Official Monthly Publication of the Society for Information Display

INFORMATION DISPLAY

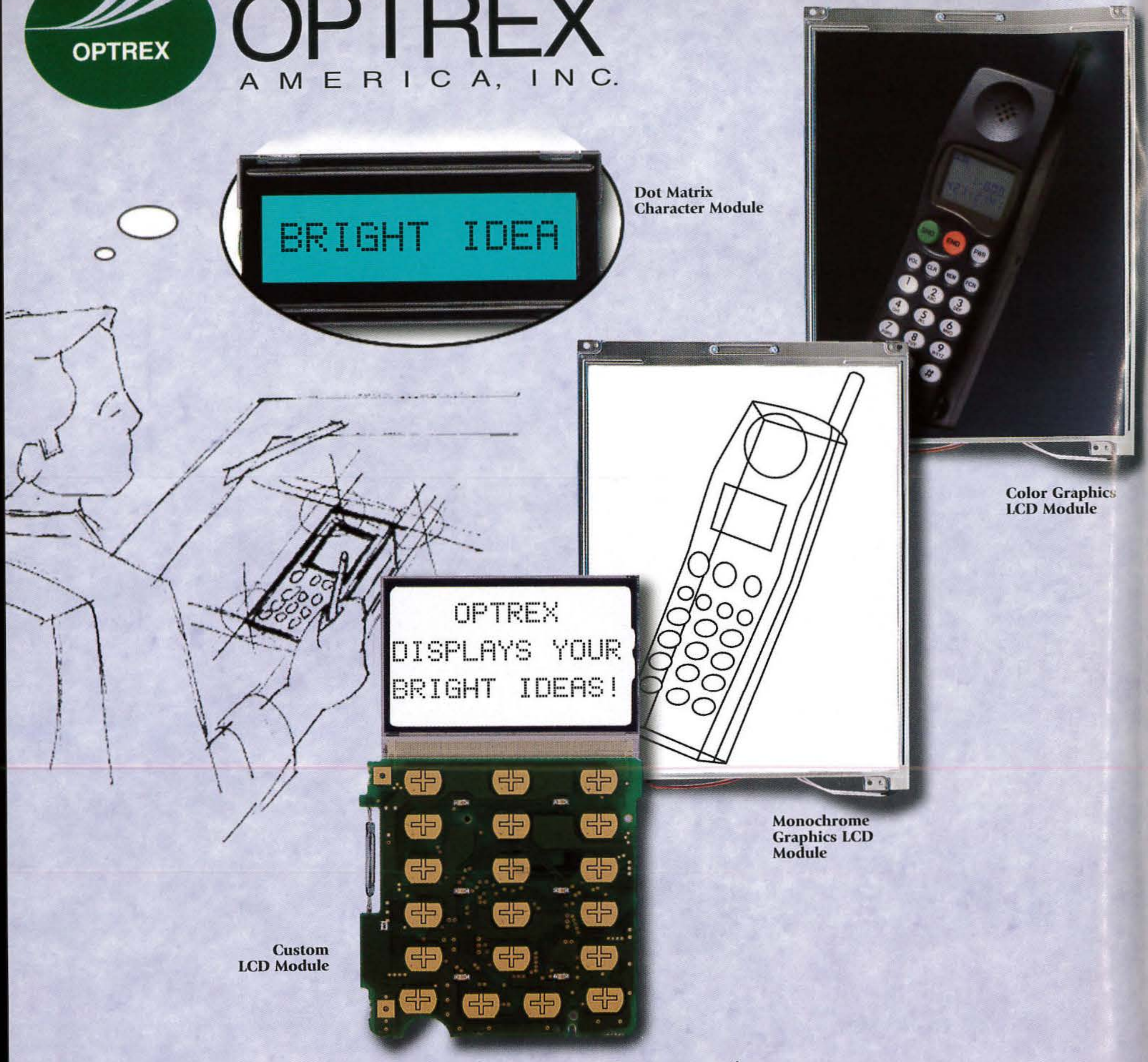
SID

October 1997 – Vol. 13, No. 10

FLAT-PANEL ISSUE – 25 YEARS OF ACTIVE MATRIX

42-in. Plasma Displays Enter Volume Production

- Birth of the Active Matrix
- Thirty Years of PDPs
- Scan-Conversion Techniques
- VESA's New Interface Standards
- LCD Monitors Proliferate in Taipei



Dot Matrix
Character Module

Color Graphics
LCD Module

Monochrome
Graphics LCD
Module

Custom
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OCTOBER 1997
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COVER: Fujitsu's ImageSite is the first 42-in.-diagonal plasma display to enter volume production, and others are on the way. PDPs have seen major technical improvements in 1997, and more are due in '98 – including some surprises.

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For more on what's coming in *Information Display,* and for other news on information-display technology, check the SID Web site on the World Wide Web: **http://www.sid.org**.

Next Month in *Information Display*

Display-Manufacturing Issue
- Inspection and test techniques
- Neck-down CRTs
- Manufacturing large PDPs
- Backlighting for direct-view LCDs
- LCD viewing-angle improvements

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editorial

The Other Displacement

Displacement refers to using an FPD where a CRT would traditionally be designed in. The CRT is thus "displaced" by the FPD.

For most of their history, FPDs have grown by creating new applications, such as notebook computers and personal information tools, that CRTs could not fill. Although this pattern continues today, the era of displacement has clearly begun. A variety of oscilloscopes, logic analyzers, medical instruments, industrial control systems, and camcorder viewfinders that once used CRTs now use flat panels.

But the big displacement play is in desktop monitors. Sales are still small, but many companies, large and small, are showing units and jockeying for position. As Bryan Norris reports in this issue, over a hundred FPD monitors and variants were shown at Computex Taipei in early June. Some vendors have been selling units for two years or more.

Joel Pollack of Sharp Microelectronics feels that the new breed of multi-line-addressed (MLA) STN-LCDs will make displacement take off. MLA displays are fast enough to show decent windowed video, and they are inexpensive enough to permit LCD monitors to be sold at only twice the price of CRT monitors. At that price, says Pollack, the market penetration for LCD monitors should be about 5%. That's a smallish slice, but it will come from a very large pie.

However, another kind of displacement may already be taking a bigger slice out of the pie - and this displacement would be hard to identify from sales statistics alone. I am speaking of CRT displacement through the sale of a notebook computer that displaces a desktop computer - along with its CRT-based monitor.

In "Portable Desktops," an article in the August issue of *PC Magazine,* Bill Howard writes, "... three out of every four notebooks sold today replace rather than complement desktop PCs." "Replace rather than complement." That sure sounds like "displacement" to me.

Let's look at this from another angle. When I wondered aloud in NEC's booth at SID '97 why people wanted to lug larger, heavier notebook computers with 13.3-in. displays around on airplanes, NEC Product Marketing Engineer David Schultz said, "They don't." According to NEC's figures, over 90% of such notebooks serve as "moveable desktops": They are used on a desk at work, then taken home and used on a desk or table. Such a computer spends the rest of its life on an automobile passenger seat or next to its owner on the floor of a commuter train.

There are other trends that nicely confuse the issue. Tei Iki of Sony in San Diego has observed that a substantial number of CRT monitors are sold with new notebooks that replace desktop systems. And the continuing overall growth in computer sales might make it harder to obtain unambiguous evidence of "displacement by notebook" from the sales figures. Still, the fragmentary evidence is intriguing.

Currently, notebook computers that can serve as desktop replacements are expensive. In a corporate environment, the high cost of system support and maintenance already makes it attractive to replace a $1500 desktop machine and

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Circle no. 2

the display continuum

There's Gold in Them Thar Hills! ...

by Aris Silzars

Even though it is a warm, lazy summer evening in late July, my thoughts are beginning to drift in the direction of creating the next "Display Continuum" column. Perhaps my reverie is being influenced by the recent news reports and pictures being sent across millions of miles of space from the recently arrived Mars-lander. Seeing these pictures has put me in an especially philosophical mood. That agile little radio-controlled vehicle being driven around the rocky surface of Mars by a bunch of "techies" in Pasadena, who probably never quite grew up, makes me rethink every science fiction story that I read during my high-school years. Never having quite grown up either, I have decided that it's just great that some of us get to play with toys costing hundreds of millions of dollars.

There is, presumably, a serious side to all this, but, as I see it, there is also an underlying problem with the present space-exploration program. While the objective of increasing mankind's knowledge of the universe is certainly a good and noble one, it falls short of what we humans have been trying to do for the last several million years. In past centuries, we could only get away with spending big chunks of the king's or queen's wealth if: (1) we were dedicated to the pursuit of a church-approved effort to guarantee that a certain few would get to heaven, or (2) we were planning to make said king or queen even richer. Since we have not changed all that much in our basic behavior, the questions we must then pose are: Where is the promise of unbounded riches? Where are the basic human motives of greed and possession? Where is the search for the fountain of youth? And, oh yes, does this get us a special deal for getting into heaven?

I suppose the closest we can come to answering at least one of these questions is to hope that somehow by understanding more about the universe we will gain greater insight into why we're here - maybe even where "here" is - and thereby have some additional data with which to try to answer the metaphysical questions most of us occasionally ask - especially during life-threatening crises and other traumatic periods. And for the general public, there is always the short-term fascination of seeing photos from the moon or Mars and comparing them to what is being promoted in the latest space movie.

But, all this doesn't allow the rich to get even richer. Therefore, it seems to me that what is needed is for the Mars Sojourner to find something really important - something far more significant than the interesting but financially useless factoids about what kind of rocks are there and that there may have been some water around a few billion years ago. We need to find something that will dramatically alter the whole complexion of space exploration - increase it by an order of magnitude or two.

For example, right here on earth a hundred years ago a few folks found gold up in the Yukon Territory. That soon caused something like a hundred thousand others to buy a year's worth of provisions and endure major hardships to travel the thousand miles from Seattle to stake their claims along the Klondike River and its tributaries. From the stories being recounted in the Seattle newspaper, there was one particularly difficult climb through a mountain pass that took weeks of struggling to get the mandatory one thousand pounds of provisions per

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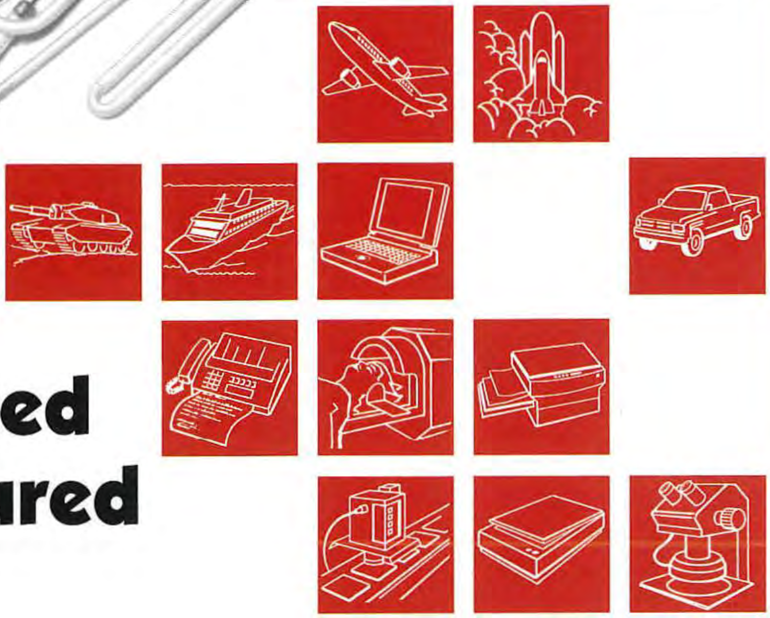

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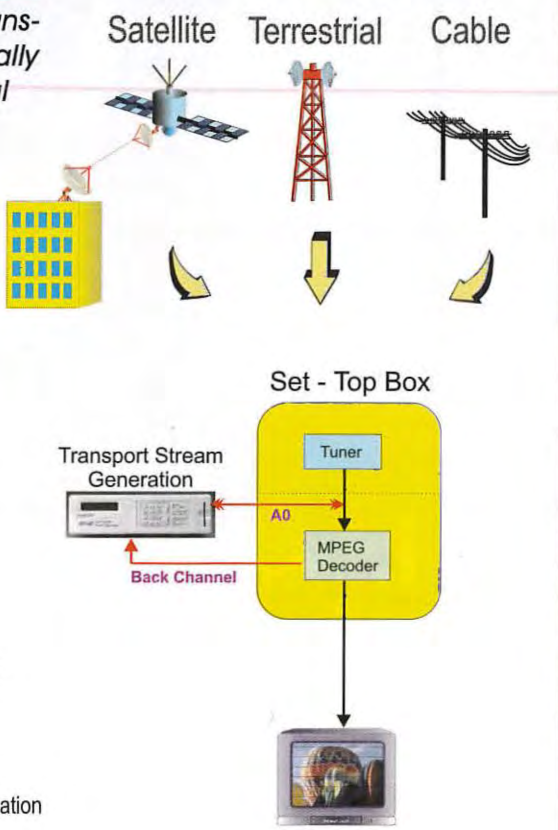

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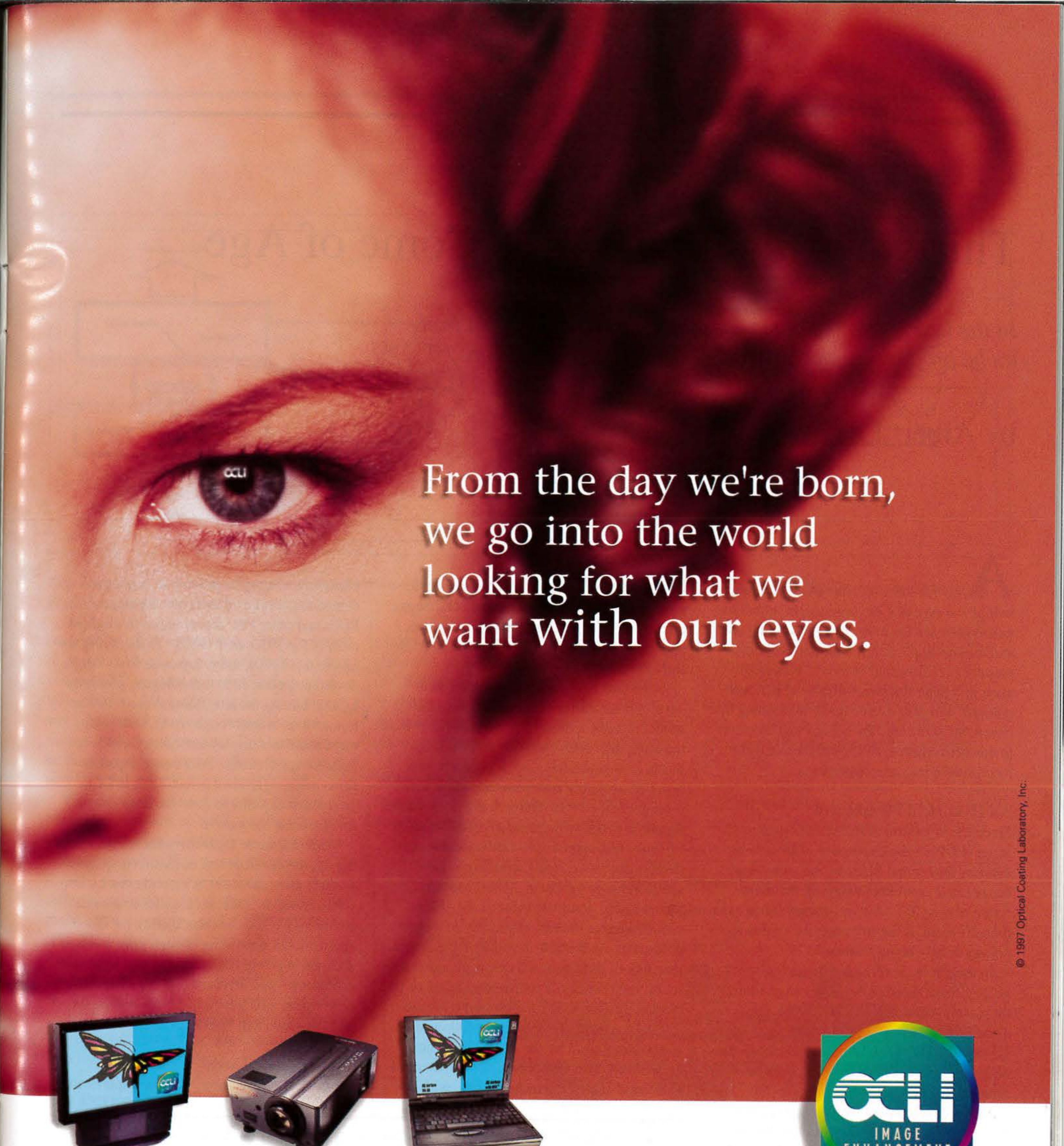

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Circle no. 9

Thirty Years Later: PDPs Come of Age

In the last 5 years, plasma-display panels have moved from niche products to the brink of high-volume production.

by Albert Lee

ANALYSTS PREDICT that the 21st century will be the Age of Convergence, in which we will experience the integration of sound, vision, and Internet applications with new technologies not even dreamed of today. Plasma displays and other flat-panel-display (FPD) technologies will play a critical role in defining this new multimedia era. By being a key element in this convergence, FPDs will inevitably be incorporated into new applications.

