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Text: 69 words:

Sharp demonstrated a 14-in. TFT-LCD for TV in 1988 when the display sizes of the mass-produced TFT-LCD and CRT TVs in the largest number were 3-in. and 14-in. respectively.
The breathtakingly high display quality in CRT-size convinced vacillating electronic companies to decide to join the burgeoning TFT-LCD industry, vaulting it to the major league status in emerging full-color portable PCs, and replaced CRTs in TVs about 2 decades later.

General Description:

In July 1987, the state of the art of thin-film-transistor liquid-crystal displays(TFT-LCDs) was the size of three inch diagonal. The small LCDs were used as displays of wrist watches and pocket calculators, using simple-matrix LCDs.

Simple-matrix LCDs were also used in small TVs and portable PCs with poor display qualities: large response times, low contrast ratio, large cross talks. Improvement needs were larger for full-color displays where displayed image must be BEAUTIFULL with larger contrast ratio, higher color saturation, shorter response times and delicate gray scale rendition.

Dominant displays used in TV and PC were CRT in those days, and alternative technologies were eagerly searched for: amongst candidate technologies were EL, Plasma, and TFT-LCD.

All candidates were flat panel displays to handle larger display contents with big portability to meet the needs of rapidly evolving information age.

Sharp gave the first priority to TFT-LCD with EL and simple-matrix LCD studied with less emphasis.

The first application for TFT-LCD was color TV as Sharp was a major player in TV market, but did not produce CRT in house.

It was decided that twenty 3-in. 384Hx240V dot panels for color TV were prepared on a large 320 mm x 300 mm rectangular (17-in. diagonal) mother glass substrate first in the world in November 1985 while 6-in. circular substrate was used in semiconductor industry.

The 3-in. TFT-LCD color TV, Sharp's 1st LCD TV, was put out on to the market June 1987. Competition was fierce and the process was not profitable.

As a next step, engineers had proposed going up to 4-in. for TV, portable video-players and PDAs , then 5.7-in. for TV and car-navigation displays for mass-production.

Isamu Washizuka, Division General Manager of Liquid Crystal Division, accepted those proposals, and at the same time, gave a mission to look into the future, and to search for TFT-LCD technology capability for TV, and instigated young engineers to study and propose larger display prototype fabrication plans without giving clear target size numbers.

Around middle of 1987, a voluntary project team was set up, headed by Mitsuo ISHII, whose leading members were Toshio AKAI for product planning role, Kohzo YANO for process engineering role and Hiroshi TAKE for electronics engineering role.

Numbers of panels, with the aspect ratio of 4:3 for TV, prepared on a rectangular mother glass substrate change stepwise.

The study showed the mother glass could accommodate four 6.6-in. panels, two 8.9-in. panels, one 14-in. panel.

The project team almost reached a consensus to adopt 8.9-in. size for a challenging target: 6.6-in. seemed to give only a small impact; 14-in. seemed to be too risky to get good panels, meaning with high display uniformity across the entire display area, no-line defects and acceptable dot defects by infant technology and equipment.

TAKE made a phone call to Magohiro ARAMOTO, general manager of TV Division located in Yaita-shi, Tochigi-ken, who was the head of a project team, comprised of TV group and LCD group which had made a decision Sharp should adopt TFT-LCD for color TV, and had always set a clear and severe target of display quality TFT-LCD group had to clear, saying this target must be cleared for TFT-LCD to be viable in TV consumer market. TAKE asked ARAMOTO on the phone what would be the minimum size of TFT-LCD to be widely used by people.

ARAMOTO's right-away answer was 14-in. as 14-in. CRT TV was mass-produced in the largest number in the Japanese consumer market in those days.

TAKE, evaluation and characterization research engineer by background, knew the difficulty to prepare 14-in. panel using the same process and equipment used to mass-produce 3-in. panels with poor yield, but decided to accept ARAMOTO's number 14-in., saying to himself the possible largest size on the mother glass would show up, more clearly than smaller sizes , problems and issues TFT-LCD had to solve and tackle with to be a viable technology in TV and other markets dominated by CRTs.

The panel should be compatible with NTSC/M TV system, and display dot number was decided to be 642Hx480V with available analog driver-LSI output numbers taken into consideration. The trios of red, green and blue primary color dots were arranged in a triangle pattern to maximize the resolution with the limited display dot number.

The target TFT-LCD panel specifications was accepted in the project team after YANO made a thorough review of the TFT-LCD process and equipment in the 3-in.-mass-producing factory to make sure 14-in. was NOT impossible , and authorized by WASHIZUKA.

WASHIZUKA, then, had AKAI sent directly to Haruo TSUJI, president of Sharp corporation, to get a fund for 14-in. TFT-LCD as LCD Division did not have any extra budget to support 14-in. project, because he knew TSUJI was the very person who most eagerly wanted to produce TV displays IN HOUSE, and was weak to a proposal from the bottom, in particular, from a young guy.

