (e.g. firmware **25**). Controller **24**  
20 receives pixel data from CCDs **10A** and **10B** by means of data lines **30A** and **30B**.

**[0020]** Controller **24** may store the pixel data in a memory **32**. Controller **24** may store the pixel data in memory **32**, for example, in a  
25 data structure comprising a first portion containing HDR information, and a second portion containing tone map data, as described in International Application No. PCT/CA2004/002199 filed 24 December 2004, which is hereby incorporated by reference herein.

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[0021] Controller **24** may also display an image based on the pixel data on a view screen **34**. View screen **34** may comprise, for example, a high luminance display to overcome ambient illumination which could make it difficult for a viewer to see the image. Alternatively, view screen  
5 **34** may comprise, for example, a high dynamic range display device such as those disclosed in International Application No. PCT/CA2002/000255 filed 27 February 2002 or International Application No. PCT/CA03/00350 filed 13 March 2003, both of which are hereby incorporated by reference herein. In such embodiments, camera **20** may comprise a hood to shield  
10 the high dynamic range display device from ambient illumination.

[0022] Camera **20** also comprises an interface **35** for allowing a user to interact with controller **24**. Interface **35** includes a shutter release **36**. Shutter release **36** may be triggered by a timer, an electronic signal, a  
15 shutter release button or the like.

[0023] Figure 3 shows a method **100** for producing a high dynamic range (HDR) image using a camera having a plurality of CCDs, such as for example, camera **20** of Figure 2. Although method **100** is described in  
20 the context of a camera having two CCDs, it is to be understood that method **100** could be practiced using a camera having more than two CCDs.

[0024] In block **102**, method **100** sets the camera's lens to an  
25 appropriate aperture. The aperture may be set by the camera's exposure control circuit. A wide variety of suitable systems for setting the shutter aperture in digital cameras are known in the art. Such systems may set the aperture to a user-determined value or may set the aperture according to an algorithm based upon detected light levels.

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**[0025]** At block **104** any charge stored in the pixels of first and second CCDs **10A** and **10B** is cleared, and an image capture period begins. At block **106** the camera's timer counts down a predetermined time period for the image capture. First and second CCDs **10A** and **10B** may each be exposed for the same duration, but this is not necessary in all embodiments. Additionally or alternatively, either or both of first and second CCDs **10A** and **10B** may be operated to capture multiple exposures during the image capture period, for example, by employing techniques such as those described in United States Patent Applications No. 11/236,155 filed 26 September 2005 and No. 11/459,633 filed 24 July 2006, both of which are hereby incorporated by reference herein.

**[0026]** In embodiments where first and second CCDs **10A** and **10B** are not exposed the same period of time, time-domain interpolation techniques may be used when combining data from first and second CCDs **10A** and **10B**. After exposure of first and second CCDs **10A** and **10B**, data representative of the charge stored in the pixels of first and second CCDs **10A** and **10B** is read out at block **108**. In embodiments where first and second CCDs **10A** and **10B** are each exposed only once, the data may be read out after the image capture period. In embodiments where either or both of first and second CCDs **10A** and **10B** capture multiple exposures, some of the data may be read out during the image capture period and some of the data may be read out after the image capture period.

**[0027]** At block **110**, data from first and second CCDs **10A** and **10B** is combined to produce a HDR image. Combining data from first and second CCDs **10A** and **10B** may comprise, for example, the use of techniques such as those described in International Application No.

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PCT/CA2004/002199. The combined data from first and second CCDs **10A** and **10B** may be stored in a memory. For example, the combined data may be stored in a data structure comprising a first portion containing HDR information, and a second portion containing tone map data, as  
5 described in International Application No. PCT/CA2004/002199, such that both normal and dynamic range images may be produced from the combined data.