An Historical Perspective

Since the invention of the plasma-display panel (PDP) at the University of Illinois in 1964 by Bitzer and Slottow, the technology has seemed capable of usurping the dominance of the CRT. But only today, after more than 30 years, is the full potential of this technology finally being realized.

In the 1960s, several American high-technology firms raced to develop and capitalize on plasma technology. IBM, Bell Labs, Zenith, RCA, Control Data Corp., Burroughs (Unisys), and Owens-Illinois all devoted significant resources to the research and development of this new technology.

Initial development by these companies helped define some of the basic technologies for realizing the color plasma panels of today. They helped define pixel structures and effective driving schemes, and introduced new phosphor materials.[1] Halfway round the world in Japan, companies such as Fujitsu, Hitachi, NEC, Sony, Toshiba, and Oki began their own development of plasma displays, built upon the work already done in the U.S. and elsewhere.

In the late 1970s and early 1980s, PDP development mirrored the situation in the semiconductor industry. American firms were reducing their reinvestments and developments in new semiconductor products as a result of declining revenues caused by stiff foreign competition. But as their sales soared, Japanese firms, with guidance from Japan's Ministry of International Trade and Industry (MITI), increased R&D spending in new semiconductor products. (Until recently, they proceeded to dominate most of the global semiconductor market, especially in memory products.) As a result, Japanese firms, more than any of their competitors, were technologically and financially prepared to advance into plasma displays.

Plasma-display development followed a similar track, and by the early 1980s most U.S.-based firms had ceased development of PDPs and other FPD technologies, with the exception of a few small firms. Japanese companies continued their development of PDPs and other FPD technologies throughout most of the 1970s and 1980s. Then, during the mid to late 1980s, many Japanese firms began developing other FPD technologies, primarily LCDs. During the late 1980s to early 1990s, tremendous breakthroughs in LCD development made this display technology viable for portable applications. As a result, Japanese firms made significant investments in LCD production capacity to meet the huge demand for notebook computers.

While Japanese LCD investments were heating up, the development of plasma displays as a viable alternative to CRTs, and even LCDs, was cooling off. Major obstacles in plasma technology – such as color quality for video applications, generating enough gray levels, acceptable power consumption, and luminous efficiency – had driven off all but a handful of developers, which included Fujitsu in Japan and Plasmaco and Photonics in the U.S.

The Race for Color

Without effective color, plasma displays were

Table 1: Comparison of ac- and dc-Plasma Technologies

Feature	dc Plasma	ac Plasma
Luminance (cd/m^2)	200	350
Life (hours)	10,000	30,000
Contrast	>100:1	>300:1
Manufacturability	Complex	Simple
Power: 40-in. full-color-display equivalent	Very High: > 400 W	High: < 350 W

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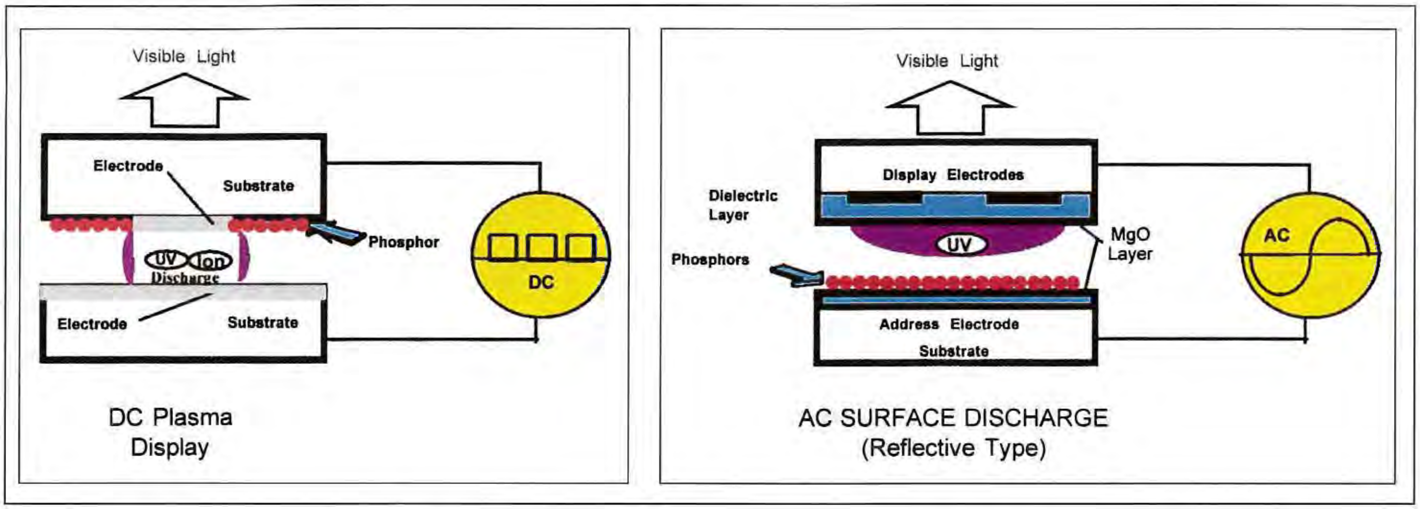

Fig. 1: *ac- and dc-plasma displays differ in their waveform and pixel structure. In dc panels, electrode polarity is fixed, while in ac panels the electrode polarity reverses.*

relegated to niche applications. The explosion of graphics-based computing had ensured that volume FPD markets would go to full-color technologies. Monochrome plasma displays were successful, however, in applications such as factory automation. This continues to be the case today, although there is a definite trend toward color in these areas as well.

PDP developers took two roads to color. Manufacturers such as NHK, Matsushita, and Oki pursued color plasma using dc-plasma technology, while Fujitsu and Thomson focused on ac-plasma technology. The main differences between the two technologies are in the drive waveforms and pixel structures (Fig. 1). In the dc panel, electrode polarity is fixed, meaning that a dc-level drive signal is used to excite the pixels. In ac displays, the electrode polarity is reversed, meaning that an ac-drive waveform is used to excite the pixels. There are advantages and disadvantages to both technologies (Table 1).

Key Developments

ac-plasma displays have become the dominant type for monochrome and, more recently, for full-color plasma. Currently, NHK and Matsushita are the only companies still developing dc-plasma displays.

Several key developments in ac-plasma that enabled it to become the dominant technology for full-color PDPs include three-electrode surface discharge (TSD), reflective three-electrode surface discharge (R-TSD) (Fig. 2), and address display period duplicated subfield (ADS) (Fig. 3). These developments brought plasma technology closer to the performance of CRTs, especially in the areas of contrast, brightness, and luminous efficiency. Other developments in barrier-rib structure and phosphors provided additional benefits (Table 2).[2]

Video-Processing Advances

Despite the breakthrough improvements in ac-plasma displays, significant advances in image quality are still needed for full-motion video applications – especially television. When full-color motion video images are shown on a plasma display, image artifacts such as color contouring, pixelization, lack of color depth/saturation, and posterizing are visible.

These artifacts are related to the fixed spatial format of the plasma display and its digital nature.[3] TV and video source material also

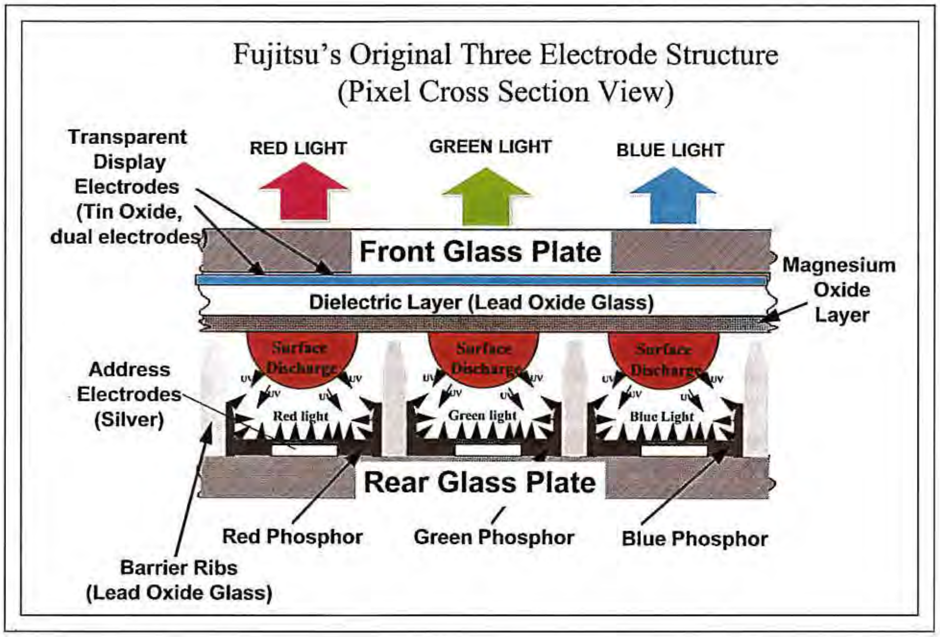

Fig. 2: *Fujitsu's reflective three-electrode surface-discharge structure extended the operational life of color plasma displays.*

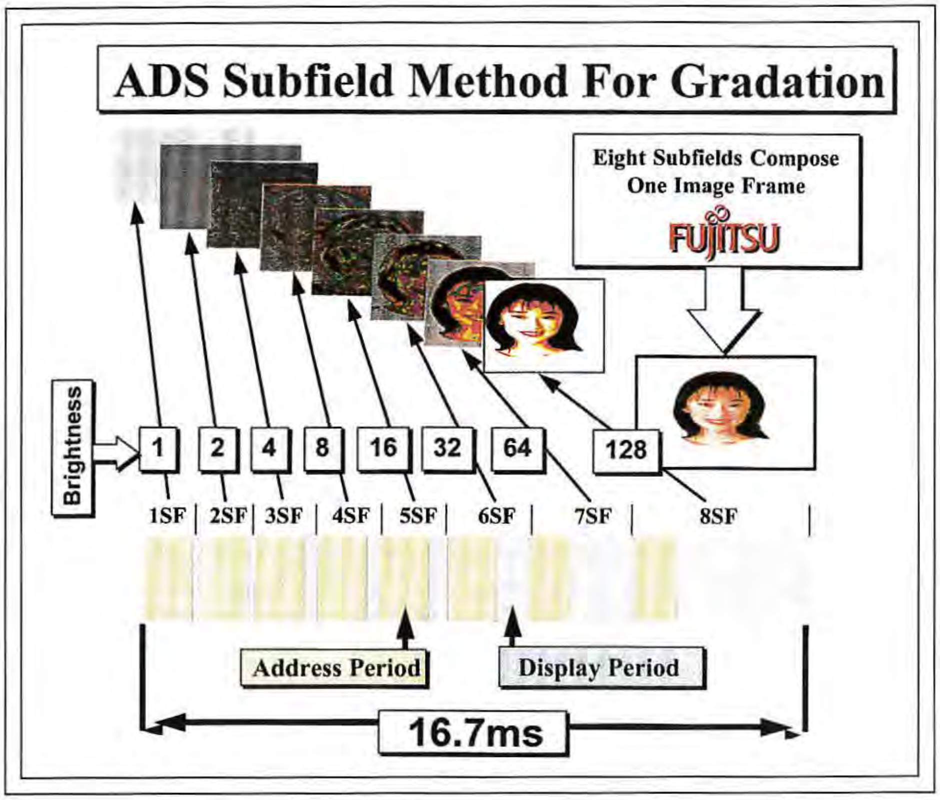

Fig. 3: *The ADS subfield method was a key technological development for enabling plasma displays to achieve gray scale and full-color video.*

presents a major obstacle because these signals are analog and interlaced.

In order to address many of these image problems, some manufacturers, such as Fujitsu, have embedded video-processing capability within the displays. This capability has become an even more attractive solution because of recent developments and pricing of digital signal processing (DSP) ICs and memory devices. DSP devices offer speed and performance and memory devices offer enormous capacities - both at attractive price points. These two elements - frame memory and signal-processing capability - are essential for embedded video processing.

Color contouring and the lack of color depth are a result of the limited color capability of current plasma displays. True-color video sources are at least 8 bits per color primary (red, green, and blue). High-quality video-broadcast sources such as HDTV are 10 bits per primary. From a technological and cost standpoint, most full-color plasma displays are not currently capable of generating such high color content. To correct this problem, manufacturers have, in some cases, implemented dithering, error diffusion, and other video-processing algorithms to increase the apparent color content of the display image.

Dithering is a technique in which, for a given input-intensity range, there is a corresponding range of $n \times n$ matrices representing a sequence of ON/OFF pixels (Fig. 4). Among these matrices, there will be an appropriate pattern of ON/OFF pixels for a given intensity. Changing the combinations of ON/OFF matrix patterns on a per-frame basis generates the appearance of more gray levels.[4] This technique is effective for increasing the apparent number of gray levels in still images, but other artifacts can be introduced with moving images.

Error diffusion is another technique that is used to reduce color contouring and to increase apparent color content. Because the input for a given pixel has a certain color depth - for example, 8 bits - and the display is capable of generating a color depth of only 6 bits, a quantization error is introduced at the pixel. The basic principle behind error-diffusion algorithms is to spread this error to neighboring pixels. With the error diffused over many pixels, the resulting image has an average brightness close to the total desired brightness of the source.[5] Combinations of these video-processing techniques and other improvements in display-driving methods have brought PDP performance closer to parity with CRTs.

These breakthrough developments in plasma technology have sparked a tremendous revival of plasma displays. In addition, the commercial availability of Fujitsu's 21- and 42-in. color plasma displays - the first color PDPs to be commercially available - has generated great interest among product developers. As a result, Japanese and Korean manufacturers, including NEC, Matsushita/Plasmaco, Pioneer, Hitachi, Samsung, Hyundai, Lucky Goldstar, and Daewoo, have all announced their intentions to develop and manufacture color plasma displays.

