DISPLAY OF THE YEAR AWARDS ISSUE

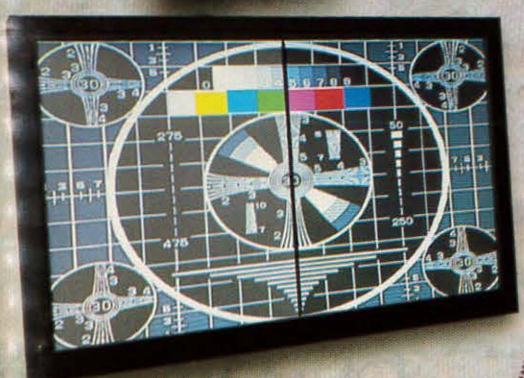
Information DISPLAY

December 1998
Vol. 14, No. 12

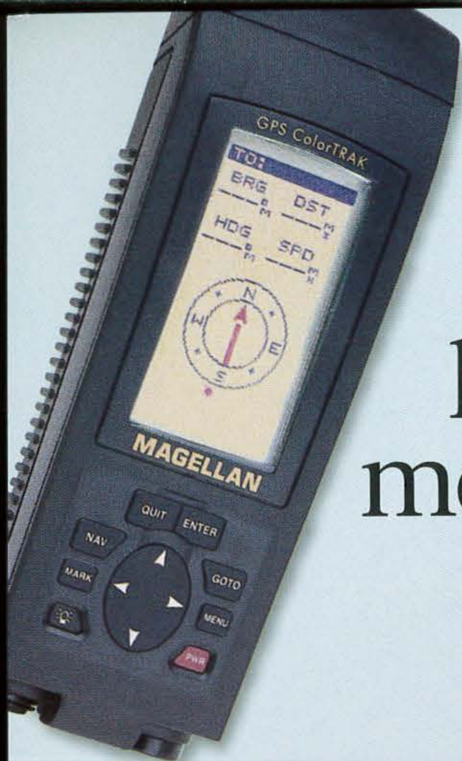
SID

Official Monthly Publication of the Society for Information Display

The Best of '98



- *Display of the Year Awards*
- *Microdisplays*
- *FPD Image Scaling*
- *Military Display Dilemma*
- *Front-Projector Measurements*



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Circle no. 1

BPA INTERNATIONAL

Earlier than industry watchers expected, Tohoku Pioneer has solved the problems of making a practical OLED display, and parent company Pioneer is including it in its GD-F1 FM Multiplex Automotive Receiver for receiving text messages from the VISC traffic-information system. The OLED earned the SID/Information Display Display of the Year Gold Award. To learn about this and the other five awards, see the article beginning on p. 12.

Credit: Tohoku Pioneer, Hughes-JVC, Silicon Image, Dai Nippon

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

Projection Issue
- What's Inside That Projector
- Computer-Video Interfacing
- How to Select an FPD
- Screen Reflection
- Asia Display '98 Review

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editorial

We Make the Box

The legendary radio and TV newsman Edward R. Murrow once said that without high-quality programming, television was just a box with lights, and wires coming out. Well, my dear readers, we make the box. By which I mean we do applied research for it, design it, manufacture it, integrate it, market it, advertise it, promote it, sell it, and write about it. And in the early years of this era of "convergence," the same applies to computer monitors and integral computer displays in relation to Internet and CD-ROM (and DVD-ROM) programming. We make the box.

For the most part, we do a very good job of making the box. The people in this industry - with only occasional exceptions, in my experience - approach their varied tasks with enthusiasm, industriousness, and integrity. Succeeding generations of boxes show larger, brighter, more detailed images, and the boxes themselves last longer, cost less, and consume less electrical power.

We are now embarking on a new era of television in which image quality will improve dramatically. We are making a *much* better box. But will the technology and economics of digital TV lead to higher-quality programming: programming that will educate us, enlighten us, give us entertainment that is occasionally intelligent, and provide us with the conscientious news reporting and analysis we need to be good citizens of our own countries and of the world - real news, not the "info-tainment" that tarnishes Ed Murrow's legacy.

One of the problems is that good news requires intelligent, knowledgeable, well-trained journalists; and good entertainment requires intelligent and well-trained writers, actors, directors, and producers. On the entertainment side, at least, U.S. television networks are already complaining about there not being enough talent to go around. It's not clear how better picture quality and more channels - which will further dilute the talent pool, divide the audience pie into smaller slices, and increase the competition for funding - will help this situation.

But neither is it clear that dividing an audience into enthusiastic, well-identified segments can't sometimes stimulate good programming. HBO was a big winner at the Emmy awards last September on the strength of creative original programming. The networks certainly have the resources to do this kind of programming, but they may feel such programs can not hold enough of a network's diverse audience. (They may also just lack the creativity and imagination.)

What effects high definition may have on programming is not easy to assess. Large, high-definition formats are certainly well suited to many sports events and movies. Will the existence of HDTV skew prime-time schedules more in this direction? Will we go through a period where visual spectacle will take precedence over other values - such as writing, directing, and acting? Will news departments be inspired to recreate a modern form of the old newsreel to replace static and largely interchangeable "talking heads"?

After the temporary technical problems are resolved, will digital TV accelerate or reverse the trend toward cable and digital TV at the expense of terrestrial broadcasting? Cable and satellite will no longer have an advantage in terms of picture quality, and broadcasters will be able to deliver more channels than they do now, at least at standard definition. So in some ways digital TV may level the playing field.

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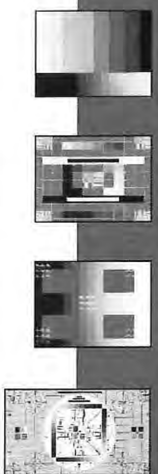

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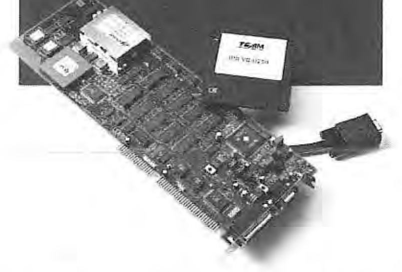

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Circle no. 2

On the Third Day of Christmas ...

by Aris Silzars

For Mathias and Nicole this had indeed been a joyous Christmas. They had felt the magic of Christmas Eve with the lighting of the tree, and having reached the relatively mature childhood ages of 10 and 8, they had been able to appreciate both the content and the symbolic meaning of their presents. On Christmas Day, all the feasting and visiting with their relatives and family had made this year's Christmas celebration the best one yet. Now, a few days later, they were getting in some serious playtime with their new toys.

Nicole had already tried out her new digital camera to take photos of her stuffed bear collection. She had also photographed all her presents, made several photo-quality prints for herself, using the color printer attached to her dad's home-office computer, and transmitted some of these images via the Internet to her two best friends across town. Now she was getting ready to send an e-mail with pictures of two of her newest stuffed bears to Grandma so that her grandmother could see how the Christmas presents she had sent looked sitting next to the other bears in Nicole's collection.

Mathias was also experimenting with one of his Christmas presents, a game-compatible digital camera. (As with parents everywhere, Mathias's and Nicole's considered keeping a good balance of presents between siblings an important goal.) Mathias was at the moment acquiring images of his surroundings so that he could personalize the software of a detective mystery puzzle on his game computer. Convincing Nicole that she should pose for him, so that he could make her one of the characters in his computer story, turned out to be the toughest challenge. However, she finally relented after he agreed to help her with her next school homework assignment.

Their parents had already sent the images of the family's Christmas to all their friends and relatives and had conversely received pictorial Christmas greetings via e-mail from most of them in return. It was great how quickly this new tradition had caught on and how the earlier tradition of sending store-bought Christmas greeting cards by mail had died out - equally quickly. After all, there was so much more interesting content in a just-captured electronic image of the family's celebration than in a pre-printed card with nothing more than a signature or, maybe at most, a copy of a letter about how great all the kids have done over the past year and/or a posed photo of the children from some earlier occasion.

Doesn't this sound like a storybook-perfect description of a future Christmas celebration some years from now? Perhaps it does, but it's not. Except for a few minor details, we are not describing future Christmases; we're talking about this Christmas, the Christmas of 1998. And the digital cameras for the kids? Rich kids only? Well, Nintendo has a digital camera on the market as an add-on to its Game Boy toy for $49.95 and pre-Christmas season sales have already exceeded 800,000 in the U.S. and Japan. And the camera for Nicole? Mattel has introduced one to go along with its Barbie toys for about $69. Both are made with CMOS sensors, which are less expensive than CCDs.

Is the day of all-electronic digital photography really upon us? Before we get too carried away with this technology-driven-lifestyle scenario, consider this letter, which came to me in response to an earlier column.

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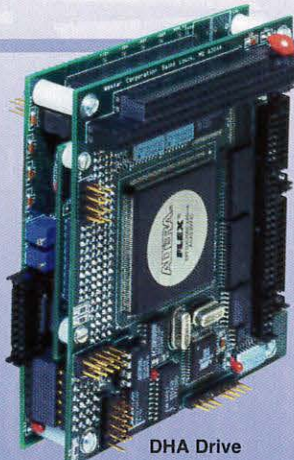
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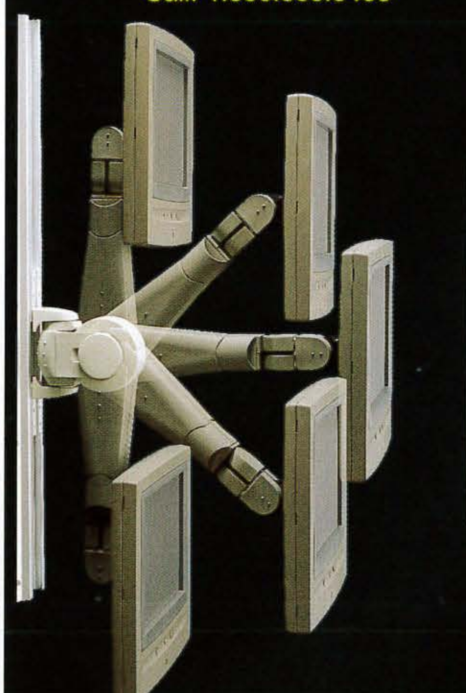

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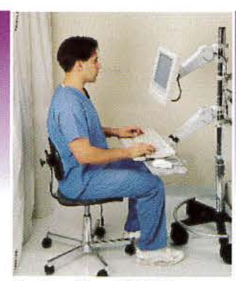
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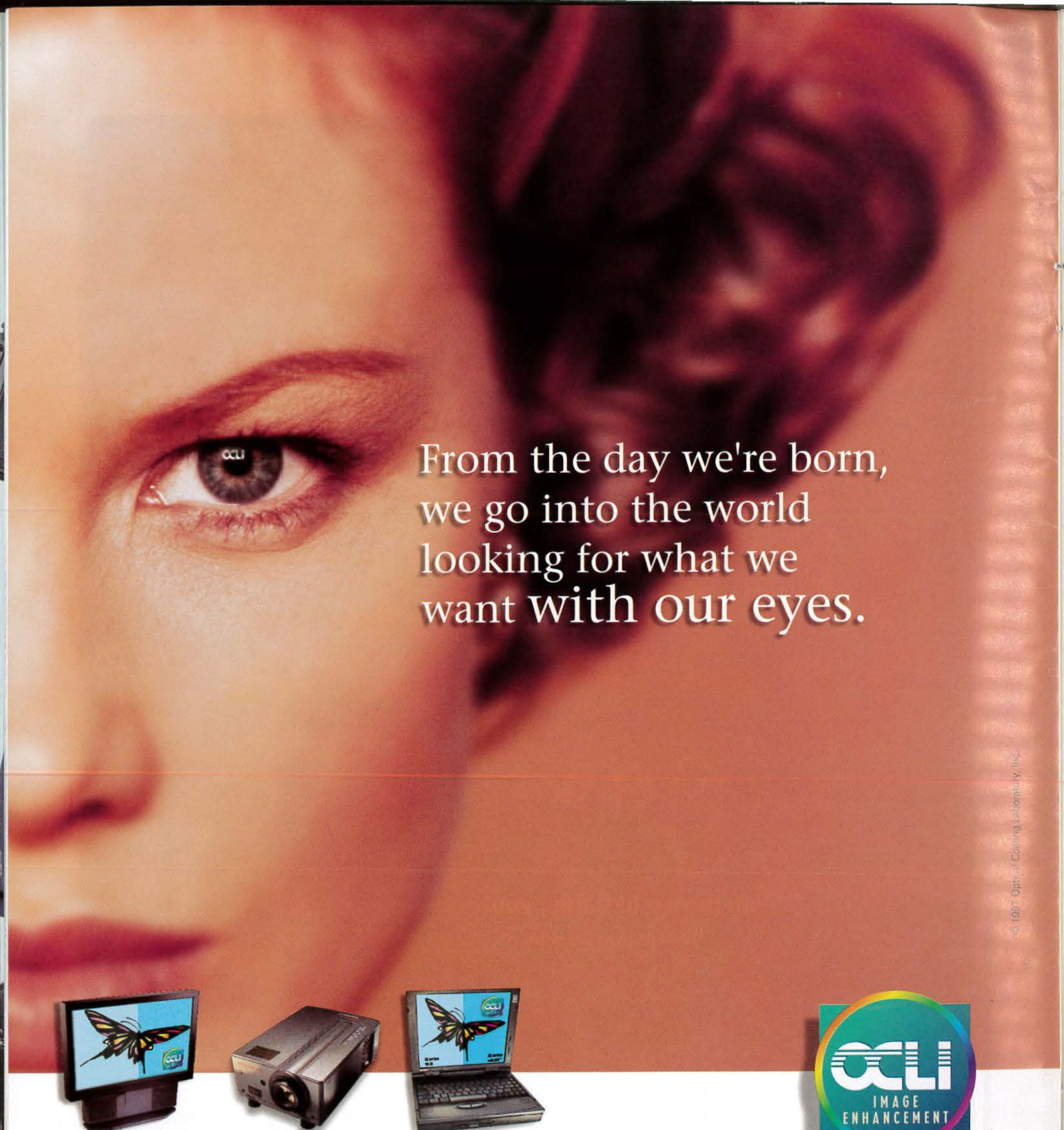

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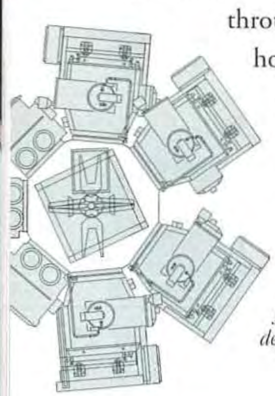

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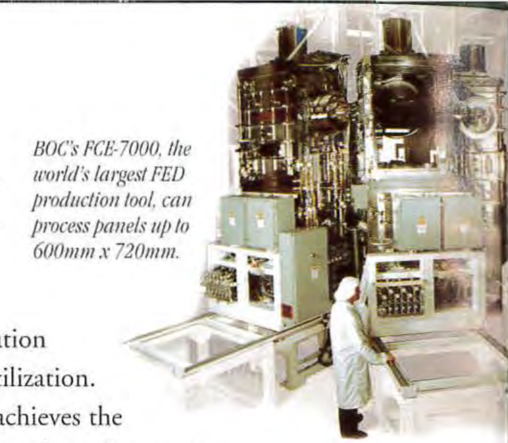

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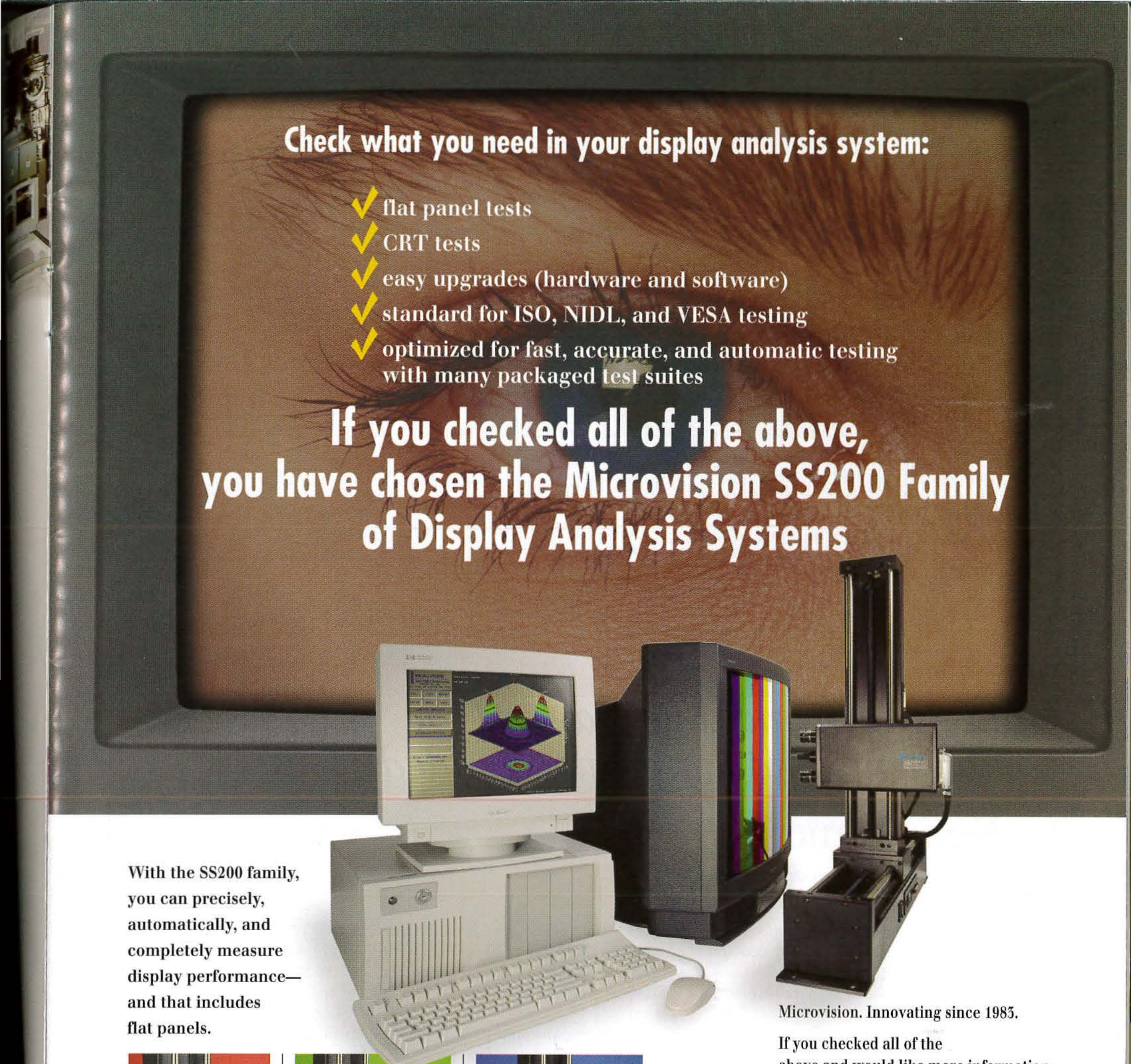

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Circle no. 10

Fourth Annual Display of the Year Awards

For 1998, a newly commercialized display technology wins the Display of the Year Gold Award, and a new award for components and materials is added.

by Ken Werner

When the members of the SID/*Information Display* Display of the Year Awards Committee (DYAC) met near Anaheim, California, during SID '98, they concluded a year-long deliberation by adding a third award honoring developments in components and materials to the two existing awards for displays and display products. The DYAC also retired the concept of giving "awards" and "honorable mentions." Starting this year, a gold and a silver award will be granted in each of the three categories.

