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(54) Title: IMAGE SENSOR AND METHOD OF SENSING
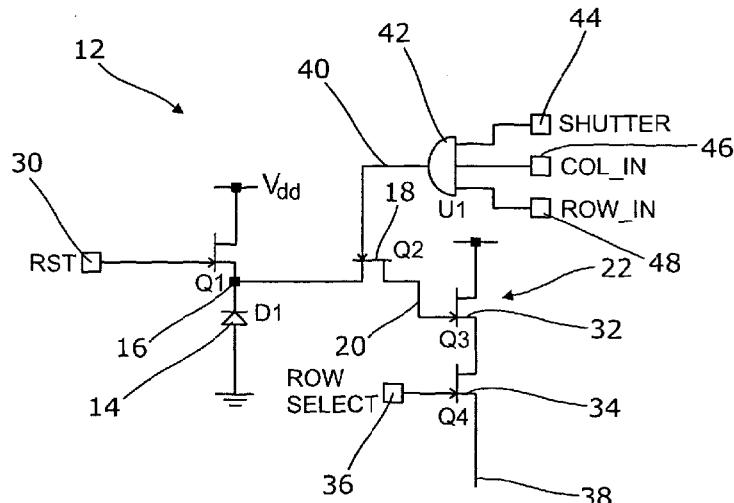
Fig. 5

(57) Abstract: An image sensor has a plurality of pixels arranged in an array, a selection means for selecting individual pixels in the array, and a shutter means for transmitting a shutter signal to the pixels. The pixels are constructed and arranged to sense incident light only when both selected and in receipt of a shutter signal. The pixels in said array can thus be triggered individually to capture light at different times.

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IMAGE SENSOR AND METHOD OF SENSING

The present invention relates to an image sensor and to an image capture device. The invention also relates to a method of capturing images. In particular but not exclusively,

5   the invention relates to a device and method for capturing both still and moving images (movies).

Electronic cameras are generally divided into two broad categories: still cameras and video cameras. However, there is a degree of overlap between the two types of camera. For example, some "video" cameras are capable of capturing both movies and still images.

10   On the other hand, some still cameras are provided with a "movie" or "video" function, which allows the camera to capture a sequence of images. These images can subsequently be shown as a movie. This invention is concerned primarily (but not exclusively) with the latter type of camera.

Electronic cameras generally include an image capture device or sensor having an array of

15   photosensitive detectors or picture elements (pixels). A moving image or movie can be captured by recording a sequence of images detected by the sensor.

The rate at which a sequence of images can be captured (the frame rate) depends in part on the size of the sensor (that is, the number of pixels in the array), and is limited by the rate at which data can be read (digitised) from the sensor. Reading information from an

20   imaging sensor at high speed introduces noise (read noise), which lowers the signal quality of the image. Accordingly, if the sensor has a large number of pixels, the frame rate will generally be rather slow. Smaller sensors with fewer pixels may provide a higher frame rate, but the resolution of the image will be correspondingly reduced.

The inventor's previous patent application WO 2008/138543A describes an image capture

25   device including a sensor with an active area comprising a plurality of pixels, and a shutter array comprising a plurality of shutter elements that can be activated individually to control the exposure of the individual pixels. The pixels are arranged in a number of pixel

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subsets that can be exposed sequentially to capture a sequence of lo-res images each comprising less than the full set of pixels, or simultaneously to capture a hi-res image comprising all or substantially all of the pixels. However, the provision of a separate shutter array adds to the size and complexity of the device.

5   It is an object of the present invention to provide an image sensor and a method of capturing images that mitigate at least some of the aforesaid disadvantages.

According to one aspect of the invention there is provided an image sensor having a plurality of pixels arranged in an array, a selection means for selecting individual pixels in the array, and shutter control means for transmitting a shutter signal to the pixels, wherein

10 each said pixel is constructed and arranged to sense incident light only when both selected and in receipt of a shutter signal, whereby pixels in said array can be triggered individually to capture light at different times.

By triggering the pixels individually, it is possible to capture either a single hi-res image using all the pixels, or one or more lo-res images using fewer than all the pixels. The

15 pixels can be triggered electronically, thus avoiding the need for a separate shutter array. The size and complexity of the device are thus significantly reduced.

Advantageously, the pixels are arranged in an array of rows and columns and are connected to receive a row select signal and a column select signal, whereby an individual pixel can be selected by transmitting a row select signal and a column select signal along

20 the row and the column in which that pixel is located. This arrangement allows each pixel to be selected individually without the need for individual control lines. This therefore avoids excessive circuit complexity. The rows and columns may be either orthogonal or non-orthogonal.

Preferably, the selection means comprises a plurality of row selection lines and a plurality

25 of column selection lines, wherein each row selection line is connected to all the pixels in a particular row and each column selection line is connected to all the pixels in a particular column. Thus it is possible to select all of the pixels individually using just two sets of control connections. The selection means preferably comprises a grid of row selection connections and column selection connections.

Advantageously, at least one of the row select signal and the column select signal is generated by a shift register. Preferably, both the row select signal and the column select signal are generated by shift registers. A shift register is an electronic device that can store a series of digital values and can shift that sequence backwards and forwards. This allows

5   the pixels to be triggered in a predetermined sequence. The digital values held in the shift registers can also be modified very easily to change the sequence in which the pixels are triggered. This makes it possible to adjust the number of pixels exposed at any one time, and the order in which the pixels are exposed.

Advantageously, each pixel includes a control means for triggering the pixel, the control

10   means being constructed and arranged to trigger the pixel only when it receives substantially simultaneously a shutter signal, a row select signal and a column select signal.

In one embodiment, the control means includes a logical AND gate having inputs for receiving a shutter signal, a row select signal and a column select signal.

15   In another embodiment, the control means includes a plurality of series-connected switch devices, each switch device being operably connected to receive at least one of a shutter signal, a row select signal and a column select signal. This arrangement is preferred in some situations to the use of an AND gate as it requires fewer transistors and therefore occupies less area on the surface of the sensor device. The switch devices may for

20   example be transistor pass switches, for example MOSFET transistors.

The image sensor preferably comprises a CMOS APS device, in which each pixel includes a device for storing an electrical charge representing the amount of light falling on the pixel. This allows each pixel to store a charge representing the incident light until all of the pixels have been exposed, after which the data from all of the pixels can be captured.

25   This increases the operational speed of the device.

According to another aspect, the invention comprises an image capture device including an image sensor according to any one of the preceding statements of invention and a data storage device for storing data from the pixels, said pixels being divided into a plurality of pixel subsets and said image capture device being constructed and arranged to capture a

plurality of time-separated lo-res images, each said lo-res image comprising the data from a different pixel subset.

Advantageously, the image capture device is constructed and arranged to capture a hi-res image by combining the data within a plurality of lo-res images.

5   The image capture device may include a control device for controlling operation of the pixel array, wherein the control device is constructed and arranged to trigger the pixels in a predefined, random or pseudo-random sequence.

