**International Application Published Under the Patent Cooperation Treaty (PCT)**

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<th>(51) International Patent Classification</th>
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<td>G02B 27/22, H04N 13/04, 15/00</td>
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<th>(11) International Publication Number</th>
<th>WO 97/43681</th>
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<td>(43) International Publication Date</td>
<td>20 November 1997 (20.11.97)</td>
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<th>(21) International Application Number</th>
<th>PCT/US97/08028</th>
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<td>(22) International Filing Date</td>
<td>13 May 1997 (13.05.97)</td>
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<td>(30) Priority Data</td>
<td>08/648,215, 15 May 1996 (15.05.96)</td>
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<td>(72) Inventors; and</td>
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**Title:** STEREOSCOPIC 3-D VIEWING SYSTEM WITH PORTABLE ELECTRO-OPTICAL VIEWING GLASSES

**Abstract**

The present invention relates to a system (4, 5) and method of viewing pairs of perspective images of 3-D objects (i.e. stereoscopic image pairs) displayed from a CRT display surface in a time-multiplexed or field-sequential manner, and more particularly to a universal method of generating control signals for synchronously changing the optical state of liquid crystal (LC) shutter panels (1A, 1B) through which the time-multiplexed perspective images can be sequentially viewed in a substantially flicker-free manner by the left and right eyes of a human viewer, independent of whether the images are displayed in NTSC, PAL, VGA or SVGA styled CRT display devices.
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STEREOSCOPIC 3-D VIEWING SYSTEM WITH PORTABLE ELECTRO-OPTICAL VIEWING GLASSES

BACKGROUND OF THE INVENTION

Technical Field

The present invention relates to a system and method of viewing pairs of perspective images of 3-D objects (i.e. stereoscopic image pairs) displayed from a CRT display surface in a time-multiplexed or field-sequential manner, and more particularly to a universal method of generating control signals for synchronously changing the optical state of liquid crystal (LC) shutter panels through which the time-multiplexed perspective images can be sequentially viewed in a substantially flicker-free manner by the left and right eyes of a human viewer, independent of whether the images are displayed on NTSC, PAL, VGA or SVGA styled CRT display devices.

Brief Description Of The Prior Art

During the course of human history, man has developed numerous ways of displaying two-dimensional (2-D) images of real and synthetic images alike. In many ways, the evolution of image display technology can be linked to particular stages of development in human civilization.

In the contemporary period, diverse types of image display devices have been developed for displaying 2-D images. Examples of such technologies include: cathode ray tube (CRT) display monitors;
liquid crystal display panels; plasma display panels; active-matrix plasma display panels; and the like. Presently, the CRT display device (i.e. CRT tube) is widely used in most video monitors of personal computer (PC) systems, as well as in most commercially produced television sets. The principal difference between a CRT computer video monitor and a CRT television display tube is the rate at which image frames or lines are displayed, and the composition of the video signals which each such display device is designed to receive and process during the image display process. In conventional CRT-based television sets, which are constructed and operate according to NTSC or PAL design criteria, the horizontal and vertical synchronization (retrace) signals are multiplexed with the RGB (i.e. color) signals to produce a single composite video signal that is transmitted over a signal conductor, reference to electrical ground. In conventional CRT-based computer display monitors, which are constructed and operated according to VGA or SVGA design criteria, the horizontal synchronization (retrace) signal, the vertical synchronization (retrace) signal, and the RGB (i.e. color) signals are each transmitted over a separate signal conductor, referenced to electrical ground, necessitating a minimum of six (6) pin electrical connector for VGA and SVGA styled video monitors. Inasmuch as these design standards create different electrical interface requirements for such types of CRT display devices, NTSC and PAL video display devices can only be driven by NTSC and PAL video signals, respectively, whereas VGA and SVGA styled video display monitor devices can only be driven by VGA and SVGA video signals, respectively. From a practical point of view, VGA or SVGA video signals generated from a graphics accelerator/video board within a
computer graphics workstation cannot be used to produce video graphics on a CRT-based television set without the use of special signal conversion equipment. Similarly, composite NTSC or PAL video signals generated from VCR player cannot be used to produce video graphics on a CRT-based computer video monitor without the use of such special signal conversion equipment.

CRT-based display devices (i.e. computer monitors) designed to be driven by VGA or SVGA video signals typically have an interlace mode and a non-interlace mode (page-flip mode), while CRT-based display devices (i.e. Television sets) designed to be driven by composite NTSC or PAL video signals have only an interlace mode. By virtue of the interlace mode, it is possible for all of the even lines of a video frame to be displayed on the surface of the CRT tube during the first portion of a display period, while all of the odd lines of a video frame are displayed on the surface of the CRT tube during the second portion of a display period, effectively doubling the image display rate at perceived by the eye of the viewer, and thereby reducing image flicker.

Today there is a movement to display stereoscopic image pairs displayed on CRT display devices in order support stereoscopic 3-D vision with full 3-D depth sensation in diverse environments.

While there exist several different techniques for achieving stereoscopic 3-D viewing, the “field-sequential” or “time-multiplexing” technique enjoys great popularity as it can be easily carried out using a pair of LCD shutter glasses. The function of the LCD shutter glasses is to sequentially present to the left eye of a viewer, the left image (of a stereo pair) displayed on a CRT display screen during left image display period, and thereafter, present the
right image of the viewer the right image of the stereo pair displayed during right image display period. Over the left and right display periods, the perceived left and right images fuse to provide stereopsis in the mind of the viewer.

There are three popular methods currently being used to rapidly alternate the left and right images of a stereo-image pair.

According to the first method, interlaced VGA and SVGA modes are used. In interlaced modes, the odd lines of the image buffer are displayed during one vertical refresh period, and the even lines are displayed in the next refresh period. To produce a stereo image, the left and right images are interleaved. In other words, the left image is stored in the odd (or even) lines of the image buffer, and the right image is stored in the even (or odd) lines of the image buffer. In this way, the left image is displayed in one frame, and the right image is displayed in the next, or vice-versa. The interlaced video mode has the advantage that it does not require timing interrupts to alternate the images; the interlacing hardware does this automatically. However, the primary problem with interlaced video modes is that they are not standardized except for at certain resolutions (primarily 1024x768 pixels). At lower resolutions, there is no guarantee that the monitor will correctly display interlaced images. A second shortcoming of interlaced 3D modes is that the effective stereo vertical resolution is halved, because the images are stored in alternating lines. In addition, setting up interlaced modes is not a standard operation on most video display adapters. The process to set up interlaced modes is different on each different adapter, and is actually impossible on some adapters.

According to the second method, the left and right images are
alternated by page swapping. In this method, the computer rapidly
swaps the two images, either by copying the images into the display
buffer one after the other, or by storing two images within display
memory and quickly changing which image the display hardware
displays by changing the VGA display start address register, making
a VESA Bios call, or some equivalent process. In this method of
alternating images, the page swapping must be synchronized with
the vertical refresh rate. This typically requires the use of an
interrupt service routine, which is called by the system timer or real
time clock interrupt. The primary problem with page swapping
is the difficulty of synchronizing the swapping with the refresh rate.
Page swapping consumes computer CPU time in order to service the
timer interrupts. Also, the page swapping can lose synchronization if
the CPU is busy performing calculations or servicing other interrupts.
Finally, the use of the timer interrupts may not be possible if other
applications or processes are using the interrupts. For example,
many sound libraries use timer interrupts, making them unavailable
for page swapping.

According to the third method, an additional vertical sync pulse
is inserted into the video signal. This extra sync pulse splits a single
video frame into two half-sized frames, causing the top and bottom
halves of the display buffer to be displayed as two separate images.
Inserting additional vertical sync pulses into the video signal suffers
the same problems as interlaced modes, that is, the monitor may not
be able to handle the non standard video signal.

The function of the LCD shutters in 3-D shutter-type viewing
glasses is to sequentially undergo a change in optical state during the
left and right image display periods, thereby allowing the viewer to
stereoscopically view sequentially displayed stereoscopic pairs. This function is carried out by electrically switching the optical state of the LCD shutters in response to trigger signals produced from the video signals. In particular, at the beginning of the left image display period, the optical state of the left eye LCD shutter is synchronously switched from its opaque state to its transparent state and the optical state of the right eye LCD shutter is synchronously switched from its transparent state to its opaque state. Then at the beginning of the right image display period, the optical state of the right eye LCD shutter is synchronously changed from its opaque state to its transparent state and the optical state of the left eye LCD shutter is synchronously changed from its transparent state to its opaque state. Such synchronously switching operations require the generation of trigger (i.e. switching) signals for driving the operations of the LCD shutters.

Presently, a number of LC shutter glasses are commercially available for use with the field-sequential stereoscopic 3-D image display technique. While some LCD shutter glasses are designed for use with CRT display devices driven by VGA video signals (i.e. computer monitors), others are designed for use with CRT display devices driven by composite video sources (e.g. television sets). However, there does not exist a pair of LCD shutter glasses that can be used with either type of CRT display device.