To date, there has been a combined total investment in excess of $3 billion for new factories (through the year 2000) with an aggregate capacity of 10,000 40-in.-class plasma displays per month. At this time, Fujitsu is the only manufacturer that has started production. Although initial availability is estimated to be 1500 per month, this number is expected to increase very quickly as more manufactur-

Table 2: Key Developments in ac-Plasma Technology

Technology	Feature	Benefit
Three-electrode surface discharge (TSD)	Operational life	30,000 hours
Reflection TSD	High luminance	200-cd/m^2 brightness
Barrier-rib structure	Simple structure	Ease of manufacture
Phosphor arrangement (stripe)	High resolution	HDTV in 40-in. diagonal
ADS subfield	Gray-scale achievable	Full-color video

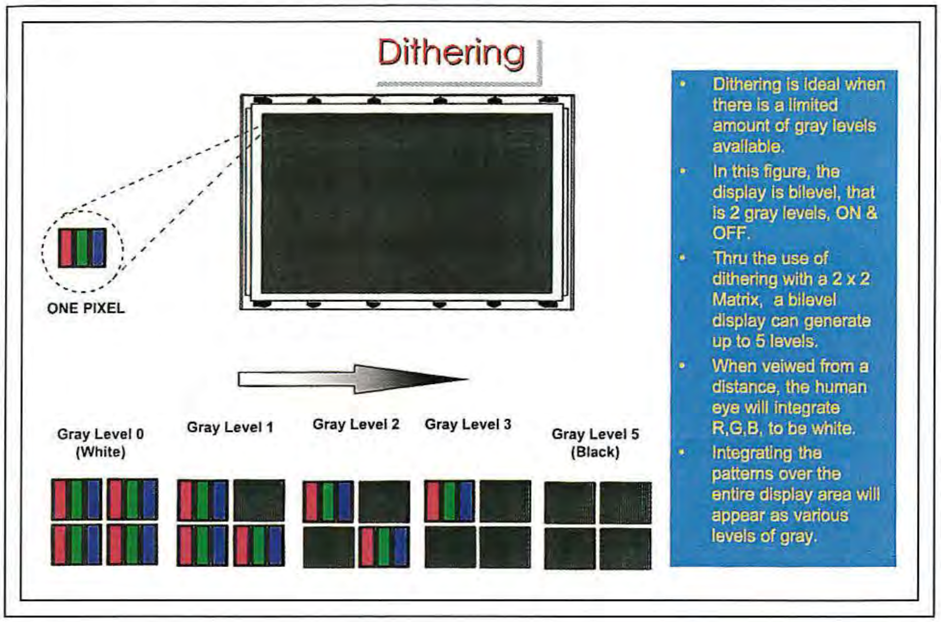

Fig. 4: *Dithering is a technique that, for a given input-intensity range, provides a corresponding range of n × n matrices representing a sequence of ON and OFF pixels. The dithered patterns increase the apparent color depth of the display image.*

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NOVEMBER
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ers reach full production. As more manufacturers enter volume production and quantities increase, market forces will cause a fairly rapid price reduction. If manufacturers' projections are accurate, we can expect prices to drop as low as $20 per diagonal inch over the next 3–5 years.

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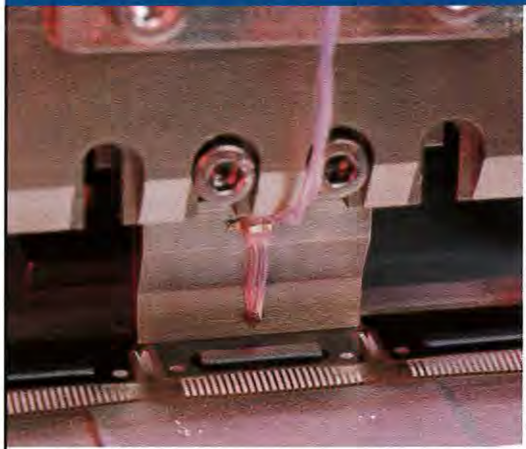

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Scan-Conversion Techniques

There are two basic ways to show interlaced video on a progressively scanned display, and both involve compromises.

by Patrick Salenbien

ONCE UPON A TIME, video displays and data displays were distinctly different devices. Video displays - as used in television receivers - were cleverly designed to show dynamic imagery with adequate screen resolution using an improbably narrow broadcast-signal channel. The data displays of the late 1950s were required to exhibit only static alphanumeric data, but they did need to present a highly stable (jitter-free) image.

With the proliferation of computers in the early 1970s, the use of CRT displays in computer terminals increased dramatically. Terminals of this era were monochrome and displayed only 25 lines of text on a screen with up to 40 characters per line. The increasing speed of computers soon permitted the implementation of far-reaching work on man-machine interfaces, and users began to use graphical user interfaces (GUIs), followed shortly by color. But screen resolution remained quite limited, with an effective standard of 320 pixels × 200 lines.

In the 80s, users started to demand higher resolution to improve the displayed quality of color graphics. So the CRT computer-display market began to evolve from the slow scanning frequencies and low screen resolutions inherited from consumer-television technology to the higher-resolution CRTs we have today.

The current resolution standard for a 19-in. color CRT display is 1280 pixels × 1024 lines. The scanning frequency, which is the speed at which lines are displayed on the screen, has increased from the old 15 kHz to 64 kHz and higher. But the old CRT driver electronics has not been able to keep up with the faster scanning rates now required of them.

Interlacing

The interlacing principle was developed quite early in the history of television to increase vertical screen resolution and reduce the bandwidth required to transmit video-camera images. In interlacing, the total video frame is divided into two fields: one containing the even-numbered scanning lines, the other the odd-numbered

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Fig. 1: If we could keep fast-scan and slow-scan systems separate, life would be relatively simple. But there is an ongoing requirement in color graphics/video systems to mix the two scanning technologies, such as when video data is used with GUIs in mission planning and control systems.

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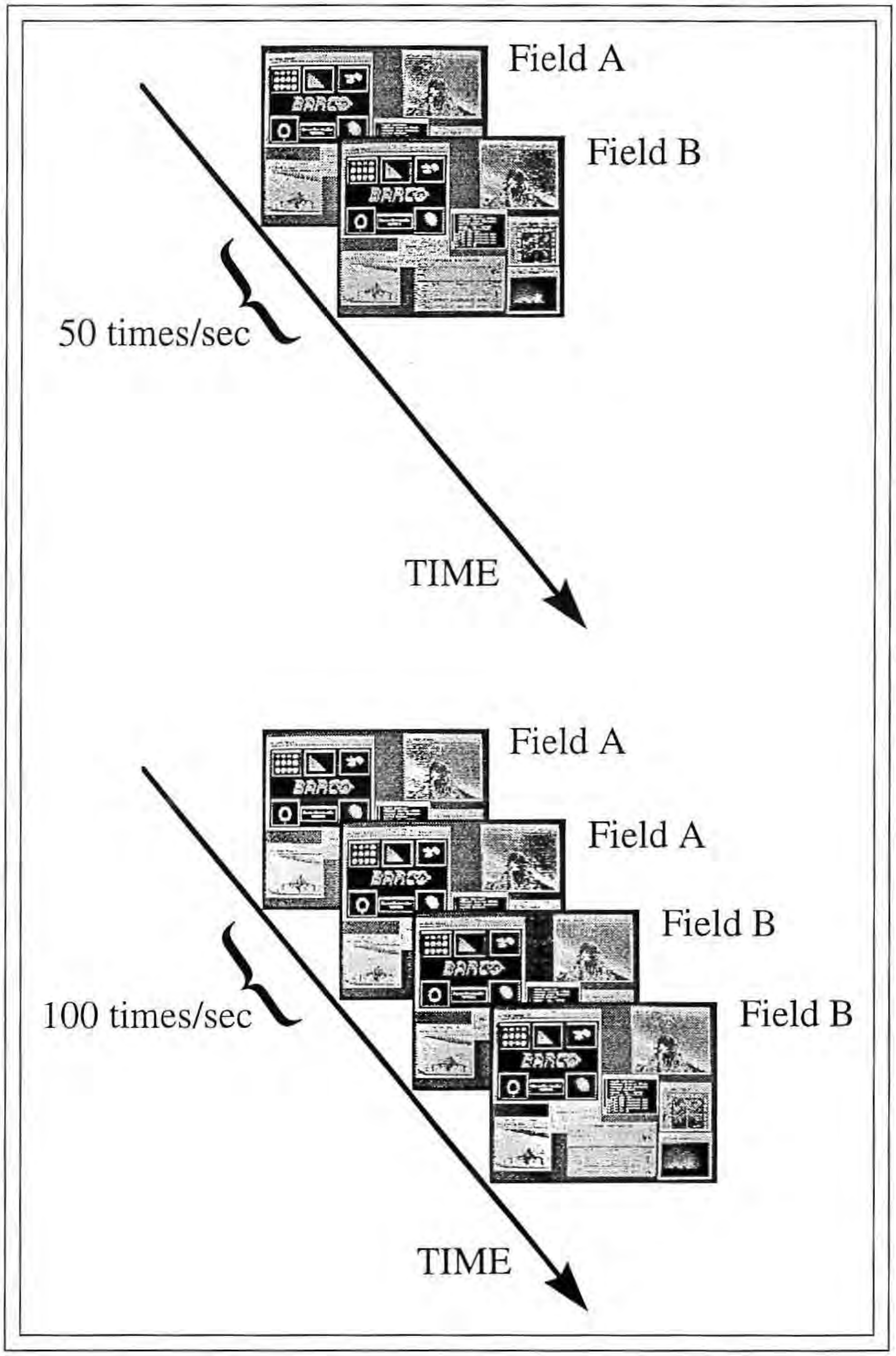

Fig. 2: *In the scan-conversion technique called field doubling, a complete field from the video source is stored into memory and is read out at twice the speed at which it was written in.*

lines. By displaying one field at a time, the electronics drivers need transmit only half the number of lines, thus reducing the speed of transmission and the required bandwidth.

The human eye is capable of integrating these two fields, and perceives the image as a single frame. If a field is refreshed (rewritten on the CRT screen) 50 times per second, the total image is displayed only 25 times per second in interlacing technology.[1] This created another problem because the human visual system detects such slow changes in the image-display intensity as annoying flicker. In order to reduce this flicker, CRT manufacturers utilized phosphors with a longer decay time.

Today's high-resolution computers and computer monitors have largely discarded the interlacing system because modern graphics generators can refresh the image at quite a bit more than 50 times per second, which reduces the flicker problem greatly. But now that the total image is scanned at a higher speed, the phosphors must have a short persistence to avoid smearing, and today's display tubes use these short-persistence phosphors. So, our problems are finally solved - as long as our color display tubes (CDTs) are only used to display computer-generated data and imagery. If, however, we try to use these tubes to display imagery produced by slow-scanning systems, such as 15-kHz video cameras, the flicker problem resurfaces because we no longer have long-persistence phosphors to help us out.

If we can keep fast-scan and slow-scan systems separate, life is relatively simple. But there is an ongoing requirement in color graphics/video systems to mix the two scanning technologies. In the military/aerospace/industrial arena, we must deal, for example, with video data from sources such as low-light-level intensifiers (LLTVs), forward-looking infrared (FLIR), and a variety of video cameras that scan at low frequencies. There are, on the other hand, GUIs used on computers for mission planning and control systems (Fig. 1). In the consumer arena, systems developers are expending substantial energy on "multimedia systems" that mix computer games, World Wide Web screens, and video input. The problem now is how to mix the two scanning frequencies.

The first component needed to solve the mixing problem is a multi-scan display, which will accept a wide range of scanning frequencies and adapt to various incoming sources. However, the minimum scanning frequency of such a display is usually 30 kHz - with the maximum being close to 90 kHz for a 19-in. CRT. The second required component is a scan converter, which adapts the interlaced video data for display on the multi-scan monitor.

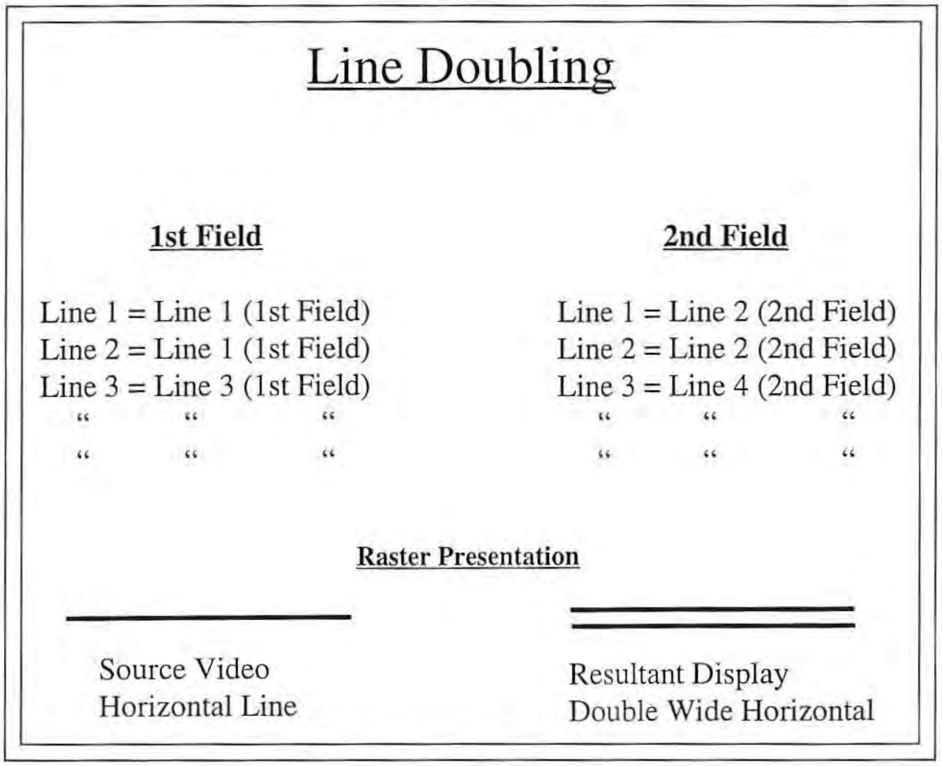

Fig. 3: *In the line-repetition method of scan conversion, each line is displayed twice in succession.*

If the two fields of interlaced video are put into an electronic memory, the information can be manipulated in various ways to increase the refresh rate and writing speed. This manipulation of information can be done in several ways.

Field Doubling

One scan-conversion technique is field doubling, in which a complete field from the video source is stored into memory and is read out at twice the speed at which it was written in (Fig. 2). This results in a doubling of the scanning frequency from 15 kHz (in the case of a video camera) to 30 kHz, which solves the issue of source-display compatibility. Each field is generated twice as fast, and the refresh rate for the field is now 100 Hz *vs.* the standard 50 Hz, which results in a flicker-free image. When using the field-doubling method, a user can try various sequences for reading out the data from the field memories. The most popular sequence used is the AABB scheme, in which the first field (A) is read out twice, after which the second field (B) is displayed twice. This system is used primarily in today's 100-Hz home television receivers.

The AABB sequence is an acceptable process for video-camera images that are rapidly changing in real time because the sequence of the scanning lines and fields is not changed from the order in which they are registered by the camera. But the field-doubling technique is not suitable for low-resolution graphical interfaces because the graphics generator will cause the two fields to be identical, causing the same line to be displayed on the screen at two different places due to the interlacing process. This will be seen as line flicker, which is very noticeable in graphics-based images with slowly varying content, such as a radar sweep.

So, although the field-doubling method eliminates frame flicker, it does not solve the line-flicker problem because of the interlacing process. Thus, the normal field-doubling or field-repetition technique is not the most favorable solution for mixing scan frequencies.