According to another aspect, the invention comprises a camera that includes an image capture device according to any one of the preceding statements of invention. The camera

10 preferably includes a lens for focussing light onto the active area of the sensor. The camera may also include a display device for displaying captured images, which is constructed and arranged to display either a single hi-res image or a sequence of lo-res images. Advantageously, the camera includes a control device for controlling the exposure of the pixel subsets.

15 According to another aspect of the invention there is provided a method of capturing images using an image sensor having a plurality of pixels arranged in an array, the method comprising selecting individual pixels in the array and transmitting a shutter signal to the pixels, whereby said pixels are triggered to sense incident light only when both selected and in receipt of a shutter signal.

20 Advantageously, the pixels in the array are triggered individually to capture light at different times.

Preferably, the pixels are arranged in an array of rows and columns and an individual pixel is selected by transmitting a row select signal and a column select signal along the row and the column in which that pixel is located.

25 Preferably, at least one of the row select signal and the column select signal is generated by a shift register.

Preferably, each pixel is triggered to sense incident light only when it receives substantially simultaneously a shutter signal, a row select signal and a column select signal.

Advantageously, the method includes capturing a plurality of time-separated lo-res images, each lo-res image comprising the data from a different one of a plurality of pixel subsets.

The pixel subsets are preferably exposed sequentially.

Advantageously, a hi-res image is generated by combining the data from a plurality of lo-res images.

The invention allows a set of time-separated low resolution ("lo-res") images to be embedded within each high resolution ("hi-res") image. The embedded lo-res images can then be viewed in sequence as a movie, or the data in those images can be combined to form a single hi-res image. Movies and still images can thus be captured simultaneously. The invention allows movies to be captured at much higher frame rates than can currently be achieved with existing sensor devices and, although the spatial resolution of the lo-res images is lower than that of the hi-res image, it is still sufficient for many purposes. The balance of resolution versus frame rate can be easily adjusted. Furthermore, the still images can be captured with no loss of spatial resolution and no significant increase in the data storage requirements of the device.

Certain embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a front view showing schematically a small portion of an image sensor according to a first embodiment of the invention;

Figure 2 is a chart illustrating shutter exposure times for respective shutter elements in the image capture device of Figure 1;

Figure 3 illustrates how a sequence of images may be captured by the image sensor;

Figure 4 is a circuit diagram of a conventional prior art pixel with a global shutter control;

Figure 5 is a circuit diagram of a pixel according to a first embodiment of the invention, with an individual pixel-level shutter control;

Figure 6 illustrates a control circuit for a pixel according to an embodiment of the invention;

Figure 7 illustrates schematically operation of the control circuit;

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Figure 8 is a circuit diagram of a pixel according to a second embodiment of the invention, with an individual pixel-level shutter control;

Figure 9 is a circuit diagram of a pixel according to a third embodiment of the invention, with an individual pixel-level shutter control; and

5   Figure 10 is a schematic diagram illustrating the main components of a camera that includes an image sensor according to the invention.

A portion of an image capture device according to a first embodiment of the invention is shown in Figures 1 to 3. The image capture device 2 includes a sensor 4 having an active area comprising a rectangular array of photosensitive picture elements (pixels) 6. The

10   sensor 4 may for example be a CMOS APS device (a complementary metal-oxide semiconductor, active pixel sensor device), or equivalent.

For simplicity, the sensor 4 shown in figure 1 is very small having only thirty-six pixels arranged in six by six pixel square array. In most real sensors the pixel array will be much larger than this and may consist of several million pixels. The pixel array may also have a

15   different aspect ratio and the pixels may be arranged in various different patterns.

More generally, the sensor 4 contains A pixels, which are divided into N subsets of pixels, which we will call subset S_1, subset S_2 ... subset S_N. Each subset contains A/N pixels. In the simple example shown in figure 1, the sensor has thirty-six pixels (A) and four subsets (N) of pixels, each subset containing nine pixels.

20   The pixels 6 of the different subsets S_1 to S_N are grouped in a number of pixel groups 8, each pixel group 8 containing one pixel from each subset. In the example shown in figure 1, each pixel group 8 contains four pixels 6, which are arranged in a square with a pixel from subset S_1 in the top left corner, a pixel from subset S_2 in the top right corner, pixel from subset S_3 in the bottom left corner and pixel from subset S_4 in the bottom right corner.

25   Therefore, in this example the sensor 4 comprises four pixel subsets S_1 to S_4 and nine pixel groups 8. The pixel groups 8 cover substantially the entire active surface of the sensor 4 and therefore each pixel subset S_1 to S_N includes pixels from substantially the entire active area of the sensor 4.

The pixels 6 in each subset S_1 to S_N are electronically linked so that all the pixels in any one subset can be triggered to capture the incident light substantially simultaneously, the exposure of the pixels being controlled by control electronics as described in more detail below. In this example, the four pixel subsets S_1 to S_4 are arranged to capture light sequentially as shown in Figure 2. Thus, the pixels in pixel subset S_1 capture light for a first period 0.25 seconds, followed by the pixels in subset S_2 for the next period 0.25 seconds, then the pixels of subset S_3 for another 0.25 seconds and finally the pixels of subset S_4 for a fourth period of 0.25 seconds. The total integration time T_i for all four pixel subsets S_1 to S_4 is therefore 1.0 second, the individual exposure time of each pixel being T_i/N (in this example, 0.25 seconds).

During exposure, each pixel integrates the charge generated when photons strike its surface. After the set integration time T_i, the charge on all the pixels is digitised and the resulting digital image data is transferred from the sensor 4 to a memory device.

The stored image data may be displayed either as a moving image (a movie) comprising a sequence of successive images, or as a single still image. To display the image data as a movie, a separate image is created from the image data captured by each pixel subset. Thus, as illustrated in Figure 3, a first image I_1 is created from the image data captured by all of the pixels in pixel subset S_1 and represents the light incident on the sensor during the first period of 0.25 seconds. Image I_2 is created from the image data captured by all the pixels in pixel subset S_2 and represents the light incident on the sensor during the second period of 0.25 seconds, and so on for images I_3 and I_4. The four images I_1 to I_4 are then displayed sequentially, as a four frame video sequence.

When generating the movie, the apparent location of each pixel in the displayed low resolution image may be shifted slightly to take account of the fact that the pixels of the different pixel subsets collect data from slightly different, but known, locations. In this example, each frame of the movie has an image size of nine pixels, which is one quarter of the resolution of the entire sensor. We refer to images that are generated using less than the full pixel set as low resolution ("lo-res") images to distinguish them from high resolution ("hi-res") images generated using substantially the full pixel set. More specifically, a lo-res image is normally generated using a fraction 1/N of the full pixel set, where N is an integer representing the number of pixel subsets.

If an extended video sequence is required, this image capture process may be repeated one or more times, with multiple data sets being captured at a rate of one data set every T_i seconds, and the captured lo-res images can subsequently be displayed in sequence.

