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Declarations under Rule 4.17:
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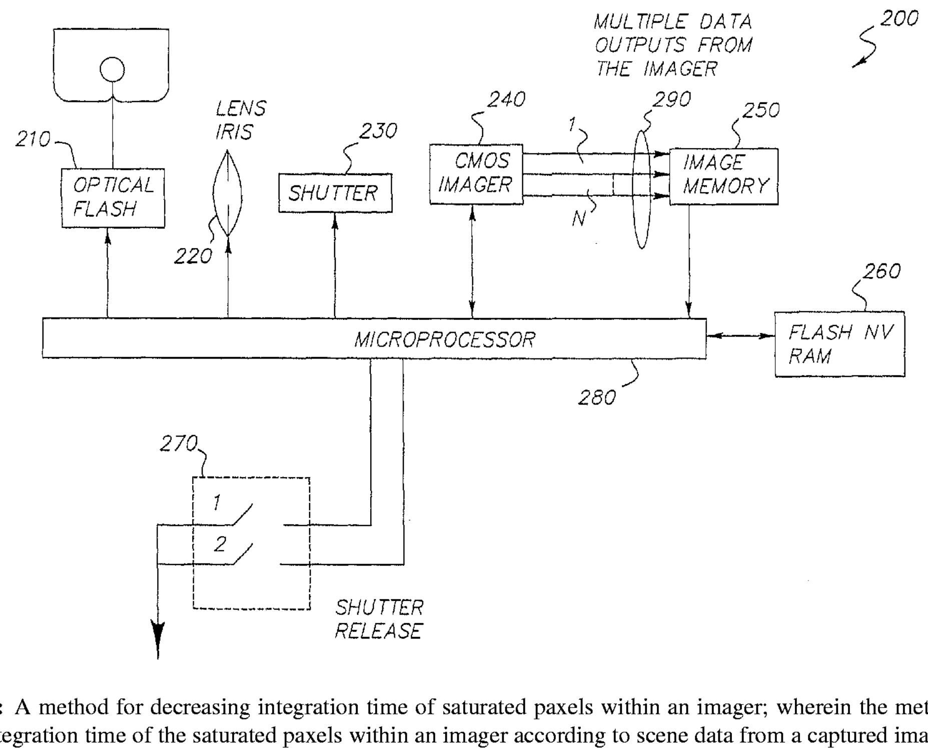
[Continued on next page]

(54) Title: EXTENDED DYNAMIC RANGE IMAGING SYSTEM



(57) Abstract: A method for decreasing integration time of saturated paxels within an imager; wherein the method includes decreasing the integration time of the saturated paxels within an imager according to scene data from a captured image.

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SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

EXTENDED DYNAMIC RANGE IMAGING SYSTEM

FIELD OF THE INVENTION

The present invention relates generally to the field of imaging, and in particular to imaging using an electronic imager with pixel address based programmable integration time.

BACKGROUND OF THE INVENTION

Imagers, particularly CMOS imagers, in the past have had problems with scenes that have a high dynamic range such that parts of the scene have highlights therein. This is termed scene exposure latitude. In these highlighted portions of the image, the pixels of the sensor become saturated, such that the digital pixel outputs are all 1's. Accordingly, the pixels of the sensor are especially saturated when the captured scene contains more dynamic range than typically can be captured; for example, a couple standing in the park with the sun over their shoulder. The normal scene can have a dynamic range of 6 to 7 stops. The image of the sun introduces another 10 stops of dynamic range. Current state of the art cameras set the exposure level to capture the couple and allow the sun to saturate the image in the resultant picture. Similar circumstances exist with images that contain specular reflections, for example, the sun reflecting off a metallic car bumper. One other exemplary troublesome scene to capture contains a car in a parking lot, at night. To expose the car correctly, the car headlights and the streetlights illuminating the parking lot will ultimately saturate the image. Consequently, for conventional imaging systems, very little error in determining exposure can be tolerated when the scene dynamic range is close to, or equal to the dynamic range of the image capture system.

What is needed is an image capture system that always has a dynamic range greater than the captured scene

SUMMARY OF THE INVENTION

The aforementioned need is addressed by the present invention by providing a method for decreasing integration time of saturated paxels within an imager; wherein the method includes decreasing the integration time of the saturated paxels within an imager according to scene data from a captured image. Another aspect of the present invention provides for an electronic image capture system that includes an imager that enables independent integration time control of paxels and an algorithm for determining the correct integration time for the paxels based on their saturation level.

ADVANTAGEOUS EFFECT OF THE INVENTION

Through multiple image captures, the integration time of the paxels is adjusted to reach the ideal compromise between scene dynamic range and captured scene signal to noise ratio.

The present invention will correct the problems sited and result in a system with greater scene exposure latitude. Hence, the present invention will result in an image capture system having the capability to capture more of the scene's dynamic range.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of an exemplary camera employing the present invention.

Figure 2 is a block diagram of an exemplary electronic imaging system employing the present invention.

Figure 3 is an exemplary flow chart of the paxel integration time adjusting algorithm for the present invention.