What has not changed is the DYAC's special character and the painstaking nature of its deliberations. The committee is not only fully international (see text box, 1998 Display of the Year Awards Committee), but consists of both distinguished members of the technical display community and distinguished technical journalists who cover displays. This combination ensures that the DYAC's deliberations are carried out with both technical sophistication and breadth of view.

All of the displays and products considered for the awards were nominated either by the members of the DYAC or by interested parties who submitted their nominations to the DYAC secretariat. The secretariat distributed the names of all the nominees to the committee members, who then voted for the winners. The DYA bylaws require the committee members to consider many factors when they vote, including technical innovation, commercial significance, and likely social impact.

To be eligible for this year's awards, displays, products, components, and materials must have become commercially available - either to OEMs or end users - between July 1, 1997, and June 30, 1998.

This year's winners were developed by companies from three continents, and the voting for our new Display Material or Component Award of the Year resulted in an absolute tie. As a result, the DYAC is awarding two gold awards and no silver award in this category for 1998.

***Ken Werner** is the editor of* Information Display. *The opinions expressed in this article are not necessarily those of the Publisher of* Information Display Magazine *or of the Society for Information Display.*

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DISPLAY OF THE YEAR AWARD

Gold Award: Tohoku Pioneer's Organic Electroluminescent Display

Since an electroluminescent effect with an organic phosphor was first demonstrated almost a dozen years ago, there has been a great deal of interest and research. But even 2 years ago, the difficulties of processing organic light-emitting-diode (OLED) materials and giving the resulting devices reliability and long life seemed formidable. Then, in 1996, Tohoku Pioneer demonstrated a green 256 × 64 dot-matrix prototype OLED with a luminance of 100 cd/m^2 and an estimated life of 10,000 hours, and later described the device at SID '97.

Now, Tohoku and Pioneer are producing a production version of the device and are incorporating it in Pioneer's GD-F1 FM Multiplex Automotive Receiver for receiving text messages from the VISC traffic-information system. The OLED's high luminance and contrast make the messages readable in most daylight conditions.

Full-color devices are on the way from both Tohoku and Idemitsu, but for now, this green device is the world's first and only commercially produced OLED. The DYAC wishes to acknowledge Tohoku's and Pioneer's solution of the many technological problems that stood between a promising electro-optical material and practical display devices.

DISPLAY OF THE YEAR AWARD

Silver Award: Fujitsu's 15-in. Multi-Domain Vertical Alignment (MVA) TFT-LCD

Makers of active-matrix liquid-crystal displays (AMLCDs) based on conventional twisted-nematic (TN) technology have struggled for years to attain video-rate switching speeds and wide viewing angles. New liquid-crystal (LC) modes have provided very wide viewing angles at the expense of response time, and wide viewing angles are now being combined with reasonable response times through the use of compensating films.

What Fujitsu has accomplished with its FLC38XGC6V/6V-01 module is to combine a novel LC mode with a multi-domain structure for a combination of wide angle (160° both horizontally and vertically) and very fast switching time (25 ms, on + off) based on the structure of the display itself, *i.e.*, without external compensation. In addition, the multiple domains are created without rubbing.

Fujitsu has exhibited a 21.3-in. demonstration unit in Japan, which was shown displaying a motion picture, suggesting the possibility of a wall-hanging TV. But the excitement now is the 15-in. MVA-TFT module, which is being delivered at a rate of several thousand a month, according to Fujitsu. With a luminance of 200 cd/m^2, a contrast ratio of 300:1, a four-tube backlight, and a choice of an LVDS or CMOS digital interface, this LCD would seem to make a particularly attractive CRT replacement for monitors.

DISPLAY PRODUCT OF THE YEAR AWARD

Gold Award: Hughes-JVC's D-ILA™ Digital Graphics G1000 Projector

Hughes-JVC has incorporated its recently developed Direct-Drive Image Light Amplifier (D-ILA™) in the first projector to use this highly effective reflective light-valve technology. Unlike the CRT-addressed ILA® devices developed previously by Hughes-JVC, the new LC-on-CMOS device is digitally addressed. At 0.9 in. on the diagonal, it is much smaller and lighter than the CRT-addressed devices.

The new projector uses three of the D-ILA™ devices working through a single lens to produce a maximum screen resolution of 1365 × 1024 pixels with a luminous flux of 1000 ANSI lumens and a contrast ratio of more than 250:1. The projector handles a full SXGA image without scaling or loss of quality, scales smoothly for lower screen resolutions, and can handle 1000 TV lines for full HDTV compatibility. With a weight of 28.6 lbs., the projector is intended to be transportable and to offer easy set-up.

The DYAC acknowledges a quarter century of dedicated light-valve development at Hughes and Hughes-JVC, culminating in the current combination of technical innovation and excellent product performance.

DISPLAY PRODUCT OF THE YEAR AWARD

Silver Award: Alcatel's One-Touch Com™

In its One-Touch Com™, Alcatel uses a 40 × 80-mm backlit LCD to combine the functions of a GSM digital cellular phone, a personal organizer, a wireless Internet e-mail communicator using SMTP and POP3 protocols, a short-message (SMS) communicator, and PC companion. A specially formatted SMS message sent to the One-Touch Com™ can update the calendar automatically. PC synchronization can be done *via* the PC's serial port or wirelessly through the integrated IrDA infrared port.

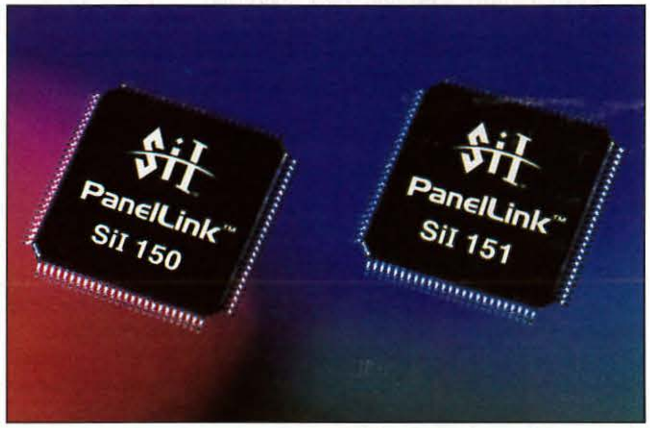
The key to getting all of this into a compact 240-gram package is the relatively large display, which can present a GUI, interactive data screens appropriate to the various functions, a soft keypad for dialing phone numbers, and a soft alphanumeric keyboard that is actuated with a stylus. To make creating messages easier, a variety of pre-written messages can be called up and modified.

Alcatel has created a sophisticated multi-functional product that could open Internet e-mail to a wide range of users, without any need for computer equipment or expertise. The product is based on a highly intelligent design that is enabled by display technology and a thoughtful user interface. The Display Product of the Year Award was created to honor this kind of achievement.

DISPLAY MATERIAL OR COMPONENT OF THE YEAR AWARD

**Gold Award: Silicon Image's PanelLink™*

In their quest to displace CRTs from the desktop, makers of flat-panel monitors (FPMs) have been impeded by the need to interface their inherently digital products to the analog output of the typical graphics controller cards in personal computers, or to supply a proprietary digital controller card. The former solution adds substantial cost and compromises image quality; the latter solution also adds cost, as well as requiring the user to open the box and install the special card – the antithesis of "plug and display."



With its invention of PanelLink™, the first implementation of transition-minimized differential signaling (TMDS), Silicon Image has set the stage for substantially less-expensive digital FPMs and universal controller cards that will economically support both TMDS and traditional analog monitors.

PanelLink™ implements TMDS with a transmitter-receiver chipset. The receiver chip (Sil 151) resides in the monitor. The transmitter chip (Sil 150) resides on either a single-purpose TMDS or universal graphics controller card. The two chips are connected with a twisted-pair cable up to 5 m long.

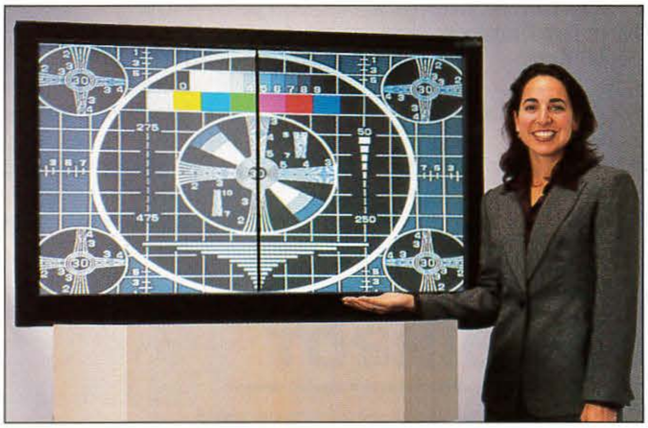
PanelLink™ is enjoying strong industry support. VESA's "Plug and Display" standard was largely built around PanelLink™, and the technology is being implemented by Compaq, IBM, ATI, Matrox, STB, LG Electronics, Princeton Graphics, Samsung, Viewsonic, Mag Innovision, Siemens-Nixdorf, Toshiba, and others.

Silicon Image has developed a technology and commercialized a display component that is helping to move the display industry, its OEM customers, and display end users into an increasingly digital flat-panel future.

DISPLAY MATERIAL OR COMPONENT OF THE YEAR AWARD

**Gold Award: Dai Nippon's Ultra Contrast Screen*

Conventional double-lenticular "black stripe" screens, used with Fresnel lenses in television and other rear-projection applications, are very effective in providing high screen gain with low reflection of ambient light for high contrast. But the pixel pitch of these screens cannot be reduced much below 0.3 mm, which makes them unsuitable for SXGA and HDTV applications.



At these higher screen resolutions, it is possible to use single-lenticular screens, but the lack of black stripes on these screens means reflections are higher and contrast lower. The addition of a contrast-enhancement filter would indeed provide increased contrast, but at the cost of screen luminance – which is in short supply in many rear-projection applications. So, as TV manufacturers moved into the HDTV era, they faced a serious dilemma.

Dai Nippon Printing Company has helped resolve this dilemma with its ultra contrast screen (UCS), a lenticular screen with 0.14-mm pitch that incorporates an internal ambient-light absorption system (ALAS) that provides improved contrast without an external black matrix or contrast-enhancement layer. As the first and only high-gain enhanced-contrast solution to date for single-light-source (LCD, DMD, etc.) rear projectors, UCS is being widely accepted.

*Because of a tie, there are two gold awards, and no silver award, in this category for 1998.

ORIGIN OF THE DISPLAY OF THE YEAR AWARDS

The idea of awards for the best displays of the year was first suggested by Professor Shunsuke Kobayashi to *Information Display* editor Ken Werner in Monterey, California, in October 1994. Following discussions with Aris Silzars, Kathy Middo, and members of the Board of Directors of the Society for Information Display, the Display of the Year Awards Committee (DYAC) was formally constituted in January 1995 in Santa Clara, California, with Professor Kobayashi as Chair. To ensure a broad perspective as well as in-depth technical understanding, it was agreed that the committee should include technical journalists as well as distinguished display professionals – a strategy that has proved very successful.

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Circle no. 11

Small Displays Have a Big Future

Depending on how we count, about 30 microdisplay vendors are seeking gold in the application hills. Can there possibly be enough to go around?

by Hiap L. Ong and Ronald P. Gale

WHEN WE THINK of liquid-crystal displays (LCDs), we tend to envision a direct-view panel that is 10–13 in. on the diagonal, such as those used in portable computers or desktop monitors. Tiny panels the size of a thumbnail are poised to play increasingly important roles in computer, communications, and entertainment applications.

What Are Microdisplays?

The proliferation of different microdisplay technologies in recent years has made it difficult to define the category with precision, but in general these displays are small in physical size with high information content. Kopin Corporation's CyberDisplay 320C is a good example, with a 0.24-in. diagonal measurement and a 320 × 240 resolution (Fig. 1). The unique and common feature of microdisplays is that the pixel size is small, ranging from roughly a 50-μm pitch down to below 10 μm, which corresponds to pixel densities from 500 to 2500 lines per inch (lpi). By comparison, a typical direct-view LCD notebook panel has a 0.28-mm pixel pitch - which is 280 μm and about 10 times larger than microdisplays.

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The tiny pixels of a microdisplay cannot be adequately resolved with the naked eye, and therefore require an optical magnification system to enlarge the image. There are two main approaches used to magnify the image: projection and virtual images (Fig. 2).

Projection systems enlarge the microdisplay image to be viewed on a large screen, typically in 20–100-in.-diagonal sizes. The display panel used is normally between 0.7 and about 3 in. on the diagonal; larger displays are easier to magnify and generally make more

Kopin Corp.

Fig. 1: The CyberDisplay 320C microdisplay from Kopin Corp. has an active display area that is only 0.24 in. on the diagonal, with 320 × 240 full-color resolution.

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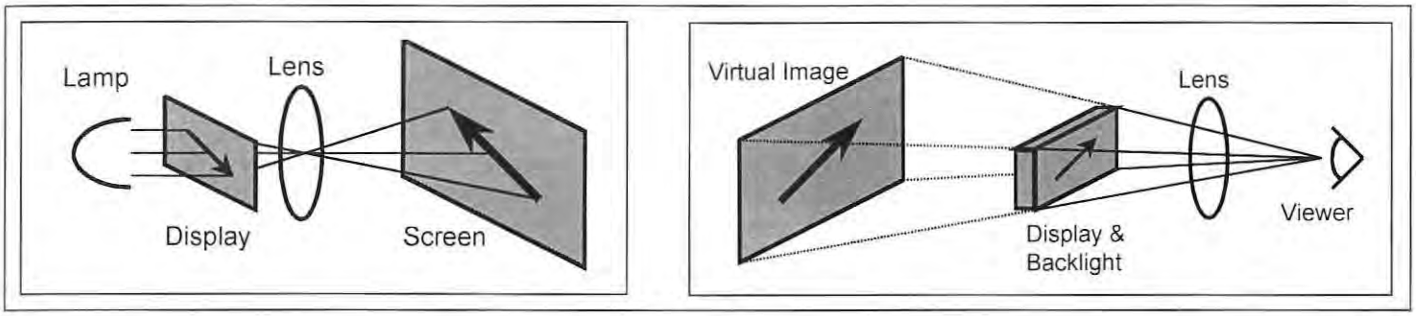

Kopin Corp.

Fig. 2: Microdisplay panels can be used either for projection displays (left) or virtual displays (right).

efficient systems, but also make for bulkier systems.

Virtual images are obtained by simply magnifying the microdisplay and having the user look directly into the optical system. The apparent image is a virtual image with an image size from 3 to 20 in. on the diagonal, depending on microdisplay size and optical-system magnification. The display sizes used in this application generally range from 0.2 to 1.0 in. on the diagonal. Typical applications for virtual-image displays require compact configurations, so most are based on a single panel.

Applications for microdisplays require high-resolution images, which in turn require high pixel densities. Data-projector resolutions range from 640 columns × 480 rows (VGA resolution) to 1600 × 1200 (UXGA resolution). Virtual-image displays tend to be more modest at this point, ranging from 320 × 240 (quarter VGA) to 800 × 600 (SVGA), although panels up to 1280 × 1024 (SXGA) are under development.

While there may be some overlap in the applications of specific microdisplays, most of the designs can be divided into projection and virtual-display applications, based on their size (Table 1). These two groups of microdisplays tend to be different in terms of resolution, cost, and intended application.

