

PATENT SPECIFICATION

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(72) Inventors: WILLIS A. ADCOCK
 FRANK L. SKAGGS

(54) TWO SENSOR TIME ENCODED COLOUR IMAGING SYSTEM

(71) We, TEXAS INSTRUMENTS INCORPORATED, a Corporation organized according to the laws of the State of Delaware, United States of America, of 13500 North Central Expressway, Dallas, Texas, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present invention relates to a colour imaging system and more particularly to an improved imaging system using two charge coupled device (CCD) image sensors for producing colour information signals in response to light received from an object. The disclosed colour imaging system may be used as part of a color television camera, particularly, a small hand held colour television camera.

Conventional colour television camera systems generate the three color signals, e.g., red, green and blue signal, using three separate vidicon tubes. Splitting the light coming from the object to be televised into three primary colours for transmission to the three vidicons and the magnetic or electrostatic deflection systems associated with each vidicon have resulted in the prior colour TV cameras being relatively large and heavy. While this prior art system produces a high quality colour signal, the bulk and weight of the camera associated with this system makes it difficult to use, for instance, in hand held applications.

In the prior art there have been suggestions for colour television image pickup systems which utilize, for instance, a striped optical filter and one or two vidicons, or similar devices such as the "plumbicon". Since white and coloured light are reproducible using three primary colours, these one or two vidicon systems must be able to discern three primary colours. Typically, a

striped optical filter is disposed in front of the vidicon interpreting two or three primary colours. The striped filter causes an alternating pattern of narrow stripes of different colour light from the object to fall upon the vidicon's sensitive surface. These stripes are selected sufficiently narrow such that the number of different segments or portions of the output signal from the vidicon, corresponding to striped pattern of light falling on the vidicon's sensitive surface, provide sufficient resolution to yield a clear picture.

The magnetic or electrostatic deflection system used with a vidicon, or similar device, causes its electron beam scan or interrogate its light sensitive surface to produce an output signal; however, its electron beam does not move with constant speed across the light sensitive target. While the output signal contains signal pulses corresponding to the intensity of light falling along the electron beam scan line, there is an inherent uncertainty as to the particular colour of light triggering a particular pulse. This uncertainty is caused by a combination of the non-constant speed of interrogation along a scan line and the lack of means for determining which colour of light produced a particular output pulse. This uncertainty makes it difficult for the decoding circuitry to discern which segments of the output signal correspond to a particular primary colour. Complex circuits have been utilized to compensate for this uncertainty. For instance, by using a parallel striped filter having a different pitch stripe for each colour, colour information is then associated with different carrier frequencies (in the output signal) corresponding to the pitch of the stripes, which information can be separated into separate colour information signals using band pass filters. Alternatively, the prior art suggests disposing the stripes at angles and using phase demodula-

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tion techniques to separate the colour information signals. In either case, the decoding circuitry is complex and because of bandwidth limitations of the vidicon, they are not totally satisfactory. These two vidicon systems used in the prior art incorporate such complex circuitry to compensate aforementioned scanning uncertainties in decoding the colour signals generated by the vidicons.

In the prior art it has also been proposed that a charge coupled device (CCD) be used as an image sensor. For instance, U.S. Patent 3,801,884 issued April 2, 1974, discloses the use of a CCD array in an image pickup system. CCD arrays having 512 by 320 cells for use as an image sensor are currently commercially available from Radio Corporation of America, Lancaster, PA. under the tradename SID51232. Image sensing CCDs are made up of an array of charged coupled cells which use a clock rather than a scanning electron beam to scan or interrogate the cells. Since highly accurate clocks are known in the prior art, the CCD image sensor does not suffer the non-linearity associated with the magnetic or electrostatic deflection system of a conventional vidicon. That is, a particular output pulse from the CCD image sensor can be associated with a particular physical location on the image sensing surface of the CCD.

There has also been a proposal to use a single CCD image sensor in colour image pickup system, as is described in U.S. Published Patent Application B502,289, dated January 13, 1976. This system utilizes a complex optical filter whose filter elements are arranged in an array and are sized approximate one-half the size of the CCD elements in the CCD array. This system further provides merely one of two colour information signals for each scan line in sequential fashion in addition to a luminance signal for each scan line.

It is, therefore, an object of this invention to improve colour television image pickup systems.

According to a first aspect of the present invention there is provided

a method of producing three video signals which together are representative of a colour image of light received from an object, the method including the steps of

passing the light through beam splitting means to produce an image on a first CCD image sensor and to produce an image on a second CCD image sensor,

the beam splitting means having a uniform effect across the field on the light of the image on the first CCD image sensor and being such that a first primary colour is filtered out of first parts but not out of second parts of the image on the second CCD image sensor,

deriving from the first CCD image sensor a first output signal representative of the image on the first CCD image sensor and deriving from the second CCD image sensor a second output signal representative of the image on the second CCD image sensor, and

processing said first output signal and said second output signal to produce the three video signals.

