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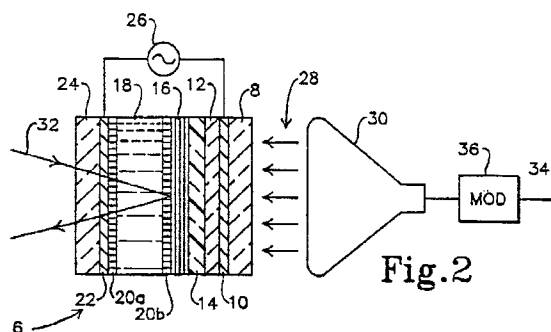
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(54) **Method and system for improving electro-optic response rate of liquid crystal light valves.**

(57) A fast response liquid crystal light valve (LCLV) system comprises an LCLV (6) that includes a liquid crystal layer (18) and responds to changes in an input video signal (28) by modifying the optical properties of said liquid crystal layer (18), the video signal comprising a series of successive video frames. Further provided are means (36) for modifying said video signal by imposing thereon a compensating signal that, in response to a change in the gray scale level of said video signal for two successive frames, provides an additional drive to force a faster response by the liquid crystal layer (18) than its response to the drive provided by the unmodified video signal, and means for applying said modified video signal to provide a modulating input to said LCLV (6).

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BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to liquid crystal light valves (LCLVs), and more particularly to a method and associated system for increasing the rate at which the liquid crystal responds to an electrical input signal.

Description of the Related Art

Light valves which employ liquid crystals as an electro-optic medium are used to spatially modulate an optical readout beam, under the control of an input drive signal pattern. They can be used to greatly amplify the input pattern by controlling a readout beam of much greater intensity, to convert spatially modulated incoherent radiation to a coherent readout laser beam with a similar spatial modulation, for optical data processing, wavelength conversion, or for other purposes that involve the conversion of an input signal pattern to a corresponding spatial modulation of a separate readout beam.

An earlier type of LCLV used a cadmium sulfide (CdS) photoconductor medium. This type of device is described, for example, in Grinberg et al., "A New Real-Time Non-Coherent to Coherent Light Image Inverter - The Hybrid Field Effect Liquid Crystal Light Valve", *Optical Engineering*, 14, 217 (1975).

A principal limitation of the CdS-based light valve is its slow response time, yielding image-after effects. A second generation silicon-photoconductor-based LCLV was next developed which retained the advantages of the CdS-based light valve, but had a considerably faster response time. The silicon-based device is described in an article by Efron et al., "The Silicon-Liquid Crystal Light Valve", *Journal of Applied Physics*, 57(4), pages 1356-68 (1985). This article also summarizes some of the prior light valve efforts.

While improving the response time of the photoconductor, the silicon-based LCLV still exhibits a slower than desirable speed of operation due to the finite time required for the liquid crystals to respond to changes in the applied voltage across the liquid crystal layer. The liquid crystal electro-optic response time increases approximately with the square of the thickness of the liquid crystal cell resident in the light valve, and becomes particularly noticeable when the cell thickness exceeds 4 microns. However, there are separate considerations that favor the use of thicker liquid crystal layers, despite their slower electro-optic response. One is that the light throughput decreases dramatically when the liquid crystal cell thickness is reduced below 4 microns. Also, the switching ratio

(effective voltage) required to drive a liquid crystal cell the device is switched between two intermediate (gray scale) transmission levels. The fastest response times generally occur when the LCLV is driven to fully on or to fully off from any other transmission level. The response times for switching between all possible gray scale levels are important in order to achieve high quality video-rate performance; changes in light throughput levels should occur in not more than two frames at 60Hz operation, or the video will appear fuzzy. While this switching speed can normally be achieved with a liquid crystal cell thickness of less than 4 microns, a poor video image will result for the majority of switching situations for this liquid crystal at thicknesses greater than 4 microns because the liquid crystal response will most often require more than two frames. Thus, a tradeoff has been required in the past between the high quality video imaging associated with a fast liquid crystal response time, and the increased light throughput and low switching ratio associated with thicker liquid crystal layers that also exhibit slower response times.

SUMMARY OF THE INVENTION

The present invention seeks to provide a method and associated LCLV system that significantly increases the response rate of the liquid crystal layer to changes in a gray scale video input for liquid crystal layers thicker than 4 microns, and yet preserves their desirable light throughput and switching ratio characteristics.

These goals are achieved by modifying the drive signal for an LCLV to impose an electronic compensating signal during the initial portion of each transition between different gray scale levels. The compensating signals force the LCLV to a more rapid response to gray scale level shifts than would be the case with the unmodified drive signal.

In a preferred embodiment, in which the LCLV drive signal is a video signal that represents a plurality of sequential video frames, the compensating signal is imposed for only the first frame following a transition between different video levels. The compensating signal is selected as a function of the video signal's absolute magnitude. It can also be selected by delaying each frame of the video signal, determining the difference if any between the video signals for the current frame and for the previous frame, and selecting the compensating signal as a function of this difference as well as of the absolute signal value. The desired compensating signals for different frame-to-frame video signal differentials are stored in a lookup table, from which they are retrieved when the absolute video signal values and/or the differential between successive frames has been determined.

The drive signal is normally provided as a pixelized signal that actuates respective regions of the unpixelized LCLV, and is modified by the electronic compensating signals on a pixel-by-pixel basis. The compensating signals preferably boost the drive signal substantially to its maximum level for transitions from a lower to a higher drive level, and lower the drive signal substantially to its minimum level for transitions from a higher to a lower level drive. The invention is applicable to photoactivated LCLVs by using the modified drive signal to modulate an optical input to the LCLV; to active matrix LCLVs by applying the drive signal directly to the active matrix and also to other types of LCLVs. It is particularly useful for liquid crystal layers with a thickness in excess of 4 microns, or with slow liquid crystal materials, and when a constant bias voltage must be applied to the entire liquid crystal layer.