Table 1: Two Roads for Microdisplays

Parameters (Typical values)	Projection Displays	Virtual Displays
Image type	Real image on screen	Virtual image
Image size	20–100-in. diagonals	3–20-in. diagonals
Display panel sizes	0.7–3-in. diagonals	0.2–1-in. diagonals
Resolution	VGA, SVGA, XGA, SXGA, UXGA	quarter-VGA, VGA, SVGA
Panel cost	\$300–\$2000	\$30–\$1000
Major vendors	20	30
Sample major applications	Projectors	Digital cameras, mobile phones

Table 2A: Microdisplay Vendors Using Polysilicon AMLCDs

Company	Location	Control	LC Mode	Color	Applications
Hitachi	Tokyo, Japan	High temp poly-Si	TN transmissive	3 panels	Projector Virtual display
Sanyo	Tokyo, Japan	Low temp poly-Si	TN transmissive	Diffraction	Projector Virtual display
Sarif	Vancouver, WA	High temp poly-Si	TN transmissive	3 panels	Projector Virtual display
Seiko-Epson	Tokyo, Japan	High temp poly-Si	TN transmissive	3 panels	Projector Virtual display
Sony	Tokyo, Japan	High temp poly-Si	TN transmissive	3 panels	Projector Virtual display

Microdisplay Technology

Most microdisplays are either transmissive or reflective, requiring a separate light source which is then modulated by the display. These displays are usually liquid-crystal (LC) based, although other technologies such as micro-mirrors or micro-mechanical diffraction are used. Individual pixels are typically controlled *via* an active matrix of transistors, implemented in either single-crystal or polycrystalline silicon, or in amorphous silicon. The high pixel density requires some level of drive-circuit integration on the display, and these drive technologies are implemented in the same process as the active matrix.

Microdisplays used for virtual-image applications may also be emissive, using electroluminescence (EL), organic EL, or field-emission technologies. These displays may also use an active matrix for pixel control. Most of these devices must be used in virtual-image applications because the brightness levels are insufficient for large-area projection.

Polysilicon (poly-Si) active-matrix LCD (AMLCD) panels are presently the main technology for projection displays, whereas single-crystal complementary metal-oxide semiconductor (CMOS) silicon AMLCDs are currently the main technology for the virtual displays. Single-crystal-silicon designs offer a few major advantages over the more traditional amorphous-Si (a-Si) and poly-Si active matrices.

First, single-crystal silicon can be used to fabricate high-quality integrated circuits (ICs) – including scanners, clocks, memory, and logic circuits – right on the display panels themselves. Therefore, the single-crystal-Si circuit can be fabricated in an IC foundry with existing equipment and processes. Single-crystal Si also yields a higher-quality pixel transistor because of much higher mobility in single-crystal Si than the poly-Si and a-Si devices. As a result, pixels can be smaller, which in turn leads to better image quality, smaller devices, and lower overall costs for these devices. The fact that more circuitry is integrated on the display periphery also leads to higher chip reliability.

Table 2B: Microdisplay Vendors Using CMOS-Based AMLCDs

Company	Location	Control	LC Mode	Color	Applications
Colorado Microdisplay	Boulder, CO	CMOS Si	NLC reflective	3 panels, Sequential	Projector Virtual display
Displaytech	Longmont, CO	CMOS Si	FLC reflective	3 panels, Sequential	Projector Virtual display
GEC	Chelmsford, UK	CMOS Si	FLC reflective	3 panels	Projector Virtual display
IBM	Yorktown Heights, NY	CMOS Si	TN reflective	3 panels	Projector Virtual display
Kopin	Taunton, MA	CMOS Si	TN transmissive	Mono, Color sequential	Virtual display
Microdisplay	San Pablo, CA	CMOS Si	TN reflective	Mono, Color sequential	Projector Virtual display
Micropix	Dunfermline, Scotland	CMOS Si, Poly-Si	FLC, TN	3 panels	Projector Virtual display
Mitsubishi	Kumamoto, Japan	CMOS Si	TN reflective	3 panels	Projector Virtual display
National Semiconductor	Santa Clara, CA	CMOS Si	PDLC reflective	3 panels	Projector Virtual display
Pioneer	Saitama, Japan	CMOS Si	TN reflective	Mono, 3 panels	Projector
Raychem	Menlo Park, CA	CMOS Si	PDLC reflective	3 panels	Projector Virtual display
Siliscape	Palo Alto, CA	CMOS Si	TN reflective	Color Sequential	Virtual display
Spatialight/ HDTV	Novato, CA	CMOS Si	TN reflective	3 panels	Projector Virtual display
S-Vision	Santa Clara, CA Twinsburg, OH	CMOS Si	TN reflective	3 panels	Projector Monitor
Thomson/ Sarnoff	Princeton, NJ	a-Si	TN transmissive	3 panels	Projector Virtual display
Three-Five Systems	Tempe, AZ	CMOS Si	TN reflective	Color Sequential	Projector Virtual display
Varitronix	Kwun Tong, Hong Kong	CMOS Si	TN reflective	Color Sequential	Projector Virtual display

Note: FLC, ferroelectric LC; NLC, nematic LC; PDLC, polymer-dispersed LC.

All but one of the single-crystal-silicon-based displays are reflective; the display circuitry and active matrices are processed on an opaque silicon wafer. The exception is Kopin Corporation's CyberDisplay, which is transmissive. The CyberDisplay uses a proprietary process to transfer the single-crystal circuit from the silicon wafer to a transparent glass substrate. The circuit operation remains unchanged, but, optically, light can pass through the display. This feature decouples the backlight from the viewing optics, making it possible to design a much simpler optical system than would be required for a reflective display.

Creating Color

When it comes to creating color images in a display panel, system designers can choose among a variety of techniques. For example, a conventional LCD panel in a notebook computer relies on spatial color filters, in which each color pixel is divided into three sub-pixels and a red, green, or blue filter is applied to each sub-pixel. Given the tiny dimensions of microdisplays, color filters are not suitable, so other approaches must be used.

For projection applications, the microdisplays tend to be monochrome – only capable of displaying one color at a time – so a common solution is to use three panels. These are illuminated by separate red, green, and blue lights, and then the three images are combined using optics to create full color – an approach similar to that used in projection cathode-ray-tube (CRT) units.

Some projectors use a single chip, and illuminate it with different colored lights. These different images are produced so quickly that the observer's brain combines them into a single full-color image; this approach is referred to as "field sequential" color. Smaller projectors based on Texas Instruments' Digital Light Processor (DLP) are one example of projectors that use field-sequential color.

For virtual-display applications, field-sequential color provides the best solution. Because the same pixel passes all three colors, this method makes most efficient use of the available light and pixels. The microdisplay panel must operate three times as fast as a panel using color filters, but the high-quality circuitry of the single-crystal panels provides the rapid response times required for such applications.

Some microdisplay panels rely on diffractive effects to create color. As with a color-

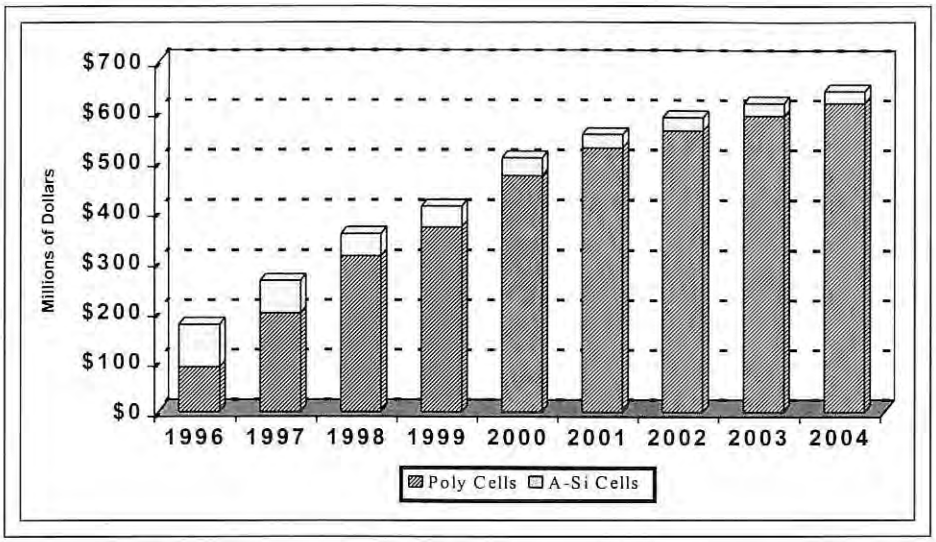

Fig. 3: *LCD-projector sales are expected to increase over the coming years. (Source: Stanford Resources, Spring 1998)*

filter design, the panel must have three subpixels – one each for red, green, and blue – which triples the required cell count compared with a monochrome panel of the same resolution. The color-separation efficiency of the diffraction approach needs to improve for better color performance, but this design does have the advantage that there is no light loss compared with the color-filter approach.

Different vendors have chosen to back different microdisplay technologies. At Kopin, we believe that CMOS-based AMLCDs offer the best technology for virtual-display applications. In addition to cost and production advantages, CMOS-based AMLCDs are well-suited for use as portable personal electronics products – such as calculators, watches, and pocket TVs – and their low-cost, low-power, and low-weight features will make them attractive microdisplays for the next generation of pocket information appliances.

Microdisplay Markets

Microdisplay technology has been available in various forms for some time, but recent advances and market trends give reason to expect that sales of these devices will grow rapidly. We expect to see many more new products introduced in 1999, along with increased competition among microdisplay vendors in both technology and marketing.

The major application for projection displays will continue to be projectors. The greatest growth potential lies in consumer products, where sales volumes are measured in the multiple millions of units. Virtual displays are well-suited for a number of consumer-product applications, including digital cameras, smart phones, videophones, PDAs, viewfinders, and head-mounted displays (HMDs).

In addition to all the competing microdisplay technologies, alternative technologies create a competitive sandwich above and below. For example, electrically controlled birefringence (ECB) twisted-nematic (TN) and supertwisted-nematic (STN) passive-matrix LCDs provide low-end choices for product designers, and poly-Si AMLCD and CRT displays stand ready to compete at the high end. In order to compete effectively, microdisplays must offer better price/performance than the other technologies. In order to compete effectively with other display technologies in these areas, it is generally believed that the price for microdisplays should be less than $50 apiece.

Currently, production capacity is available at low cost in Asian integrated-chip foundries; these are capable of fabricating chips with 0.35–1.0-μm design rules. As a result, reduced costs for microdisplays in general – and virtual-display chips in particular – may be possible in the short term.

Microdisplays offer size, power, and resolution advantages that place them in a good position to compete with other technologies. For example, direct-view ECB TN- and STN-LCDs are commonly used in mobile phones. As the need for more information content increases, virtual displays will be needed to provide users with access to e-mail, digital images, information services, videophones, and Web browsers.

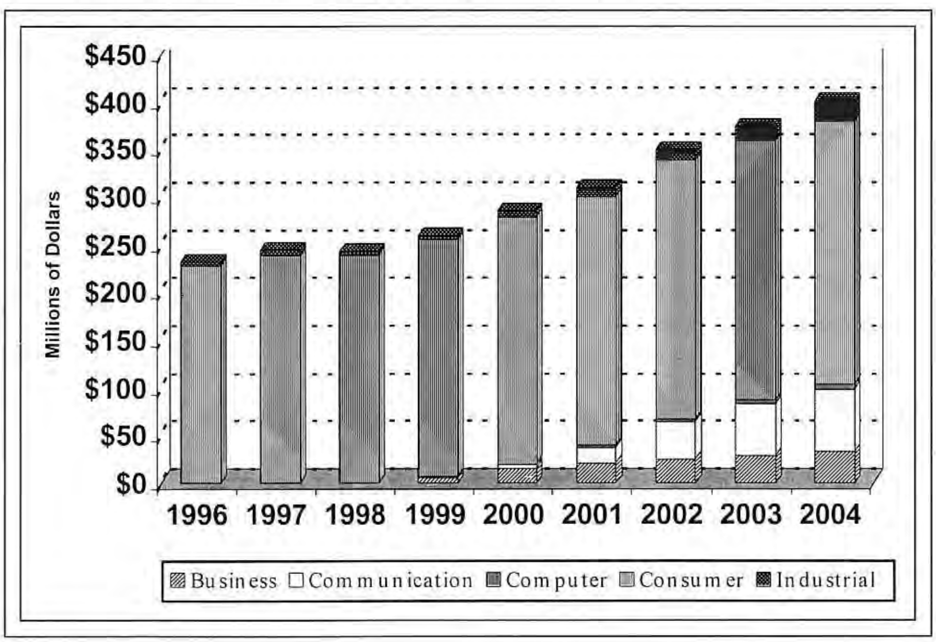

Fig. 4: *Miniature-LCD sales are now expected to increase rapidly. (Source: Stanford Resources, Spring 1998)*

Table 2C: Microdisplay Vendors Using Other Technologies

Company	Location	Control Matrix	Light Modulation/ Generation	Color	Applications
Daewoo	Seoul, Korea	PLZT (ceramic)	Actuated mirror	Color wheel 3 panels	Projector
Display Research Labs	Palo Alto, CA	CMOS	Vacuum-fluorescent phosphor	Monochrome	Virtual display
FED Corp.	Hopewell Junction, NY	CMOS Si	Organic LED	3 phosphors	Virtual display
Ise	Mie, Japan	CMOS	Vacuum-fluorescent phosphor	Monochrome	Virtual display
Microvision	Seattle, WA	CMOS Si	Microelectro-mechanical (MEM) system	3 lasers	Virtual display
Micron Display Technology	Boise, ID	Silicon	Field emission	Monochrome 3 phosphors	Virtual display
Motorola	Tempe, AZ	CMOS Si	GaAs LED matrix	Monochrome	Virtual display
Planar	Beaverton, OR	CMOS	Thin-film EL	Mono LC shutter	Virtual display
Reflection Technology	Waltham, MA	Mechanical scanner	GaAs LED array	Monochrome 3 panels	Virtual display
Silicon Light Machines	Santa Clara, CA	CMOS	Diffraction Micro-mechanical	Inherent color	Projector Virtual display
Texas Instruments	Dallas, TX	CMOS	Micro-mechanical Mirrors	Color wheel, 3 panels	Projector

Note: TFEL, thin-film electroluminescence; LED, light-emitting diode.

Virtual displays are in a good position to capture this market, as can be seen in comparing a typical STN panel with the Kopin CyberDisplay 320C LCD. Compared with the monochrome STN resolution of 32 × 100, the CyberDisplay offers 320 × 240 resolution, and in color. The direct-view STN offers up to a 3-in.^{2} image size, but the virtual image of the CyberDisplay can range from 5.4 to 10.5 in.^{2}, depending on the angle of the field of view. The CyberDisplay has a 100:1 contrast ratio – compared with 20:1 for the STN-LCD – and draws one-half to one-thirteenth as much power, with a 6–75-g weight savings.

Another potential application is as an image viewer on a digital camera. Compared with a typical 1.8-in. direct-view AMLCD panel, the CyberDisplay offers an image size 3–7 times as large, higher resolution (320 × 240 compared with 93 × 220 pixels), one-seventeenth the power draw, and one-third the weight.

In general, forecasts for the projector and virtual-display microdisplay markets are positive. According to data provided by David Mentley, Vice President of Display Research, Stanford Resources, Inc., LCD projector and microdisplay sales are expected to nearly double over the next 6 years (Figs. 3 and 4).

Microdisplay Vendors

The strong potential for the various microdisplay markets has drawn the attention of many different vendors, and competition is expected to be fierce. More than 30 vendors are participating in the microdisplay field. Some of the major microdisplay vendors are Colorado MicroDisplay, Displaytech Inc., Kopin Corp., MicroDisplay Corp., Siliscape, and Three-Five Systems. Each company has its own approach, and is aiming its technology at a specific set of applications (Tables 2A, 2B, and 2C).

At Kopin, we believe that we have taken the early lead in three important key areas: technology, manufacturing, and marketing. Kopin was the first virtual-display vendor to demonstrate the use of color-sequential techniques for color generation, and it has made many innovative technology advances in low-power, low-voltage, high-speed TFT-LCD device design and fabrication. In manufacturing, Kopin has increased its display production volume in its own U.S. production line, and has also established a high-volume TFT-LCD foundry in Taiwan. In marketing, Kopin has established important partnership agreements with a number of major vendors, including Siemens, Motorola, Gemplus, and FujiFilm Microdevices.

Small Displays Have a Big Future

With the ever increasing demands for the high-resolution portable and personal communications devices, microdisplays offer a compelling solution. Microdisplays already command the data-projector market. Personal communications products with virtual displays will become available to consumers in the near future, and these products will have tremendous appeal because they will be capable of displaying graphics information while maintaining both long battery life and low cost. It looks as though the "next big thing" may be very small indeed. ■

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editorial

continued from page 2

But I am reminded that the television remote control was invented (by Eugene Polley and Robert Adler) because Zenith founder Eugene McDonald was convinced that TV viewers would not tolerate commercials. While McDonald waited for the collapse of commercial television and its replacement with commercial-free subscription television, he believed viewers would appreciate a wireless remote for muting the sound of commercials. It took a long time, but subscription TV is here in the form of cable and satellite distribution. With picture quality eliminated as a distinguishing characteristic, which form of distribution will viewers choose? Or will they continue to choose both?

The science-fiction writer Robert Heinlein once wrote that people get the elected officials they deserve; they get people very much like themselves. We also get the television (and Internet and CD-ROM) programming we deserve; we get what we watch and pay for. As consumers, viewers, and citizens we can encourage ennobling drama, perceptive news analysis, insightful comedy, and new modes of education and information distribution.

As members of the display community, we make the box.

- KIW

We welcome your comments and suggestions. You can reach me by e-mail at kwerner@sid.org, by fax at 203/855-9769, or by phone at 203/853-7069. The contents of upcoming issues of ID are available on the ID page at the SID Web site (http://www.sid.org).

