Development of a Super-High-Definition TFT LCD (28-inch QSXGA)

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Abstract

A 28-inch QSXGA super-high-definition TFT LCD having 5.24 million pixels (2560 x RGB x 2048) has been developed. The display has great abilities in representation of images: high resolution of more than 2000 scanning lines, large size of 28" diagonal, and 24-bit full color. In addition, a digital interface has been adopted to realize the reproduction of images without any noises. The display was developed based on demands for super-high-definition applications such as digital archives, medical images, air traffic control systems, and so on. This paper explains the technology for the super-high-definition TFT LCD.

Introduction

The evolution in TFT LCD production technology thus far has been remarkable, and we are now witnessing the advent of panels up to 28 inches in size (768 scanning lines for TV) and up to UXGA in resolution (1,200 scanning lines for PC monitors). In comparison to CRTs having similar specifications, users are recognizing the added value offered by these displays stemming from the fact that they are based on LCD, such as thinner profiles, lighter weight, and lower power consumption, and they have been well received in the marketplace. Recently, efforts have begun toward achieving higher resolutions-new areas of higher added value unreachable by ordinary CRTs. One of these areas is super-high-pixel density displays, and 200-ppi displays, significantly exceeding the 110 ppi said to be the limits of CRTs, have already been developed. They are beginning to find use as "electronic paper" and in high-image-quality notebook PCs, PDAs, mobile phones, and similar applications. Another area is super-high-definition displays whose development we describe here. These units can be expected to find application in markets where the capability to display highly dense image content in excess of 2,000 scanning lines is required, such as digital archives, medical images, air traffic control displays, and the like[1)2)].

Photo 1 Super High Definition TFT LCD (28" QSXGA).

One CRT-based super-high-resolution display, a 30-inch 2048 x 2048 color monitor, is already on the market. However, technical issues exist such as problems with the electron beam size limiting luminance to only around 100 cd/m^2, and installation adjustments being difficult due to high susceptibility to geomagnetic effects. There are also problems from a practical viewpoint, such as the fact that they are 80 cm deep and weigh around 100 kg. As a result, users are eagerly anticipating the development of new super-high-resolution displays. Fully exploiting the advantages of TFT LCDs, such as higher resolutions, thinner profiles, lighter weight, and immunity from geomagnetic effects, etc., will enable the development of super-high-resolution displays far surpassing CRTs, and can be expected to facilitate the creation of new markets.

1. Specifications required by high-resolution displays

Fig. 1 is a map of potential application products based on resolution and screen size of TFT LCDs. For conventional high-resolution displays used for PC monitors, size generally ranges from 13 to 20 inches (measured on the diagonal) and resolution from XGA (768 scanning lines) to UXGA (1200 scanning lines). However, for displays capable of handling super-high-definition images such as monitors used for digital archives, medical images, and air traffic control, resolutions of at least 2000 scanning lines and screen sizes ranging from 20 to 30 inches are being demanded. **Table 1** lists the specifications required of these super-high-resolution displays. In addition to resolution and size, these applications demand characteristics such as brightness, contrast, number of displayable colors, and grayscale capabilities beyond those of ordinary monitors.

2. Panel design

Table 2 lists the ranges of potential single scan-line times (1H) for various resolutions. A natural consequence of the high number of scan lines (2048) is that the 1H time is around half that of conventional high-resolution displays. Further, the charging time during which the signal is applied to the pixel electrode via the TFT (T_{on}) is the available time remaining after the scan-line and signal-line delay times are subtracted from the 1H time. Because increased bus-line resistance due to the large format (28 inches) and increased bus-line capacitance due to the high resolution (QSXGA) lead to longer delay times, it is to be expected that the time available for charging the pixels will become extremely tight. **Fig. 2** illustrates the results of a simulation using a conventional design. From these results, it is clear that panel development using existing processes would be difficult based on conventional designs, and that a major breakthrough, for example, development of a copper bus-line process (resistivity of 2 $\mu\Omega$cm), significantly improved a-Si TFT mobility (more than 1.0 cm^2/Vs), and the like, would be required.

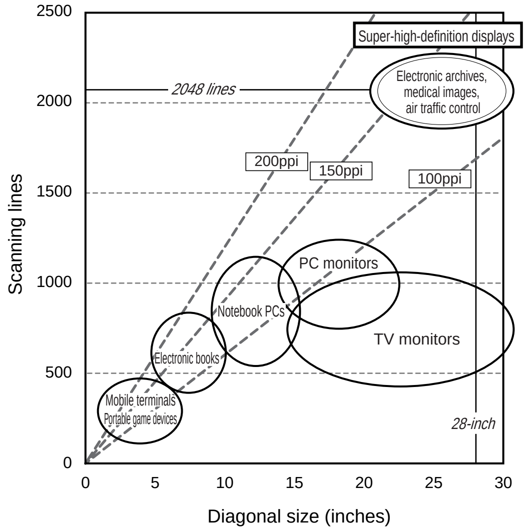

Fig. 1 Application Map (Diagonal Size - Resolution).

