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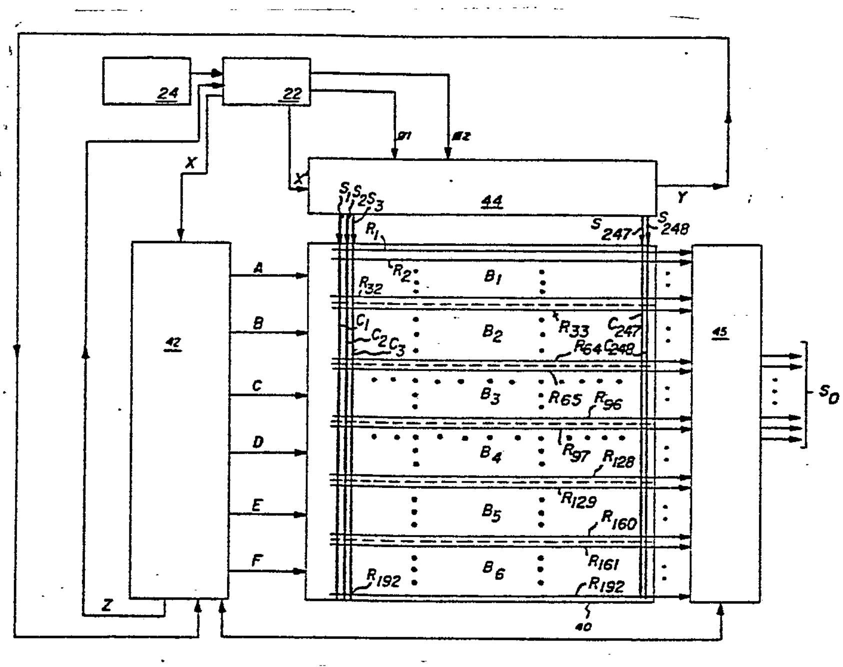

(57) Abstract

Unique solid state imaging apparatus comprising an area image sensor (40) which is adapted to be read out at exceptionally fast frame rates. The individual photosites of the sensor are formated into a plurality of blocks (B1-B6) for purposes of readout, each block comprising a plurality of photosite rows (R1-R32) which can be read out in parallel. Circuitry (42, 44) is provided for sequentially enabling the individual blocks of photosites for read out, and for sequentially addressing the photosites of each row in an enabled block, all of the rows in an enabled block being addressed simultaneously, whereby all rows of photosites in each block are read out in parallel, and the plurality of blocks of photosites are read out sequentially.

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SOLID-STATE IMAGING APPARATUS AND METHOD FOR READOUT

The present invention relates to improvements in electronic imaging and to solid state imaging apparatus in which the sensor component is designed to be read out at unusually fast frame rates.

The use of solid-state area image sensors in video cameras has become increasingly popular in recent years. Such cameras are lighter, more compact and more reliable than their "tube-type" counterparts that use vidicons, orthicons or other electron tube devices for image sensing. The solid-state sensors presently available for use in video cameras provide acceptable resolution and are readable at the standard video frame rate of 30 frames per second.

A typical solid-state area image sensor is comprised of an array of charge-integrating photosites (e.g., photocapacitors, photodiodes, etc.) arranged in rows and columns. Each photosite responds to incident radiation to provide, when appropriately addressed and read-out, a signal corresponding to the brightness of one picture element (pixel) of frame information. Such sensors are generally read out a line at a time, in a serial fashion, by one of the following three generally known methods of serial line readout: (1) <u>Line Transfer:</u> According to the line transfer method of sensor readout, clock pulses from a line address circuit cause lines of image information to be sequentially transferred to an output register. Readout of the output register is synchronized with the line transfer of image information to provide a line sequential video output signal; (2) Frame Transfer: In the frame transfer approach, an accumulated charge pattern for an entire frame (or field) is periodically shifted into a storage area. The charge pattern residing in the storage area is then transferred a line at a time into a readout register from which a video output signal is taken; and (3) Interline Transfer: In the interline transfer method, a charge pattern is accumulated at integration sites and then periodically transferred into storage columns. The transferred charge is then shifted, a line at a time, into a readout register from which a line-by-line video output signal is taken. These prior art readout schemes are discussed in more detail in Hobson, "Charge-Transfer Devices", published by Halsted Press, 1978, pages 169-172, and Sequin and Tompsett, "Charge Transfer Devices", published by Academic Press, 1975, pages 152-157.