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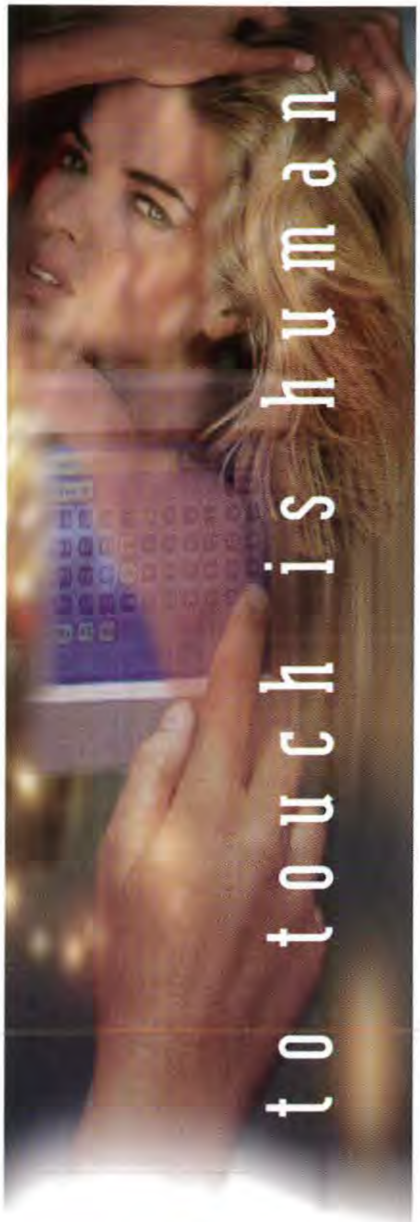

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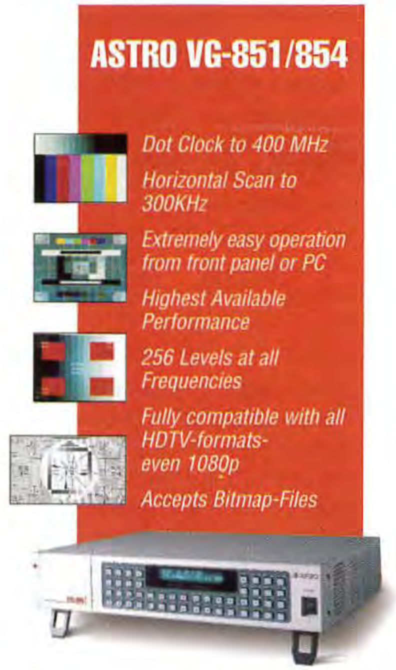

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Image Processing for Flat-Panel Displays

If FPD-based monitors are to challenge CRTs, we must have the electronics to solve the "native-format problem" – and we do.

by Ernest Yeung

NO LONGER LIMITED to just notebook computers, flat-panel displays (FPDs) are appearing in other parts of our daily lives in various forms, from plasma-display panels (PDPs) in our living rooms to liquid-crystal-display (LCD) monitors on our desktops. The fastest growing market segment for FPD products is as stand-alone screens, instead of being incorporated into a larger system (such as the screen of a medical instrument). Sophisticated electronics can produce high-quality images seamlessly from a range of different video and graphics formats, and have become the "behind-the-scenes" heroes of the FPD revolution.

In order to display different source signals, the FPD controller must master several complex tasks. If the resolution of the image is different from the panel's native resolution, the source image must be scaled up or down to fit. The timing of the source signal and the display must be synchronized, even though the clock frequencies are not as accurate as they might be. In some instances, the frame rate must be converted to the slower rates required by most FPDs. And the electronics must be able to identify the resolution and frequencies of source signals as accurately and rapidly as possible. The following provides some insight into how these problems are solved.

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Image Scaling

Video and graphics devices produce a variety of display formats and resolutions. In order to maximize the compatibility and market potential of their products, FPD manufacturers strive to support as many different resolutions as possible with the same panel. This is less of a problem with CRT-type displays because their scanning rate can be changed relatively easily. FPDs are direct-address digital devices with a fixed resolution, which creates problems when trying to display a higher- or lower-resolution image.

One early solution to displaying a low-resolution image on a high-resolution display (which is still used in some laptop computers) is to display the unscaled image surrounded by a black border, leaving a significant region of the display unused. As the resolution of current display panels increases, this method becomes less acceptable because more of the screen becomes unused and the image region becomes uncomfortably small. A more acceptable solution is to scale, or resize, the image to the full resolution of the display panel, using a real-time image scaler.

Primitive image scalers simply replicate input pixels to create a larger image when displaying a lower-resolution image, or discard pixels to reduce the image size of higher-resolution images. Slightly more complex systems interpolate between pixels to smooth the output image. These systems do not offer satisfactory results, and phase sensitivity is the most prominent problem. Depending on the sampling phase at a given location on the display, certain pixels are processed by the image scaler while others are ignored. This discrimination causes distortion in the output image – lines of identical thickness in the original image appear to be of different thickness in the scaled result. This can distort text and make it difficult to read, while curved lines often take on a jagged edge.

An enlarged photograph of an LCD monitor with an inferior image scaler, displaying text and graphics scaled from 800 × 600 (SVGA) to 1024 × 768 (XGA), shows that the vertical and horizontal lines at the edge of the image do not appear to have the same thickness, though they are supposed to be the same. The text also suffers from random distortion, making it hard to read [Fig. 1(a)]. Consumers who pay a premium price for LCD monitors and other FPD products expect nothing less than exceptional image quality on their displays. Mediocre image scalers render the scaled output of an FPD system inferior to even low-end CRT systems, making them unattractive to the consumer.

High-quality image scalers employ sophisticated digital-signal-processing (DSP) techniques and algorithms. The exact implementation of these scalers is usually proprietary and the product of cutting-edge research. These scalers ensure that the resampled output image closely resembles the input and remains free of undesirable artifacts and distortion. Note that when the same source material as in the prior example is scaled and displayed on an LCD monitor which employs a high-quality image scaler, the lines are not distorted and

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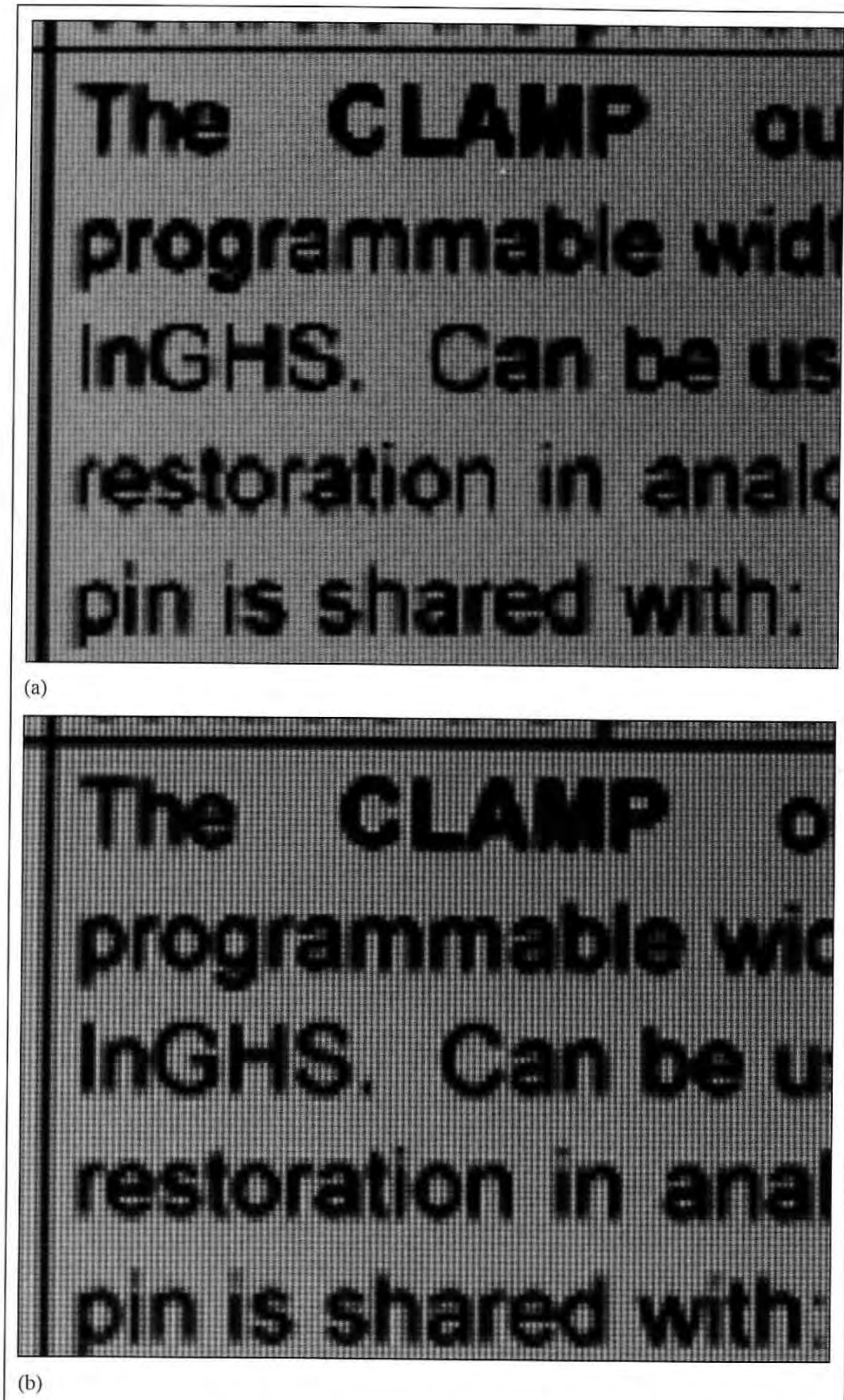

Ernest Yeung

Fig. 1: *These magnified views of an 800 × 600 image scaled up to a 1024 × 768 panel show the difference between (a) inferior and (b) high-quality image-scaler technology.*

the text is sharp and easier to read [Fig. 1(b)]. Simple image scalers can be implemented in programmable logic chips, but high-quality image scalers are generally available as application-specific integrated circuits (ASICs) due to their high complexity.

Aspect-ratio conversion – particularly for plasma screens – is another application of scaling technology. Many display panels intended for home-entertainment applications have an aspect ratio of 16:9 in order to accommodate both wide-screen movies and possible future HDTV broadcast images. The overwhelming amount of video material available to consumers today – from television broadcasts to movies on videotapes – is formatted in the 4:3 (12:9) ratio. Without aspect-ratio conversion, either the top and bottom parts of the image must be cropped off (similar to pan and scan) or black borders must be shown on the left and right sides of the screen (similar to letterboxing). Neither of these approaches represents a satisfactory solution because one discards image data and the other leaves a significant portion of the screen unused. Furthermore, either technique would further extend the "pan-and-scan *vs.* letterbox" debate raging in the consumer-video market today. The best solution would take maximum advantage of wide-screen displays with current video material, which can be accomplished by "stretching" the image horizontally to fill the entire screen.

A simple way to alter aspect ratio is to magnify the video image by a larger amount horizontally than vertically. The resulting image would look squeezed, however, and less pleasing to the eye. A more advanced technique relies on non-linear scaling. Because the region of interest in most video material is at the center of the image, scaling should not be applied to this area to ensure that it remains distortion-free. At a predetermined horizontal distance from the center, a small amount of horizontal magnification is applied to the image. The magnification ratio is gradually increased towards the sides of the original image. Although this process is non-linear, the result is pleasing and natural because it preserves all the content of the original source image while still filling the entire screen (Fig. 2).

Display Synchronization

If the input and display images differ in reso-

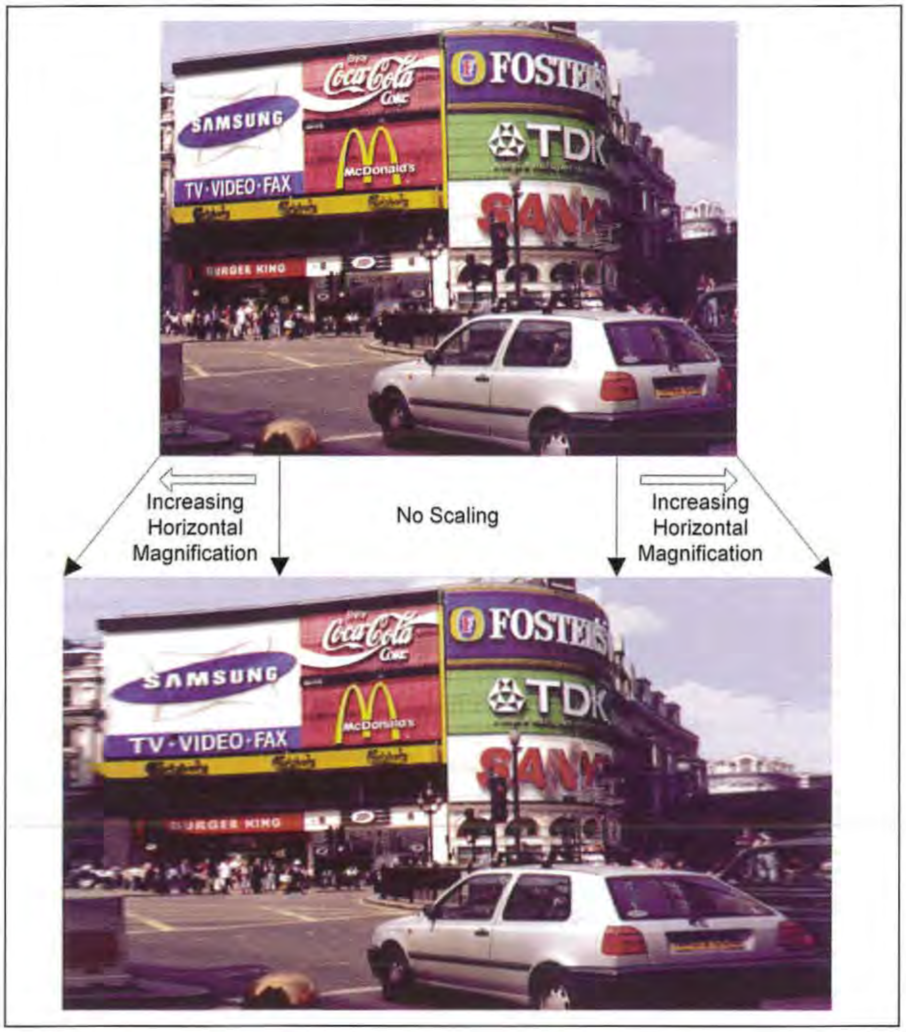

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Fig. 2: Non-linear aspect-ratio conversion makes it possible to scale traditional 4:3 images to the new wider 16:9 format by expanding the outer edges of the image and leaving the center region unchanged.

lution, two separate clocks are needed in order to accommodate the different amounts of image data. Since the clock frequencies are generally not accurate, the input and display images will drift away from each other as time goes by and the display image will be corrupted. Hence, a mechanism is needed to ensure that the input and display images are synchronized with each other. At this point in the process, the input frame rate equals the output frame rate, so a synchronized system means one input frame must result in exactly one display frame.

A common display-synchronization technique employs a ***lock event.*** This event is a pre-programmed point in the input region. When this point is reached, the system forces the output display to return to a specific point in the output region, usually to the beginning of a display frame. The lock event is determined by a combination of various factors, such as the input format, the system latency, and the capacity of the image-scaling memory buffer (required by most high-quality image scalers).

This display-synchronization mechanism continually forces the output display image to be in lockstep with the input video to guard against any variation in clock frequency and clock jitters.

Other display-synchronization methods exist, some of which are available only to FPDs. For example, the total number of clock cycles in a line is not critical for FPD applications, so a ***line-lock*** technique is often used; this technique is a proprietary technology for which a patent has been applied. The issue of display synchronization is often overlooked, and its correct implementation is crucial for a reliable display system.

Frame-Rate Conversion

Most FPDs today support a screen refresh rate up to 60 Hz. While this is not a problem for video signals – NTSC runs at 59.94 Hz, while PAL runs at 50 Hz – graphics controllers for computers and workstations can generate output at 85 Hz or faster. The frame rate of the graphics signal must be reduced to accommodate the slower FPD. On the other hand, it might be necessary to display a slow input signal on a fast FPD, which would require speeding up the signal's frame rate. To accommodate source material with different frame rates, many display systems incorporate a frame-rate converter.

A frame buffer with independent write and read clocks can be used as a simple frame-rate converter. The graphics data can be written into the frame buffer at the input frame rate, continuously updating the buffer memory with new images. At the same time, data is read out of the buffer memory and displayed at the output frame rate. This implementation is inexpensive and simple and is used in desktop LCD monitors, as well as in many systems. Here, some output frames may consist of image data from more than one input frame, a condition known as ***frame tearing.***

Frame tearing sounds worse than it looks and is generally unnoticeable when displaying computer graphics or video sources with little motion between frames. In order to prevent frame tearing, a frame buffer with memory capacity for two frames can be used. While one buffer is being updated with input data, the data in the other buffer is read out and displayed. Careful management of the read and write memory access pointers will ensure that they never cross each other, and frame tearing does not occur. This technique is known as ***double buffering,*** and it adds only minimal cost overhead, especially when the pointer management is already implemented in an ASIC.

