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(54) **Electronic imaging apparatus using multicolor photoconductive particles.**

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The problem of providing color separation in a single exposure cycle, electronically addressable, photoelectrophoretic imaging system is solved by the provision of electronic imaging apparatus using multicolor photoconductive particles, the apparatus comprising an array of separately addressable electrodes (E_1-E_6) that are energized selectively in imagewise timed relation with sequential series of light pulses, each pulse being of a wavelength to which only one of the different particle color types in the imaging picture is responsive and each series including at least one pulse of each such wavelength.

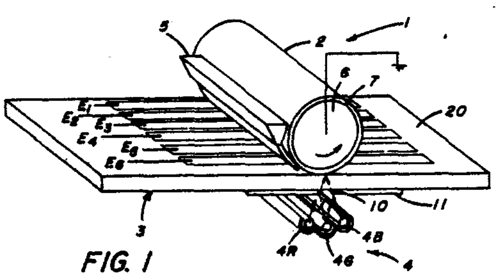

FIG. 1

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ELECTRONIC IMAGING APPARATUS USING MULTICOLOR PHOTOCONDUCTIVE PARTICLES

TECHNICAL FIELD

The present invention relates to electrophotographic imaging and in particular to apparatus for implementing such imaging in response to electronic signals representative of an original.

BACKGROUND ART

Photoelectrophoretic migration imaging involves the light image exposure of a liquid suspension, comprising dielectric liquid carrier and photoconductive toner particles, while between two electrodes that provide a migration inducing field. In operation, the suspended toner particles attain a charge and migrate from the suspension to one of the electrodes. Upon exposure the illuminated particles migrate to the other electrode in accordance with the exposing light image pattern.

Certain difficulties have arisen during efforts to commercialize photoelectrophoretic migration imaging systems. For example, high density images are difficult to attain in such systems. Further, in color imaging using this technique, it would be useful to have capabilities for color adjustment. Since the image density is dependent in part on light intensity, filtering to achieve color adjustment is not a desirable approach. Also, it is envisioned that office systems of the future may utilize image transmission, and it is not apparent how optically-addressed copiers can readily accommodate such a future need.

In view of one or more of the problems and/or desired capabilities noted above, there have been described in literature proposals for electrically-addressable photo-electrophoretic imaging systems. For example in U.S. Patent 3,682,628 a point light source is scanned, line by line, across the photoelectrophoretic suspension, through a transparent electrode. The opposite electrode is selectively energized, in accordance with a video signal representative of the image to be formed, and photoconductive particles in suspension are selectively activated on coincidence of the point light source and an energized condition of the electrode. However, this system cannot provide color separation, so that separate exposures of separate mono-particle suspensions to form three different color separation images (e.g., cyan, magenta and yellow) are required. This requires additional equipment and time as compared to conventional tri-particle suspension systems. Additionally, the procedure requires registry of three images during transfer, and such transfer is extremely difficult to accomplish accurately.

SUMMARY OF THE INVENTION

In accordance with the present invention the problem of providing color separation in a single exposure cycle, electronically-addressable photoelectrophoretic imaging system is solved by apparatus comprising a pair of spaced electrode members and an illuminating means including a light source for uniformly exposing at an imaging zone located between the electrode members successive portions of a developer containing a mixture of photoconductive pigment particles of different color types and respectively sensitive to light in different wavelength ranges. Electrical signals are applied to one of the electrode members comprising a plurality of separately addressable electrodes, hereinafter referred to as "addressing electrodes" whereby upon coincidence of an energized condition of at least one of the/addressing electrodes and light from said source, discrete particle migration fields are created between the electrode members. The illuminating means provides series time-separated light pulses in timed relation with respect to the imagewise energization of the addressing electrodes each series including a plurality of pulses at least one pulse in each series corresponding in wavelength to the sensitivity of one of the particle color types. The imaging suspension at the exposure zone can thus be addressed, line by line, with appropriate color-separation information for each picture element on the line.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is hereinafter described in connection with the attached drawings which form a part hereof and in which:

Fig. 1 is a perspective schematic view of an imaging station in accordance with one embodiment of the present invention;

Fig. 2 is a diagram illustrating one technique for timing illumination with respect to electrode movement in accordance with the present invention;

Fig. 3 is a schematic side view of one original scanning station in accordance with the present invention;

Fig. 4 is a schematic top view of the scanning station shown in Fig. 3; and

Fig. 5 is a block diagram illustrating one control arrangement for the apparatus shown in Figs. 1-4.