Figure 4 is an exemplary diagram of a paxel used with the Bayer color filter array pattern according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, the present invention will be described in the preferred embodiment as utilizing a microprocessor as a controller and also executing the paxel integration time algorithm. Those skilled in the art will readily recognize that the equivalent of this system may also be constructed in hardware only.

The present invention determines the geographic locations of the bright or highlight areas of an image. An adaptive exposure algorithm, employed by the present invention, decreases the integration time of the paxels in the highlight areas of the image so that these paxels are exposed correctly, i.e., close to, but not at saturation. In this way, one can capture a scene that has higher dynamic range than what could be captured using conventional methods. The additional dynamic range is the dynamic range captured by the paxels with reduced integration time. This invention takes advantage of the ability to program the integration time of paxels within an imager independently of each other as described in further detail in U.S. Serial No. 10/654,313 filed on 03 September 2003 in the name of Robert M. Guidash, and incorporated herein by reference.

To solve the dynamic range problem, in an exemplary embodiment, the present invention employs CMOS imaging sensors that enable individual, pixel level, programming of integration time, based on the pixel X-Y address. In a single exposure it is possible to have alternate rows of pixels with varying integration time. It is also possible to group pixels in small X-Y groups. These small X-Y groups are termed paxels. The X-Y size of these paxels can be dynamically changed. Typically, these paxels are based on the color filter array pattern used to detect different colors in the image. For example, the Bayer color filter array pattern (CFA) has a Green-Red alternate on the first line with a Blue-Green alternate on the next line. This CFA pattern is repeated for all lines in the imager. One may set alternate rows of the imager with significantly different integration times. The present invention utilizes blocks of pixels, i.e., paxels in the same way. Some blocks may have long integration times, some may have short integration times.

In one embodiment of the present invention, scene data as captured by an imager is analyzed and assessed for saturation in a paxel by paxel basis. The imager may be an imager with an individual X-Y addressable integration time. Herein, integration time is defined as the amount of time that the imager is allowed to absorb an image during the capture process. For the present invention, the integration time of only the saturated paxels is decreased. Additional images are repeatedly captured, analyzed, and assessed under different integration times, until the number of saturated paxels is nearly zero.

Referring to Fig. 1, one embodiment of the present invention shows a camera system 100 having an optical flash 110, controlled by a microprocessor 120. The microprocessor 120 also controls a shutter 130, an imager 140, an image memory 150, and a flash non-volatile memory 160. A dual stage, dual contact shutter release switch 170 inputs signals to the microprocessor 120. One skilled in the art will realize that the present invention can also be implemented using a single stage, single contact shutter release switch 170.

The microprocessor 120 executes a paxel integration time algorithm 300, shown in Fig. 3, that controls the relationship between the imager 140 and the image memory 150, in addition to the known functionality of the microprocessor 120 for camera system 100. In general, an image is captured from the imager 140 to the image memory 150 and the paxel integration time algorithm 300 shown in Fig. 3 determines the correct integration time for each paxel in the final image.

The imager 140 can be a CMOS imager or a CCD imager that has independent X-Y addressable integration times for groups of pixels, known as paxels. In the embodiments described herein, flash non-volatile memory 160 is used, however, one skilled in the art will recognize that EPROMs, battery-backed RAM, and fusible link ROM are some other memory options that can be substituted for use with the present invention.

A second embodiment employs an electronic imaging system 200, shown in Fig. 2 (which may be an electronic still camera, a motion capture system, or a machine vision system, or any device employing imaging capabilities).

Figure 2 illustrates that camera system 200 includes a CMOS Imager 240, with the paxel programmable integration capability. CMOS imager 240 also has multiple, parallel data signal outputs 290. These multiple, parallel data signal outputs 290 improve the CMOS imager's 240 readout rate. Consequently, the time to final picture is decreased. In all other ways the operation is the same as the first embodiment shown in Fig. 1.

Referring to Fig. 3, a paxel integration time algorithm 300 is shown for decreasing integration time of saturated paxels within an imager according to scene data from a captured image. A shutter operation 310 for operating shutter release switch 170 as shown in Figs. 1 and 2 is used to determine the overall exposure for camera systems 100 and 200. In image capture operation 320 a first image is captured to memory 150 or 250 (according to either Fig. 1 or Fig. 2). Each paxel is tested for saturation in operation 330. All paxel values are derived by averaging the 4 pixels that make up each paxel to one value. If that value is equal to or greater than a maximum value (K) the corresponding paxel is considered to be saturated. Upon completion of operation 330, the X-Y locations of the saturated paxels are recorded in operation 340. Subsequently, the saturated paxels are totalized in operation 350. A conditional operation 360 determines that if the quantity of saturated paxels is 0, the image is written to non-volatile flash memory in operation 365. Alternatively, for conditional operation 360, if the quantity of saturated paxels is not zero, the quantity of saturated paxels is counted in operation 370. An optional conditional operation 362 is interspersed between conditional operation 360 and write operation 365 when a dual stage shutter release switch 170 or 270 is used for camera 100 or 200, respectively.

