FIRST ANNUAL PROJECTION ISSUE

Information DISPLAY

January 1999
Vol. 15, No. 1

SID

Official Monthly Publication of the Society for Information Display

Projectors Get the Job Done

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


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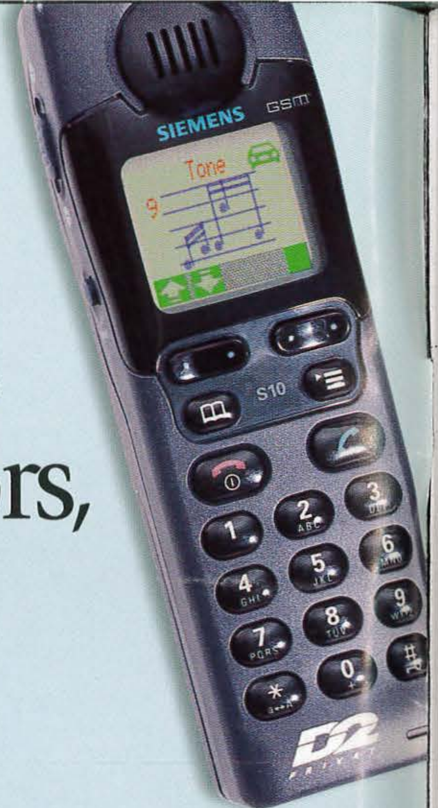
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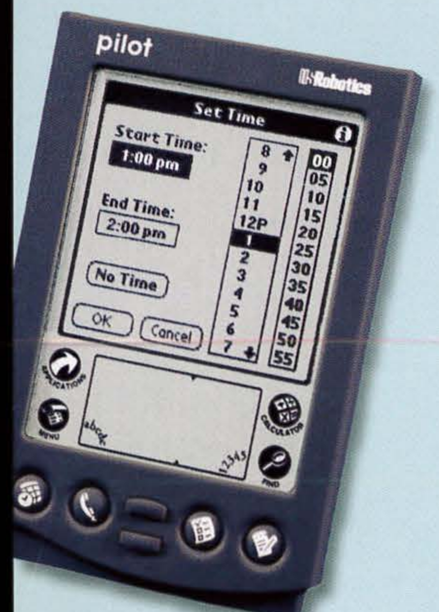
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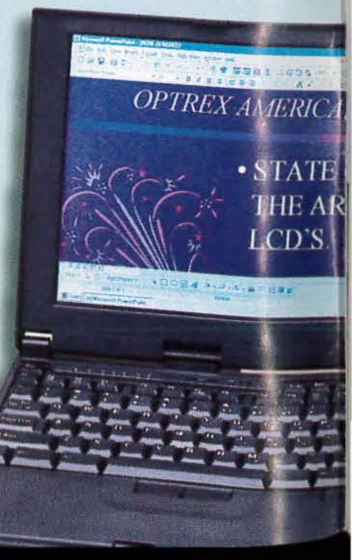

COVER: Projectors are the display technology of choice in many applications. Here, six rear-mounted Digital Projection Power 2V projectors, each throwing 2500 lm on a 10.5 × 14-ft. screen, provide the high-energy atmosphere desired by the designers of this nightclub at the new Las Vegas Rio Suite Hotel & Casino.

Credit: Digital Projection

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

Flat-Panel Issue

- Inventing the ac Plasma Panel
- Plasma-Panel Advances
- Sharp's New Generation of AMLCDs
- FPD Interfacing
- Ibero-American Workshop Review