DESCRIPTION OF THE INVENTION

Referring to Fig. 1, one embodiment of an imaging station 1 in accordance with the present invention comprises a cylindrical imaged electrode 2, an imaging electrode 3 and illumination means 4. The imaged electrode 2 can be of a type known in the art and include an electrically-conductive core 6, coupled to ground, and an outer peripheral dielectric layer 7. The external surface of layer 7 can be used as the imaged surface, i.e., the surface on which the utilized image is formed, and the photoconductive toner image formed thereon can be transferred to another sheet or fixed directly to layer 7 (in the latter instance the layer 7 could be removably secured to the core 6). Suspension supply means 5, of a type known in the art, such as an extrusion hopper can be provided for supplying a uniform layer of photoelectrophoretic imaging suspension on electrode 2 or electrode 3.

The illumination means can comprise separate elongate sources 4R, 4G and 4B for providing, respectively, pulses of a different wavelength radiation, e.g., red, green and blue light. It will be appreciated that other types of electromagnetic radiation in the visible, ultraviolet or infrared ranges can be utilized if the particles respond thereto and the term "light" is used herein to include all such radiation. Each source desirably can include means such as a reflector for directing illumination therefrom onto an exposure slit 10 defined, e.g., by opaque mask 11, and extending transversely across the copying path.

Imaged electrode 2 is mounted for rotation about a fixed axis at a position such that portions of its peripheral surface, i.e., the external surface of layer 7, successively pass a position opposite exposure slit 10. Mounted for movement along a path so that successive transverse portions thereof pass between imaged electrode 2 and mask 11 is imaging electrode ——— 3. In the illustrated embodiment the imaging electrode ——— comprises an electrically-insulative matrix 20 which supports a plurality of elongate addressing electrodes E_1, E_2 . . . E_6 which are arranged in parallel orientation extending in the direction of electrode movement, generally orthogonal to exposure slit 10. The addressing electrodes desirably are substantially light transparent, electrically isolated from one another by matrix 20 and extend for a distance at least as great as a dimension of a document to be reproduced. In certain applications it may be desirable to overcoat the electrodes with a dielectric material, e.g., silicon monoxide or silicon dioxide, to prevent air breakdown between adjacent electrodes 2 and 3. The resolution of the reproduction produced by a particular image station 1 will depend in part on the electrode size and spacing distance so that they are desirably narrow and closely spaced, e.g., 40-80 per cm. However, it will be appreciated that embodiments in which the electrode concentration is less than 40 per cm will be useful in some applications, for example low resolution visual displays. The exposure slit 10 can have substantially the same width as the electrodes; however, in some embodiments it may be desirable to have a larger slit dimension. The electrodes and exposure slit shown in Fig. 1 are larger than would be used in most applications for purpose of illustration. During imaging each addressing electrode is selectively energized to a voltage level in accordance with successive portions of an image pattern to be reproduced and in cooperation with the light pulses from source 4 provide controlled deposition of the cyan, magenta and yellow pigment photoconductive particles in the tri-particle suspension which are at exposure slit 10.

A brief description of one mode of operation of the image station thus far described is believed useful before proceeding to the description of the apparatus which provides image and control signals to the image station. During operation, a photoelectrophoretic suspension is supplied at the nip between the imaged electrode 2 and the imaging electrode ——— 3. This can be accomplished by means known in the art, e.g., an extruding hopper for placing a layer on one of the electrodes at a location upstream from the nip. The imaging electrode 3 is moved past exposure slit 10 from left to right and the imaged electrode 2 is rotated counterclockwise as viewed in Fig. 1 so that successive portions of the imaged electrode surface move past the exposure slit. For purpose of explanation the surface of the imaged electrode 2 can be thought of as comprising a plurality of transverse strips or bands of width equal to the width of the exposure slit. In turn each transverse band can be considered as divided into a series of discrete segments, each defined by the projection of an addressing electrode on the transverse band. Each discrete segment (formed by the successive coincidence of an addressing electrode and the illuminated bands) forms a picture element, abbreviated herein "pixel". In accordance with the present invention each pixel is subjected to individual color separation imaging.