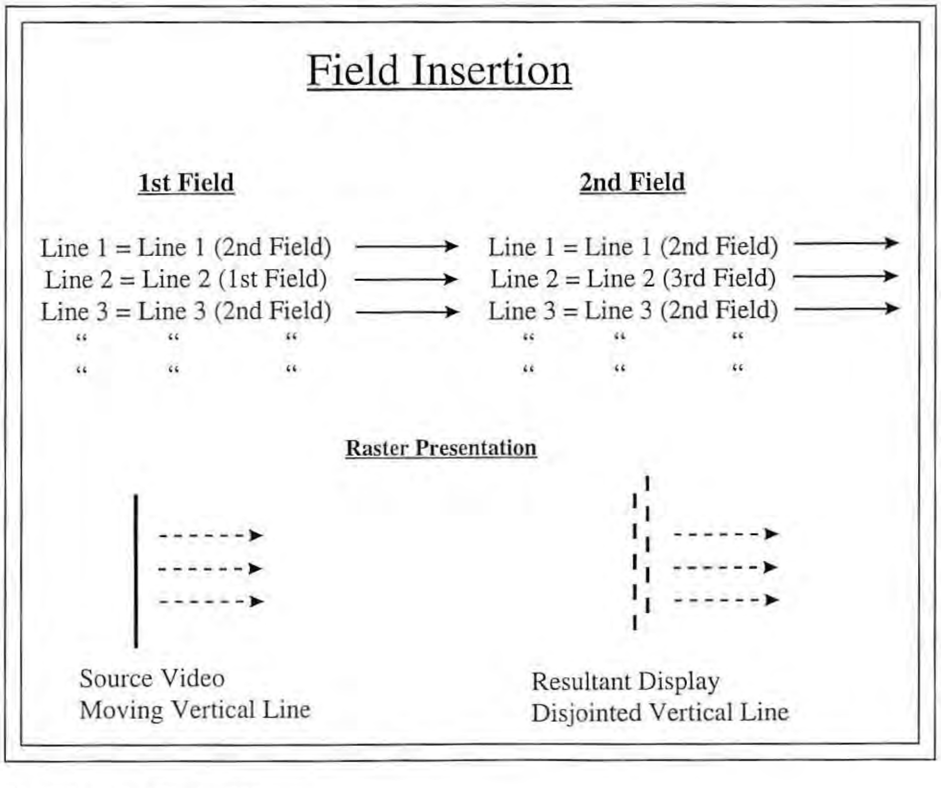

Fig. 4: *The field-insertion technique involves the insertion of the lines of the first field between the lines of the second field.*

RADAR DISPLAY CONTROL

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RADAR DISPLAY RADIUS

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RANGE RING INCREMENTS

40

☑ Range Rings

☑ Vector Fill

☑ Freeze

Clear

FADE RATE

1

FADE MODE

○ Sync

● ASync

THRESHOLD LEVEL

10

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Fig. 5: *In the adaptive line-doubling technique, the scan converter switches between line repetition and field repetition on a pixel-by-pixel basis. As a result, images from electronic sources are rendered with a quality that is better than the 15-kHz video displayed on a standard-resolution CRT.*

Line Doubling

In the line-doubling method, each line generated by the video source is stored sequentially into the memory and is read out at double speed. This process can be attained by two separate techniques: line repetition and field insertion.

The line-repetition method displays each line twice in succession (Fig. 3). The field-insertion technique involves the insertion of the lines of the first field between the lines of the second field (Fig. 4). Then the lines of the second field are copied, in turn, into the third frame. In this process, each line is utilized twice during each frame, once in the current field and once in the next field.

The line-repetition technique is best suited for moving images, since all lines displayed in a single field were generated in that sequence. But line repetition still does not solve the flicker problem because each field still contains only odd or even lines.

In the field-insertion technique, the lines are not displayed in the same sequence in which they are generated, which produces artifacts in images with a lot of motion content. The artifacts are produced by the delay this process introduces. In the field-insertion technique, line 2 of the first field is written between lines 1 and 3 of the second field, while lines 1 and 3 of the second field will be copied into the third field. Thus, each following field will contain partly the same "old" video information and partly "new" information. For rapidly moving video images, the position of an object registered during its motion by the even lines will be entirely different from the information registered by the odd lines. Consequently, video images of moving objects will show artifacts because the lines from two different fields are being inserted into a new field.

Again, normal line repetition or field insertion will not solve the frequency-mixing problem. Depending on the content and origin of the video image, each of the two doubler methods has certain benefits and drawbacks.

Adaptive Line Doubling

In adaptive line doubling, the scan converter uses a specific algorithm to verify whether there are any changes in a pixel from one field to the next. The switching between line repetition and field insertion is done on a pixel-by-pixel basis. When no change is detected, the field-doubling technique is utilized, and the pixel is copied into the next displayed line. When a change is detected, the line-doubling method is used by copying the pixel in both lines.

For moving and non-moving images, a compromise solution is used that produces adequate image rendering - rendering that is better than the 15-kHz video displayed on a standard-resolution CRT (Fig. 5). This technique is adequate for video pictures obtained through electronic input devices, such as cameras, because it eliminates line flicker.

Video and Graphics Scan Doubling

Camera-based video sources do not usually require high bandwidth and high resolution, so products have been developed specifically for this application. Among these is BARCO's video scan doubler, which offers both of the line-doubling systems and adaptive line doubling. For higher-resolution requirements, such as some color graphics generators, frequency mixers require expanded and faster memory. Versions of such a product, called a graphics scan doubler, have been developed by BARCO and others. Such products utilize both line-doubling methods, with the user deciding which method best suits his or her needs.

Until recently, the design of these high-performing graphics scan doublers was limited by the availability of fast memory chips with adequate chip control management. Now, with the rapid design advances being made in adaptive line-doubling techniques, BARCO, among other companies, is committed to the research, design, and commercialization of new and enhanced scan-converter products that will provide improved image-storage and image-processing capabilities in the years to come.

Notes

[1] This article assumes the 50-Hz refresh rate common in European television systems and early computer monitors, rather than the 60-Hz refresh common in North America and Japan. ■

The Monitor Interface: Time for a Change?

New, powerful VESA standards are now available to provide relief for monitor makers and their struggles to make do with the now-obsolescent VGA interface.

by Ian Miller

THE CURRENT VIDEO INTERFACE – usually called "the VGA interface" and used by almost 100% of the computer industry – is nearing the end of its useful life and is in need of replacement. Let's see why, and then offer a solution based on open industry standards.

What's Wrong with the Current Interface?

Prior to the introduction of the VGA interface in 1986, the then-standard CGA and EGA PC monitors used digital interfaces and supported very limited addressabilities and color range. The VGA interface, at 640 × 480 pixels and 60-Hz refresh, and with an analog interface capable of supporting a vastly greater color depth, was a major step forward. It was such a leap forward that it took a few years for the graphics subsystems driving the monitors to develop the capability of exploiting the color depth at an affordable cost, but today high addressability with 24-bit color depth is almost standard.

As the industry has pushed addressability, color depth, and refresh rates to levels that were not envisaged in 1986, the bandwidth requirements on the interface have also grown rapidly. Table 1 gives some typical values of required data rates.

The analog interface is well suited to CRT-monitor designs, but to meet the requirements for electromagnetic compatibility the industry has been forced to add filters of various types to the interface, which limit the actual bandwidth transmitted. So we now have a situation in which increasingly sophisticated software and graphics subsystems are generating images with detail that even the best monitor cannot display because all the information is not being transmitted across the interface. The bandwidth situation alone is enough to warrant consideration of a new video interface, but another major factor – the advent of new display technologies in monitors, most noticeably the TFT-LCD – has added a sense of urgency.

Flat-panel monitors have been available in various forms for several years, but all market forecasts now indicate that these monitors will take over a significant percentage of the overall market within a few years. Most of these flat-panel technologies use digital signals internally, but the general practice today is to add the electronics needed to convert the analog waveforms of the VGA interface to digital signals in the monitor. Such a monitor is relatively easy to market because it plugs into the

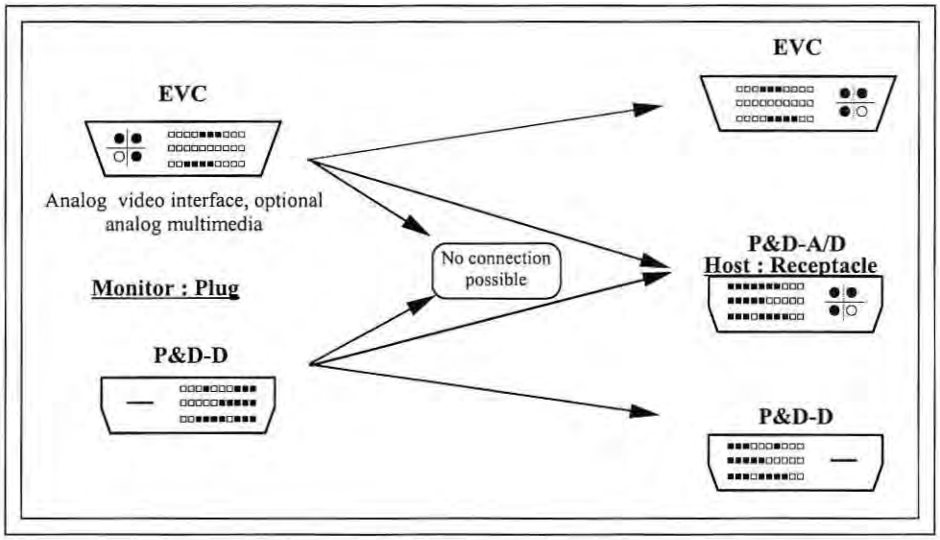

Fig. 1: The EVC and P&D connector family. The shell configuration allows only appropriate monitor plugs to be inserted into each host receptacle. The black pins and sockets indicate the pins and sockets used in minimum configurations.

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existing video connector, but implementing the analog-to-digital technology effectively is very difficult and expensive. Companies jealously guard the real cost of providing the analog-to-digital conversion, but there is general agreement that the cost ranges upward from around $120, depending on the display addressability and performance.

All of the TFT-LCD monitors seen by the author suffer from image-quality problems caused by set-up difficulties and/or drift of the electronics. The nature and magnitude of the problems vary considerably, but even the best LCD monitors leave something to be desired.

In summary, the VGA interface was never designed to handle today's bandwidth requirements. The new display technologies would be better served if we adopted a digital-interface technology.

The Next Steps

How do we reconcile the apparently contradictory requirements of a high-bandwidth analog video interface for CRT-based displays and a digital interface for LCDs? The industry has responded by developing two complementary standards for video interfaces through the Video Electronics Standards Association (VESA). These standards, the VESA Enhanced Video Connector (EVC) standard and the VESA Plug and Display (P&D) standard, differ in the signal sets present in the interfaces (Fig. 1) and in the connector shells. The difference between the shells prevents a P&D plug from being inserted into an EVC receptacle, thus preventing damage to some of the drivers and receivers that could be caused by connecting them to inappropriate signals.

Table 1: Typical Bandwidth Requirements

Addressability (H × V)	Refresh (Hz)	Data Rate (Mbyte/s)
640 × 480	60	75
800 × 600	72	150
1024 × 768	75	236.25
1024 × 768	85	283.5
1280 × 1024	75	405
1280 × 1024	85	472.5
1600 × 1200	75	607.5
1600 × 1200	85	688.5

The VESA EVC Standard

The EVC standard, first published in November 1995, provides a high-bandwidth impedance-matched analog video interface. The EVC interface provides for the use of the VESA Display Data Channel (DDC) to transmit monitor-capability data – the EDID or extended display identification data – from the monitor to the graphics system. In addition, the EVC interface has a number of optional extensions, including digital serial buses (USB and IEEE-1394) and multimedia data (audio and video) carried in analog formats (Table 2).

The VESA P&D Standard

The P&D standard, first published in June 1997, provides the same high-bandwidth impedance-matched analog video interface as the EVC standard. On top of that, it adds a digital interface based on a transition-minimized differential-signaling technology.[1] (It is worth noting that this is the only industry-standard digital monitor interface.)

P&D requires use of the VESA DDC2 protocol to transmit configuration data from the monitor using the new 256-byte VESA EDID structure, which has been specially written to add technology type and additional configuration requirements to the existing structure. For example, the EDID can specify which display technology the monitor is using and which interface (analog or digital) the monitor requires to transmit its video data.

The EDID data is used to configure the P&D interface automatically. Like EVC, P&D has a number of optional extensions, which are summarized in Table 2.

The technical purists will argue, and they are correct by some definitions, that a differential-signaling scheme is not digital, but in the sense that the differential signal can only represent a "1" or a "0" in this scheme, they are also wrong.

Used appropriately, these interfaces will produce a single host-end video connector that will provide high-performance video support in either analog or digital format and that can be accessed by a very wide range of display technologies. This should help minimize confusion and potential errors of the "Where do I plug in this monitor cable?" sort. In addition, the various options are available as required. Note that the P&D standard also has a digital-interface-only subset, which permits a cost reduction for systems without an analog-interface requirement.

Using EVC and P&D Interface Standards

Systems and monitor designers must consider a number of factors before deciding whether they should implement the EVC or P&D standard.

Systems Design. If the implementation is intended for attaching only analog monitors (primarily CRTs), then the obvious choice is the EVC connector because this allows use of the analog multimedia options, if required. However, for many new designs this choice will be inappropriate because it is likely that support for a mix of display technologies will be required over the life of the product. In that case, the better choice is the P&D connector, which provides a choice of either analog or digital video interface.

A secondary but important issue is use of the optional features. If these features are needed, the designer can obtain cost and space savings by taking advantage of the single connector and simultaneously ease the cable-management problem.

Monitor Design. The choice of connector for the monitor cable should be defined by the preferred interface. A CRT monitor using the analog interface gains nothing by using the P&D plug, and a digital-interface LCD monitor cannot work using the EVC plug because it provides no digital-interface support. Stated more simply: Monitors requiring the analog interface should use the EVC plug, and monitors requiring the digital interface should use the P&D plug.

Either monitor can then be plugged into the P&D receptacle on the host and access the

Table 2: EVC and P&D Feature Summary

Feature	EVC	P&D
Analog video	Yes	Yes
Digital video	No	Yes
DDC	Yes	Yes
Pixel clock (option)	Yes	Yes
USB (option)	Yes	Yes
IEEE-1394 (option)	Yes	Yes
Charge power (option)	Yes	Yes
Audio in/out (option)	Yes	No
Video in (option)	Yes	No

appropriate video interface, but only the analog-interface monitor equipped with the EVC plug can plug into the EVC receptacle, which offers the analog video interface only (Fig. 1).[2]

A Bit More Detail

Video Interface Capability. The analog-interface signal connector pins are specified at 2.4-GHz bandwidth to provide expansion capability well into the future. The standard currently specifies a maximum clock rate over the digital interface of 112 MHz, which can support 1280 × 1024 pixels at 60 Hz and 24 bits of color. The targeted clock rate of 160 MHz is capable of supporting 1600 × 1200 pixels at 60 Hz and 24 bits of color.

Hot Plugging. The P&D standard supports hot plugging of monitors with automatic reconfiguration of the display subsystem when the new monitor is connected. This protects the interface drivers and receivers, and also protects the monitor from being driven by inappropriate frequencies - which is particularly important in some flat panel implementations, and provides benefits to the end user.

The EVC standard supports a subset of the P&D hot-plugging scheme since it only has to concern itself with the requirements of analog-interface monitors.

Cable Length. A visit to any computer store will provide evidence that there is a market for longer interface cables. Using the VGA interface, cable length is usually restricted by the need to meet EMC standards to a maximum of about 1.8 m, but the P&D interface is specified at up to 10 m. This provides much greater flexibility in laying out the monitor relative to the system unit.

USB and IEEE-1394. Pins are reserved for these serial buses - the same pins on P&D and EVC - to allow full implementations to be carried, including power. Implementing either or both of these buses will restrict the cable length, if compliance with their respective standards is maintained. But a 5-m cable is still possible, which significantly increases flexibility over today's norm.

Charge Power. This capability, common to EVC and P&D, recognizes that a monitor, regardless of technology, is likely to be powered from an ac source. Consequently, the monitor can provide charging power to a portable computer, avoiding the need for a docking station or external power brick.

Pixel Clock. This optional line, originally introduced as part of the EVC standard but now supported by both EVC and P&D, recognizes that driving a fixed-pixel display over the analog interface would be much simpler if a pixel clock was available.