INFORMATION DISPLAY (ISSN 0362-0972) is published eleven times a year for the Society for Information Display by Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003; Leonard H. Klein, President and CEO. EDITORIAL AND BUSINESS OFFICES: Jay Morreale, Managing Editor, Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003; telephone 212/460-9700. Send manuscripts to the attention of the Editor, ID. Director of Sales: Michele Klein, Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003; 212/460-9700. SID HEADQUARTERS, for correspondence on subscriptions and membership: Society for Information Display, 31 East Julian Street, San Jose, CA 95112; telephone 408/977-1013, fax -1531. SUBSCRIPTIONS: Information Display is distributed without charge to those qualified and to SID members as a benefit of membership (annual dues $55.00). Subscriptions to others: U.S. & Canada: $36.00 one year, $5.00 single copy; elsewhere: $72.00 one year, $6.50 single copy. PRINTED by Sheridan Printing Company, Alpha, NJ 08865. Third-class postage paid at Easton, PA. PERMISSIONS: Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limits of the U.S. copyright law for private use of patrons, providing a fee of $2.00 per article is paid to the Copyright Clearance Center, 21 Congress Street, Salem, MA 01970 (reference serial code 0362-0972/99/$1.00 + $0.00). Instructors are permitted to photocopy isolated articles for noncommercial classroom use without fee. This permission does not apply to any special reports or lists published in this magazine. For other copying, reprint or republication permission, write to Society for Information Display, 31 East Julian Street, San Jose, CA 95112.

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A Drink from Admiral Yi's Well

Following Asia Display, I traveled with Dr. Kyung Y. Park, Supervisor of Samsung Display Devices' (SDD) PDP Team to visit SDD's new home in Chonan City. Along the way, we stopped at a shrine to Admiral Yi (but sounding much more like "Lee" to my Western ears) Sun-shin, consisting of a beautiful botanical garden surrounding the Korean hero's boyhood home.

Admiral Yi had an undisputed genius for naval tactics, as demonstrated by his many victories during the Japanese invasions of Korea that began in 1592 and 1597. The ratio of his opponent's losses to his own were invariably of Desert Storm proportions. During the Battle of the Noryang Sea in late 1598, the last battle of the war, Yi's force destroyed 200 of the 500 ships sent to evacuate what remained of Japan's forces in Korea. Yi was struck by a Japanese musket ball during this engagement and died instantly.

Near Yi's home is the well that served the family during his time. Dippers hang alongside the well, and Park told me it was traditional for Korean visitors to dip water from the well and drink from the dipper - after ritually spilling a little on the ground three times - and both of us drank in this way. I asked if the feeling among Koreans was that they would somehow attain some of Yi's courage and wisdom by drinking from his well, but Park would not be led down this mystical path. "No," he said, "it is more like nostalgia for a simpler time when pure water came from the earth, and it is also a way of perhaps feeling closer to Admiral Yi." Still, my mystical interpretation persisted (in my own mind, if nowhere else) as we left the shrine.

On the following day, I visited the impressive Chonan high-technology complex as Dr. Park's guest, and was introduced to Chang Bae Park, the PDP Team's director. The complex is home to some operations of SDD and Samsung Electronics, both of which produce display products. SDD had 1998 sales revenues of US $3 billion from sales of color picture tubes (CPTs), color data tubes (CDTs), liquid-crystal displays (LCDs), vacuum fluorescent displays (VFDs), and light-emitting diodes (LEDs). Batteries and color filters are new lines of business, with products already in production at this "clean and green" plant. Input devices (digitizers and touch panels) and plasma-display panels (PDPs) are in development.

The Chonan facility is new. The buildings, with 173,000 m^2 of floor space, were completed in November, 1997. The PDP pilot line, which was the focus of this visit, was completed in March, said Kyung Park, and an impressive 42-in. PDP prototype was completed in time to be introduced at Asia Display.

During my tour of the impressive pilot line, I was shown an operating developmental prototype of a 50-in. 16:9-wide VGA display - and was the first outsider to see it operating, I was told. There were a few line and pixel defects of the sort one expects to find in a

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Information DISPLAY

Circle no. 2

the display continuum

A Family's Evening Out – in the Year 2015 ...

by Aris Silzars

Jeff was happy to be turning into his driveway at last after another typically busy day working for a large semiconductor company. Traffic had been heavy, as usual, and the last few years at work had been especially difficult for him because of management's never-ending demands to improve the heat-management capabilities of the latest 3-D multichip modules. The growing acceptance of these plug-in modules, popularly known as "knowledge cubes," incorporating what had previously been done with software, had really made his electronic packaging and heat-management engineering skills vital.

