Intelligent and Green Energy LED Backlighting Techniques of Stereo Liquid Crystal Displays

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1. Introduction

As modem society has been reshaped rapidly into the multimedia information society, large size of display devices is required. Thin-film-transistor liquid- crystal-displays (TFT-LCDs) are one of the most popular display devices from small to large size. TFT-LCDs need backlight source, because they are not a self luminance device. Backlight for LCDs is becoming more important with growth of the LCD size. Up to now, multiple fluorescent lamps such as cold cathode fluorescent lamp (CCFL), external electrode fluorescent lamp (EEFL) and flat fluorescent lamp (FFL) are generally used as LCD backlight source. Since, the conventional backlight of LCDs illuminates at the full luminance regardless of the images to be displayed, it wasted power and contrast ratio is row due to the light leakage in dark state.

Recently, as the luminance efficiency of light emitting diode (LED) has been improved and the cost of LED is going down, the LED is the substitutive solution for the backlight source. Moreover, since LED has many advantages such as long lifetime, wide color gamut, fast response, and so on, LEDs are expected to replace the conventional fluorescent lamps for backlight source of LCD in near future. Although, LED backlight driving systems have been developed and introduced to the market, further reduction of power consumption and cost reduction are still demanded to be widely used as backlight source. In segmented dimming and local dimming methods which have usually adapted to CCFL and LED backlight source, the whole backlight is divided into several segmented and block, backlight scaling is adapted to each segmented and block, respectively. The more division of backlight, the more power saving can be achieved. Therefore, local dimming method can save power consumption more effectively than segmented dimming one. Especially, segmented dimming method has limitation of power saving when the image is bright vertically. Therefore, local dimming is the best way to have local dimming effects. However, local dimming method results in huge increase in the number of drivers needed for large number of division. To compromise between segmented dimming and local dimming methods, a new LED backlight system for LCD TVs which involves the time division X-Y segmented driving method that utilizes row and column switches to control the individual division screen is proposed.

Even though the refresh time of an LCD panel is as fast as a CRT display, there are still some problems to be solved before this LCD panel can be implemented to be a time-multiplexed stereo display, vision and panel seem to be redundant. First of all, LCD is a hold-type display, which is different from the impulse operation type of CRT. This has been a very good property of an LCD while it works at 2D display mode because it can avoid blinking or flickering at the refresh rate of 50 or 60 Hz. For a CRT display, viewers will still experience slight image flickering at the refresh rate of about 60Hz. Nevertheless, while working in 3D page-flipping mode and watched through shutter glasses, the hold-type operation causes a problem.

When the left-image begins to fill out the pixels, the left-eye shutter opens immediately. However, at this moment and the following 1/120 sec., the left-image at the upper part of the screen becomes more and more image area of screen, the right-image at the lower part of the screen becomes less and less image area of screen. That means, the viewer will see both images at the same time through his right eye. This situation will induce strong double image (or crosstalk) and destroy the 3D perception seriously.

1.1 Intelligent and green energy LED backlighting techniques

1. Scanning backlight method. The setup is as following:
   The backlight unit is separated into several regions. Let’s take 4 segmented regions as the example as in Fig.1. the pixel response time is less than three fourths of the frame time when the illumination period is one quarter of the frame time. Arranging for the required illumination period to end just before the new image is written into the panel provides the most relaxed requirement for panel response time; i.e., the response time can be longer (Fig. 1). A novel controlled circuit architecture of scanning regions for 120Hz high frequency and high resolution stereoscopic display is shown in Fig.2. Setup all the parameters of scanning backlight method by counting the amount to decide turning time between 4-regions 、and 2-regions LED backlight type. If counted times equal to 100 then jump to next backlight segmented region.
   For 4-region scanning backlight method, when the panel is filled in segmented regions 1, 2, 3 and 4 by the new image, the backlight lights up are in the corresponding regions 4, 1, 2 and 3. In anticipation of an image for a left eye and right eye is shown in the region 1 of the panel, we turned on region 3 of the backlight unit. Analogize the image shown in region 2 and turned on region 4 of the backlight unit. For 2-region scanning backlight method, when the panel is filled in regions 1 and 2 by the new image, the backlight lights up in the corresponding regions 2 and 1. For avoiding seeing both L-image and R-image at the same time, the backlight regions R1 have to be off until R1 filled up the image. Analogize the backlight regions R2 have to be off until R2 filled up the image.
2. In backlight strobe method as shown in Fig.3, Setup the parameters of backlight strobe method by counting the amount to decide turning on time of full screen (full screen of one frame 1/120sec counted amount equal to 400). Setup the parameters of backlight strobe duty time by counting the amount to decide turning time on full screen backlight regions. If counted times equal to (400 - 400*9/10) then jump to next full screen backlight region. The backlight is turned off when the image data refreshes. The backlight only turns on at the system time, or at most a little bit longer than the system time. But the system time is short compared with the time between two adjacent vertical synchronization signals (less than 10%), the display brightness operated under this method is probably quite small.

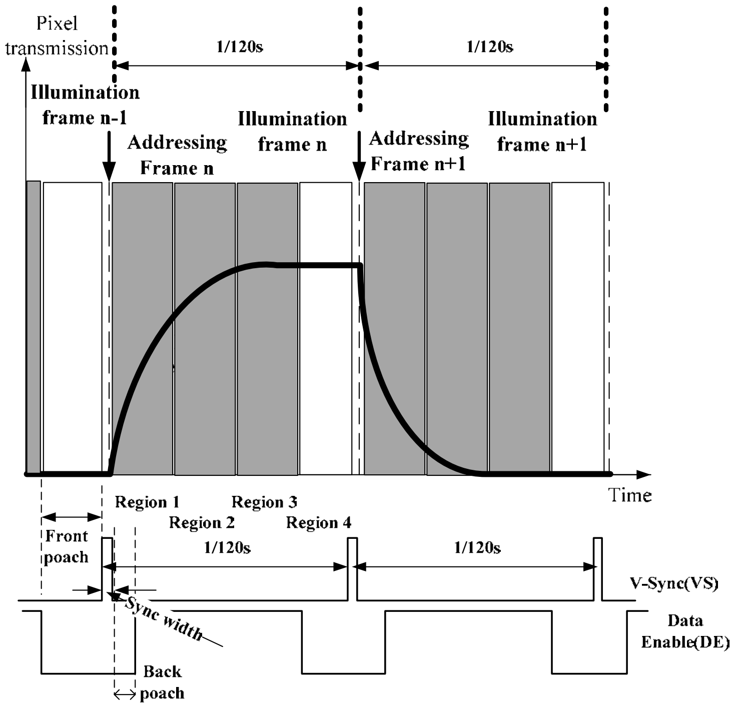


Fig. 1. Schematic diagram of scanning backlight method

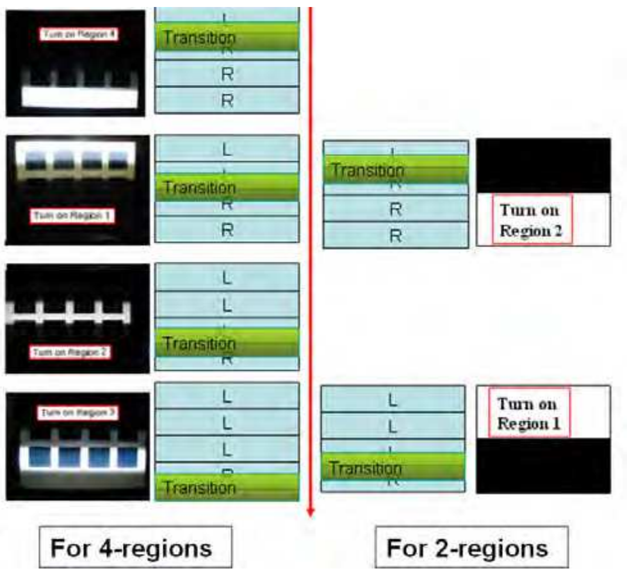


Fig. 2. Synchronization Signal LED backlight architecture

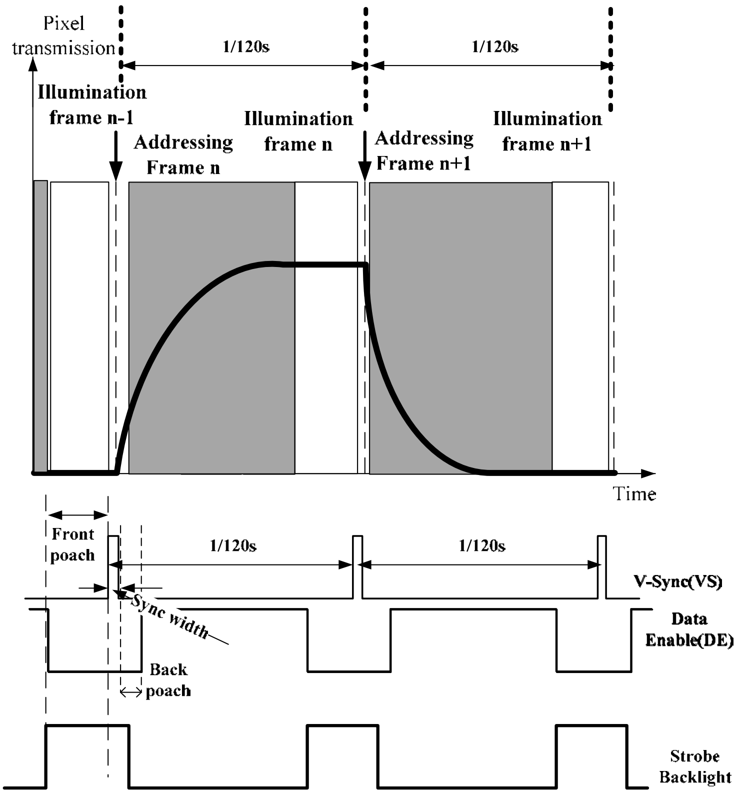


Fig. 3. Time scheme of backlight strobe method

In this research, we have successfully designed and demonstrated a decent performance with 120Hz optimized synchronization signal between LED brightness/darkness flash and adjusted shutter glasses signal. It has been demonstrated that the 120Hz scanning characteristic from upper row to lower row of the horizontally arranged of stereoscopic image. A quadrate image for a left eye is projected by the light from the left eye image file and a circle image for a right eye is projected by the light from the right eye file through a liquid crystal panel.