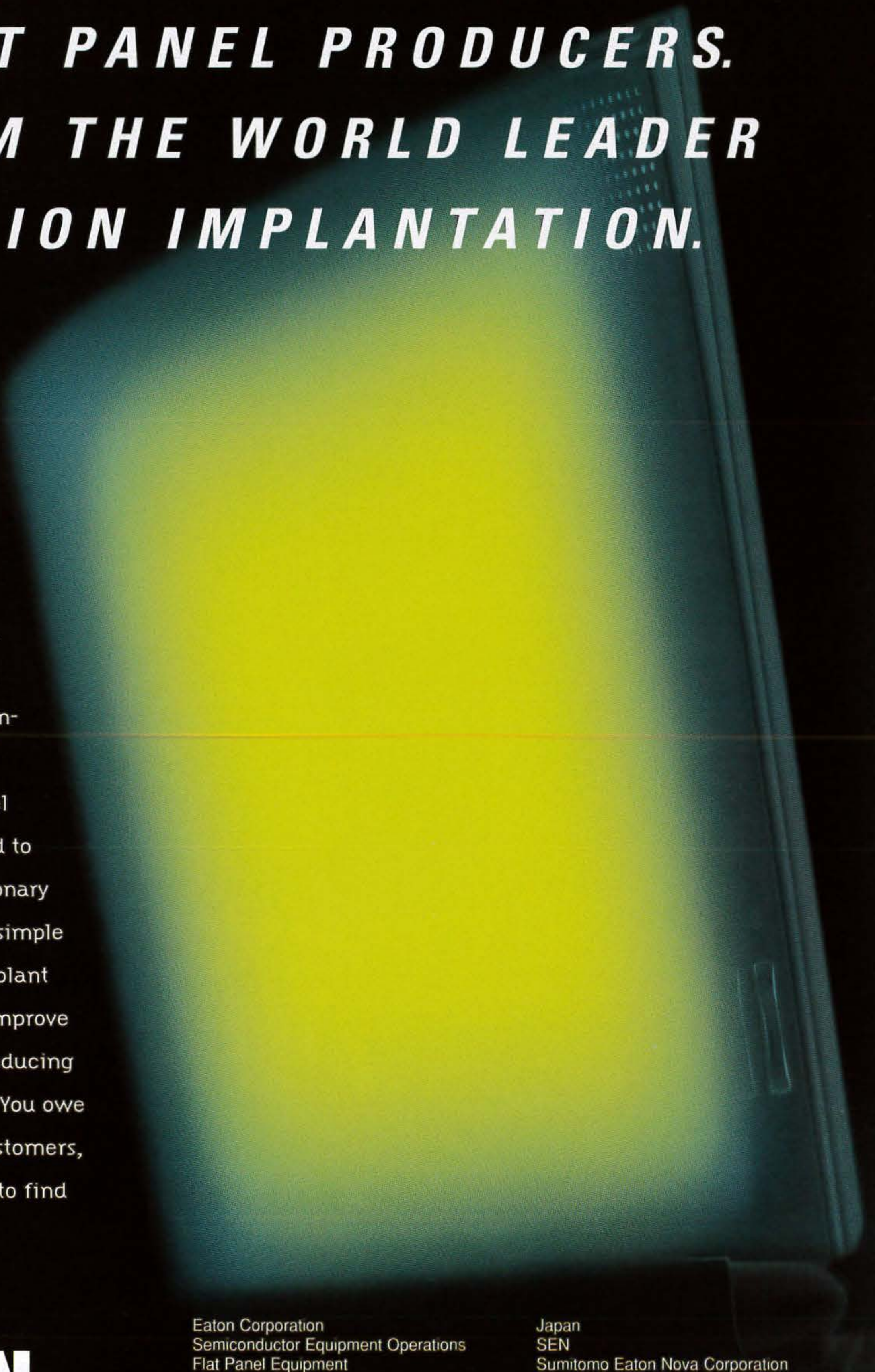
Summary

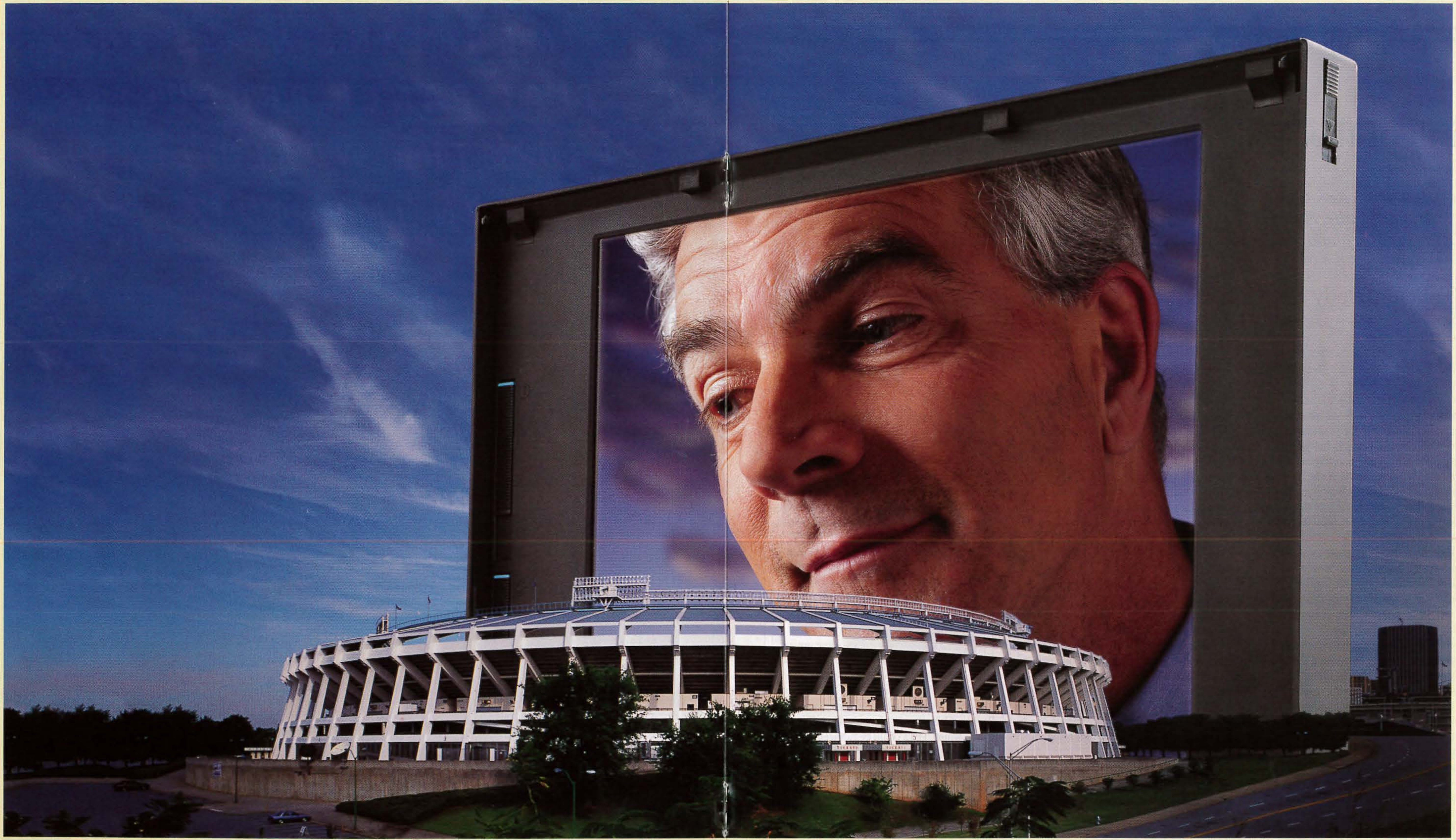
There are good technical reasons why it is necessary to begin the difficult transition from the current, widely used VGA interface to a new interface based on the EVC and P&D standards (as appropriate). The end result will be high-performance display support with the flexibility to choose the most appropriate interface. These benefits will come with only a small cost increment over the VGA interface for analog implementations and with a major cost savings for digital implementations.

Notes

[1] TMDS is a trademark of VESA and uses PanelLink™ from Silicon Image.

[2] The IEEE-1394 interface option in both EVC and P&D could be used for video data, particularly to monitors with a frame buffer. ■





Birth of the Active Matrix

Twenty-five years ago, thin-film-transistor technology was a struggling alternative to MOS for the fabrication of FETs – until it found its ideal application.

by T. Peter Brody

THE BIRTHPLACE of solid-state electronics is customarily taken to be Bell Laboratories, where in 1949 Shockley and his co-workers first demonstrated the point-contact transistor, followed shortly by the junction and the junction field-effect transistors. While the semiconductor industry was certainly launched on licenses granted by Bell Labs, a patent had been awarded in 1934 to a German inventor, Oscar Heil, for a thin-film transistor using a tellurium film![1] There is no evidence that Heil's device ever found a practical application, but it surely would have worked: the patent clearly describes all the essentials of a thin-film FET and its operation.

Shockley's group tried to fabricate a TFT using germanium (Ge). The device did not work because the large density of surface traps in the evaporated Ge film prevented any useful conductivity modulation. This failure led Bell Labs to abandon work on TFTs, and transistor development followed the p-n junction path exclusively until TFT investigations were taken up by others in the early 60s.

***T. Peter Brody** pioneered active-matrix display technology between 1968 and 1979 at Westinghouse Research Laboratories, where his group fabricated the world's first AMLCD in 1972. He is now the president of Active Matrix Associates, a consulting firm located at 5823 Kentucky Ave., Pittsburgh, PA 15232; telephone 412/362-4471; fax 412/441-2932; e-mail: pbrody@mail.1m.com. This article was adapted from the author's keynote address at the 1997 SID Symposium, delivered in Boston on May 13, 1997.*

The Rise of the Integrated Circuit

In the 50s, discrete bipolar transistors were manufactured in a great variety of shapes, sizes, and performance levels, at steadily diminishing cost, displacing most vacuum tubes and initiating the age of digital systems. Modern computers began to emerge and semiconductor logic circuits soon became large and complex. The problem of mounting and interconnecting large numbers of discrete devices presented itself, and gave rise to the idea of forming many of these devices on a single substrate, interconnecting the devices *in situ*.

At this time, bipolar junction devices were exclusively used in computer circuits, but many semiconductor workers realized that for the logic circuits of the future, device performance was less important than fabrication simplicity, yield, and real estate occupied on the wafer. This realization produced a search for a simpler, more compact switching device, and led to the idea of the MOSFET and its thin-film version, the TFT.

In the late 50s and early 60s, many laboratories were doing research on both MOSFETs and TFTs, with most of the effort going into MOS. Major laboratories working on both types of devices included RCA, GE, Hughes, IBM, Raytheon, Zenith, Philips, and Westinghouse, as well as several universities. Ironically, Japanese semiconductor labs were concentrating exclusively on the MOSFET. By the mid-1960s, the MOS emerged as the clear winner and most laboratories dropped work on TFTs, with only RCA and Westinghouse continuing with any significant effort. RCA dropped out in the early 70s, leaving Westinghouse in sole possession of a deserted field.

Early TFT Work at Westinghouse

Our group at Westinghouse worked on TFTs in the early 60s, encouraged by reports on thin-film tunneling devices and the RCA papers on CdS TFTs. In 1962 Westinghouse established an Integrated Circuit Division, which turned out to be quite hostile to our work. (Their slogan at the time was "Bipolars forever.") The TFT effort survived because we strongly and consistently maintained that thin-film electronics would become important if the right uses could be found for it, and because we managed to obtain some government contracts – and even some support from other Westinghouse divisions despite the opposition of the IC division.

In 1967 we hit some "pay dirt." Derrick Page and I designed a vacuum-deposition system in which TFTs could be fabricated in a single pump-down cycle, eliminating atmospheric interface contamination, which was a major cause of non-reproducibility. We decided to investigate tellurium films in the system, following the RCA group, which had reported good results with this material. We found Te TFTs very easy to make, and because of the high carrier mobility – around 800 cm^2/V-sec – they were capable of quite high frequency performance: 60-MHz cut-off frequencies were obtained in comparatively crude devices patterned by simple stencil masks.

One day, Derrick Page had the idea of trying to make a Te TFT on a strip of paper instead of

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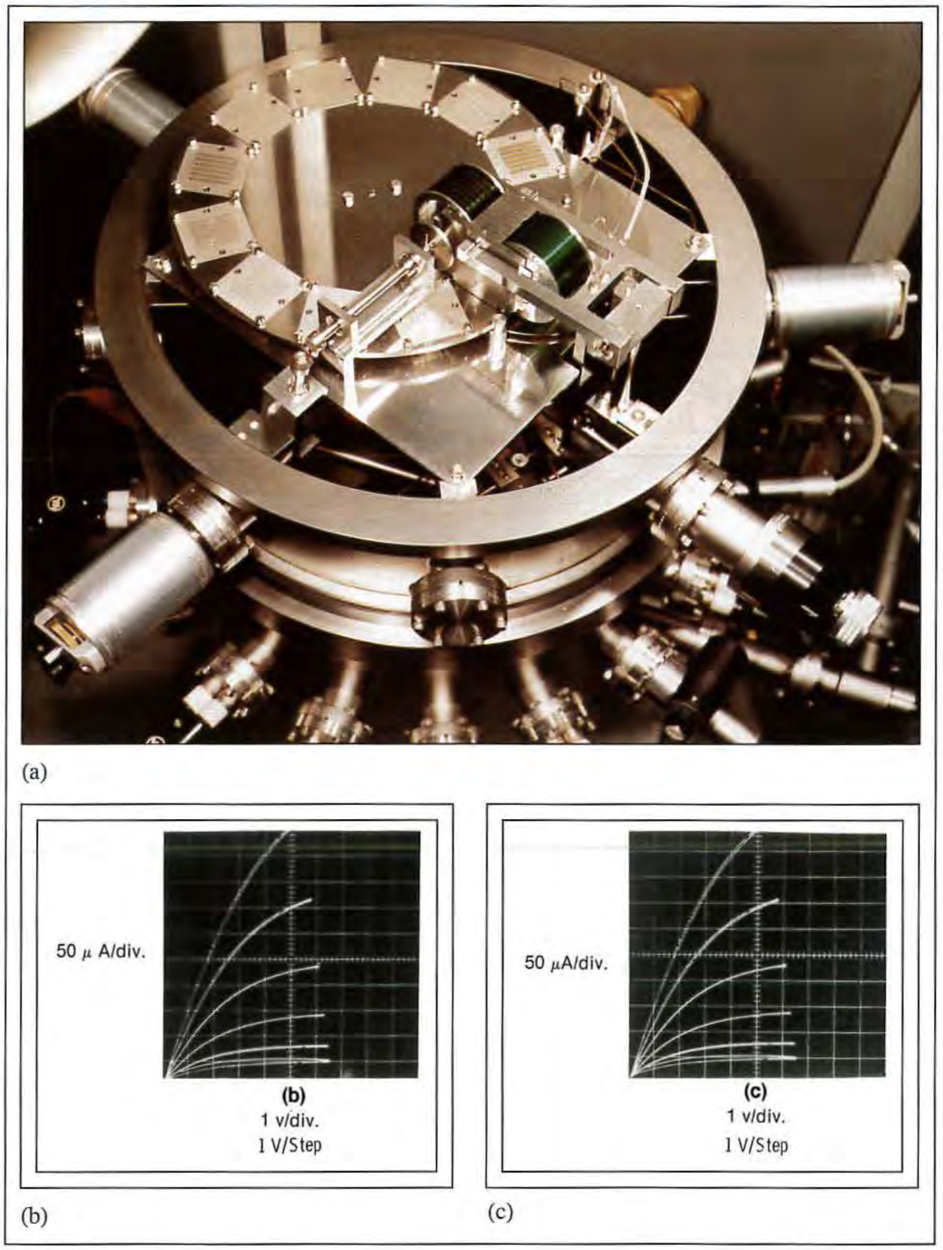

T. Peter Brody

Fig. 1: *(a) This 12-station deposition system was used to fabricate TFT arrays on a variety of flexible substrates, including paper and aluminum foil. The flexible-substrate dispenser is slightly above the center of the photo. The "paper TFT" transistor characteristics (b) after deposition and (c) after 1000 hours of operation were unchanged.*

the usual glass substrate. Amazingly, the TFT worked on the very first try, and shortly thereafter we made TFTs on a wide range of flexible substrates, including Mylar™, polyethylene, and anodized supermarket aluminum foil.

Aluminum foil worked particularly well because the substrate acted as an excellent heat sink. For example, we used a single 0.030-in.-wide by 0.0005-in.-long TFT as an audio amplifier and obtained almost 0.5 W of audio output from it. The flexible TFTs were undamaged and remained operational when bent into a 1/16-in. radius. They could also be cut in half, with both halves operational.