According to a second aspect of the present invention there is provided

a colour imaging system which in use produces three video signals which together are representative of a colour image of light received from an object, the system including

(a) a first CCD image sensor and a second CCD image sensor,

(b) beam splitting means for receiving light from an object and producing a first image on the first CCD image sensor and producing a second image on the second CCD image sensor, the means having a uniform effect across the field on the light of the first image and being such that a first primary colour is filtered out of first parts of the second image,

(c) processing means for deriving a first output signal from the first CCD image sensor and a second output signal from the second CCD image sensor and producing from the first and second output signals the three video signals.

In an embodiment of the invention, two CCD image sensors are utilized. Green light from an object is directed to the first image sensor while combined red and blue light is directed to the second image sensor by a partially reflective mirror. A striped optical filter is disposed between the light source and the second image sensor by a partially reflective mirror. A striped optical filter is disposed between the light source and the second image sensor such that alternating stripes of red and red+blue light are imaged on the second image sensor's sensitive surface. The output from the red and red+blue image sensor is converted into separate red and blue colour information signals by examining the pulses or segments of the image sensor signal corresponding to red stripes of light to generate the red colour information signal and by examining the pulses or segments of the image sensor signal corresponding to red+blue stripes of light and subtracting the pulses or segments of the signal corresponding to adjacent red stripes therefrom to produce the blue colour information signal. Alternative embodiments disclosed use different combinations of primary colours to produce three colour information output signals and use a striped filter which passes alternating stripes of red and blue light.

Figure 1 shows in block diagram form the paths of light to the two image sensors and the paths of electrical signals from the sensors to the output.

Figure 2 is an exploded perspective view of the striped filter disposed over an image sensor.

Figures 3 and 4 are cross-sectional views through the striped filter and the image sensor.

Figure 5 is a block diagram schematic of a first embodiment of the system for decoding the electrical signals from the image sensors.

Figures 6 (a) and (b) are graphs on which is plotted curves of green light, red light and blue light as well as the photopic response of the human eye.

Figure 7 is a block diagram of a second embodiment of the system for decoding the electrical signals from the image sensors, and

Figure 8a is a diagram depicting the preferred direction of scanning in relation to the direction of stripes and

Figure 8b is a diagram depicting an alternative scanning direction.

Referring now to Figure 1 there is shown in diagrammatic form our two sensor time encoded colour television image system. A ray of light 11 from an object 10 to be televised passes through a lens 12 which focuses the ray of light 11 on a pair of image sensors 14 and 15. The ray of light is separated into two portions 11a and 11b which are directed to the respective image sensors 15 and 14 by a partially reflective mirror 13. Partially reflective mirror 13, in this embodiment, passes one primary colour of light while reflecting two primary colours of light. The two reflected primary colours of light in ray 11a pass through a striped filter 16 before striking the sensitive surface of image sensor 15. In an alternative embodiment partially reflective mirror 13 passes two primary colours and reflects but one primary colour with striped filter 16 being disposed in front of image sensor 14, resulting in a colour television image system still having one CCD image sensor producing a signal corresponding to one primary colour and a second CCD image sensor producing a signal corresponding to two primary colours as is produced by the embodiment depicted in Figure 1.

The two image sensors 14 and 15 produce electrical signals representative of the amplitude and position of light impinging the sensitive surfaces thereof. The signals are applied to a decoder circuit 17 which decodes the signals and produces red, green and blue colour signals, as well as a luminance signal. Utilizing any three of the aforementioned signals, the fourth can be generated therefrom. While the decoder circuit 17 need only produce three of such

colour information signals, the decoder is depicted as producing four colour information signals (e.g., the red, green and blue colour signals as well as a luminance signal) because of a common usage of such signals in the television broadcasting industry. However, the matrix circuit could produce the L, I & Q signals also known in the television broadcasting industry.

Referring now to Figure 2, there is shown an exploded perspective view of a CCD image sensor 15 with the optical striped filter 16 disposed between CCD image sensor 15 and object 10. The aforementioned partially reflective mirror 13 (Figure 1) is not shown in Figure 2 for sake of clarity. It should also be understood that filter 16 would typically be disposed adjacent to image sensor 15.

Light from object 10 is focused by lens 11 onto the image sensing surface 21 of image sensor 15. Light is inhibited from falling on storage surface 22 of CCD image sensor 15, for instance by an opaque layer (not shown) or other means. It should be understood, moreover, that storage surface 22 is used to facilitate the production of video signals which are properly timed for use with standard broadcast television systems and that such a storage surface is not required to operate a CCD image sensor nor is it required in the practice of the present invention. If storage section 22 is not used, however, a shutter (not shown) is typically disposed between object 10 and CCD image sensor 15.

Image sensor 15 is shown as being of the three phase frame transfer type, which can be advantageously used to produce an output signal having a 2:1 interlace, such as that used in standard broadcast television. It should be understood, however, that our invention is operable with CCD image sensors of the two or four phase frame transfer type as well as CCD image sensors utilizing other clocking schemes.