A second conditional operation, operation 375 determines if the quantity of saturated paxels is greater than a constant, N. In operation 385, the integration time of the saturated paxels is decreased a large increment (1/4 the exposure time or 2 stops, in this example). One stop is a halving of the signal or a 2X reduction. Two stops is a 4X reduction in signal. A large increment is used in order to minimize the number of captures needed to acquire the correctly exposed image with greater overall dynamic range. (An aggressive reduction in integration time is used until one approaches the correct integration time. Then, a smaller incremental reduction in integration time is used for greater accuracy). If the quantity of saturated paxels is less than a constant, N, in operation 380, the integration time of the saturated paxels is decreased a lesser increment (1/2 the exposure time or 1 stop, in this example).

Operation 390 resets the paxel counter used at operation 350. Operation 395 records the paxel integration times. A new image is captured in operation 320 and the algorithm is repeated until the "0 saturated paxel" criteria, at operation 360, is met. The extended dynamic range image is then recorded at operation 365 along with the integration times associated with their respective paxels and the paxel X-Y location. This information is used in the image reconstruction process, albeit during post capture.

If the quantity of saturated paxels is equal to or less than a constant, N, and greater than a constant, M, the integration time of the saturated paxels is decreased a small increment (3/4 the exposure time or ½ stop, in this example). A small increment is used so that the system does not severely under expose the paxels that were overexposed. If the quantity of saturated paxels is equal to or less than a constant, M, the exposure is considered correct, and the image is captured.

Both integration times are recorded since this is information that is needed for the downstream image reconstruction algorithm. The premise is that the higher the quantity of saturated paxels, the more saturated the image. A second image is captured and the process is repeated. This continues until there are no saturated paxels. The image stored in picture memory is now written to the Flash memory. The dual integration time choice enables the system to get to the correct overall exposure with a fewer number of image captures. This method can be extended to multiple decision points with multiple changes in integration time of the saturated paxels.

Averaging the pixels, derives each paxel, to a single value (e.g., in a 2x2 Paxel; however the paxel size can vary). Referring to Fig. 4 and paxel diagram 400, several paxel arrays are shown; for example, a 2x2 multi-color paxel 420 as well as a 4x4 multi-color paxel 430. Also shown are a 2x2 green paxel

440, a 2x2 red paxel 450, a 2x2 blue paxel 460, and a 4x4 green paxel 470. A paxel 410 used with the Bayer color filter array pattern, for implementation with an imager, is also shown.

Alternative embodiments of the present invention are contemplated. For example, in one embodiment an electronic imaging system that is running continuously and contains a CMOS Imager 240, with the paxel programmable integration capability. The electronic imaging system 200 runs continuously. When the shutter release button is pushed the first 0 saturated paxel image is stored. The time to picture capture is decreased. In all other ways it works as the earlier described embodiment.

Another embodiment is an electronic still camera imaging system 200 that uses a dual stage shutter release switch. When the first switch is closed the camera is started. This invention finds the correct integration time for the normal and saturated paxels. When the second switch is closed the first image containing no saturated paxels is then stored in non-volatile flash memory 260. This invention contains a CMOS Imager 240, with the paxel programmable integration capability. The time to picture capture is decreased.

Yet another embodiment is an imaging system 10 that contains a CMOS Imager 240, with the paxel programmable integration capability. This system uses any or all of the ideas contained in earlier embodiments. The primary purpose for this embodiment is to form the sensor for a camera exposure determination system. It can be used with film cameras or electronic cameras. This embodiment can employ sensors of low resolution and therefore, would be fast in operation and low in cost.

It is recognized that this invention will work with an imager 140 or 240 that has an electronic shutter. It is also recognized that this invention will work with imagers that require a mechanical or electromechanical shutter.

Accordingly, the invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

100	camera system
110	optical flash
120	microprocessor
130	shutter
140	imager
150	image memory
160	flash non-volatile memory
170	dual stage, dual contact shutter release switch
200	electronic imaging camera system
210	optical flash
220	lens iris
230	shutter
240	CMOS imager
250	image memory
260	flash non-volatile RAM
270	dual stage, dual contact shutter release switch
280	microprocessor
290	multiple data outputs
300	flowchart
310	operation
320	operation
330	operation
340	operation
350	operation
360	operation
362	operation
365	operation
370	operation
375	operation
380	operation

385 operation
390 operation
395 operation
400 exemplary Paxel arrays
410 paxel with Bayer Color Filter Array
420 2x2 multi-color paxel
430 4x4 multi-color paxel
440 2x2 green paxel
450 2x2 red paxel
460 2x2 blue paxel
470 4x4 green paxel

CLAIMS:

1. A method for decreasing integration time of saturated paxels within an imager, comprising the step of: decreasing the integration time of the saturated paxels within an imager according to scene data from a captured image.

2. The method claimed in claim 1, wherein the saturated paxels are geographically located by X-Y addressing of paxels within the captured image.

3. The method claimed in claim 1, wherein a magnitude of the decreased integration time is relative to an amount of the saturated paxels.

4. The method claimed in claim 3, wherein a large amount of the saturated paxels causes a large magnitude of the decreased integration time.

5. The method claimed in claim 3, wherein a small amount of the saturated paxels causes a small magnitude of the decreased integration time.