More specifically, referring to Fig. 2 in conjunction with Fig. 1, the time period which each transverse band passes over the exposure is schematically denoted T, the line period. Within each line period T the present invention contemplates at least three separate subperiods "t", during which each band is exposed respectively to three successive pulses of light of different wavelength, e.g., red, green and blue light from sources 4_R, 4_G and 4_B. The coincident occurrence, during an exposure period t, of an energized electrode and a light pulse will create deposition of suspension particles activated by that light wavelength, e.g. cyan, magenta and yellow, on the aligned pixel of the imaged electrode 2. The coincidence of a light pulse and a non-energized addressing electrode results in no particle deposition.

Thus, if none of the addressing electrodes E were energized during an entire imaging cycle, i.e., rotation of electrode 2 through one revolution and synchronous movement of electrode 3 from a left-most position to a right-most position, no particles would be deposited on any pixel of electrode 2, even though the illumination means 4 provided its three sequential exposure pulses during each of line periods T of the cycle. This is because particle migration will not occur in absence of an electrical field, even though the photoconductive particles are activated by the light pulses. However, if all electrodes were energized during (and only during) the red pulse subperiod t of each line period T in a copy cycle, only the photoconductive particles activated by the red light (e.g., cyan particles) would migrate to each pixel on the image electrode 2. Similarly if the electrodes were activated during the red and green subperiods, cyan and magenta particles would migrate to each pixel. If the electrodes were energized during all three subperiods the yellow particles would also migrate in response to the coincidence of addressing electrodes energization with blue light exposure.

Thus it will be appreciated that by proper control of the time of energization of each addressing electrode, in relation with the three sequential exposing light pulses t which occur during each line period T, the tricolor photoelectrophoretic suspension can be caused to migrate and form a color separation image.

Referring now to Figs. 3-5, an embodiment is illustrated for providing image information to the addressing electrodes E of image station 1, in response to scanning of a color original. As shown in Figs. 3 and 4, the original 30, e.g., a photographic color negative transparency, is moved past a scanning station 31. The scanning station can comprise a panchromatic light source 32 and separate photosensor systems 34, 35 and 36 located on the opposite side of the original. To provide color separation information, each photosensor system respectively includes, a lens 37, 38 and 39, a color filter 40, 41 and 42 and a photocell 43, 44 and 45. The filter-photocell combination of each system is selected to provide information as to a different color separation component of the portion of original passing thereunder. For example, light from lamp 32 color modulated by the original 30, is focused by lens 37 onto photocell 43 passing through filter 40. Assuming system 34 to be a red color information sensor, the filter 40 is a red filter and the photocell 43 is red-light sensitive. Sensor systems 35 and 36 can similarly be formed as green and blue information sensors respectively. As shown in Fig. 4, each of the photosensors 43, 44 and 45 respectively comprises a plurality of discrete photosensors 43a, 43b . . . 43f corresponding in number to the number of addressing electrodes E_1, E_2 . . . E_6 of the imaging station 1. Each of the discrete sensors 43a-f, 44a-f and 45a-f detects color information from a pixel element of the original, one line at a time.

As shown in Fig. 4, the original 30 is supported for movement past the photosensor systems on a transparent platen 50 having timing marks 51 thereon. A detector 52 is supported in alignment with the path of movement of the timing marks, and can include, e.g., a light source on one side of platen 50 which directs light through the timing marks to a photocell on the other side. Similar detection marks can be placed on electrodes 2 and 3 and the signals fed to a control system for maintaining movement of the original 30 and the electrode 2 in synchronization. It is essential that the imaged electrode 2 be moved in optical synchronism with the movement of the original and various other synchronization techniques known in the art can be utilized to accomplish this result. In a preferred embodiment the imaging electrode 3 also is moved to provide zero relative velocity with respect to contiguous portions of electrode 2, however, this is not essential. It is of course necessary that the periods of energization and nonenergization of the addressing electrodes E be properly related to the movement of the original and imaged electrode and with respect to the three exposure pulses which occur during the line periods T of those elements.