While he liked the idea of being a packaging engineer and highly in demand, he didn't like the high-pressure environment, and he didn't like having to always meet such tight schedules for new product introductions. Sure, it was great for consumers to be able to acquire the latest voice-recognition, image-manipulation, or text-processing capabilities, configured as plug-in hardware modules in cute little cubes, but introducing several new products each week was really becoming quite a challenge for him and for his company - especially since some of these little modules put out as much heat as a good-sized light bulb. What did everyone think - that these little cubes could be made like popcorn? Sure, they were easy to use and fun to collect, but didn't people realize all the engineering that had to go into the development of each one of them?

Thus, is was quite understandable that Jeff was glad to be home. He was also glad that his wife Diane was there to greet him. Maybe she would give him some sympathy after his tough day. But just as he was about to say, "Would you like to hear the latest that my boss came up with today?" his wife beat him to it with her own opening comment, "You wouldn't believe what one of my clients did to me today. I don't even want to talk about it. I've decided that we can just take the kids and go out this evening."

Well, this wasn't exactly what Jeff had in mind, but being a pretty understanding guy, and quick at assessing such family situations, he responded with, "Hey, that's just what I was thinking on my way home. How about going for a hamburger and a movie?" "OK, I'll get the kids and we'll join you in the car in a few minutes," responded Diane.

Actually, Jeff didn't mind this abrupt change in his plans all that much. Whether at home or in the car, this would give the family some time together. And in any case, cars over the last few years had evolved to be quite suitable for these kinds of family gatherings. Jeff could still remember the time, around the turn of the century, when the new and dramatically redesigned VW Beetle had made such a hit and when behemoth-sized sports utility vehicles (SUVs) became so dangerous to small-car drivers that special laws had to be enacted to prevent the deadly accident situations they created. And even though the car companies had never been known as brilliant innovators, there had been a gradual evolution to vehicles that were comfortable, functional, and reasonably safe.

Remembering back to that time, when he was still just a graduate student, brought a smile to Jeff's face. He had bought one of the new VW Beetles right after getting his M.S. in E.E., and here he was driving a vehicle 15 years later

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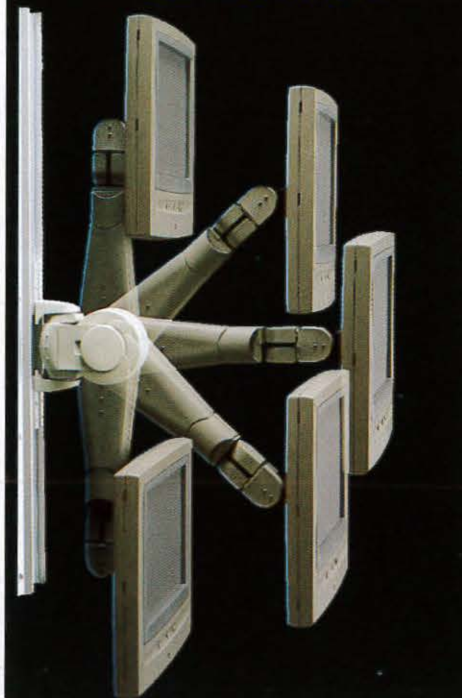

