

2D/3D Switchable Displays

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Abstract

New three dimensional (3D) displays switching electrically between 2D and 3D modes are discussed. The principles of operation and design considerations for particular applications are described.

Introduction

A display is presented that can be electrically switched between an autostereoscopic (no glasses) 3D mode and a full resolution 2D mode. This 2D/3D display can be used in a range of products from computer monitors to mobile displays. There are many applications including 3D games, amusement, image capture and display. The 2D mode allows the user to enjoy the same performance as current displays, with the added advantage of 3D for enhanced reality and enjoyment.

In September 2002, Sharp announced mass manufacture of electrically switchable 2D/3D displays. The first product was launched in November 2002: a 2.2" 2D/3D mobile phone for NTT DoCoMo (SH251iS).

1. History

In 1992, SLE began researching 3D displays - an exciting new application that added to Sharp's high quality Liquid Crystal Displays.

The first systems¹⁾ comprised two standard LCDs mounted at 90° with beam combining optics to send the image from one LCD to one eye and the image from the second LCD to the second eye. However, this particular set-up was too large and probably too expensive for the mass market. In 1994 we achieved our first single-panel 3D display²⁾ based on the parallax barrier method³⁾. These displays were called "3D-only displays" since the 3D effect was permanent. These displays allowed a single user to enjoy 3D from certain positions. This technology was improved in 1996 with the invention of the "sweet spot indicator" to help the user find the best 3D viewing position. This indicator is one of the key distinguishing factors of Sharp's 3D technology⁴⁾.

Up until 1997, the 3D displays were not suitable for conventional 2D applications since only 3D images



Fig. 1 SH251iS Mobile phone with 2D/3D display.

could be viewed. The breakthrough came by using polarisation optics to allow switching between full-resolution 2D and no-glasses 3D modes. 8.4" and 13.8" displays were built that allowed switching between 2D and 3D by a simple mechanical method (see⁵).

In October 2001 a key target was finally achieved: the first prototype of a 2D/3D display that could be electronically switched between modes. The key advantages are that the 2D image quality is identical to a standard 2D display, whilst the no-glasses 3D mode provides exciting and comfortable to view images with enhanced reality.

2. Principle of an autostereoscopic display

The basis of our 3D display without glasses (autostereoscopic) is the "parallax barrier". The parallax barrier comprises alternating transmissive and non-transmissive columns aligned with the columns of the LCD pixels. The transmissive columns generate two regions in space (or viewing windows) in front of the display as shown in Fig. 2 and Fig. 3.

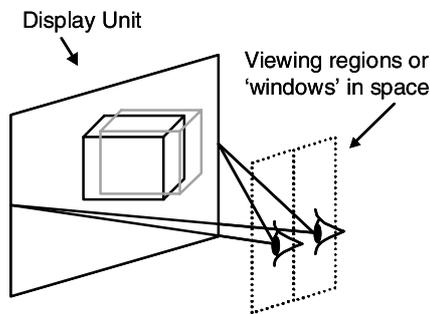


Fig. 2 Viewing windows created in space.

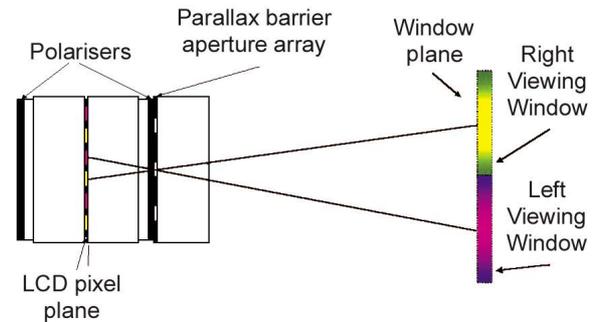


Fig. 3 Parallax barrier display.

Two 2D images are displayed on the LCD. When the observer places the right eye in one viewing window (one 2D image) and the left eye in the other (the second 2D image) then a 3D image will be perceived. Each eye sees a different 2D image and this creates a 3D perception.

3D viewing distance can be estimated with the parameters in Fig. 4. The important features are pixel pitch and the distance between parallax barrier and LCD. The 3D viewing distance can be matched with the best 2D viewing distance so that the user is in a comfortable position for enjoying 3D. This emphasis on user comfort is another key distinguishing factor for Sharp 2D/3D displays.

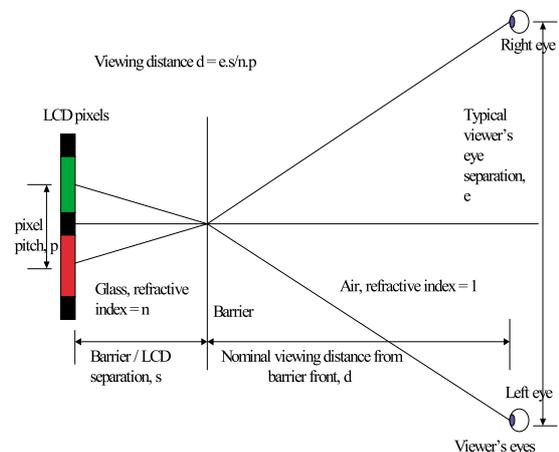


Fig. 4 Viewing distance calculation.