Table 1 Target Characteristics.

	Required specifications	Development target
Size	20- to 30-inch	28-inch
Resolution	Greater than 2000 scanning lines	2048 scanning lines, 2560 x RGB x 2048
Brightness	Above 200 cd/m^2	200 cd/m^2
Contrast	Greater than 300:1	300:1
Number of colors	At least 24-bit color (8-bits per primary)	24-bit color (8-bits per primary), 256 value levels (16.7 million colors)
Grayscale characteristics	γ=2.2	γ=2.2, smooth grayscale characteristics
Frame rate	At least 60 Hz	72 Hz
Interface	Digital I/F	Digital I/F

Table 2 1H time (60Hz - 75Hz)

Resolution	Scan lines	1H(μsec)
VGA	480	26.7 ~ 31.7
XGA	768	16.7 ~ 20.7
SXGA	1024	12.5 ~ 15.6
UXGA	1280	10.7 ~ 13.3
QSXGA	2048	6.0 ~ 7.5
QUXGA	2400	5.0 ~ 6.5

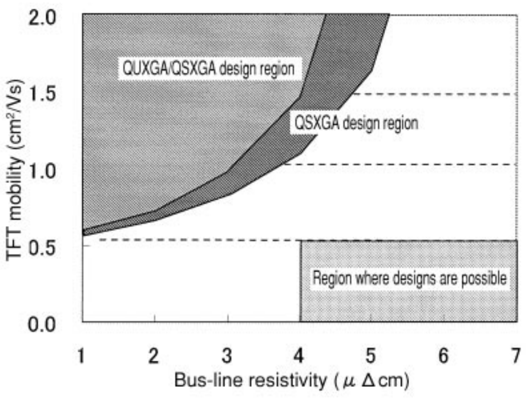

Fig. 2 Simulation Result (Conventional Design).

For the present development, the authors adopted a partitioned scanning scheme within the panel as shown in **Fig. 3** that ought to make it possible to shorten the development time as well as enable development and mass production using existing fabrication lines. This scheme allows the effective 1H time to be on the order of conventional high-resolution displays. **Fig. 4** shows the results of a design simulation using this in-panel partitioned scan system. From the results, it is clear that adopting this in-panel partitioned scan system makes it possible to design panels up to QUXGA while maintaining ample margins, even using existing fabrication processes.

It should also be noted that all of these designs utilize Sharp's proprietary UHA (Ultra High Aperture) technology.

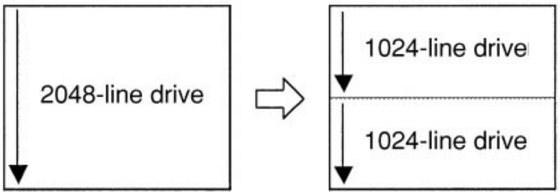

Fig. 3 Scanning method.

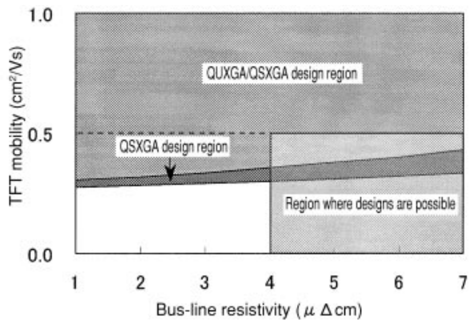

Fig. 4 Simulation results (Innovative Design).

3. Circuit design

Fig. 5 shows the circuit logic configuration. Along with adopting the in-panel partitioned scanning system, the input image signal is also split into upper and lower screens. In addition, to facilitate the use of existing technology and components as much as possible in the processing and transmission of the image signal, the upper and lower screens were further divided into two left and right screens with the goal of reducing the transmission frequency. Overall, the design is one in which individual SXGA driver circuits are formed for each of the four partitioned screens. The drive timing of the four screens is designed so that it is synchronized to one, thereby eliminating distortion or drift, and is controlled on the motherboard. It should also be noted that, for signal transmission within the substrate, a new on-board LVDS transmission scheme was adopted capable of accommodating the increase in transmission distances accompanying the large-format panel.