6. A method for addressing X-Y paxels in an imaging system, comprising the steps of:

a) capturing a first image;

b) testing the first image for saturation on a paxel by paxel basis, wherein the paxels are groups of pixels associated geographically with each other;

c) recording an X-Y address for each saturated paxel within the first image;

d) determining the number of saturated paxels;

e) comparing the number of saturated paxels to a constant, N, where the number of saturated paxels is greater than zero;

f) varying integration time of the saturated paxels according to the number of saturated paxels being greater than or less than the constant N;

7. An electronic image capture system comprising an imager that enables independent integration time control of paxels and an algorithm for determining the correct integration time for the paxels based on their saturation level.

8. The electronic image capture system as recited in claim 7 using multiple means for determining the integration time for saturated paxels.

9. The electronic image capture system as recited in claim 7 that runs continuously to reduce the time to capture a picture.

10. The electronic image capture system as recited in claim 7 that utilizes a dual, staged, shutter release switch, wherein said switch initializes the electronic image capture system to capture a final image.

11. The electronic image capture system as recited in claim 1 wherein the imager enables independent integration time control of paxels and an algorithm for determining the correct integration time for the paxels based on their geographic location within a captured image and light recorded from the captured image.

12. The electronic image capture system, claimed in claim 11, wherein said imager includes multiple signal outputs for thereby reducing image capture time.

13. The electronic image capture system as recited in claim 7 comprising a coarse resolution imager that enables independent integration time

control of paxels and an algorithm for determining the correct integration time for the paxels based on their geographic location within the captured image.

14. The electronic image capture system claimed in claim 13, wherein the imager gathers scene exposure information for a camera exposure determination algorithm.

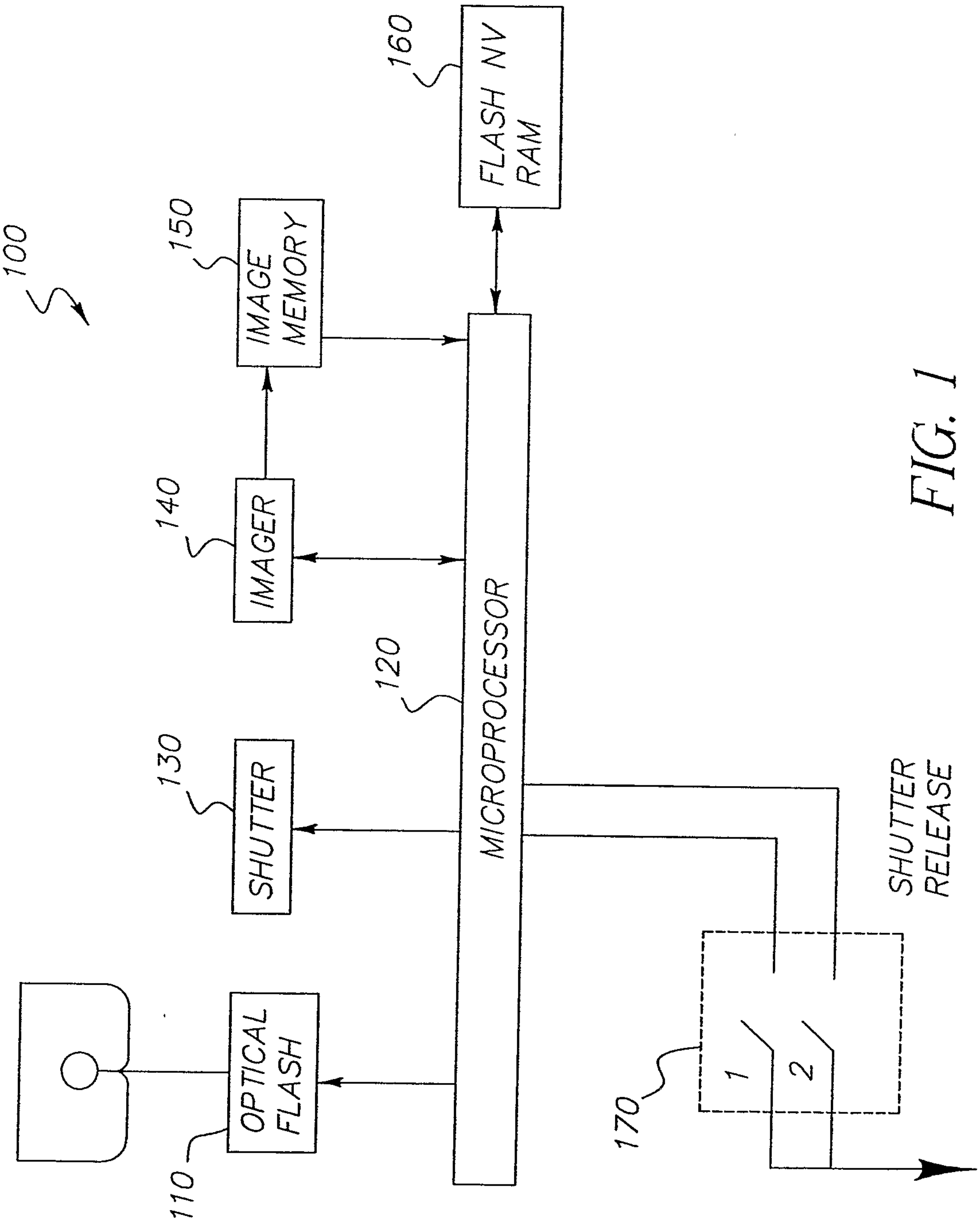

100
OPTICAL FLASH
110
SHUTTER
130
MICROPROCESSOR
120
IMAGER
140
IMAGE MEMORY
150
FLASH NV RAM
160
SHUTTER RELEASE
1
2
170