**[0028]** Although the inventors have determined that two CCDs are  
10 generally sufficient to produce a HDR image, cameras according to certain embodiments of the invention may comprise more than two CCDs. For example, use of more than two CCDs may provide for additional dynamic range and/or colors in the resulting image. Also, in some embodiments, at least one of the two or more CCDs may be specifically adapted for  
15 capturing HDR pixels.

**[0029]** A controller in a camera may be programmed to combine data from two or more CCDs to yield HDR image data and to store the HDR image data in any suitable HDR format. Where this is done, it can be  
20 appreciated that HDR images can be obtained in a way that is essentially transparent to a user.

**[0030]** Certain implementations of the invention comprise computer processors which execute software instructions which cause the processors  
25 to perform a method of the invention. For example, one or more processors in a controller for an electronic camera may implement the method of Figure 3 by executing software instructions in a program memory accessible to the processors. The invention may also be provided in the form of a program product. The program product may comprise any

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medium which carries a set of computer-readable signals comprising instructions which, when executed by a data processor, cause the data processor to execute a method of the invention. Program products according to the invention may be in any of a wide variety of forms. The  
5 program product may comprise, for example, physical media such as magnetic data storage media including floppy diskettes, hard disk drives, optical data storage media including CD ROMs, DVDs, electronic data storage media including ROMs, flash RAM, or the like or transmission-type media such as digital or analog communication links. The computer-  
10 readable signals on the program product may optionally be compressed or encrypted.

**[0031]** Where a component (e.g. a software module, processor, assembly, device, circuit, etc.) is referred to above, unless otherwise  
15 indicated, reference to that component (including a reference to a “means”) should be interpreted as including as equivalents of that component any component which performs the function of the described component (i.e., that is functionally equivalent), including components which are not structurally equivalent to the disclosed structure which performs the  
20 function in the illustrated exemplary embodiments of the invention.

**[0032]** As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof.  
25 Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.

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WHAT IS CLAIMED IS:

1. An electronic camera comprising:
  - two or more image sensor arrays, at least one of the image  
5 sensor arrays having a high dynamic range;
  - a shutter for selectively allowing light to reach the two or  
more image sensor arrays;
  - readout circuitry for selectively reading out pixel data from the  
image sensor arrays; and,
  - 10 a controller configured to control the shutter and the readout  
circuitry, the controller comprising a processor and a memory  
having computer-readable code embodied therein which, when  
executed by the processor, causes the controller to:
    - 15 open the shutter for an image capture period to allow the  
two or more image sensor arrays to capture pixel data; and,
    - read out pixel data from the two or more image sensor  
arrays.
2. A camera according to claim 1 wherein the computer readable code,  
20 when executed by the processor, causes the controller to store the  
pixel data read out from the two or more image sensor arrays in a  
high dynamic range data structure.
3. A camera according to claim 2 wherein the high dynamic range data  
25 structure comprises a first portion containing high dynamic range  
information and a second portion containing tone map data.
4. A camera according to claim 1 wherein the computer readable code,  
when executed by the processor, causes the controller to combine the

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pixel data read out from the two or more image sensor arrays to produce high dynamic range image data.

- 5 5. A camera according to claim 4 comprising a view screen for displaying an image based on the high dynamic range image data.
6. A camera according to claim 5 wherein the view screen comprises a high dynamic range display device configured to display a high dynamic range image.
- 10 7. A camera according to claim 6 comprising a hood for shielding the high dynamic range display device.
8. A camera according to claim 1 wherein the at least one of the image sensor arrays having a high dynamic range comprises a low resolution image sensor array.
- 15 9. A camera according to claim 8 wherein another one of the image sensor arrays comprises a high resolution image sensor array.
- 20 10. A camera according to claim 1 wherein the at least one of the image sensor arrays having a high dynamic range comprises a charge coupled device specifically adapted to capture HDR pixels.
- 25 11. A method for producing high dynamic range image data in an electronic camera comprising two or more image sensor arrays, at least one of the image sensor arrays having a high dynamic range, the method comprising:

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allowing light to reach the two or more image sensor arrays for an image capture period;

reading out pixel data captured by the two or more image sensor arrays during the image capture period; and,

5 combining the pixel data read out from the two or more image sensor arrays to produce high dynamic range image data.