Prior art LC shutter glasses suffer from a number of shortcomings and drawbacks. In particular, many prior art LC shutter glasses attempt to synchronize the shutter transition to the beginning of each video frame. Once a vertical reset pulse or similar signal is detected, pulse coded information is sent to toggle the
optical state of the shutters. However, as this information is sent at the beginning of each field of video, it must be of very short duration in order to allow sufficient time for the shutters to change state before the vertical blanking interval ends. This prior art shutter-state control/synchronization technique requires providing high speed circuitry in the LC eyewear (or associated receiving unit) in order to decode these short time-domain shutter control pulses. Moreover, such circuitry utilizes battery power, and thus shortens the effective life of the batteries aboard the electro-optical shutter glasses. Another shortcoming of prior art shutter glasses is that a background excitation voltage is required to keep the pi-cell shutters in the transmissive state.

Other prior art LC shutter glasses attempt to synchronize the shutters using "white line" synchronization codes and vertical retrace pulses widths, and produce spectral - flicker which is objectional during stereoscopic viewing.

Thus there is a great need in the art for an improved stereoscopic viewing system which avoids the shortcomings and drawbacks associated with prior art systems and methodologies.

DISCLOSURE OF THE INVENTION

A primary object of the present invention is to provide a stereoscopic 3-D image viewing system for stereoscopically viewing 3-D images displayed on either a CRT computer or video display device.

Another object of the present invention is to provide such a system, in which lightweight stereoscopic 3-D shutter-type viewing glasses are used to view stereoscopic image pairs displayed on a CRT
computer or video display device according the time-multiplexing display technique.

Another object of the present invention is to provide such a system, in which signal decoding and processing is minimized within the stereoscopic 3-D shutter-type viewing glasses in order to reduce the cost of manufacture thereof, while providing extended battery life.

Another object of the present invention is to provide a pair of LCD shutter glasses having a passive mode of operation for use in decoding polarized spatially-multiplexed images displayed from an spatially-multiplexed image display system.

Another object of the present invention is to provide a pair of LCD shutter glasses having a spectral mode of operation for decoding spectrally multiplexed images displayed on an image display system.

Another object of the present invention is to provide such a system, in which a means is provided for detecting stereoscopically-encoded video synchronization signals from a computer or other video source and transmitting field information for controlling remote pairs of optical state varying LCD shutters via pulse width modulated or pulse encoded infrared signals.

Another object of the present invention is to provide such a system, in which one shutter switches to the transmissive state while the other shutter switches to the opaque state synchronized to a specific field of information displayed on the CRT or display device.

Another object of the present invention is to provide a stereoscopic viewing system, which has a display mode that allows two viewers, wearing two separate pairs of LCD glasses of the present invention to view two separate images simultaneously on the same display screen. for example, to play a head-to-head video game on the
same viewing screen without interference.

Another object of the present invention is to provide a stereoscopic viewing system, wherein the polarization axis of the LCD shutters glasses can be passively oriented in opposing directions and thus be used as a pair of electrically-passive polarizing glasses to stereoscopically view spatially multiplexed images (SMI).

Another object of the present invention is to provide a stereoscopic viewing system, having several different modes of operation which make it possible for a viewer, in a multi-format stereoscopic environment, to view a variety of stereoscopic images with the same viewing glasses.

Another object of the present invention is to provide a method of generating synchronization signals for use in a stereoscopic viewing system which employs low cost, twisted nematic (TN) liquid crystal (LC) displays as the optical shutters, and control signals adjusted for the slower transition times and inherent process variations associated therewith.

Another object of the present invention is to provide a synchronization signal generation scheme which has the inherent ability to detect interlaced and non-interlaced modes in computer generated or standard video signals, and transmit appropriate shutter control signals via an infrared link to the remote shutter glasses.

Another object of the present invention is to provide such a synchronization signal generation system, in which the synchronization control signals generated therefrom are adjustable for the slower transition times and inherent process variations associated with optical shutters constructed from low-cost twisted nematic (TN) liquid crystal (LC) display panels which do not require any background excitation
voltage while in the clear state, and thus longer battery life can be achieved.

Another object of the present invention is to provide a pair of LC optical shutter glasses constructed from low-cost twisted nematic (TN) liquid crystal (LC) display panels which do not require any background excitation voltage while in the clear state, and thus longer battery life can be achieved.

Another object of the present invention is to provide a pair of LC optical shutter glasses, in which the shutter drive circuitry is effectively disposed into a “sleep” mode until a change of optical state is required by the shutter panels, thereby substantially increasing battery life.

Another object of the present invention is to provide a novel shutter-based stereoscopic viewing system, having a synchronization signal transmitter with a multi-synch detection capability for interpreting both interlaced and non-interlaced video conditions, generating synchronization signals and transmitting the same to optical shutters glasses for controlling the optical state of the same.

Another object of the present invention is to provide a universal multi-sync signal detection device that can detect synchronization signals, polarities and frequencies present in all VGA and SVGA video formats, as well as, NTSC and PAL composite video sources; determine the image field rate from these signals; determine the presence or absence of stereoscopically encoded video signals; and transmit the appropriate signals for controlling the optical shutters in the remote viewing glasses.

Another object of the present invention is to provide a shutter glasses with decoding circuitry that detects the presence of pulse width
modulated or pulse encoded infrared signals, recognize a difference between two adjacent states and sets the corresponding optical shutter state.

Another object of the present invention is to provide shutter glasses with decoding circuitry which, when detecting no difference between two adjacent IR pulses, automatically determines that a non-stereoscopic video condition exists and places both optical shutters in the optically transmissive state indicating a non-stereoscopic video image is to be viewed.

Another object of the present invention is to provide shutter glasses with decoding circuitry which, when detecting alternating pulse widths of two predetermined lengths, automatically determines that a stereoscopic condition exists, and simultaneously alters the optical state of the LCD shutters at the corresponding video field rates for viewing stereoscopic video images.

Another object of the present invention is to provide shutter glasses with decoding circuitry which, when detecting no IR pulses, automatically enters a sleep mode or off sleep-state which will place both optical shutters in the optically transmissive state.

Another object of the present invention is to provide shutter glasses which do not require any background excitation voltage to keep the shutters in the optically transmissive state.

Another object of the present invention is to provide such shutter glasses, in which the polarization state of the optical-state varying shutters are oriented orthogonally when operated in their electrically-passive transmissive state, for use in stereoscopically viewing linearly polarized spatial multiplexed images.

Another object of the present invention is to provide a
stereoscopic 3-D image viewing system based on the spatially- 
multiplexed image (SMI) display form, in which the shutter glasses of 
the present invention are used in their electrically-passive 
transmissive state, for stereoscopically viewing linearly micropolarized 
polarized SMIs displayed from an LCD panel.

Another object of the present invention is to provide a means to 
synchronize the glasses to the display using vertical retrace pulse 
signaling, or any coded signals on the horizontal or vertical retrace lines, 
or any signals or codes in the RGB video information, or any codes or 
signals in a special parallel or serial line, or any other signalling method 
in the VGA or video or computer signal.

Another object of the present invention is to provide a line 
blanking hardware or software system to automatically convert 
line-interleaved stereoscopic images into time-sequential stereoscopic 
images for viewing with a 3D stereoscopic viewing system.

Another object of the present invention is to provide a line 
blanking hardware or software system to automatically convert 
line-interleaved stereoscopic images into spectrally multiplexed 
stereoscopic images for viewing with a 3D stereoscopic viewing system.

Another object of the present invention is to provide a line 
blanking hardware or software system to automatically convert 
line-interleaved or page-flipped (time sequential) stereoscopic images 
into anaglyphic spectrally multiplexed stereoscopic images for viewing 
with a 3D stereoscopic viewing system.

Another object of the present invention is to provide hardware 
system to automatically convert line-interleaved or page-flipped (time 
sequential) stereoscopic images into spectrally multiplexed stereoscopic 
images inside of the video display system either before the DAC 
(digitally) or after the DAC (analog).
Another object of the present invention is to provide hardware system to automatically convert line-interleaved or page-flipped (time sequential) stereoscopic images into anaglyphic spectrally multiplexed stereoscopic images inside of the video display system either before the DAC (digitally) or after the DAC (analog).

Another object of the present invention is to provide a hardware system (or dongle) to automatically convert line-interleaved, interlaced, page-flipped (time sequential), over-under, side-by-side, spectral, anaglyphic, or other spatial or temporal stereoscopic images into a different stereoscopic image format (line-interleaved, interlaced, page-flipped (time sequential), over-under, side-by-side, spectral, anaglyphic, or other spatial or temporal format) for use on a compatible 3D stereoscopic viewing system.

Another object of the present invention is to provide a hardware configuration where a narrow band retarder material is inserted between the LC shutter and the analyzing polarizer to convert the viewing system from a time-sequential multiplexed viewing mode into a spectrally multiplexed viewing mode.

Another object of the present invention is to provide all of the functionality described in this patent for wire-less viewing systems and also for wired or tethered viewing systems.

These and other object of the present invention will become apparent hereinafter.