Despite these results, which received wide international publicity, our TFT programs were still threatened by the IC division, which kept telling laboratory management that we were wasting company money. Once again, we had to come up with an idea to keep the work alive, and once again we survived. (Death threats are a valuable spur to invention.)

Based on our flexible-transistor capability, we devised a continuous-fabrication process that used reels of anodized Al foil as substrates. Devices and circuits could be fabricated in a single vacuum cycle on successive positions of the reel, which at the end of the fabrication cycle looked like exposed frames of 35-mm photographs (Fig. 1).

With this idea and some demonstration circuits, we made the rounds of a number of Westinghouse manufacturing divisions with the proposal that our technology would allow them to make custom circuits for themselves. The tactic worked and we quickly picked up enough support to continue, and even expand, our TFT work. Our section's life expectancy was undoubtedly enhanced by the demise of the IC division. They were forced out of business in 1968 and were thus no longer able to agitate against our TFT work.

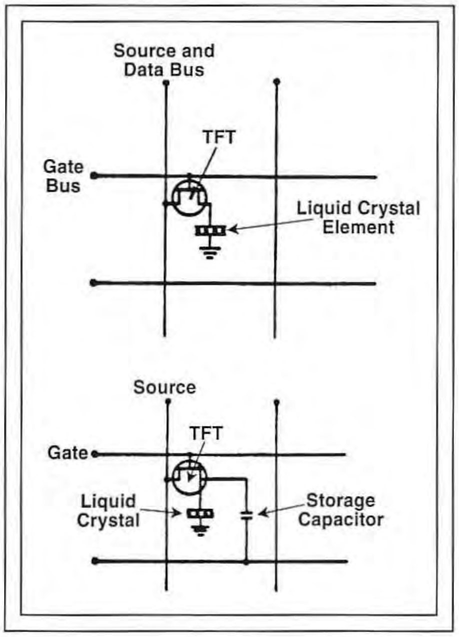

Fig. 2: *The simple design for the elemental matrix circuits used in the first AMLCD is still being used today.*

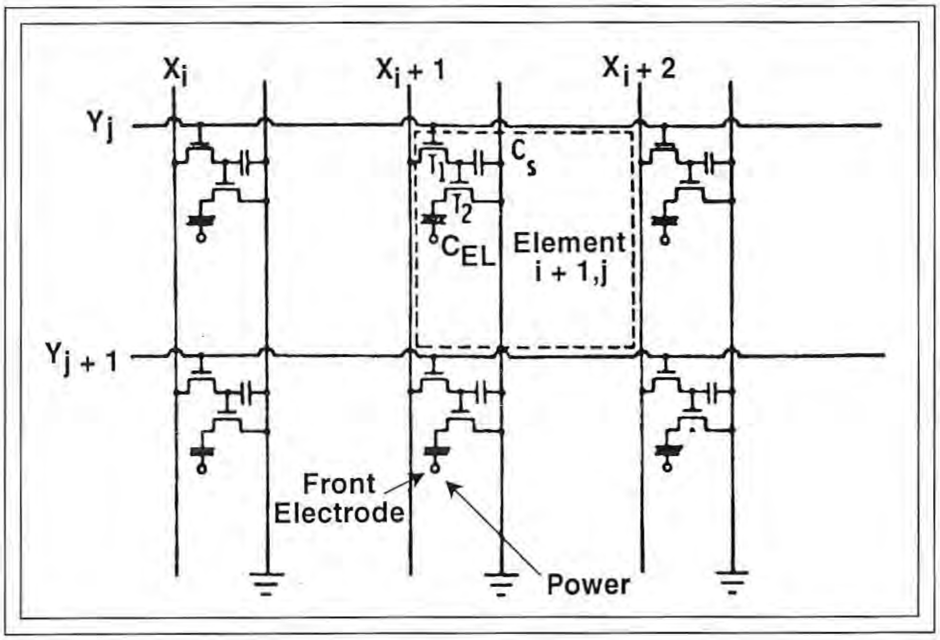

Fig. 3: *For emissive displays, the energy stored in the memory cell in the circuit of Fig. 2 is insufficient to turn on the associated pixel, so more-complex designs were required.*

Having learned the correct survival strategy, we continued to pursue and obtain additional divisional support, and we built up a highly capable group oriented entirely toward the exploitation of our TFT capability. The section grew into a department called Thin Film Devices. Thus, in the late 60s, when every other semiconductor laboratory and company gave up on TFTs as being of no use, we found a number of very useful applications - applications sufficiently promising to be supported by short-term-oriented divisions with quarterly profit responsibilities.

All this took place before we started on any TFT display applications, but the seeds of active matrix were already present in a creative and well-motivated group of workers who had to prove to a skeptical world that, indeed, TFTs were of *some* use and were perhaps quite important, even though it was not yet clear where the breakthrough would occur. By this time, we also had a fully reproducible fabrication process and design rules that allowed us to predict device performance accurately.

We were convinced that one day TFTs would come into their own. The only question was, could we keep going long enough to find where that would be? The only other group that could have made the breakthrough to active matrix was Paul Weimer's group at RCA Laboratories. In the early and mid-60s, they were in a leadership position and formulated ideas similar to ours at Westinghouse. But towards the end of the decade, RCA Labs' management, tired of seeing TFT as a perennial also-ran against MOSFET, put the group out of existence - just when we began to think seriously about the display application.

Large-Scale Display Integration

In early 1968, we had demonstrated flexible transistors and built some higher-voltage devices that switched more than 100 V. The thin-film group was originally part of the department that had worked on electroluminescence in the 60s and had actually built a rudimentary EL display of discrete devices, with each EL element controlled by a dedicated ferroelectric switch.

Going through some old departmental files, I saw the EL-FE reports and decided to see whether we could turn an EL nightlight on and off with one of our high-voltage TFTs. Our attempt worked the first time, and I would say that this was the seminal event in the genesis of our active-matrix concepts. It had nothing to do with liquid crystals at the time.

In reflecting on the flat-panel-display (FPD) problem, I started to read the literature - and was amazed to find the huge number of attempts made over the previous 20 years to develop a viable technology, none of them reaching maturity. It seemed to me that most of the attention had been given to electro-optical materials and their physics, but remarkably little to the problem of addressing the materials and distributing the picture information to the pixels.

The EL-FE display scheme was the stimulus. It embodied the idea of having a control element associated with each picture element, which was one of the key ideas of the active-matrix scheme.

The goal was clear. In ordinary addressing, the problem of crosstalk always arose, growing with the number of rows and columns to be addressed. It had to be eliminated for a viable FPD technology. The provision of a control element at each pixel allows us to control that element independently of all others and eliminate crosstalk.

Another important motivator was the realization that all existing FPDs and FPD concepts were electronic hybrids. The (usually) matrix-addressed display panel used certain electro-optic phenomena, such as gas discharge, electroluminescence, light-emitting diodes, incandescent filaments, electrochromics, or electrophoretic suspensions. But the addressing of the display rows and columns was performed by a totally different electronic system, usually discrete line and column drivers, or, later, multi-output integrated circuits that had to be separately mounted and then interconnected with the display.

None of these schemes was aesthetically pleasing, and we decided that the messy external interconnection of thousands of terminations had to be eliminated before a sensible and economically viable FPD system could be built. Of course, we visualized a fully integrated display circuit with TFT row and column drivers! Thirty years later, the world is still waiting for such a display. Therefore, our display philosophy became: "Solve the addressing problem and the materials will fall into place." Two factors thus came together in a fortunate combination: a strategy for attacking the addressing problem and a well-developed TFT capability that was searching for a significant application.

We felt that a larger-scale version of silicon chip-integration principles was needed and could be developed through the use of TFTs. At this point, we coined the name "Large

Scale Display Integration" (which was used until we introduced the modern term "active matrix" in 1975). Indeed, our model of what was needed began to look much like a coarse-scale version of a DRAM.

Between 1968 and 1971, we were mainly thinking in terms of an AMEL display, and we tried to get funding for such a display program from a large number of government and military agencies. We focused on EL because liquid-crystal technology was then in its infancy: dynamic scattering was the only optical effect known, and field effects had not yet been discovered.

While money-hunting, we refined our thinking about the display problem. We now said that the function of an addressing matrix should really be that of separating the task of addressing (or scanning) the picture elements from that of supplying power to the display material. Dennis Gabor provided moral support for the approach, saying one should provide "an array of elements capable of switching a common supply of energy in proportion to a signal which they receive once in a scanning period."

This formulation leads at once to the concept of a large-area dynamic memory as the appropriate circuit representation of the display matrix. One could write into this memory at high speed, irrespective of the response characteristics of the display medium, and the setting of the memory element would determine the supply of energy to the display pixel.

As it happens, for liquid crystals the small amount of energy stored in the memory elements is in itself enough to power the pixel. This leads to the particularly simple elementary circuit that was published in 1973 - and is still being used today (Fig. 2). For emissive displays, or other types of materials for which the energy stored in the memory cell is insufficient to turn on the associated pixel, we need more-complex but still easily realizable designs, such as the one we used in our AMEL work, which is also still used today (Fig. 3). Both types of circuits, however, embody the same basic principle.

Work Starts at Last

By 1971 liquid-crystal technology had emerged as an alternative target for active-matrix addressing, and we finally obtained a small contract from the Air Force for the construction of a 6 × 6-in. AMLCD, and another small contract from the Army for an AMEL display of the same size.

In those days, there was no specialized equipment available for active-matrix fabrication, so we had to design our own. We retained the concept of trying to complete all deposition steps in a single pump-down cycle because we found that this was key to device stability and reproducibility. But the process also involved evaporating all materials - metal, semiconductor, and insulator - through a single variable aperture mask. The "experts" told us this would lead to unacceptable cross-contamination, but the process worked, and by early 1972 we produced operating active-matrix circuits with this primitive set-up.

We now had to learn the art of liquid-crystal alignment, filling, and sealing. After some failed approaches, we used Janning's recently published oblique SiO evaporation method. This worked, and within a short time we had our first operating AMLCDs. One of the first things we did with our TFT-LC panels was to put them in a projector and project a much enlarged image on the screen. This seemed

T. Peter Brody

Fig. 4: A 120 × 120-pixel AMEL display was operational by 1973.

We were soon being supported by all three of the U.S. military services, but our problems were not over. Military contracts were normally reviewed by government committees staffed by industry experts in the various fields. In our case, the committee was staffed exclusively by semiconductor-industry executives who had killed off their own TFT programs several years before. They wasted no time in attacking our contracts as a "waste of government funds," and managed to kill our Air Force contract after just 1 year.

The Army AMEL program was allowed to continue for the time being because Elliott Schlam, our contract officer, supported the program vigorously. Of course, we had to deliver under this contract, which we did.

The loss of our Air Force contract, successful though the work had been, intensified company pressure on us. But we survived because all our technical programs were progressing well, and by 1973 we also had a working AMEL display (Fig. 4).

By 1974 we had demonstrated an AMEL panel capable of showing off-the-air video - the first active-matrix TV screen ever built - which earned us considerable recognition and some company support (Fig. 5). The Westinghouse Electron Tube Division started to supplement our government funding with divisional funds, which allowed us to go from the early 20-lpi display to 30 and eventually 70 lpi. We were also able to begin work on the row and column scanners, and we built a 64 × 64-element AMEL memory display with our Navy funding. We encountered no significant problems in any of this work.

But this happy and creative period did not last long. In 1976 Westinghouse closed down a large portion of its Electron Tube Division, which brought about a large cut in company funding. Despite technical success, a sizable manufacturing-methods contract from the Army, a renewal of our Navy AMLCD funding, and the international recognition our work had received, we were in trouble once again.

T. Peter Brody

Fig. 5: *The world's first active-matrix TV screen was built in 1974 using AMEL technology.*

The End of the Westinghouse Road

I was confident that we would extricate ourselves from this hole, also, but it was not to be. In one of many high-level management changes, our former chief supporter, the Business Unit Manager, was promoted and replaced by a manager with an accounting background and an aversion to high-risk projects. Because of our large Army contract, he was unable to shut us down for 2 years, but he managed to cancel the project at the end of the contract period - to the dismay of the Army, which was counting on Westinghouse to start manufacturing the displays.

Underlying Westinghouse's decision was the fact that even in 1978 nobody else seemed to be pursuing TFT technology, which left the corporation very uncomfortable about being out of step with the industry. Westinghouse laboratory management invited me to stay on and choose a "more useful" line of research, but after 15 years I was not prepared to abandon thin-film electronics. I therefore resigned and set about trying to raise money for an AMLCD company of my own.

This search succeeded after 2 years of intense effort and resulted in the formation of Panelvision, the world's first AMLCD company. However, by that time the big Japanese companies were in hot pursuit - and you know the rest of the story.

Acknowledgments

I gratefully acknowledge the critical contributions of the great team assembled at Westinghouse, with special mention of Derrick Page, Juris Asars, Fang-Chen Luo, Karl Yu, Paul Malmberg, Bob Stapleton, Joe Murphy, Leon Sienkiewicz, Ed Greeneich, Zoltan Szepesi, Willy Lehman, Bill Rogers, and Dave Davies.

Notes

[1] O. Heil, British Patent 439,457, Dec. 1935 (German Patent dated 1934). ■

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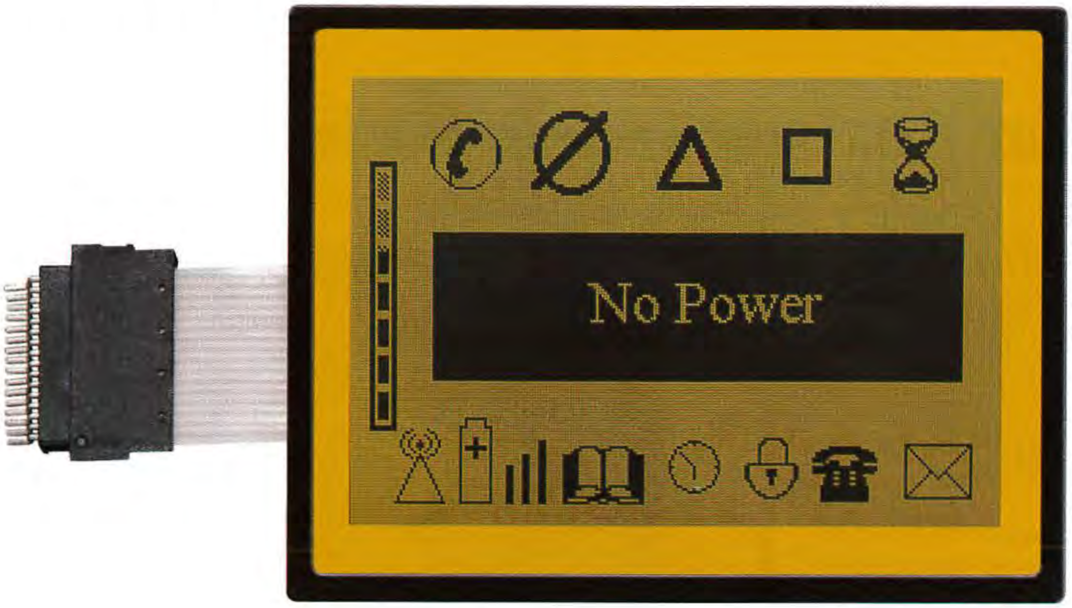

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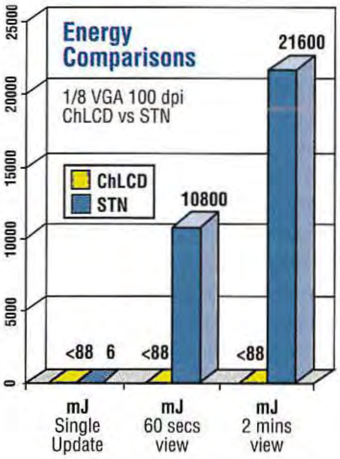

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Circle no. 16

show report

The Tiger Roars in Taipei

Computex Taipei provides a first-hand look at the world's leading monitor-making region, the ascendancy of large screens, and the growth of LCD monitors.

by Bryan Norris

ONCE AGAIN, Computex provided an excellent opportunity to see an astounding array of new and forthcoming display products *and* to learn a multitude of amazing facts about Taiwanese manufacturers.

