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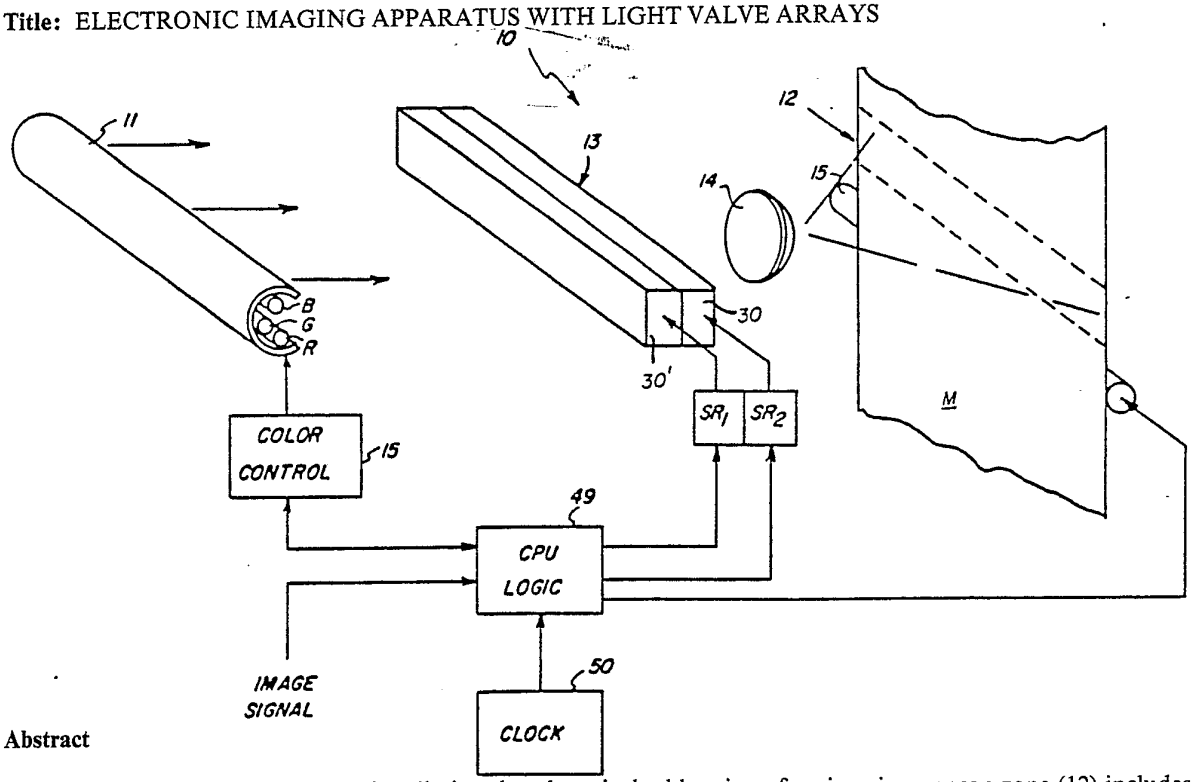

(57) Abstract

A light valve device (10) for locationally-interlaced, optical addressing of an imaging or scan zone (12) includes an array (13) having a plurality of location-address sectors (A, B, C...), each including a plurality of discrete light valve pixel portions (A_1, A_2, A_3, A_4, B_1, B_2, B_3, B_4,....) which are electrically addressable to control the passage of light. Each light valve pixel portion is coupled for common electrical address with one light valve pixel portion of each of the other location-address sectors, so as to form intersector groups, but is independently addressable with respect to light valve pixel portions of its own location-address group.

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ELECTRONIC IMAGING APPARATUS WITH LIGHT VALVE ARRAYS

The present invention relates to improvements in electronic imaging apparatus of the type which employ light valve arrays for controlling the passage of light, on a picture element-by-picture element basis, to a photosensitive medium to record an image thereon.

Recently, it has been found that light valve arrays are useful in electronic imaging for optically addressing (i.e., exposing to light of various intensity) the individual picture elements of an image to be formed. One preferred light valve configuration comprises a piece of ferro-electric ceramic material, such as lanthanum-doped lead zirconate titanate (PLZT), which is sandwiched between crossed polarizers and electrically activatible to operate in a Kerr cell mode. An array of such light valves comprises such crossed polarizers having positioned therebetween a panel of PLZT material that has a plurality of electrodes formed on one of its major surfaces. The electrodes are arranged in an interdigitated manner to facilitate the selective application of discrete electrical fields across (in a direction perpendicular to the direction of viewing) discrete surface areas of the panel. The PLZT material underlying each of such surface areas, together with the crossed polarizers positioned fore and aft, constitutes a light valve in the array. Upon applying an electric field across such surface area, the underlying PLZT material becomes birefringent and rotates the direction of polarization of incident light by an extent dependent on the field magnitude. This results in transmission of light through the PLZT materials and cooperating polarizers

varying as a function of the respective addressing fields.