For high-end video displays, ***temporal filtering*** – filtering many input frames to gener-

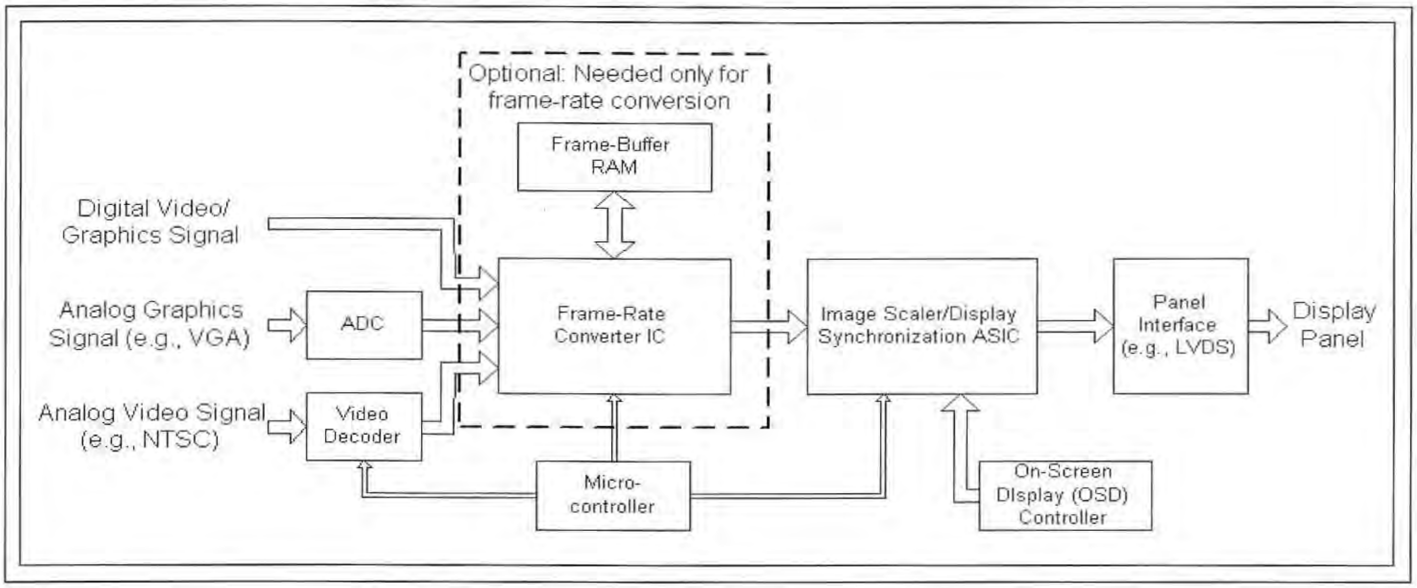

Fig. 3: An image scaler is one key component of a controller for an FPD system.

ate an output frame - may be performed to eliminate the effect of frame tearing. For most video systems, the cost and complexity of temporal filtering does not justify the marginal increase in quality.

Format Detection

A buzzword in the consumer technology market is "plug-and-play," highlighting the consumer's unwillingness to fumble with a system for hours before getting it to work. When a new video source is connected to an FPD system, consumers expect the system to detect the format of the incoming signal and reconfigure itself automatically. Unfortunately, there are many different video and graphics formats, and the problems are made more difficult by the large number of non-standard permutations that exist for the various formats. Fortunately, the image signal formats can be detected with ease, using a bit of ingenuity.

Video-signal frame rates are easy to detect because the vertical synchronization (VSYNC) signal present in most video systems occurs exactly once per frame. The frame-rate information itself is often unimportant because in most cases the frame-rate converter would convert the input frame rate to one which is more appropriate for the display panel. A more challenging issue is to locate the active region of a video signal - the image itself. The active region is surrounded by a blanking region that should not be displayed. Since the blanking region often contains black image data and the active region usually contains non-black image data, a generally accepted method of ***active detection*** is to simply examine the image data. This simple method works surprisingly well, and its reliability can be improved if a non-black test image can be provided to the system.

The detection of the incoming video signal is useful for other reasons, such as the configuration of video decoders and analog-to-digital converters, or support for automatic power-down features. The detection itself is usually performed using a hybrid hardware/firmware solution. The hardware is needed to process the high-speed image data and to provide "hooks" so the system microcontroller can have access to the pixel data. The microcontroller firmware provides the flexibility needed to cope with new formats and to handle infrequent computations that are more cost-effectively performed in firmware. For example, when a display system is powered on, certain internal clock phase adjustments have to be made. The FPD controller can provide the microcontroller with access to the pixel data, and an algorithm in the microcontroller firmware can analyze the pixel data to determine the optimal phase setting.

System Overview

An FPD controller must be designed to handle all these tasks (Fig. 3). The controller may have to accept graphics and video signals in both analog and digital formats. Analog signals are digitized by a video decoder or multiple analog-to-digital converters, while digital signals can be processed directly. If needed, a frame-rate-converter ASIC (with its companion frame-buffer memory) can provide the display panel with the required frame rate. The heart of the system is an image-scaler and display-synchronization ASIC, which scales the source material to fit the display panel and ensures that the proper synchronization is always achieved. If desired, an on-screen-display (OSD) controller can be added, providing a convenient user interface for display-system configuration. The image data is finally transmitted to the display panel *via* a panel interface. The system can be highly integrated, and its cost can be surprisingly low.

The Big Picture

There has been extraordinary progress made in FPD technology. The display panels today are bright, sharp, and power-efficient, and they are fast becoming cost-effective alternatives for many applications that were traditionally handled by other display technologies. Credit for this success must be shared with the advances made in the electronics that drive these FPDs. Working together, the high-quality display panels and sophisticated controlling electronics create the excellent images that drive the FPD revolution. ■

The Military Display Dilemma

The U.S. military can no longer use CRTs, and cannot afford to acquire LCDs – unless it substantially modifies its "corporate culture."

by Kenneth E. Sola

THE U.S. MILITARY can no longer use CRTs as primary displays on its platforms. The burdens of CRT weight, bulk, power demand, and heat generation, tolerated for so long, have been increasing with display size. The continued availability - and the rising cost - of CRT-display replacements has become a serious issue. The problem is already critical on the Air Force E-3 AWACS and Navy S-3B Subhunter aircraft.

Perhaps a more ominous problem is the reduction in airframe life caused by carrying the excessive weight loads of CRTs. The U.S. Navy EP-3E Electronic Intelligence (ELINT) aircraft carries 1377 lbs. of fully militarized CRTs on its missions (Fig. 1). (Some of these CRTs weigh 165 lbs. each.) This aircraft is already overweight to the point where non-mission-critical equipment, such as bunks and galley tables, is being removed. Airframe life is being reduced to a critical point on this aircraft because of the display load, since gross take-off weight, total flight hours, and flight in turbulent weather (which is common for the EP-3E) are major contributors to wing and airframe fatigue.

Susceptibility to electromagnetic interference (EMI) and reliability are also CRT problems. But perhaps the most pressing reason for the military to replace CRT displays on its ships, submarines, aircraft, and ground vehicles is the mounting pressure to convert to flat-panel displays (FPDs). This persistent siren call is becoming so loud that it can no longer be ignored.

But can the military afford FPDs? The answer may be no. Price is not the primary issue. (It rarely is with the military, and FPD technology is rapidly becoming cost-competitive with CRTs.) The determining factor is performance. If FPDs are to replace CRTs as the primary visual display on military platforms, FPD performance must be equivalent to that of CRTs.

Until automatic-target-recognition systems are mature enough to replace human operators, military visual displays must enhance or maintain - and certainly not degrade - the military operator's ability to detect, identify, track, and successfully engage targets. It would appear that at least one type of FPD - the liquid-crystal display (LCD) - is ready for military prime time. Are these LCDs mature

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Fig. 1: The U.S. Navy EP-3E Electronic Intelligence (ELINT) aircraft caries 1377 lbs. of CRTs, and will soon be replacing many of them with LCDs.

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enough to support military missions? Can they provide the resolution, information-coding capability (especially color), brightness, dimmability, response time, and overall range and flexibility of the venerable CRT? Can LCDs be gracefully integrated with software suites that produce on-screen displays carefully optimized for the current spectrum of CRT phosphors and drivers? Are the estimates of LCD reliability valid? What about the dependability of long-term supply - a critical military acquisition issue. (As this is written, there are indications that one of the two remaining onshore suppliers of military LCDs is in serious financial difficulty, and this follows the demise of two other suppliers over the last year or so.) What risks do we incur by a lemming-like stampede to FPDs?

These and other questions were answered in a recently completed evaluation of LCDs conducted at the Naval Air Warfare Center, Aircraft Division (NAWCAD), Patuxent River, Maryland.[1]

Can LCDs Perform? A Benchmark Study

Early in 1998, the U.S. Navy decided that one type of large-area high-resolution LCD technology was ready for a closer look. This was the highly touted NEC 2000 glass from Nippon Electric Corporation (NEC). Using a unique form of in-plane crystal switching, this display solved the limited off-axis viewing problem so bothersome with earlier LCDs. Although the pixel dimensions, 1280 × 1024, are the same as those of current 19-in. CRTs, the NEC 2000's fully addressable 20.1-in.-diagonal size and roughly 200-in.^{2} surface increases the total display area by approximately 30% over the 19-in. CRT. We at Patuxent River evaluated this panel as integrated by seven suppliers. The LCD evaluation focused on the applicability of NEC 2000 LCD glass to the military crewstation. The government labs used military sensor inputs, 37 military operators as test subjects, and replicated, as much as possible, fleet operational conditions during testing. Testing included signal detection and target identification in active and passive acoustics (Fig. 2), three forms of radar video [surface surveillance, synthetic aperture radar (SAR), and inverse synthetic aperture radar (ISAR)], and electro-optical video.

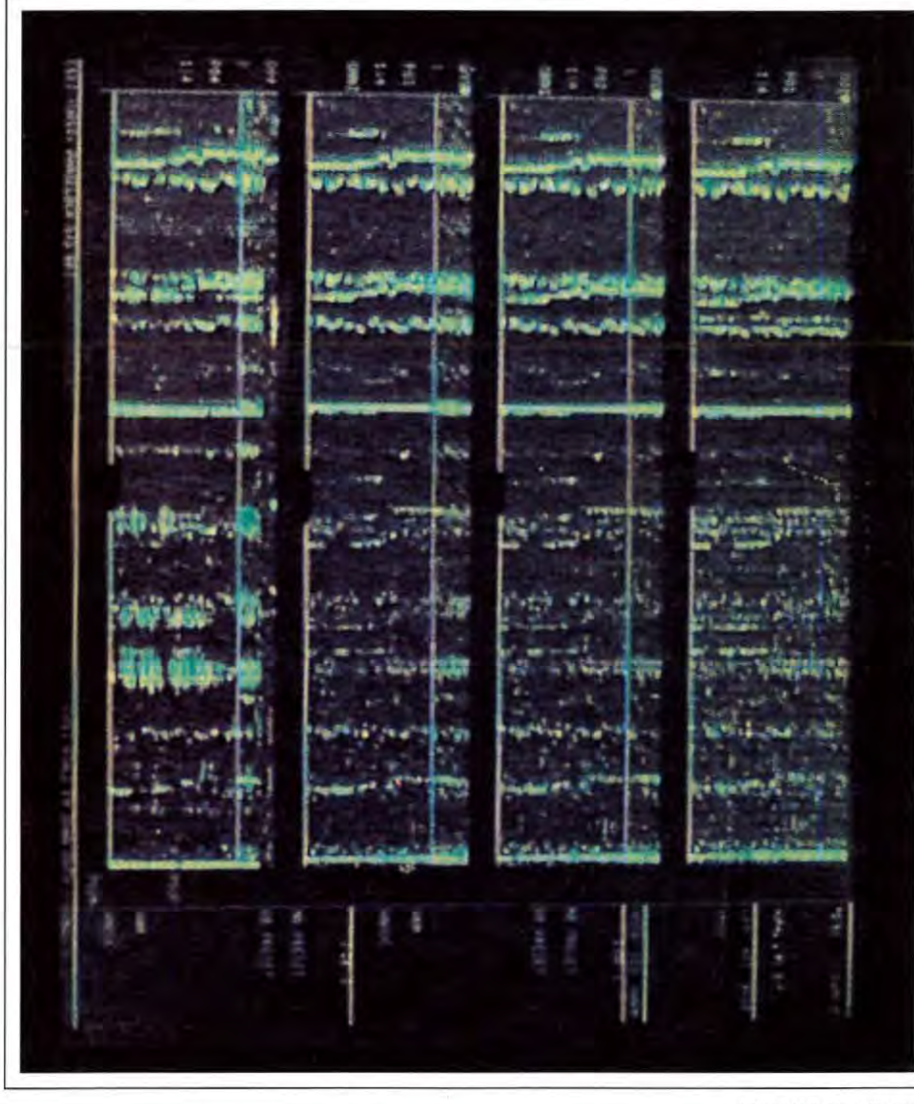

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Fig. 2: A passive acoustic sensor display in Navy LCD evaluation.

The video capability of NEC 2000 LCD glass was of special interest in this testing, since questions regarding video capabilities had already been raised. (Tom Holzel eloquently expressed these concerns in the March 1997 issue of *Information Display*.[2]) To clearly isolate the differences in video performance between CRTs and the NEC 2000 LCD glass, live and videotaped sensor videos were supplemented with generated video test patterns during testing (Fig. 3). These generated patterns were presented dynamically: they rotated, moved across the screen, and rapidly changed resolution, and the checkerboard patterns underwent reversal of their contrast levels. These patterns clearly demonstrated operationally significant differences between the CRTs and LCDs in the "'dynamic' contrast ratio" discussed by Holzel.

Some units were subjected to cold-soak testing at 50°F, and all units were evaluated in the photometrics laboratory for luminance, off-axis viewing, color gamut, and other parameters (Fig. 4). Because the goal of the study was to determine if these LCDs could replace the color CRTs currently in the crewstations, all testing was conducted in a comparative mode. The test subjects continuously compared each LCD submitted for testing against high-performance CRTs in a completely controlled evaluation designed by experimental psychologists familiar with the military missions (Fig. 5).

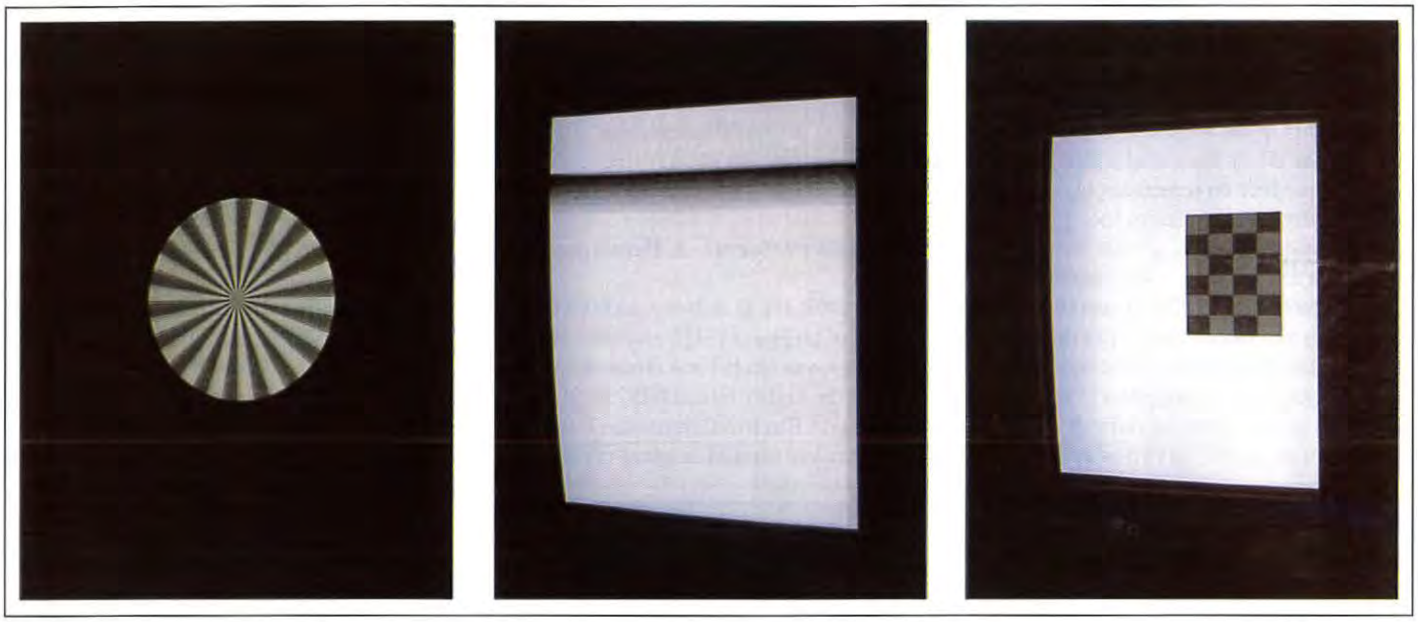

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Fig. 3: Three of the generated test patterns used to isolate differences in CRT and LCD video performance.

The original plan was to test only a small sample of the display industry's integrations of NEC 2000 glass; the plan changed. Seven suppliers offered units for evaluation: Aydin, BARCO, Codar, GTE, L3 Communications, Raytheon, and Tech Electronics. Some units were configured with EMI shielding consisting of either metal mesh or grounded indium tin oxide. Most were not EMI-shielded.

There was a wide range of performance and operator preference among these units, despite the fact that all used the same LCD glass. The final report, in which the suppliers' identities are coded, contains the full details and results of this LCD evaluation.[1] A summary of the results, negative and positive, is provided here.

Negative results. Smearing of rapidly moving video images was evident. Waterfall acoustic gram blink (flicker at dense variable-intensity screen updates) occurred on all units. (BARCO has since solved this problem.) High backlight levels and backlight non-uniformity were common. Display control suites varied widely; some were unacceptable.

Positive results. There was extraordinary industry response in reviewing the test plan, suggesting differentiators, offering units for evaluation, and responding to the problems noted. Off-axis viewing was not a problem with NEC 2000 glass. The LCD received high scores from the operators/evaluators in many of the tests, and scored higher than the CRT in character clarity and some forms of radar video.