For this purpose, a control circuit such as disclosed in Fig. 5 can be provided. As indicated in that figure the red, green and blue light intensity signals generated by a set of photosensors, e.g., 43a, 44a and 45a (Fig. 4) associated with a corresponding linear electrode, e.g., E_1 (Fig. 1), are directed to the input terminals of a conventional multiplexer logic package 70. The multiplexer 70 is controlled by a sequential logic device 71 such as a shift register, counter or flip flop, which provides sequentially three digital selection signals that control the successive output of the red, green and blue light intensity signals from multiplexer 70. A pulse clock 72 provides a series of synchronizing timing pulses to device 71 which resets to an inactivating condition after each series of red, green and blue outputs and remains inactive until the mark sensor 52 signals the commencement of another output of color information for the next successive line of the original. As shown, the device 71 also provides sequential digital signals to the light sources 4R, 4G and 4B to control sequential actuation of the red, green and blue sources in synchronism with the red, green and blue color information output from the multiplexer 70.

Upon output from the multiplexer 70, the analog signal representative of the intensity, e.g., red light intensity of a pixel, is converted by an analog-to-digital converter 74 to a digital signal representative of the range of intensity within which the signal resides. This red intensity digital signal addresses a read only memory 75 which, in response provides to digital-to-analog converter 76 an analog signal indicative of the appropriate voltage to be impressed on the corresponding addressing electrode during the red light period t. That is, the extent of cyan particle deposition on imaged electrode 2 is proportional to the magnitude of the electrical field impressed during exposure, as well as to the intensity and quality of exposure. Therefore a tone scale for each color component can be provided by varying the field, i.e., the voltage impressed on an addressing electrode, with uniform intensity illumination.

Upon receipt of the next clock pulse, the green light intensity signal would be output from multiplexer 70 through the conversion circuitry, in synchronism with actuation of the green illumination source. Similarly in response to the third clock pulse, the blue light signal would be output; and the next subsequent clock pulse will reset device 71 to its initial condition, awaiting initiation of another activating sequence by mark sensor 52, when the original has advanced another line.

It will be appreciated that signal processing and timing circuitry described above will exist for each aligned R, G and B photosensor set and its corresponding electrode (i.e., 43a, 44a, 45a and E_1 . . . 43f, 44f, 45f and E_6). Also it will be understood that the color information of a particular type, e.g., red, green or blue, is transmitted in parallel to each pixel in a given line. That is, first the output of photosensors 43a-f will transmit the red information to the electrodes in synchronism with the red light pulse, then the sensors 44a-f will transmit green information to the electrodes during the green light line exposure and finally sensors 45a-f will transmit the blue information to the electrodes during blue exposure. When this tricolor exposure sequence has been completed for each line of the original, a copy sequence is complete.

As an example of typical parameters for use in the present invention, at an electrode speed of 25.4 cm per second, with an electrode spacing of 10 addressing electrodes per milimeter (75 μm electrode width and 25 μm gap) light exposures of about 40 mW/cm^2 and voltages in the range of 0-500 volts produced images having good color separation, density and sharpness.

It will be apparent that the cumulative time for each series of three exposure periods t must not exceed the line period T, which will be equal to the exposure slit width "W" divided by the velocity "V" of the imaged electrode surface. It is preferable, to obtain good color overlap, that $t \ll W/V$. This can be accomplished by proper selection of the clock pulse rate in conjunction with the rate of movement of the imaged electrode.

Although the invention has been described with respect to a particular embodiment it will be appreciated that significant modifications and a wide variety of alternative structures can be utilized for practice of the present invention.

For example in certain embodiments of the invention, tone scale might not be required. In these embodiments the read only memory and related converting circuitry could be eliminated and the analog signals from the photocells could be input directly to the addressing electrodes with proper signal delay and signal proportioning circuitry. Further, if desired certain color correction functions could be effected by detecting qualities of the sensed original intensity signals electronically comparing those signals and providing compensation processing for the signals output to the addressing electrodes.