LED scanning backlight stereoscopic display with shutter glasses is provided to realize stereoscopic image viewing even in a liquid crystal display. In a frame time, some kinds of brightness/darkness characteristic from upper row to lower row of the horizontally arranged rows of LED in the backlight module, cooperating with the scanning of the LCD, to thereby realize an effect similar to scanning. The general strategy that we employ is to integrate all relatively small-signal electronic functions into one ASIC to minimize the total number of the components. This strategy demonstrates that both the cost is lowered and the amount of the printed circuit board area is reduced. Based on this concept, a smart three dimensional multiplexed driver for LED switching chip with more than 640 LEDs are proposed and the circuit architecture is shown in Fig. 4. It is difference from the traditional two dimensional arrays driven by scanning scheme. Three lines are employed to control one LED, including voltage, shift register, and data line. Each LED requires a voltage line for the

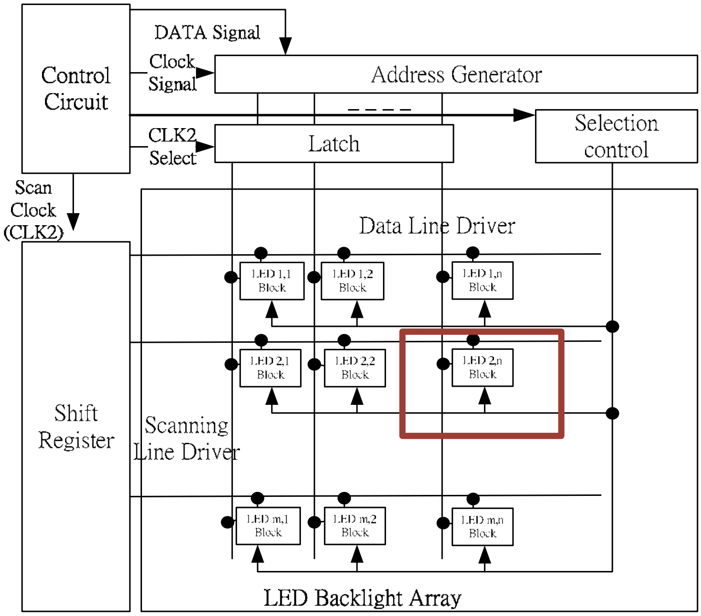


Fig. 4. Block diagram of control algorithm for LED backlight array module

driving current and shares the same ground with the other resistors. The resistors are individually addressable to provide unconstraint signal permutations by a serial data stream fed from the controller. The shift register is employed to shift a token bit from one group to another through AND gates to power the switch of a LED group. The selection of a LED set is thus a combined selection of the shift register for the group and the data for the specific LED. Such an arrangement allows encoding one data line from the controller to provide data to all of the LEDs, permitting high-speed scanning by shortening the LED selection path and low IC fabrication cost from the greater reduction of circuit component numbers.

2. 3D display backlight and application

Throughout the proposed system, lower power consumption are successfully obtained as well as high contrast ratio even with less number of drivers than that of conventional local dimming method. This chapter also contains a new adaptive dimming algorithm and image processing technique for the proposed stereo LCD backlight system.

Recent progress in stereo display research has led to an increasing awareness of market requirements for commercial systems. In particular areas of display cost and software input to the displays are now of great importance to the programme. Possible areas of application include games displays for PC and arcade units; education and edutainment; Internet browsing for remote 3D models; scientific visualisation and medical imaging.

Intelligent and green power LED backlighting techniques of two-dimensional (2D) to three-dimensional (3D) convertible type, shutter glasses type, mult-view time multiplexed naked eye type, and multi-viewer tracking type for stereo liquid crystal displays are shown as follows.

2.1 Two-dimensional (2D) to three-dimensional (3D) convertible display

Convertible two-dimensional-three-dimensional display using an LED array based on modified integral imaging as shown in Fig.5. This type propose a two-dimensional (2D) to three-dimensional (3D) convertible display technique using a light-emitting diode (LED) array based on the principle of modified integral imaging. This system can be electrically converted between 3D and 2D modes by using different combinations of LEDs in the LED array without any mechanical movement. The LED array, which is controlled electrically, is used for backlight, and a lens array is used for making a point light source array with higher density. We explain the principle of operation and present experimental results.

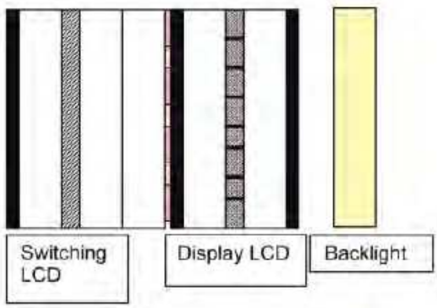


Fig. 5. Display configuration

2.2 Shutter glasses type stereoscopic displays

This type proposes to employ multi-dimensional controller for driving LED backlight scanning in a 120Hz LCD for overcoming the hold-type characteristic of an LCD in time-multiplexed stereoscopic displays. A synchronization signal circuit is developed to connect the time scheme of the vertical synchronization for reducing scanning time. The general strategy is to integrate three dimensional controller and all relatively small-signal electronic functions into one ASIC to minimize the total number of the components. The display panel, LED backlight scanning, and shutter glass signals could be adjusted by vertical synchronization and modulation to obtain stereoscopic images. Each row of LED in a backlight module is controlled by multi-dimensional data registration and synchronization control circuits for LED backlight scanning to flash in bright or dark. LED backlight scanning stereoscopic display incorporated with shutter glasses is provided to realize stereoscopic images even viewed in a liquid crystal display as shown in Fig.6. The eye shutter signal is alternately switched from the left eye to the right eye with 120Hz of LCD Vertical synchronization (V-sync). This kind of low cross-talk shutter glasses stereoscopic display with an intelligent multiplexing control of LED backlight scanning has low cross-talk below 1% through a liquid crystal shutter glasses.

2.3 Multi-view time multiplexed autostereoscopic displays

Three-dimensional displays which create 3D effect without requiring the observer to wear special glasses are called autostereoscopic displays. A number of techniques exist – parallax barriers, spherical and lenticular lenses, the latter being the most common one. Depending on the design parameters, various tradeoffs between screen resolution, number of views and optimal observation distance exist. The most popular ones, so called multiview 3D displays,

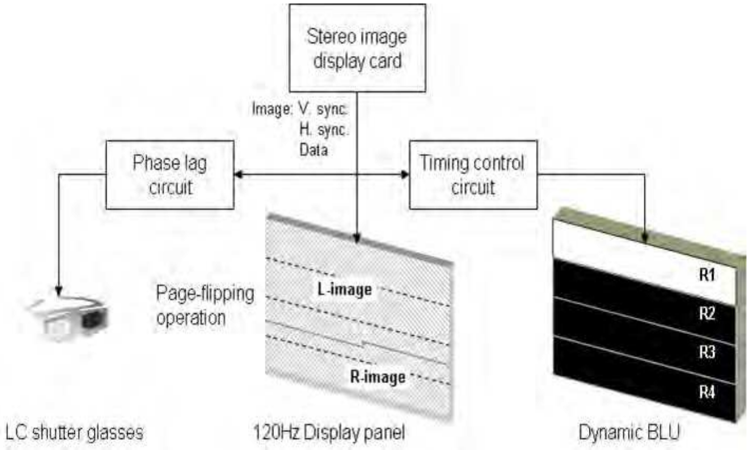


Fig. 6. Schematic diagram of dynamic backlight method

work by simultaneously showing a set of images ("views"), each one seen from a particular viewing angle along the horizontal direction. Such effect is achieved by adding an optical filter, which alters the propagation direction for the information displayed on the screen.

Currently, several 2D/3D switched displays had been proposed such as switched barrier and LC-lens. However, both of the parallax barrier and the cylindrical lens arrays still has the issues of narrow viewing angle and low resolution when displaying the 3D images. Besides, in order to balance the horizontal versus vertical resolution of an autostereoscopic a display, a slanted lens array is used. This causes the high crosstalk of stereo display and the subpixels of a view to appear on nonrectangular grid. This type describes the work aimed at developing optical system; active barrier dynamic backlight slit multi-view full resolution and lower crosstalk 3D panel as shown in Fig.7. The panel of 240Hz displays the corresponding images of the four viewing zones by the same time sequence according to temporal multiplexed mechanism.

All modern multiview displays use TFT screens for image formation. The light generated by the TFT is separated into multiple directions by the means of special layer additionally mounted on the screen surface. Such layer is called "optical layer", "lens plate" and "optical filter". A characteristic of all 3D displays is the tradeoff between pixel resolution (or brightness or temporal frequency) and depth. In a scene viewed in 3D, pixels that in 2D would have contributed to high resolution are used instead to show depth. If the slanted lenticular sheet were placed vertically atop the LCD, then vertical and horizontal resolution would drop by a factor equal to the number of views.

This type addresses the specific technological challenges of autostereoscopic 3D displays and presents a novel optical system that integrates a real-time active barrier dynamic backlight slit system with a naked eyes multi-view stereo display. With 240Hz display and tunable frequency LED backlight slits, only a pair of page-flipped left and right eye images was necessary to produce a multi-view effect. Furthermore, full resolution was maintained for the images of each eye. The loading of the transmission bandwidth was controllable, and the binocular parallax and motion parallax is as good as the usually full resolution multi-view autostereo display.

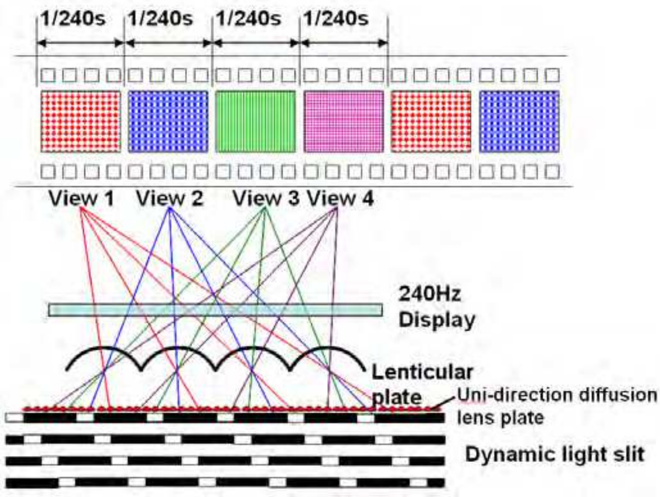


Fig. 7. The structure of the proposed multi-view 3D display

A lenticular-based 3D display directs the light of neighboring sub-pixels into different directions by means of small lenses placed immediately in front of the sub-pixels. In this manner different pictures can be transmitted into different directions. Usually a multitude of directions is chosen, e.g. 4 different views. Two of these views can be seen by the left and right eye respectively, and as such create a stereoscopic (3D) image. Fig.7. shows the structure of the proposed multi-view 3D display. Only one eye individually receives the image at one corresponding viewing zone at its displaying time period, such as 1/240 second. As a result, the 3D image can be created for the viewer by naked eyes. Each view is 60Hz.