Further features and advantages of the invention will be apparent to those skilled in the art from the following detailed description, taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph, described above, that relates light throughput and switching ratio to the thickness of a liquid crystal cell;

FIGs. 2 and 3 are diagrams, not to scale, respectively of a photoactivated LCLV and an active matrix LCLV operated in accordance with the invention;

FIG. 4 is a block diagram of a circuit that can be used to generate the compensating signals used to modify the liquid crystal drive signal;

FIG. 5 is a hypothetical video signal trace illustrating the principles of the invention;

FIGs. 6a and 6b are oscilloscope traces showing applied drive voltages to a liquid crystal cell and the cell's response in the absence of the compensating signals used by the invention, for both increases and reductions in the drive signal level;

FIGs. 7a and 7b are graphs similar to FIGs. 6a and 6b of a liquid crystals cell's response to changing drive signals, but with the addition of the invention's drive signal modification; and

FIG. 8 is a diagram that illustrates the reduction in video frames required for a liquid crystal cell to respond to a change in gray scale drive level achieved with the invention.

DETAILED DESCRIPTION OF THE INVENTION

A diagram of the invention as applied to a photoactivated LCLV 6 is given in FIG. 2. A somewhat simplified form of a conventional LCLV is

shown, but the invention is applicable to numerous variations on the basic LCLV structure, so long as it functions to improve the liquid crystal response rate as described herein. The LCLV 6 includes a transparent input substrate 8, generally glass, upon which is formed a transparent back electrode layer 10 such as indium tin oxide (ITO) or P+ + semiconductor, and a layer of photoconductor material 12 such as silicon and cadmium sulfide. A light blocking layer 14, such as SiO₂ or CdTe, prevents light entering the readout side of the device from entering the photoconductor, while a dielectric or metal matrix mirror 16 on the readout side of the light blocking layer 14 reflects a readout beam. A liquid crystal layer 18 is sandwiched between alignment layers 20a and 20b on the readout side of the mirror, with a counter-electrode layer 22 and a front transparent substrate 24 formed in turn on the readout side of the liquid crystal cell.

An AC voltage source 26 is connected across the back electrode 10 and counter-electrode 22 to establish a bias that sets an operating point for the liquid crystal. In operation, an input image 28 from an optical source such as cathode ray tube (CRT) 30, a scanning laser or the like is applied to the input side of the LCLV, while a linearly polarized readout beam 32 is transmitted through the liquid crystal cell 18 and reflected back from the mirror 16 through a cross polarizer (not shown). The input image 28 produces a corresponding spatial voltage distribution across the liquid crystal cell, altering the localized alignment of the liquid crystals in accordance with the applied voltage pattern. This results in a spatial modulation of the readout beam 32, permitting a transfer of information from the input image 28 to the readout beam.

The CRT 30 or other optical device provides the input image 28 on a pixelized basis. The LCLV input surface may be considered to be divided into a corresponding pixel array, typically on the order of 500×500 or 1,000×1,000 pixels, or more. Each separate LCLV pixel is provided with an individual illumination from the CRT 30, which may be the same as or different from the illumination of adjacent pixels, and may change at a different rate from adjacent pixels. The resistance of each pixel in the photoconductor layer 12 varies negatively with its degree of illumination by the CRT, such that voltage is shifted from the photoconductor layer 12 to the liquid crystal cell 18 at each pixel in response to an increase in illumination. The additional voltage across the LCLV increases the light throughput for that pixel, and thereby increases the intensity of the processed readout beam 32 for the same pixel.

The CRT 30 is typically driven by a video signal at a 60 frame per second rate, with each successive pair of frames corresponding to the

image at a particular time. In accordance with the invention, the video signal presented at a video input terminal 34 is modified to alter the output image 28 from the CRT so as to force a faster response from the liquid crystal in the light valve. For this purpose a modification circuit 36 is provided that receives its input from the video terminal 34, modifies it to enhance the liquid crystal response time, and provides the modified video signal as a drive for the LCLV 6 via the CRT 30.

The invention is also applicable to other types of LCLVs, such as the active matrix device 38 illustrated in FIG. 3. The active matrix LCLV has several elements in common with the photoactivated LCLV of FIG. 2, and these are indicated by the same reference numerals. However, the back electrode, photoconductor layer and light blocking layer of the photoactivated device are replaced by a conductive grid 40 that divides the back face of the LCLV 38 into a pixel matrix with an activation transistor for each pixel. A video signal is applied directly to the grid 40 over a bus 42 that includes either a separate input line for each pixel, or more preferably input lines for each row and column in the matrix; with the latter arrangement the application of signals to the row and column lines is coordinated with the activation of the pixels in a known manner to produce a scanning of the video signal across the LCLV. A drive signal modification circuit 36' is also used to modify the video drive signal for the active matrix device. The drive for other types of LCLVs, such as transmission-mode photoactivated and active matrix devices, CCD (charge coupled device) and electron-beam driven devices, can be similarly modified to improve their liquid crystal response times.

The invention operates by imposing a compensating signal onto the initial portion of a new video signal level, following a switch in gray scale levels. The compensating signal is provided on a pixel-by-pixel basis, with each pixel treated independent of the others. In most video applications the video level for a particular pixel will be held substantially constant for at least several video frames. It has been found that a significant increase in the liquid crystal response rate, sufficient to achieve a full response within the desired two frames in most cases, can be achieved by applying the compensating signal for only the first frame following a transition in gray scale video levels. However, the invention is not limited to a single frame compensating signal, and may if desired be implemented with an compensating signal that extends for more than a single frame.