BRIEF DESCRIPTION OF DRAWINGS

For a complete understanding of the Objects of the Present Invention, the following Detailed Description of the Illustrative Embodiments should be read in conjunction with the accompanying
Drawings, wherein:

Fig. 1 is a perspective view of a generalized stereoscopic 3-D image viewing system of the present invention, suitable for desktop virtual reality (VR) and 3-D computer graphics applications, comprising a CRT-based display device, wireless stereoscopic 3-D viewing glasses having electro-optical viewing shutters, and a remote device for device for generating shutter-state control signals through real-time vertical and horizontal synchronization signal analysis, encoding these shutter-state control signals, and transmitting the same to the wireless stereoscopic 3-D viewing glasses for reception, decoding and control of the optical states of the viewing shutters;

Fig. 1A is a perspective view of the stereoscopic 3-D eyewear and shutter-state control signal transmitter of the illustrative embodiment;

Fig. 1B is a cross-sectional schematic representation of the twisted nematic (TN) liquid crystal (LC) viewing shutter panel installed in the left and right viewing aperture of the head-supportable frame of the stereoscopic 3-D eyeglasses of the illustrative embodiment;

Fig. 1C is a cross-sectional schematic representation of the twisted nematic (TN) liquid crystal (LC) viewing shutter panel as illustrated in Fig. 1B incorporating a narrow band retarder to convert the system to a spectral multiplexing mode;

Fig. 2A is a block schematic system diagram of the first illustrative embodiment of the stereoscopic 3-D image viewing system of the present invention, shown in Fig. 1, wherein the shutter-state control signal transmitter and CRT VGA/SVGA video monitor are connected to the output port of a VGA/SVGA video card aboard a computer graphics system by way of a split connector (i.e. Dongle), with the wireless stereoscopic 3-D glasses being operably connected, in a wireless manner,
to the shutter-state control signal transmitter by way of an IR signalling link;

Fig. 2B is a block schematic system diagram of a second illustrative embodiment of the stereoscopic 3-D image viewing system of the present invention, wherein the video input of the shutter-state control signal transmitter is connected to the composite video output of a (NTSC or PAL styled) CRT-based television set or video monitor by way of a split connector (i.e. dongle), and the output port of a video tape player/recorder being connected to the input port of the CRT-based television set or video monitor, with the wireless stereoscopic 3-D glasses being operably connected to the shutter-state control signal transmitter in a wireless manner by way of an IR signalling link;

Fig. 2C is a block schematic system diagram of a second illustrative embodiment of the stereoscopic 3-D image viewing system of the present invention, wherein the video input of the shutter-state control signal transmitter and the output port of a video tape player/recorder are connected to the composite input of a (NTSC or PAL styled) CRT-based television set or video monitor by way of a split connector (i.e. dongle), with the wireless stereoscopic 3-D glasses being operably connected to the shutter-state control signal transmitter in a wireless manner by way of an IR signalling link;

Fig. 3 is a schematic diagram of the shutter-state control signal transmitter of the present invention, wherein its computer input port is provided with an input signal from a VGA/SVGA computer video source (e.g. VGA/SVGA graphics and video accelerator card), and alternatively, its video source input port is provided with an input signal from a NTSC or PAL composite video signal source (e.g. VCR/player);

Fig. 3A is a high level flow chart illustrating the steps performed
out by the Shutter-State Control Signal Generation Process of the present invention, carried out aboard the shutter-state control signal transmitter of the illustrative embodiment of the present invention;

Fig. 4 is a schematic block diagram of the wireless stereoscopic 3-D glasses of the present invention, showing the various electronic and opto-electronic components embedded within the lightweight, head-supportable frame thereof;

Fig. 5A is a schematic representation of (i) the vertical synchronization pulse signal associated with a standard 2-D VGA/SVGA formatted video signal produced from a standard VGA/SVGA video board in a computer system or workstation, (ii) the horizontal synchronization pulse signal associated with the standard 2-D VGA/SVGA formatted video signal produced therefrom, (iii) the horizontal synchronization signal pulse count (HSPC) generated by the shutter-state control signal transmitter hereof over each vertical synchronization signal pulse period (VSPP), and the absence of a L-pulse train or R-pulse train being generated in response thereto;

Fig. 5B is a schematic representation of (i) the vertical synchronization pulse signal associated with a standard 3-D VGA/SVGA interlaced (i.e. interleaved) formatted video signal produced from a standard VGA/SVGA video board in a computer system or workstation, (ii) the horizontal synchronization pulse signal associated with the standard 3-D VGA/SVGA interlaced format video signal produced therefrom, (iii) the horizontal synchronization signal pulse count (HSPC) generated by the shutter-state control signal transmitter hereof over each vertical synchronization signal pulse period (VSPP), and (iv) the L-pulse train generated after detecting a right perspective image to be displayed, in anticipation of the next left perspective image to be
displayed on the CRT display, and the R-pulse train generated after
detecting a left perspective image to be displayed, in anticipation of the
next right perspective image to be displayed on the CRT display;

Fig. 5C is a schematic representation of (i) the vertical
synchronization pulse signal associated with a Page-Flipped formatted
video signal produced from a standard VGA/SVGA video board
programmed in accordance with the image formatting method of the
present invention, (ii) the horizontal synchronization pulse signal
associated with the standard Page-Flipped formatted video signal
produced therefrom, (iii) the horizontal synchronization signal pulse
count (HSPC) generated by the shutter-state control signal transmitter
hereof over each vertical synchronization signal pulse period (VSPP),
and (iv) the L-pulse train generated after detecting a right perspective
image to be displayed, in anticipation of the next left perspective image
to be displayed on the CRT display, and the R-pulse train generated
after detecting a left perspective image to be displayed, in anticipation of the
next right perspective image to be displayed on the CRT display;

Fig. 5D is a schematic representation of (i) the vertical
synchronization pulse signal associated with a video-interlaced (i.e.
interleaved) formatted video signal produced from a (NTSC or PAL)
composite video signal source in accordance with the image formatting
method of the present invention, (ii) the horizontal synchronization
pulse signal associated with the video-interlaced formatted video signal
produced therefrom, (iii) the horizontal synchronization signal pulse
count (HSPC) generated by the shutter-state control signal transmitter
hereof over each vertical synchronization signal pulse period (VSPP),
and (iv) the L-pulse train generated after detecting a right perspective
image to be displayed, in anticipation of the next left perspective image
to be displayed on the CRT display, and the R-pulse train generated
after detecting a left perspective image to be displayed, in anticipation
of the next right perspective image to be displayed on the CRT display;

Fig. 6A is schematic diagram of the stereoscopic 3-D viewing
glasses of the present invention, shown being operated in its electrically
passive mode (i.e. battery-power OFF), wherein the left eye viewing
shutter is induced into an optically transparent polarization state P1,
while the right eye viewing shutter is induced into an optically
transparent polarization state P2, orthogonal to P1;

Fig. 6B is schematic diagram of the stereoscopic 3-D viewing
glasses of the present invention, showing being operated in its
electrically-active mode (i.e. battery-power ON), where during a first 2-
D image display period the stereoscopic viewing glasses receive infrared
(pulse-train encoded) shutter-state control signals from the shutter-
state control signal transmitter so as to drive both left and right eye
viewing shutters into an optically opaque state, and then during a
second 2-D image display period the stereoscopic viewing glasses
receive infrared ("pseudo" pulse-train encoded) shutter-state control
signals from the shutter-state control signal transmitter so as to drive
both left and right eye viewing shutters into an optically transparent
state;

Fig. 6C is schematic diagram of the stereoscopic 3-D viewing
glasses of the present invention, showing being operated in its
electrically-active mode (i.e. battery-power ON), where during a left
image display period the stereoscopic viewing glasses receive infrared
L-pulse-train encoded shutter-state control signals from the shutter-
state control signal transmitter so as to drive the left-eye viewing
shutter into an optically transparent state and the right-eye viewing
shutter into an optically opaque state, and then during a right image
display period the stereoscopic viewing glasses receive infrared (R-
pulse-train encoded) shutter-state control signals from the shutter-state
control signal transmitter so as to drive the left-eye viewing shutter
into an optically opaque state and the right-eye viewing shutter into an
optically transparent state;

Fig. 7 is a schematic representation of another embodiment of the
stereoscopic 3-D image viewing system of the present invention, based
on the spatially-multiplexed image (SMI) display format, in which the
stereoscopic 3-D shutter glasses of the present invention are operated in
their electrically-passive (transmissive or clear) state, for stereoscopic
viewing of 3-D images represented in linearly-micropolarized polarized
SMIs displayed from an LCD panel;

Fig. 8 is a schematic representation of another embodiment of the
stereoscopic 3D imaging viewing system of the present invention in
which hardware line blanking (possibly in the form of a dongle) is used
to covert the non-interlaced, line-alternate stereoscopic image to a
alternate page-flipped right and left views;

Fig. 9 is a schematic representation of another embodiment of the
stereoscopic 3D imaging viewing system of the present invention in
which hardware color signal blanking (possibly in the form of a dongle)
is used to covert the non-interlaced, line-alternate stereoscopic image to
a alternate page-flipped spectrally multiplexed right and left views;

Fig. 10A is a schematic representation of another embodiment of
the stereoscopic 3D imaging viewing system of the present invention
implementating a full color analgyph conversion, in which color signal
blanking and summing hardware (possibly in the form of a dongle) is
used to coNvert the non-interlaced, line-alternate stereoscopic image to
an anaglyph stereoscopic image format;

Fig. 10B is a chart showing the various forms of anaglyph which can be supported by the color signal blanking and summing hardware illustrated in Fig. 10A and Fig. 11; and

Fig. 11 is a schematic representation of another embodiment of the stereoscopic 3D imaging viewing system of the present invention implementing a full color analglyph conversion, in which color signal blanking and summing hardware (possibly in the form of a dongle) is used to covert page-flipped stereoscopic images to an analglyph stereoscopic image format.