2.4 Multi-viewer tracking stereoscopic display

Many people believe that in the future, autostereoscopic 3D displays will become a mainstream display type. Achievement of higher quality 3D images requires both higher panel resolution and more viewing zones. Consequently, the transmission bandwidth of the 3D display systems involves enormous amounts of data transfer. This type integrated a viewer-tracking system and a synchro-signal LED scanning backlight module with an autostereoscopic 3D display to reduce the crosstalk of right/left eye images and data transfer bandwidth, while maintaining 3D image resolution. Light-emitting diodes (LED) are a dot light source of the dynamic backlight module as shown in Fig.8. When modulating the dynamic backlight module to control the display mode of the stereoscopic display, the updating speed of the dynamic light-emitting regions and the updating speed of pixels were synchronal. For each frame period, the viewer can accurately view three-dimensional images, and the three-dimensional images displayed by the stereoscopic display have full resolution. The stereoscopic display tracks the viewer's position or can be watched by multiple viewers. This type demonstrated that the three-dimensional image displayed by the stereoscopic display is of high quality, and analyzed this phenomenon. The multi-viewer tracking stereoscopic display with intelligent multiplexing control of LED backlight scanning had low crosstalk, below 1%, when phase shift was 1/160s.

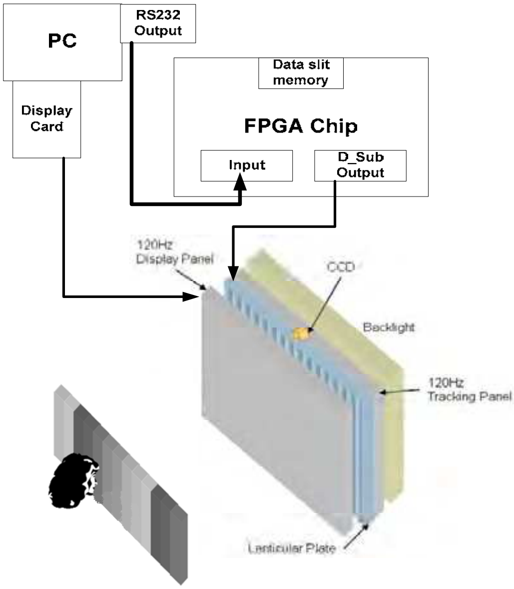


Fig. 8. Viewer-tracking 3D display system

Due to the LCD with physical delay characteristic (low response speed), both images are alternately switched from one to the other by switching the light emitting full panel. Thus, stereoscopic images are shown to a viewer. As a result, all kinds of low cross-talk stereoscopic display with an intelligent multiplexing control LED scanning backlight have low crosstalk below 1% through a liquid crystal display.
Intelligent and green energy LED backlighting techniques of stereo liquid crystal displays have been successfully designed and demonstrated a decent performance of all kinds of stereo types display system with optimized synchronization signal between LED brightness/darkness flash and adjusted driving signal enabled by a 3-Dimensional controlling IC. At high scanning rate from upper row to lower row, the system demonstrated horizontally arranged clear stereoscopic images. This method of backlighting also allows dimming to occur in locally specific areas of darkness on the screen. This can show truer blacks and whites at much higher dynamic contrast ratios, at the cost of less detail in small bright objects on a dark background, such as star fields.

3. Experimental and results

3.1 Two-dimensional (2D) to three-dimensional (3D) convertible display

As LED backlight of flat panel display become large in format, the data and gate lines turn into longer, parasitic capacitance and resistance increase, and the display signal is delayed. Three dimensional architecture of multiplexing data registration integrated circuit method is used that divides the data line into several blocks and provides the advantages of high accuracy, rapid selection, and reasonable switching speed.
The design concept can be easily scaled up for large LED backlight array format TFT-LCD elements system without much change in the terminal numbers thanks to the three

dimensional hierarchy of control circuit design, which effectively reduces the terminal numbers into the cubic root of the total control unit numbers and prevent a block defect of the flat panel. The TFT-LCD unit lights, line(s) in the vertical or horizontal axis appear dim, but not completely on or off. These defects are generally the result of a failure in the row (horizontal) or column (vertical) drivers or their connections. The TFT-LCD includes an extension part defect such as an extension piece overlapping with a pixel electrode of boundary pixels at a boundary data line applying a data signal to the boundary pixels.

3.1.1 Experimental results and discussion

A LED backlight of flat panel display with three dimensional architecture of multiplexing data registration integrated circuit having a plurality of scanning electrodes, a plurality of data electrodes extending perpendicularly to the scanning electrodes, and liquid crystal filling a space between the scanning electrodes and data electrodes, pixels being formed at each intersection of the scanning and data electrodes together with the liquid crystal, the display panel being divided into an even row part and a odd row part; a scanning control circuit for scanning the scanning electrodes by sequentially supplying scanning voltages to each scanning electrode and by maintaining the same for a predetermined period, the scanning electrodes located in the even row part of the panel and the scanning electrodes located in the odd row part being scanned separately but simultaneously in the same directions from upper to lower of the panel; an image data control circuit for sequentially supplying image data voltages to the data electrodes in synchronism with scanning of the scanning electrodes, the scanning electrodes are scanned in such a manner that the image data is written on the pixels in a selecting period, the written image data is held on the pixels in a holding period and the image data is eliminated in an eliminating period; In traditional control circuit design for TFT-LCD elements array system, each TFT-LCD element requires one driver switch. As a result, when the TFT-LCD backlight of LEDs' pixels scale up into a large array, the numbers of input/output ports will increase enormously. To handle large array of driving circuits for such large pixels array, 2D circuit architecture was employed for the traditional driving circuit to reduce the IO number from n*n into 2n+1. However, firstly, this reduction still can not meet the requirement for high speed signal scanning with low data accessing points when switch numbers greater than 640×480 pixels. It would be necessary to increase the display frequency to 240 Hz or higher to eliminate flicker. If the display frequency is 240 Hz, a period of time for writing one frame is 4.17 ms. Assuming the number of scanning electrodes is 480, a period of time available for writing one line is only 8.7 microseconds. The number of scanning electrodes has to be larger than 480 to display a high resolution image, making the writing period further shorter. Secondly, no technology is ever completely perfect, of course, and the LCD can still suffer from some defects in the displayed image. In this technology, though, most defects in the basic electronics, such as failure of the backlight or the row or column drivers, result in a completely unusable display, and so when such occur in production they are easily detected and corrected. It is extremely rare for a product to ship with any such problems.

To achieve this, In this study, a three dimensional data registration flat panel display scheme (Fig. 9) to reduce the number of data accessing points as well as scanning lines for large array TFT-LCD element with switch number more than 640×480 is proposed (Fig.10). The total numbers of data accessing points will be $N=3\times\sqrt[3]{Y}+1$, which is 68 for 640×480 switches by the 3D novel design, the scanning time is reduced up to 30% (The scanning speed is also

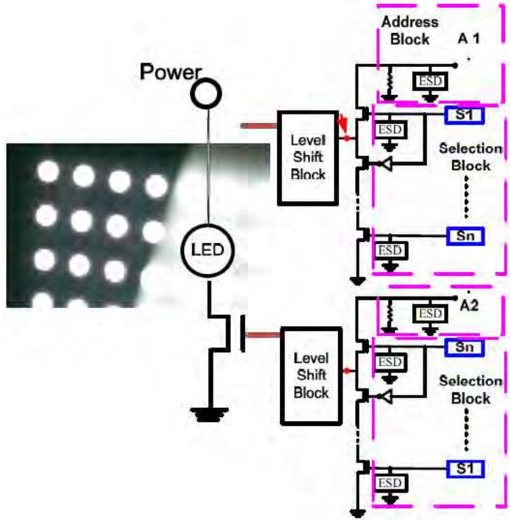


Fig. 9. Photograph of LEDs backlight sets

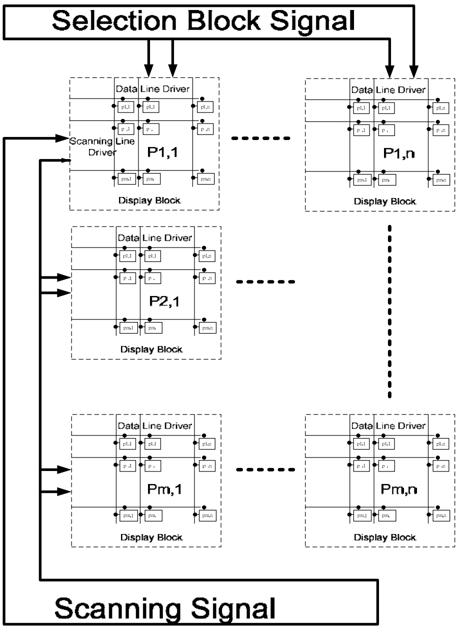


Fig. 10. 3D scanning display block array

increased by 3 times) thanks to the great reduction of lines for 3D scanning, instead of 2D scanning. Fig. 11 is shown pad connections from 1D, 2D, and 3D control circuits. Fig.12. is localized dimming LED backlight.

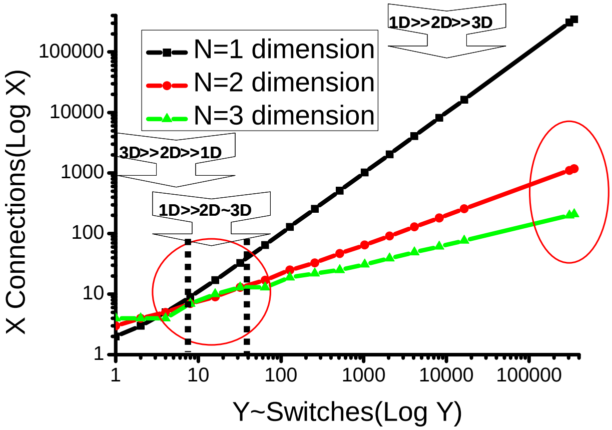


Fig. 11. Pad connections from 1D, 2D, and 3D control circuits

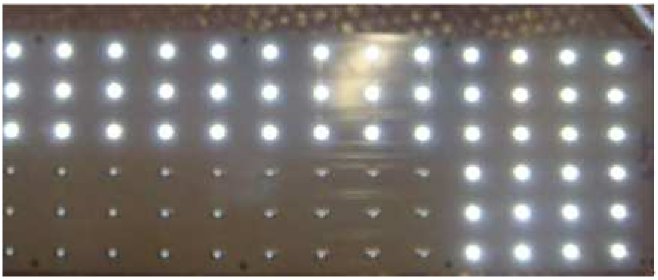


Fig. 12. Localized dimming LED backlight

3.1.2 Localized 2D/3D switchable maked-eye 3D display

The patented 2D/3D control module is made of a low-resolution panel with micro-retarder film, the LCD paneland backlight dynamically controlled form a patented architecture that can switch 2D/3D mode display area, provides three-dimensional image web application. Area by demand, 2D/3D switchable, 2D coexists with 3D on the one screen, 2D area shows small character clearly and 3D area shows multi-view naked-eye stereo image.