The compensating signal is preferably equal to the maximum, fully on signal level for gray scale increases in the video input, and equal to the fully off, minimum signal level for reductions in the gray

scale video input. While such compensating signal levels can be conveniently realized, the invention is not limited to any particular compensating signal magnitude, and if desired different modified video signal levels could be used for different magnitudes of gray scale transitions by appropriate programming of the lookup table (52). In addition, although the liquid crystal response to a transition between a fully on or fully off level and a gray scale level is normally faster than the transition between two gray scale levels (even if the gray scale-to-gray scale differential is smaller), the invention could also be applied if desired to transitions between gray scale and fully on or fully off levels.

FIG. 4 is a block diagram that illustrates one embodiment of a modification circuit that can be used to modify the input video signal at terminal 34 as called for by the invention. Numerous alternate circuits could be designed to provide electronic compensating functions; that illustrated in FIG. 4 can be implemented on the DIGIMAX® image processing system supplied by Datacube Corporation.

The video input at terminal 34 is in analog format, and is converted to a digital signal by analog-to-digital converter 44; an eight-bit conversion will generally be sufficient. Each video frame is stored for one frame interval in a frame delay store 46. When the next video frame arrives it is subtracted from the first frame held in store 46 by a frame subtract element 48 on a pixel-by-pixel basis; at the same time the second frame is loaded into a second frame delay store 50 to set up the subsequent cycle. The output of the frame subtract element 48 is fed to a lookup table 52, which outputs a desired modification for the video signal. This output is a function of the polarity, and if desired also the size, of the pixel-by-pixel frame difference signal from the frame subtract element 48. The lookup table output signal is then added in a frame adder 54 on a pixel-by-pixel basis to the second frame signal held in the frame delay 50 to generate the desired compensating video signal that, after conversion back to analog format in a digital-to-analog converter 56, is applied to the CRT 30 (for a photoactivated LCLV), or directly to the LCLV 38 (for an active matrix device). This analog signal provides the extra drive that is used to significantly reduce the fall and rise times of the liquid crystals.

The lookup table 52 may store modification signals based upon the pixel-by-pixel differences between successive frames, the absolute value of the second frame pixels, or both. For this purpose the second frame signal can also be fed via line 58 to the lookup table, which is then programmed to accept both inputs and to generate the optimum compensation signal. For example, assume that the

system is programmed to generate a compensating signal equal to 100% of the fully on level for frame-to-frame increase in the gray scale level, and a fully off 0% signal for frame-to-frame reduction in the gray scale level. In this case the table will obtain the polarity of the gray scale change from the frame subtract element 48, and the absolute value of the second frame from line 58. The modification signal to be added to the delayed second frame is then selected from the lookup table as that signal value necessary to boost the second frame level to 100% (for an increase in gray scale level), or to reduce it to 0% (for a reduction in gray scale level). If there is a concern that such a compensating will be too large in the case of a relatively small gray scale differential, smaller modifications may be programmed into the lookup table for such cases. If such an approach is taken, the compensating value will also generally be a function of the difference between the second frame level and either 100% (for a gray scale increase) or 0% (for a gray scale reduction).

Several gray scale transitions and possible compensating signals that can be generated for each are illustrated in FIG. 5. Assume that the video signal is initially at a 40% gray scale level (line 60), and that it increases during a subsequent frame to 70% (line 62). For the first frame (or additional frames if desired) following the transition, a compensating signal 64 at a 100% video level is applied. After the compensating signal has terminated, the particular pixel being observed reverts to the 70% level until the next change in video level, which is illustrated as a drop to the 50% level (line 66). The liquid crystal response to this reduction in the gray scale level is hastened by applying a new compensating signal 68 down to the 0% level during the next succeeding frame. The video signal is then assumed to remain at 50% for several frames, after which it increases to the 60% level (line 70). If it is believed that a 100% compensating signal will produce an overshoot in the liquid crystal response to greater than 60%, a somewhat less than fully on compensating signal 72 can be employed for this case.

The video signal is next shown as dropping down to 20% (line 74), with another 0% signal 76 during the first frame at this level. Finally, another 10% reduction down to the 10% level (line 78) is illustrated. Although this reduction equates to the same absolute magnitude of gray scale differential as the prior transition from 50% to 60%, for which a reduced compensating signal 72 was assumed to be employed, the new gray scale level of 10% is close enough to the 0% level that a full 0% signal 80 can still be employed.

The results obtained with a 5.3 micron test cell that employed a negative dielectric anisotropy, low

viscosity liquid crystal, for an increase in the normalized average light throughout from 25% to 75% and then back down to 25% without the input signal modification of the invention, are illustrated in FIGs. 6a and 6b; corresponding results obtained with the addition of the compensating signal are illustrated in FIGs. 7a and 7b. In each case the test cell was addressed with pulses at a 60Hz repetition rate. The unmodified drive pulses are shown in FIG. 6a, while the resulting light throughput that corresponds to the liquid crystal response is shown in FIG. 6b. 5.89 RMS peak voltage pulses 82 were initially applied to produce the 25% light throughput, and then increased to a 7.245 RMS peak voltage level 84. The liquid crystal response along curve 86 required 7 frames, or about 117ms, to complete--this would produce a poor gray scale quality. When the operation was reversed, with the voltage peaks reduced from the 75% level 84 back to the 25% level 82, another significantly long response time along curve 88 was required for the liquid crystal to react.

In FIG. 7a the voltage was again increased from the 25% to the 75% level, but a 100% compensating pulse 90 was inserted for the first frame following the transition. The result, shown in transmission curve 92, was a reduction in the liquid crystal response time from seven frames down to two frames. When the voltage was dropped back to the 25% level a 0% compensating pulse 94 (i.e., a skipped pulse) was inserted for the first frame following the transition, and the response time was again significantly improved as shown by the light transmission curve 96.