In U.S. Patent 4,229,095 there is disclosed various embodiments of electronic color-imaging apparatus that utilize such light valve arrays to effect multicolor exposure of panchromatic recording media. For example, a color image is formed electronically by selectively opening and closing individual light valves of such arrays in synchronization with the energization of red, green and blue exposing sources and according to the red, green and blue color information for the pixels of that image. One preferred embodiment disclosed in that patent comprises a linear light valve array disposed in spaced transverse relation to the recording media feed path. The light valves of the array are addressed concurrently with image information, a line at a time, and the movement of the recording medium, and the red, green and blue color exposures are synchronized with successive actuations of the linear array.

It can be appreciated that light valves must address many picture elements (pixels) per image line in order to form images having even moderate detail. The number of pixels per line increases in accordance with the resolution requirements of the imaging application, e.g., becoming as large as 100 pixels per centimeter or larger for high quality continuous tone imaging. Each pixel of the image to be formed must be independently addressed with light in accordance with the unique content of the image to be reproduced.

In using a light valve array to optically address the individual pixels of an image, discretely activatible pairs of electrodes must be provided for each pixel-addressing light valve of the light valve

array. Heretofore, it has been common for each electrode pair to be provided with its own high voltage "off-on" switch, e.g., a transistor amplifier. The cost and complexity of these many switches and their connection and packaging present problems in electronic imaging with light valve devices.

One technique for minimizing the number of switches in a light valve array is to use a smaller number of transversely-spaced light valves in the light valve array and then effect multiple passes of the recording medium, with a transverse-indexing of the array (or recording medium) between passes. For example, if the light valves are spaced with a three-pixel inter-space and the recording medium is transported past the light valve array four times, only one-fourth the usual number of high voltage switches is required. However, multiple passes substantially increased the time required to form an image, and the transverse indexing can present registration problems.

An object of this invention, therefore, is to provide an improved electronic imaging apparatus of the light valve variety, one which is capable of relatively high speed imaging without requiring the use of one light valve-addressing switch per picture element of an image to be recorded, or the above-mentioned multiple pass/transverse indexing technique.

The electronic imaging apparatus of the invention comprises a pair of optically aligned light valve arrays which, when appropriately addressed with electrical signals, cooperate in optically addressing each pixel of an image to be formed on a photosensitive recording medium. Generally speaking, one light valve array determines the location of the pixels being optically addressed, and the other determines the image information (i.e. light level)

to which each pixel is optically addressed. The number of light valves in the locationally-addressing array is equivalent to the desired image resolution (pixels/centimeter in the case of a linear light valve array, or pixels/square centimeter in the case of an area array), whereas the number of valves in the informationally-addressing array is only a fraction (e.g. one-fourth) the number of valves in the locationally-addressing array. Each light valve in the informationally-addressing array is provided with its own address switch, and each is optically aligned with a different group of light valves of the locationally-addressing array which define a location-address sector. Each light valve in a location-address sector is electrically coupled for common electrical addressing with one light valve in each of the other location-address sectors, and one address switch is provided for each group of electrically coupled light valves. The apparatus of the invention further comprises circuitry for sequentially addressing the light valves in each location-address sector (causing each of such valves to switch from a light-blocking to a light-transmitting condition) while the light valves of the informationally-addressing array are simultaneously addressed with image information. By virtue of the arrangement of the two light valve arrays and the electrical addressing circuitry disclosed herein, the number of electrical addressing switches is reduced to only a fraction of that required by prior art apparatus.

The invention will be better understood from the ensuing detailed description of preferred embodiments, reference being made to the accompanying drawings in which:

Figure 1 is a schematic illustration of one embodiment of electronic imaging apparatus in accordance with the present invention;

Figures 2 and 3 are schematic views of prior art light valve array configurations and addressing means;

Figure 4 is an enlarged perspective view of a light valve array structured in accordance with the present invention, which is useful, for example, in the Fig. 1 embodiment of the present invention;

Figure 5 is a diagram illustrating preferred addressing electronics for use with the light valve array shown in Fig. 4;

Figure 6 is a schematic perspective view showing a locationally-interlaced-scan device in accordance with the present invention; and

Figure 7 is a schematic perspective view showing an area light valve device constructed in accordance with the present invention.

Referring now to Fig. 1, there is shown one illustrative embodiment of electronic imaging apparatus 10 incorporating structural and functional improvements in accordance with the present invention. In general, the apparatus 10 comprises an illumination source 11 which directs flood illumination toward an imaging zone 12 via a light valve imaging device 13 and imaging lens 14. As is known in the art, it is the general function of such apparatus for imaging device 13 to modulate light from source 11, pixel by pixel, in accordance with the image to be reproduced. In the illustrated embodiment the light valve imaging device 13 is a linear array and is disposed to control the passage of light to successive transverse strip portions of a light-sensitive recording medium M as it is moved past the imaging zone 12, e.g. by drive means 15.

Apparatus 10 is adapted for electronic color imaging, and separate red (R), green (G) and blue (B) light sources are provided at source 11 for sequential energization by control 15 during line imaging periods. It will be appreciated from the subsequent description that the structural approach of the present invention has significant advantage in many other electronic imaging configurations, e.g. where only one color light is used or in an area light valve array configuration where the image medium remains stationary during exposure.