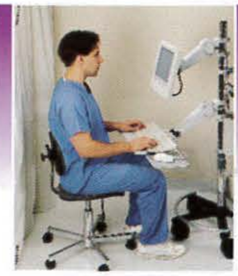

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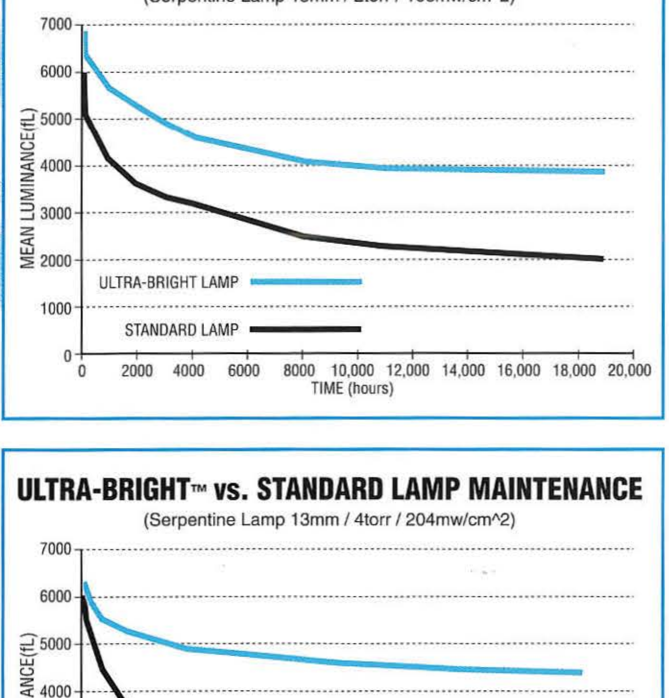

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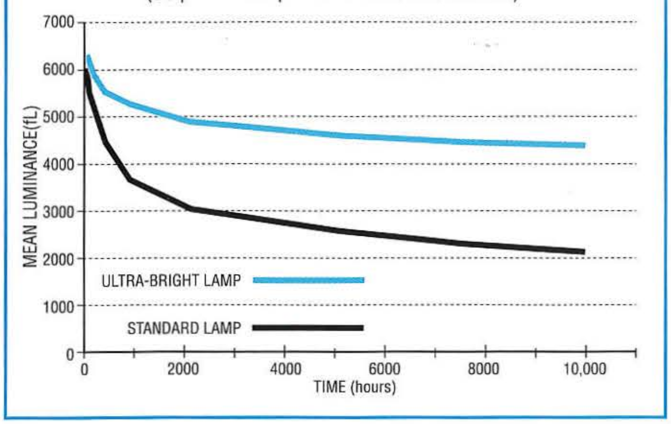

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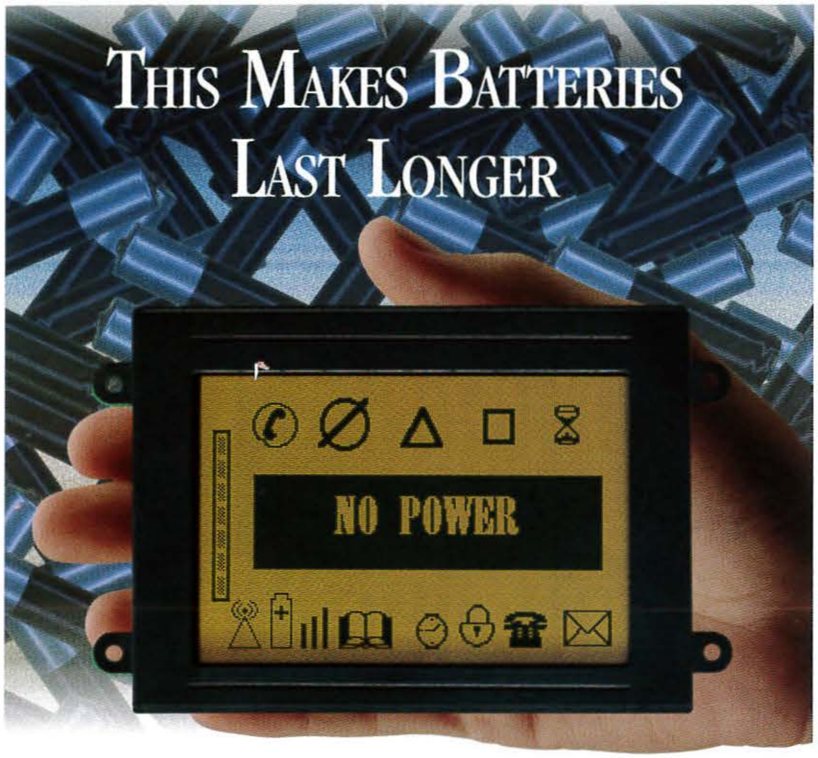

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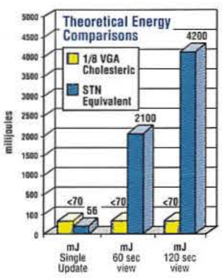

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Circle no. 10

What's Inside That Projector?