Irrespective of which of the above-discussed serial line readout schemes is used for sensor readout, it is not feasible to read out a state-of-the-art, high resolution, solid-state area image sensor at high frame rates (i.e., above about 120 frames per second). The reason is that stray capacitances and other inherent electrical properties of the array limit the readout data rate to about 10 MHz. If one frame contains 60,000 pixels, for example, the maximum frame rate obtainable would be about 120 frames per second. At present, therefore, there are no video cameras using solid-state image sensors that operate at frame rates much in excess of 120 frames per second. For some applications, however, much faster frame rates are required. For example, recording the motion of a rapidly moving object requires a frame rate high enough to "freeze" the object; if the object is not "frozen", successive frames will tend to smear into each other. As will be appreciated, the required frame rate depends, in general, upon the particular application and the amount of image smear that can be tolerated. In certain industrial applications, such as recording a test car crash under simulated conditions, or the breaking of a bottle during a manufacturing process, frame rates as high as 2,000 frames per second, or more, are desired.

One possible approach to obtaining faster frame rates from an area image sensor is to read out all sensor lines simultaneously, i.e., in parallel. With parallel line readout, the time required to read out a frame of information roughly corresponds to the time required to read out a single line since all lines are read out simultaneously. A significant drawback of the parallel line method of readout, however, is that numerous individual "line" signals are produced that must be processed separately, but in a virtually identical manner. Such multi-signal processing is almost impossible (as a practical matter) in view of the fact that the levels of the signals to be processed may be quite low and the signals may have marginal signal-to-noise ratios. As a result, parallel line readout is generally limited to low resolution applications wherein only a relatively few lines of information are to be processed.

To summarize, inherent difficulties are

encountered if one attempts to obtain "fast" frame rates from a current state-of-the-art area image sensor by using the serial line method of sensor readout; on the other hand, while "fast" frame rates are feasible using the parallel line method of sensor readout, the results are far from satisfactory because of the practical problems associated with the electronic processing of numerous parallel signals.

In accordance with the present invention, there is provided a method for reading out information from a solid-state area image sensor in a fraction of the time that would be required were the sensor read out according to any of the serial line readout methods discussed above. By following the teaching of the invention, frame rates on the order of thousands of frames per second are obtainable without the need for processing numerous signals such as result from the parallel line method of sensor readout.

In a preferred embodiment, an area image sensor is read out in "blocks" of photosites, each block being comprised of a plurality of adjacent photosite rows. A block of photosites is enabled for readout by the application of an enablement signal to all of the photosites within the block. All of the photosite rows in an "enabled" block are read out in parallel, that is, simultaneously, by sequentially applying address signals to the photosites in each row of the block. The output signal so produced is, therefore, comprised of block information in a "serial" format, while the information content of each block is comprised of a plurality of line signals in a "parallel" format, such line signals corresponding to the individual photosite rows within that block.

According to the invention, there is also provided a solid-state imaging apparatus comprising a sensor which is adapted to be read out according to the above-mentioned method of the invention. Such a sensor comprises an area array of photosites which are operatively connected to form a plurality of blocks, each block comprising a plurality of photosite rows which can be read out in parallel. Circuitry is provided for sequentially enabling the individual blocks of photosites for readout, and for sequentially addressing the photosites of each row in a block, all rows in a block being addressed simultaneously, so that all photosite rows in a block are read out in parallel, and the plurality of photosite blocks are read out sequentially.

In the detailed description of the preferred embodiments of the invention presented below, reference is made to the accompanying drawings, in which:

Figs. 1 and 2 illustrate the block readout concept of the present invention;

Fig. 3 illustrates an area image sensor which is adapted for block readout in accordance with the invention;

Fig. 4 illustrates a color area image sensor which is adapted for block readout; and

Figs. 5a and 5b illustrate other arrangements of photosite blocks which are considered within the scope of the invention.