The improvements of apparatus 10, according to the present invention, pertain to the light valve imaging device 13, including its addressing, and will be described in more detail below. However, first a brief description of a typical prior art light valve array and address structure will be helpful in appreciating the advantages of the present invention.

Thus, the linear light valve array 20 shown in Fig. 2 comprises a plurality of discrete, separately-addressable valve portions P_1, $P_2 \ldots P_x$ on a PLZT panel 21 and cooperating crossed polarizers 22 and 23. Prior art address means for light valve array 20 is shown in more detail in Fig. 3 where it can be seen that valve portions P_1 and P_2 are defined by a common ground electrode 24 and independently addressable electrodes 25, all formed on panel 21. High voltage electronic switches 26 (e.g. transistor amplifiers) are provided to selectively energize electrodes 25 of each valve portion, with voltage V, in response to a signal from addressing control means 27, e.g. a serial-in, parallel-out shift register. In addressing the light valve array 20, each of the elements of shift register 27 are loaded with information signals ("V" or "0") in accordance with the appropriate "on or

off" condition for the image pixel corresponding to its optically coupled valve portion of the light valve array 20. Upon output of these signals from the shift register 27, the switches 26 appropriately energize, or leave unenergized, electrodes 25. Thus, each valve portion of light valve array 20 requires its own high voltage electronic switch 26 to isolate the low-voltage signal circuitry, including shift register 27, from the high-voltage energizing circuitry including electrodes 25.

Referring now to Figs. 4 and 5, there is shown one preferred embodiment, in accord with this invention, for the light valve device of the Fig. 1 embodiment. Thus, light valve imaging device 13 comprises a high-resolution, locationally-addressing light valve array 30 which includes addressable electro-optic panel 31, formed for example of PLZT ceramic material, and cooperating crossed polarizing means 32 and 33. It will be appreciated that although the portions of the Fig. 4 structure are shown in spaced relation, they usually will be contiguous. The panel 31 comprises a plurality of discrete valve portions A_1, A_2...; B_1, B_2...; C_1, C_2...; etc., which are defined along the length of the panel by grounding and addressing electrode structure. The addressing electrode structure can be like that shown in Fig. 3.

In accordance with the present invention, the addressing electrodes within the different location-address sectors, viz. A_1-A_4, B_1-B_4, C_1-C_4, etc., of the panel 31, are energizable independently of the other electrodes comprising such a sector. That is, the addressing electrode for valve portion A_1 is energizable independently of the electrodes for valve portions A_2, A_3 and A_4. However, as shown in Fig. 5, each addressing

electrode, within the location-address sectors, is electrically coupled to one corresponding addressing electrode in each of the other sectors. Thus, addressing electrodes of valve portions A_1, B_1, C_1, D_1 are connected to a common electrical bus line L_1 and form an inter-sector valve portion group of the locationally-addressing light valve array. Similarly, the A_2, B_2, C_2 electrodes are coupled to bus line L_2, the A_3, B_3, C_3 electrodes are coupled to bus line L_3 and the A_4, B_4, C_4 electrodes are coupled to bus line L_4 to form other inter-sector groups.

The electrode bus lines L_1, L_2, L_3 and L_4 respectively are coupled to high voltage switches 41, 42, 43 and 44, e.g. transistor amplifiers. Those switches are adapted to selectively energize their respective buses (and the coupled addressing electrodes) with a high voltage "V" in response to location-address signals from location-address means SR_2, e.g. a shift register or a resettable counter. For example, address means SR_2, bearing signals as indicated would activate switch 41 to an "on" condition but leave switches 42, 43, 44 in the "off" condition. Thus, valve portions A_1, B_1, C_1, etc., would be turned to an "on" (light transmitting) condition by their addressing electrodes, but the remaining illustrated electrodes would remain "off." In successive portions of a line period, switches 42, 43 and 44 are respectively switched "on" with all other switches "off" so that within each line period all valve portions of the modulator panel 31 have been turned "on" in an interlaced fashion.

It is to be noted that the structure thus far described does not provide imagewise control of light passing to the exposure zone. Instead, it

provides locationally-interlaced optical addressing of a line at imaging zone 12. Further, it should be noted at this stage, that only four high voltage switches are utilized for twelve valves as compared to one for each valve portion in prior art devices. It will be understood that the electronic economy of this configuration is significantly more than represented by the Fig. 4 and 5 illustration, because light valve panel 31 for a complete line will have many more valve portions than shown, e.g. 200 per inch.