On balance, NEC 2000 glass – as offered by some suppliers, properly driven, and properly integrated into the military-platform display systems – was indeed qualified to replace on-board CRTs. Based on these findings, the Navy proceeded immediately to draft a perfor-

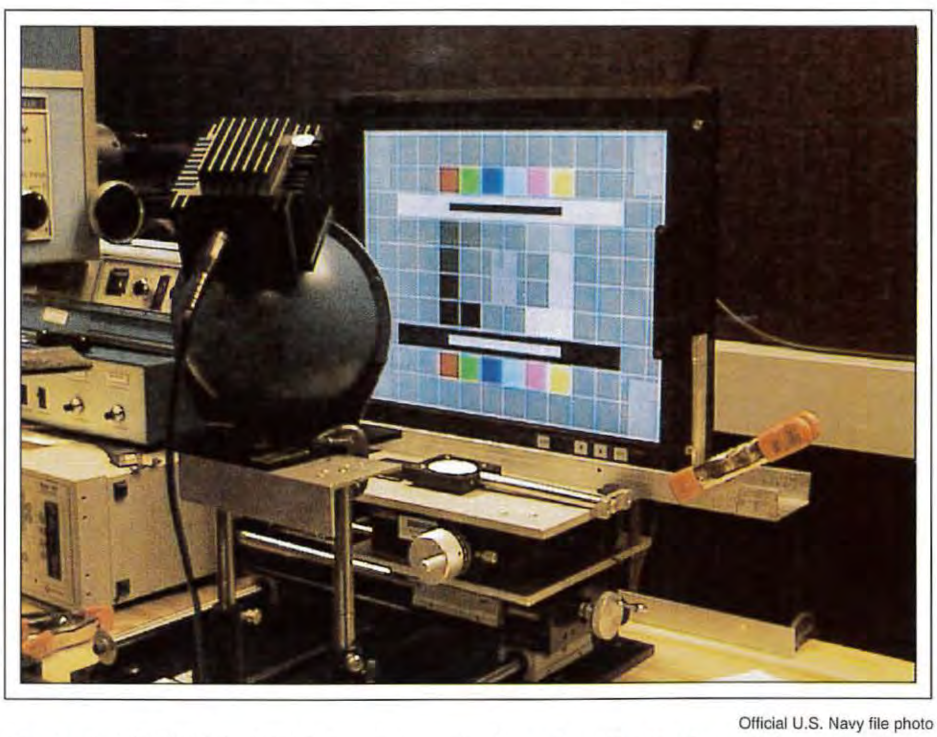

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Fig. 4: An NEC 20.1-in. LCD being photometrically evaluated at the Navy's laboratories in Patuxent River, Maryland.

Official U.S. Navy file photo

Fig. 5: LCDs and CRTs were tested side by side in the Navy's LCD evaluation. This phase of the testing compared the electro-optical sensor output.

mance-based display specification and to initiate an acquisition program to replace CRTs at the tactical crewstations in many of its large aircraft, including the EP-3E aircraft. Integration of these displays into these platforms is planned for the very near future.

The Military Can't Afford FPDs

If LCD deployment in large Navy aircraft is now proceeding rapidly, why is the military "stymied" and perhaps unable to afford FPDs? Quite simply, it is because display technology evolves rapidly, but military attitudes and acquisition practices are inclined to change at a glacial rate. As a result, the military really cannot afford FPDs - not until it radically changes many of its attitudes.

The military community is very much like the rest of us, who, when moving, carry junk from one house to the next. There is a great deal of inflexibility in specifying and procuring systems. We insist on having all that we currently have - even though much of it is bad - as well as having all of the best of what's new.

We have not fully embraced the concept of commercial off-the-shelf (COTS) equipment. We sometimes insist on unrealistic durability and longevity - even when the longevity of rapidly evolving systems is a clear and absolute negative (as in computers, for example). But most important of all, we cannot cooperate among ourselves.

There are currently dozens of ongoing military display acquisitions throughout the Services. There is little or no collaboration - or even sharing of information - between the programs. We bought unwisely throughout the halcyon years of the military - *i.e.*, before the dissolution of the Soviet Union - and we have not yet faced up to the new realities. Our house is cluttered and inefficient. It is time to clean that house.

Sadly, although the plan for that housecleaning lies clearly before us, it is not being executed. We simply have to do the following:

- Begin effective inter- and intra-Service collaboration.
- Accept the utility (and inevitability) of COTS.
- Radically revise our specification of system "requirements."
- Accept the logic of "engineering tradeoffs" completely.
- Adapt our minds and our missions to the best, most cost-effective solutions.
- Increase our emphasis on the Integrated Product Team (IPT) concept in cooperation with the display industry.

Admiral N. Gorschkov, former Admiral of the Soviet Fleet, once restated a very popular cliché: "'Better' is the worst enemy of 'good enough'." If we systematically apply this to military display acquisition, we arrive at the following:

- CRTs are not "good enough" (*i.e.*, we can no longer accept them). Therefore, something "better" is required.
- Among the flat-panel technologies, LCDs are better - and good enough right now to replace CRTs, with some compensations and workarounds.
- However, our disjointed and over-specified acquisition processes are not "good enough." We must improve them.
- But we are not yet capable of making the changes in attitude necessary to update our acquisitions to be in tune with the *Zeitgeist*, the realities of our current world.

We are faced with these final truths. The military cannot accept CRTs. Neither can the military afford to acquire FPDs, given current acquisition practices. Finally, the military cannot continue to procrastinate in solving this dilemma.

References

[1]Ken Sola, Karen Garner, and Mike Mikulewicz, "The Liquid Crystal Display (LCD) Evaluation," U.S. Navy Technical Report, Report No. NAWCADPAX-98-79-TR, 9 July-11 September 1998.

[2]Tom Holzel, "The Emperor and His Flat Panel Displays," Guest Editorial in *Information Display* **13**/3, 3 (March 1997). ■

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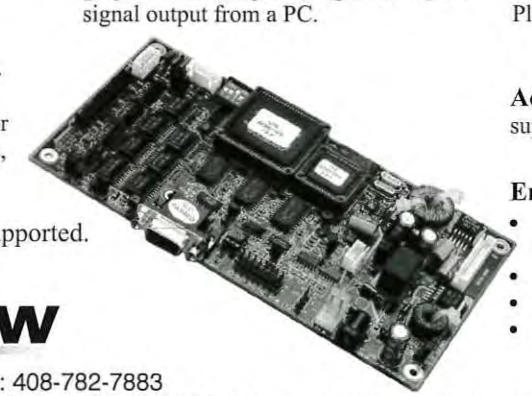

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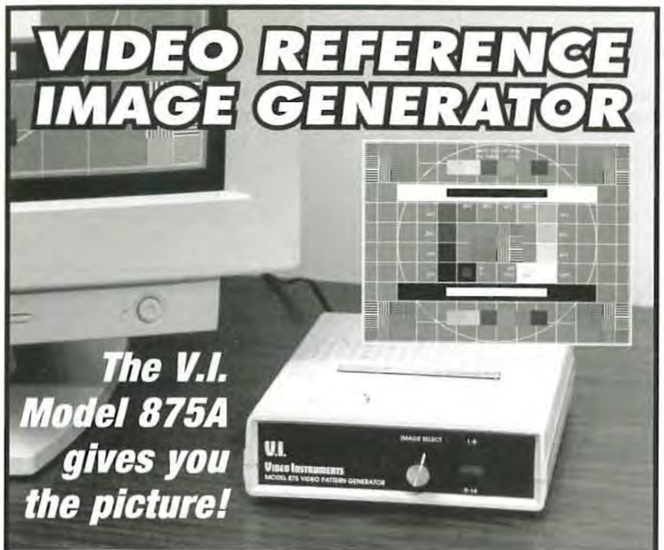

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Is the Measurement of Front-Projector Characteristics an Impossible Task?

A lot goes on between the projection lens and the eye that projector manufacturers can't control, but it is possible to make accurate front-projection-display measurements in stray-light conditions – if we're careful. This is the third in a series of articles from NIST.

by Paul A. Boynton and Edward F. Kelley

SPECIFICATIONS of electronic projection displays such as contrast ratio are often based on measurements made in ideal darkroom conditions. But everyone does not have access to a facility that provides such conditions. Stray light from sources in the room, both direct and reflected off surfaces such as walls and tables, as well as back-reflections, contribute to the measured value and give an inaccurate indication of the projector's light output. So how can we verify that the projector that we have purchased is operating according to its specifications?

Leveling the Playing Field

When measuring front-projection displays – those in which the screen is not an integral part of the system – the goal is to establish the intrinsic characteristics of the projector, independent of the screen and viewing room. This allows for a more accurate comparison of the display quality of different projectors. Minimizing the effects of ambient light achieves "a level playing field."

What we see in a typical front-projection environment is more than simply the performance of the projector (Fig. 1). In a typical user environment, a projector is set up and an image is projected onto a screen. The observed quality, however, depends not only on the projector performance, but also on the reflective properties of the screen and the surrounding environment, as well as any ambient-light sources.

If we wish to quantify what the viewer observes, then we must account for the stray light falling upon the screen and for screen gain. These are not trivial tasks, and because the environment affects the displayed image they do not necessarily provide useful infor-

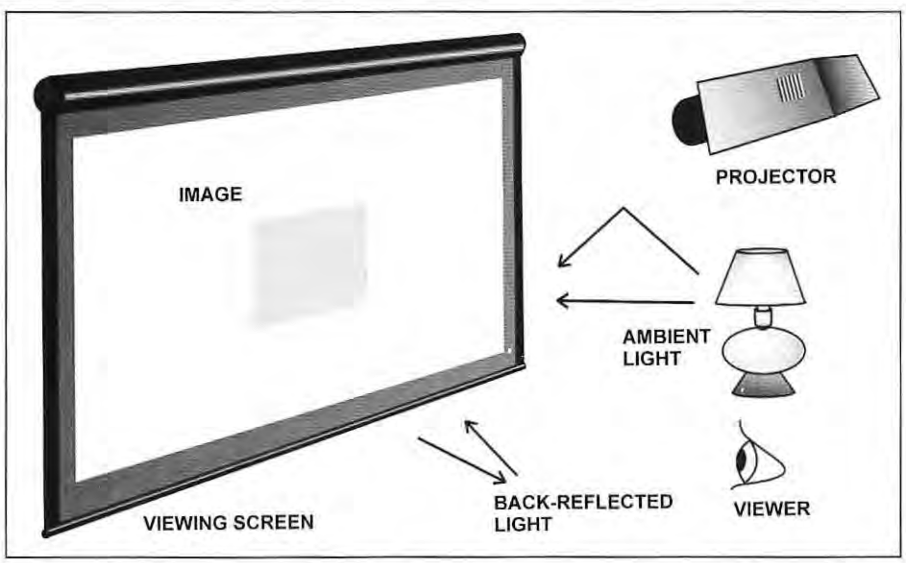

Fig. 1: The quality of the image we see in a typical front-projection environment depends not only on the projector performance, but also on the reflective properties of the screen and the surrounding environment, as well as any ambient-light sources.

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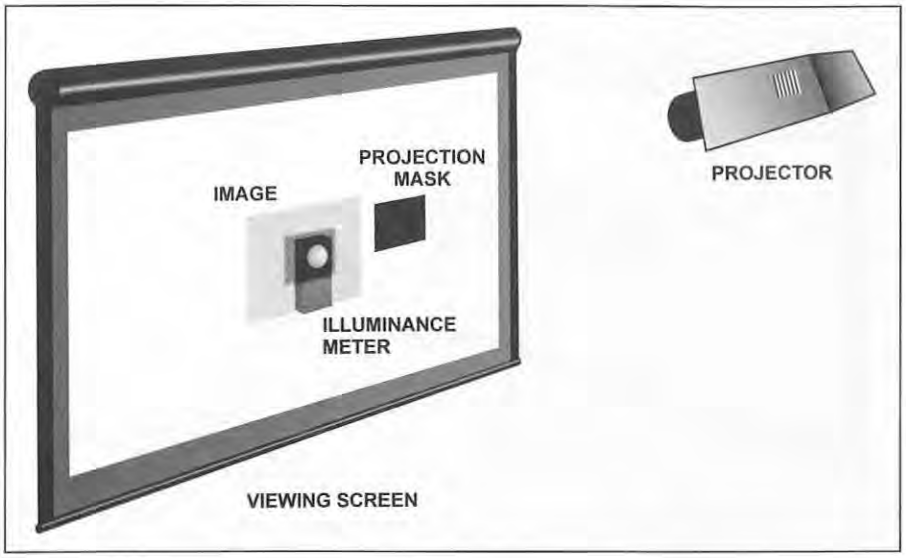

Fig. 2: *By using a black projection mask to eclipse the projected light, an illuminance meter will indicate the approximate amount of stray light illuminating the detector.*

mation about whether a particular display performs according to specifications or how it compares with other displays. Use of a black screen would reduce back-reflections, but we might still need to contend with other stray-light sources. The use of a simple black mask - called a projection mask - will provide us with the compensation we need to assess our display without corruption from stray light.

Using a Projection Mask

Let's assume we want to measure the luminance of a black rectangle on a white background, with the black rectangle being 25% of the screen size, based on diagonal measure (Fig. 2). The light output at the center of the rectangle in the image plane of the screen is measured with an illuminance meter. This measurement includes contributions from any stray light. Next, a black mask is placed less than 1 m away from the screen such that the projected light striking the screen and the illuminance meter is eclipsed. With this projection mask in place, the illuminance meter, placed in the image plane of the screen, will provide a reading that indicates the approximate amount of stray light illuminating the detector. By subtracting this value from the first measurement, a more accurate value of the black luminance of the projected image is obtained.

The size and distance of the projection mask can have a substantial effect. For our tests, the optimum distance of the mask from the projection screen was between 30 and 50 cm, but this can depend upon the room and projector configuration. If the projection mask is placed too near the screen, it will obscure some of the reflected light. If too far away, the diffraction around the mask and forward scattering by dust particles in the air may contribute to the measurement. To be safe, the projection-mask size is kept no smaller than the diameter of the projection lens to ensure that the projector is effectively eclipsed. Of course, the mask must be larger than the measurement area.

The projection mask can be mounted on a floor stand with rods, suspended from the ceiling with string, or by any other suitable means. Whatever method is employed, the mask must be held steady and parallel to the image plane. If a stand is used, it should be covered with black felt to minimize reflections that would interfere with the measurements.

Stray-Light-Elimination Tube

A second, more complex approach involves using a series of glossy black cones inside a glossy black tube (Fig. 3). The projected light enters one end of the tube, which has a 15-cm inner diameter. An illuminance meter is placed at the other end of the tube, 61 cm away. Four cones are placed in opposing pairs, while a shallow fifth cone surrounds the meter. The apex angle of the cones should be 90°, *i.e.,* 45° on each side of the symmetry axis of the cone.

The projected image is focused onto the meter. Any stray light entering the tube will be reflected away from the detector surface by the cones; hence the name, stray-light-elimination tube (SLET). For extreme conditions, such as a room with overhead lights switched on, this method is preferred because it eliminates a great deal of stray light. Using the SLET, we have obtained the same results (within 1%) with room lights either on or off. The SLET is still in its evaluation stage but was used to verify the projection-mask method for this article.

Halation and Contrast

To demonstrate the effectiveness of these methods, as well as to indicate the seriousness of back-reflections, we projected a series of halation images - a black rectangle on a white background - onto a white screen using a liquid-crystal-display (LCD) projector with a metal-halide lamp. The laboratory walls, ceiling, floor, furniture, and equipment were painted flat black, covered with black felt, or manufactured with black material.

The black rectangle was varied from 5 to 100% of screen size (linear size based upon the screen diagonal), and the black-luminance level was measured and plotted against rectangle size. The black-luminance level decreases with increasing rectangle size (Fig. 4), but the level varies less dramatically if back-reflections are taken into account. The SLET and the projection-mask methods produce similar results.

Halation refers to light from bright areas of an image leaking into dark areas. An example would be the internal reflections between the front glass of a cathode-ray-tube (CRT) display and the phosphor surface. The increase in the black luminance with decreasing box size after making corrections for stray light is probably due to the veiling glare from the projection lens. (Veiling glare is a result of light scattering and reflecting at lens surfaces, at imperfections in the glass, at soiled areas on the glass, and at the barrel and other mechanical parts of the lens.)

Another common projection-display measurement is the contrast ratio of a 4 × 4 checkerboard pattern at 16 points (Fig. 5).[1,2] The illuminance at the center of each rectangle is measured, and the average of the white levels divided by the average of the black levels gives one measure of contrast. Our results show a 34% improvement in the contrast measurement when using the projection-mask method.

What About Luminance Measurements?

So far, we have only discussed measurements using an illuminance meter. Using a luminance meter poses a more difficult problem because we must now consider the reflective properties of the screen and the veiling glare of the light-measuring-device (LMD) lens (Fig. 6). Many screens direct or "shape" most of the projected light back in the direction of the viewer more than a perfectly white Lambertian surface would. Such shaping is called "screen gain" and can been defined as the ratio of the luminance of the screen at a specific point (usually center screen) to the luminance of a Lambertian diffuser placed at the same point on the screen.

However, when considering stray light, we must realize that the screen's reflective properties are rather complicated. The reflected light measured from the screen depends upon the incident angle of the various light sources (such as the projector, room lights, and reflections), the viewing angle of the measurement, and the reflection properties of the screen surface. [A general way to express this reflection is through the bidirectional reflectance distribution function (BRDF), a rather complex measurement.[3]]

Ideally, we can avoid the screen issue altogether. Using a nearly perfectly white Lambertian standard at each measurement point in the image plane would provide an accurate measurement unaffected by screen gain. Thus, measuring the luminance of the white standard with and without the projection mask, and taking the difference, will provide us with a measurement point corrected for reflections. Because the surface is Lambertian, the angle of measurement can be slightly off-axis with negligible error.