The image sensing surface 21 and the storage sensing surface 22 are each shown with 9 rows of electrodes, the electrodes being further grouped into 11 columns. The electrodes in any given row are connected in common to one of the busses A, B, C, A', B', or C'. The electrodes are shown as being separated into columns to more clearly depict the light sensitive areas of the semiconductor material underlying the electrodes. The separation between rows is exaggerated for sake of clarity.

Busses A, B, C, A', B', and C' are clocked to transfer the charges stored under the electrodes (in a semiconductive substrate) from image sensing surface 21 to storage surface 22. Busses A', B', C', D, E and F are clocked to transfer the charges stored in storage surface 22 to a charge

detection amplifier 26 via a video output terminal 25. Methods of clocking CCD image sensor to obtain a video signal are well known in the art and therefore, we have not explained in detail the operation of the CCD image sensor.

Since this is a three-phase system, three adjacent electrodes, separately connected to the A, B and C busses, comprise one row of sensitive cells 20 (Figures 3 and 4). The boundaries between the columns of cells 20 are defined by charge barriers 28 (Figure 3) disposed in or near the semiconductive substrate. Exemplary of such cells, are those cells indicated by reference A, B, C and D. It should be evident that there are thirty-three such cells 20 in the depicted image sensing surface 21 and that it requires many more than that number of cells to produce a high resolution image.

If interlace scanning is utilized, then the electrodes are clocked differently in alternate frames to form cells A, B, C, and D during one frame and intermediate cells, such as the cell denoted by reference E, during a next frame. It should be understood that the cells are not physically moving, rather the centers of the light sensitive area are being electrically displaced. Clocking the image sensor 15 differently in successive frames effects a 2:1 interlace similar to that used in standard television broadcasting.

Each light sensitive cell of image sensor 15 produces a pulse at output terminal 25 when the cells are read out by properly clocking busses A, B, C, A', B', C', D', E and F. Each pulse is indicative of the amount of light impinging the corresponding cell since the last time a pulse was read out of that cell.

Filter 16 is arranged with stripes 17 being positioned to cause a different colour light to impinge each column of cells. As a frame is being read out of image sensor 15, the first pulse read out in the first scan line corresponds to the light impinging Cell A through stripe F, the second pulse in the first scan line will correspond the light impinging cell B through stripe G and the last pulse in the last scan line will correspond to the light impinging cell C through stripe H. Thus the output signal from image sensor 15 comprises a series of pulses with adjacent pulses in any given scan line corresponding to different colours of light passing through filter 16. The pulses are typically processed by a charge detection amplifier 26 before being processed by decoder circuit 17. A charge detection amplifier is a well known apparatus and is here used with the CCD image sensors to convert the CCD output charge pulses to a suitable voltage or current signal for further processing.

Since accurate clocks for driving busses

A, B, C, A', B', C', D, E and F are known and since in the present embodiment, adjacent cells 20 in a scan line correspond to different colours in filter 16, the output pulses from image sensor 15 each correlate with the colour of light which produced such pulse to a high degree of certainty; this certainty is not achievable with a conventional vidicon because of the aforementioned non-linearity associated with the magnetic or electrostatic deflection circuits. In the practice of the present invention, it is desirable that the output pulses from the area imaging sensor utilized exhibit a high degree of certainty as to the correspondence of a particular segment of pulse of the output signal from the device to the particular colour of light from the object which generated that segment or pulse. Thus, it can be seen from the foregoing discussion that a CCD image sensor fulfills this criterion.

Figure 3 is a sectional top view through image sensor 15. Referring to Figure 3, filter 16 is shown disposed adjacent to image sensor 15, it being understood, that filter 16 could be applied directly to image sensor 15. One of the electrodes 24 associated with a cell 20 is shown disposed over an insulating layer 27 which is in turn disposed over a semiconductive substrate 23 wherein the charges for each cell 20 are stored. Channel stops 28 provide charge isolation barriers between columns of cells 20. While image sensor 15 is shown with preferable front side illumination, it should be understood that the invention is also operable with back side illuminated CCD image sensors.

Figure 4, is sectional side view through CCD image sensor 15 and filter 16. Filter 16 is not depicted with stripes in this view because the section view is being taken through a single stripe. Three electrodes 24 are depicted as being associated with a single cell 20, in agreement with the three phase system depicted in Figure 2, it being understood that two and four phase and other clocking systems are as well operable in the practice of our invention.

Referring again to Figure 1, in an embodiment in which semi-reflective mirror 13 transmits green light and reflects red and blue light, then ray 11b corresponds to the green light emanating from the object and ray 11a corresponds to red + blue light would then impinge upon image sensor 15 after being filtered by striped filter 16. Referring again to Figures 2 and 3, the first embodiment of striped filter 16 is respectively selected to pass the red + blue light to selected columns of cells 20 and to pass only red light to the interleaved columns of cells 20. In such first embodiment, the striped filter 16 depicted in Figure 3 passes, for instance, both red and blue light where the

filter is depicted as being clear and passes only red light where the filter is depicted by shading lines. The output from CCD image sensor 15 comprises a series of pulses corresponding the amplitude and position of light impinging upon its sensitive surface with some pulses of the information corresponding to the red + blue light impinging upon its sensitive surface and with other pulses corresponding to only the red light falling upon its sensitive surface, these pulses being interleaved according to the pattern of stripes formed by filter 16.