How the locationally-addressing light valve structure described above can be utilized to accomplish improved electronic imaging in accordance with the present invention, can be understood by considering the remaining structure shown in Figs. 4 and 5. Thus, light valve imaging device 13 further comprises a low-resolution, informationally-addressing light valve array 30' comprising addressable electro-optic panel 35 positioned between polarizers 34 and 36. Polarizer 34 has the same polarization direction as polarizer 33 and both are crossed with respect to polarizer 36. It can be seen that light introduced through polarizer 36 will only pass polarizers 33-34 if rotated 90° by the energization of valve portions A, B, C, etc., of panel 35. Similarly, light which does pass polarizers 33-34 will only pass polarizer 32 (which also is crossed with respect to polarizers 33-34) if rotated 90° by the energization of the pixel portions of locationally-addressing panel 31. The relative location of panels 31 and 35 can be interchanged with the same optical effects resulting. Polarizers 34-35 can be a single polarizing means; however, dual polarizers are preferred for maximum light contrast between on-off conditions.

As shown in Figs. 4 and 5, the low-resolution, information address valves A, B, C, etc., of panel 35 are optically aligned with respec- tive location-address sectors A_1-A_4, B_1-B_4, C_1-C_4, etc., of panel 31. Referring to Fig. 5, it can be seen that each of information-address valves A, B, C of panel 35 have their addressing electrodes (not shown) connectable to a source of high voltage "V" by high voltage switch means 45, 46, 47, respectively. Switch means 45, 46, 47 are in turn actuatable between an off-on condition by serial-in, parallel-out shift register SR_1. As described in more detail below, successive sets of information signals (each containing information representative of a plurality of spaced image pixels along a line of the image to be reproduced) are cyclically input to the shift register SR_1 and output in synchronization with the activation of switches 41-44 by SR_2, the energization of light source 11 and the movement of image medium M.

Referring again to Fig. 1 as well as Figs. 4 and 5, one preferred mode of operation for electronic imaging in accordance with the present invention can be described. Thus, while a given line of the recording medium M is in the exposure station 12, color control 15, acting in response to signals from central processing unit (CPU) 49 and clock 50 effects at least three sequential light exposure periods, one each of red, green and blue light. During each such light exposure period locationally-addressing light valve array 31 is actuated under control of unit 49 and SR_2, sequentially turning on the inter-sector pixel groups A_1, B_1, C_1, through A_4, B_4, C_4, etc. During each activation of an inter-sector pixel group of locationally-addressing array 30,

appropriate image information is input to register SR_1 for informationally-addressing array 30'.

For example, if the image to be reproduced requires red light exposure of pixel A_1 (of a line of the recording medium then located at the exposure zone), information address sector A will be energized to an "on" condition during the sub-period of location-address by panel 31 that energizes the inter-sector pixel group containing pixel portion A_1. If the B_1 pixel of that line also required red light, information address sector B would also be energized during this sub-period; otherwise it would not. During recording of a complete line of three-color information, this sequence is repeated for each inter-sector group of locationally-addressing panel 31 and for each light color. It will be appreciated that the information signals input to shift register SR_1 for panel 35 must be properly formatted to correspond with the electrode connections of panel 31 and the activation program of register SR_2. Various means to accomplish proper signal format will occur to those skilled in the art based on the foregoing description.

One technique for obtaining a properly formatted signal, directly from the detecting-scan of a record member to be reproduced, is illustrated in Fig. 6. This embodiment also illustrates the independent utility of the present invention's locationally-addressing, light valve array configuration as a detecting scanner. As shown in Fig. 6, a record member T (e.g. a transparency image to be reproduced by electronic imaging apparatus 10) is moved along a scan path past scanning detector 60 by drive means 61, which is controlled e.g. by a known servo device under the regulation of clock 50. Note,

in this embodiment clock 50 also regulates CPU 49 of imaging apparatus 10.

As transparency T moves past scan station 62, successive line portions are illuminated by white light source 63. Imaging optics 64, e.g. an array of gradient index fiber lenses, are located on the opposite side of the scan station and direct light that is transmitted by the transparency to light valve scan array 66. Array 66 is constructed with the same elements 31, 32, 33 as shown in Fig. 4 and has addressing means like that shown for panel 31 in Fig. 5.

Thus different inter-sector groups of valve portions of scanning light valve array 66 are energized in succession as described previously, and during their "on" condition transmit light passing through the transparency T. Color filter discs 67, 68, 69, etc., are rotated between photodetectors 71, 72, 73, etc., and respective location-address sectors of array 66. The rotation of filters is controlled by clock 50 to be in proper timed relation with the color exposure periods of the imaging apparatus 10. Clock 50 also controls the successive, locationally-interlaced activations of inter-sector groups of light valve array 66 to provide a complete interlaced line scan during each color period (in proper timed relation with corresponding activations of inter-sector groups of panel 31).

Thus signals from detectors 71, 72, 73, etc., will comprise the proper image information (for each pixel of each line of the transparency T), in the proper format, to address to shift register SR_1 of apparatus 10 in proper timed relation with the activation of array 31 by its address means SR_2. As indicated in Fig. 6, the parallel signals from the detectors are transformed to a serial form by

parallel-to-serial shift register 76, after having any desired image-enhancement signal processing performed thereon by image process and control logic 77.

Although the Fig. 6 scanner is one useful apparatus for producing a properly formatted image signal for the apparatus shown in FIGS. 4 and 5, record members to be reproduced can also be scanned by conventional scanners (e.g. flying spot scanners or CCD arrays). Proper signal formatting is then effected with dedicated hardware and/or software.