Liquid crystal cells with three different thicknesses were used to demonstrate the improvement in response time for thicknesses greater than 4 microns. The cells were formed between a pair of 1.25cm thick optical flats, with 600 Angstrom thick indium tin oxide electrodes, a liquid crystal alignment layer and SiO_x spacer pads used to maintain the cell gap thickness. Voltage waveforms were applied to the test cells to simulate the output of a photoactivated light valve. Cell thicknesses of 3.6, 4.4 and 5.3 microns were tested, with bias voltages of 3.45, 3.40 and 3.15 volts RMS respectively at 10kHz. The peak-to-bias voltage ratio for the 3.6 micron cell was 1.85 for 25% light throughput, 2.19 for 50%, 2.66 for 75% and 4.50 for 100%; with the 3.6 micron cell the peak-to-bias voltage ratio was 1.75 at 25% light throughput, 1.97 at 50%, 2.21 at 75% and 2.90 at 100%; for the 5.3 micron cell it was 1.87 for 25% light throughput, 2.09 for 50%, 2.30 for 75% and 2.75 for 100%. At the beginning of each 16.67ms frame the voltage rose rapidly to the peak level for the given throughput, and then decayed back to the bias level. The decay times ranged from 4.5ms for the 4.4 micron cell at 25%

light throughput, to 12ms for the 3.6 micron cell at 100%.

FIG. 8 compares the gray scale response times for the three cell thicknesses, in terms of the number of voltage level transitions that resulted in a full liquid crystal response in not more than two frames, with and without the compensating signal. Little improvement was gained by the compensating signal for the 3.6 micron cell, which was already quite fast. However, the response times of the 4.4 and 5.3 micron cells were improved by a factor of about 3. Whereas two or fewer pulses were required to complete the liquid crystal response in only about 25% of the voltage transitions without the compensating signals, 75% or more of the responses were completed in two pulses or less when the compensating signals were added. In each case the voltage transitions were between the various combinations of 0%, 25%, 50%, 75% and 100% light throughput.

The invention has thus been shown to produce a significant improvement in the liquid crystal response time, with an accompanying enhancement of the gray scale video quality. While several illustrative embodiments of the invention have been shown and described, numerous variations and alternate embodiments will occur to those skilled in the art. Such variations and alternate embodiments are contemplated, and can be made without departing from the spirit and scope of the invention as defined in the appended claims.

Claims

1. A method of increasing the response rate of a liquid crystal light valve (LCLV), (6; 38) comprising the steps:
 - providing a drive signal for said LCLV (6; 38) with a magnitude that varies over time between different successive levels (60, 62, 66, 70, 74, 78; 82, 84),
 - modifying said drive signal (60, 62, 66, 70, 74, 78; 82, 84) by imposing thereon compensating signals (64, 68, 72, 76, 80; 90, 94) for the initial portions of transitions between different drive signal levels (60, 62, 66, 70, 74, 78; 82, 84), said compensating signals (64, 68, 72, 76, 80; 90, 94) driving said LCLV (6; 38) to a more rapid response to drive signal level shifts that the LCLV (6; 38) would exhibit without said compensating signals (64, 68, 72, 76, 80; 90, 94), and
 - applying said modified signal to provide a modulating input to said LCLV (6; 38).
2. The method of claim 1, characterized in that said drive signal (60, 62, 66, 70, 74, 78; 82, 84) comprises a video signal that represents plu-

ality of sequential video frames, and said compensating signal (64, 68, 72, 76, 80; 90, 94) is imposed on the first frame of said video signal on a pixel-by-pixel basis following a transition between different video signal levels.

3. The method of claim 2, characterized in that said compensating signal (64, 68, 72, 76, 80; 90, 94) is imposed for only the first frame of said video signal following a transition between different video signal levels.
4. The method of claim 2, characterized in that said compensating signal (64, 68, 72, 76, 80; 90, 94) is imposed only for transitions between different gray scale video signal levels.
5. The method of any of claims 2 - 4, characterized in that the compensating signal (64, 68, 72, 76, 80; 90, 94) for a particular video signal transition is determined by delaying (46, 50) the video signal, determining (48) the difference if any between the video signals for the current frame and for the previous frame, and selecting (52) the compensating signal (64, 68, 72, 76, 80; 90, 94) as a function of said difference.
6. The method of any of claims 2 - 6, characterized in that the compensating signal (64, 68, 72, 76, 80; 90, 94) is selected as a function of the video signal's absolute magnitude.
7. The method of any of claims 1 - 6, characterized in that compensating signals (64, 68, 72, 76, 80; 90, 94) corresponding to different drive signal transitions (60, 62, 66, 70, 74, 78; 82, 84) are stored in a lookup table (52), and the compensating signal for a particular transition is selected from said lookup table (52).
8. The method of any of claims 1 - 7, characterized in that said drive signal (60, 62, 66, 70, 74, 78; 82, 84) is provided as a pixelized signal for actuating respective regions of said LCLV (6; 38), and is modified by imposing thereon said compensating signals (64, 68, 72, 76, 80; 90, 94) on a pixel-by-pixel basis.
9. The method of any of claims 1 - 8, characterized in that said drive signal (60, 62, 66, 70, 74, 78; 82, 84) has a maximum signal level, and said compensating signals (64, 68, 72, 76, 80; 90, 94) boost the drive signal (60, 62, 66, 70, 74, 78; 82, 84) substantially to said maximum level for transitions from a lower to a higher drive signal level.