Referring now to Figure 5, there is shown in block diagram from a schematic at a first embodiment decoder circuit 17 according to the present invention. As aforementioned, the output from the image sensor 15 which corresponds to two colours of light is a signal comprising interleaved pulses or segments of colour information. In Figure 5, the output from image sensor 15 shown as $Y_n, Z_{n+1}, Y_{n+2}, Z_{n+3}, \dots$ the capital letters referring to the signal amplitude for a particular colour or combination of colour while the subscripts indicate the time since the beginning of a scan line at which the particular signals are generated by the sensor. The letters X, Y and Z are used in Figure 5 to denote the signals representing the colours or combination of colours generated by the image sensors 14 and 15, to demonstrate the general applicability of this first embodiment decoding circuit 15. The relationship of the colours X, Y & Z to the colours utilized in the preferred embodiment, e.g., red, green and blue will henceforth be described in detail.

The output from the two colour image sensor 15' (i.e., the CCD image sensor 15 including striped filter 16) is applied to an analog switch 30 which is operated in timed relation to the clock interrogating the two colour image sensor 15'. Techniques for operating analog switch 30 in timed relation to such a clock signal which is indicative of which colour of light produced the segment of output signal from two colour image sensor 15' then received by analog switch 30, are well known in the art. Analog switch 30 has two outputs, one output providing to the Y signal at times $n, n+2, n+4$ and so forth and the second output providing the Z signal at times $n+1, n+3$ and so forth. The Y signal is passed through a delay circuit 31 which delays the Y signal one time segment (e.g., one pulse width), that is, pulse Y_n will appear at the output of delay circuit 31 at time $n+1$, pulse Y_{n+2} at time $n+3$ and so forth. The Z signal is applied to one input of subtracting circuit 32, the output from delay circuit 31 being applied to the other input of subtracting circuit 32. The Y signal, being delayed one segment time, is subtracted from the Z signal appearing at that segment

time. Consequently, the output from subtracting circuit 32 comprises a series of pulses corresponding to the quantities $(Z_{n+1} - Y_n), (Z_{n+3} - Y_{n+2})$ and so forth.

It is preferable to make the quantity $Z - Y$ represent a pure colour to simplify later signal processing. Thus Z corresponds to the combined light of two primary colours and Y corresponds to one of those two primary colours; for instance, if Z were red + blue and Y were red, then $Z - Y$ would correspond to blue.

Again referring to the analog switch 30, the delay circuit 31 and the subtracting circuit 32, it should be evident to one skilled in the art that the $Z - Y$ and Y pulses occurring at the outputs of subtracting circuit 32 and delay circuit 37 will each be one half the frequency of the signal from dual colour image sensor 15' and further will have one half the duty cycle. Thus the $Z - Y$ and Y pulses occur only at segment times $n+1, n+3, n+5, \dots$ To produce $Z - Y$ and Y output signals at $n+2, n+4, \dots$ segment times, these $Z - Y$ and Y outputs are applied to inputs of sample and hold circuits 37 to cause the signals appearing at segment time $n+1$ to appear at the outputs of sample and hold circuits at segment times $n+1$ and $n+2$. Similarly, inputs appearing at segment time $n+3$ appear at the outputs of sample and hold circuits 37 at segment times $n+3$ and $n+4$. Thus, the pulses representing Y and $Z - Y$ occur at one half the frequency of the pulses representing X, the Y and $Z - Y$ pulses being two time segments long while the X pulses are but one time segment long. The reason this lower frequency in the $Z - Y$ and Y channels does not unduly degrade picture quality is subsequently discussed more fully.

The output from the single colour sensor 14 is applied to a sample and hold circuit 33 and thereafter to a delay circuit 34 which delays the X signal one time segment, thereby keeping it in proper timing with the delayed Y signal. The X, $Z - Y$, and Y outputs are shown in Figure 5 as a series of varying amplitude pulses, having the aforementioned frequency relationships. Sample and hold circuits 33 and 37 are employed to capture that part of each CCD output pulse which contains amplitude information and to reject those parts which do not contain amplitude information, in addition to the previously mentioned purpose for sample and hold circuit 37. Sample and hold circuits 33 and 37 and their use with CCD imaging arrays are well known in the prior art.