Referring now to Fig. 7, an alternate embodiment of the present invention is shown. Specifically, area array 80 comprises high-resolution locationally-addressing panel 81 and low-resolution informationally-addressing panel 85. Area polarizers (not shown) are provided between and on each end of the light valve arrays, with polarization directions as described with respect to the Fig. 4 linear array configuration. A plurality of location-address means I, II, III, etc., each such as SR_2 shown in Fig. 5 for array 31, are provided respectively for each linear row of area array 81. Likewise, information-address shift registers S-1, S-2, S-3 and S-4 are provided to control low-resolution information sectors I-A through IV-C, etc. Thus, it will be appreciated that by operating each row of locationally-addressing area array 81 in the mode described with respect to Figs. 4 and 5 and similarly coordinating the activation of corresponding rows I-IV of low-resolution area array 85, a stationary recording medium can be imaged in an electrically efficient fashion similar to that previously described with respect to linear array embodiments.

What is claimed is:

1. Electronic imaging apparatus for optically addressing the individual picture elements of an image to be formed on a photosensitive recording medium, such apparatus including a plurality of electrically addressable light valves, a light source for illuminating such light valves and circuitry for selectively addressing such valves to cause each of such valves to switch between light-blocking and light-transmitting conditions, characterized in that said light valves are arranged to form first and second optically aligned arrays (30, 30'; 81, 85), said first array comprising a plurality of light valves which are grouped to form a plurality of location-address sectors (A_1-A_4; B_1-B_4; C_1-C_4, etc.), each light valve in one of said sectors being electrically coupled for common electrical addressing with one light valve in each of the other sectors; and said second array comprising a plurality of independently electrically addressable light valves (A, B, C), each being optically aligned with a different one of said plurality of location-address sectors (A_1-A_4; B_1-B_4; C_1-C_4), and in that said circuitry comprises first electrical addressing means (SR_2; 41-44) for sequentially electrically addressing the electrically coupled light valves in said location-address sectors; and second electrical addressing means (SR_1; 45-47) for simultaneously electrically addressing the light valves of said second array with an image information-bearing signal in timed relation with the electrical addressing of the light valves of said first array.

2. The apparatus as defined in claim 1 characterized in that said first and second arrays are linear arrays of light valves.

3. The apparatus as defined in claim 1 characterized in that said first and second arrays are area arrays of light valves.

4. The apparatus as defined in claim 1 characterized in that said first and second electrical addressing means comprises shift registers (SR_2; SR_1).