All records were again broken as Computex Taipei '97, Asia's largest information-technology (IT) exhibition, opened its doors from the 3rd to the 7th of June. Most of this year's 772 Taiwanese and 93 overseas exhibitors - up over 20% from 714 last year - entertained around 37,000 local visitors and 15,761 overseas buyers at booths in the enormous and lavish main hall of the huge Taipei World Trade Centre (TWTC) (Fig. 1). The "invasion" of foreign visitors was led by the Japanese delegation of 3223, closely followed by 3128 from the U.S.A., and 2118 from Europe. Taiwan's star companies occupied more luxurious accommodations on two floors of the Stellar Hall in the adjacent Taipei International Convention Centre (TICC). Here, manufacturers such as ***Acer, Action, Compal, Chuntex (CTX), First International Computer (Leo),***

TWTC

Fig. 1: *Computex Taipei '97 was held in the enormous and lavish main hall of the huge Taipei World Trade Centre (TWTC).*

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Sampo

Fig. 2: A host of suppliers purported to offer a 19-in. monitor, but they can't deliver until 19-in. CDTs are delivered to them by Hitachi, currently the only manufacturer of 19-in. tubes. This nice-looking unit from Sampo is typical of what will soon be available.

Mitac, Proview Electronics (EMC), and ***Tatung*** could accommodate potential buyers in a less frenzied environment. Meanwhile, on the third floor of the TICC, it was back to mini-booths and limited aisle space for a host of new, perhaps start-up, companies.

Taiwan's IT hardware production continues to increase. From 1995 to 1996, it grew 20.8% to reach US$16.4 billion. Once again, this put Taiwan third in the world behind the U.S.A.'s $71.5 billion and Japan's $70.7 billion, and ahead of Singapore ($15.9 billion), U.K. ($11.5 billion), Germany ($7.3 billion), France ($7.2 billion), and Italy ($7.0 billion). But in terms of quantities produced, Taiwan Inc. is the number one producer in nine product categories: monitors, motherboards, scanners, mice, keyboards, graphics cards, switching-mode power supplies, notebook computers, and terminals! And more than 90% of the island's production is exported.

Taiwanese monitor manufacturers increased their output 11.2% over the 1995 figure to make some 34.8 million monitors in 1996, nearly half of them produced in their offshore plants in southeast Asia and mainland China. (In percentage terms this represented 54.3% of worldwide production, one or two percentage points down on 1995.) Just over half of all these monitors were made by the big six: ***Philips, Lite-On, Acer, Tatung, ADI,*** and ***CTX*** - brands not unknown in the U.S.A. and Europe! The production increase in 1996 was more modest, up 8.3% to 7.8 billion U.S. dollars, reflecting the very competitive market situation and sharply decreasing prices.

Although there was a general concern over the "collapse" of monitor markets in Europe during the second quarter of this year, the 50 or so display-product manufacturers/vendors at Computex Taipei had lots of new products to show and demonstrate enthusiastically to any audience. As always in Taipei, it was quite often a case of "If we were to make this model, Sir, how many of them would you like to buy?" This was especially true for the latest "hot" CRT monitor: the 19-in.-diagonal tube-size model, which is certainly not to be confused with the old 19-in.-visual U.S. size.

Building 19-in. Monitors without Tubes

As at the March CeBIT Show in Germany, a host of suppliers purported to offer a 19-in. monitor (Fig. 2). In the local press there was even a claim by one manufacturer that 20,000 of its 19-in. units had actually been built. But persistent questioning on the stand finally resulted in the comment that these were just the chassis! Thus, this manufacturer, like all the other makers, was eagerly awaiting delivery of 19-in. CDTs from ***Hitachi,*** which is currently - and will be for some time yet - the only supplier of this new tube size.

Nevertheless, with 19-in. models prominent on the stands of ***ADI, Compal, Lite-On, MAG, Optiquest (ViewSonic), Pacific Technology, Royal, Sampo,*** and ***Shamrock,*** there was no doubt that the Taiwanese makers, as well as the Europeans, consider this to be an important screen size of the future. All participants were hoping to have stock in their overseas warehouses by the last quarter of 1997. The betting at Taipei was that ***MAG*** and the exclusively OEM supplier ***Capetronic*** would be the first of the Taiwanese makers to the post. This screen size therefore appears destined to replace 20-in. shadow-mask-tube models completely, *and* to take market share from both 21-in. models and high-end 17-in. product.

This year saw an even greater promotion of the now readily available 17-in. models. The whole Taiwanese industry is convinced that it must move away from the smaller-screen markets if it is to stay profitable - at least as far as its U.S. and European customers are concerned. Thus there was also extra emphasis

ADI

Fig. 3: Among the hundred-odd LCD monitors shown at Computex were several that rotated to convert from a landscape to a portrait display. Among them was ADI's 13.3-in. TFT-LCD monitor.

on 20- and 21-in. displays as even more suppliers added these sizes to their portfolios. Interestingly, many of the models with these screen sizes have upper horizontal scan frequencies (HSFs) limited to the more economical 82 kHz. Nevertheless, nearly all the new models were seen to be fully featured units. Many have the latest environmental specifications, and quite a few brag the universal serial bus (USB) as a feature or an option. For example, five models in ***ADI***'s new MicroScan family have TCO '95, and the 4P, 5P, and 6P have USB. Multimedia monitors were everywhere, and, increasingly, the trend is to offer 3-year warranties. New 17's from ***Compal*** and ***Forefront*** follow the example of ***Microvitec*** of the U.K. in using ***Toshiba***'s new high-brightness Microfilter™ tube.

Small Monitors: Small Margins/High Volumes

Large screens may be the wave of the future, but 15-in., and even 14-in., models have not been forgotten. Because there is *still* a huge market for these - not only in the emerging Asia-Pacific regions but also in Europe (particularly the Mediterranean countries, France, and the U.K.) - the Taiwanese exhibitors naturally presented a large selection. Two categories of 15-in. monitors are still available: the SVGA (48–56 kHz) economy version from makers such as ***Acer, Cheer, Delta, GVC, Lite-On, KFC, Mitac, Royal, Sampo, Shamrock, Tatung,*** and ***TVM,*** and the prestigious 15-in. (64 kHz and above) product from these and virtually all the other suppliers there. (In order to keep manufacturing costs to a minimum, virtually all 14/15's are now made "offshore.")

Most of the 14-in. CRT monitors on display seemed to have HSFs of 30 to 48 or 50 kHz. (Surprisingly, the top limit was sometimes higher, probably to allow the producers to use the same chassis as in their 15-in. models.) Diligent searching of all the data sheets produced a single 31.0–35.5-kHz model in the very extensive ranges of the ***Acer*** clan, which includes ***AcerView, Acer Peripherals,*** and ***Anigo/Addonics.*** Even the AM-1450K from ***A Plus Info Corp.,*** probably the last remaining model with a 0.39-mm-dot-pitch tube, boasted a 30–50-kHz HSF.

For the niche market, very-large-screen models (24, 27, and 29 in.) were being exhibited by some new suppliers. For example, the traditional ***Chun Yun*** line-up of 20–37-in. models, which this year included a 29-in. monitor-TV, and ***ViewSonic/Optiquest***'s 29-in. model were joined by a 27-in. model from ***Tatung.***

At the other extreme of the CRT-tube scale, Taiwanese makers continue to provide most of the 9/10-in. color monitors. Their offerings were again to be seen on the ***Axion/(Action), Bridge, Carry-I, CEM (Channel Electronic Corp.), ETC, Jean (Wen), KFC (Smile), Trans 2000,*** and ***TVS*** stands. Many of these suppliers, along with ***Anbonn, Acula, Jenor, Sunshine,*** and ***Three SOMA*** are still "pitching" with 9- and/or 14-in. monochrome models!

Some of these are new names to you? Add to them ***Acana*** from ***Peripheral Corp./TVM,*** also promoting ***Belinea*** models in its catalogue, ***Begonia ViviScan,*** and ***pixo*** (***Pacific Technology***'s new brand name for its new non-Trinitron models, which include the 19 in.). And how about ***GVC***'s "Golden Age of Impressionism" range: the "Cézanne 14," the "Monet 15," and the "Van Gogh 17″"?

STN-LCDs Live alongside TFTs

Computex Taipei '97 reinforced the fact that 1997 is indeed the year of the LCD monitor. Counting the variants, over 100 models were being hotly promoted by over 20 excited exhibitors. Long-established ***Rightech Corp. (RTC)*** and ***Slimage (Soaring Technology)*** each had over 20 models in various sizes and formats from which to choose. Overall, the sizes of the panels used ranged from the old 9.4-in. monochrome to the latest 15.5-in. product, with 13.8 and 12.1 in. appearing to be the most popular sizes.

Most suppliers appeared to be backing both horses by having both DSTN and TFT displays, thus confounding those pundits who said that STN was dead and that it was all AM-TFT from now on. The dual-horse suppliers included many of the big names, such as ***ADI, Compal*** (which claimed to be the world's largest supplier of LCD monitors), ***CTX, KFC, Leo/FIC, MAG, Mitac, Proview,*** and ***Shamrock.*** Indeed, the *BYTE Magazine* "Best Display" at Computex Taipei '97 award went to "***MAG Technology***'s 15-in. DSTN-LCD monitor [which] sells for less than US$1500 retail [and whose] XGA output is super clear and the display can rotate 90° for horizontal or vertical viewing." Also rotatable are ***ADI***'s 13.3-in. TFT (Fig. 3) and 15.5-in. DSTN XGA models, and the 15-in. DSTN models from ***Art Media*** (***Pacific Technology***'s normal brand name). ***CTX***'s new PanoView models don't rotate but they come with a very flexible rise-and-tilt mechanism that "gives the user dozens of viewing positions."

One thing is for certain, if this end user had been given the choice of any one CRT or LC display from the multitude on show at Computex, it would be obsolete by the time my mind was made up! ■

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editorial

continued from page 2

a $2500 notebook with a single $5000 desktop-replacement notebook. But this year's $5000 computer is next year's $2500 computer, and that could spread the desktop-replacement trend to corporate employees farther down in the computer pecking order and to a broader slice of the small-office/home-office (SOHO) market.

Such a trend could cut into the CRT-monitor business earlier than has been anticipated, but it could also cut into the anticipated LCD-monitor business. After all, if a major point in favor of an LCD monitor is to save desktop real estate, you can save even more by replacing the entire desktop system with a notebook that contains a really good display.

For panel makers, this could change their mix between 13.3- and 15.5-in. panels. For would-be LCD-monitor makers, it could slow the growth of a business that is now only in its infancy. And makers of high-end notebook PCs, who are already pressed to keep up with demand, may experience even greater pressures and profits.

Whether they go into monitors, notebooks, or both, it is all but certain that a growing number of high-information-content LCDs will be sold.

- Ken Werner

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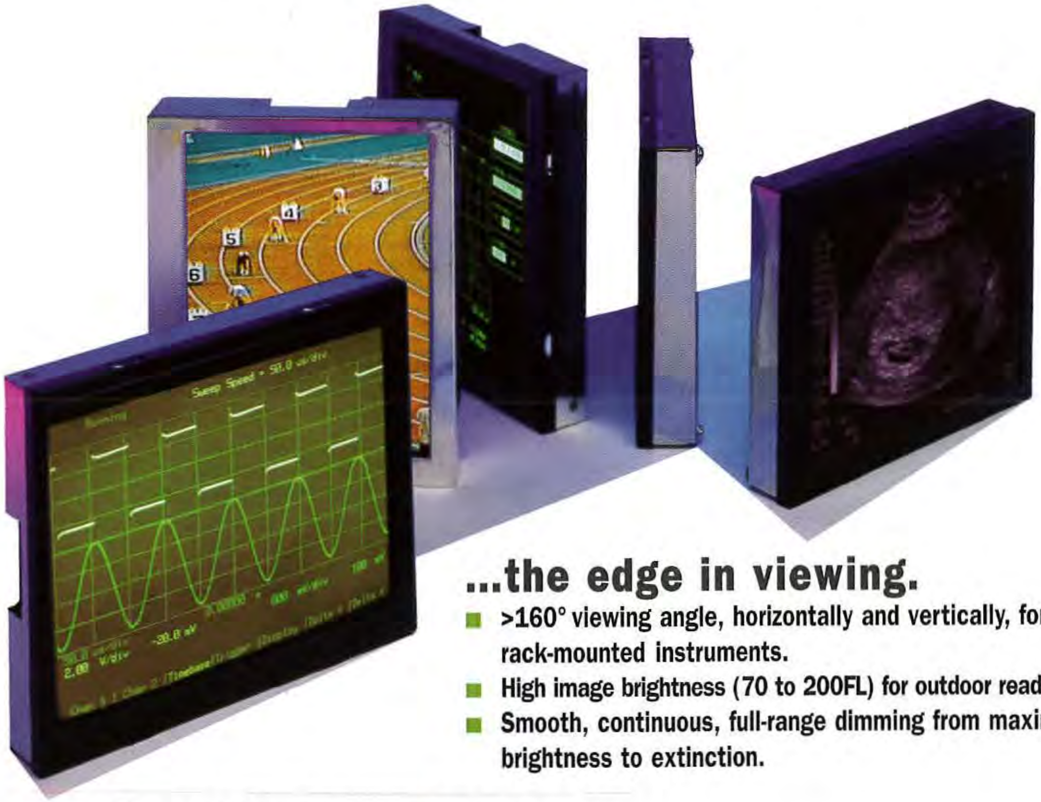

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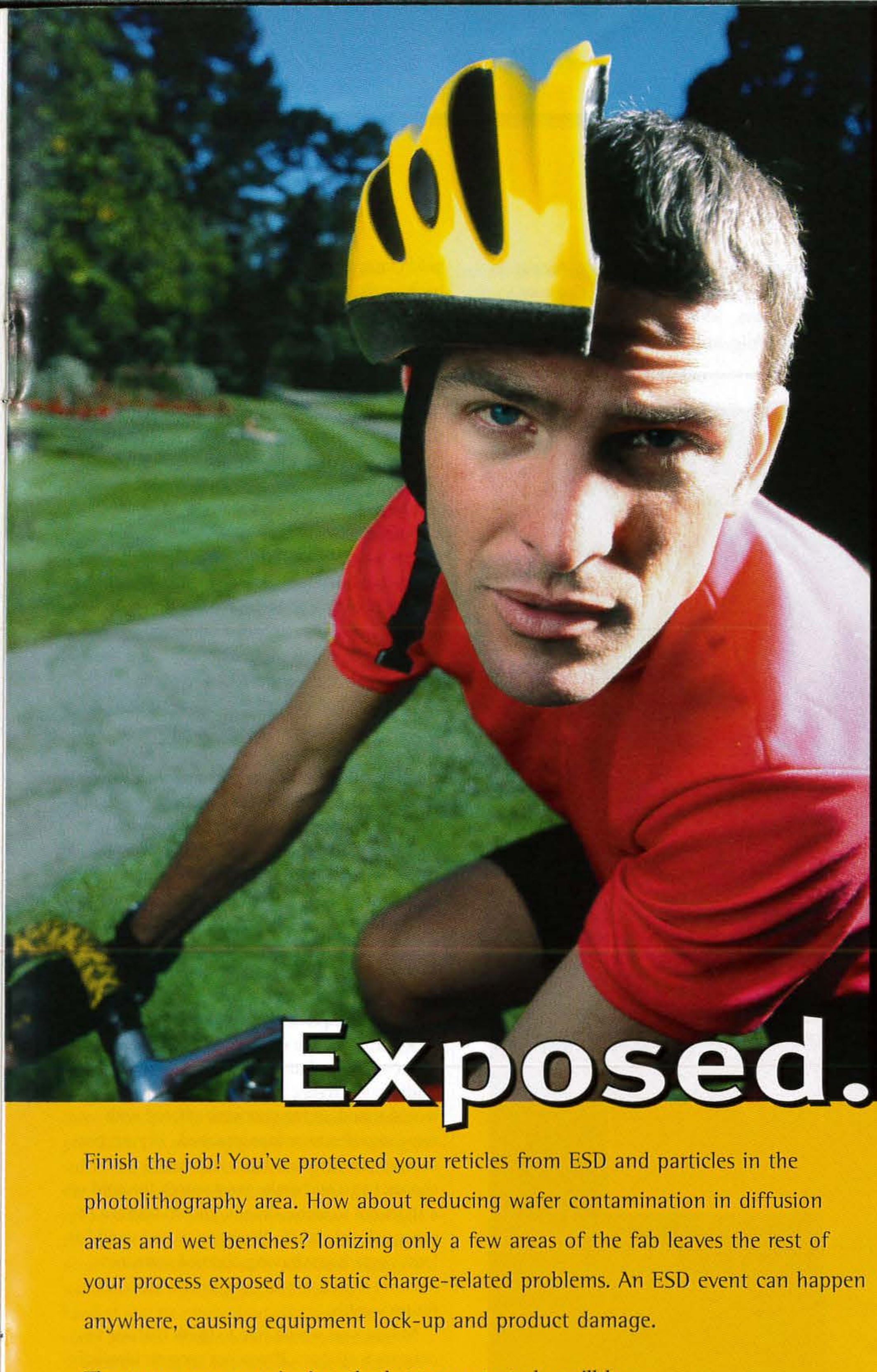