To display a still image, the data from all the pixels on the sensor is used to create a full
5   frame, high resolution image. In this example, this will be a thirty-six pixel image. The high resolution image can be generated by combining the data from all four lo-res images to create the single hi-res image.

A circuit diagram for a conventional prior art pixel 12 is shown in Figure 4. A typical CMOS APS image sensor for a camera generally includes an array of such pixels. The
10   pixel 12 includes a photosensor device 14, a transistor transfer switch 18, a readout circuit 22 and a transistor reset switch 24.

The photosensor device 14 comprises a photodetector, for example a photodiode or phototransistor. The photosensor device 14 provides an output signal at photosensor connection 16, which is represented by voltage V_p. This output signal is connected to a
15   first terminal of the transistor transfer switch 18. A second terminal of the transfer switch 18 provides a readout connection 20 for a readout voltage V_s and is connected to the readout circuit 22. The gate terminal of the transfer switch 18 is connected to receive a shutter signal from a shutter node 28. In this example, the transfer switch 18 is an n-channel MOSFET (metal oxide semiconductor field effect transistor), which only conducts
20   when it receives an *on* signal from the shutter node 28.

The reset switch 24 comprises another MOSFET transistor. In this example, the source terminal of the reset switch 24 is connected to a fixed power supply voltage V_{dd}. The gate terminal of the reset switch 24 is connected to receive a reset signal from a reset node 30. The drain terminal is connected to the photosensor device 14 through photosensor
25   connection 16.

The readout circuit 22 comprises a conventional selectable source-follower readout circuit, which includes a source-follower transistor 32, a select transistor 34 connected to receive a row select signal 36, and an output node 38 for an output signal V_{out}, which is connected to the source connection of the select transistor 34. The readout circuit 22 is designed to
30   sense the voltage at the readout connection 20 of the transfer switch 18. The gate of the

select transistor 34 is connected to receive a select signal from a row select node 36 that selects which pixel in a column of pixels is connected to the output node 38.

In use, a reset signal is applied through the reset node 30 to the gate of the transistor reset switch 24, thus causing the reset switch 24 to conduct. The reset switch 24 applies a high
5   voltage V_{dd} to the photosensor 14, which stores a charge owing to the intrinsic capacitance of the circuit components. Having reset the pixel, the reset signal then turns off.

In order to sense the intensity of the light falling on the pixel, an *on* signal is applied via the shutter node 28 to the gate of the transfer switch 18. This allows the stored charge to discharge through the photodetector 14. The rate at which the charge discharges depends
10   on the photocurrent I_p through the photodetector 14, which in turn depends on the intensity of light incident on the photodetector. The voltage V_p at photosensor connection 16 thus decreases at a rate that depends on the intensity of light falling on the photosensor 14.

The photosensor 14 thus provides an output signal V_p at photosensor connection 16 that is proportional to a time integral of the detected light. This output signal V_p is applied to the
15   input of the readout circuit 22 via transfer switch 18 and the readout connection 20.

At the end of a predetermined exposure time, the shutter signal goes *off*, thus disconnecting the photosensor 14 from the readout circuit 22. The readout circuit stores the output signal V_p at the moment of disconnection. The readout circuit 22 is thus isolated from the photosensor at a capture moment that is determined by the timing of the *off* shutter signal.
20   The readout circuit 22 samples the photosensor signal V_p at the capture moment and provides a read out signal at output node 38. The exposure time is thus determined by the duration of the *on* shutter signal.

Conventionally, the *on* shutter signal is delivered simultaneously to all the pixels in the array. Therefore, all the pixels operate to sense the incident light simultaneously. The
25   output signals from the pixels are then fed to an electronic processor (not shown), which digitises the signals and combines them to form a hi-res image file.

A modified pixel circuit according to a first embodiment of the invention is shown in figure 5. This pixel circuit 12 is similar in most respects to the conventional pixel shown in figure 4 and includes a photosensor device 14, a MOSFET transistor transfer switch 18,
30   a readout circuit 22 and a transistor reset switch 24. The photodetector 14, which may for example be a photodiode or phototransistor, provides an output signal at a photosensor

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connection 16. This output signal is connected to a first terminal of the transistor transfer switch 18. The second terminal of the transfer switch 18 provides a readout connection 20 for a readout voltage V_s and is connected to the readout circuit 22.

The reset switch 24 comprises another MOSFET transistor. The source terminal of the
5   reset switch 24 is connected to a fixed power supply voltage V_{dd} and the gate terminal of the reset switch 24 is connected to receive a reset signal through reset node 30. The drain terminal is connected to the photosensor device 14 through photosensor connection 16.

The readout circuit 22 comprises a conventional selectable source-follower readout circuit, which includes a source-follower transistor 32, a select transistor 34 connected to receive a
10   row select signal through row select node 36, and an output node 38 for an output signal V_{out}, which is connected to the source connection of the select transistor 34. The readout circuit 22 is designed to sense the voltage V_s at the readout connection 20 of the transfer switch 18 without drawing any current from the output. The gate of the select transistor 34 is connected to receive a select signal through row select node 36 that selects which pixel
15   in a column of pixels is connected to the output node 38.

The gate terminal of the transfer switch 18 is connected to receive a control signal from the output connection 40 of a logical AND gate 42. The AND gate 42 has three inputs which are connected to a shutter node 44, a column select node 46 and a row select node 48 through which they receive respectively a shutter signal, a column select signal and a row
20   select signal. The AND gate 42 provides an *on* control signal at output connection 40 only when all three input signals are *on*. If one or more of the input signals is *off* the control signal provided at the output connection 40 of the AND gate 42 will be *off*.

As previously indicated, the transfer switch 18 only conducts when it receives an *on* signal at the gate terminal of the switch. Therefore, owing to operation of the AND gate 42 it
25   only conducts when all three of the inputs of the AND gate 42 are *on*. That is, the transfer switch 18 only conducts when the shutter signal, the column select signal and the row select signal are all *on*. Therefore, operation of the pixel can be controlled by applying *on* and *off* signals to the column select node 46, the row select node 48 and the shutter node 44. This allows each pixel in the pixel array to be activated individually, and makes it
30   possible to capture a sequence of time-dependent lo-res image files as described above.

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These lo-res images can then be viewed separately in sequence as a movie or they can be combined to form a single hi-res still image.

An example of a control circuit for controlling operation of the individual pixels in a pixel array is illustrated schematically in Figure 6. In this example, the column and row select

5   signals are generated by a column select shift register 50 and a row select shift register 52, which are connected to a grid of control connection lines 54. Each row connection line 56 is connected to the row select nodes 48 of all the pixels in a single row of pixels, and each column connection line 58 is connected to the column select nodes of all the pixels in a single column of pixels. Every pixel in the pixel array is therefore connected via a single

10   row connection line 56 and a single column connection line 58 to the shift registers 50, 52.