In accordance with the present invention, a technique for sensor readout is provided in which the frame rate is increased dramatically over that obtainable with the above-mentioned serial line readout method. Moreover, such technique reduces the number of signals that must be identically processed to a fraction of the number resulting from the parallel line method of sensor readout. The underlying concept of the present invention is illustrated in Fig. 1 which shows a "monochromatic" area image sensor 40 (i.e., the photosites are sensitive to the same wavelength range of radiations) that is comprised of an array of photosites arranged in 192 horizontal rows R_1-R_{192} and 248 vertical columns C_1 - C_{248}. Thus, there are a total of 47,616 (i.e., 192 X 248) photosites, each being represented by the intersection of a row R and a column C in Fig. 1. Each photosite, as discussed below in connection with the description of Fig. 3, is "readable" (i.e., adapated to provide a signal indicative of its illumination level) upon the application thereto of an enablement signal and an address signal.

In accordance with the invention, the photosites of sensor 40 are formatted into six blocks, B_1 through B_6, of 32 photosite rows each. To begin readout, a clock-driven driver circuit 22 (driven by clock 24) transmits a block start signal X to a conventional shift register 42 or similar circuit. Upon receipt of this start signal, shift register 42 produces a signal A which enables all 32 rows of block B_1 for readout. Upon receipt of a column start signal X' from driver 22, column address electronics, shown in the form of a column shift register 44, then sequentially addresses the photosite columns of the entire area image sensor 40 by sequentially providing address signals S_1, S_2, S_3,...S_{248}. Since only the block B_1 photosite rows (rows 1-32) have been enabled, however, only these rows of block 1 are actually read out. (The photosites in the not-enabled blocks, while addressed, are unaffected by the readout of rows R_1-R_{32}, and continue to integrate charge in response to incident radiation.) After all 248 columns of photosites have been sequentially addressed, an "end of row" signal Y from the column shift register 44 causes the block select shift register 42 to terminate enable signal A and to transmit an enable signal B. When enable signal B is present, only the block B_2 photosite rows are enabled, leaving all other blocks in a not-enabled state. Column readout then proceeds as described for the block B_1 photosite rows. This process is repeated until all six blocks of photosite rows are sequentially read out, at which time an "end of frame" signal Z from the block select shift register 42 resets the driver 22 for readout of the next frame. A multiplexer 45, which functions as a switch, reduces the number of active output lines from 192 to 32, the output signal S_0 appearing on the 32 active output lines corresponding to the 32 photosite rows being read out.

The frame information produced as described immediately above is in neither the conventional parallel nor the conventional serial line format discussed previously. The block information is produced in series; and each block within the series contains 32 signals arranged in parallel which correspond to the photosite rows in the respective blocks. By means of such a format, reduction in the time required for sensor readout by a factor equal to the number of photosite rows in a block is provided. Thus, a 192-row sensor that can be read out at a maximum frame rate of, say 60 frames per second using the aforementioned serial line readout method can, by means of the above-described inventive format, be read at a rate of 1920 frames per second, i.e., 32 x 60.

Fig. 2 illustrates, graphically, how frame information is formatted and recombined according to the invention to form a video display. A scene S, imaged by an optical system 47 onto the area image sensor 40, is "sampled" by block enable pulses. As will be noted, the frame information F_I corresponding to each block is shown in "pictorial form" directly above its respective block enable pulse. And, by the use of appropriate delay circuits 49, the blocks of information are recombined to form the complete playback video display V_D. In the drawing η is equal to the time required to read out each block.

Fig. 3 shows a specific example of an area image sensor 40 (and corresponding electrical schematic diagram) that is read out in blocks in accordance with the present invention. (The electrical circuitry for operating the column shift register 44 and block select shift register 42 is not shown, it being similar to that shown in Fig. 1.) Referring first to the electrical schematic diagram, each photosite 50 includes two gates S1 and S2, each gate being part of a field effect transfer (FET). Each gate S1 in a photosite row is connected to a common electrode for that row, in the form of a block select bus line 52, and all block select bus lines 52 of a block are connected in common to a single block enable bus line 53. The block select shift register 42 enables a block of photosite rows for readout by applying an enablement signal to the block enable bus line 53, thereby setting each gate S1 within the enabled block to its closed state. All photosite rows in an enabled block are then column-wise read out simultaneously as the column shift register 44 sequentially addresses the photosite columns. As each column is addressed by signals S_1, S_2, S_3,...192, the gates S2 within the addressed column are closed, thereby causing signals from respective photosites which are both enabled and column-addressed to be applied to respective read channels 54 common to all photosites in the given rows.