For simultaneous display of 2D and 3D information, we have develop an integrates naked-eye 2D/3D display window technology, called integrated 2D/3D windows (i2/3DW), that can display 2D and 3D images with flexibility and best quality on the same screen. As for stereo 3D gaming, there are dialog windows or pop-up windows in the stereo 3D game frames. Without an integral 2D/3D display, 2D texts in the 3D mode windows appear in broken and blurred characters. This situation is very much annoying especially for small fonts. But, with i2/3DW's localized 2D/3D switchable display technology, 3D gaming becomes true joy because 2D texts will be as clear as they are on a 2D screen while the 3D game scenes would still be the same fascinating as on a 3D device. Fig. 13 shows the construction of an i2/3DW display made according to technology from ITRI. It comprises three "primary "component layers." The first at left is a conventional liquid crystal display panel (LCD panel). Table 1 shows the specifications of the image liquid crystal panel.

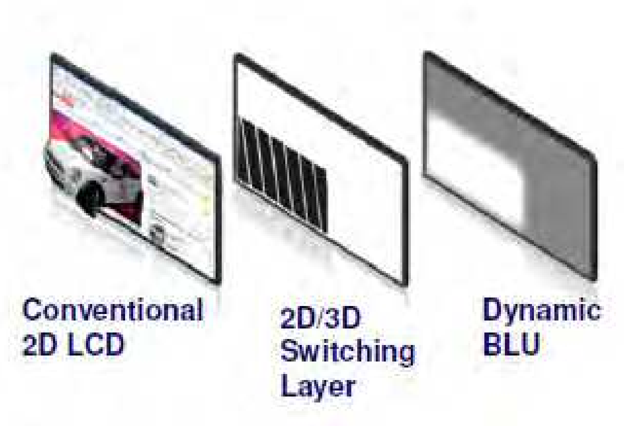


Fig. 13. The structure of 2D/3D switching design for integrated 2D/3D display

Property	Specification
Resolution	1680 x 1050, SXGA+
Panel Diagonal	22 inch diagonal
Speed	60Hz
contrast	800：1

Table 1. Image Liquid Crystal panel specification

The third at right is a dynamic back-light unit (DBLU), one that is similar, for example, to an LED matrix-based BLU now seen in many laptop PC display panel but with brightness of each (or at least groups) of the LED elements in the matrix separately controllable. There is a second component layer, the 2D/3D switching component, inserted between the first and third that is responsible for the automatic switching of individual pixels in the first between its 2D and 3D display mode. This technology uses a microretarder-based switching device to partially switch various parts of the display screen between 2D mode and 3D mode. Structurally, a microretarder plate has an interleaved pattern of half-wavelength-retardation and zero-retardation stripes. Working together with the microretarder is a liquid crystal (LC) switching panel inserted between the microretarder and the polarized backlight of the device. Each "pixel" of the LC switching panel functions as the switching unit cells between 2D and 3D mode regions. As a general rule of thumb, the smaller these "pixels" are, the smaller the 2D/3D switching cells can be. Though, for any practical application, the number of units required for the 2D/3D switching LC panel lands in where barely enough but with the lowest cost case, for example, 16 by 10.

3.2 Shutter glasses type stereoscopic displays

In such a shutter-glasses type stereoscopic display, the display signal (including vertical synchronization, horizontal synchronization and data) is sent from the display card to the LCD panel. The switching of the shutter glasses is driven by the vertical synchronization signal from the display card. Due to the possible phase lag between the shutter glasses and

the LCD panel, a phase lag circuit is set between these two devices. The scanning or the strobe of the dynamic backlight is driven by the same vertical synchronization signal.
Two experimental setups are used to implement the two dynamic backlight methods.

1. In scanning backlight method, a novel controlled circuit architecture of scanning regions for 120Hz high frequency. Setup all the parameters of scanning backlight method by counting the amount to decide turning time between 4、and 2 LED backlight regions. If counted times equal to 100 then jump to next backlight region. For 4-region scanning backlight method, when the panel is filled in regions 1, 2, 3 and 4 by the new image, the backlight lights up in the corresponding regions 3, 4, 1 and 2. In anticipation of an image for a left eye and right eye is shown in the region 1 of the panel, we turned on region 3 of the backlight unit. Analogize the image shown in region 2 and turned on region 4 of the backlight unit. For 2-region scanning backlight method, when the panel is filled in regions 1, and 2 by the new image, the backlight lights up in the corresponding regions 2, and 1. For avoiding seeing both L-image and R-image at the same time, the backlight regions R1 have to be off until R1 filled up the image. Analogize the backlight regions R2 have to be off until R2 filled up the image.
2. In backlight strobe method, Setup the parameters of backlight strobe method by counting the amount to decide turning on time of full screen (full screen of one frame 1/120sec counted amount equal to 400). Setup the parameters of backlight strobe duty time by counting the amount to decide turning time on full screen backlight regions. If counted times equal to (400 - 400*9/10) then jump to next full screen backlight region. The backlight is turned off when the image data refreshes. The backlight only turns on at the system time, or at most a little bit longer than the system time. But the system time is short compared with the time between two adjacent vertical synchronization signals (less than 10%), the display brightness operated under this method is probably quite small.

In order to tell which method is better for a shutter-glasses stereoscopic display, three experiments are done. They are 4-region scanning backlight, 2-region scanning backlight and backlight strobe methods. One of the most important properties of the 3D display, the crosstalk, is used in these experiments to tell which method is better. The test pattern is in a video stream form, which is like the left diagram.
The crosstalk is given by equations (1) and (2):

$$C_L = \frac{BW - BB}{WB - BB} \tag{1}$$

and

$$C_R = \frac{WB - BB}{BW - BB} \tag{2}$$

Where

WB represents a video stream with all-white as left-eye images, all-black as right-eye images),
BW represents a video stream with all-black as left-eye images, all-white as right-eye images),
BB represents a video stream with all-black for both left and right eyes.
C_L and C_R represent the crosstalk experienced by the left eye and right eye

The CS-100 Spot Chroma Meter is used in this research to measure all the luminance values. The images are displayed in page-flipping mode using the resolution and color-depth set in Stereo/Page-flip Setup as shown in Fig.14 and Fig.15.

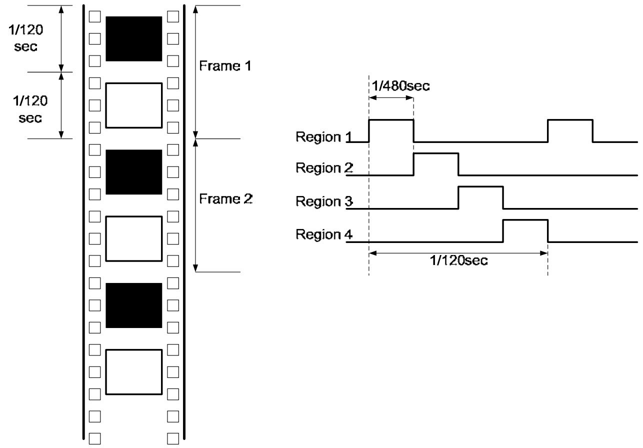


Fig. 14. LED scanning backlight duty cycle

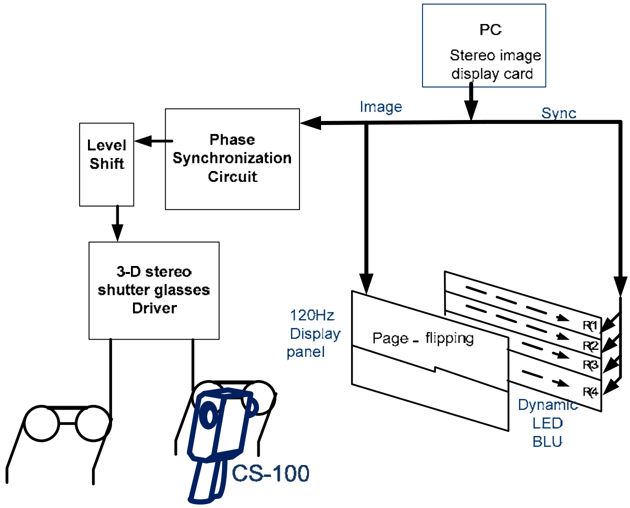


Fig. 15. The CS-100 measurement stereoscopic display system

The scanning backlight method turns on several (e.g., 2 or 4) horizontal regions of the backlight in turn, corresponding with the fill-out of the LCD panel. The backlight strobe method is to synchronously apply a control signal to the whole backlight to provide flashing effect rather than scanning. Both methods can control the brightness of the backlight module by adjusting the duty cycle of the control signal (Fig.14). Table 2 shows the specifications of the image liquid crystal panel.

Property	Specification
Resolution	1680 x 1050
Panel Diagonal	22 inch diagonal
Speed	120Hz
contrast	1,000:1 (20,000:1 'MEGA' Dynamic Contrast)
Response time (G2G)	5ms (2D), 3ms (3D)

Table 2. Image Liquid Crystal panel specification

3.2.1 Results and discussion

There is a phase difference between the vertical synchronization signal and the shutter glasses switching time. A phase lag circuit is applied to correct the difference. The waveform shown in Fig. 16 is an adjusted result.

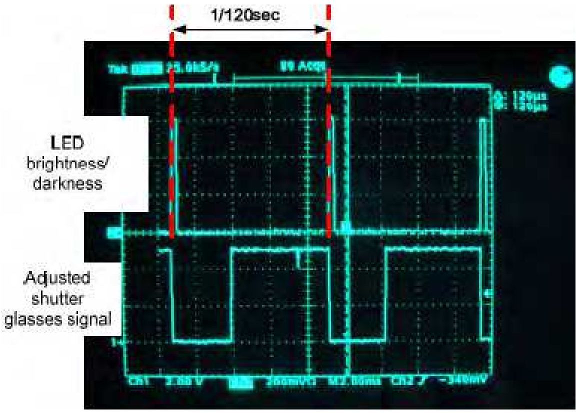


Fig. 16. Optimized synchronization signal

The synchronized shutter glasses can be used to separate the left-eye image and the right-eye image. However, even the block and transparent function of the shutter glasses is perfect, if the synchronization is not exact, or the response time of the liquid crystal is not fast enough to operate with 100 to 120 Hz, the viewer will still experience serious crosstalk. Therefore, reduction of the crosstalk is very important while making a stereoscopic display. The observation of cross-talk reduction effect special pattern is clearly shown in Fig.17. The display content is a video stream with small squares as the left-eye image and small circles for the right eye.