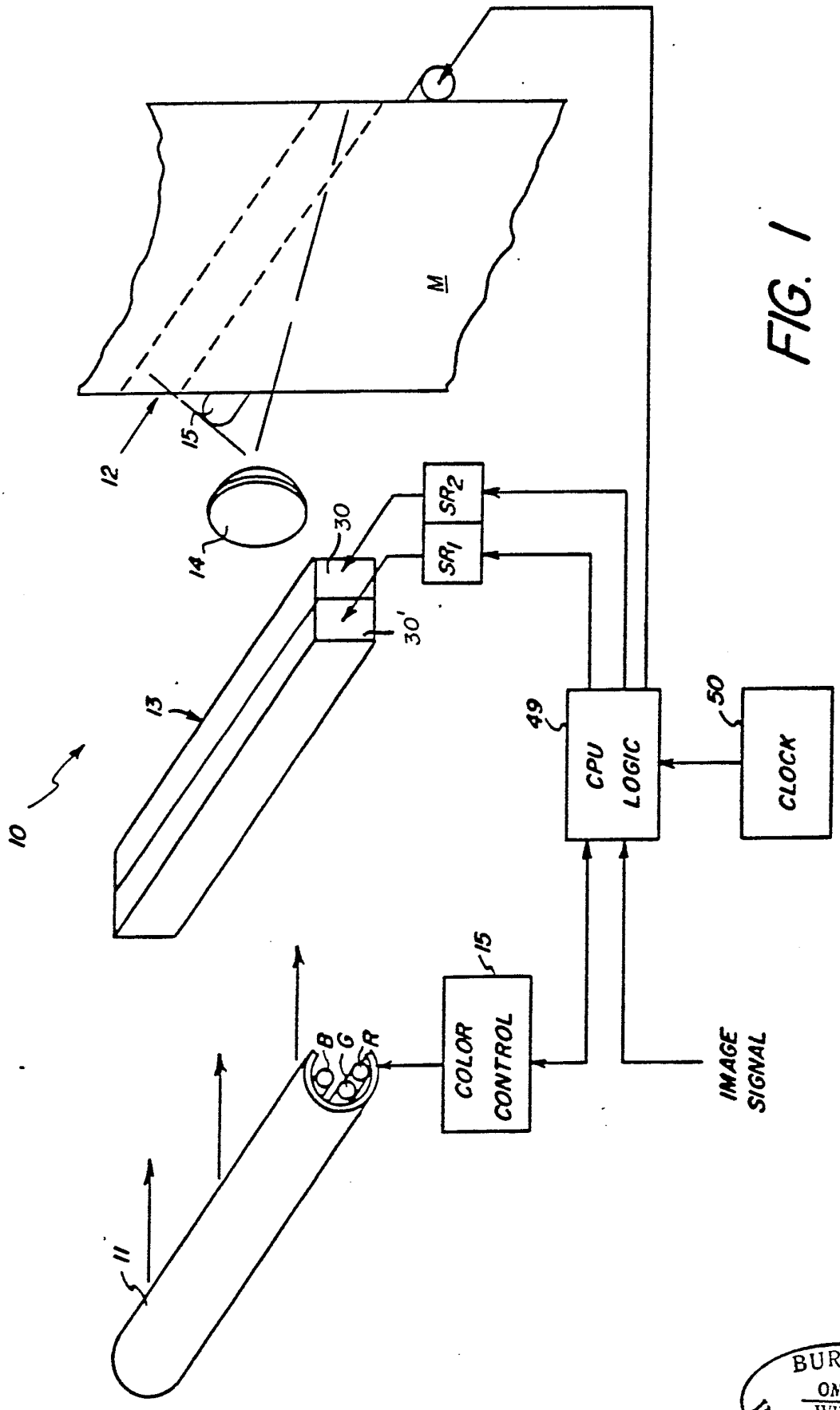
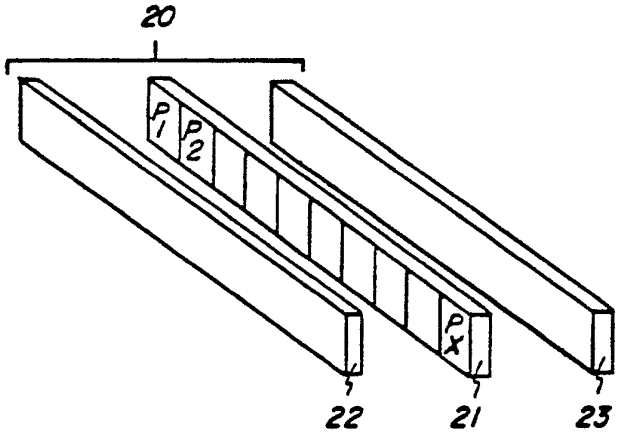
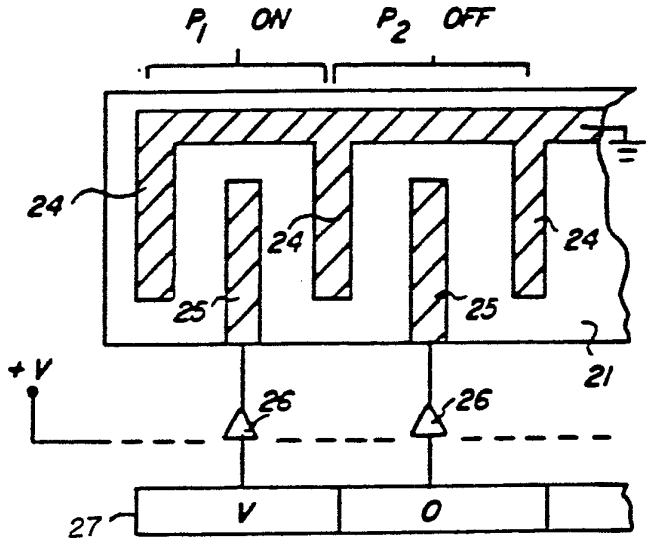