The block readout technique of the present invention is not limited to monochrome area image sensors. Fig. 4 shows a color area image sensor 40' of a type disclosed in U.S. Patent No. 4,117,510 wherein red, green and blue filters overlie respective rows of photosites. According to the readout method disclosed in U.S. Patent No. 4,117,510, the red, green and blue (R,G,B, respectively) signals from photosite rows R_1, R_2 and R_3 are read out simultaneously and combined to give one effective line of resolution L_1 of a scene imaged on the sensor. Next, the red. green and blue signals from photosite rows 4, 5 and 6 are read out and combined to give a second effective line of resolution L_2, and so on for the remaining photosite rows. By following the block readout technique of the present invention, the time required for sensor readout can be greatly reduced. In the illustrative example shown in Fig. 4, the sensor is divided, for purposes of readout, into four blocks B_1-B_4, each block being comprised of two effective lines of resolution (six photosite rows) of a scene imaged on the sensor. In this example, sensor readout would take only one-half as long as the readout method taught in U.S. Patent No. 4,117,510. In general, accelerated sensor readout is obtained by reading the sensor in blocks of photosites, wherein each block is comprised of a plurality of photosite rows that collectively represent two or more effective lines of resolution. For a three color system, such as described in connection with Fig. 4, each block of photosites will be comprised of six or more photosite rows because fewer photosite rows per block will not represent at least two effective lines of resolution.

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. For example, the blocks of photosites need not be comprised of adjacent photosite rows but, rather, can be comprised of any plurality of photosite rows. Further, based on the above description of the invention, it will be apparent that a block of photosite need not necessarily comprise rows of photosites which extend across the entire width of the array. Rather, the photosites of a block could be grouped as illustrated in Figs. 5a and 5b. In Fig. 5a, each block of photosites comprises a plurality of sub-rows of photosites, the number of sub-rows being equal to the number of photosites in an entire column. In Fig. 5b, each block of photosites comprise contiguous sub-rows and sub-columns of photosites. The designated blocks of photosites are successively read out in a manner similar to that described above. A block can also take the form of a matrix of photosites, some or all of which photosites are not adjacently disposed.

Claims:

1. Solid-state imaging apparatus including (a) an area image sensor comprising an array of photosites arranged in a plurality of rows, each row defining a line of resolution of an image focused on the array, each of such photosites being adapted to be read out, upon receipt of both an enablement signal and an address signal, to produce an output signal indicative of the photosite illumination, and (b) circuit means for sequentially applying both enablement and address signals to the photosites to achieve readout, characterized in that said image sensor includes a plurality of electrode means (52, 53) operatively coupling selected rows of photosites together to form a corresponding plurality of blocks (B_1, B_2) of photosites, each of said electrode means being adapted to transmit an enablement signal to photosites within a block simultaneously, and in that said circuit means comprises first circuit means (42) operatively coupled to said plurality of electrode means for sequentially applying enablement signals to said plurality of blocks of photosites, and second circuit means (44) for sequentially applying an address signal to the photosites in each row, said address signal being simultaneously applied to all rows in a block while an enablement signal is applied to said block, whereby all rows of photosites in each block are read out in parallel, and said plurality of blocks of photosites are read out sequentially.