The luminance of the 3D LCD is measured and recorded as WB, BW and BB charts. The measurement distance is 1 meter and the recording unit is "nit". The crosstalk is calculated by the equations 1 and 2. As a result, the luminance of a 4R scanning backlight display for one viewing zone is 28.825 nits, that of a 2R scanning backlight display for one viewing zone is 57.25 nits, and that of backlight strobe display is 28.45 nits.

The crosstalk under different scanning conditions is calculated from data, including the cases of 4-Region and 2-Region scanning backlight method, and backlight strobe method (1 Region). The crosstalk of 4R and 2R scanning backlight displays are 3.2% and 5.08% respectively, and that of backlight strobe display is 1.68%.

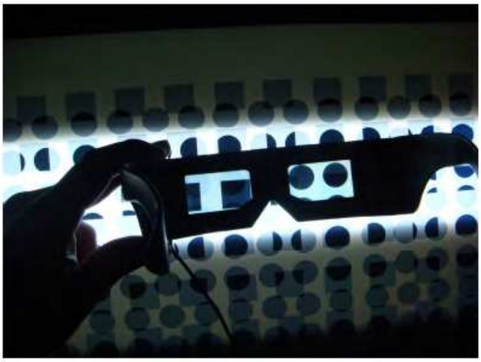


Fig. 17. Special pattern with eye shutter.

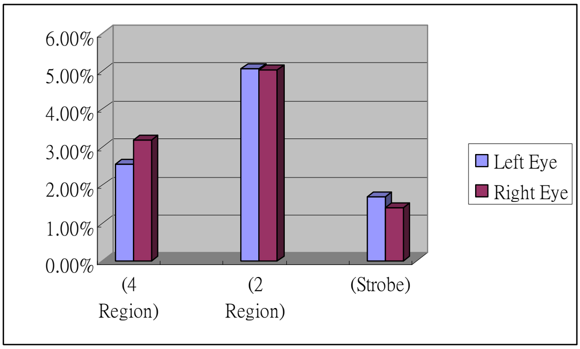


Fig. 18. Results of crosstalk calculation of different dynamic backlight methods

According to the results of and 18, the brightness of the 4R scanning backlight and the widened backlight strobe is about half of the 2R scanning backlight. But the crosstalk performance of the widened backlight strobe crosstalk is the best of three methods. Only about 1.68%. Although the 4R scanning backlight display crosstalk is higher than widened backlight strobe, it still performs better than the 2R scanning backlight one.

3.3 Multi-view time multiplexed autostereoscopic displays

Multi-view displays use TFT screens for image formation . The light generated by the TFT is split into multiple directions by the means of special optical layer (called also lens plate or optical filter) mounted in front of the TFT. The intensity of the light rays passing through the filter changes as a function of the angle, as if the light is directionally projected. There are two important points to note when considering multi-view screens: (1)They are not directly compatible with standard stereo-scopic footage or software. This is because, rather than display two distinct views to the viewer (as with most other stereoscopic displays), they provide up to 5, allowing the viewer to walk around the screen whilst maintaining the 3D effect. (2)Due to the display showing 4 or 5 views simultaneously, each view contains only 1/4 or 1/5 of the standard resolution of the display panel. An optimal lens, designed to handle a single situation, would be shaped to contain only as many distinct views as local participants; maximizing each views resolution would require a lens width sufficient to cover the same number of subpixels as views.

Our current prototype system uses a lenticular lens multiview technique with a time-multiplex autostereoscopic display based on active directional backlight (active dynamic backlight). Throughout the proposed system, lower power consumption are successfully obtained as well as high contrast ratio even with less number of drivers than that of conventional local dimming method. This architecture also contains a new adaptive dimming algorithm and image processing technique for the proposed stereo LCD backlight system. Recent progress in stereo display research has led to an increasing awareness of market requirements for commercial systems. In particular areas of display cost and software input to the displays are now of great importance to the program. Possible areas of application include games displays for PC and arcade units; education and edutainment; Internet browsing for remote 3D models; scientific visualisation and medical imaging. Intelligent and green power LED backlighting techniques of two-dimensional (2D) to three-dimensional (3D) convertible type, shutter glasses type, multi-view time multiplexed naked eye type, and multi-viewer tracking type for stereo liquid crystal displays are applied for 3D display system.

According to the time sequence for turning the groups of the light source, multiple viewing zones at multiple directions are created. To meet the requirements of different one-eye images, we propose that the real-time active barrier dynamic backlight slit system on stereo-display. To confirm our design workable, we did the optical simulation using Advanced Systems Analysis Program (ASAP) software. The detector is set at the convergent point, and the intensity profiles of the four views are shown in Fig. 19. The intensity profiles are evolving every 1/240 sec, and the separation of peaks is about 60 mm, quite close to the design value, 65 mm. The small inaccuracy resulted from the absorption of black matrix, and it makes the dead zone explicit. Setting the pixel size larger, or the black matrix smaller would improve the results. On the other hand, the center-viewing group has the least crosstalk, and side lobe groups have larger crosstalk, especially when viewing groups departs from center very much. The increase of crosstalk arises from the abbreviation when light is not close to the optical axis. Thus, the profiles of the four views confirm our design workable. Table 3 shows the specifications of the image liquid crystal panel.

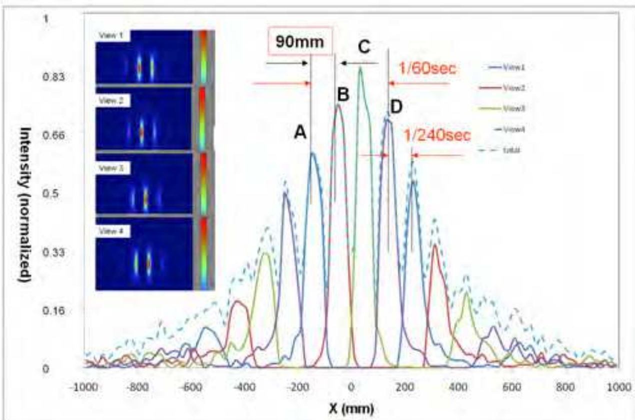


Fig. 19. The optical simulation using ASAP software

Property	Specification
Resolution	1024 x 768
Panel Diagonal	6.0 inch diagonal
Speed	240Hz
contrast	1000：1

Table 3. Image Liquid Crystal panel specification

3.3.1 Experimental results

The photographs of displayed images used the luminance meter (Konica Minolta CS-200) as shown in Fig. 20. The distance from the optical sensor to the center of LED backlight panel is in 60 cm, which is the normal range of distance for watching a 3D computer monitor. Measurements of angle are done from observation point -50 degree to observation point +50 degree; view 2 is the central view. The illuminance meter has an analog output to the oscilloscope and the illuminance signal can be recorded and processed by a computer.

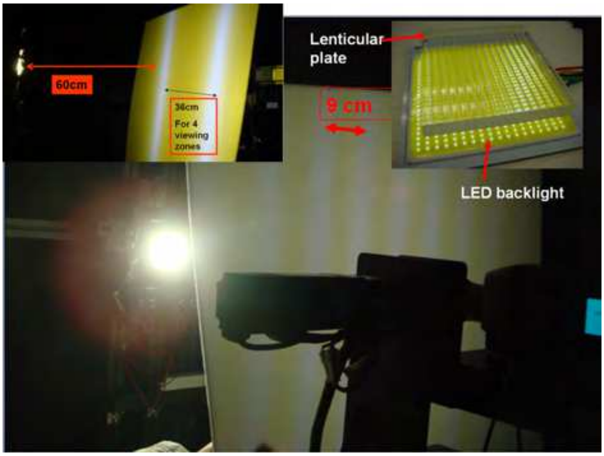
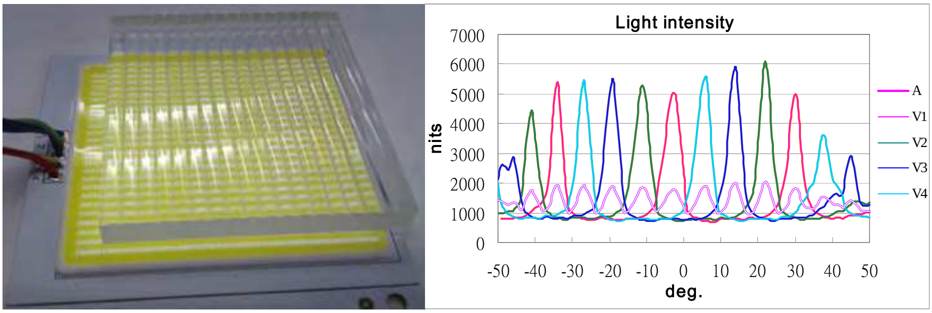


Fig. 20. Four views backlight

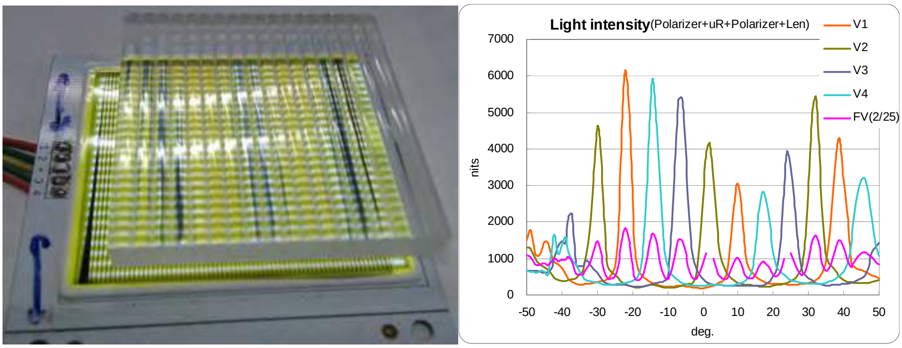
In this research, we observed backlight light stain structure for 3D image display based on lenticular lens array. In Fig.21, the photo is illustrated for four viewing zones 1-4 located at the viewing location. Each viewing zone uses 1/240 second to display one image. The light source at specific location is grouped corresponding to each lenticular lens of the lenticular lens array. For the four viewing zones, each lenticular lens has four groups 1-4 of light sources corresponding to four viewing zones 1-4. The four groups of light are sequentially turned on for 1/240 second. The group 1 of light source is turned on, and then the group 2 of light source is turned on next for 1/240 second. Likewise, the groups 3 and 4 of light source are sequentially turned on for 1/240 second. Generally, the multiple viewing zones equally shares 1/60 second for one image frame. The viewable zone area from first viewing zone to be contiguous to second viewing zone is 90 mm, and for 4 viewing zone of viewable area is 360 mm(The separation of viewing zones is about 90 mm, and overall width of viewing group is 360 mm) as shown in Fig. 20.