**DETAILED DESCRIPTION OF THE BEST MODES FOR CARRYING OUT THE PRESENT INVENTION**

As shown in Fig. 1, the stereoscopic 3-D image viewing system of the present invention 1 comprises a number system components, namely: a CRT-based display device 2; a video signal source 3 for producing video signals representative of either 2-D images, or stereoscopic image pairs for 3-D stereoscopic viewing using the time-multiplexed (i.e. field-sequential) display format; wireless stereoscopic 3-D eyewear (e.g. viewing glasses) 4 having left and right electro-optical viewing shutters for the left and right eyes of its user, respectively; and a remote transmitting device 5 for (i) generating shutter-state control signals (through real-time vertical and horizontal synchronization signal analysis), (ii) encoding these shutter-state control signals, and (iii) transmitting the same to one or more pairs of stereoscopic 3-D viewing glasses wirelessly lined to the transmitter, for reception, decoding and use in switching the optical states of the viewing shutters (e.g. from optically opaque to optically transmissive).
In general, the system has three principal modes of operation, namely: a Passive (Polarizing) Viewing Mode shown in Fig. 6A; an Active Head-to-Head 2-D Viewing Mode illustrated in Fig. 6B; and an Active Stereo 3-D Viewing Mode illustrated in Fig. 6C. While each of these modes of operation will be described in great detail hereinafter, suffice it to say for now that in each such mode of operation, each viewer wears a pair of the stereoscopic 3-D viewing glasses so that its left and right electro-optical viewing shutters thereof are positioned before his or her left and right eyes, respectively, while displayed images are viewed through such viewing shutters under the control of the shutter-state control transmitter of the present invention.

In accordance with the present invention, the CRT-based display device 2 can be, for example, a CRT-based television set adapted for receiving a composite video signal (hereinafter “composite video signal”), or a CRT computer monitor of the VGA or SVGA style adapted to receive RGB video signals and horizontal and vertical synchronization signals (hereinafter “computer video signal(s)”) over separate electrical lines in a manner well known in the art. These CRT-based display devices will be referred to as a “CRT video display” or a “CRT computer display”, respectively. The CRT video display always operates in interlaced mode, and therefore the interlaced method of multiplexing will be used with this display device. The CRT computer display, on the other hand, may be programmed to operate using either the interlaced method or the Page Flipped method of multiplexing. In both types of CRT display devices, the image streams are distinguished using the horizontal and vertical sync pulse timings. For interlaced modes for both CRT display devices, the CRT display device itself varies the synchronization pulse timings to indicate the field identity. For page-
flipped modes on the CRT computer display, the display driver
hardware is programmed to vary the sync pulse timings as the pages
are flipped. It should also be noted that the method of varying the sync
pulse timings could be used to communicate other forms of information
to the transmitter. For example, certain patterns could be used to turn
the glasses on or off, or for other purposes.

Similarly, the video signal source 3 can be, for example, either a
VCR/player, CD-ROM laser disc player as, a computer graphics system
with a VGA/SVGA video board, a stereoscopic video camera, or other
image signal generation device as shown the various configurations set-
up diagrams of Figs. 2A through 2C. As shown in this diagrams, a
simple video signal connector (i.e. “dongle”) can be used to easily
interface the shutter-state control signal transmitter with CRT computer
and video devices and composite and computer video signal producing
devices, according to different system configurations.

When using a video signal source that produces a “composite video
signal”, then a CRT-based display device adapted for receiving
composite video signals must be used with the stereoscopic 3-D image
viewing system. Likewise, when using a video signal source that
produces a “computer video signal”, then a CRT-based display device
adapted for receiving computer video signals must be used with the
stereoscopic 3-D image viewing system. Notably, however, the shutter-
state control signal transmitter of the present invention is uniquely
adapted for receive composite video signals provided over a RCA-type
jack, as well as computer video signal provided over standard VGA or
SVGA multiwire cables, and thus is a “universal” shutter-state control
signal transmitter, unknown in the prior art.

As shown in Fig. 1A, stereoscopic 3-D eyewear of the present
invention comprises: a lightweight plastic frame 8 having a frontal frame portion 8A with viewing apertures within which left and right eye electro-optical viewing shutter panels 9A and 9B mounted; and ear-engaging portions hinged to the frontal frame portion and embodying miniature electronic circuit board(s) 10 and battery 11 in an ultra-compact manner. An infrared (IR) light sensing diode 12 is mounted within the center of the frontal frame portion, for receiving IR encoded signals carrying pulse train information transmitted from the transmitter. As will be described in greater detail hereinafter, the IR signals are received, decoded and used to generate shutter drive signals DL and DR for the left and right eye viewing shutters, which controllably switch the optical state of the viewing shutters 9A and 9B, in synchronism with the stereoscopic image pairs being sequentially displayed on the CRT display device, to realize the field-sequential stereoscopic display technique.

As shown in greater detail in Fig. 1B, each electro-optical viewing shutter 9A, 9B in the stereoscopic eyewear of the present invention comprises a cell structure 13 consisting of first and second glass plates 14 and 15 approximately 1” square. Each glass plate is coated with optically transparent electrode forming material 16 (e.g. ITO) and then coated with polyamide alignment layer. The polyamide alignment layers on the first and second glass plates are rubbed or puffed, in directions that are 90° with respect to each other, in a manner well known in the art. These rubbing directions will cause the polyamide molecules to orient themselves and subsequently orient the liquid crystal molecule that they come in contact with. The complete cell is assembled by putting a spacer 17 of a certain thickness between the glass plates, which fixes this thickness to a desired value. Thereafter,
the cell is filled with nematic liquid crystal material 18. The cell is then sealed using a suitable adhesive. Linear polarizer sheets 18 and 19 are then laminated to the outer surfaces of the sealed cell. These two polarizers have orthogonal polarization states P1 and P2. Prior to sealing of the cell, two contacts 20 and 21 are attached to the transparent electrodes on the first and second glass plates. These electrodes allow a state control voltage to be applied across the cell for switching purposes.

By virtue of the orthogonal rubbing directions of the polyamide layer, the liquid crystal material with the cell will experience a twist of the molecular directions such that top surface will align in one direction and the bottom surface will align in a direction that is perpendicular. This serves to rotate the polarization direction of light that enters from one side of the cell to another direction that is 90° from the first one exiting the cell. In the absence of the voltage (i.e. in a passive state), the cell will therefore be rendered optically transparent. As soon as a voltage is applied across the cell, the liquid crystal molecules therein will be directly aligned along the direction of the applied electric field that is perpendicular to the cell, and thus the polarization direction of an electric field component of light entering the first surface of the cell will not undergo any rotation. Consequently, in this actively driven state, the electric field intensity of light entering the first surface of the cell is automatically extinguished by the second polarizer, thereby rendered the cell in its optically opaque (i.e. dark state).

Notably, switching speed of the cell can be enhanced and lower excitation voltages used if the cell thickness is kept to a minimum (e.g. the range of 5 microns). By achieving this design constraint, it is possible to avoid the need for high voltage DC-DC converters (as
required as with current technologies) and obtain long operational life.

As schematically illustrated in the "video signal source/CRT display blocks" of Fig. 3, namely 3 and 3', the stereoscopic viewing system of the present invention supports two different techniques for displaying time-multiplexed (i.e. field-sequential) image streams, namely: the interlacing method, and the page flipping method.

The interlacing method uses the interlaced (i.e. interleaved mode of the display device, wherein the odd lines of an image buffer are displayed in one vertical sweep of the cathode ray, while the even lines of the image buffer are displayed during the next vertical sweep. In the interleaved mode, the two image streams are interleaved by placing one image stream on the odd lines of the buffer, and one image stream on the even lines, which produces a single interleaved image stream. The interleaved image stream is then converted to a time multiplexed pair of image streams by the interlacing hardware of the display device.

In the page-flipped mode, the page flipping method of time-multiplexing image streams involves alternately displaying images from the two image streams, either by copying them one after another into a single image buffer, or by copying them into two separate image buffers and then rapidly switching the display device between the two buffers.

In Fig. 3, the shutter-state control signal generator and transmitter") 4 is described in greater detail. As shown, the transmitter comprises: a compact housing 25 suitable for placement upon or attachment to a CRT display device or video signal producing device; a VGA/SVGA video signal input jack 26 mounted through the housing; a composite video signal input jack 27 mounted through the housing; a printed circuit (PC) board 28 upon which an integrated RISC processor 29 (e.g. 8 bit RISC Microcontroller No. PIC16C64 from Microchip, Inc.,)
with associated RAM, ROM and the like, programmed receive and process the horizontal and vertical synchronization signals provided to the computer video signal input port 26; an integrated video signal processing device 30 (e.g. LM1881 IC) for receiving and processing the composite video signal provided to the composite video signal input port 27; power distribution circuitry 31 for distributing DC power provided by an external 12 Volt AC-DC transformer 32; a system bus (not shown); IR LEDs 33 driven by a transistor-based driver circuit 34 under the control of the RISC processor; and visible LEDs 35 driven directly the RISC processor 29, for indicating power ON/OFF and pseudo video input.

As illustrated in Fig. 3, video signal processing device 30 perform three primary functions in the present application. At Block 30A, it clamps the AC component of the composite video input signal to a DC level. At Block 30B, it strips the horizontal and vertical synchronization signals of the composite video signal waveform and passes them onto Block 30C. At Block 30C, the horizontal and vertical synchronization signals are separated and provided to different input ports of the RISC processor. The horizontal and vertical synchronization signals from the computer video signal input port are also provided to a different set of input ports of the RISC processor. The function of the RISC processor 29 is to sample the horizontal and vertical synchronization signals at its high-speed inputs, and in the event that horizontal and vertical synchronization signals are simultaneously provided to the RISC processor from both the composite and computer video signal input ports, then the computer video signal input port is accorded priority, for conflict avoidance.