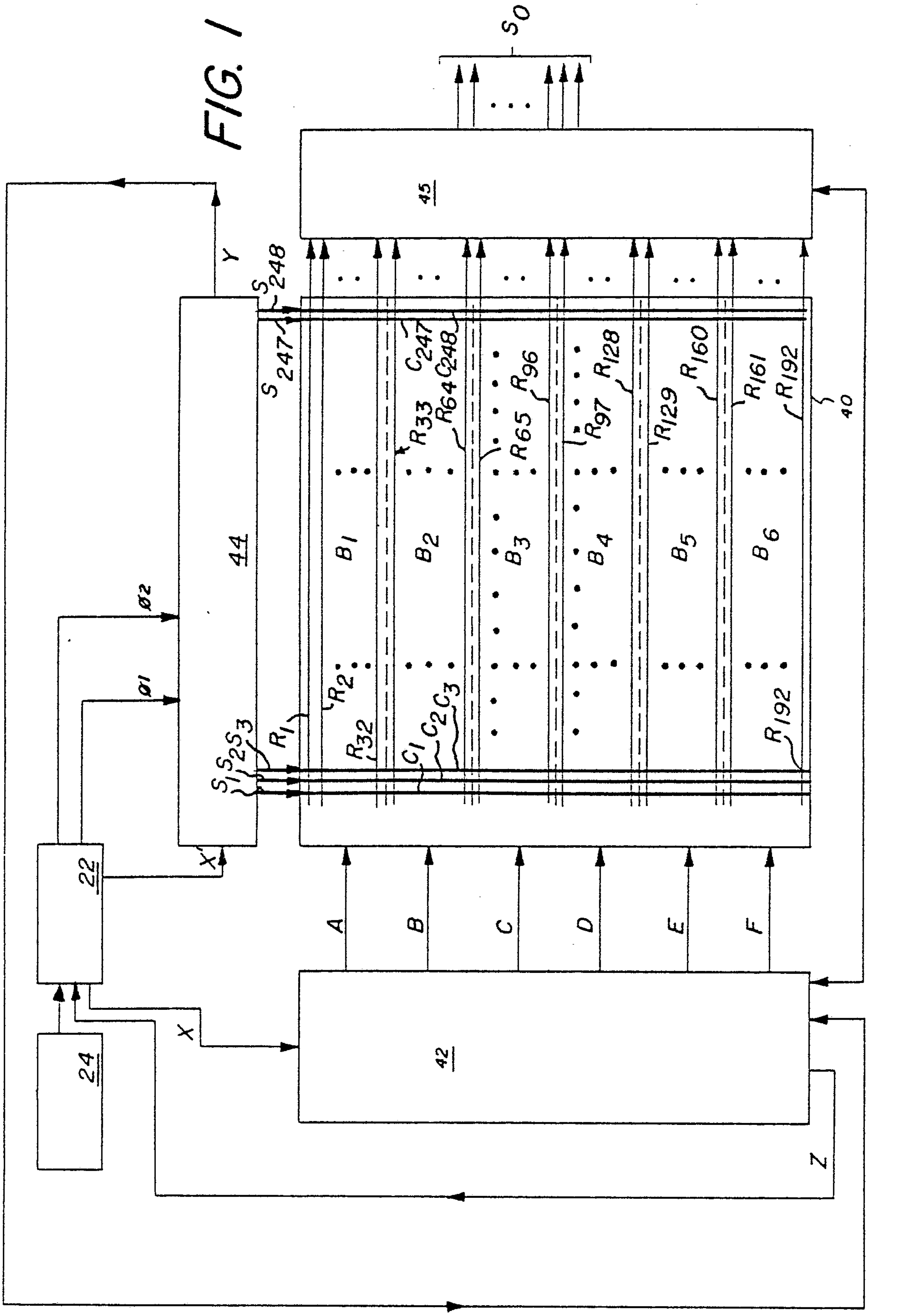
2. The apparatus as defined in Claim 1 wherein said first and second circuit means comprise first and second shift registers, respectively.

3. The apparatus as defined in Claim 1 wherein all photosites are sensitive to substantially the same wavelength range of radiation.

4. A method of reading out an area image sensor containing an array of photosites arranged in rows, each of said photosites being of a type that is readable upon the application thereto of an enablement signal and an address signal, said method being characterized by the steps of:

sequentially applying an enablement signal to respective blocks of photosites, each of said blocks being comprised of a plurality of adjacent rows of photosites that represent at least two effective lines of resolution of a scene imaged upon said array of photosites; and