FIG. 1

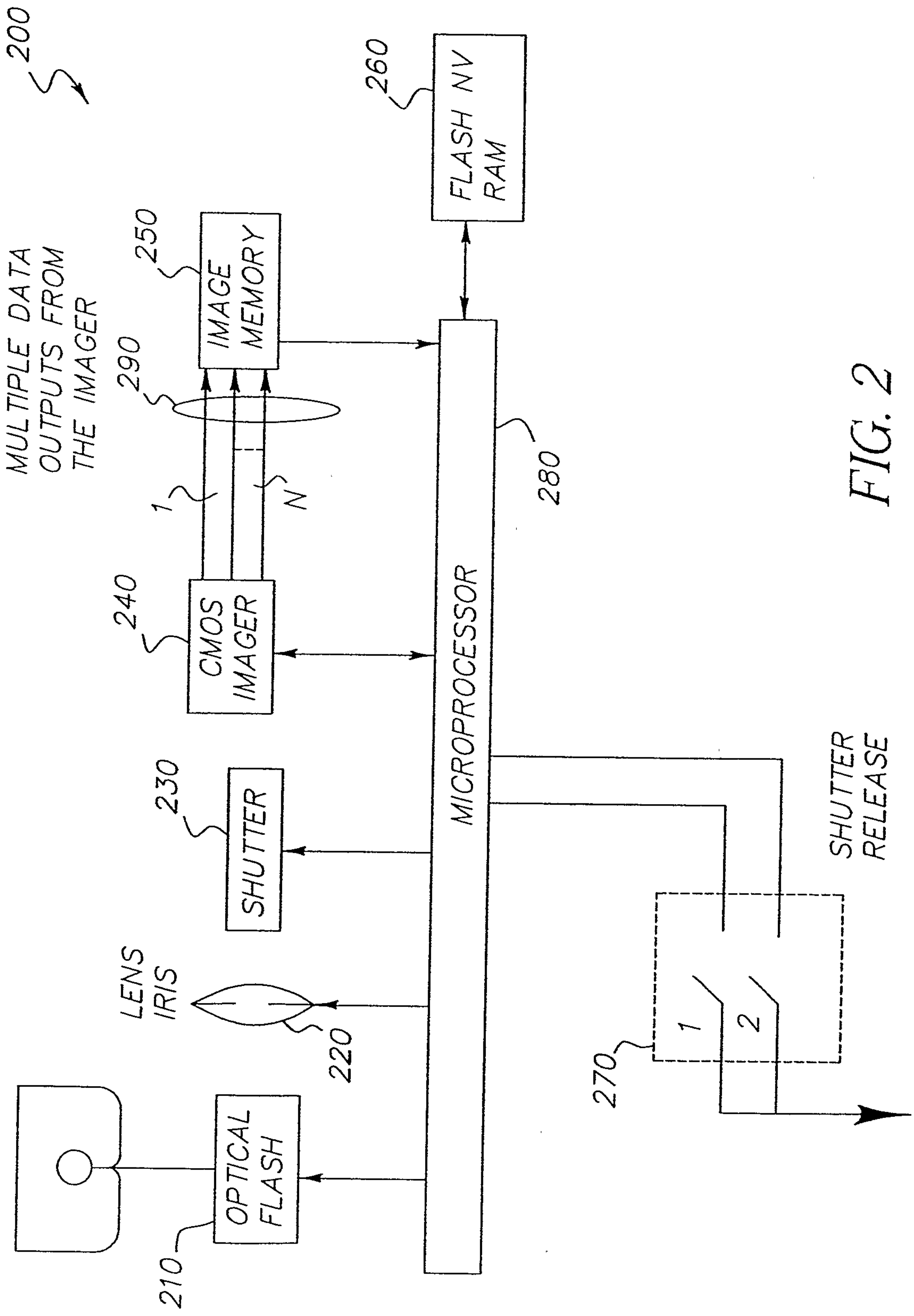

200
MULTIPLE DATA OUTPUTS FROM THE IMAGER
250
IMAGE MEMORY
260
FLASH NV RAM
290
1
N
240
CMOS IMAGER
280
MICROPROCESSOR
230
SHUTTER
LENS IRIS
220
SHUTTER RELEASE
1
2
270
OPTICAL FLASH
210