The primary function performed by the RISC processor within transmitter unit 4 is analyze the pulse structure of horizontal and
vertical synchronization signals at its input ports and generate, as output, digitally encoded shutter-state control signals (i.e. pulse trains) which are then used to transmit IR versions thereof towards the stereoscopic 3-D viewing glasses of the present invention. In general, this process involves: analyzing (i.e. counting) the number of horizontal synchronization pulses occur within each vertical synchronization pulse period (VSPP); produce and buffer therefor a horizontal synchronization pulse count (HSPC); and then if the HSPC indicates that a left image will be displayed next display period, then assign a first digitally encoded pulse sequence (i.e. L-pulse train) to this HSPC, and if the HSPC indicates that a right image will be displayed next display period, then assign a second (different) digitally encoded pulse sequence (i.e. R-pulse train) to this HSPC (e.g. where the length of the R-pulse train is 2 times the length of the L-pulse train, as illustrated in Fig. 4).

This process is detailed in Fig. 6A. This process is repeated in a cyclical manner provided that there is video signal input to the shutter-state control signal transmitter. As indicated at Block A in Fig. 3A, the RISC processor initializes the "odd count" HSPC index j and the "even count" HSPC index k. Then at Block B, the RISC processor waits for the start of a vertical synchronization pulse period (VSPP). At Block C, the RISC processor generates a current horizontal synchronization pulse count (HSPC) for the current VSPP and buffers the same in memory. At Block D, the RISC processor determines whether the current is "odd" or "even". If the current HSPC is "even", then at Block E the RISC processor resets (i.e. clears) the "odd count" HSPC index (i.e. sets j=0), and increments the "even count" HSPC index k by +1 (i.e. sets k=k+1). Then at Block F the RISC processor determines whether the "even count" HSPC index k is
greater than the preset "Even-Count HSPC Threshold" K. If it is, then the RISC processor returns to Block B and resumes the process, as shown in Fig. 3. If the "even count" HSPC index k is not greater than the preset "Even-Count HSPC Threshold" K, then the RISC processor proceeds to Block G and waits for the Pulse Transmit Time, necessary to achieve the Left Image Display Anticipation, to be described in greater detail hereinafter. Then at the correct Pulse Transmit Time, the RISC processor performs the digital pulse train encoding and IR driver enabling to transmit an IR L-type digital pulse train from the IR diodes 33, and thereafter returns to Block B, as shown.

If, however, the RISC process determines at Block D that the current HSPC is "odd", then at Block I the RISC processor resets (i.e. clears) the "even count" HSPC index (i.e. sets k=0), and increments the "odd count" HSPC index j by +1 (i.e. sets j=j+1). Then at Block J the RISC processor determines whether the "odd count" HSPC index j is greater than the preset "Even-Count HSPC Threshold" J. If it is, then the RISC processor returns to Block B and resumes the process, as shown in Fig. 3. If the "odd count" HSPC index j is not greater than the preset "Even-Count HSPC Threshold" J, then the RISC processor proceeds to Block K and waits for the Pulse Transmit Time, necessary to achieve the Right Image Display anticipation process of the present invention, to be described in greater detail hereinafter. Then at the correct Pulse Transmit Time, the RISC processor performs the digital pulse train encoding and IR driver enabling to transmit an IR R-type digital pulse train from the IR diodes 33, and thereafter returns to Block B, as shown.

The above process supports all three mode of system operation illustrated in Fig. 6A, 6B and 6C. When the process follows the loop
through Blocks B-C-D-E-F-G-H-B, and/or Blocks B-C-D-I-J-K-L-B, the Active Stereo 3-D Mode is enabled, shown in Fig. 6C. When the process follows the loop through Blocks B-C-D-E-F-B, and/or Blocks B-C-D-I-J-B, the Passive 2-D Mode is enabled, shown in Fig. 6A. When no horizontal or vertical synchronization signals are provided to the RISC processor, the process of Fig. 3A is not carried out and the system is in its Passive (Polarizing) Viewing Mode, illustrated in Fig. 6A. In this system mode, there are no IR digitally encoded shutter-state control signals sent from the transmitter to the stereoscopic 3-D viewing glasses hereof and thus the viewing glasses enter its Power-Conservation Mode. As will be described in greater detail below, when the viewing glasses enters its Passive Mode, its RISC processor (embodied within the frame) goes into its ultra-low power consuming "Sleep Mode". The stereoscopic eyewear remains in its Passive Mode until either an IR L-pulse train or an IR R-pulse train is received at the stereoscopic viewing glasses, at which time the stereoscopic viewing glasses reenters its Active Mode.

As illustrated in the system diagram of Fig. 4, the stereoscopic viewing glasses embody miniature PC board, on which is mounted: an ultra-low power consuming, IC pulse amplifier 40 for amplifying electrical pulses produced by IR photodiode 12 mounted on frontal frame portion; a RISC processor (e.g. 8 bit RISC Microcontroller No. PIC16C64 from Microchip, Inc.) with associated RAM, ROM and the like, programmed to receive and process the digitally-encoded pulse trains transmitted by the shutter-state control signal transmitter; 6.0 Volt battery 10; transistor-based LCD driver circuitry 42 for producing shutter drive signals DL and DR, to left and right TN LC shutters 9A, 9B; a DC-DC converter IC 43 for providing a stepped up voltage to the power input of transistor-based LCD driver circuitry 42; a FET-based power-
control-switch 44 connected between battery 10 and the power input
port of the DC-DC converter 43.; a power-off timer 45; and an oscillator
46, arranged as shown.

As shown in Fig. 4, a number of functions elements are realized
within programmed RISC processor 41 within the stereoscopic eyewear
of the present invention. In particular, a waveform shaping circuit 47 is
provided for shaping up (i.e. squaring-up) the output signal from IC
pulse amplifier 40. Also, a L-pulse-train/R-pulse train decoder 48 is
provided within the programmed RISC processor 41, for analyzing each
digital pulse trains from the waveform shaping circuit 47 and
determining whether it is represents a left shutter-state control signal
(i.e. L=1) or a right shutter control signal (i.e. R=1 ). These decoded
shutter-state control signals are provided as signal input to the
transistor-based LCD driver circuitry 42. The function of transistor-
based LCD driver circuitry is to generate a left shutter drive voltage DL
when a left shutter-state control signal (i.e. L=1) is received as input,
generates a right shutter drive voltage DR when a right shutter-state
control signal (i.e. R=1) is received as input, and generate no shutter
drive voltage when a neither a left or right shutter-state control signal
is received as input to transistor-based LCD driver circuitry.

During operation, the system of the present invention may receive
any one of four differently formatted video signals, automatically
analyze the horizontal and vertical synchronization signals thereof, and
produce appropriate shutter controls signals for automatically operating
the stereoscopic shutter glasses of the present invention in accordance
therewith, without operator intervention. As such, the system of the
present invention embodies a substantial level of programmed
intelligence, while retaining a great degree of simplicity and ease of use.
These four situations are schematically depicted in Figs. 5A, 5B, 5C and 5D.

In Fig. 5A, the timing relationship is graphically illustrated between the horizontal and vertical synchronization signals of a standard 2D VGA computer video signal. As shown, an consistent with the logic of the process of Fig. 3A, the HSPC is the same for each VSPP (i.e. no difference is found between two adjacent pulses for more than a preset number of fields). Thus, the process of Fig. 6 within the transmitter assumes that a non-multiplexed image stream is present, and transmits control signals which place both shutters in the transmissive state indicating a non-stereoscopic video image is to be viewed.

In Fig. 5B, the timing relationship is graphically illustrated between the horizontal and vertical synchronization signals of an interlaced-encoded 3-D VGA computer video signal. As shown, consistent with the logic of the process of Fig. 3A, the HSPC is the “odd” for a left image to be displayed and “even” for a right image to be displayed.

During system operation, the function of the transmitter is to decode and interpret the identity of the field from the sync pulse timings. However, there is very little time between the end of vertical sync to the beginning of the next displayed field. Because the LCD shutters may be slow to respond, this could potentially result in the shutters being in the wrong state at the beginning of the next field. To correct this problem, a novel anticipation and correction scheme is used.

In Fig. 5C, the timing relationship is graphically illustrated between the horizontal and vertical synchronization signals of a page-flipped 3D VGA computer video signal. As shown, and consistsant
with the logic of Fig. 3A, the width of the VSPP is adjusted by software control so that the HSPC is odd for a left image to be displayed and even for a right image to be displayed. In a similar fashion, other signal encoding techniques can be used to place these pulse codes or signals in any physical connected signal line of the video port.

As indicated in the pulse train timing diagrams of Figs. 5B through 5D, this Left/Right Image Anticipation scheme relies on the assumption that the displayed image stream alternates on almost every field. In this case, it is assumed that the next field will be the other image stream, and the signal is sent to the shutters to set them to this anticipated state, before the field identity is actually confirmed by observing the sync pulse timings. The signal is transmitted at the correct time (i.e. Pulse Transmit Time), taking into account the electrical and optical properties of the TN-LC shutters, to ensure that the shutter is at the correct optical state when the image is displayed. If it is discovered that the displayed field did not alternate as expected, a second signal is sent to the shutters to correct the error, and force the shutters back into the correct state. For video displays and for interlaced computer displays the correction will not actually need to be done, since the display hardware enforces the alternating image streams. For page flipped methods, where the image stream multiplexing is performed in software, it is possible that the computer will not keep up with the vertical refresh rate of the monitor, in which case the correction scheme will minimize any adverse impact. By using the anticipation and correction scheme, it is possible to use slower electronics in the shutter system, reducing power consumption and extending battery life.