We can take advantage of the diffuser's properties to convert from a luminance measurement (in cd/m^2) to illuminance measure-

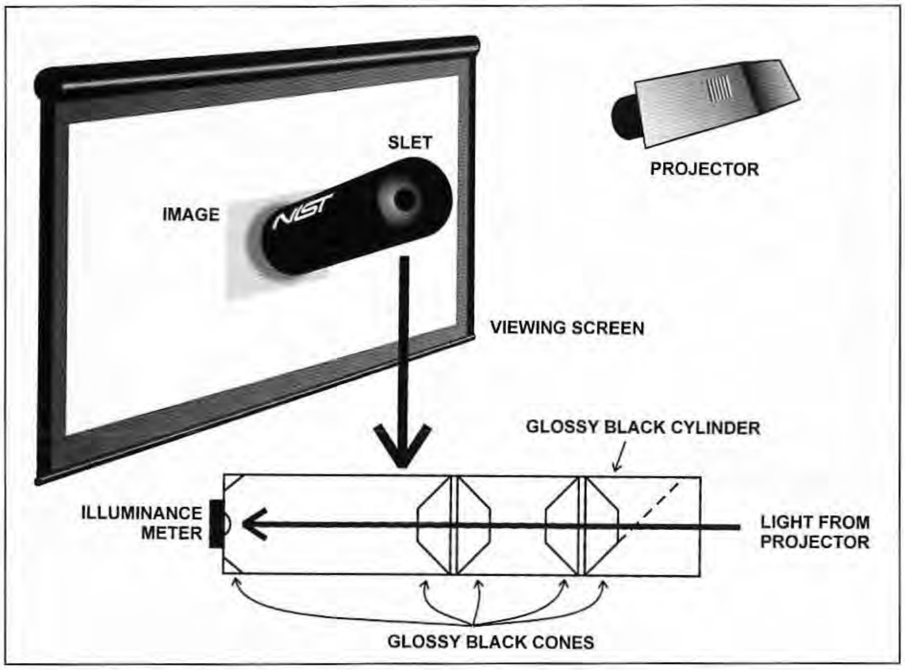

Fig. 3: A stray-light-elimination tube (SLET) is a more complicated device than a projection mask. But for extreme conditions, such as a room with overhead lights switched on, this method is preferred because it eliminates a great deal of stray light.

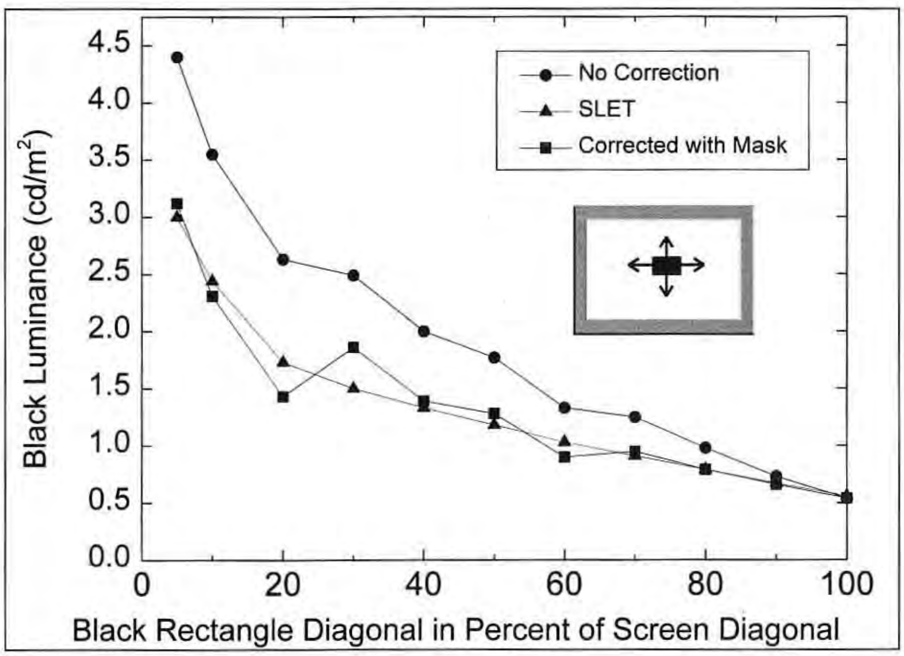

Fig. 4: As the size of the black rectangle in a series of halation images increases from 5 to 100%, the black-luminance level appears to decrease, but the level varies less dramatically if back-reflections are taken into account. The SLET and the projection-mask methods produce similar results.

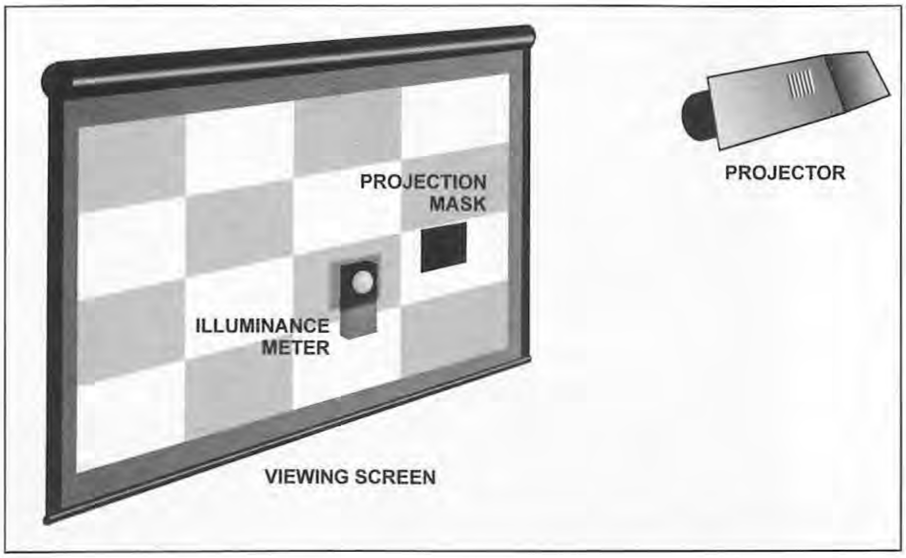

Fig. 5: Using a projection mask produced a 34% improvement in a contrast measurement made in our laboratory.

ments (in lm/m^2, or lux). By using the simple relationship $L = (\rho/\pi)E = qE$, where ρ is the fraction of light reflected from the surface (luminance factor), and $q = \rho/\pi$ is called the luminance coefficient. This equation is only valid for a Lambertian reflector. Materials with $\rho \geq 99\%$ can be obtained.

Because we are subtracting two measurements with the same surrounding background, any veiling-glare contribution from the LMD lens will cancel out. However, if we wish to make an absolute measurement with stray light included, then some technique must be employed to minimize this glare. We can accomplish this using a black cone mask with an apex of 45°.

The cone mask is placed in front of the LMD such that the outer (larger) diameter faces the LMD and prevents any light from the display from reaching the LMD lens. The inner diameter (aperture) should be small enough to keep out stray light but large enough to prevent vignetting between the LMD aperture and the aperture of the cone. This cone mask has been used to improve the measurement of black luminance of direct-view transmissive displays by reducing the effect of veiling glare in the lens of the measuring instrument.[4]

If we wish to determine the veiling-glare contribution of our LMD lens, we can place a glossy black mask across the black image, tilting it slightly if necessary to eliminate specular reflections from the projector. We must be sure the mask displays only reflections from a dark area of the room, from a light trap, or from some other essentially black reference. The measured luminance of this mask gives an indication of the degree of veiling glare in the LMD.

Other Precautions

Although many readers may find them obvious, we'll mention a few other precautions. Illuminance measurements can be sensitive to deviations off the normal axis. In our measurements, a 3% error resulted from a 10° misalignment of the luminance meter's axis with the screen perpendicular. This sensitivity is a function of distance from the source – the closer to the projector, the more important normality becomes.

Room reflections and other stray-light sources may increase this variability. Varying the distance of the detector from the projector also changes the illuminance. As the distance of the detector from the projector increases, the illuminance decreases at a rate of $1/r^2$, where r is the distance from the projector (inverse square law). So, if $r = 3$ m, then a 10-cm error in the placement of the illuminance meter represents a 0.7% error in the illuminance measurement. If the operator must hold the instrument in the image plane for the duration of the measurement, then care should be taken to avoid reflections from the operator's face, arms, hands, and clothing. Standing as far off to the side as possible and wearing dark clothing will help to minimize such contributions. Finally, we must be sure that the mask or the projected image of interest completely covers the detector surface or completely covers the measurement aperture.

Take Nothing for Granted

As in all measurements, take nothing for granted. If in doubt about whether the viewing room produces back-reflections onto the screen, try using the small black projection mask and determine how much stray light contributes to the measurements (if at all). We certainly found stray-light contributions in our darkroom environment. Straightforward techniques, such as those described in this article, are simple to implement and will help provide assurance that we are accurately characterizing our projection display.

References

[1]ANSI/PIMA 177.228-1997, "American National Standard for Audio-Visual Systems-Electronic Projection - Fixed Resolution Projectors."

[2]ANSI/PIMA 177.228-1998, "American National Standard for Audio-Visual Systems-Electronic Projection - Variable Resolution Projectors," Draft 5.

[3]E. F. Kelly, G. R. Jones, and T. A. Germer, "Display reflectance model based on the BRDF," *Displays* **19**/1, 27-34 (June 1998).

[4]P. A. Boynton and E. F. Kelley, "Accurate Contrast Ratio Measurements Using a Cone Mask," *SID Intl. Symp. Digest Tech. Papers*, 823-826 (May 1997). ■

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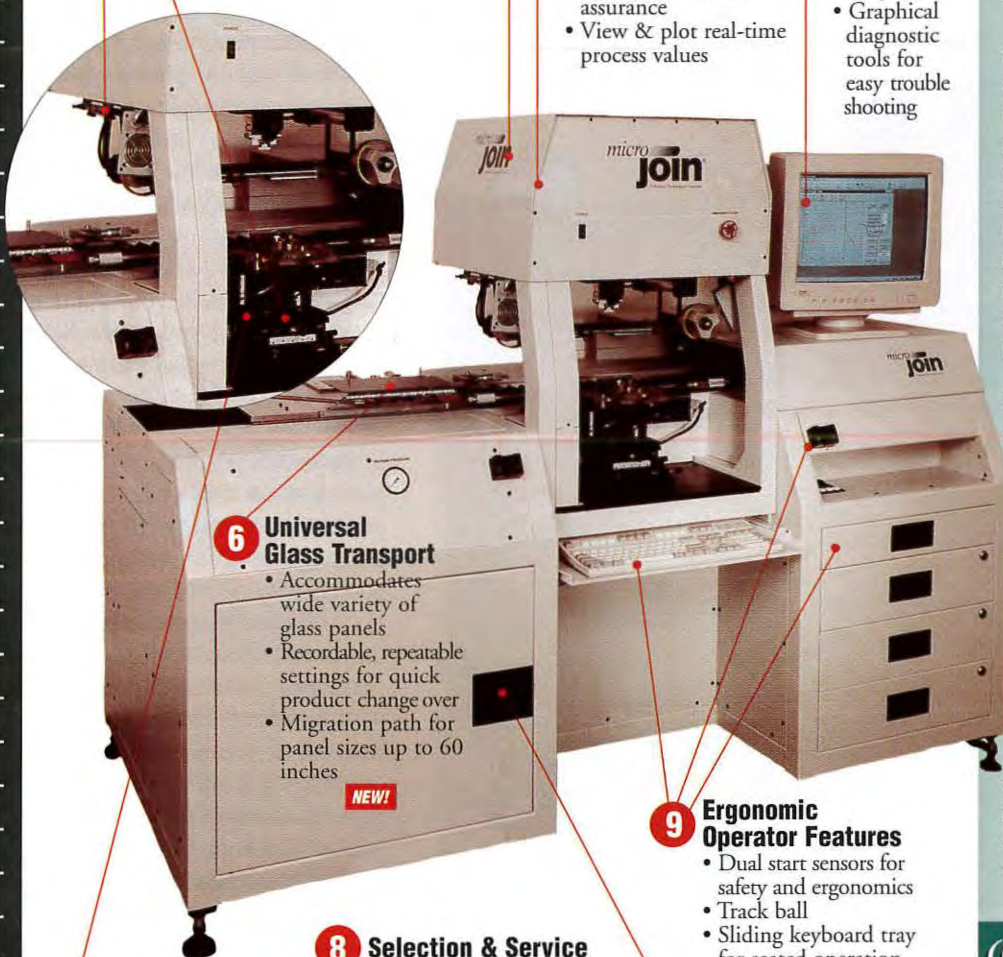

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continued from page 4

Dear Mr. Silzars:

A friend in CRT manufacturing handed me a copy of "The Display Continuum" for April/May. I am in the photographic retail and photo finishing business, and have been for nearly 30 years. Your comments about electronic photography are of great interest to me.

In closing your article you state, "The biggest mistake I think most technology forecasters make is to assume that once a new technology is developed its acceptance is a given." I suggest that you should apply this caveat when considering the future of photography. From my perspective, there are two great obstacles to the digital photography revolution. The first and most obvious is the basic laziness of the consumer. Granted, for the professional, digital is the direction photography should and will head. However, the amateur is a long way from being willing and interested in sitting down at the computer and making prints from his 100 or so vacation photos. Even printing a dozen or so photos may require more time than they are willing to expend.

The second issue is subtle, but may prove to be the most important. It has long been an old story that when a house catches fire, the owner rescues his family first, pets second, and his family photos next. Every time you snap a picture, you are capturing a memory for the future. You are archiving. We reprint negatives and restore photos taken from as long ago as the turn of the century. We also print pictures taken only minutes ago. All these pictures are in many different formats, but are stored on film. We can easily make good quality prints from virtually any format. Can you read the files you prepared on your computer 10 years ago? Can you find them? What if you accidentally hit the delete button when cleaning up your hard drive? It is one thing to lose an old correspondence or spreadsheet, but how about the pictures of your children growing up? That is another matter.

When the Polaroid was introduced, many believed that it would replace conventional photography. That was not the case. The digital camera is in many ways the Polaroid of the next millennium. It is good for some uses, but totally inappropriate for others. You may still be right, though. Perhaps in the next 5 years 50% of all photos taken will be with digital cameras. I hope and believe, however, that the pie will become so big that those 50% of all photos will be in addition to

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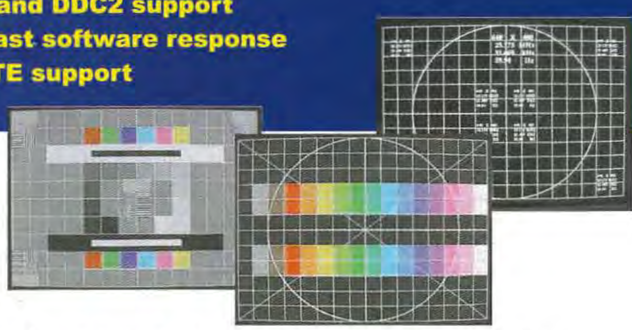

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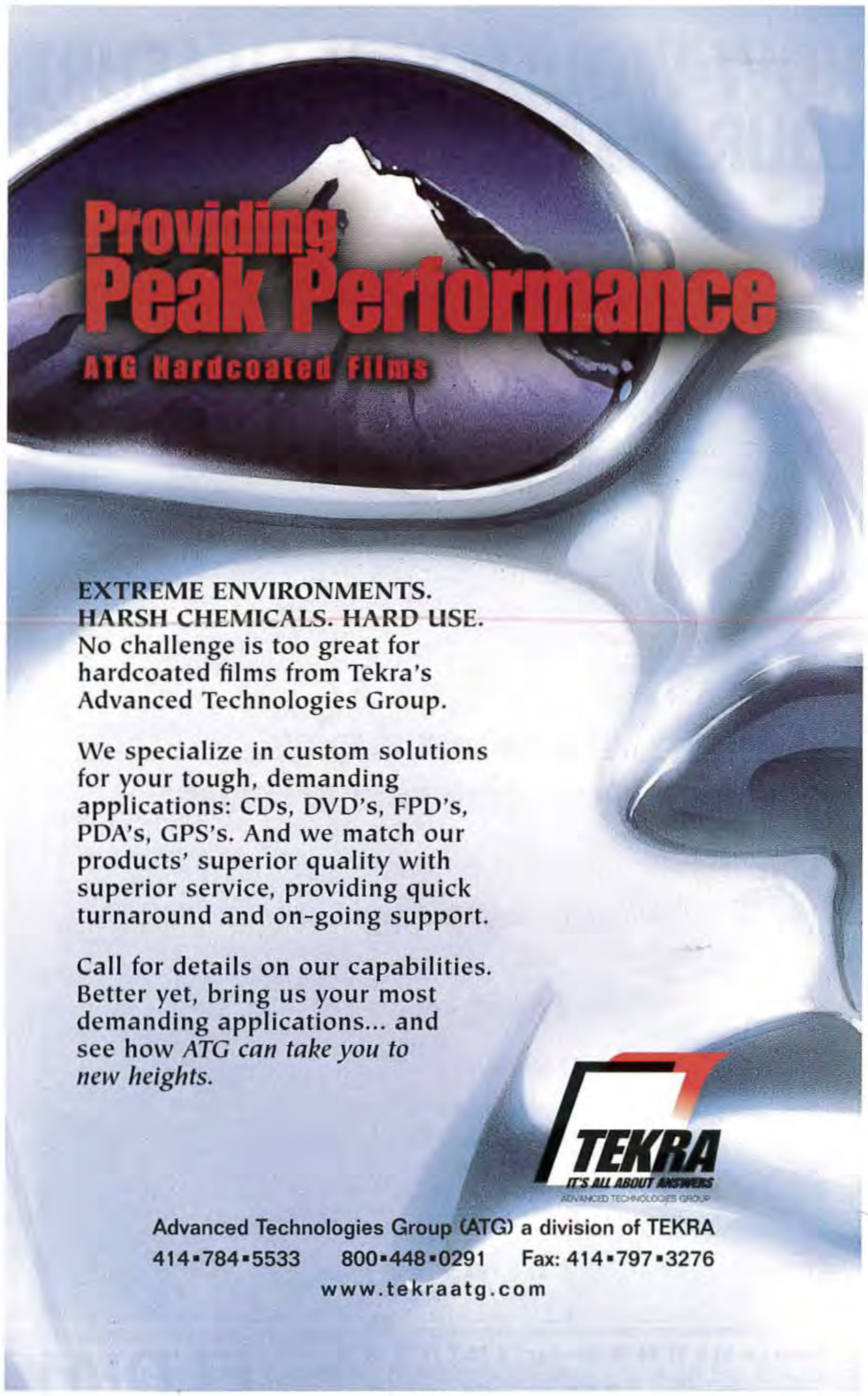
Well, what about it? Television didn't replace movies, video conferencing hasn't yet had measurable impact on business travel, and the idea of the paperless office now sounds pretty silly. Is digital photography just another technology-driven gadget that will only supplement "real" photography in certain specialized applications?