FIG. 2

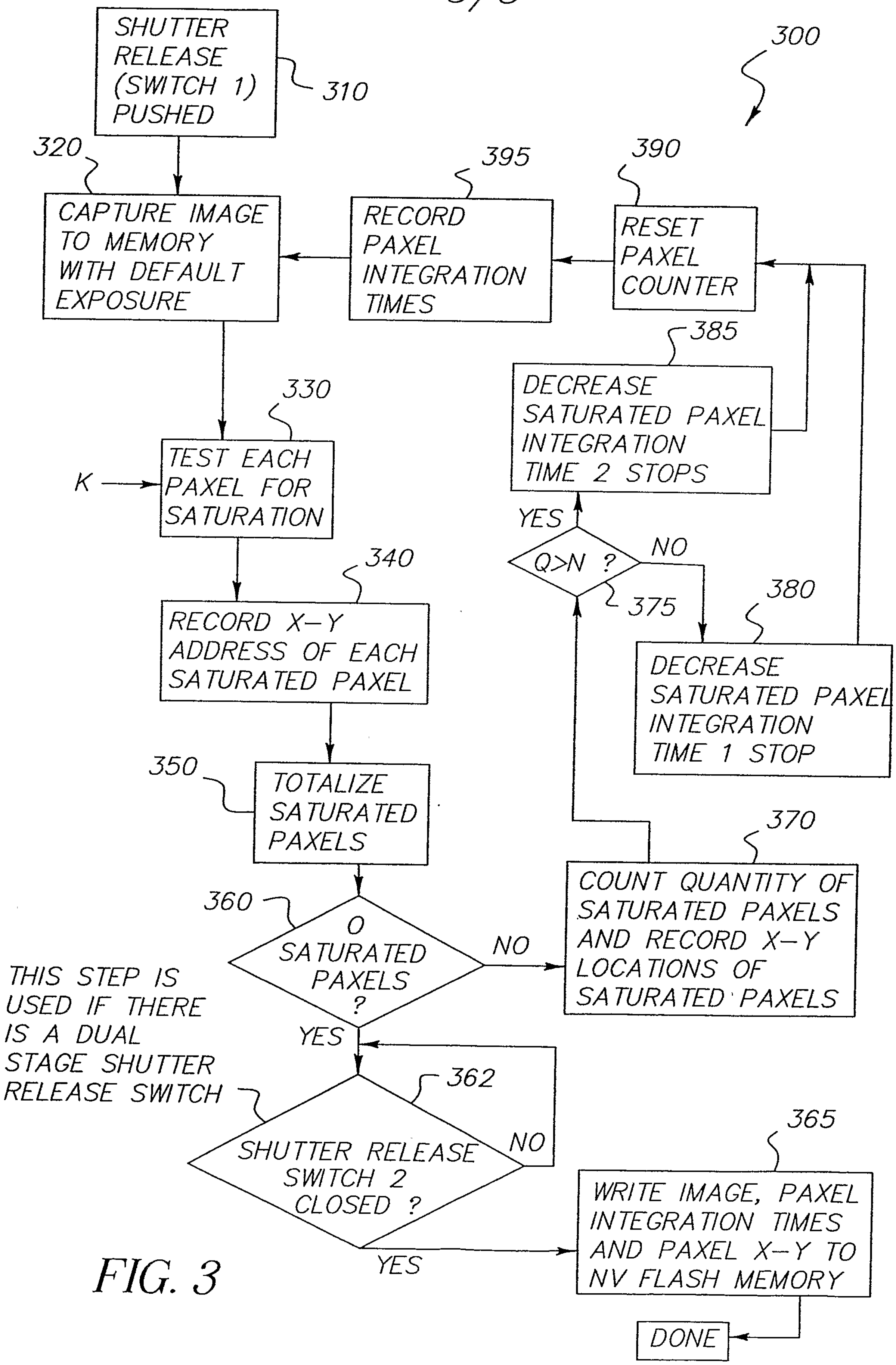

300
SHUTTER RELEASE (SWITCH 1) PUSHED
310
320
CAPTURE IMAGE TO MEMORY WITH DEFAULT EXPOSURE
395
RECORD PAXEL INTEGRATION TIMES
390
RESET PAXEL COUNTER
385
DECREASE SATURATED PAXEL INTEGRATION TIME 2 STOPS
330
K
TEST EACH PAXEL FOR SATURATION
YES
Q>N ?
NO
375
380
340
RECORD X–Y ADDRESS OF EACH SATURATED PAXEL
DECREASE SATURATED PAXEL INTEGRATION TIME 1 STOP
350
TOTALIZE SATURATED PAXELS
370
360
0 SATURATED PAXELS ?
NO
COUNT QUANTITY OF SATURATED PAXELS AND RECORD X–Y LOCATIONS OF SATURATED PAXELS
THIS STEP IS USED IF THERE IS A DUAL STAGE SHUTTER RELEASE SWITCH
YES
362
SHUTTER RELEASE SWITCH 2 CLOSED ?
NO
365
WRITE IMAGE, PAXEL INTEGRATION TIMES AND PAXEL X–Y TO NV FLASH MEMORY
YES
DONE