Yellow stripe pattern is created by phosphor of yellow color. White LEDs are blue LED chips covered with a phosphor that absorbs some of the blue light and fluoresces with a broad spectral output ranging from mid-green to mid-red. So, the backlight modular was taken on yellow stripe.

The configuration of uni-direction diffusion lens plate is shown in Fig. 21(b). The panel of 240Hz displays the corresponding images of the four viewing zones by the same time sequence according to temporal multiplexed mechanism. The uni-direction diffusion lens plate can condense the light individually belonging to each the lenticular lens at transverse direction. The lenticular lenses of the lens array receive the light and deflect the light into each viewing zone in a time sequence, respectively.



(a) Lenticular/LED



(b) Lenticular/Optical film/LED

Fig. 21. The crosstalk under different observation scanning angles

According to the time sequence for turning the groups of the light source, multiple viewing zones at multiple directions are created. To meet the requirements of different one-eye images, we propose that the real-time active barrier dynamic backlight slit system on stereo-display. The center viewing group has the least crosstalk, and side lobe groups have larger crosstalk, especially when viewing groups departs from center very much. The crosstalk under different observation scanning angles is showed from data in Fig. 21, including the cases of 4-views field scanning. The crosstalk of view 1 is about 5% respectively, the results are better than slanted lenticuler lens type.

3.4 Multi-viewer tracking stereoscopic display

This study integrated an autostereoscopic display with a viewer-tracking system. Fig. 22. illustrates the basic structure of the display and table 4 shows the specifications of the image liquid crystal panel. In the proposed structure, a retarder inserted between the image panels rotated the light beam at 90°; simultaneously, a lenticular plate adjusted the light direction to show the light slit from the tracking display. Retarder film is a clear birefringent material that alters the phase of a polarized beam of light. A quarter wave plate can convert linearly polarized light (oriented at 45° from the direction of the fast/slow axis) into circularly polarized light. Conversely, the wave plate can convert a circularly polarized beam into linearly polarized light.

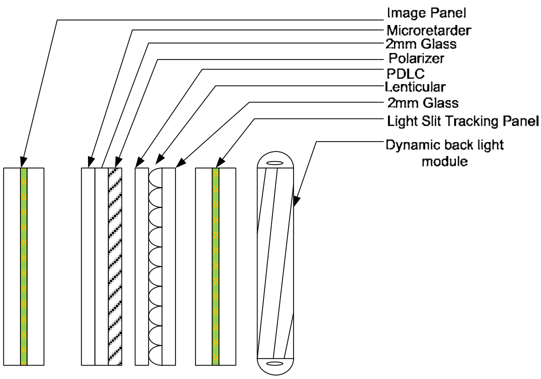


Fig. 22. The structure of the proposed viewer-tracking display panel

Property	Specification
Resolution	1920 x 1080
Panel Diagonal	23.6 inch diagonal
Speed	120Hz
contrast	1000：1
Response time (G2G)	2ms (3D)

Table 4. Image Liquid Crystal panel specification

In this study, when the polarization direction of the incident light formed an included 45° angle with the optical axis of the retarder, the polarization of the light passing through the $\lambda/2$ retardation regions rotated by 90° and became orthogonal to the polarization of the light passing though the 0° retardation regions. The molding method fabricated the lenticular plate with polymeric film as the substrate material. One of the light slit pattern pairs adjusted the direction of light from the tracking panel to the viewer’s eyes through the lenticular plate.

In this display, the PDLC panel played an important role in the function of the 2D/3D switch. When the PDLC panel was turned to clear state, the microretarder interacted with the polarizers to form a parallax barrier pattern as shown in Fig.23, making the display autostereoscopic. In a case where the PDLC panel is in a diffusive state, the light passing

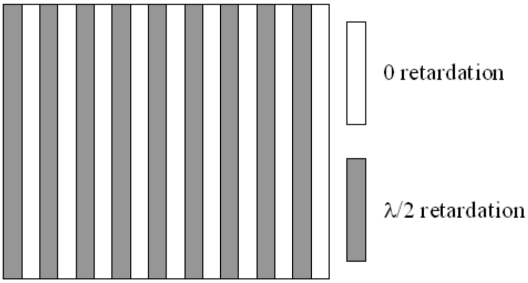


Fig. 23. The pattern of a microretarder

through the PDLC destroys the polarization. The microretarder then loses its function as a parallax barrier, and the display becomes a general 2D display.

This study developed autostereoscopic display apparatus and a display method. The autostereoscopic display apparatus included a display panel, a backlight module, a tracking slit panel and an optical lens array. In a frame time, the display panel and tracking panel share the same synchronization signal for the display panel. The tracking panel controls the light of the backlight module. The tracking panel features tracking slit patterns and switches the slit patterns according to the synchronization signal. Until all screen data is updated, the backlight module is inactive during the frame time. A light provided by the part of the backlight regions passes through the tracking slit set, optical lens array, and the display panel in such a way that each eye separately perceives images. As shown in Fig. 24, when the viewer moves to the left, the tracking slit set changes its pattern to display the correct image.

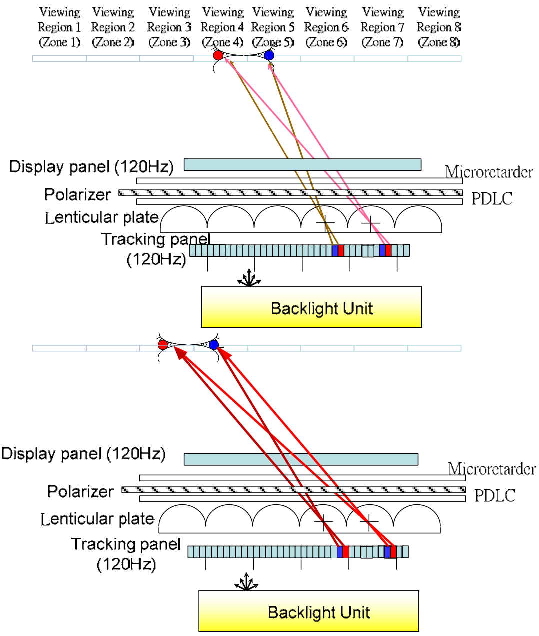


Fig. 24. Relations between viewer and tracking panel

The autostereoscopic display integrated a webcam as the real-time detection device for tracking of the viewer's head/eye positions, so that the display showed left and right eye images correctly. The computer vision-based tracking method detects viewer's eyes over a specific range and under conditions of low and fluctuating illumination. By capturing the image of the viewer in front of the display, the viewer's position is calculated and the related position data is transferred to the field programmable gate array (FPGA) controller through RS232. When the viewer recognizes that he/she is standing at the borders of the viewing zones, analyzing the captured viewer images determines the border positions of the viewing zones. The resulting eye reference pattern allows the tracker to locate the viewer's eyes in live video images. If an observer moves away from his original position, the tracking slit will vary its pattern according to the viewer's new position. The viewer still perceives two eye images separately before exceeding the webcam detection range. Fig. 25 shows the viewer-tracking system.

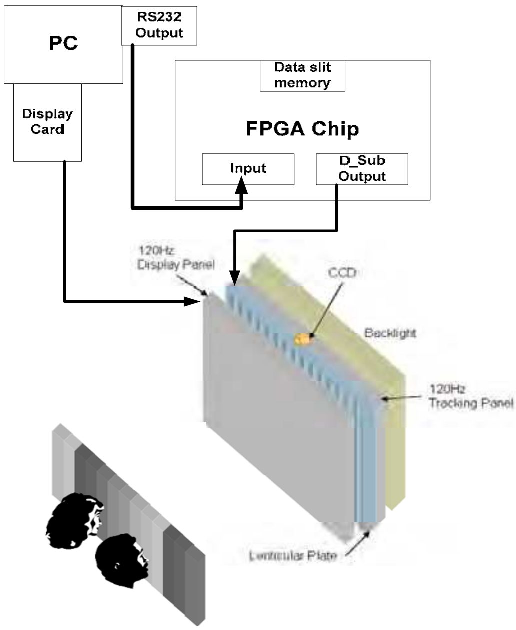


Fig. 25. Viewer-tracking 3D display system

This research addresses the specific technological challenges of autostereoscopic 3D displays and presents a novel system that integrates a real-time viewer-tracking system with an autostereoscopic display. Our successfully designed prototype utilized a FPGA system to synchronize between a display panel and tracking slit panel. With 120Hz display and tracking panels, only a pair of page-flipped left and right eye images was necessary to produce a multi-view effect. Furthermore, full resolution was maintained for the images of each eye. The loading of the transmission bandwidth was controllable, and the binocular parallax and motion parallax is as good as the usually lower resolution multi-view autostereo display.

(B) LED Backlight architecture

Many types of LED backlights are applied to 2D or 3D displays. To date, research on 3D display systems has generally focused on providing uniform, collimated illumination of the LCD, rather than addressing low crosstalk issues. This study investigated the method of using an autostereoscopic multi-viewer tracking 3D display with a synchro-signal LED scanning backlight module to reduce the crosstalk of right eye and left eye images, enhancing data transfer bandwidth while maintaining image resolution. Fig. 26A is a schematic view of a stereoscopic display. Fig. 26B is a block diagram illustrating the stereoscopic display; the stereoscopic display can track the viewer's position and be watched by multiple viewers.

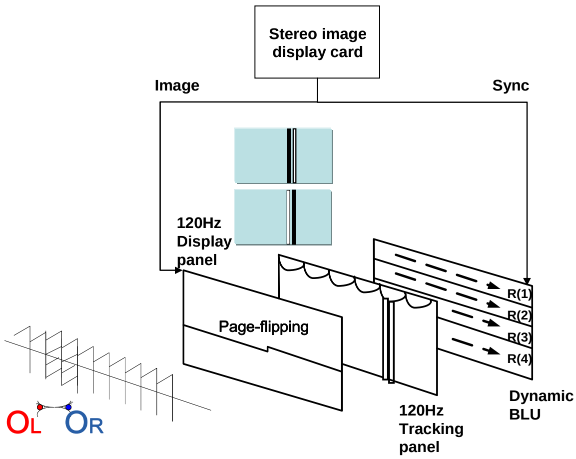


Fig. 26A. The schematic view illustrating a stereoscopic display.