As all of you know, my tendency is to approach new technologies with considerable caution and skepticism. I agree with Mr. Lundgren that often the technologists ignore what the customer is really after. Are the digital formats to be trusted when we think in terms of 50 or more years of family memories? The formats may change with time, but at least with film the image is always retrievable and printable as long as the film materials hold out. But even here, there are some well-documented cases of film that was put on the market that couldn't hold an image for much more than about 10 years. The early color negative films made by Kodak were especially bad for losing their images - sometimes known as the "lost decade" among professional photographers. Today's color films can be considered archival for periods exceeding 50 years if the right brand of film is selected and if reasonable care is taken with its post-processing storage.

So far we have good cause to worry about storing our archival information on digital media. The 5¼-in. floppy-disk format lasted for only about 5 years. The 3½-in. disk has done somewhat better, but now the new Macintosh computers don't have a floppy drive. If you have an image stored on a floppy disk, how are you supposed to read it into your new iMac computer? Is having to purchase an external disk drive the start of some new trend, and, therefore, does it mean that we really should be concerned about the future readability of information in which we may have long-term interest? (And that, of course, applies to more than just photos.)

In spite of these reservations, I am going to make the bold prediction that



Circle no. 21

digital photography is going to be the "third wave" in computer-technology evolution. The first wave was the development of the PC itself. Most of us would identify the birth of the Information Age with the IBM PC and the Apple IIe. It's interesting to think back how many failed attempts there were to try to make the PC a "useful" home appliance. Not only were we going to do word-processing and spreadsheets, but we were going to play all kinds of mentally challenging games on our computers, keep detailed personal financial records, manage our grocery lists, and control our home heating systems and kitchen appliances. Well, the word-processing function and the spreadsheet survived pretty well, even though these were not considered as sufficient justification for having a home computer. A few database functions such as address lists and specialized small-business-management programs also turned out to be handy. But at least half of the laptop computers I see lit up on airplanes these days are being used to play solitaire. So much for using the computer to challenge the intellect!

The second wave has been the Internet. This function was not anticipated by ***any of the brilliant minds*** trying to come up with relevant uses for the early PCs. It evolved from a number of initially unrelated events. But once a few clever users figured out that the Internet could be accessed from their PCs, everyone wanted in. The Internet introduced a powerful communications capability to the PC. And this has been the giant driving force for many people to become computer-literate who otherwise would have ignored PCs. Internet-connected PCs create a communications medium that does not replace the telephone, or the fax, or even conventional mail, but which facilitates a whole new and virtually cost-free worldwide communications capability. It's personal, but not as personal as the telephone. I can give you bad news by e-mail easier than by a personal call. I can send a little or a whole bunch, but if I want you to see certain kinds of information in a certain way, I may still want to use a fax or even the mail, including an overnight service. I can search for information such as stock quotes and other time-dependent data, and I can do it better via the Internet than by any other means. However, if I want lots of details, or if I'm not sure what I'm looking for, a trip to the bookstore or the library may still serve me better.

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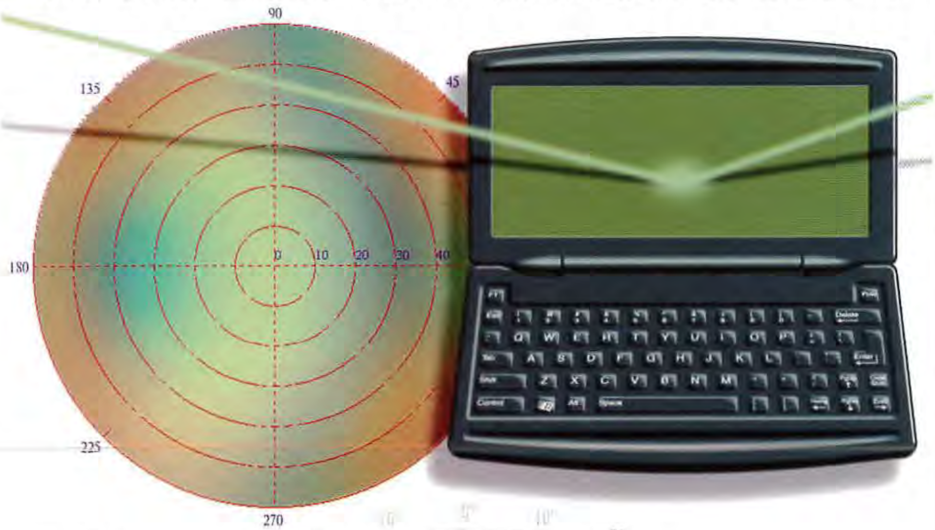

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Circle no. 22

Because of the Internet, stock-market players, collectors, job seekers, and all that ilk of worldwide merchants and communicators have had to improve their typing skills, whether they wanted to or not. And they have had to learn how to left-click and right-click, and to move that little pointy-thing all around the screen. As a consequence, the world of the personal computer has expanded manyfold.

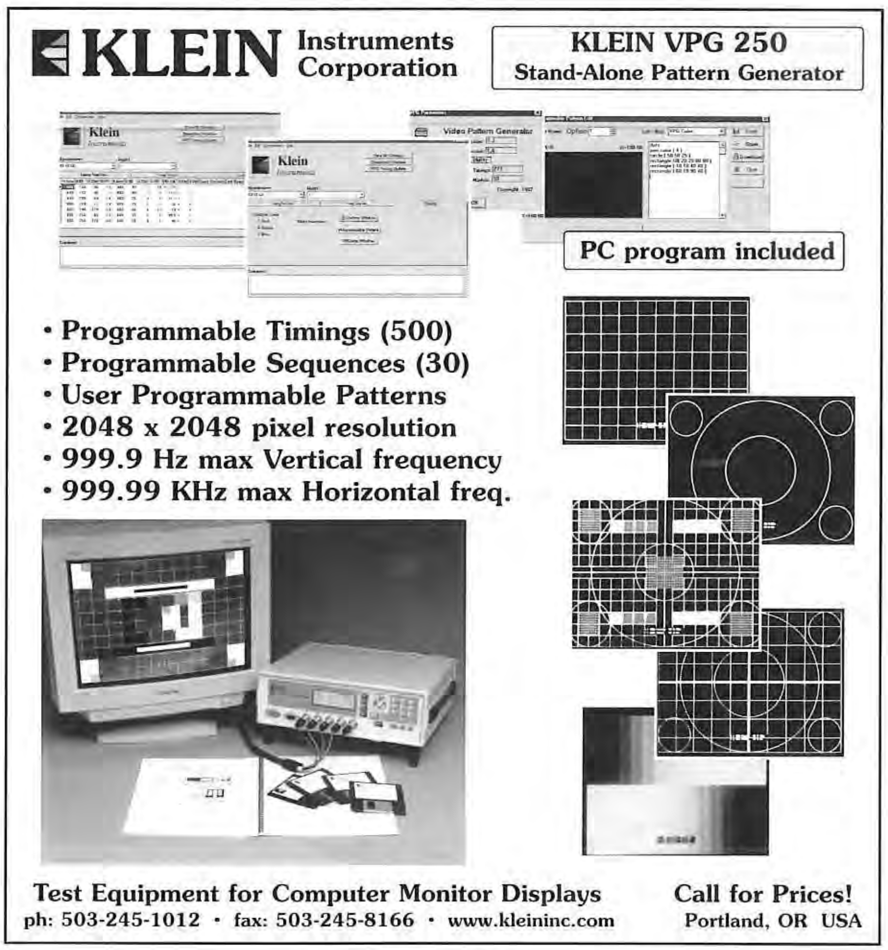
Now, I predict that the third wave will be full-color imaging, and it's almost upon us. Within this, I include image acquisition, image manipulation, image storage, image reproduction, and image transmission.

The change will first be driven by professional users and then will be immediately followed by younger (all school ages, including college) computer users. The multiplicity of professional uses have already been evolving for several years and include everything from technical reports to news stories, real-estate brochures, and high-quality archival storage and retrieval. The younger generation will appreciate digital imaging because it will give them the ability to communicate with their friends by pictures in addition to words, the ability to manipulate images (enhancing their appearance, for example), and the potential for quick results (instant gratification). Ultimately, the new technology will create some new and as yet unanticipated changes.

Should we, therefore, conclude that Kodak, Fuji, and other film and photographic-paper makers should plan their orderly demise and think in terms of how many more years they can survive before they close their doors? I don't think so. Just as the Internet has not and will not replace the phone, fax, or FedEx, digital imaging will not replace some film uses for many years to come. Consider, for example, that even digitally produced images are often most conveniently put onto 35-mm slides, especially if it's for a presentation to a large audience. Or consider the scenario of photos from an extended vacation. For this situation, I would agree with Mr. Lundgren. The easiest way to look at them is to first get them all printed using conventional chemically based processing and then to do a sorting from the hard copies. Putting hundreds of images onto a PC and then taking the time to bring each one up and look at it without having the ready comparison with the others would indeed be a frustrating task.

What we consumers really want is to be able to choose the image-capture medium we find the most convenient for a given situation, and then to be able to convert it to whatever other medium we may want for our subsequent enjoyment - film to disk, disk to CD, digital-camera module to disk, CD or disk to film, and so forth. All media are fine for us as long as we can acquire, manipulate, store, print, and transmit our favorite images. And multiple formats are great for that extra assurance that the images we really care about won't be lost.

Oh, how our past comes back to haunt us! Some years ago in this column, I passed on to you the words that "Displays are windows to the Information Age." And here we are, limited in our ability to view multiple images by having too small a "window." Oh, sure, you could argue that it's possible to put up more than one picture at a time by dividing up the monitor screen into segments, but that all sounds like so much more effort than spreading a bunch of photographs, maybe a hundred or more, all over the dining room table. Which would *you* rather do? By the way, your answer might not be the same as mine. Would bigger and higher-



Circle no. 23

resolution displays solve this problem? Not all that well, it seems to me.

Do you remember 8-mm home movies? It sure didn't take long for the video camera to replace those. However, at the professional level, where image quality is important, film continues to be used. What about the quality of digital images? How do current digital-camera images compare with 35-mm-film photographs? At the one-megapixel level, which is typical for the majority of today's consumer cameras, they are not as good. A carefully made 35-mm photograph is equivalent to about a 2-megapixel digital image. A good-quality 35-mm-film-based photograph can be enlarged to an 8 × 10-in. image or occasionally even an 11 × 14-in. image without showing significant grain or lack of sharpness. The current one-megapixel digital cameras look comparably good at printed-image sizes of about 5 × 7 in. However, I would expect parity to be achieved within the next two to three years, when we begin to see two-megapixel cameras at a selling price of under $1000 (comparable to typical full-feature 35-mm cameras).

Consumer-affordable printing technology is similarly not yet quite as good as chemically based photography, but it's also getting closer, and we will be at parity within about 3 years. However, for many consumer and even commercial applications parity is not required. Newspaper photos, real-estate and other advertising brochures, and technical-report images do not need the ultimate large-format image quality. A 4 × 6-in. photo is typically all that is needed. The current digital cameras can do those instantly and, to the casual user, with quality indistinguishable from 35-mm photographs.

The younger set just wants to do interesting stuff and have fun doing it. They are typically more willing to try new things even if the new technology doesn't meet every quality criterion of the older technologies. If a reasonable-looking image can be put up on the computer screen, manipulated, printed, and sent to friends via e-mail, then let's just do it. In a few months, we'll do even better ones. That's the way the world works, doesn't it?

So the third wave of computer technology will impact us all. The professionals have already picked up on it through the various CAD programs that today pervade every field, from art to advertising, engineering, fashion design, news reporting, photography, publishing, and television. Now the rest of us will have our opportunity, with the younger generation picking it up the fastest.

The home computer with Windows95 or Windows98 and Internet access is already becoming a mature product. The third wave will build around this maturing capability by introducing the widespread use of input devices, such as digital cameras and scanners, and output devices, such as photo-quality color printers, color fax machines - and of course, bigger, brighter, and higher-resolution displays.

We display engineers have much to be thankful for this Holiday Season. We are going to be much needed to create the displays that will meet the expectations of the image-driven Information Age. What better present could Santa Claus bring us than to let us know that we will be in demand for years to come? With that, ***I wish every one of you the best of Holiday Seasons and a coming year filled with great opportunities to apply your talents to creating great displays for future generations to use.***

Should you wish to send me your comments that perhaps could become the seeds of a future column, please provide them to me by the medium of your choice (since none of them are, so far, in any noticeable stage of decline). My e-mail address is silzars@ibm.net, my fax is 425/557-8983, my telephone number is 425/557-8850, and the post office seems to know that I am at 22513 SE 47th Place, Issaquah, WA 98029. ■

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6 SEPTEMBER **99**

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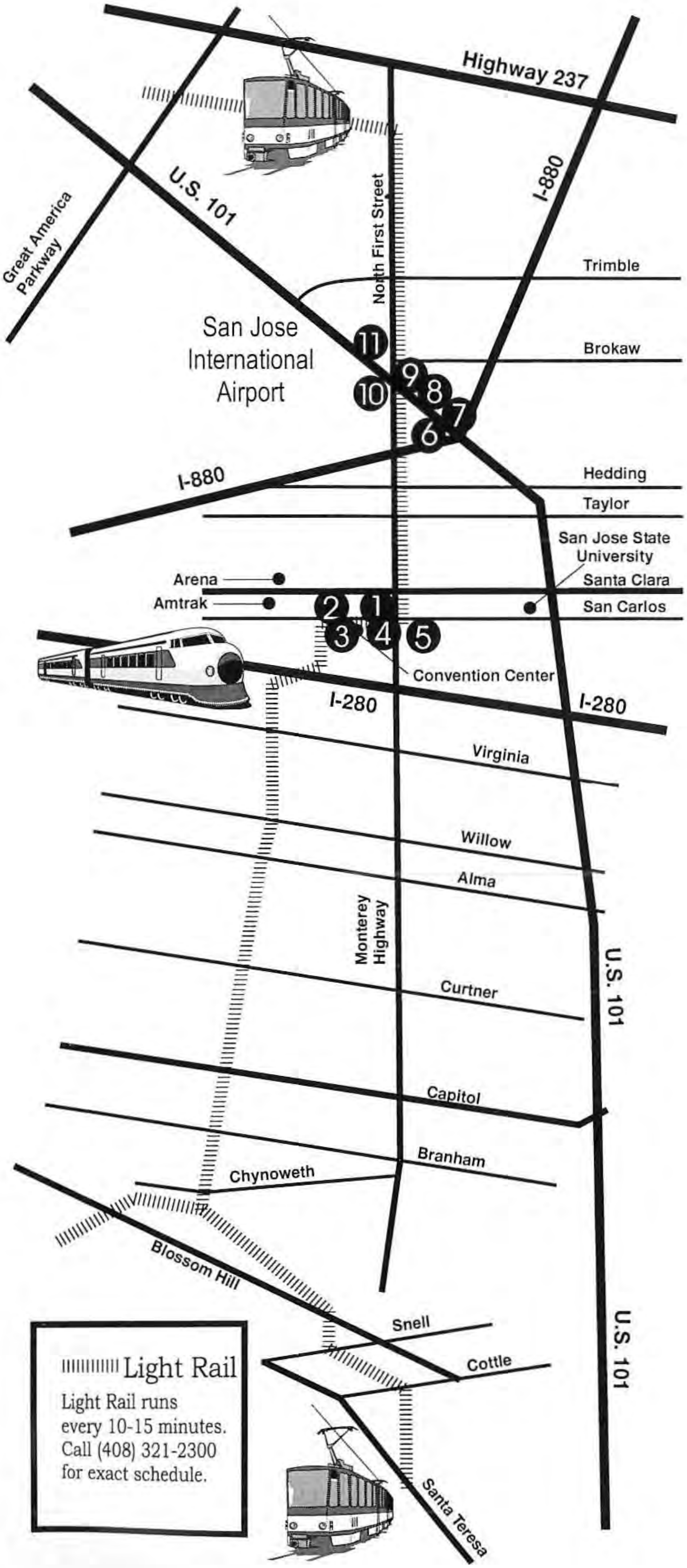

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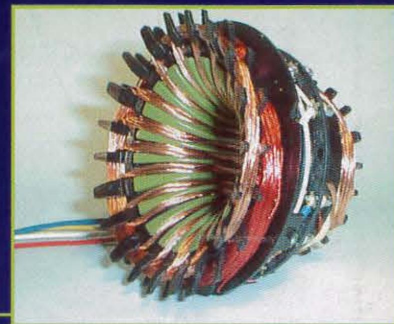

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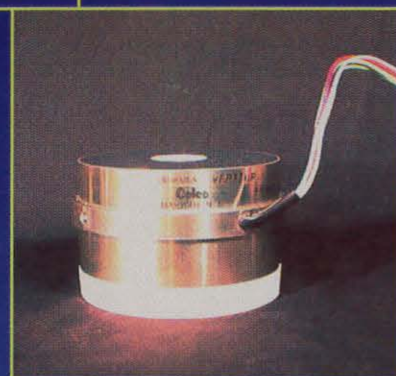

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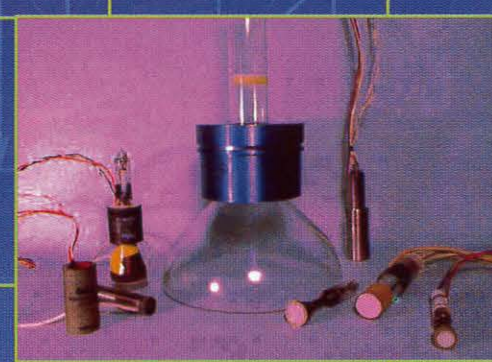
Bottom: F-18 Map Display Yoke



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