sequentially applying an address signal to the photosites in each photosite row of an enabled block, said address signal being simultaneously applied to all rows in an enabled block, so that all rows of photosites in an enabled block are read out in parallel, and said blocks of photosites are read out sequentially.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R1
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R32
R33
R64
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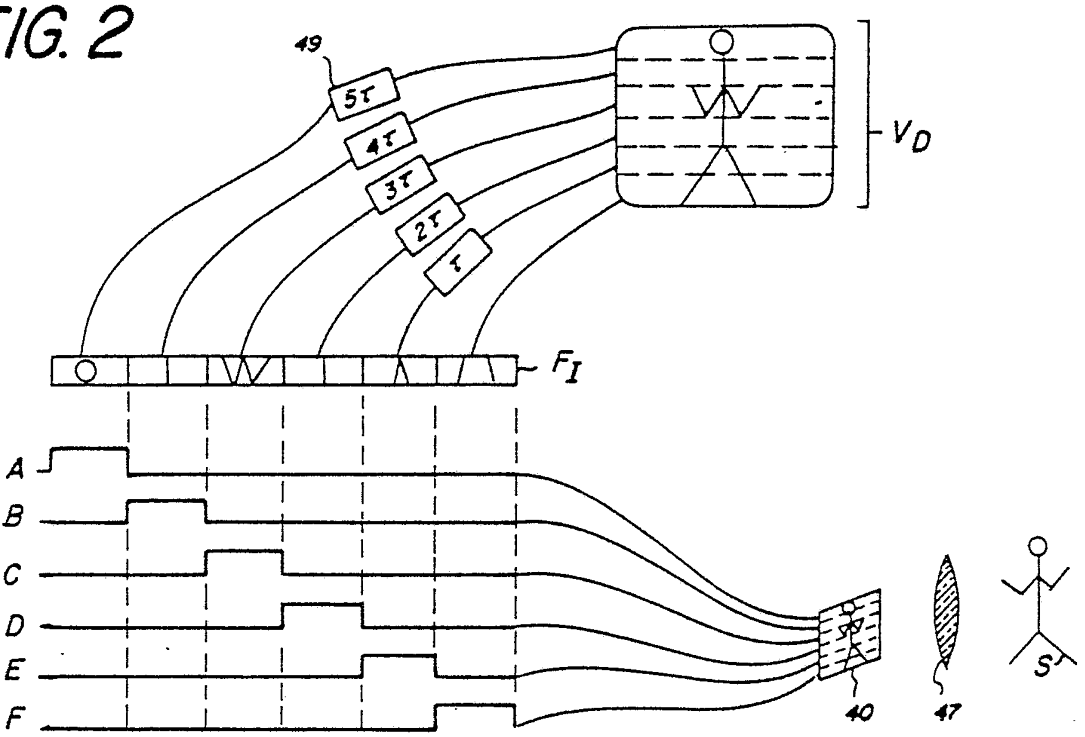
C248