As a new X colour information pulse is generated each segment time, the X pulses occur at segment times $n+1, n+2, n+3$ and so forth. As aforementioned, the $Z - Y$ and Y pulses are generated by the decoder

circuit only for each two segment times. The X output is then passed through a low pass filter 35 which has bandwidth of approximately 3 megahertz. Similarly the Z-Y and Y signals are passed through low pass filters 36 and 37 each of which has a bandwidth approximately 1.50 megahertz. The outputs from the three low pass filters 35 and 36 supply three colour signals, and similarly the three outputs may be applied to the input of a luminance adder matrix 38 to generate a luminance signal. It can be seen that the low frequency portions of the luminance signal, i.e., those below 1.50 megahertz comprise portions of X, Z-Y and Y signals whereas the higher frequency portions of the luminance signal, i.e., those between approximately 1.50 megahertz and 3 megahertz, are made up of primarily the X signal; this dependence on primarily the X signal for the higher frequency portions of luminance signal provides a pleasing picture to the human eye, especially if the X signal is selected to represent either the white light or the green portions of the colour signal for reasons which are discussed below. The bandwidth of the Z-Y and Y filters 36 is limited to 1.50 MHz, (as might be suggested by the fact that the Z-Y and Y signal frequencies are half the frequency of the X signal) to reduce the propensity of the system to generate moire interference patterns in accordance with information processing theory. Using a 1.50 MHz filter does not reduce picture quality to the human eye.

As the physical size of a source of light decreases, that is, as the subtended angle of incidence in the human eye loses its ability to discern colour information before it loses its ability to discern the presence of the object. Effectively, the response of the human eye to colour information has a narrower bandpass than its response to luminance information. Therefore, in colour television systems, the colour signals need not have the same bandwidth as the luminance signal simply because there is no purpose in displaying information which the human eye cannot discern.

Referring now to Figure 6(a), there is graphically shown the curve of wavelength versus relative amplitude of green light passed by partially reflective mirror 13 in relation to the photopic response of the human eye. As perfect filters are difficult to manufacture, a green trim filter may be used with mirror 13 to eliminate unwanted blue light from the light-impinging image sensor 14. Given the excellent correspondence between green light and the photopic curve and since the aforementioned insensitivity of the human eye to the colour of light having small angles of incidence affects red and blue light before it affects green light, the higher frequency X colour information

signal, which is capable of representing smaller size objects, preferably corresponds to the colour green (or to luminance information). In Figure 6(b), the frequency distribution of the red and blue colour light impinging two colour sensor 15' is depicted. The infrared response is preferably limited by an infrared filter used with lens 12 while ultraviolet response is typically limited by image sensor 15 response.

Thus it is preferred that the high frequency signal from the single colour sensor 14 comprise the green colour information while the red and blue colour information be directed to the two colour sensor 15'. Therefore, in Figure 5, in the practice of the preferred first embodiment, X may be replaced by G to represent green, Y may be replaced by R to represent red, Z may be replaced by B plus R to represent red plus blue and Z-Y consequently can be replaced by simply B for blue. Two colour sensor 15' produces interleaved segments corresponding to red plus blue and red alone utilizing the partially reflective mirror 13 which directs red plus blue light towards the CCD image sensor 15 and a red and clear striped filter 16 as was previously discussed with reference to Figures 1 and 3.

Alternatively, the X channel can correspond to luminance information if the partially reflective mirror 13 is selected to pass red and blue light, in addition to green light, to image sensor 14. Then the X output from decoder circuit 17 corresponds essentially to luminance information and a green matrix circuit must be used, in lieu of luminance adder 38, for instance. The green matrix circuit is then responsible to the X (luminance), Z-Y (blue) and Y (red) signals for subtracting the red and blue signals from the luminance signal to generate a green colour information signal. The X channel is this alternate embodiment provides a luminance colour information signal.

Referring now to Figure 7, there is shown in block diagram form a schematic of a second embodiment of decoder circuit 17. As in the first embodiment of decoder circuit 17, the output from the image sensor 15 which corresponds to two colours of light is a signal comprising interleaved pulses or segments of colour information. In Figure 7, the output from dual colour sensor 15' is shown as $Y_n, Z_{n+1}, Y_{n+2}, Z_{n+3}, \dots$. The capital letters referring to the signal amplitude for a particular colour while the subscripts indicate the time since the beginning of the scan line at which the particular signals are generated by two colour sensor 15'. The letters X, Y and Z are used in Figure 7 to denote the signals representing the colours generated by CCD image sensors 14 and 15, to demonstrate the general applicability of the second embodiment of

the decoder circuit 17. The relationship of the colours X, Y and Z to the colours utilized in the second embodiment, e.g., red, green, and blue, will henceforth be described in detail.

The output from the second embodiment of two colour image sensor 15' comprises interleaved segments or pulses corresponding to two different primary colours. This differs from the first embodiment where the interleaved segments or pulses corresponded to pulses representing two primary colours and pulses corresponding to one of those two primary colours. In the second embodiment, the two different primary colours are produced using a striped dichromatic optical filter 16 which alternating passes only red light in one of the set of stripes and only blue light from the interleaved stripes.