2.1 Design considerations for electrically switching 2D/3D display

If normal text is read using a standard 3D display, the text can be distorted. Additionally, as the user moves from one viewing window to another, there are often brightness variations. It is therefore important to be able to "switch off" the parallax barrier function to obtain a high quality 2D mode. This switching can be

achieved by use of a patterned retarder parallax barrier and removable polariser⁵. The switching is achieved mechanically by the addition of a secondary polariser. This mechanical switching is ideal for low-cost application, but may be impractical for others. Electrical switching can be achieved by the addition of a component that can rotate the polarisation of light (3D) or leave it unaffected (2D). This additional component could be a simple liquid crystal cell. A possible configuration is shown in **Fig. 5**.

In 2D mode, the two columns of the patterned retarder parallax barrier transmit equally. Importantly, the 2D image quality is the same as a standard LCD panel. In 3D mode, one column of the patterned retarder parallax barrier transmits and the other column is opaque, resulting in a 3D mode.

Other aspects of the design depend on the particular application. For example, the same 3D effect can be achieved with a parallax barrier at the rear of the display (between backlight and LCD) rather than at the front (between LCD and user). This rear parallax barrier arrangement is useful for "Advanced TFT" transfective displays that operate in both transmissive and reflective modes. With a rear parallax barrier, the reflected brightness is identical to a standard 2D display. The transmitted brightness is reduced. With a front parallax barrier, both the reflected and transmitted brightness would be reduced.

3. The road to production

In late 2001 the electrically switched 2D/3D technology was shown to Sharp's Communications Systems Group, who wanted to integrate 3D into future mobile phones. A key to commercial success was the detailed discussion that followed, where the possible technical options were compared with detailed understanding of customer's requirements. In keeping with Sharp's history of high quality "only-one" products, a higher risk but higher performance option was chosen.

A very successful and intensive collaboration followed between CSG, SLE and Sharp's Mobile LCD Group, responsible for mass manufacturing the displays. SLE made initial prototypes of 2" displays and then improved the design and performance. Additionally, a number of "test" displays were created to help Mobile LCD group define manufacturing tolerances.

At this stage the only 3D displays that had been produced were "hand-made" prototypes built at SLE. The design and processing knowledge had to be transferred to Mobile LCD group, with the aim of setting-up a mass manufacturing line.

In order to be "first to market", a challenging target of 9 months was set to complete this knowledge transfer. To help the information flow between SLE and Mobile LCD BG, two researchers from SLE spent 9 months in Sharp Tenri working closely with colleagues from Mobile LCD BG. This 9-month visit was a key part of the successful commercialisation.

The commercialisation included replicating the SLE fabrication route in Japan. Once all production problems had been overcome, the next step was to decrease the production cost, and increase the yield. For example, several chemicals are needed to make the parallax barriers. Cost and time reduction in mass manufacture is possible using chemicals that can be applied in the manufacture of both LCDs and parallax barriers. SLE and Mobile LC BG continue to investigate novel processes that will simplify manufacture.

SLE benefited greatly from spending 9 months at Sharp Tenri by understanding the methods and constraints

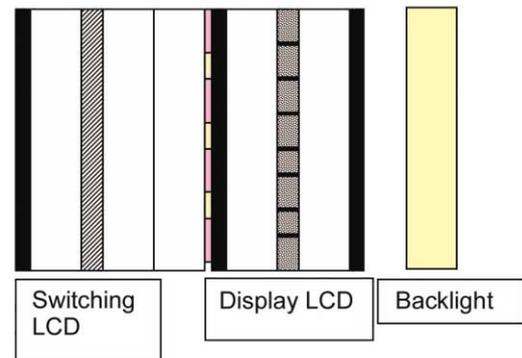


Fig. 5 Display configuration.

of mass manufacture. This will help us to better consider business group constraints and needs when deciding future IP.

4. 3D contents

The Sharp 2D/3D display is an integrated system - software is as important as the hardware for good 3D. Alongside the hardware development, a key part of the research at SLE has been understanding and developing protocols to allow comfortable 3D. The protocols control the depth in images. The depth information for the protocols comes from several Human Factors studies commissioned by SLE.

Another important area for content generation is 3D image capture from stereo digital photography. One approach is to have a single camera with two sensors. Another approach is to have a single camera/sensor and a prism adapter to produce two views. Yet another approach is a single camera mounted on a sliding rail to capture two images. Another alternative approach is to take two separate images with a single camera and then apply software correction of image errors. All these approaches are part of SLE's current and future activities in this area.

5. Future challenges

The immediate future should involve the extension of the electrically switching technology to a wider range of applications. For example, it can be effectively applied to larger area displays such as computer monitors (**Fig. 6**)

For future research, there are many possible advances to widen the appeal of Sharp's 2D/3D displays.

For example, we will aim to widen the position in which a 3D image can be viewed and therefore increase viewing freedom. This is particularly important for gaming applications. Additionally, we will aim to develop a method for efficient 3D image capture. New manufacturing processes will be examined to develop cheaper, easier to produce components.

A further target will be to allow multiple viewers to see the effect at the same time. This would be a key requirement towards the ultimate goal of 3D LCTV.



Fig. 6 3D computer monitor.

Conclusions

A display system has been developed and described that allows simple switching between a full resolution, full colour 2D mode and a high quality, comfortable, no-glasses 3D mode.

Close collaboration between research and business groups lead to a successful commercialisation of a new technology. The future research in 3D involves 3D image capture and development of a system with enhanced "look-around" capability.

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