Notably, as the transmitter hereof transmits shutter-state control
signals prior to the vertical blanking interval (as indicated in Figs. 5B through 5D), the Left and Right image pulse (train) information may be of much larger widths. Consequently, thus the detection circuitry within the stereoscopic viewing glasses of the present invention can function at much slower clocking speeds and with battery life greatly increased. In order to accomplish the Left/Right Image Anticipation scheme at the transmitter, the transmitter processor must be capable of detecting the vertical refresh rate of the video transmission, determining the field identification for the present field (odd or even) and transmitting the field information of the next video field just prior to the end of the current video field being displayed, as shown at Blocks G-H and K-L of Fig. 3A. To accommodate the difference in TN LCD turn-on and turn-off times, the L/R pulse train width can be shifted within the video field. By carefully controlling the construction of the optical shutter and the characteristics of the pulse transitions, it is possible to create a universal stereoscopic viewing system with exceptionally long battery life.

For current computer systems the Video Graphics Adaptor (VGA) controls the video signals sent to the monitor. These signals consist of the horizontal sync pulse, the vertical sync pulse and the red, blue and green (RGB) video signals. The RGB signals vary depending on the image data to be displayed. The vertical and horizontal sync pulse timings vary depending on the resolution of the image being displayed.

The horizontal and vertical pulses dictate the scan rate of the display. The horizontal sync pulse occurs once every horizontal line. The vertical sync pulse occurs once every screen refresh period. Internal to the VGA is a horizontal scan line counter that is incremented by one on every horizontal sync pulse. When its value is equal to value loaded into the Vertical Total Register in the VGA control logic memory

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the scan line counter is reset to zero. Vertical events are driven when the scan line counter equals one of the values set in the relevant vertical registers. The basic events are vertical sync, display enable and vertical blanking. Each of these is represented in several of the VGA registers. The Vertical Total Register dictates how many scan lines are present on the screen. The vertical sync pulse begins when the scan line counter equals the value in the Vertical Start Register and ends when the scan line counter equals the value in the Vertical End Register. The vertical sync pulse signals the monitor to begin the display of a new image on the screen, sending the electron beam back to the top left corner of the display.

Proper control of these register values and subsequent sync pulse timings provides a basis for controlling a pair of LCD shutter glasses synchronized to sequentially displayed stereoscopic images. The display timings can be encoded in such a manner that one sync pulse condition can signify the display of right eye information and a second sync pulse condition will signify the display of left eye information. Proper encoding of the sync signals can therefore convey information to the optical shutters to remain in an optically clear non-shuttering state when 2D images are displayed or switch states in response to 3D stereoscopic pairs alternatively displayed on the monitor.

When displaying 2D images, the image data is written into a frame memory. The scan-line counter will automatically increment on each horizontal sync pulse. When the scan line counter equals the value in the Vertical Start Register the vertical sync pulse output changes state. The scan line counter continues to increment on each horizontal sync pulse. When the counter reaches the value stored in the Vertical End Register the vertical output returns to its initial state signifying the end
of the vertical sync period. Thus the vertical sync period may be any number of horizontal pulse wide and is completely under the control of the application program being executed.

If normal VGA timings are present, the same number of horizontal sync pulses will be present during every vertical sync period. The interval between vertical sync signals can be measured. A register in the field identification circuitry will be loaded with the frame rate information. The number of horizontal sync pulses during the vertical interval are counted by a pulse train counter and the outcome is compared with results obtained during the immediately preceding vertical sync period. By varying the number stored in the Vertical End Register the number of horizontal pulses occurring within a vertical sync period can be varied and thus contain discernable information to communicate frame identification. If subsequent vertical sync pulses contain the same number of horizontal pulses the 2D mode is identified and the shutters will be driven both open. If the number of horizontal pulses within the vertical sync period is made to increase or decrease by 1 in adjacent vertical periods, page flip 3D stereoscopic mode is identified and the shutters can be made to open or close in synchronization with displayed images.

Specifically, if the time between vertical sync pulses is monitored, information relating to frame rate can be measured. Since the TN shutters have a finite switching time this information is important in predicting and anticipating when the next frame of display information is to start. By counting the number of horizontal sync pulses present during a vertical sync period and comparing it to subsequent counts contained in adjacent vertical sync periods, information to identify frame information can be encoded and an appropriate sequence of
action be taken to ensure proper synchronization of the optical shutters and the displayed information.

The page flip mode will enable stereo pairs to be displayed and viewed at the nominal frame rate of the display. By enabling interlace mode, since alternating odd and even fields of the display are written sequentially, if odd line field contained for example the left eye perspective image and the even line field contains the right eye perspective image, stereo pairs can be viewed with this system at twice the frame rate which will essentially eliminate perceived flicker in the image by the observer. Since a half horizontal line shift is intrinsic to the interlace mode in VGA systems, to identify interlace mode if the horizontal sync pulses contained within the vertical sync period will vary in number by 1. Since this is the same condition created to detect the varying number of encoded sync pulses indicating page flipped stereo pairs, the exact circuitry can be utilized to operate in interlace mode to offer stereo viewing with minimum flicker.

Since the system hereof is capable of displaying stereo pairs from an interlace video format, it is also possible to input composite video from any standard NTSC or PAL video source such as a video cassette recorder or stereo camera. Composite video has field identification encoded in the seriation pulses present during the vertical retrace period. An odd number of seriation pulses indicates an odd field and an even number of seriation pulses indicates an even field. The composite video decoder circuit decodes the odd and even field information encoded in the composite video signals and creates a vertical sync and horizontal sync signal that mimics those present in VGA generated images. In this manner the same circuitry can be utilized for displaying stereo pairs from a standard video source.
The system hereof can be used to view two independent image streams from a single CRT or similar display device, either for the purpose of producing a single stereoscopic view or for the purpose of providing two individuals or groups the ability to view two different views. Images from the two image streams are time multiplexed on the display device, and then demultiplexed by means of electrically controlled optical shutters which are synchronized to the displayed images. In this way, each shutter transmits images from only one image stream, while blocking the other image stream.

Since the polarization axis of the LCD shutters can be oriented in opposing directions the viewing glasses may also be used in a passive state to view spatially multiplexed stereoscopic images. Such features make it possible for a viewer in a multi-format stereoscopic environment to view multiple forms of stereoscopic images with the same glasses.

Since the shutters used are TN LCD and not pi-cell technology, no background excitation voltage is needed to keep the shutters in the transmissive state. In this case since the polarizes inherently required in the structure of the optical state varying shutters are oriented orthogonally, they now function as passive polarized viewing glasses for viewing linearly polarized spatial multiplexed images.

If the two shutters are both synchronized to the same image stream, the user will see only that image stream. This mode, illustrated in Fig. 6B, would make it possible for two users or sets of users to view separate images on the same display, for the purpose of playing a head-to-head video game, for example. If the two shutters are synchronized to two different image streams, the user will view one image stream with one eye, and the other image stream with the other eye, allowing
the production of 3D stereoscopic images.

A further enhancement to the systems described herein is to provide a hardware line-blanking system which reduces the requirement on the software drivers, software applications, and video board display hardware.

This line blanking device of the present invention consists of a piece of hardware connected between a computer display adapter and it’s monitor, which accepts as input a non-interlaced video signal with associated horizontal and vertical sync signals, and outputs a modified video signal which alternately contains information either from the odd or even lines of the original signal and can optionally modify the color information to support various spectral and anaglyphic stereoscopic formats as illustrated in Figs. 8 through 11. This is done by allowing the video color and intensity information to pass through unaffected for one line, blanking that signal for the duration of the next line, passing the next line, blanking the next, and so on, thereby only displaying the information from the odd (or even) lines of the original video signal. During the next frame, the displayed and blanked lines would be swapped, thereby displaying the information from the even (or odd) lines of the original signal (see Fig. 8). The device could simultaneously modify the sync pulse widths to communicate information to the shutter glasses (signal) about which image (left or right) is currently being displayed.

There are many different ways to implement a device which would perform the functions described above. The most likely form of the invention would be as a “dongle” with male and female video ports on either end and some means of communication (wire, infrared, etc) linking the dongle to the LCD shutter glasses. The dongle device would
contain the necessary circuitry, which could be analog or digital, to toggle the video RGB signal lines on or off after each horizontal sync pulse.

The schematic drawing of Fig. 12 illustrates one possible implementation for the dongle device. In this illustrative embodiment, analog switches are connected to each of the three video data (RGB) lines, and these switches would be controlled by the output of a flip-flop. This flip flop would be toggled by each horizontal sync pulse. An additional flip-flop would be toggled by the vertical sync, and the output of this flip flop could be used to set or reset the first flip flop. The second flip-flop would control whether the odd or even lines were to be displayed, while the first flip-flop actually controlled whether each line was displayed or blanked (See Fig. 12). Of course, this same functionality could be achieved using a single chip computer or other method.