The output from the two colour image sensor 15' is applied in the second embodiment to an analog switch 30 which is operated in time relation to the clock signal which is indicative of the colour of light produced by the segment or pulse of the output signal from two colour image sensor 15'. Analog switch 30 has two outputs, one of the output corresponding to the Y colour at times n, n+2, n+4, and so forth with another output corresponding to the Z colour at times n+1, n+3, n+5, and so forth. The Y colour output and the Z colour output from analog switch 30 are passed through sample and hold circuits 37 which (1) capture that part of each CCD output pulse which contains amplitude information and rejects those parts which do not contain amplitude information and (2) holds the pulse over two segment times, similarly as was done in the first embodiment, such that the Y_n signal appears at segment times n and n+1, the Y_{n+2} signal appears at segment times n+2 and n+3 and so forth: the X_{n+1} signal appears at segment times n+1 and n+2, and so forth. The output from image sensor 14 is passed through a sample and hold circuit 33 as was done in the first embodiment. The X, Y and Z outputs from the three sample and hold circuits are then passed through their respective low pass filters 35 and 36 to produce three colour information signals X, Y and Z.

The decoder circuit disclosed as the first embodiment, allows stripe filter 16 to have alternating color and clear stripes thus requiring but one filter medium, e.g., opaque to blue light, in the filter design. In the second embodiment, on the other hand, the striped filter 16 must have alternative stripes of filter medium. Thus the first embodiment of the invention permits the use of a simpler, single medium striped filter having alternating clear and colour stripes.

As can be seen from Figure 7, the pulses entering X channel low pass filter 35 occurs

at approximately twice the frequency as the Y and Z pulses entering Y and Z low pass filters 36. For the aforementioned reasons regarding the sensitivity of the human eye, we prefer to practice the second embodiment of our invention with the X channel corresponding to green (or white light) and the Y and Z channels corresponding to red and blue.

While we prefer to practice our first and second embodiments of our invention with the X channel corresponding to the green colour signal, it should be evident to one trained in the art, however, that other colour schemes may be used with the present processing systems. For instance, instead of using primary colours red, blue and green, their opposites may be used, namely cyan, magenta and yellow or the X channel may correspond to the luminance information, as aforementioned.

Further, while the direction of scanning the image sensor has preferably been shown at right angles to the direction of stripes and the stripe filter 16, the stripes may be disposed essentially parallel to the direction of scanning the image sensor 15. As is shown in Figures 2 and 8a, the scan line (labelled scan 1 - scan 5 in Figure 8a) are disposed at right angles to striped filter 16, which alternately passes red and red plus blue light in the preferred first embodiment or alternately passes red and blue light in the second embodiment. Of course, other colours may be used in filter 16 as aforementioned. The direction of stripes may be nonperpendicular to the direction of scanning, for instance, parallel thereto, as shown in Figure 8b. In this alternative embodiment, an entire scan line of video information is stored for comparison with an adjacent line.

Having described the invention in connection with certain specific embodiments thereof it is to be understood that further modification may now suggest itself to those skilled in the art.

For instance, optical resolution reducing filters may be disposed between the object and image sensor 15 for the purpose of reducing optically produced moire patterns. Also, because it is difficult to fabricate a single filter having exactly the transmissivity or reflectivity desired, trimming filters may be used therewith to more closely attain the desired transmissivity or reflectivity. It is to be understood that the invention is not limited to the specific embodiments disclosed.

WHAT WE CLAIM IS:-

1. A method of producing three video signals which together are representative of a colour image of light received from an object, the method including the steps of passing the light through beam splitting

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the decoder circuit 17. The relationship of the colours X, Y and Z to the colours utilized in the second embodiment, e.g., red, green, and blue, will henceforth be described in detail.

The output from the second embodiment of two colour image sensor 15' comprises interleaved segments or pulses corresponding to two different primary colours. This differs from the first embodiment where the interleaved segments or pulses corresponded to pulses representing two primary colours and pulses corresponding to one of those two primary colours. In the second embodiment, the two different primary colours are produced using a striped dichromatic optical filter 16 which alternating passes only red light in one of the set of stripes and only blue light from the interleaved stripes.

The output from the two colour image sensor 15' is applied in the second embodiment to an analog switch 30 which is operated in time relation to the clock signal which is indicative of the colour of light produced by the segment or pulse of the output signal from two colour image sensor 15'. Analog switch 30 has two outputs, one of the output corresponding to the Y colour at times n , $n+2$, $n+4$, and so forth with another output corresponding to the Z colour at times $n+1$, $n+3$, $n+5$, and so forth. The Y colour output and the Z colour output from analog switch 30 are passed through sample and hold circuits 37 which (1) capture that part of each CCD output pulse which contains amplitude information and rejects those parts which do not contain amplitude information and (2) holds the pulse over two segment times, similarly as was done in the first embodiment, such that the Y_n signal appears at segment times n and $n+1$, the Y_{n+2} signal appears at segment times $n+2$ and $n+3$ and so forth; the X_{n+1} signal appears at segment times $n+1$ and $n+2$, and so forth. The output from image sensor 14 is passed through a sample and hold circuit 33 as was done in the first embodiment. The X, Y and Z outputs from the three sample and hold circuits are then passed through their respective low pass filters 35 and 36 to produce three colour information signals X, Y and Z.