AKAI went to TSUJI alone, and made a presentation and described 14-in. TFT-LCD project, and requesting to support the project by supplying the fund.

Understanding the meaning of the size 14-in., the dominant size of color CRT TV, TUSJI accepted the request and instructed the department concerned on the spot to prepare the fund for the project.

One of the team members recalls the events that happened after that. Washizuka insisted on using only existing manufacturing equipment. This meant they now had to use the stepper that had been used for the 3-in panels for the exposure of a 14-in panel. They subdivided the panels into nine areas and used the stepper nine times. The major problem was the length of the conduction lines. They knew the statistical value for line breaks from their experiences in manufacturing the 3-in panels. By extending the statistical values, they predicted that the 14-in panel was not going to make it, if existing design rules were used. They brainstormed and came up with the idea of subdividing a dot into four identical subdots. The subdots were driven by two source lines having identical signals and with two gate lines also having identical signals. The source lines were driven from the two ends of the panel; so were the gate lines. With this four-fold redundancy and two-end supply scheme, even if there was a break in one line, the signal could be propagated without interruption. By using four identical subdots, a defect in one subdot was not noticeable when a moving picture was displayed. Three dots were arranged in a triangular shape to maximize display resolution with limited dot numbers—each having a red, green, and blue filter, thus, forming one pixel. The pixel had 12 subdots and the panel was made of 1284 960 subdots. Except for the conduction line, they did not expect too much of a problem. The production facility, however, was in almost full use for manufacturing the 3-in panels. Yano quietly pushed a panel through the manufacturing line whenever he found a short period of time when the line was not being used for production. The experiment was a so called “Friday afternoon” experiment. Having been started in August 1987, the process of pushing the panel through the production line was finally finished in February 1988. To the surprise of all the people involved, the first 14-in panels looked okay when examined by the naked eye. They secured four good panels. The next task was to operate the panel with appropriate peripheral circuits. Take recalls that a module group had prepared an application-specific integrated-circuit controller. As for the drivers, they did not have time and money to design a new one, so they used the drivers for the 4-in display. Even the source and gate lines were driven from both ends, he had to operate the driver at three times its specification. The 4-in source driver was designed to operate at approximately 6.5 MHz. Instead, it was operated at 13 MHz. The driver overheated and required a fan cooler. In April 1988, they tested the panel. The first trial exhibited only a black picture. Examining the problems and fixing them, they could demonstrate a still picture, but the size in the horizontal direction was one-half the full panel size, which meant that the source driver clock was operating at only half the required frequency. By brute force, they gradually increased the voltage of the logic circuit. Suddenly, a full-size moving picture appeared, but the picture showed a long tail when tracing a fast moving object.

Engineers needed another day to fine-tune driving circuit parameters to make the most of 14-in. TFT-LCD panel characteristics, and finally succeeded in demonstrating the 14-in full-color full-motion display with sharp and vivid color: high contrast ratio, high color saturation, quick response times, in particular, the size of 14-in. of that display quality was formidable even to the 6-engineers' eyes which had got accustomed to a small 3-in. TFT-LCD whose properties in room ambient brightness, had appeared to be better than those of CRTs, which had not been recognized clearly before.

The size of 14-in. disclosed the 2 intrinsic properties of a color-TFT-LCD which brought about a different level of display quality, in particular in room ambient brightness, than that of CRTs and surprised 6 engineers who surrounded the 14-in. TFT-LCD displaying laser-disk test movies.

The first intrinsic property is “low reflection” caused by micro-primary-color filters provided to every display dot; the second “sharp contrast-resolution MTF(Modulation Transfer Function) curve shoulder” by sharp display dot edge which is independent of display brightness.

Sharp 14-in. TFT-LCD demonstration clearly showing the possibility of CRT replacement in 1988, at least display qualitywise , was a product of more than 4-year close cooperation of Sharp TV people located in Yaita-shi, Tochigi-ken, and TFT-LCD people in Tenri-shi, Nara-ken.

The 2 properties are independent of display sizes: 3-in. had been simply too small for the properties recognized by naked eyes.

Subsequently, the panel was shown to the president. The panel was too good to be true. His first reaction was that Washizuka was fooling him with a phony set up; it was only sometime later that he realized to his surprise it was the real thing.

On June 24, 1988, Sharp announced the 14-in TFT color LCD unit [113] , followed by the technical presentation of [114]. The display was 27-mm thick, including a back light, approximately 1/13 of a conventional CRT display, and its weight was 1.8 kg, approximately 1/4 of a CRT display. Most importantly, the display size of 14 in was the minimum required for a television receiver serving ordinary households and the display could be mounted on a wall.

The announcement sent a message to engineers and managers that TFT-LCDs, which had been serving the niche market for portable 3-in. TVs, and PDAs, now could serve the market for home appliances such as television receivers. and emerging portable PCs, in particular, color note-PCs for business use.

portable PCs

The world first laptop PC , TOSHIBA T-1100, was put on the market in 1985 with 640Hx200V dot black/white simple-matrix LCD.