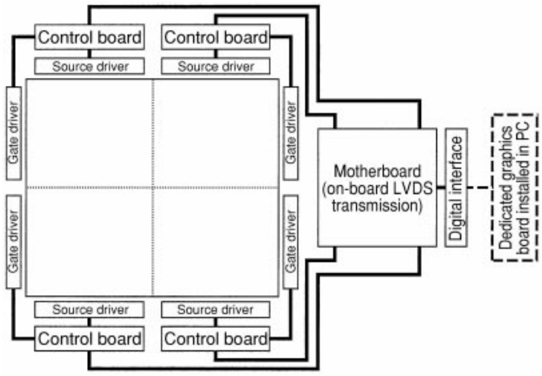

Fig. 5 Circuit Composition.

In addition, new 8-bit digital driver and controller ICs were developed for this display. The design of the 8-bit digital driver is optimized to the 2.2 γ (gamma) value of the target specifications to achieve smooth grayscale characteristics. **Fig. 6** shows the γ characteristics measured for the display. The control ICs have the signal processing capacity to handle up to UXGA resolutions, and the overall circuit configuration is also designed to be able to accommodate resolutions up to QUXGA (2400 scanning lines).

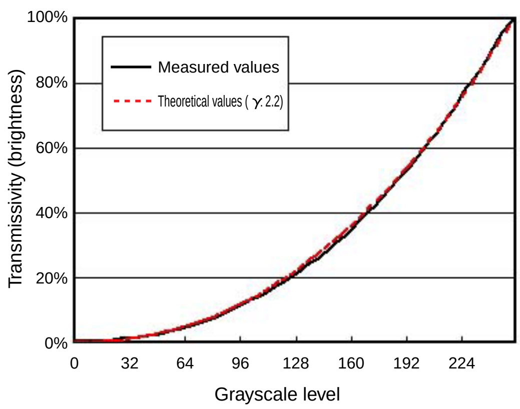

Fig. 6 γ Characteristics.

It should also be noted that, in adopting the present in-panel partitioned scan system, the polarity inversion drive scheme has been optimized so that no partition lines are visible between the upper and lower screens.

4. Backlight design

An edge-lit, thin-profile backlight unit was developed. Panel transmissivity is lower in conventional large-format high-resolution panels, and adopting an edge-lit backlight scheme is difficult. The use of UHA technology, a proprietary development of Sharp, makes it possible to use an edge-lit system.

In an effort to give the unit a thinner profile, a CCFT (cold cathode fluorescent tube), 2.6 mm in diameter and approximately 600 mm in length, was used as the backlight. Three tubes each (for a total of six tubes) were arranged in a delta configuration on the top and bottom lengthwise edges of a light guide plate 8.0 mm in thickness. Despite its being a 28-inch QSXGA display, i.e., a large-format, high-resolution LCD module, we were able to achieve a thin form factor, with a module thickness of only 37 mm.

Table 3 Display Specifications.

Display size	28.3-inch (on the diagonal)
Resolution	2560 x RGB x 2048
Aspect ratio	5:4
Pixel pitch	0.219 mm (116 ppi)
Display luminance (adjustment range)	200cd/m^2 (60% to 100%)
Contrast	300:1
Number of colors	24-bit color (8-bits per primary), 256 value levels (16.7 million colors)
Viewing angle	160° right/left; 130° up/down
Gamma (γ) value	2.2
Frame rate	72Hz
Interface	Digital I/F
Power source	AC 100 to 220 V, 50/60 Hz
Power consumption	75 W
External dimensions	640 (W) x 37 (D) x 530 (H) mm
Weight	11.5 kg

5. Display specifications

Table 3 gives the specifications for the super-high-resolution TFT LCD developed at this time. All the development target values shown in **Table 1** were able to be reached, and further, a display overwhelmingly superior to CRT displays in terms of external dimensions (depth), unit weight and power consumption was achieved. **Photo 2** shows an external view of the module.

Photo 2 28" QSXGA TFT-LCD Module.

Conclusions

By applying new technologies to a foundation of previously acquired design technologies for panels, driver/control logic, and mechanical elements, the authors succeeded in developing in a short time-frame a 28-inch QSXGA super-high-resolution TFT LCD that can be manufactured using existing mass production facilities. In comparison with existing super-high-resolution CRT displays, its specifications-such as one-twentieth the depth, one-tenth the weight, double the luminance, and immunity to geomagnetic effects-essentially eliminate troublesome issues associated with CRTs. The development of this 28-inch QSXGA display will make a major contribution to stimulating new markets for super-high-resolution display systems in the future.

In a desire to see a further expansion of application markets, the authors plan to work toward mass production, and in the future, incorporate additional new technologies, such as more advanced wide viewing angle and high-speed video technologies.

Acknowledgments

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