Each shift register 50,52 stores a set of *on* and *off* signals, which are applied via the grid 54 of connection lines to the pixels in the pixel array. The shutter nodes 44 are connected to a common shutter connection (not shown) so that they all receive a shutter signal at the same instant.

15   In use, the pixels are controlled by the signals received at the shutter node 44, the column select node 46 and the row select node 48. Owing to operation of the logical AND gate 42, each pixel senses light only when all three signals are *on*. Therefore, by controlling the column select and row select signals delivered to the column select and row select nodes 46,48 the operation of the individual pixels can be controlled.

20   An example of a typical control sequence for a simple 2x2 four-pixel sub-group is illustrated in Figure 7. In this example, the column select shift register 50 and the row select shift register 52 each store a set of alternating control signals in the form 1,0,1,0,1,0,..., where "1" is *on* and "0" is *off*. In the first step, the row1 and column1 signals are *on* and the row2 and column2 signals are *off*. The pixel in subset S_1 is therefore

25   *on* and the pixels in subsets S_2, S_3 and S_4 are *off*. In the second step, the column select shift register 50 has advanced one step so that the sequence of alternating control signals is now 0,1,0,1,0,1,..., whereas and the row select shift register 52 has not advanced. As a result, the pixel in subset S_2 is now *on* and the pixels in subsets S_1, S_3 and S_4 are *off*.

In the third step, the column select shift register 50 and the row select shift register 52 have

30   both advanced one step so that the pixel in subset S_3 is now *on*, and in the fourth step, only the column select shift register 50 has advanced one step so that the pixel in subset S_4 is

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now *on*. In the next step, the column select shift register 50 and the row select shift register 52 both advance one step to take the sensor back to the situation illustrated as step 1.

As another example, in a control sequence for a 4x4 sixteen-pixel sub-group, each shift register can store a control sequence in the form 1,0,0,0,1,0,0,0, etc. When this control sequence is applied to the pixels in the array only one pixel in each group will be activated. By advancing the row select control register three times, the other three pixels in the same column will be activated in turn. The row select and column select registers can then both be advanced one step to activate the first pixel in the next column, and so on to activate each of the other pixels in the pixel sub-group.

Many other control sequences are of course possible. It is not essential that the pixels are activated in a regular pattern as described above. In fact, in some situations it may be advantageous to activate the pixels in a pseudo-random sequence, which can be achieved by varying the control sequences stored in the shift registers or by advancing the registers in different patterns, including single or multiple steps, either forwards or backwards.

Part of a modified pixel circuit according to a second embodiment of the invention is shown in figure 8. This pixel circuit is similar to the pixel circuit shown in figure 5, except that the AND gate 42 is replaced by a control circuit 60, which is described in more detail below. One advantage of this pixel circuit over the previous circuit shown in figure 5 is that it requires fewer transistors and is more compact (the AND gate being a relatively large component), thus allowing more pixels to be provided on the sensor per unit area.

The modified pixel circuit depicted in figure 8 includes a photosensor device, a MOSFET transistor transfer switch 18, a readout circuit and a transistor reset switch. However, for the sake of clarity only the transfer switch 18 is shown in figure 8, the other components of the circuit being exactly as shown in figure 5.

The gate terminal 40 of the transfer switch 18 is connected to receive a control signal from the control circuit 60. The control circuit 60 includes two series-connected MOSFET control transistors 62,64 and the gate terminals of those transistors are connected respectively to a column select node 46 and a row select node 48 to receive in use a column select signal and a row select signal. The shutter node 44 is connected to the gate terminal 40 of the transfer switch 18 via the two control transistors 62,64. The shutter *on*

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signal can therefore only be delivered to the gate of the transfer transistor 18 when both the column select signal and the row select signal are also *on*. The gate terminal 40 of the transfer switch 18 is tied to a ground connection 66 via a resistor 68, to ensure that the transfer switch 18 remains off when no *on* signal is received from the control circuit 60.

5   In operation, the control circuit 60 provides an *on* control signal at output connection 40 only when all three input signals are *on*. Therefore, the transfer switch 18 will only conduct when the shutter signal, the column select signal and the row select signal are all *on*. Operation of the pixel can be controlled by applying *on* and *off* signals to the column select node 46 and the row select node 48, and by applying the shutter signal to the shutter

10   node 44. This allows each pixel in the pixel array to be activated individually, and makes it possible to capture a sequence of time-dependent lo-res image files as described above. These lo-res images can then be viewed separately in sequence or they can be combined to form a single hi-res image.

Part of another modified pixel circuit according to a third embodiment of the invention is

15   shown in figure 9. This pixel circuit is similar to the pixel circuit shown in figure 8, except that instead of the resistor 68, the control circuit 60 includes two additional MOSFET transistors 70,72 that are connected in parallel between the gate terminal 40 of the transfer transistor 18 and the ground connection 66. The gate terminals of these additional transistors are connected respectively to nodes 74,76 that receive in use inverted column

20   select and row select signals. The purpose of these additional transistors 70,72 is to hold the transfer transistor 18 in an *off* condition when either or both of the column select and row select signals is *off*.

The location of pixels in each subset does not have to follow a regular pattern as shown in Figure 1. An apparently random location within the pixel group can be chosen by

25   implementing a numerical scheme, which uses a random number generator with a user supplied seed value and shuffles the location of each pixel within the pixel group. A randomized scheme has two advantages. First, the location of each pixel in the low-resolution image is randomly assigned, even though the average distance between the pixels is the same. The advantages of having randomly distributed pixels vs. a regular

30   under-sampled array for image reconstruction is well explained in United States Patent 4574311, Random Array Sensing Devices, Resnikoff, Poggio, and Sims. Second, the low-

resolution image sequence can only be recovered if the shuffled sequence of integers giving the correct timing is known. If the shuffled sequence is generated by an algorithm that incorporates a random number generating algorithm which is given a key, then the image sequence can only be recovered if the key is supplied by the person viewing the

5   image sequence. This allows image sequences to be encrypted and protected from unauthorized viewing.

As an alternative to the rectangular geometry as shown in Figure 1, pixel groups can have irregular polygonal shapes. Pixel groups can therefore cover regions of interest exactly, while excluding unnecessary pixels. An example of a possible use is in the life sciences,

10   where a user may wish to monitor the activity of a small number of cells in a microscopic field of view. The user can draw a polygonal shape around the cells of interest, and an algorithm can divide the pixels within these shapes into groups which will be exposed at different times.

If the subject imaged by the sensor was moving during the exposure time, the image may

15   contain some "motion blur". The amount of motion blur will generally be greater than with a conventional still camera sensor in which all the pixels are exposed simultaneously, since the total integration time is greater than the exposure time of the individual pixels. However, for subjects having little or no movement, the image quality will be substantially equal to that of a conventional sensor.