12. A method according to claim 11 wherein allowing light to reach the two or more image sensor arrays for the image capture period  
10 comprises capturing multiple exposures with one of the image sensor arrays.

13. A method according to claim 12 wherein reading out pixel data captured by the two or more image sensor arrays during the image  
15 capture period comprises reading out a first exposure of the one of the image sensor arrays during the image capture period.

14. A method according to claim 11 comprising storing the high dynamic range image data in a memory accessible by the camera.  
20

15. A method according to claim 14 wherein storing the high dynamic range image data in the memory comprises storing the high dynamic range image data in a data structure comprising a first portion containing high dynamic range information and a second portion  
25 containing tone map data.

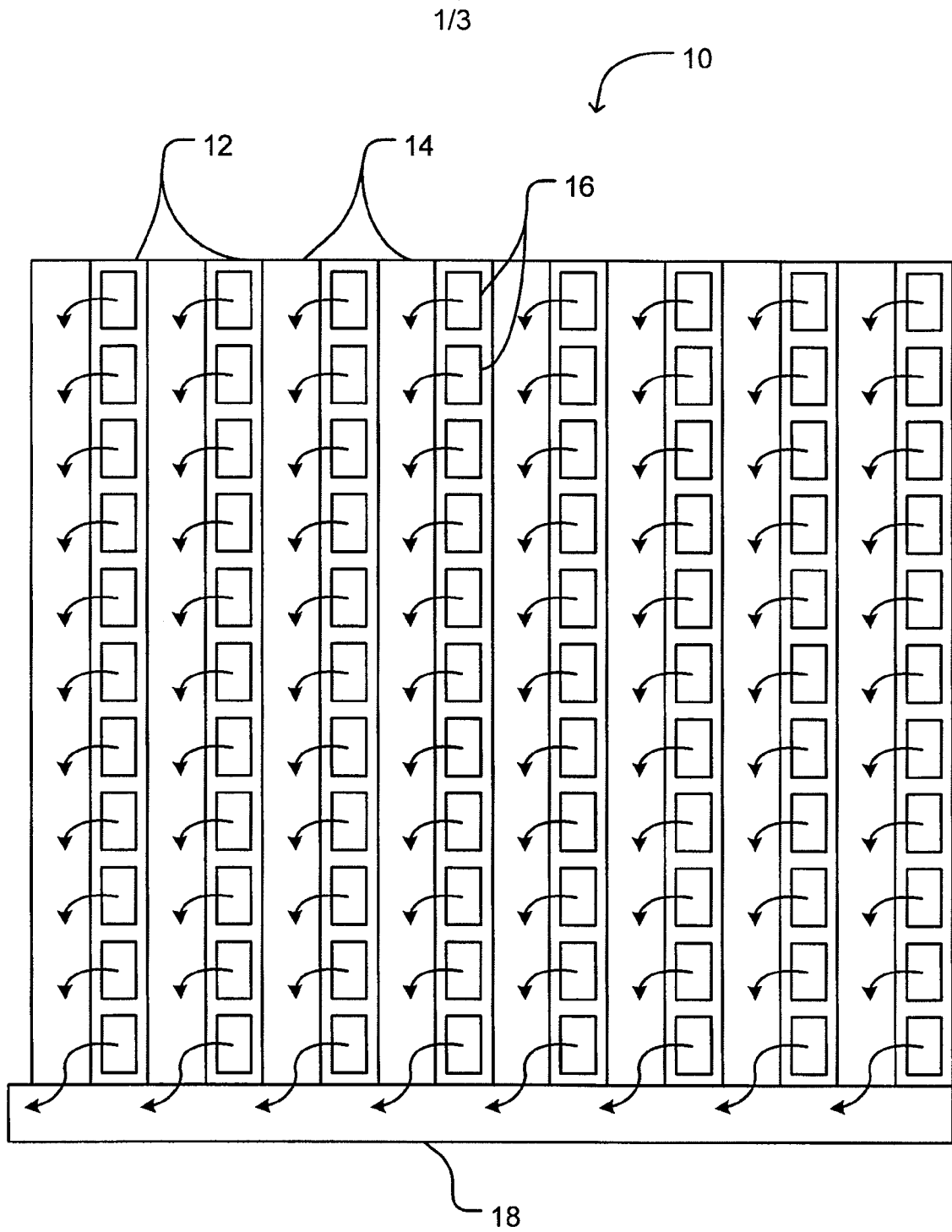


Figure 1

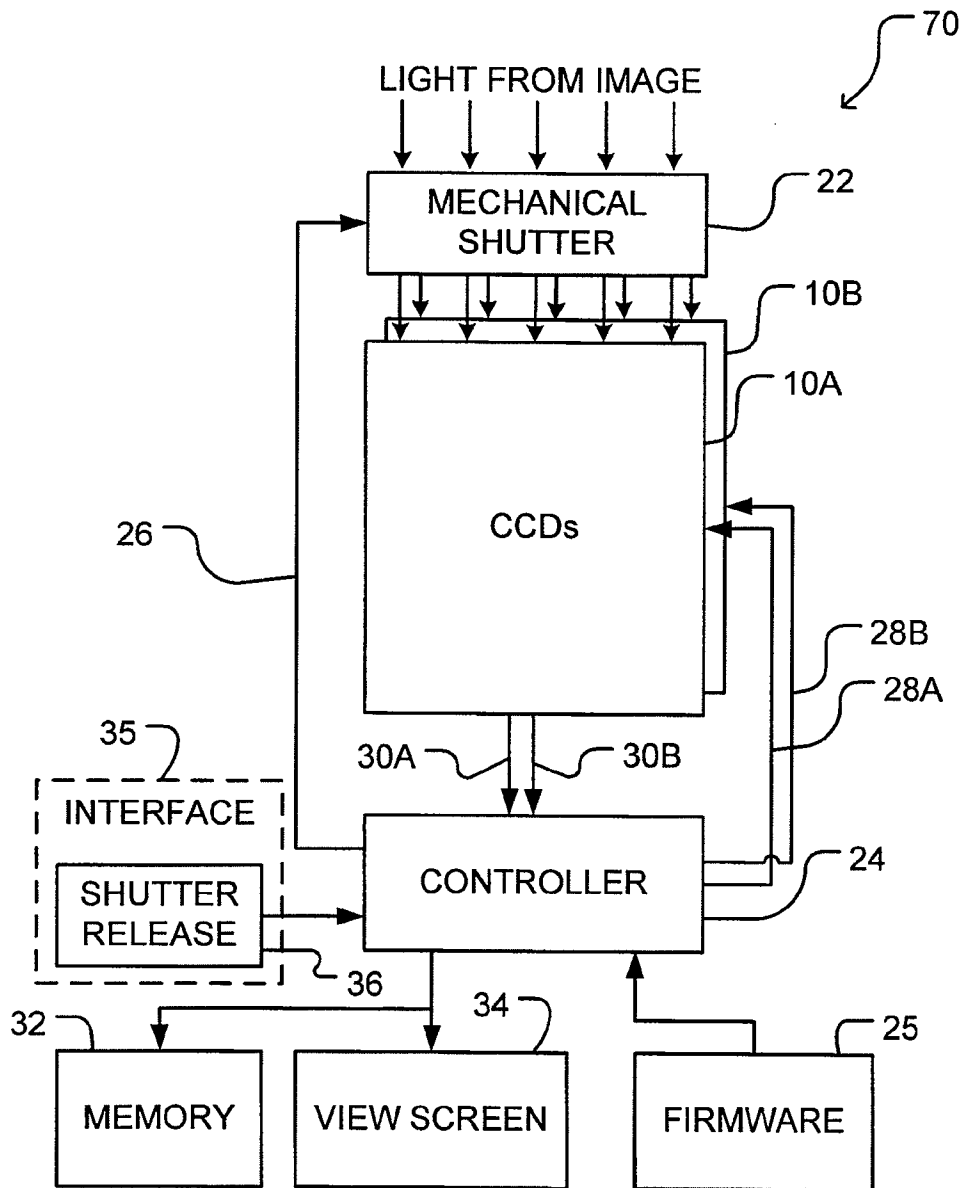


Figure 2

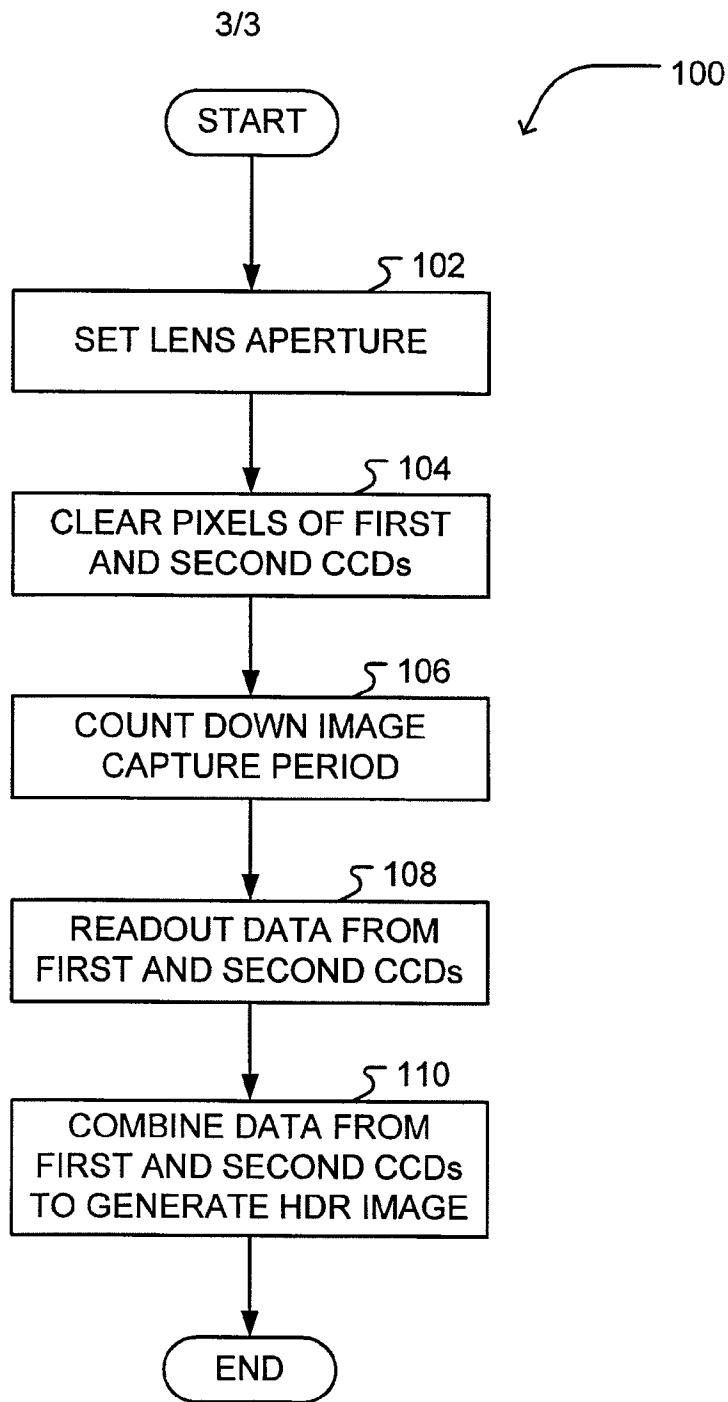


Figure 3