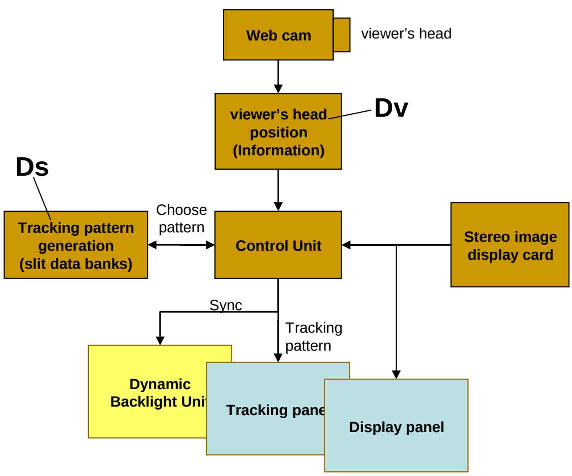


Fig. 26B. The block diagram illustrating the stereoscopic display

The backlight module of the stereoscopic display is a dynamic backlight module featuring many light-emitting regions R(1)~R(4). Fig. 26A excludes the control unit and optical lens array. In the stereoscopic display, the graphic card outputs and transmits the vertical synchro-signal to the control unit. After receiving the synchro-signal, the control unit outputs the synchro-signal to control (turn on or off) the light-emitting regions R(1)~R(4).

To meet the requirements of different one-eye images, we propose that the dynamic LED backlight tracking panel has have many backlight slit sets. According to the position information of viewer O and the vertical synchro-signal, one of the slit sets of the tracking panels is selected and turned-on. Each slit set includes either left or right eye slits. Light emitted from the dynamic backlight module passes through the either left or right eye slit and the display panel, and projects onto one eye of viewer O. Similarly, light emitted from the dynamic backlight module passes through the either left or right eye slit and the display panel, and projects onto the other eye of viewer O. In this way, the pair images are projected to the two eyes of viewer O, who can see accurate three-dimensional images. For example, light emitted from the dynamic backlight module passes through the left eye slit of the slit set and the display panel, and projects onto the left eye O_L of viewer O. Similarly, light emitted from the dynamic backlight module passes through the right eye slit of the slit set and the display panel, and projects onto the right eye O_R of viewer O. The one-eye slits are stripe-shaped and the lengths of the one-eye slits are approximately equal to the longitudinal length of the display panel.

When the display panel displays an image based on the vertical synchro-signal, the slit set of the tracking panel is enabled. Meanwhile, pixels in the updated region of the display panel display a left-eye image, but pixels in the non-updated region of the display panel still display the previous right-eye image. Light passing through the slit set of the tracking panel and the non-updated region of the display panel can be projected onto left eye O_L of viewer O (i.e. a crosstalk phenomenon) if no alternative methodology is applied. This research proposes using a dynamic backlight module to suppress the crosstalk. The light-emitting regions R1~R4 of the dynamic backlight module are separately controlled according to the vertical synchro-signal.

During a frame period, the light-emitting regions R(1) and R(2) corresponding to the updated region are turned on and the light-emitting regions R(3) and (4) corresponding to the non-updated region are turned off. In this way, only the light-emitting regions R(1) and R(2) provide light, so that no light passes through the slit set of the tracking panel and the non-updated region of the display panel. This reduces the crosstalk phenomenon of the stereoscopic display system.

As shown in Fig. 26A and Fig. 26B, the display method of the stereoscopic display comprises the following steps:

First, slit data banks (Ds) corresponding to the many viewing angles of the stereoscopic display apparatus is established. Next, the control unit receives information (Dv) on the position of the viewer. The control unit compares the position information and the slit data banks stored in advance. Meanwhile, the control unit outputs the vertical synchro-signal from the graphic card to control the output mode of the dynamic backlight module and operation mode of the tracking panel. The display panel is driven to display images (i.e. image updating) according to the vertical synchro-signal output from the graphics card. Many of the light-emitting regions (R(1)~R(4)) of the dynamic backlight module are stripe-shaped and the light-emitting regions R(1)~R(4) extend across the slits of the tracking panel. The extending direction of the light-emitting regions R(1)~R(4) is perpendicular to the extending direction of the slits of the tracking panel. Many of the light-emitting regions (R(1)~R(4)) of the dynamic backlight module are array in an arrayed manner.

3.4.1 Crosstalk analysis

To avoid ghost images, the backlight modular provides backlight control signals which are dependent on the position of an associated part of the panel. The system is provided for controlling synchronization timing between backlighting and pixel refresh, in dependence of a location of a section within the display panel. The backlight unit is separated into several regions. Let's take 4 regions as the example, the pixel response time is less than three fourths of the frame time when the illumination period is one quarter of the frame time. Optical sensor and CS-100 Spot Chroma Meter of luminance crosstalk measurement of the 4-regions 、2-regions scanning and strobe backlight method without lenticular. Frame sequential(page flip, temporal multiplexed) process, the process is referred to as alternate frame sequencing.

Crosstalk is a critical factor determining the image quality of stereoscopic displays. Also known as ghosting or leakage, high levels of crosstalk can make stereoscopic images hard to fuse and lack fidelity. Crosstalk is measured by displaying full-black and full-white in light-emitting regions R(1)~R(4) of the display system without lenticular and using an optical sensor to measure the amount of leakage between channels.

For example, the optical sensor is placed at the left eye position (either behind the left eye of 3D glasses, or in the left eye viewing zone for an autostereoscopic display) and measurements are taken for the four cross-combinations of full-white and full-black in the left and right eye-channels. An additional reading is also taken with the display in the off state. These readings can then be used in the crosstalk equations described above. This metric can be called black-and-white crosstalk and this metric is often used because maximum crosstalk occurs when the pixels in one eye-channel are full-black and the same pixels in the opposite eye-channel are full-white. According to the results, the brightness of the 4R scanning backlight and the widened backlight strobe is about half of the 2R scanning backlight. But the crosstalk performance of the widened backlight strobe crosstalk is the best of three methods. Only about 1.68% left. Although the 4R scanning backlight display crosstalk is higher than widened backlight strobe, it still performs better than the 2R scanning backlight one.

In the study, the CS-100 Spot Chroma Meter was used to measure the brightness of the backlights, which can be controlled using the duty cycle of backlight signal, as shown in Fig. 27. Moreover, photodiode s3072 was used to measure the optic characteristics of the display device.

To view the correct image from the tracking display, the synchronization relationship between image display and backlight requires calibration. Fig. 28 shows that the V-sync signal exceeds the backlight signal in 1/160s. If the V-sync signal triggers the backlight signal directly, the observer sees three white regions and one black region (not fully white or fully black). As the human eyes determine light source, a vertical signal must trigger the first region backlight (the dotted line of Fig. 28). Fig. 29 is the crosstalk of right eye and left eye under three different brightness conditions. The phase of the V-sync signal exceeds the phase of the backlight signal in 1/480s. It is too dark if the duty cycle is lower than 50%, so the three chosen duty cycles all exceeded 50%. According to Fig.29, the differences in brightness do not significantly affect the crosstalk. The performances of both eyes were approximately in agreement. The experiment selected maximum brightness.

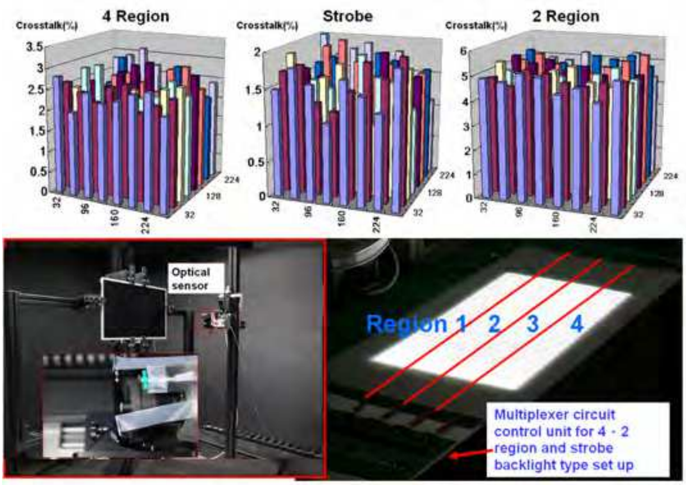


Fig. 27. Optical sensor and CS-100 Spot Chroma Meter of luminance crosstalk measurement of the 4-regions , 2-regions scanning and strobe backlight method without lenticular

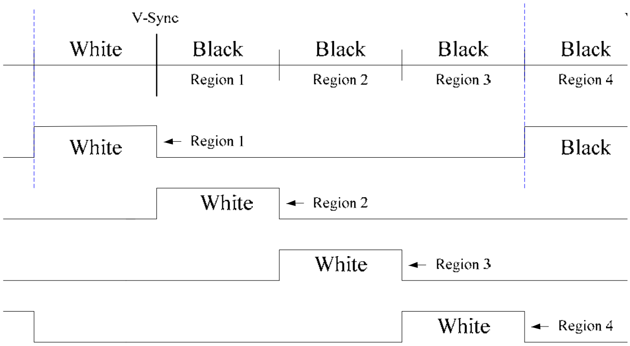


Fig. 28. The synchronization relationship between image display and backlight (from top to bottom)

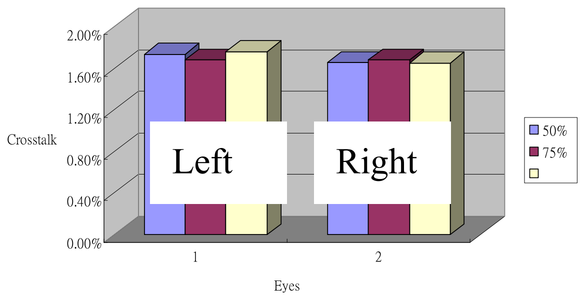


Fig. 29. The crosstalk under different brightness conditions

Fig. 30 shows the crosstalk of the right eye and left eye with different phase shifts between the V-sync signal and backlight signal, where the duty cycle of backlight signal is 100%. The lowest crosstalk only occurs when phase shifts are 1/160s, not both 1/480s and 1/160s. Here, light leaking to other regions and the response time of the liquid crystal affect the crosstalk (Fig.31). Fig. 31 is the response reaction of the liquid crystal from full black to full white. The horizontal axis is time (5 ms per grid) and the vertical axis is voltage (20 mV per grid). One display frame is 1/120 second, approximately equal to 8 milliseconds. The response waveform can be divided into four sections (2ms per section). The waveform of the liquid crystal still rises (section II) when the phase of V-sync signal exceeds the backlight signal in 1/480s (≒2ms); here, the phase does not reach a bright state. But, the phase shifts of 1/240s (≒4ms) and 1/160s (≒6ms), located at region III and region IV, respectively, gradually near the bright state; this explains the difference in crosstalk.