20   Alternatively, it may be possible to select various different image capture modes, such as a "movie/still" mode in which the pixel elements are actuated sequentially as described above, or a "still-only" mode in which all the pixel elements operate simultaneously. In movie/still mode the captured los-res images can be viewed either sequentially as a movie, or together as a hi-res still image (possibly with some motion blur). In still-only mode the

25   motion blur will be equivalent to that of a conventional sensor, but because a set of time-separated lo-res images will not then be captured the possibility of viewing the images sequentially as a movie will not be available.

Alternatively, a set number of pixels can be used to obtain a blur free high res. image, while the remainder can be used for obtaining a series of low res. images as previously

30   described. The number of pixels for the high res. low blur image can be selected by the user in order to ensure the desired picture quality. For example, 50% of the pixels can be

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devoted to create a high resolution blur free image, where the pixels of this subgroup are distributed over the entire array. These pixels would be exposed simultaneously, for a short time equal to the optimal exposure time for a blur free image set by the user. The remaining pixels would be divided into N-1 groups as before, and exposed sequentially to generate a movie sequence. The distribution of the pixels in the high resolution group can be regular (for example, every second pixel), or the pixels can be randomly distributed, or pseudo randomly distributed (so that the average density over a defined sub area of pixels is constant, but individual pixels within that area are chosen using a known random distribution). Missing pixels in the high resolution image can be compensated for by using any of a variety of available signal processing techniques. The advantages of having randomly distributed pixels vs. a regular under-sampled array for image reconstruction is well explained in United States Patent 4574311, Random Array Sensing Devices, Resnikoff, Poggio, and Sims.

A practical example will now be described in which the invention is implemented in a digital SLR camera having an 8.2 megapixel sensor with dimensions of 2340 x 3500 pixels. An equivalent conventional camera is currently available, which is capable of capturing full frame images at a rate of five frames per second. If the present invention were implemented in that camera it could for example capture ten 0.82 megapixel lo-res images within each full frame image. Those lo-res images could then be viewed sequentially in movie mode at a rate of fifty frames per second, and a frame size of 738 x 1108 pixels. Alternatively, each set of lo-res images can be recombined to create a high resolution 8.2 megapixel still image.

It will of course be apparent that by embedding more low resolution images within each full frame image even higher frame rates can be obtained. Alternatively, if a lower frame rate is adequate, a higher resolution movie can be captured.

In the process described above, the interval between the successive exposures used to create the embedded lo-res images is equal to the duration of the individual exposures. The next exposure therefore starts as the previous one ends, and the total integration time Ti is equal to Nt, where N is the number of pixel subsets and t is the exposure time for the individual pixels. Alternatively, the interval between the exposures and the exposure time may be adjusted so that the exposure times overlap or are spaced apart. This would allow

the user to compensate for motion blur or low light conditions. For example, instead of using exposure times of 0.25 seconds as illustrated in Figure 2, the exposure time may be reduced to 0.15 seconds. The exposure timings of the individual pixel subsets may be as follows: pixel subset 1 from 0 to 0.15 seconds, pixel subset 2 from 0.25 to 0.4 seconds,

5   pixel subset 3 from 0.5 to 0.65 seconds and pixel subset 4 from 0.75 to 0.9 seconds. The total integration time will then be less than Nt.

As another example, the exposure time can be increased to 0.4 seconds, the individual exposure timings then being as follows: pixel subset 1 from 0 to 0.4 seconds, pixel subset 2 from 0.25 to 0.65 seconds, pixel subset 3 from 0.5 to 0.9 seconds and pixel subset 4 from

10   0.75 to 1.15 seconds. In this case pixel subset exposures overlap (1 overlaps with 2, 2 overlaps with 3, 3 overlaps with 4 and 4 overlaps with 1). The exposure interval may therefore be optimised according to the speed at which the subject is changing or moving.

Various applications of the invention are envisaged. Some of these will now be described.

Consumer cameras

15   The invention may be implemented within a camera that is intended primarily for capturing still images, to provide the possibility of capturing movies at a relatively high resolution and frame rate. For example, as indicated above, a camera that can take a sequence of 8.2 megapixel images at a rate of five frames per second would be capable of providing a movie sequence of 0.8 megapixel images at a frame rate of fifty frames per

20   second.

An advantage to the consumer is that the original high resolution photographs are conserved, and the data storage requirement (image size in memory) is the same as a conventional digital camera. Applications may include video acquisition and security camera operation, allowing the simultaneous capture of high resolution images for scene

25   detail and low resolution image sequences.

The basic elements of a camera are illustrated schematically in Figure 10. This camera 80 includes a lens 82 that focuses an image onto a CMOS sensor 84. Exposure of the individual pixels forming the sensor 84 to the incident light is controlled by a central processor unit (CPU) 88, which also reads data from the sensor. This data is stored in a

30   memory device 90, for example a flash memory card. The camera includes a shutter

release 92 and a control switch 94 that is linked to the CPU 88 and may be used to set, for example, the operational mode of the camera. The operation modes may for example include a "movie/still" mode in which the camera captures a set of time-separated lo-res images within each hi-res frame that may be viewed either as a movie or a high resolution

5   still image, or a "still-only" mode in which the pixels are all exposed simultaneously to form a still image with minimal motion blur. The camera may also include other conventional features, such as a viewfinder, a display unit for checking settings or viewing captured images, lens controls for controlling the aperture, focal length and focussing of the lens 82, a flash unit, a data output port and so on.

10   Security/Machine Vision

Cameras that are used to monitor a changing 3D scene, which are common in surveillance applications and robotics/machine vision, must contend with several challenges. One issue is that if an object moves relative to the camera, the magnitude of movement of the image across the sensor will be inversely proportional to the distance of the object from the

15   camera. This will cause motion blur to be more pronounced for objects close to the camera, obscuring necessary detail. For example, surveillance of a group of walking people on a street or in a building lobby would produce blurred images of their faces if they are close to the camera. Decreasing the shutter time for the whole image would potentially degrade image quality for objects far from the camera, as the total light

20   collected from far objects will be less.

The present invention can address this issue by varying the number of pixel groups (and hence the temporal and spatial resolution as well as total exposure time) within one frame, so as to optimise imaging of several objects within the scene. Advantageously, objects closer to the camera are proportionately larger, reducing the spatial resolution requirements

25   and allowing for increased temporal resolution. The size of the pixel groups can be chosen using *a priori* knowledge of the scene (for example, vehicles monitored travelling on a highway by an elevated camera facing the direction of traffic flow would become proportionately smaller toward the top of the image, allowing the use of a gradation of pixel group sizes to maintain the average number of pixels per car). Alternatively, the size

30   of the pixel groups can be chosen dynamically using algorithmic methods (for example, by obtaining the optical flow from motion blur in a static image, as described in Berthold and

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Shunck, "Determining Optical Flow", Technical Report, MIT, 1980) or range finding equipment (e.g. laser range finders or similar).