10. The method of any of claims 1 - 9, characterized in that said drive signal (60, 62, 66, 70, 74, 78; 82, 84) has a minimum signal level, and said compensating signals (64, 68, 72, 76, 80; 90, 94) lower the drive signal substantially to said minimum level for transitions from a higher to a lower drive signal level.
11. The method of any of claims 1 - 10, characterized in that said LCLV (6; 38) is photoactivated, and said modified drive signal is applied to modulate an optical input to said LCLV (6; 38).
12. The method of any of claims 1 - 10, characterized in that said LCLV (6; 38) includes an active pixel matrix (40) for modulating said LCLV (6; 38) in response to an electrical modulating signal applied to said active matrix, and said modified drive signal is applied to modulate said active matrix.
13. A method of increasing the gray scale response rate of a liquid crystal layer (18) to an input video signal (60, 62, 66, 70, 74, 78; 82, 84), the video signal (60, 62, 66, 70, 74, 78; 82, 84) representing a series of successive video frames, comprising:
 modifying said video signal (60, 62, 66, 70, 74, 78; 82, 84) by imposing thereon a compensating signal (64, 68, 72, 76, 80; 90, 94) during a new frame that has a new gray scale video signal level different from the gray scale video signal of the immediately preceding frame, said compensating signal (64, 68, 72, 76, 80; 90, 94) providing a harder drive urging the liquid crystal layer (18) to conform to the new video signal level faster than the drive provided by the video signal (60, 62, 66, 70, 74, 78; 82, 84) without said compensating signal, and
 applying said modified video signal to provide a modulating input to said liquid crystal layer (18).
14. The method of claim 13, characterized in that said compensating signal (64, 68, 72, 76, 80; 90, 94) is imposed for only the first frame after a change in the gray scale level of said video signal (60, 62, 66, 70, 74, 78; 82, 84).
15. The method of claim 13 or claim 14, characterized in that said compensating signal (64, 68, 72, 76, 80; 90, 94) is selected by delaying (46, 50) each frame of the video signal, (60, 62, 66, 70, 74, 78; 82, 84) determining (48) the difference if any between the video signal for the delayed frame and the immediately following frame, and selecting (52) the compensating signal (64, 68, 72, 76, 80; 90, 94) for said immediately following frame as a function of said difference.
16. The method of any of claims 13 - 15, characterized in that the compensating signal (64, 68, 72, 76, 80; 90, 94) is selected as a function of the absolute magnitude of the video signal.
17. The method of any of claims 13 - 16, characterized in that said video signal (60, 62, 66, 70, 74, 78; 82, 84) has maximum and minimum signal levels, and said compensating signals (64, 68, 72, 76, 80; 90, 94) boost and lower the video signal (60, 62, 66, 70, 74, 78; 82, 84) substantially to said maximum and minimum levels for frame-to-frame increases and reductions in the video signal level, respectively.
18. A fast response liquid crystal light valve (LCLV) system, comprising:
 an LCLV (6; 38) that includes a liquid crystal layer (18) and responds to changes in an input video signal (60, 62, 66, 70, 74, 78; 82, 84) by modifying the optical properties of said liquid crystal layer (18), the video signal (60, 62, 66, 70, 74, 78; 82, 84) comprising a series of successive video frames,
 means (36, 36') for modifying said video signal (60, 62, 66, 70, 74, 78; 82, 84) by imposing thereon a compensating signal (64, 68, 72, 76, 80; 90, 94) that, in response to a change in the gray scale level of said video signal (60, 62, 66, 70, 74, 78; 82, 84) for two successive frames, provides an additional drive to force a faster response by the liquid crystal layer (18) than its response to the drive provided by the unmodified video signal (60, 62, 66, 70, 74, 78; 82, 84), and
 means (56) for applying said modified video signal to provide a modulating input to said LCLV (6; 38).
19. The LCLV system of claim 18, characterized in that said video signal modifying means (36, 36') provides said additional drive only for the second of said successive frames and not for any succeeding frames until another change in the video signal's gray scale level occurs.
20. The LCLV system of claim 18 or claim 19, characterized in that said modifying means (36, 36') comprise means (46, 50) for delaying the frames of said video signal (60, 62, 66, 70, 74, 78; 82, 84), means (48) for comparing each delayed frame with the following frame to identify differences between the two frames, and means (52) for selecting said compensating

signal as a function of said difference.

- 21.** The LCLV system of any of claims 18 - 20, further characterized by means (52, 58) responsive to the absolute magnitude of the video signal (60, 62, 66, 70, 74, 78; 82, 84) for selecting said compensating signal (64, 68, 72, 76, 80; 90, 94). 5
- 22.** The LCLV system of claim 21, characterized by said compensating signal selecting means (52, 58) further comprising a lookup table (52) storing the compensating signal levels (64, 68, 72, 76, 80; 90, 94) that correspond to said video signal magnitudes. 10 15
- 23.** The LCLV system of any of claims 18 - 22, characterized by said modifying means (36, 36') further comprising means (54) for summing said compensating signal (64, 68, 72, 76, 80; 90, 94) with the video signal (60, 62, 66, 70, 74, 78; 82, 84) for the following frame. 20
- 24.** The LCLV system of any of claims 18 - 23, characterized in that said video signal (60, 62, 66, 70, 74, 78; 82, 84) comprises a pixelized signal for modifying the optical properties of respective pixels of said liquid crystal layer (18), and said modifying means (36, 36') imposes said compensating signal (64, 68, 72, 76, 80; 90, 94) on said video signal (60, 62, 66, 70, 74, 78; 82, 84) on a pixelized basis. 25 30
- 25.** The LCLV system of any of claims 18 - 24, characterized in that said LCLV includes a photoconductor layer (12) for modulating a voltage (26) across said liquid crystal layer (18) in response to an optical scanning signal (28), and said means (30, 36) for applying the modified video signal to modulate the LCLV includes an optical scanning means (30) that responds to said modified video signal by optically scanning said photoconductor layer (12). 35 40
- 26.** The LCLV system of any of claims 18 - 24, characterized in that said LCLV (6; 38) includes an active pixel matrix (40) for modulating a voltage across said liquid crystal layer (18), and said means (36') for applying the modified video signal to modulate the LCLV (38) comprises means for applying the modified video signal to said active matrix (40). 45 50
- 27.** The LCLV system of any of claims 18 - 26, characterized in that said liquid crystal layer (18) is at least about 4 microns thick. 55

- 28.** The LCLV system of any of claims 18 - 27, characterized in that said liquid crystal layer (18) is any thickness that is too thick to allow the liquid crystal material to fully modulate in less than one frame period when activated with standard, uncompensated drive signals (60, 62, 66, 70, 74, 78; 82, 84).