Other devices and modes can be used for achieving a color tone variation, or gray scale, if desired. For example, the addressing electrodes can be energized, during each pixel exposure period for each color of light, according to a variable duty cycle. That is, if a low density red component is desired for a pixel, the electrode might have a constant voltage energization but, for example, a 10% duty cycle during that particular red light exposure period for the pixel. Similarly, if high red density was desired the duty cycle might be, e.g., 90%. At electrode speeds of about 25,4 cm/s, ———— AC voltages of about 1000 Hz and 0-500 volts have been found useful for this mode of practicing the present invention. Similarly, a stepped voltage signal can be provided for address to the electrodes during each pixel color exposure period and the electrode selectively addressed by that signal during the stage of its period at which it is at the desired voltage level step. In practicing the invention in accordance with the two foregoing modified procedures it is possible in some instances to utilize an exposure slit larger than the desired pixel width without loss of resolution. That is, resolution can be controlled by the signal frequency.

With respect to the imaging station it will be appreciated that the structure herein described as the imaged and addressing electrodes could be reversed, i.e., the utilized image could be formed on the surface having the addressing electrodes. In that embodiment it would usually be essential that the rate of movement of the addressing electrodes be the same as the scanning rate of the original. However, signal storage means, e.g., a magnetic disc, could be provided if it were desired to operate in non-synchronous or off-line modes. It will of course be appreciated that the imaging electrode could be a cylindrical drum to facilitate continuous operation. Also, the imaging electrode could remain stationary and the light source move to effect the invention on successive suspension zones. If a separate transport web was utilized to move suspension over the exposure zone, the addressing electrode structure could comprise simply a row of discrete addressable electrode pixels opposite the illumination source.

The illumination source could also take alternative forms. For example, chopped pulses could be provided by rotating a filter cylinder, having red, green and blue light filter sections, around the longitudinal axis of a constant panchromatic light source. The rotation of the cylinder would then be timed with respect to the address of the electrodes. Or, a multicolor filter array could be translated past the exposure slit at an appropriate rate to provide properly timed light pulses. Also, embodiments of the invention can be provided in which light is not projected through the addressing electrodes, e.g., by making the opposite electrode transparent.

The illustrated embodiment provided the imaged electrode at ground potential; however, this is not necessary as some applications may desirably utilize that electrode at a different potential level.

INDUSTRIAL APPLICABILITY

The above described apparatus can be used industrially as a color copier. More specifically, the apparatus can be used industrially as an electronically addressed color copier having an image transmission capability that is advantageous in simplicity and cost.

CLAIMS

1. Imaging apparatus comprising a pair of spaced electrodes, illuminating means including a light source for uniformly exposing at an imaging zone located between the electrodes successive portions of a developer containing photoconductive pigment particles and means for applying electrical signals to one of the electrodes to selectively energize said electrode whereby upon coincidence of an energized condition of said electrode and light from the source, discrete particle migration fields are created between the spaced electrodes, characterized in that said apparatus is for use with a developer containing a mixture of pigment particles of different color types respectively sensitive to light in different wavelength ranges, that the selectively energizable electrode (3) comprises a plurality of separately-addressable electrodes (E_1-E_6) and that said illuminating means (4) provides series of time-separated light pulses in timed relation with respect to the selective energization of said separately addressable electrodes each series including a plurality of pulses, each pulse being of a wavelength to which only one of said particle color types in said developer is responsive and each series including at least one pulse of each such wavelength.

2. The apparatus defined in claim 1, characterized in that said illuminating means comprises a plurality of light sources (4_R, 4_G, 4_B) which provide repetitive series of light pulses directed to uniformly illuminate an elongate imaging zone.

3. The apparatus defined in claim 1, characterized in that said means (70, 71) for applying said signals to said separately addressable electrodes includes means (34, 35, 36) for sensing the color density values of successive lines of an original to be reproduced and for providing in response thereto electrical signals for regulating the extent of energization of said separately-addressable electrodes.

4. The apparatus defined in claim 3, characterized in that said separately-addressable electrodes are

uniformly spaced linear electrodes, each electrode being electrically insulated from the others, said electrodes being generally coplanar and supported for movement past said imaging zone so that said light pulses from said illuminating means are generally transverse of said electrodes.