FIG. 3

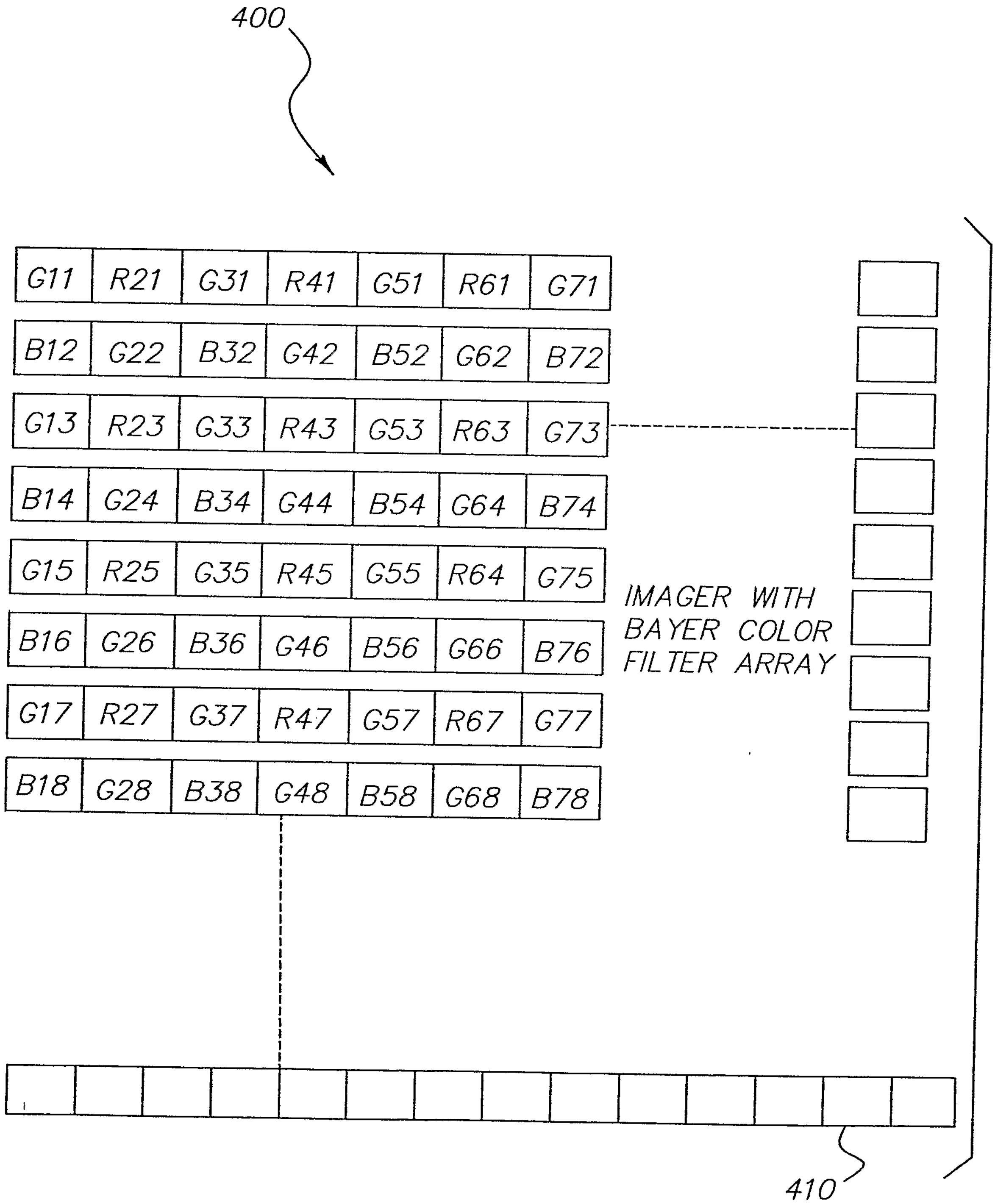
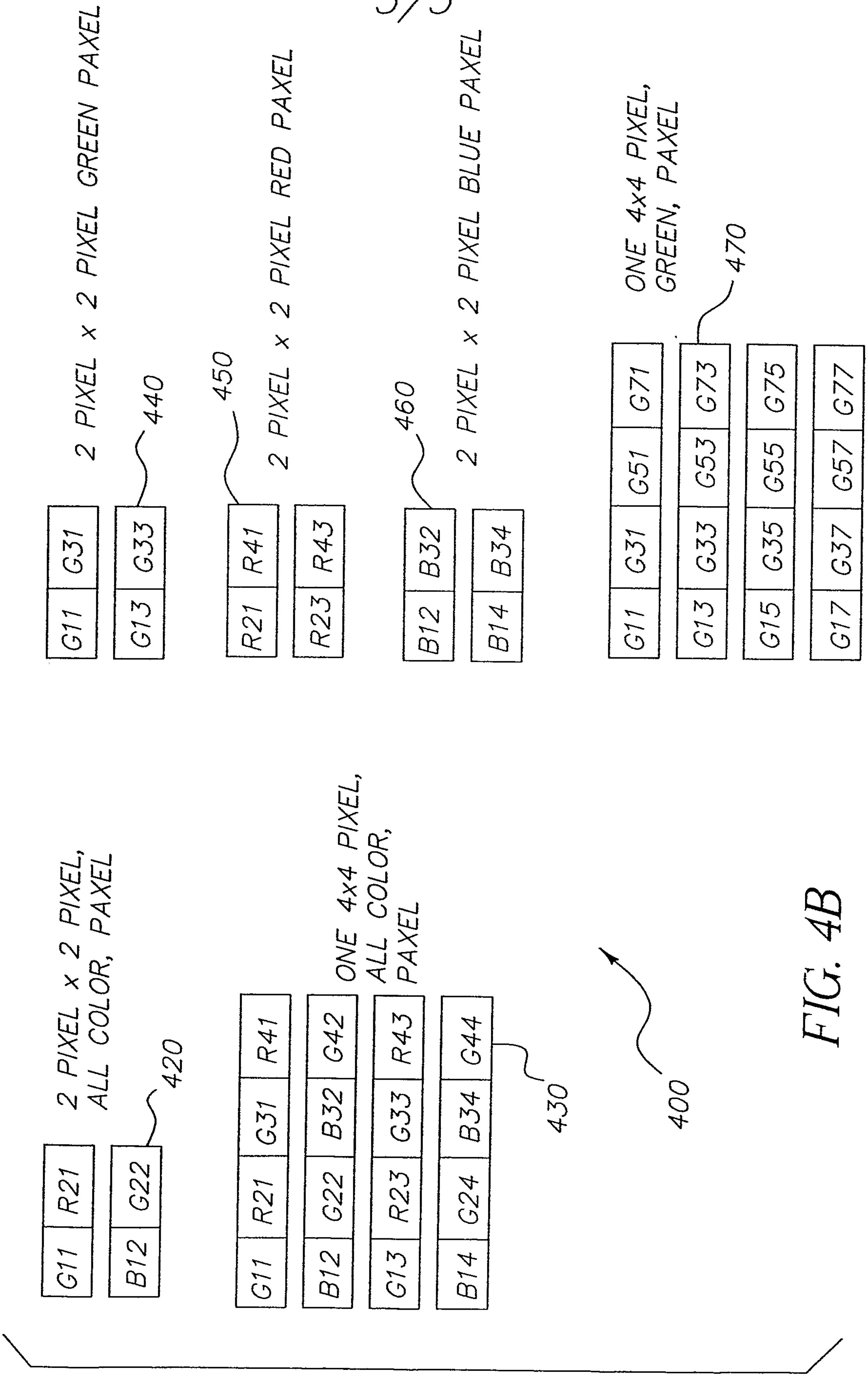