The decoder circuit disclosed as the first embodiment, allows stripe filter 16 to have alternating color and clear stripes thus requiring but one filter medium, e.g., opaque to blue light, in the filter design. In the second embodiment, on the other hand, the striped filter 16 must have alternative stripes of filter medium. Thus the first embodiment of the invention permits the use of a simpler, single medium striped filter having alternating clear and colour stripes.

As can be seen from Figure 7, the pulses entering X channel low pass filter 35 occurs

at approximately twice the frequency as the Y and Z pulses entering Y and Z low pass filters 36. For the aforementioned reasons regarding the sensitivity of the human eye, we prefer to practice the second embodiment of our invention with the X channel corresponding to green (or white light) and the Y and Z channels corresponding to red and blue.

While we prefer to practice our first and second embodiments of our invention with the X channel corresponding to the green colour signal, it should be evident to one trained in the art, however, that other colour schemes may be used with the present processing systems. For instance, instead of using primary colours red, blue and green, their opposites may be used, namely cyan, magenta and yellow or the X channel may correspond to the luminance information, as aforementioned.

Further, while the direction of scanning the image sensor has preferably been shown at right angles to the direction of stripes and the stripe filter 16, the stripes may be disposed essentially parallel to the direction of scanning the image sensor 15. As is shown in Figures 2 and 8a, the scan line (labelled scan 1 - scan 5 in Figure 8a) are disposed at right angles to striped filter 16, which alternately passes red and red plus blue light in the preferred first embodiment or alternately passes red and blue light in the second embodiment. Of course, other colours may be used in filter 16 as aforementioned. The direction of stripes may be nonperpendicular to the direction of scanning, for instance, parallel thereto, as shown in Figure 8b. In this alternative embodiment, an entire scan line of video information is stored for comparison with an adjacent line.

Having described the invention in connection with certain specific embodiments thereof it is to be understood that further modification may now suggest itself to those skilled in the art.

For instance, optical resolution reducing filters may be disposed between the object and image sensor 15 for the purpose of reducing optically produced moiré patterns. Also, because it is difficult to fabricate a single filter having exactly the transmissivity or reflectivity desired, trimming filters may be used therewith to more closely attain the desired transmissivity or reflectivity. It is to be understood that the invention is not limited to the specific embodiments disclosed.

WHAT WE CLAIM IS:-

1. A method of producing three video signals which together are representative of a colour image of light received from an object, the method including the steps of passing the light through beam splitting



means to produce an image on a first CCD image sensor and to produce an image on a second CCD image sensor,

the beam splitting means having a uniform effect across the field on the light of the image on the first CCD image sensor and being such that a first primary colour is filtered out of first parts but not out of second parts of the image on the second CCD image sensor,

deriving from the first CCD image sensor a first output signal representative of the image on the first CCD image sensor and deriving from the second CCD image sensor a second output signal representative of the image on the second CCD image sensor, and

processing said first output signal and said second output signal to produce the three video signals.

2. A method according to claim 1 wherein the beam splitting means is such that the image on the second CCD consists of light of a second primary colour in the first parts and of light of the second and first primary colours in the second parts and is such that the second output signal includes pulses representative of the intensity of the light of the second primary colour in the first parts of the image interleaved with pulses representative of the aggregate of the first primary colour and the second primary colour of the light of the image in the second parts of the image.

3. A method according to claim 1 or 2, wherein said first video signal is formed by processing the first output signal and the second and third video signals are formed by processing the second output signal and each video signal includes a series of pulses, the pulses of said first video signal occurring at essentially twice the frequency of the occurrence of pulses of both the second and third video signals.

4. A method according to claim 3, wherein the step of processing the second output signal includes the step of delaying said second output signal for the duration of a pulse of the first video signal.

5. A method according to claim 3, wherein the step of processing said second output signal includes the step of: subtracting the pulses representative of the intensity of the light of said second primary colour from the pulses representative of the aggregate of the intensities of the light of said second and first primary colours, thereby obtaining pulses representative of the intensity of the light of said first primary colour.

6. A method according to claim 5, wherein said step of processing the second output signal includes the steps of sampling and holding said pulses representative of the intensity of the light of said second primary colour and said pulses representative of the

light of first primary colour, for the duration of two of the pulses of the first video signal.

7. A method according to claim 5, further including the steps of passing each of said first, second and third video signals through a respective low pass filter.

8. A method according to any preceding claim wherein said first beam includes the light of a third primary colour essentially alone.

9. A method according to claim 1, wherein the step of decoding said second output signal is accomplished by subtracting portions of said second output signal representative of the intensity of light of said second primary colour from adjacent portions of said second output signal representative of the aggregate of the intensities of the light of said second and first primary colours to produce said third video signal; and wherein said portions representative of the intensity of the light of said second primary colour from said second video signal.