5. The apparatus defined in claim 3, characterized in that said illumination means provides at least one series of light pulses for each line of electrical signals applied to said separately addressable electrodes.

6. The apparatus defined in claims 3 and 4, characterized in that said means for applying electrical signals includes means (70) for applying successive groups of signals, each group containing the information for one line of the image to be reproduced.

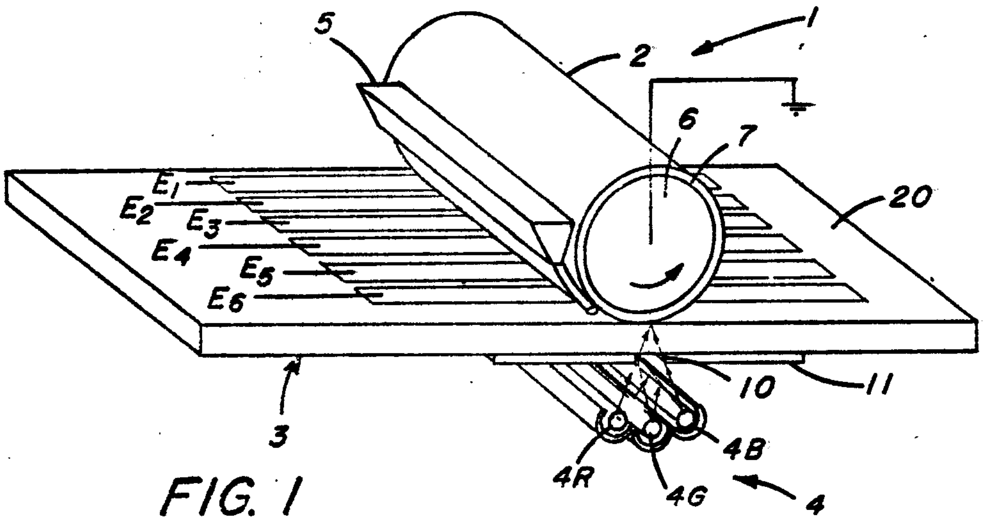
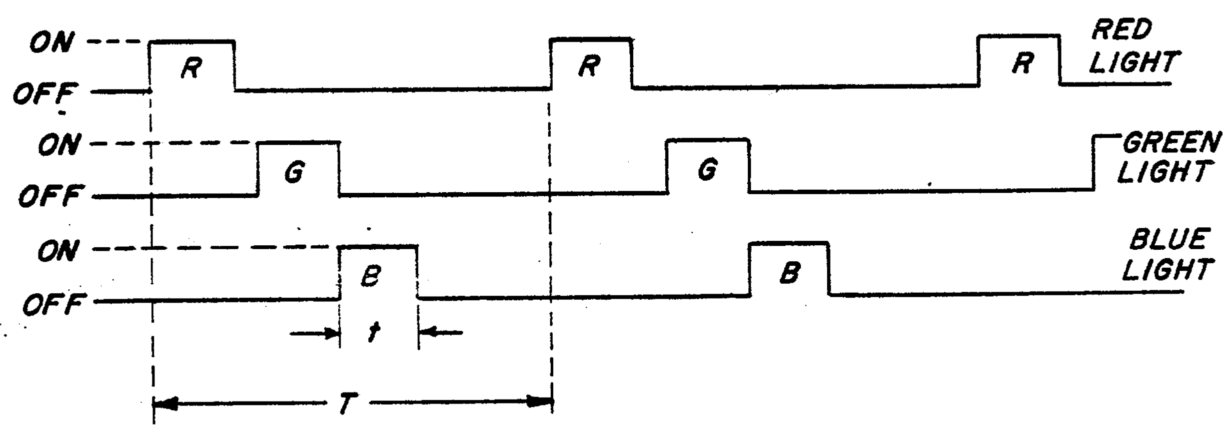

5
2
1
6
7
20
E1
E2
E3
E4
E5
E6
3
10
11
4B
4R
4G
4

FIG. 1


ON
OFF
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RED LIGHT
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FIG. 2