The first 640Hx480V(VGA) dot black/white simple-matrix LCD was mounted to Compaq Portable SLT/285 in 1988.

Portable PCs with black/white LCDs had always a video terminal supposed to be hooked to color CRTs.

Electronics giants such as Toshiba, IBM, and NEC, which had been performing only research into TFT-LCDs, but were not involved in the business of manufacturing them, now joined the burgeoning TFT liquid-crystal industry too to meet the emerging color portable PC demand.

The 14-in display development vaulted the TFT-LCD industry to major-league status.   The door to TFT-LCD industry was open!

The world first wall-hanging 8.6-in. color TFT-LCD TV was put on the market in 1990 by Sharp; the world first note PC with color TFT-LCD in 1991 by NEC.

In 2001, Sharp launched AQUOS Big-Bang operation, and put 3 TVs: 13-in., 15-in. and 20-in. at a time to the market to replace CRT TV in the Japanese Sharp market, and this operation lead to the avalanche of CRT to LCD shift in TV in the world market.

When he invented the Dynamic Scattering Mode LCD in 1964, George Heilmeier of RCA Laboratories thought a wall-sized flat-panel color TV was just around the corner [9]; as a matter of fact, it was far short for a television display. Finally in 1988, his dream of the wall-hanging television became a reality after a quarter of a century. In The Wall Street Journal [17], Heilmeier remarked: “I think you need to give the credit to the people who persevered and worked on LCDs for 25 years. I don’t spend too much time wringing my hands about it, but I have a lot of satisfaction knowing we had the same vision in the 1960s.”

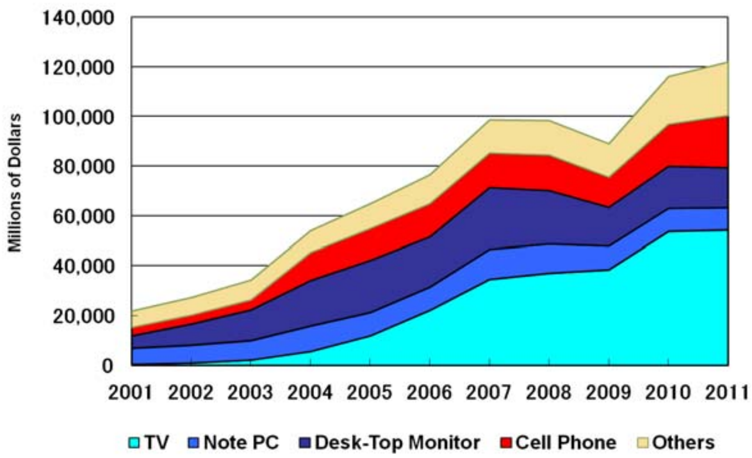
The Active-Matrix TFT display developed in 1988 and its descendants are now used in almost any electronic equipment. The LCD industry took over CRT industry in 2001 (Table 1), and in the-number-of-unit wise in 2005 [1]

Among various technologies, LCD now dominates the electronic display market (Table 1).

	2,000	2,002	2,004	2,006	2,008	2,010
AM LCD	16,797	18,201	58,872	71,184	95,249	109,445
PM LCD	5,570	5,137	6,893	5,108	3,184	
all LCD	22,367	23,338	65,765	76,292	98,433	109,445
CRT	23,400	20,086	18,907	16,435	4,518	1,870
PDP		2,203	5,490	7,688	6,793	7,800
OLED		92	410	550	610	1,467
Others		1,306	1,402	1,457	1,441	1,460

Table 1. Electronics Displays. in unit of Million dollars, all sizes, AM and PM (IHS iSuppli)

The use of Active-Matrix LCDs started from Note PC and Desk Top Monitor in 1990s, and then moved to TV in late 2000s (Fig. 17).



uppli)

Today, the number of LCDs in consumer's and businessman's use is considered to be over 9.4 Billion units world-wide (accumulating the shipments of TFT-AM LCDs for phones, monitors, PCs, and TVs from 2009 to 2011; IHS iSuppli). The number is greater than the world population of 7 Billion. The invention of LCD is not only one of the greatest technical achievements in the 20th century; it has greatly enriched our life and enhanced business activities.

TAKE now recalls an episode in SID '84 held in San Francisco: he was on the panel, chaired by Dr.Lalatos from Xerox, Rochester, discussing future TV displays.

a- Si TFT-LCD, p-Si TFT-LCD, and CRT were taken up. TAKE represented a-Si TFT-LCD technology.

Toward the end of the panel discussion session, a question from the audience was made to him, saying "Do you think it is possible to make 14-in. display with a-Si TFT technology?"

His answer was:

I have a faith in a-Si TFT technology, and it's quite possible a-Si-TFT could be used for 14 display.

But, I have to quickly add a dictionary says "Faith means to believe without clear evidence".

The audience went into a big laughter.

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