The schematic drawing of Fig. 9 illustrates another possible implementation of the dongle device, wherein line-alternate stereoscopic images are converted into spectrally multiplexed images. Instead of blanking lines as described above, the dongle system device blocks out specific color signals. The first time the line-alternate stereoscopic image passes through the dongle, the green color is removed from the right image lines and the red and blue colors are removed from the left image lines which produces the first field of a spectrally encoded stereoscopic image. The second time the line-alternate stereoscopic image passes through the dongle, the red and blue colors are removed from the right image lines and the green color is removed from the left image lines which produces the second field of a spectrally encoded stereoscopic image. This dongle system allows line-alternate
stereoscopic images to be easily converted into a spectral format which
will reduce the perceived flicker. Details regarding the spectral
multiplexing display process and the problems associated with spectral
flicker are disclosed in PCT Application Serial No. PCT/US96/09539 filed

The schematic drawing of Fig. 10A shown another possible
implementation of the dongle device, wherein line-alternate
stereoscopic images are converted into anaglyph stereoscopic images.
In a fashion analogous to that illustrated in Fig. 9, a line-alternate
stereoscopic image has its color components selectively removed or
summed to convert it to any of a number of anaglyphic formats. Fig.
10B shows a chart which lists the popular anaglyph formats which the
system of the present invention can support.

The schematic drawing of Fig. 11 shows another possible
implementation of the dongle device, wherein page flipped stereoscopic
images are converted into spectral stereoscopic images or anaglyph
stereoscopic images. For page-flipped stereoscopic images, from either a
computer display adapter or a video source, the right and left
stereoscopic image pairs are sequentially output to the display. There is
typically a special jack which is used to indicate whether a right or left
image is being output. Sometimes this signalling is encoded into the
video information either in the rgb lines or in the sync lines. When the
proposed device (or dongle) detects a right image, it modifies the color
of the image to encode the right view in anaglyph or spectral formats.

When the dongle device detects a left image, it modifies the color of the
image to encode the left view in anaglyph or spectral formats. The
specific color mappings used depend on the particular spectral or
anaglyph format, well known by those skilled in the art. In addition to
being implemented as an external device, the dongle device can also be implemented as an analog device after the computer card DAC or as a digital device before the computer card DAC.

The systems described above are not limited to computer display systems but can also be applied to component video systems and composite systems which are converted into component formats for TV and video monitor applications.

If a narrow band retardation element is introduced anywhere along the optical path between the pre-polarizers (19) and post polarizers (20) of the cell shown in Fig. 1B, then the cell can be converted to a spectral decoding cell. The narrow band retardation element allows selected wavelengths of light to be rotated 90 degrees (orthogonally). By selecting red, green, or blue components this narrow band retardation element will allow this cell configuration to decode spectral multiplexing. If the TN cell is in the normal state, then light passing through it will have its red and blue components polarized in state P1 (for example) and its green component polarized in state P2. This selective rotation of the green component is achieved by the incorporation of the narrow band retardation element described above.

If the TN cell is in the energized state (i.e. a voltage is applied), then light passing through it will have its red and blue components rotated to polarization state P2 and its green component rotated back to polarization state P1 by the narrow band retardation element described above.

The present invention has been described in great detail with reference to the above illustrative embodiments. It is understood, however, modifications to the illustrative embodiments will readily occur to persons with ordinary skill in the art. All such modifications
and variations are deemed to be within the scope and spirit of the present invention as defined by the accompanying Claims to Invention.
CLAIMS TO INVENTION:

1. A stereoscopic 3-D image viewing system for stereoscopically viewing 3-D images displayed on either a CRT computer or video display device.

2. The stereoscopic 3-D image viewing system of claim 1, wherein stereoscopic 3-D shutter-type viewing glasses are used to view stereoscopic image pairs displayed on a CRT computer or video display device according the time-multiplexing display technique.

3. The stereoscopic 3-D image viewing system of claim 1, signal decoding and processing is minimized within the stereoscopic 3-D shutter-type viewing glasses in order to reduce the cost of manufacture thereof, while providing extended battery life.

4. A stereoscopic 3-D image viewing system for stereoscopically viewing 3-D images displayed on either a CRT computer or video display device.

5. The stereoscopic 3-D image viewing system of claim 4, wherein a pair of lightweight stereoscopic 3-D shutter-type viewing glasses are used to view stereoscopic image pairs displayed on a CRT computer or video display device according the time-multiplexing display technique.

6. The stereoscopic 3-D image viewing system of claim 4, wherein signal decoding and processing is minimized within the stereoscopic 3-D shutter-type viewing glasses in order to reduce the cost of manufacture thereof, while providing extended battery life.
7. The stereoscopic 3-D image viewing system of claim 4, wherein a pair of LCD shutter glasses having a passive mode of operation for use in decoding micropolarized spatially-multiplexed images displayed from an spatially-multiplexed image display system.

8. The stereoscopic 3-D image viewing system of claim 4, wherein a means is provided for detecting stereoscopically-encoded video synchronization signals from a computer or other video source and transmitting field information for controlling remote pairs of optical state varying LCD shutters via pulse width modulated infrared pulses.

9. The stereoscopic 3-D image viewing system of claim 4, wherein one shutter switches to the transmissive state while the other shutter switches to the opaque state synchronized to a specific field of information displayed on the CRT or display device.

10. The stereoscopic 3-D image viewing system of claim 4, which has a display mode that allows two viewers, wearing two separate pairs of LCD glasses to view two separate images simultaneously on the same display screen, thereby allowing the two viewer to play a head-to-head video game on the same viewing screen without interference.

11. The stereoscopic 3-D image viewing system of claim 5, wherein the polarization axis of the LCD shutters glasses can be passively oriented in opposing directions and thus be used as a pair of electrically-passive polarizing glasses to stereoscopically view spatially multiplexed images (SMI).
12. The stereoscopic 3-D image viewing system of claim 4, which has several different modes of operation which make it possible for a viewer, in a multi-format stereoscopic environment, to view a variety of stereoscopic images with the same viewing glasses.

13. A method of generating synchronization signals for use in a stereoscopic viewing system which employs low cost, twisted nematic (TN) liquid crystal (LC) displays as the optical shutters, and control signals adjusted for the slower transition times and inherent process variations associated with the optical shutters.

14. A device for generating synchronization signals for use in controlling a pair of remote shutter glasses, said device comprising:
   means for detecting interlaced and non-interlaced modes in computer generated or standard video signals, and
   means for transmitting shutter control signals via an infrared link to said remote shutter glasses.

15. A device for generating synchronization signals for use in controlling optical shutters constructed from twisted nematic (TN) liquid crystal (LC) display panels having an optically transparent state and an optically opaque state, said synchronization signal generation system comprising:
   means for generating synchronization control signals; and
   means for adjusting said synchronization control signals to the slower transition times and inherent process variations associated with said optical shutters without the use of any background excitation
voltage while said optical shutters are operated in their optically transparent state.

16. A pair of battery-powered shutter glasses comprising:
   a pair of optical shutters having an optically transparent state and an optically opaque state, wherein each said optical shutter is formed from a twisted nematic (TN) liquid crystal (LC) display panel that does not require any background excitation voltage while said optical shutter is operated in its optically transparent state, thereby increasing battery life.

17. The pair of battery-powered shutter glasses of claim 16, which further comprises:
   shutter drive circuitry that is disposed into a sleep-mode until a change of optical state is required by said optical shutters, thereby substantially increasing battery life.

18. A shutter-based stereoscopic 3-D viewing system, comprising:
   a pair of optical shutters glasses;
   a synchronization signal transmitter having a multi-synch detection capability for interpreting both interlaced and non-interlaced video conditions; and
   means for generating synchronization signals and transmitting the same to said optical shutters glasses for controlling the optical state thereof.

19. A universal multi-sync signal detection device for use with a pair of remote viewing glasses having optical shutters, said universal
multi-sync signal detection device comprising:

means for detecting synchronization signals, polarities and
frequencies present in all VGA and SVGA video formats, as well as, NTSC
and PAL composite video sources;

means for determining the image field rate from said
synchronization signals;

means for determining the presence or absence of stereoscopically
encoded video signals; and

means for transmitting the appropriate signals for controlling the
optical shutters in said remote viewing glasses.

20. Shutter glasses for use with a control device that produces pulse
width modulated IR shutter control pulses, said shutter glasses
comprising:

a pair of optical shutters; and

decoding circuitry for detecting the presence of pulse width
modulated IR shutter control signals, recognizing a difference between
two adjacent pulses therein and setting the corresponding optical state
of said optical shutters.

21. Shutter glasses for use with a control device that produces IR
shutter control pulses, said shutter glasses comprising:

a pair of optical shutters; and

decoding circuitry which, when detecting no difference between
two adjacent IR control pulses, automatically determines that a
non-interlaced video condition exists and places both of said optical
shutters in the optically transmissive state indicating a non-stereoscopic
video image is to be viewed.

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22. Shutter glasses for use with a control device that produces shutter control pulses having alternating pulse widths of two predetermined lengths, said shutter glasses comprising:
   a pair of LCD-type optical shutters; and
   decoding circuitry which, when detecting alternating pulse widths of two predetermined lengths, automatically determines that an interlace condition exists, and simultaneously alters the optical state of the LCD-type optical shutters at the corresponding video field rates for viewing stereoscopic video images.