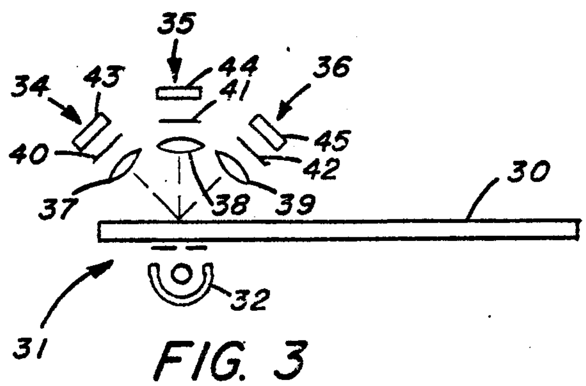

FIG. 3

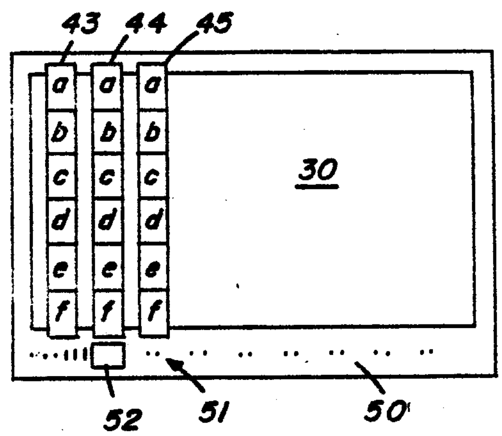

FIG. 4

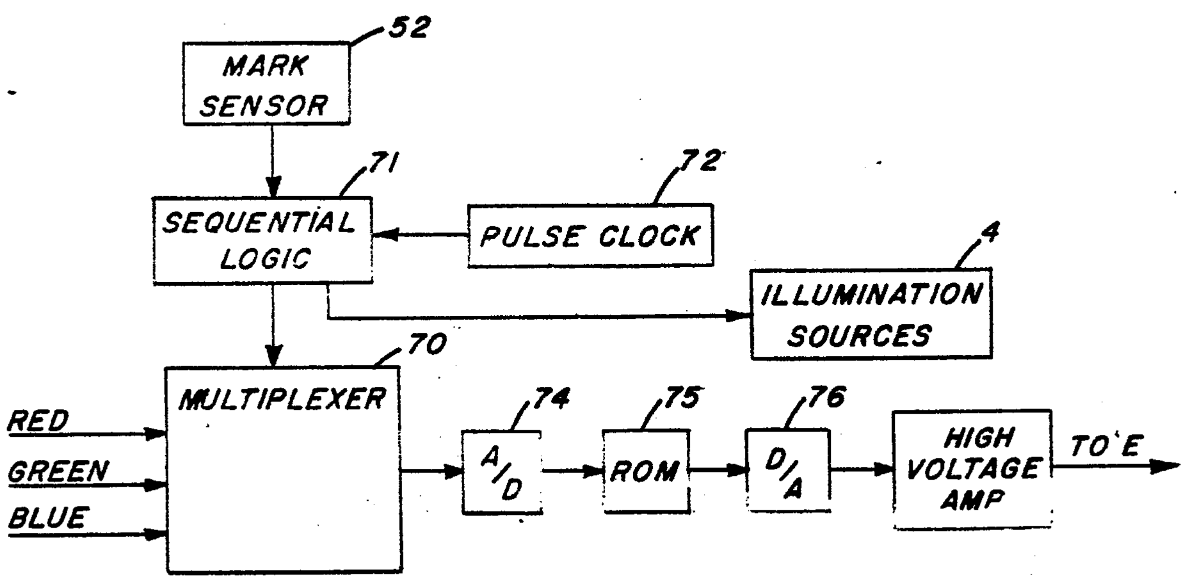

FIG. 5

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European Patent Office

EUROPEAN SEARCH REPORT

Application number
EP 78 20 0098

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.²)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
			G 03 G 17/04
DA	US - A - 3 682 628 (R.W.GUNDLACH) * Column 2, line 53 to column 3, line 7 * --	1	
A	US - A - 3 787 206 (W.L.GOFFE) * Column 2, line 39 to column 3, line 15 * ----	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.²)

G 03 G 17/04

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent [illegible]

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	[illegible]	[illegible]

EPO Form 1503 [illegible]

BAD ORIGINAL