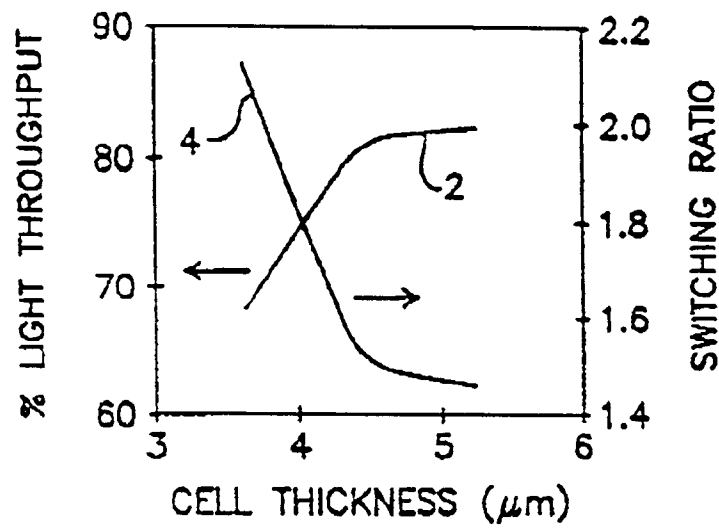


Fig.1

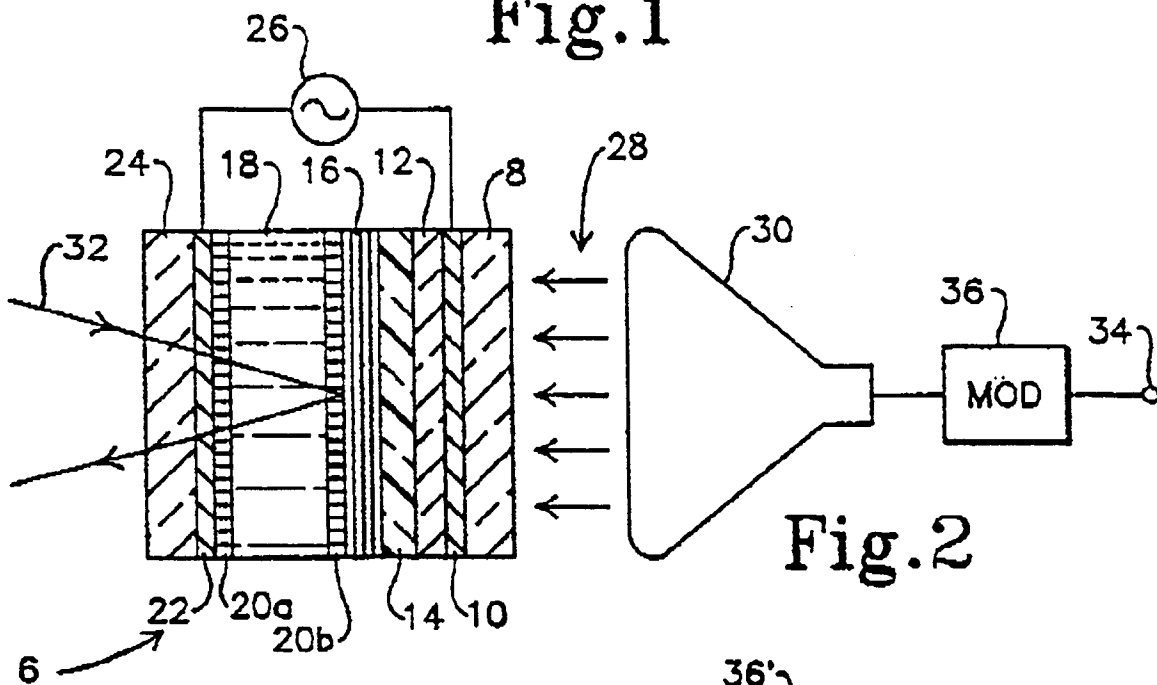


Fig.2

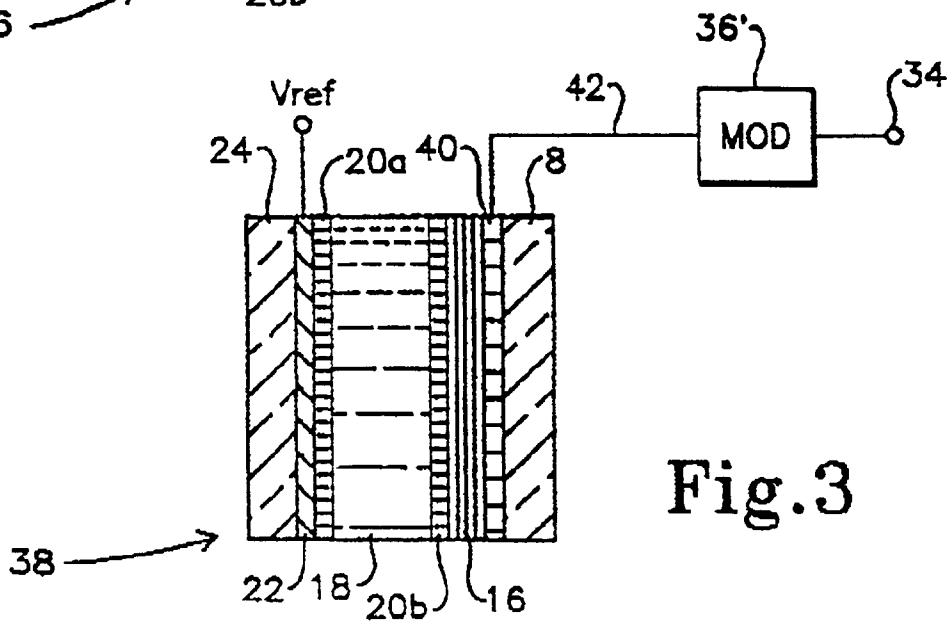


Fig.3

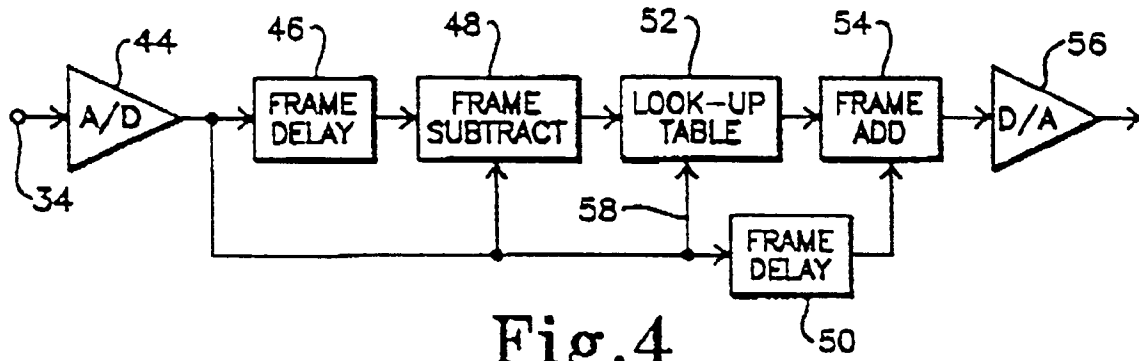


Fig.4

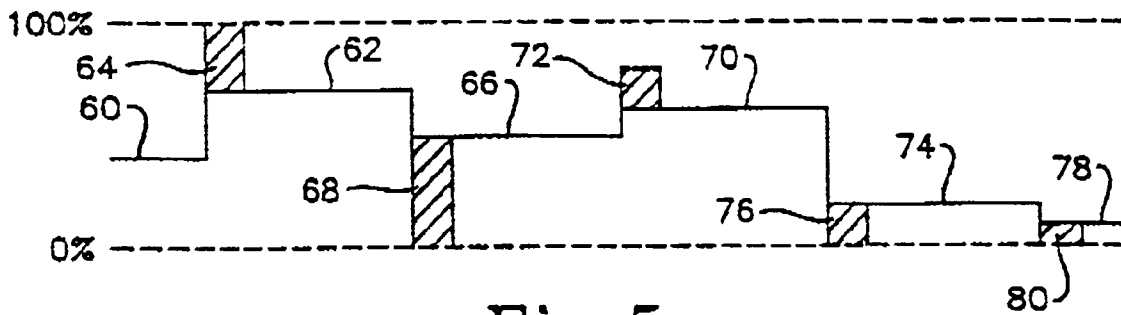


Fig.5

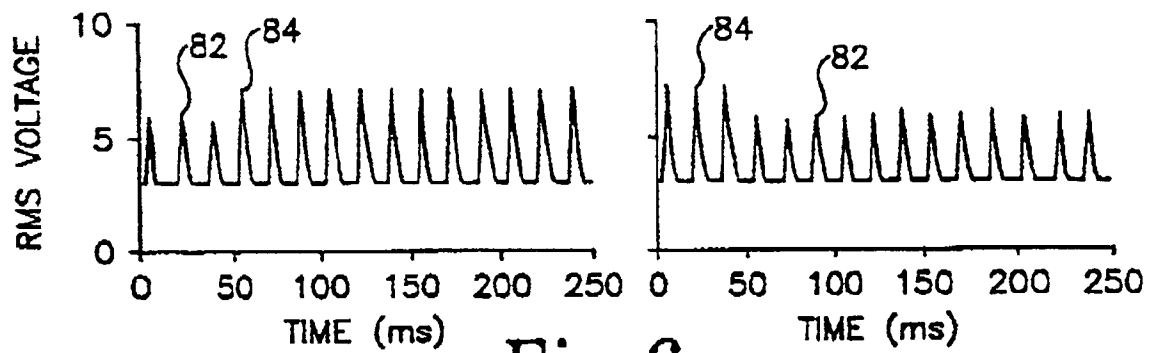


Fig.6a

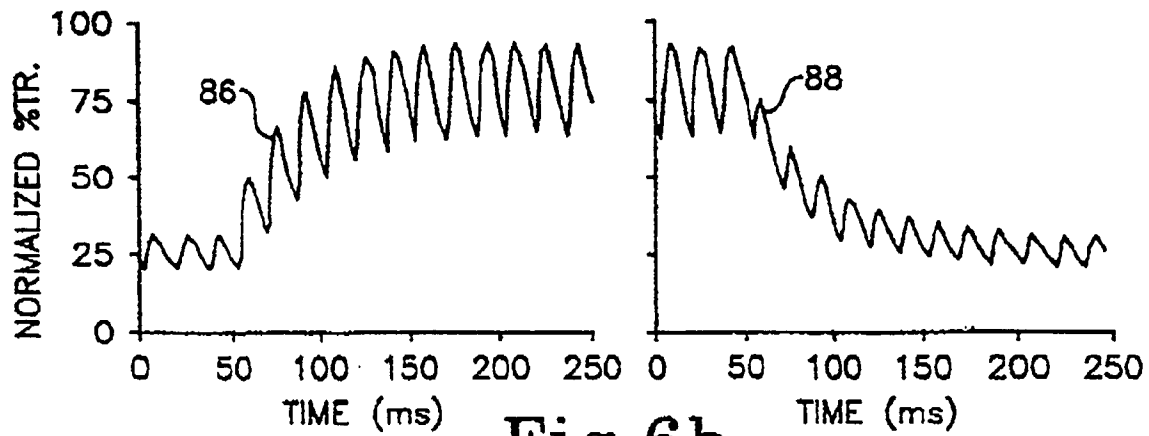
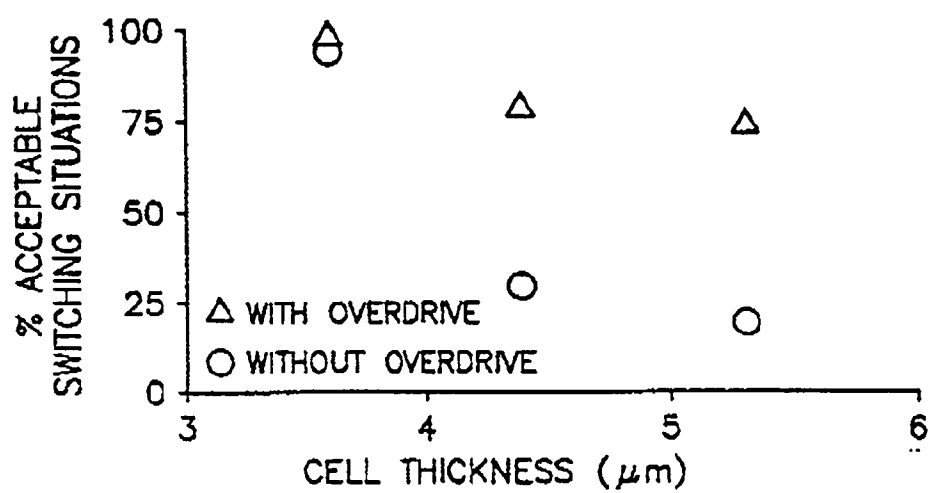
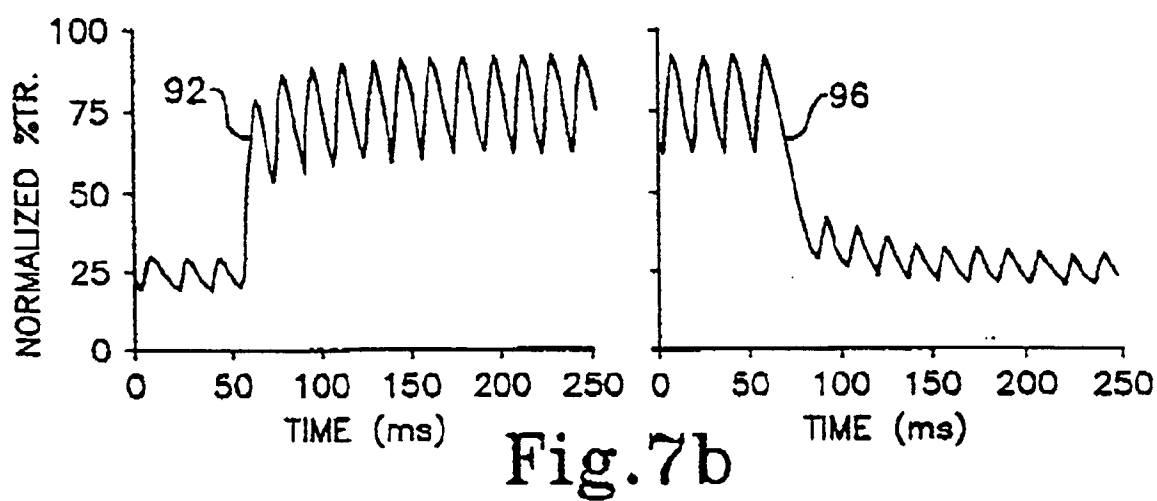
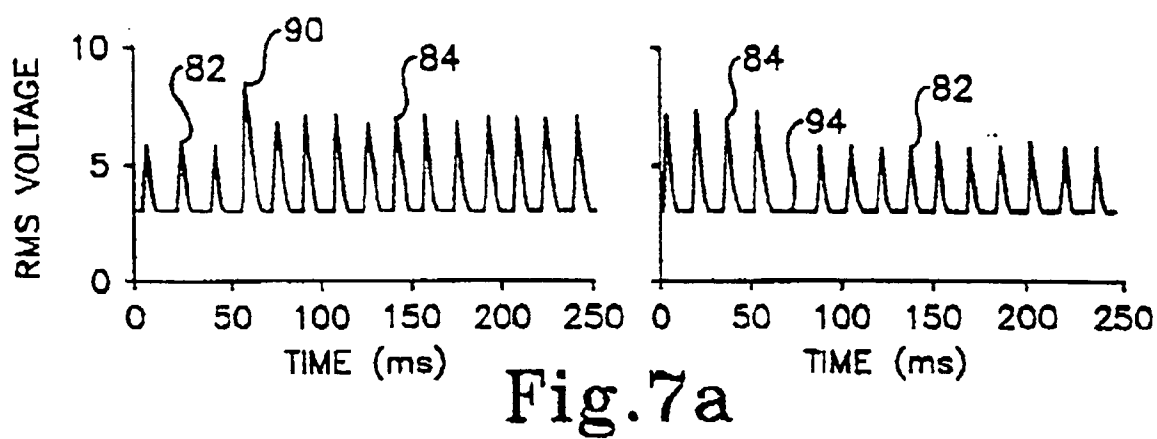


Fig.6b





European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 93 12 0725

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
P, A	PATENT ABSTRACTS OF JAPAN vol. 17, no. 448 (P-1594) 17 August 1993 & JP-A-05 100 208 (CANON INC.) 23 April 1993 * abstract *	1, 13, 18	G09G3/36 G09G3/02
A	EP-A-0 187 533 (SONY CO.)		
A	PROCEEDINGS OF THE SID. vol. 29, no. 4, 1988, LOS ANGELES US pages 275 - 277 J. TRIAS ET AL. 'A 1075-line video-rate laser-addressed liquid-crystal light-valve projection display.'		
A	CONFERENCE RECORDS OF 1982 INTERNATIONAL DISPLAY RESEARCH CONFERENCE 19 October 1982, NEW YORK, N.Y., U.S.A. pages 72 - 75 DUANE HAVEN 'Electron-beam addressed liquid-crystal light-valve.'		
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			G09G
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 15 April 1994	Examiner Farricella, L
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