10. A method according to claim 1, wherein the beam splitting means is such that the image of the second CCD sensor in the first parts comprises light of a second primary colour and in the second parts comprises light of a first primary colour.

11. A method according to claim 10, wherein said second output signal includes a series of pulses, the pulses representative of the intensity of the light of said second primary colour being interleaved with pulses representative of the intensity of the light of said first primary colour.

12. A method according to claim 10 or 11, wherein the three video signals each include a series of pulses, the pulses of said first video signal occurring at essentially twice the frequency of the pulses of both the second and third video signals.

13. A method according to claim 11, wherein the step of processing said second output signal is accomplished by separating the pulses representative of the intensity of the light of said second primary colour from the pulses representative of the intensity of the light of said first primary colour.

14. A method according to claim 13, wherein the step of processing said second output signal further includes the step of sampling and holding said pulses representative of the intensity of the light of said second primary colour and said pulses representative of the light of said first primary colour each for the duration of two of said pulses of the first video signal.

15. A method according to claim 13, further including the step of passing each of the three video signals through a respective low pass filter.

16. A method according to any of claims 10 to 15, wherein said first and second parts



alternate across the field of the image on the second CCD sensor and are produced by the use of a striped optical filter.

17. A method according to claim 16, wherein said striped optical filter has essentially constant width stripes, some of said stripes being of material opaque to the light of said second primary colour and others of said stripes being of material opaque to the light of said first primary colour.

18. A method according to claim 16, wherein said second primary colour is red, wherein said first primary colour is blue and wherein the image on the first CCD image sensor consists substantially of green primary coloured light.

19. A method according to claim 8 further including the step of selectively combining the three video signals to produce a luminance signal.

20. A method according to claim 1, wherein said image on the first CCD image sensor consists substantially of green coloured light and wherein said image on the second CCD image sensor consists substantially of red plus blue coloured light.

21. A method according to claim 20, wherein said second primary colour is red and said first primary colour is blue.

22. A method according to claim 20, wherein said second primary colour is blue and said first primary colour is red.

23. A method according to any preceding claim wherein the light splitting means includes a partially reflective mirror.

24. A method according to claim 1, wherein said light splitting means includes a striped optical filter to filter out the first primary colour from the first parts of the image on the second CCD image sensor.

25. A method according to claim 24, wherein said striped optical filter has essentially constant width stripes, some of said stripes being of a material opaque to light of at least one primary colour.

26. A method according to claim 25, wherein said one primary colour is blue.

27. A colour imaging system which in use produces three video signals which together are representative of a colour image of light received from an object, the system including

(a) a first CCD image sensor and a second CCD image sensor,

(b) beam splitting means for receiving light from an object and producing a first image on the first CCD image sensor and producing a second image on the second CCD image sensor, the means having a uniform effect across the field on the light of the first image and being such that a first primary colour is filtered out of first parts of the second image,

(c) processing means for deriving a first output signal from the first CCD image

sensor and a second output signal from the second CCD image sensor and producing from the first and second output signals the three video signals.

28. An imaging system according to claim 27 wherein said beam splitting means includes a partially reflective mirror.

29. An imaging system according to claim 27 or 28, wherein said beam splitting means includes a striped optical filter to filter out the first primary colour from the first parts of the image on the second CCD image sensor.

30. An imaging system according to claim 28, wherein said striped optical filter has essentially constant width stripes, some of said stripes being of material opaque to light of least one primary colour.

31. An imaging system according to any one of claims 27 to 30 wherein

(a) the processing means produces a first video signal from the first output signal and produces a second video signal and a third video signal from the second output signal,

(b) the beam splitting means is such that the light of the second image in second parts thereof comprises light of a second and the first primary colour,

(c) the processing means includes analogue switch and subtracting means for separating the component of the second output signal which represents the light in the first parts of the second image from the light in the second parts of the second image and producing a difference signal therefrom representing the light of the first primary colour in the second image, and producing from the difference signal the second video signal and producing the third video signal from the component of the second output signal which represents the light in the first parts of the second image.

32. An imaging system according to claim 31, wherein said first, second and third video signals each consist of a series of electrical pulses.

33. An imaging system according to claim 32, wherein the pulses of said first video signal occur at essentially twice the frequency of the pulses of both the second and the third video signals.

34. An imaging system of claim 33 further including a delay circuit means for delaying said first video signal and the component of the second output signal representing the light in the first parts and the second image for the duration of a pulse of the first video signal.

35. An imaging system according to claim 31, 32, 33 or 34 wherein the processing means includes sample and hold means for processing the first and second output signals.

36. A method according to claim 1, and substantially as herein described with refer-

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ence to the accompanying drawings with or without the modification described with reference to Figure 7 of the accompanying drawings.

- 5 37. An imaging system according to claim 27 and substantially as herein described with reference to the accompanying drawings with or without the modification described with reference to Figure 7 of the
- 10 accompanying drawings.

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ABEL & IMRAY,
Chartered Patent Agents,
Northumberland House,
303-306 High Holborn,
London, WC1V 7LH.

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