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continued from page 4

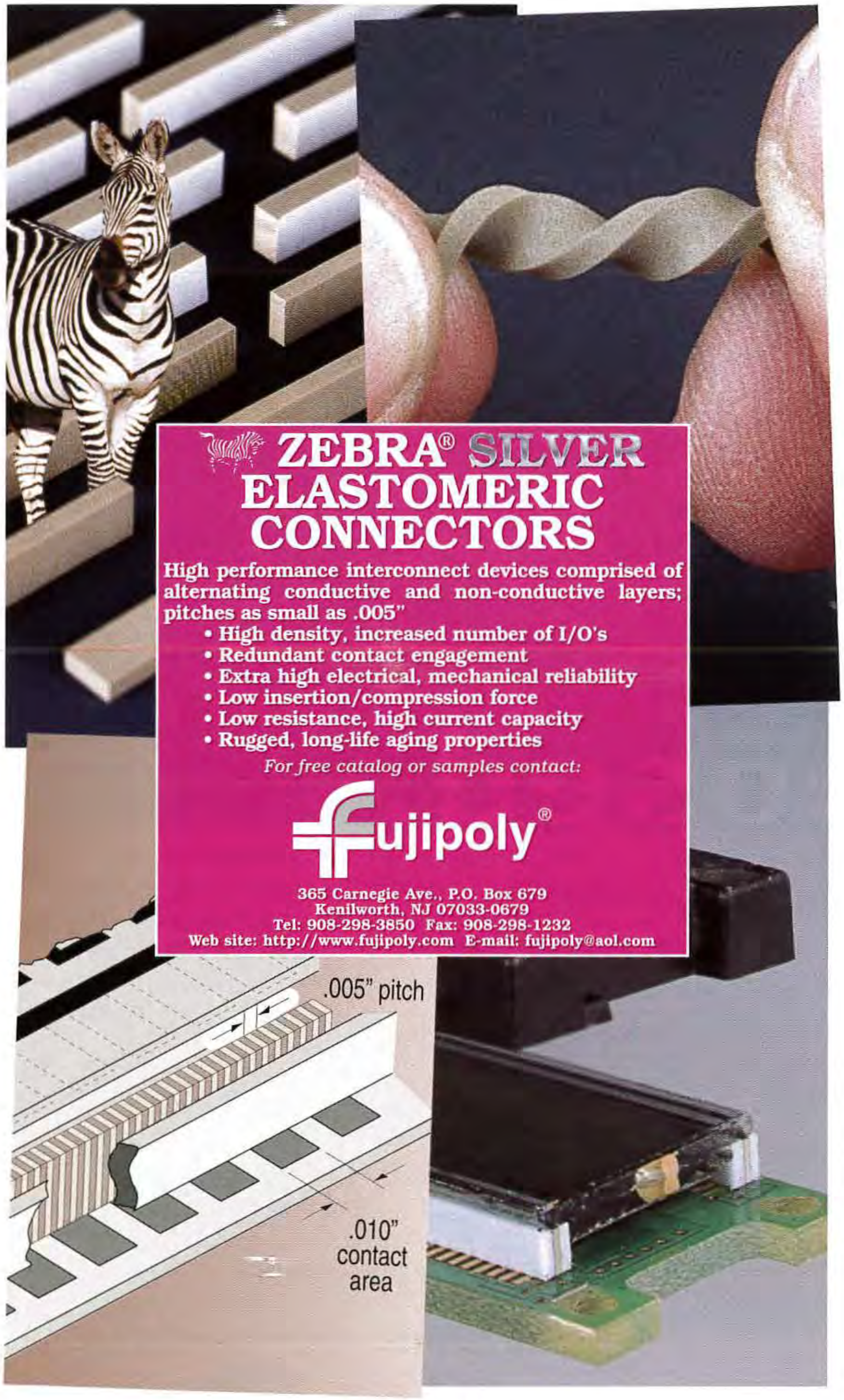
person to the other side. Some even undertook this journey while enduring the harsh winter storms, when temperatures plunged to over 50 degrees below zero.

This gold rush created a whole infrastructure of suppliers, helpers, and – I'm sure – other experts. Most of the suppliers made money, while most of those hoping to find gold came back disappointed or didn't come back at all. Of the 100,000 who made the attempt, only 30,000–40,000 actually got there. Of those, about 4000 found at least some gold and perhaps a few hundred found enough to get rich. Of these few who found the hoped-for riches, most subsequently lost them in the gambling halls or on other risky ventures. Apparently, greed causes us humans to take some pretty wild chances both before and after we find our pots of gold.

But then, hasn't it always been like that? Columbus didn't sail the ocean blue just so he could find interesting rocks, plants, and dirt to take back to Queen Isabella. For him to be able to show his face back at the castle, those rocks had better be of gemstone quality, the plants had better be important foods or spices, and the dirt had better have a nice shiny yellow color. And if that wasn't possible, at least he'd better be able to talk a good story about how he had discovered a new short-cut to more easily get to these items.

Those early explorers had to know how to get their expeditions funded. I'm sure that what they had to go through then isn't all that different from what we do today to get a new venture funded. Most likely, once you got your audience with the queen's venture-fund manager your business plan had better have in it how you were going to make a pretty great return on the queen's investment. Those three little ships that the queen was willing to buy for you and the bunch of scrummy sailors her soldiers – carrying sharp pointy things – would round up for you were offered with some significant strings attached. If your persuasive powers were up to it, you got your chance to go and make your search for gold or a short-cut to some already known sources of other valuable stuff. Worst case, you would at least come home having claimed some new territory which would provide the hope of future wealth.

Maybe you would like to think that we've outgrown all that. If you are such an idealistic thinker, ponder for a moment the excitement that a moon or Mars landing would create if that little radio-controlled vehicle found fifty-carat gem-quality diamonds or emeralds strewn about among all those other interesting but useless rocks. Gold wouldn't be quite as interesting since the cost of bringing it back wouldn't make the discovery economically feasible. But, nevertheless, wouldn't it be something to see pictures come back from the



moon or Mars showing goose-egg-sized nuggets of gold sitting there just for the taking? I guess a cute little alien sitting on a rock wouldn't be too shabby either.

Well, we can dream, can't we?

The event that is credited with starting the rush for riches into the Yukon Territory was the arrival in Seattle of the steamship *Portland* with about two-thirds of a ton of the stuff in its hold. That happened just one hundred years ago. In fact, it was only two hundred years ago that Lewis and Clark made their journey to explore this part of the world. That this event took place only about four-times-my-age ago is among the scariest pieces of information that my mind has recently processed. How can it be, that only 4× (where × is me) years ago we "civilized" folks didn't even know that this place existed? Lewis and Clark didn't find gold, nor were they trying to, but they sure found some great real estate and a bounty of nature's riches in the rivers, mountains, lakes, and forests.

Thus, in ×-time, the history of Seattle goes something like this: 4× years ago Lewis and Clark found the Northwest, 2× years ago the business of provisioning people to go search for riches in the Yukon Territory created a healthy economy and lots of growth for Seattle, and today at 0× the discovery of software riches is creating even greater wealth for a few and a healthy business environment for many others. How's that for cutting through a lot of unnecessary historical details?

And just as during the gold-rush days, when there were people who helped bankroll and provision the more aggressive ones wishing to suffer the hardships of searching for more of the shiny nuggets that had made the first-comers so wealthy, today there are those who will provision the start-up of new software companies. And most of the new software miners will also end up disappointed and empty handed just like their gold-seeking predecessors. Not all. There will be a few notable successes. But no one will be able to duplicate those incredible first finds uncovered by Bill Gates and his early cohorts.

That, however, is hardly being viewed as a deterrent. Today, Seattle has software gold fever every bit as much as in the heady days of the Yukon gold rush. Each day's newspaper brings the latest information about which new start-up is doing what, which new venture has just been funded, and how much richer the Microsoft bunch has become. By recent count, there are now well over 500 new software companies who have staked their claim in this part of the world. And that's not counting all the freelance and contract folks out there doing a bit of small-time mining of their own. The venture funds (provisioners) are increasing their presence almost daily. Many are setting up branch offices or starting up new funds just to work these seemingly lucrative finds. That, of course, means that even more folks will be enticed to try their hand at finding riches in these fast-flowing electronic streams.

Fortunately, we in the display community have always been a more stable and unflappable lot. One hundred years ago, when everyone else was heading for the Yukon Territory, we could see the foolishness of their ways. So, instead of joining in the rush, we decided to create something much more significant that would live many years longer than the gold rush. Instead of finding material riches, we decided to create an entirely new way for humanity to function.

We invented the CRT! As a result of this creation, soon came television (at about 1.1×), then the desktop computer (at 0.2×), and finally the whole Information Society. The CRT allowed us to convert electromagnetic radiation and computer-generated data into information-bearing images that approach the processing bandwidth of the human brain.

Then, while the Information Society was still struggling through its birth with the advent of the desktop PC, we decided that it would be important for people to be able to carry information with them and to create it at their convenience in any location. So we invented the liquid-crystal flat-panel display. As a result of our work, the laptop-computer business came to pass and the Information Society came into full swing.

Our work never received the attention or publicity that was given the Yukon gold miners or that is being lavished on software developers today. We did such a good job that much of our work was and is taken for granted. Nevertheless, we remain the critical path for information flow from computing machine to the human brain. The need for further developments in display technologies exists: We need flat-panel displays with higher resolutions at lower cost for desktop and laptop computer applications, we need miniature displays for portable communications devices, we need large displays (direct view or projection) for the television systems of the twenty-first century, we need new electronic displays for outdoor signs and advertising, and we need new displays for quasi-hardcopy applications. And that is just a sampling of where the Information Society may take us.

Unfortunately, because we have not attracted as much attention as – or found the incredible wealth of – the software developers, we have a tougher time getting new businesses started and are consequently beginning to fall behind the needs of the Information Age. At least in the U.S. – but I think in other parts of the world as well – it is harder to find the "provisioners" to fund us to develop the next-generation displays. A software company can begin with a great concept and a few engineers to write the computer code. Manufacturing costs are minimal and time to market can be short. A venture fund has the potential of realizing a quick and substantial return if the new software is a "hit" in the marketplace. On the other hand, a display technology typically takes several years to develop, and the manufacturing start-up costs are higher.

One must therefore be clever in finding the right combination of technology and investors to permit realistic development of a new display technology. One approach may be to find a specialty market that allows the technology to establish itself on $20–50 million in sales. At that level, an investment of $10–20 million may be all that is needed to create a successful business. That is still a higher start-up investment than for a one-product software company, but it will most likely result in a business with greater staying power.

Without interesting new displays, the companies working to develop new software will encounter increasing limitations on the products they can introduce. This would be just as true if Intel and other semiconductor companies were to stop bringing out new and more capable processors, or if memory costs and capability stopped improving. Without the ability to improve and specialize hardware to meet particular market needs, new software would be of limited usefulness.

Up to now, we in the display community have been the quietly competent ones. For the Information Society to continue to grow at its accustomed pace, that may have to change. Soon the rest of the world will realize what we have known all along: without superb displays

display continuum

to translate "compute" power into information that can be analyzed by the human brain, the Information Society is not even a "twinkle." It will be up to us to make sure this twinkle glows ever brighter in the years to come.

Whether you have a condo on Mars or have established an outpost in the Yukon Territory, I would enjoy hearing from you. You may reach me by fax at 425/557-8983, by phone at 425/557-8850, or by e-mail at silzars@ibm.net. And for the few of you who still take the time to send a genuine handwritten letter, you may reach me at 22513 S.E. 47th Place, Issaquah, WA 98029. ■

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Display Technology

The Third International Conference on the Science and Technology of Display Phosphors. Co-sponsored by the Phosphor Technology Center of Excellence, Defense Research Projects Agency, and Society for Information Display. Contact: Bill Klein, Palisades Institute for Research Services, Inc., 201 Varick Street, Suite 1006, New York, NY 10014; 212/620-3377, fax -3379, e-mail: bklein@newyork.palisades.org.

Nov. 3-5, 1997 Huntington Beach, CA

Fifth Color Imaging Conference: Color Science, Systems & Applications. Co-sponsored by IS&T and SID. Contact: IS&T, 7003 Kilworth Lane, Springfield, VA 22151; 703/642-9090, fax -9094.

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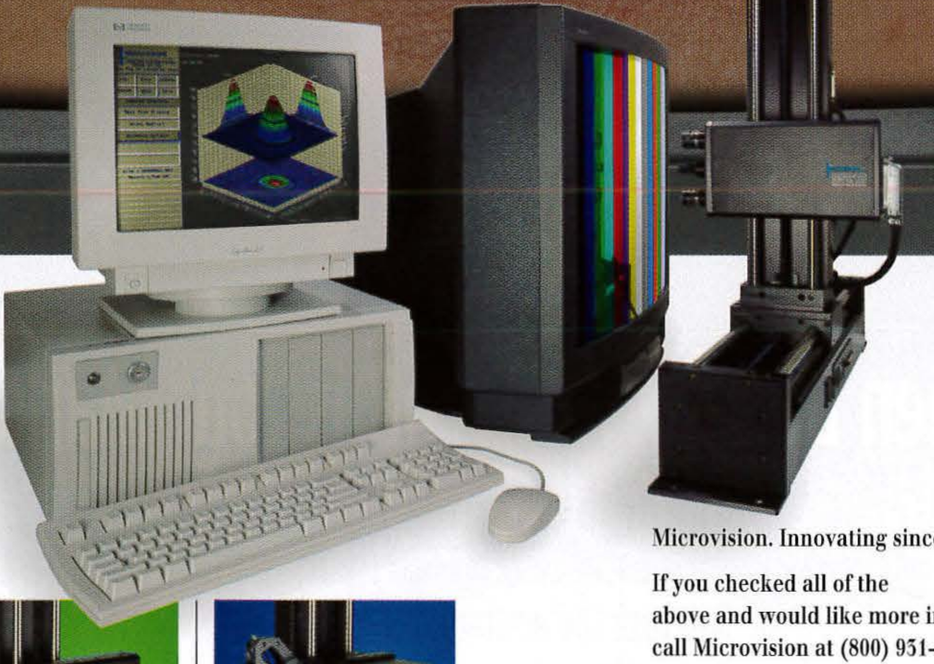

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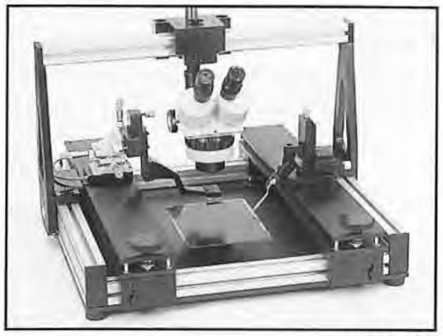

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