400
G11
R21
G31
R41
G51
R61
G71
B12
G22
B32
G42
B52
G62
B72
G13
R23
G33
R43
G53
R63
G73
B14
G24
B34
G44
B54
G64
B74
G15
R25
G35
R45
G55
R64
G75
B16
G26
B36
G46
B56
G66
B76
G17
R27
G37
R47
G57
R67
G77
B18
G28
B38
G48
B58
G68
B78
IMAGER WITH BAYER COLOR FILTER ARRAY
410

FIG. 4A



2 PIXEL x 2 PIXEL, ALL COLOR, PAXEL
G11 R21
B12 G22
420
ONE 4x4 PIXEL, ALL COLOR, PAXEL
G11 R21 G31 R41
B12 G22 B32 G42
G13 R23 G33 R43
B14 G24 B34 G44
430
400
2 PIXEL x 2 PIXEL GREEN PAXEL
G11 G31
G13 G33
440
2 PIXEL x 2 PIXEL RED PAXEL
R21 R41
R23 R43
450
2 PIXEL x 2 PIXEL BLUE PAXEL
B12 B32
B14 B34
460
ONE 4x4 PIXEL, GREEN, PAXEL
G11 G31 G51 G71
G13 G33 G53 G73
G15 G35 G55 G75
G17 G37 G57 G77
470

FIG. 4B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/019483

A. CLASSIFICATION OF SUBJECT MATTER
H04N5/335 H04N5/217 H04N3/15

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

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, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 734 582 A (GIBBONS ET AL) 29 March 1988 (1988-03-29) abstract column 1, lines 11-14 column 1, lines 20-55 column 2, lines 59-62 column 6, lines 27-64	1,2,7-9
X	US 4 862 276 A (WANG ET AL) 29 August 1989 (1989-08-29) column 2, lines 13-28 column 2, lines 30-40 column 11, lines 38-46 column 6, lines 27-64	1,2,7-9

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 November 2005	06/12/2005

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, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lauri, L

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/019483

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 008 486 A (STAM ET AL) 28 December 1999 (1999-12-28) column 2, lines 39-64 column 4, lines 5-51	1,2,7-9
X	US 6 606 121 B1 (BOEHM MARKUS ET AL) 12 August 2003 (2003-08-12) abstract column 3, lines 5-20 column 3, lines 21-42 column 6, lines 41-66 column 7, lines 45-50	1,2,7-9
A	US 2003/076432 A1 (LUO QIANG ET AL) 24 April 2003 (2003-04-24) abstract paragraphs ‘0008!, ‘0010!, ‘0031!	1-14
A	US 2002/027606 A1 (YADID-PECHT ORLY) 7 March 2002 (2002-03-07) abstract paragraph ‘0016! paragraphs ‘0030! - ‘0037! claim 1	1-14
A	US 4 484 223 A (TSUNEKAWA ET AL) 20 November 1984 (1984-11-20) abstract column 4, line 59 - column 5, line 54 claims 1-3	1-14
A	JP 05 022670 A (CANON INC) 29 January 1993 (1993-01-29) the whole document	1-14
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