Data/graphics projectors use a wide variety of imaging technologies and devices. Here's a look at who's using what – and why.

by Arlie Conner

THE CURRENT CROP of projection systems rely on a variety of different imaging devices and technologies, making the market much more complex than it used to be. In the beginning of projection history, photographic film was the only medium. The first move to electronic imaging depended on CRT-based systems, but their low light output and unwieldy size and weight made them vulnerable to replacement by the smaller and more efficient projectors based on liquid-crystal (LC) and integrated-circuit (IC) imagers.

Passive-matrix liquid-crystal-display (LCD) panels played a role during the early days of the digital-projection market, but they are no longer used in modern projectors. Instead, active-matrix panels provide the image quality - especially contrast and gray-scale fidelity - that users demand, and can be found in the vast majority of the projection systems being offered for sale today (Fig. 1).

The "active" in active matrix refers to the presence of an active element - such as a transistor - at each pixel element. While this improves the panel's image quality and response time, these panels require more advanced and technologically challenging manufacturing processes. Not only must the device be cosmetically near-perfect - since the array will be optically magnified and presented as a projected image to the beholder's eye - but every transistor on the panel must work correctly. These challenges translate into yield ratios, which in turn translate into panel prices, and, in the highly competitive projector market, panel manufacturers are always seeking ways to deliver a better image at a lower cost.

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The Colored Panel

Aside from those presenters who still use photocopied overhead transparencies, the world of presentations has moved beyond black and white to full color. This also adds a level of complexity to designs, in ways that may not be immediately obvious.

Returning to ancient history again for a moment, photographic films rely on multiple dye layers, each of which absorbs light of a different color. This process is called "subtractive" because each layer subtracts a differ-

Lightware, Inc.

Fig. 1: Lightweight and bright projectors based on active-matrix panel technology have come to dominate the projection-system marketplace. Lightware's "Scout" model, which is now available, weighs less than 5 lbs., projects an 800 × 600 image, and costs about $3000.

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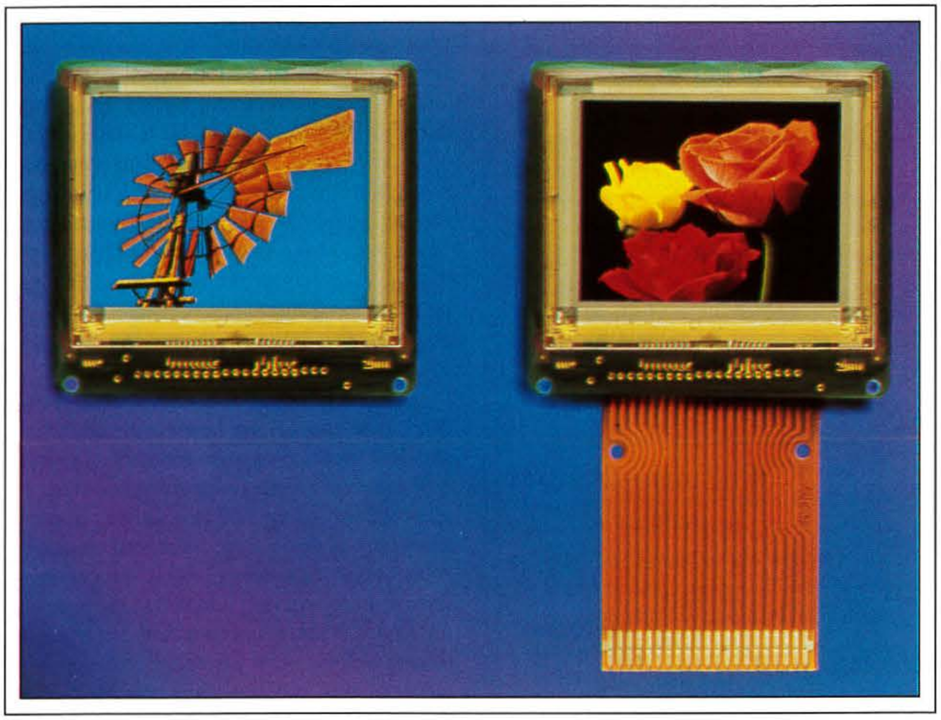