FIG. 1

FIG. 2



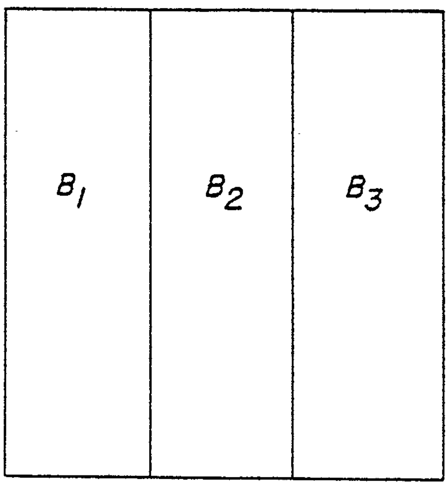


FIG. 5a

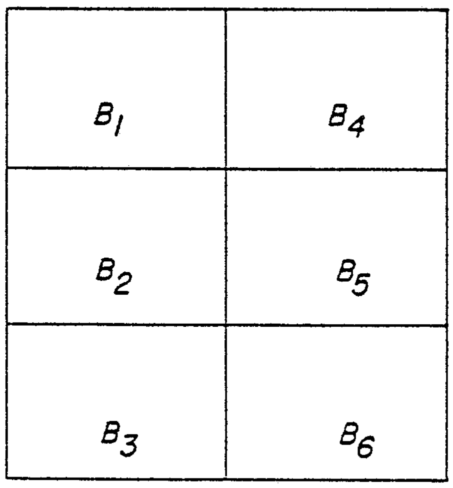


FIG. 5b

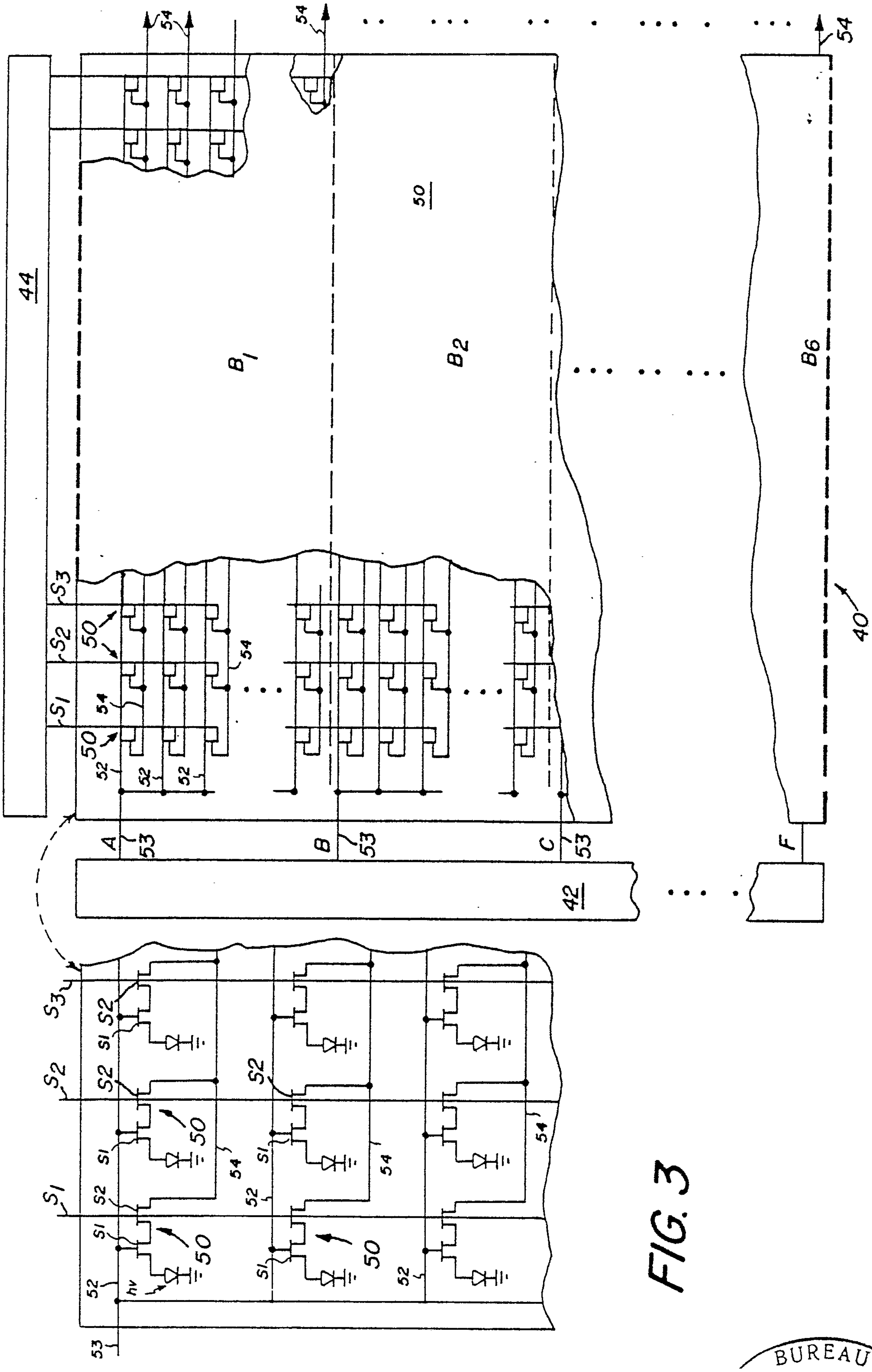
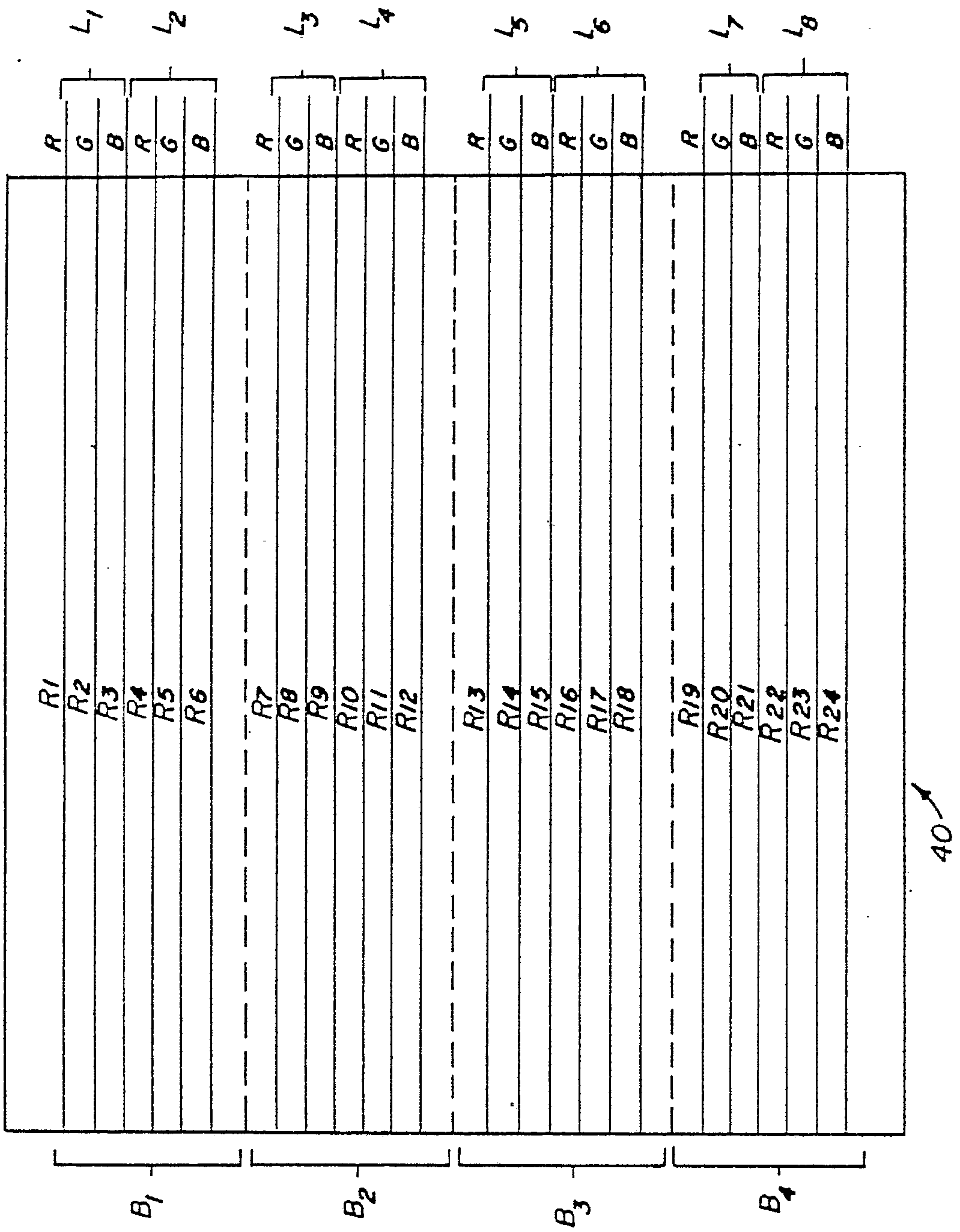


FIG. 3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B4

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/US80/01643

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.[3] H04N 3/15.
U.S. CL. 358/213

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	358/43, 44, 48, 50, 212, 213 357/24, 30 250/208, 209, 211R, 211J

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X,P	US, A, 4,212,034, Published 08 July 1980, Kokie et al	1-4
X	US, A, 4,117,510, Published 26 September 1978 Ohta et al	1-2,4
X	JP, A, 52- 6416, Published 18 January 1977, Ota	1,4

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"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
24 March 1980	30 MAR 1981
International Searching Authority [1]	**Signature of Authorized Officer [10]**
ISA/US	John C Martin John C. Martin

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