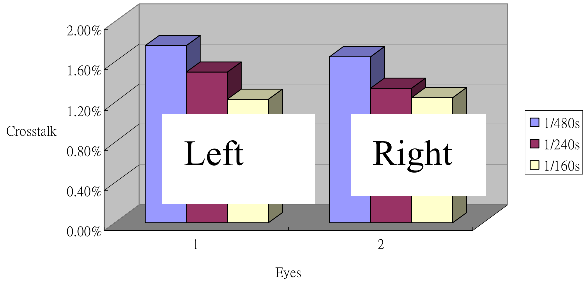


Fig. 30. The crosstalk under different phase shift conditions

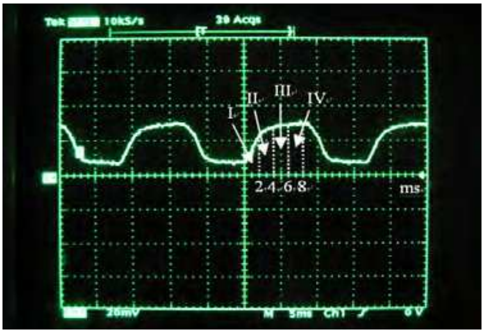


Fig. 31. The response time of liquid crystal from dark state to bright state

3.4.2 Measured results

(A) The optical properties measurement

Detailed and quantitative measurements were used in the autostereoscopic display. To measure the borders and the performance of the viewing zones, a luminance meter, Minolta CS-200, was located at the designed viewing distance (630mm from the display), which reduced the display panel's optical interference during measurement. Only the backlight module, including a backlight, tracking panel, and lenticular plate, was used in optical luminance measurement experiments. In this backlight structure, no additional brightness was lost in the optical path.

Fig. 32 shows the results of the luminance intensity experiment. The entire measuring process was completed in a darkroom, which provided measurements of fairly high quality. In the luminance intensity experiment, only 40 degrees on both sides of the center of the backlight module was measured; the intensity value was captured every 0.5 degree. When measuring, only one viewing zone of the tracking panel was switched on. The luminance meter was used to scan the viewing zones horizontally. The maximum peak luminance value of the viewing zone was approximately 514 cd/m^2 when CS-200 detected the luminance intensity value near the center of the backlight module. The minimum peak luminance intensity value of the backlight was approximately 364 cd/m^2 at the edge of the viewing group. The luminance intensity range of the viewing group in front of the backlight module ranged between 264 and 514 cd/m^2. The intersection point between two adjacent luminance intensity curves may determine the borders of the viewing zones.

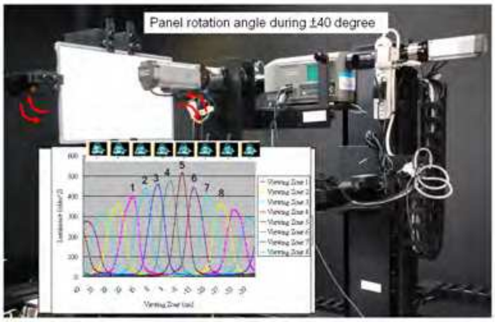


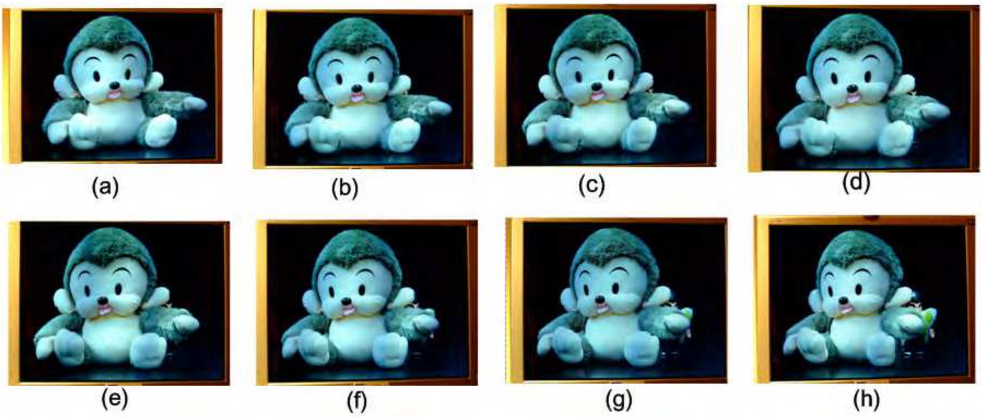
Fig. 32. Luminance intensity distribution of lenticular-type BLU

After luminance intensity measurement of viewing zones 1 to 8 was completed, data could be combined to yield a luminance intensity distribution figure to verify the optical design parameters. The peak luminance intensity value of viewing zone 4 is in front of the center of the backlight module. The tracking panel was slightly misaligned with the lenticular plate. Due to the light intensity distribution of the tracking panel and the entrance angle difference of the light path between the backlight and the lenticular lens, a stronger luminance intensity curve was measured in the central part of the viewing group. The viewing group of the 3D display system was approximately 53 cm wide at a viewing distance of 63 cm, indicating that each viewing zone is 6.625 cm wide on average.

In building a viewer-tracking-based autostereoscopic display, the viewer’s position and border positions of the viewing zones are the key parameters. To accurately define the viewer’s position, the black and white pictures for both eyes were displayed as calibration images. The positions of the borders in the viewing zones could be determined by analyzing the images of the viewer captured while the viewer reported to be at the border positions.

(B) Motion parallax function result

For a 3D display to simulate the natural vision of human beings, both binocular parallax and motion parallax are required. For a multi-view autostereoscopic display system, viewers can see stereoscopic images with binocular parallax and motion parallax within a group of viewing zones. However, a high number of viewing zones is necessary to achieve smooth motion parallax for a sufficiently large view. This normally causes significant reduction of image resolution. While maintaining good image resolution, we implemented smooth motion parallax by adopting viewer tracking function and real-time image updating in a two-view autostereoscopic display system.



(a) 35° image content, (b) 40° image content, (c) 45° image content, (d) 50° image content, (e) 55° image content, (f) 60° image content, (g) 65° image content, (h) 70° image content.

Fig. 33. The viewer-tracking-based 2D/3D switchable autostereoscopic display

This study used an ad-boost algorithm capable of evaluating important features to quickly track viewers. If the viewer's eyes were detected in specific viewing zones in front of the display, the viewer's position would determine the images of the corresponding viewing angles shown. When the viewer's eyes move inside the same viewing zones, full stop needs moving, the images for the new viewing angles are fed into the same viewing zones. The viewer experiences the motion parallax because he/she sees different images from different angle.

When the viewer's eyes continue to move and finally cross the border of the viewing zones, the images of the new angle are reversed left-and-right and presented in real-time on the display.

In this study, tracking stability was good with viewing angles ranging from -15 degrees and 15 degrees. The refresh rate achieved 30 frames per second when the resolution of the capturing image was set to 160×120. To match the resolution of the display, the resolution of image content for each eye was 840×1050. The image content was rendered from the 3D model built from 3D Max or directly captured using cameras. For the webcam coordinates, the accuracy of one pixel was about 6.25 mm according to the viewing angle of the webcam indicated and the designed viewing distance in the autostereoscopic display. Therefore, the rendering or capturing angle was set to 0.5 degree according to the accuracy of one pixel. As shown in Fig. 33, the 2D/3D switchable auto- stereoscopic display correspondingly provides about 160 pairs of stereo images to the viewer moving in the viewing angle of the system. The viewer is consistently able to experience the reality of motion parallax.

4. Conclusion

The design of the three dimensional hierarchy with control circuit for large LED backlight array, which effectively reduces the terminal numbers into the cubic root of the total control unit numbers and prevent a block defect of the flat panel. The display panel is divided into many scanning block parts, each part is separately and simultaneously scanned in the same directions to write images on the pixels on the respective scanning electrodes. These defects are generally the result of a failure in the row (horizontal) or column (vertical) drivers or their connections. We have reached the advantages of high accuracy, rapid selection, and reasonable switching speed flat panel.

Several shutter-glasses type stereoscopic displays have been measured to analysis difference of their 3D performance. The less the backlight regions are, the brighter the display with scanning backlight method is. Therefore, a 2R scanning backlight is brighter than a 4R one. Nevertheless, due to better separation of a 4R scanning backlight, the crosstalk of it is less than that of a 2R scanning backlight. However, from the other aspect, the uniformity of a scanning backlight method is usually not as good as than backlight strobe method. For a higher luminance and lower crosstalk, it is suggested to combine the 4R scanning backlight method and backlight strobe method. In this way, a 120Hz LCD can be made a very good performance stereoscopic display with shutter glasses.

In full resolution multi-view autostereoscopic display research, we have successfully designed and fabricated the optical system, high density active barrier dynamic LED backlight, the slit pitch is 700um, and the LED chip size is 10×23mil for full resolution multi-view autostereoscopic display. From the measurement results, the dynamic LED backlight optical system can yield ideal parabolic curvature and the crosstalk is lower than 5%. Besides, the lenticular lenses of the lens array optical system was successfully received the light and deflected the light into each viewing zone in a time sequence, which could be one of the candidates for future full resolution time-multiplexed 3D applications.

A viewer-tracking-based auto- stereoscopic display of a synchro-signal LED scanning backlight system that can correspondingly send different pairs of stereo images based on the viewer's position. Additionally, an 8-view autostereoscopic display was implemented with full resolution in the display panel, achieving high 3D image quality in the preliminary configuration. Further modifications, e.g. higher precision for viewer-tracking positioning and design of more viewing zones in the display system, may improve system performance.

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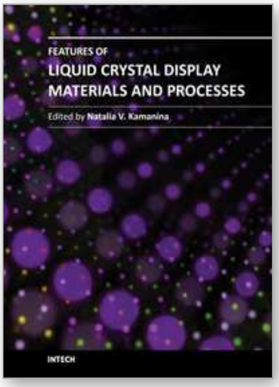

Features of Liquid Crystal Display Materials and Processes
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Following the targeted word direction of Opto- and Nanoelectronics, the field of science and technology related to the development of new display technology and organic materials based on liquid crystals ones is meeting the task of replacing volume inorganic electro-optical matrices and devices. An important way in this direction is the study of promising photorefractive materials, conducting coatings, alignment layers, as well as electric schemes that allow the control of liquid crystal mesophase with good advantage. This book includes advanced and revised contributions and covers theoretical modeling for optoelectronics and nonlinear optics, as well as includes experimental methods, new schemes, new approach and explanation which extends the display technology for laser, semiconductor device technology, medicine, biotechnology, etc. The advanced idea, approach, and information described here will be fruitful for the readers to find a sustainable solution in a fundamental study and in the industry.