Additionally, specific regions of interest can be imaged at different resolutions independent of the pixel group pattern used in the majority of the image. For example, a camera
5   monitoring traffic could obtain high spatial resolution images of the licence plates of vehicles by controlling the exposure time of an appropriately chosen rectangle of pixels, while monitoring vehicle motion with low spatial resolution.

Vehicle speed and licence plate detection could be accomplished without a radar device in such a system by using the camera to continuously monitor vehicle motion at low spatial
10   resolution (using sufficiently large pixel groups). A computer algorithm would calculate vehicle speed and dynamically change the pixel groups to image either the whole scene or just the licence plates at high spatial resolution when required.

CLAIMS

1.   An image sensor having a plurality of pixels arranged in an array, selection means for selecting individual pixels in the array, and shutter control means for transmitting a shutter signal to the pixels, wherein each said pixel is constructed and arranged to sense incident light only when both selected and in receipt of a shutter signal, whereby pixels in said array can be triggered individually to capture light at different times.

2.   An image sensor according to claim 1, wherein the pixels are arranged in an array of rows and columns and are connected to receive a row select signal and a column select signal, whereby an individual pixel can be selected by transmitting a row select signal and a column select signal along the row and the column in which that pixel is located.

3.   An image sensor according to claim 2, wherein the selection means comprises a plurality of row selection lines and a plurality of column selection lines, wherein each row selection line is connected to all the pixels in a particular row and each column selection line is connected to all the pixels in a particular column.

4.   An image sensor according to claim 3, wherein the selection means comprises a grid of row selection lines and column selection lines.

5.   An image sensor according to any one of claims 2 to 4, wherein at least one of the row select signal and the column select signal is generated by a shift register.

6.   An image sensor according to any one of claims 2 to 5, wherein each pixel includes a control means for triggering the pixel, the control means being constructed and arranged to trigger the pixel only when it receives substantially simultaneously a shutter signal, a row select signal and a column select signal.

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7.   An image sensor according to claim 6, wherein the control means includes a logical AND gate having inputs for receiving a shutter signal, a row select signal and a column select signal.

8.   An image sensor according to claim 6, wherein the control means includes a plurality of series-connected switch devices, each switch device being operably connected to receive at least one of a shutter signal, a row select signal and a column select signal.

9.   An image sensor according to any preceding claim, the image sensor comprising a CMOS APS device.

10.   An image capture device including an image sensor according to any one of the preceding claims and a data storage device for storing data from the pixels, said pixels being divided into a plurality of pixel subsets and said image capture device being constructed and arranged to capture a plurality of time-separated lo-res images, each said lo-res image comprising the data from a different pixel subset.

11.   An image capture device according to claim 10, said image capture device being constructed and arranged to capture a hi-res image by combining the data within a plurality of lo-res images.

12.   An image capture device according to claim 10 or claim 11, including a control device for controlling operation of the pixel array, wherein the control device is constructed and arranged to trigger the pixels in a predefined, random or pseudo-random sequence.

13.   A camera including an image capture device according to any of claims 10 to 12.

14.   A method of capturing images using an image sensor having a plurality of pixels arranged in an array, the method comprising selecting individual pixels in the array and transmitting a shutter signal to the pixels, whereby said pixels are triggered to sense incident light only when both selected and in receipt of a shutter signal.

15.   A method according to claim 14, wherein the pixels in the array are triggered individually to capture light at different times.

16.   A method according to claim 14 or claim 16, wherein the pixels are arranged in an array of rows and columns and an individual pixel is selected by transmitting a row select signal and a column select signal along the row and the column in which that pixel is located.

17.   A method according to claim 16, wherein at least one of the row select signal and the column select signal is generated by a shift register.

18.   A method according to claim 16 or claim 17, wherein each pixel is triggered to sense incident light only when it receives substantially simultaneously a shutter signal, a row select signal and a column select signal.

19.   A method according to any one of claims 14 to 18, including capturing a plurality of time-separated lo-res images, each lo-res image comprising the data from a different one of a plurality of pixel subsets.

20.   A method according to claim 19, including exposing the pixel subsets sequentially.

21.   A method according to claim 19 or claim 20, including creating a hi-res image by combining the data from a plurality of lo-res images.
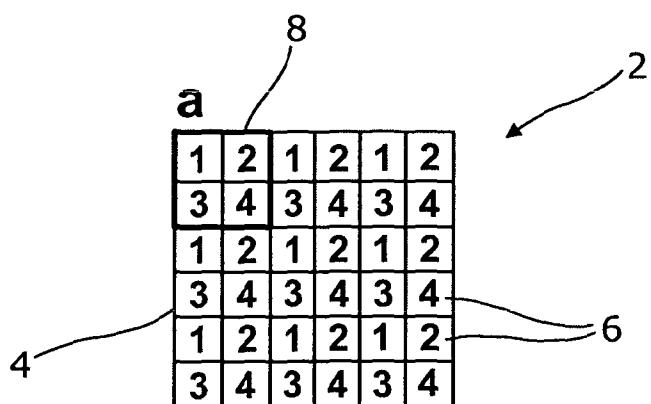
a

1	2	1	2	1	2
3	4	3	4	3	4
1	2	1	2	1	2
3	4	3	4	3	4
1	2	1	2	1	2
3	4	3	4	3	4

Fig. 1

b

Pixel number

Exposure t (s)

Fig. 2

c

1	1	1
1	1	1
1	1	1

0 - 0.25 s

2	2	2
2	2	2
2	2	2

0.25 - 0.5 s

3	3	3
3	3	3
3	3	3

0.5 - 0.75 s

4	4	4
4	4	4
4	4	4
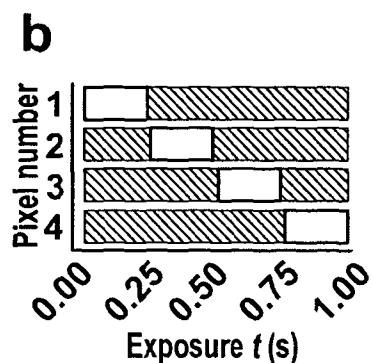
0.75 - 1 s

Fig. 3

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Fig. 4 (Prior Art)