FIG. 1



PRIOR ART

FIG. 2



PRIOR ART

FIG. 3

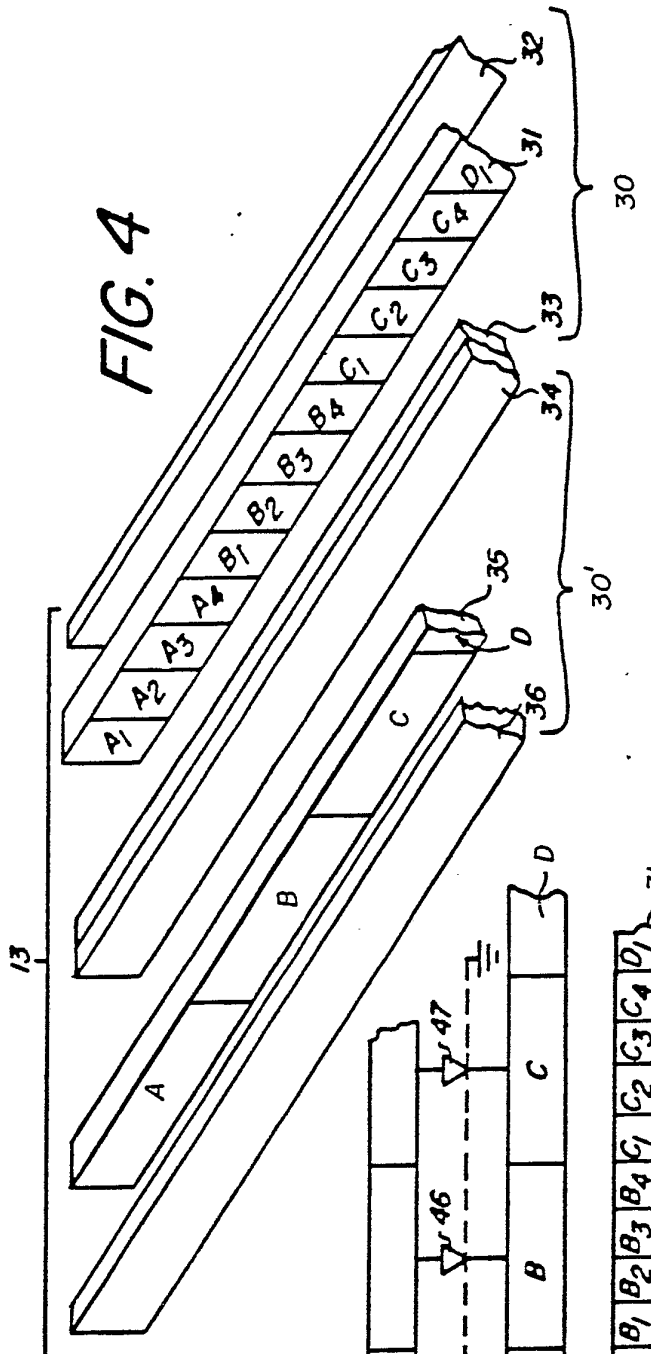


FIG. 4

FIG. 5

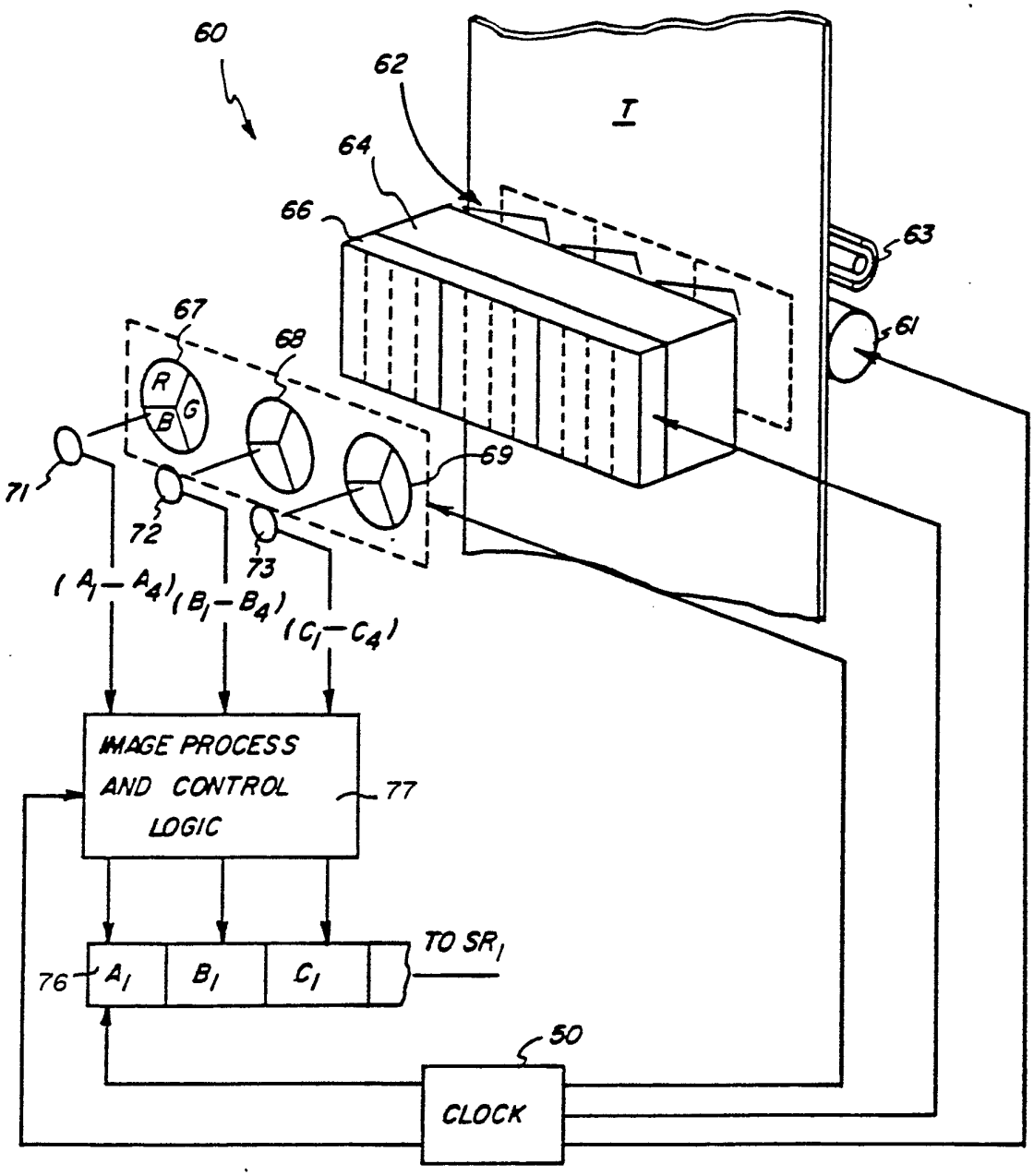


FIG. 6

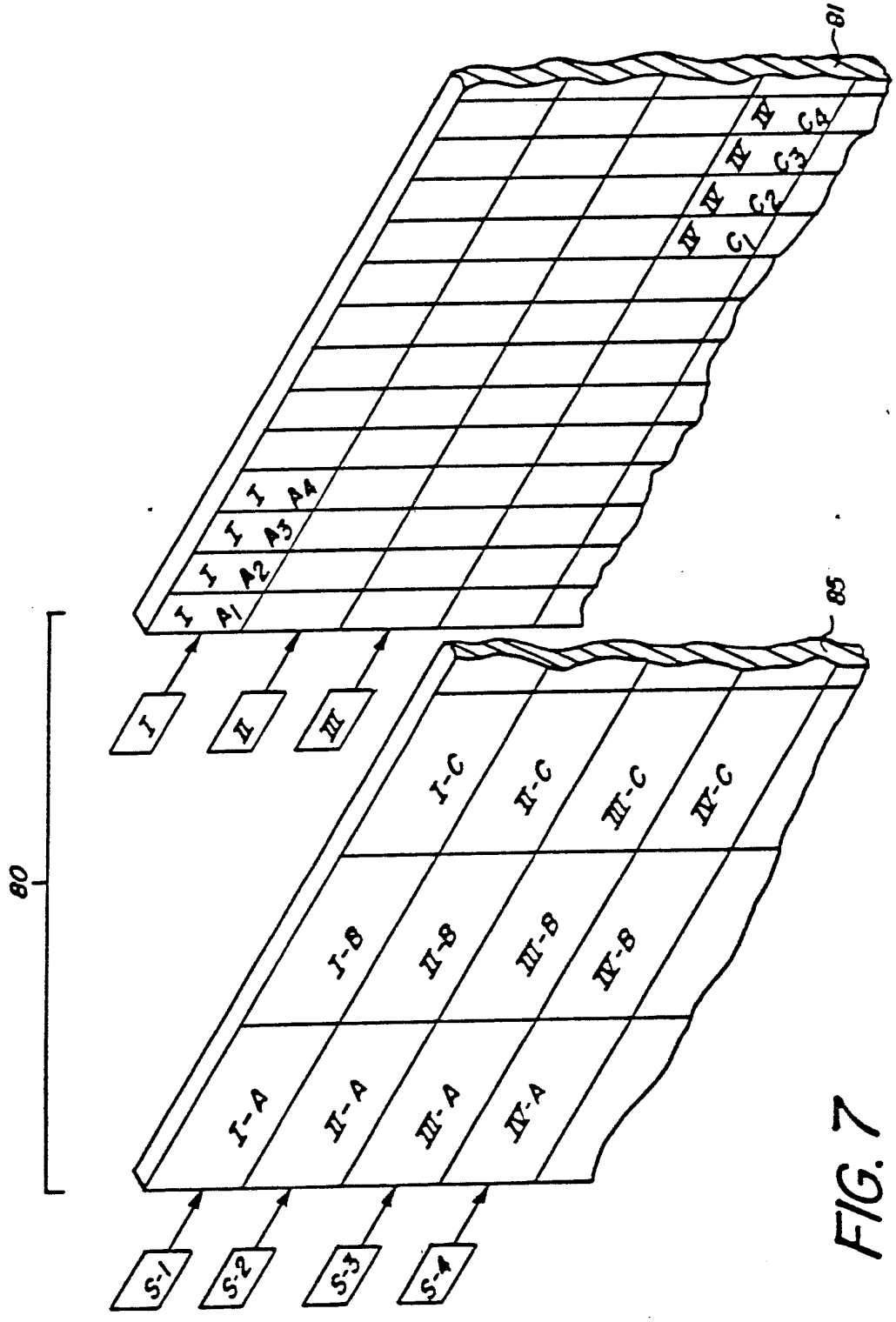


FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No PCT/US82/00703

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

Intl. Cl.[3] H 04 N 1/22
U.S. Cl. 358/75

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U. S.	358/75, 78, 60, 61, 213, 285, 286, 296, 300, 302; 355/4, 5, 18, 32, 37, 38, 67, 70, 71; 350/370, 374, 378, 380, 400, 403; 353/20

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]
A,P	US, A, 4,316,196, Jacobs, 16 February 1982	
A	US, A, 4,129,357, Frosch, 12 December 1978	
A	US, A, 3,930,119, Schmidt, 30 December 1975	
A	US, A, 3,891,560, Chester, 24 June 1975	

* Special categories of cited documents: [15]

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
18 August 1982	03 SEP 1982
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	Michael A. Masinick