23. Shutter glasses for use with a control device that produces IR shutter control pulses, said shutter glasses comprising:
   a pair of optical shutters; and
   decoding circuitry which, when detecting no IR shutter control pulses, automatically enters a sleep mode which will place both optical shutters in the optically transmissive state.

24. Shutter glasses comprising:
   a pair of optical shutters having an optically opaque state and an optically transmissive that does not require any background excitation voltage.

25. Shutter glasses comprising:
   a pair of optical-state varying shutters having an electrically-passive transmissive state,
   wherein the polarization state of the optical-state varying shutters are oriented orthogonally when operated in their electrically-passive
transmissive state, for use in stereoscopically viewing linearly polarized spatial multiplexed images.

26. A stereoscopic 3-D image viewing system based on the spatially-multiplexed image (SMI) display format, comprising:
   a pair of optical shutter glasses having an electrically-passive transmissive state, wherein linearly micropolarized polarized SMIs displayed from an LCD panel can be stereoscopically viewed therethrough.

27. A system which uses vertical retrace pulse signaling or other signalling on different video signal lines to differentiate between the right and left images (signalling to the glasses and/or xmitter).

28. Anticipation circuitry in combination with battery-powered shutter glasses having a pair of optical shutters, said anticipation circuitry comprising:
   means for determining when to change the state of said optical shutters in order to minimize the consumption of battery power.

29. A pair of 3-D shutter glasses capable of supporting spectral multiplexing for all video formats.

30. A system which works in both wireless and wired modes for all techniques mentioned above.

31. A pair of multi-mode shutter glasses comprising:
a first mode of operation for supporting passive viewing;
a second mode of operation for supporting time sequential viewing; and
a third mode of operation for supporting spectral shuttering.

32. The multi-mode shutter glasses of claim 31, which further comprises:
a fourth mode of operation for supporting or anaglyph viewing.

33. The multi-mode shutter glasses of claim 32, which further comprises: a fifth mode of operation for supporting head-to-head viewing.

34. A system for 3-D stereoscopic viewing comprising:
means for converting page-flipped or line-alternate stereoscopic image formats into time sequential spectral or anaglyph stereoscopic formats.

35. A system for 3-D stereoscopic viewing comprising:
means for carrying out line-blanking in order to reduce software and video card requirements of said system.

36. A stereoscopic 3-D viewing system comprising:
portable electro-optical viewing glasses; and
shutter-state control signal transmitter having multiple modes of operation for stereoscopic viewing of 3-D images displayed in different stereoscopic image formats.
37. A line-blanking device connectable between a computer display adapter and a monitor, for use in connection with shutter glasses, said hardware line-blanking device comprising:

means for accepting as input, a non-interlaced video signal with associated horizontal and vertical sync signals; and

means for outputting a modified video signal which alternately contains information either from the odd or even lines of the non-interlaced video signal.

38. The line-blanking device of claim 37, which further comprises:

means for modifying the color information of said non-interlaced video signal in order to support various spectral and anaglyphic stereoscopic formats.

39. The line-blanking device of claim 38, which comprises:

means for allowing the video color and intensity information of said non-interlaced video signal to pass through unaffected for one line;

means for blanking said non-interlaced video signal for the duration of the next line;

means for passing the next line of said non-interlaced video signal, blanking the next line thereof, and so on, thereby only displaying the information from the odd (or even) lines of said original non-interlaced video signal; and

means for displaying the information from the even (or odd) lines of the original non-interlaced signal during the subsequent display frame.
40. The line-blanking device of claim 38, which further comprises:
means for simultaneously modifying the sync pulse widths in
order to communicate information to said shutter glasses about which
image (left or right) is currently being displayed.
(Same system as shown in Figure 1B with the addition of the narrow band retardation element indicated by the star "**")

Figure 1C.
FIG. 3A
Interface encoding of VGA vertical timing illustrating the use of the standard half line offset present in interface signals to identify start of right and left stereoscopic displayed images. Choice of which image follows the longer sync pulse is irrelevant.

FIG. 5B
Page flip encoding of VGA vertical timing to identify start of right and left stereoscopic displayed images. Choice of which image follows the longer sync pulse is irrelevant.

since $T_1 > T_2$, left eye follows even here, right eye follows after $T_2$. 

= the Y axis (controlled manually in VGA code)
(Whole page is drawn)

Vertical Sync

Sync 1

Display Image Right

Sync 2

Display Image Left

Horizontal Sync

Pulse Count

L-Pulse Train

1-Pulse Train

Delay

Delay

Since $T_s$, $T_2$,
- Left Image follows even HREF,
- Right Image follows odd HREF,
- Use PHASE (Constant signal on VDC cycle)

FIG 52
Fig. 6A: "3-D View Mode" with PZ, P1, Q1, and Q2

Fig. 6B: 2-D View Mode with L=1, R=1

Fig. 6C: Field-Sequential 3-D View Mode with L=0, R=1 and L=1, R=0
Proposed Device

Example of "color" anaglyph conversion - assumes red filter over left eye and blue/orange filter over right eye.

<table>
<thead>
<tr>
<th>Display Adapter or Video Output</th>
<th>Right Image (rgb colors)</th>
<th>Left Image (rgb colors)</th>
<th>Right Image (rgb colors)</th>
<th>Left Image (rgb colors)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image on Monitor</td>
<td>Right Image (blue and green color)</td>
<td>Left Image (red color)</td>
<td>Right Image (blue and green color)</td>
<td>Left Image (red color)</td>
</tr>
</tbody>
</table>

Figure 10A.
Chart showing various Anaglyph mapping techniques

The equations show how the colors in the input images from the display adapter or video output are converted to colors in the actually displayed image. The mappings listed below assume that the red filter of the anaglyph glasses is over the left eye and that a blue or green filter is over the right eye. If the anaglyph glasses are reversed (red filter over right eye) than the mappings must be suitably adjusted - i.e. the red entries are flipped with the blue/green entries.

**For full color anaglyph conversion, the mappings are:**

\[
\begin{align*}
\text{Red(output)} &= \text{Red(left)} \\
\text{Green(output)} &= \text{Green(right)} \\
\text{Blue(output)} &= \text{Blue(right)}
\end{align*}
\]

**For full grey anaglyph conversion, the mappings are:**

\[
\begin{align*}
\text{Red(output)} &= \frac{\text{Red(left)} + \text{Green(left)} + \text{Blue(left)}}{3} \\
\text{Green(output)} &= \frac{\text{Red(right)} + \text{Green(right)} + \text{Blue(right)}}{3} \\
\text{Blue(output)} &= \frac{\text{Red(right)} + \text{Green(right)} + \text{Blue(right)}}{3}
\end{align*}
\]

**For pure anaglyph conversion for red/blue glasses, the mappings are:**

\[
\begin{align*}
\text{Red(output)} &= \frac{\text{Red(left)} + \text{Green(left)} + \text{Blue(left)}}{3} \\
\text{Green(output)} &= \text{no green value} \\
\text{Blue(output)} &= \frac{\text{Red(right)} + \text{Green(right)} + \text{Blue(right)}}{3}
\end{align*}
\]

**For pure anaglyph conversion for red/green glasses, the mappings are:**

\[
\begin{align*}
\text{Red(output)} &= \frac{\text{Red(left)} + \text{Green(left)} + \text{Blue(left)}}{3} \\
\text{Green(output)} &= \frac{\text{Red(right)} + \text{Green(right)} + \text{Blue(right)}}{3} \\
\text{Blue(output)} &= \text{no blue value}
\end{align*}
\]

(Note: for all mappings which average red, green, and blue components together, other linear combinations of the three colors can be used to compensate for the eye's sensitivity to various colors for example)

**Figure 10B.**
Figure 12.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJERT MATTER
IP(C):G02B 27/22; H04N 13/04; H04N 15/00
US CL:359/464, 465; 348/43, 56, 58
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S.: 359/464, 465; 348/43, 56, 58

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
348/55, 57

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
APS icd, shutter, passive, pulse width modulat?

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X A</td>
<td>US 3,737,567 A (KRATOMI) 05 June 1973 (05.06.73), see entire document.</td>
<td>1-6, 9, 12-16, 24</td>
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<td>7, 8, 10, 11, 17-23, 25-29, 31-40</td>
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<tr>
<td>X A</td>
<td>US 5,193,000 A (LIPTON ET AL) 09 March 1993 (09.03.93), see entire document.</td>
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</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
* A* document defining the general state of the art which is not considered to be of particular relevance
* E* earlier document published on or after the international filing date
* L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
* O* document referring to an oral disclosure, use, exhibition or other means
* P* document published prior to the international filing date but later than the priority date claimed
* T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
* X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
* Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

Date of the actual completion of the international search
01 AUGUST 1997

Date of mailing of the international search report
09 SEP 1997

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
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JON W. HENRY
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Form PCT/ISA/210 (second sheet) (July 1992)
## INTERNATIONAL SEARCH REPORT

### DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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</thead>
<tbody>
<tr>
<td>X, P</td>
<td>US 5,523,886 A (JOHNSON-WILLIAMS ET AL) 04 June 1996 (04.06.96), see entire document.</td>
<td>1-4, 12</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>5-11, 13-29, 31-40</td>
</tr>
</tbody>
</table>
INTERNATIONAL SEARCH REPORT

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. □ Claims Nos.: 30
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. □ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

□ The additional search fees were accompanied by the applicant's protest.

□ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet(1))(July 1992)