Fig. 5

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Fig. 6

Fig. 7

4/5

60

46   48

COL_IN   ROW_IN   64   44

62

68   Q1   Q2   SHUTTER

R1   40

66   Q3

18   Fig. 8

46   48

76   ROW_IN   COL_IN   ROW_IN

74 COL_IN   72   64   44

Q2   Q4   Q5   SHUTTER

66   Q1

40

Q3

70

18   Fig. 9
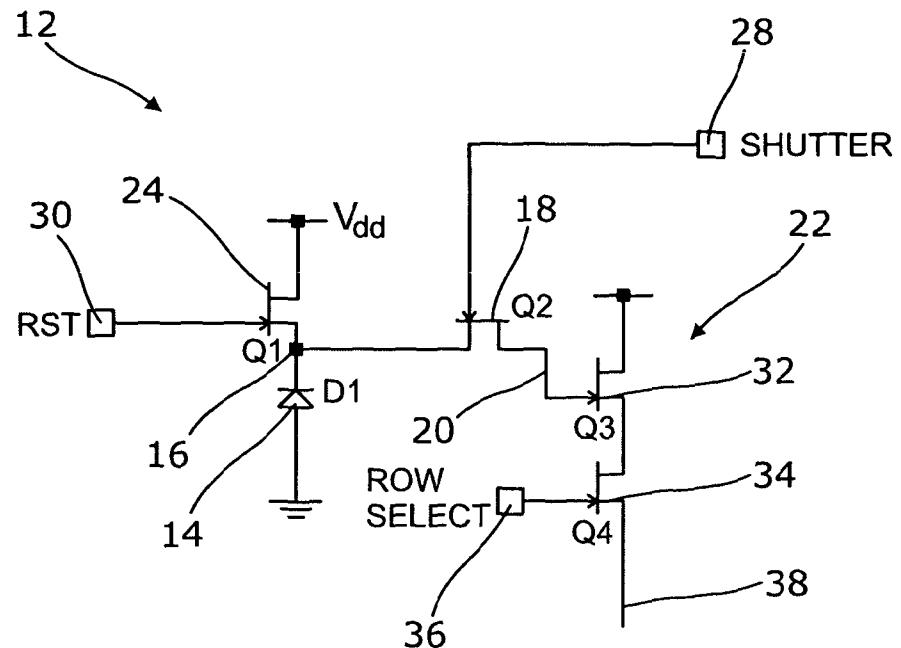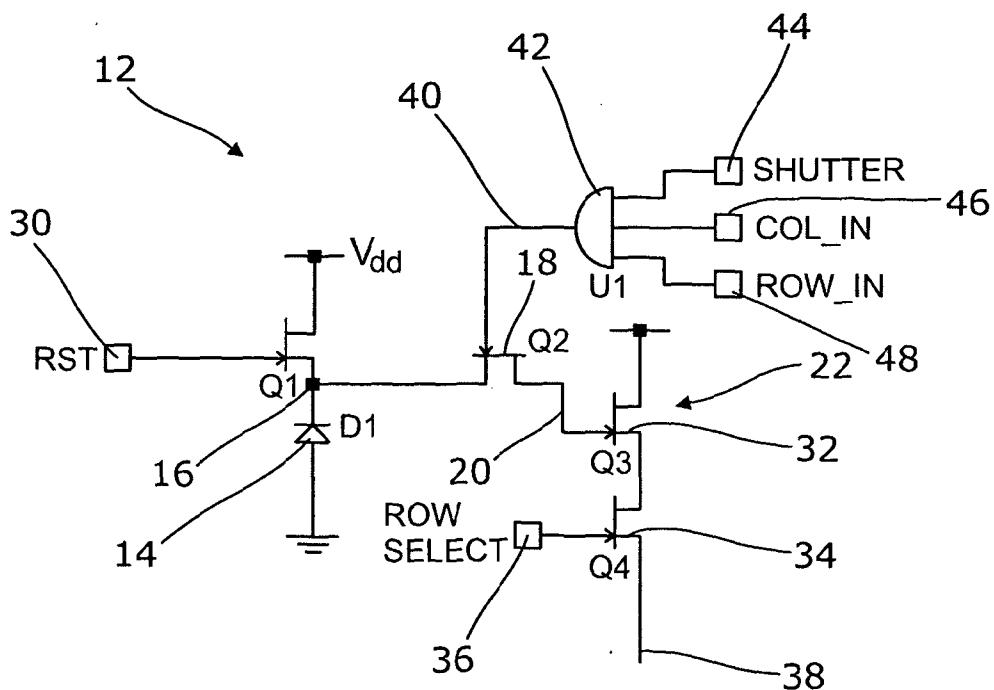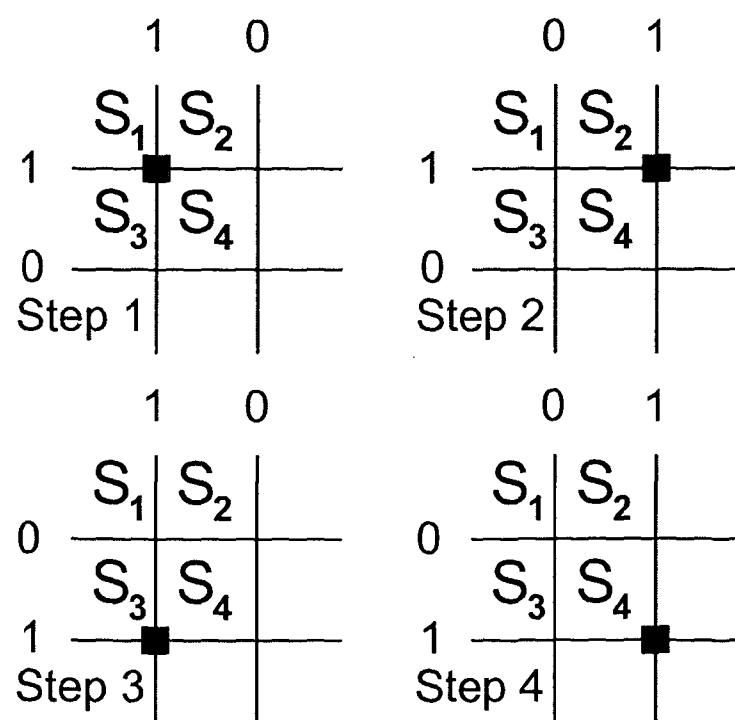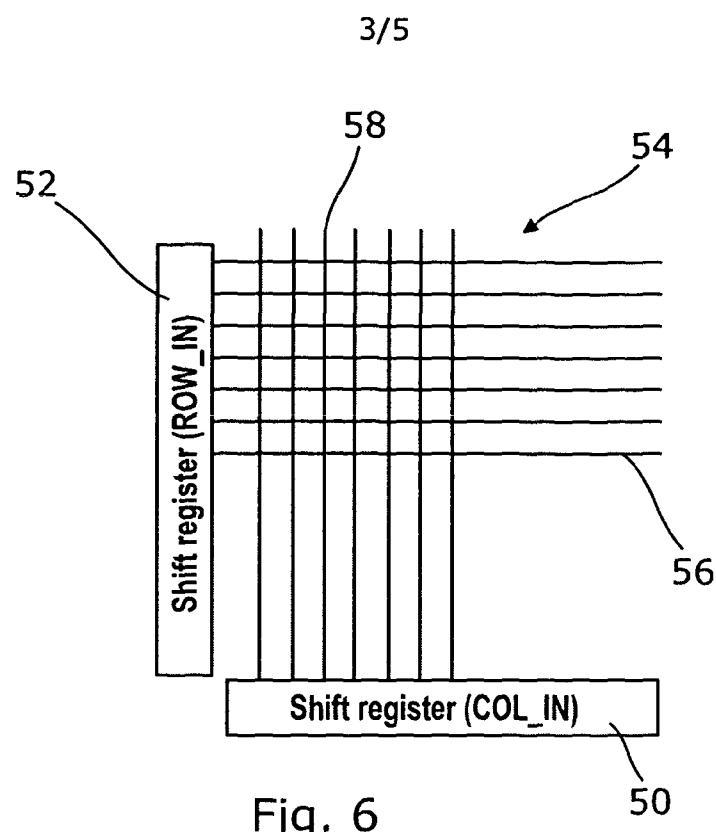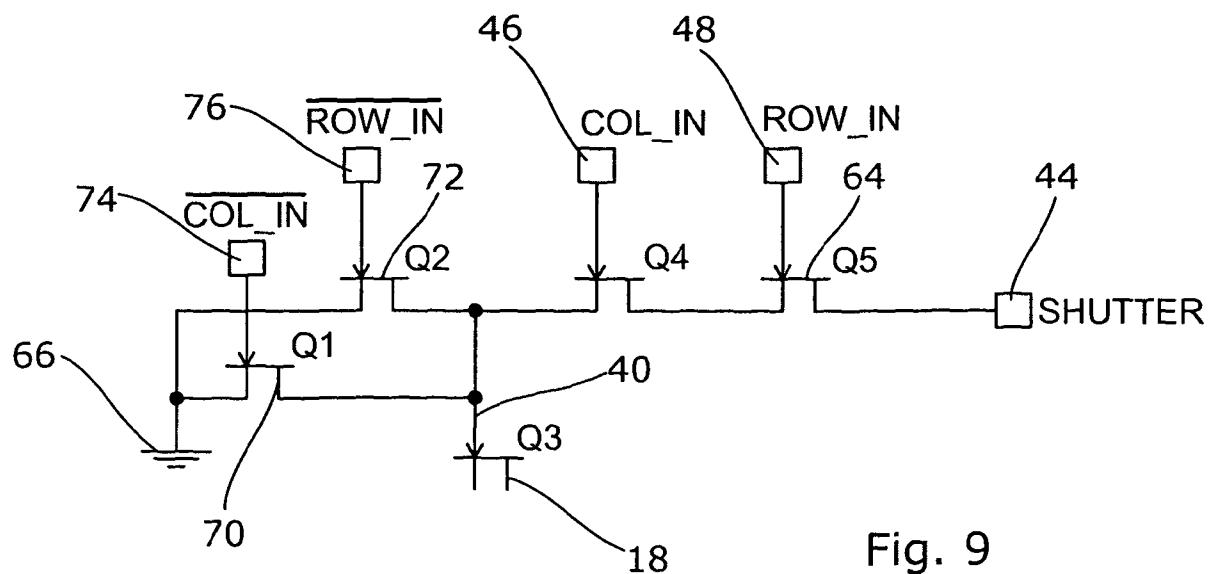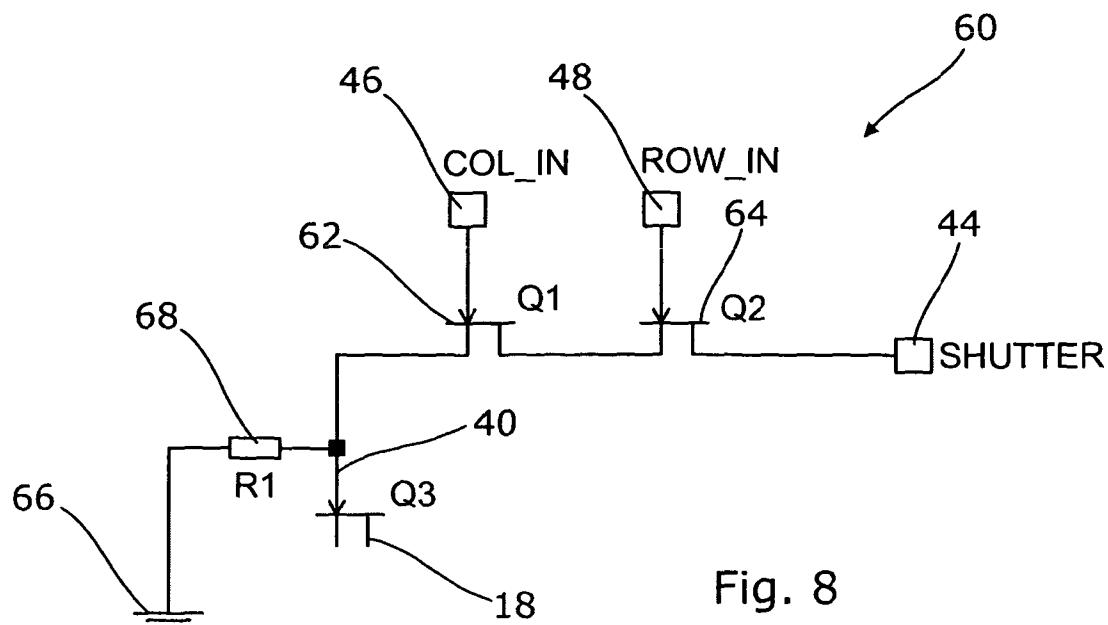
5/5

Fig. 10

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04N5/232   H04N5/3745   H04N5/343
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04N   H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ORLY YADID-PECHT ET AL: "CMOS Active Pixel Sensor Star Tracker with Regional Electronic Shutter", IEEE JOURNAL OF SOLID-STATE CIRCUITS, IEEE SERVICE CENTER, PISCATAWAY, NJ, USA, vol. 32, no. 2, 1 February 1997 (1997-02-01), XP011060425, ISSN: 0018-9200	1-3,6,9, 14-16,18
Y	abstract; figure 1	4,5,7,8, 10-13, 17,19-21

Y	WO 2008/138543 A1 (ISIS INNOVATION [GB]; BUB GIL [GB]) 20 November 2008 (2008-11-20) cited in the application pages 6,12	10-13, 19-21

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| [X] | Further documents are listed in the continuation of Box C. | [X] | See patent family annex. |

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 November 2011	22/11/2011

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ogor, Mariëlle

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INTERNATIONAL SEARCH REPORT

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	CHYE HUAT AW ET AL: "A 128X128-PIXEL STANDARD-CMOS IMAGE SENSOR WITH ELECTRONIC SHUTTER", IEEE INTERNATIONAL SOLID STATE CIRCUITS CONFERENCE, IEEE SERVICE CENTER, NEW YORK, NY, US, vol. 39, 1 February 1996 (1996-02-01), XP000685586, ISSN: 0193-6530 figure 2 -----	1,10,13, 14
A	US 6 720 592 B1 (KINDT WILLEM JOHANNES [US] ET AL) 13 April 2004 (2004-04-13) figure 5 -----	1,10,13, 14
A	WO 99/09737 A1 (INTEL CORP [US]) 25 February 1999 (1999-02-25) page 2, lines 1-11 page 3, line 12 -----	1,10,13, 14

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