Epson

Fig. 2: This Epson 1.3-in. poly-Si TFT display is a popular choice for the current generation of lightweight projectors.

ent color of light, and only the desired colors are allowed to pass. The initials of these color layers - cyan, magenta, yellow, and black (using "K" for "blacK") - give the technique its acronym: CMYK. Cyan is the name for the turquoise that removes the red light, yellow removes blue light, and magenta removes the green light. To further enhance the contrast and produce a true balanced black, the black layer is added. This CMYK approach is used for almost all printed matter and for color photographic materials.

The other way to get color images is to add lights of different colors; a mix of red, green, and blue light (RGB) will be perceived as white. When looking closely at a television screen, the image can be seen as being made up of these three colors, and this same approach forms the basis for nearly all color projection systems as well.

Inventors have come up with three distinct ways to combine red, green, and blue light to create a full-color image.

• **Colored Filters.** One method - used for direct-view LCDs, such as those in notebook computers - is to use a single panel with three (or more) separate cells for each individual pixel in the display. Colored filters are applied to each cell, so that the light they transmit is colored red, green, or blue. When three adjacent cells of these different colors all transmit light, the pixel appears to be white. The drawback with this method is that much of the useful projection light energy is absorbed because it is difficult to separate the illumination light into RGB components and put each component through its respective color stripe. Thus, as an example, about 70% of the white light is absorbed upon transmitting through each color subpixel area, and the total transmission of such "single-panel" systems is on the order of 3-8%. (In fact, the theoretical practical limit is at about 10% for such a single-panel imaging device.) Many single-panel systems use this approach.

One important variation on this single-panel method is the "color-filterless" system invented by Hiroshi Hamada of Sharp Corp. This process places a microlens element over each set of three LCD cells to direct the light from three tilted color dichroic mirrors. The lens is designed in such a way that it directs the light from just one mirror through a given subpixel, so that the cell passes light of just that color without the need for absorptive filters. This method promises to increase the nominal transmission value of the LCD from the 5% range of a similar color-filtered panel up to 20-30%. The design is also known as angular color separation (ACS) because the tilted dichroic mirrors separate the RGB lighting paths into three distinct and separate angular channels.

• **Field-Sequential Color.** Another way to get full color from a single panel is to illuminate the display engine with red, green, and blue colors in rapid succession. This approach requires a panel capable of very fast switching because it must be able to create three separate images in the time that other designs have to create only one. It also requires a rapidly changing colored light source, such as a spinning color filter wheel (similar to old-fashioned Christmas-tree lighting devices) or another type of color shutter. Single-chip projectors using a reflective digital-micromirror-device (DMD) IC from Texas Instruments are the most familiar designs to use this approach.

• **Color Separation.** Many projection systems create full-color images by using three separate imaging devices. Each of the three devices is dedicated to the creation of red, green, or blue images, which are then combined optically to create a single image. The white projection light is separated by means of color-separating reflecting dielectric thin-film interference filters. These so-called dichroic mirrors are not absorptive, but rather they direct the color channels of light into different directions and onto the three imaging devices by means of reflection. Nearly all of the high-end systems use a three-panel or three-chip design based on this approach. This technique has the theoretical advantage of using 100% of the available light (though it is about 70% in practice) without losing any to absorptive colored filters. The three-device designs do require that the three images be converged precisely, and generally the whole projection system will be bigger and more expensive than a single-panel or single-chip design.

Active-Matrix Display Devices

The buying public (and some of the less-technical media) have adopted "LCD projector" as the generic term for any digital projection system, but in fact there is a wide range of different imaging-device technologies at work inside the current crop of projectors. There are some important variations among the different

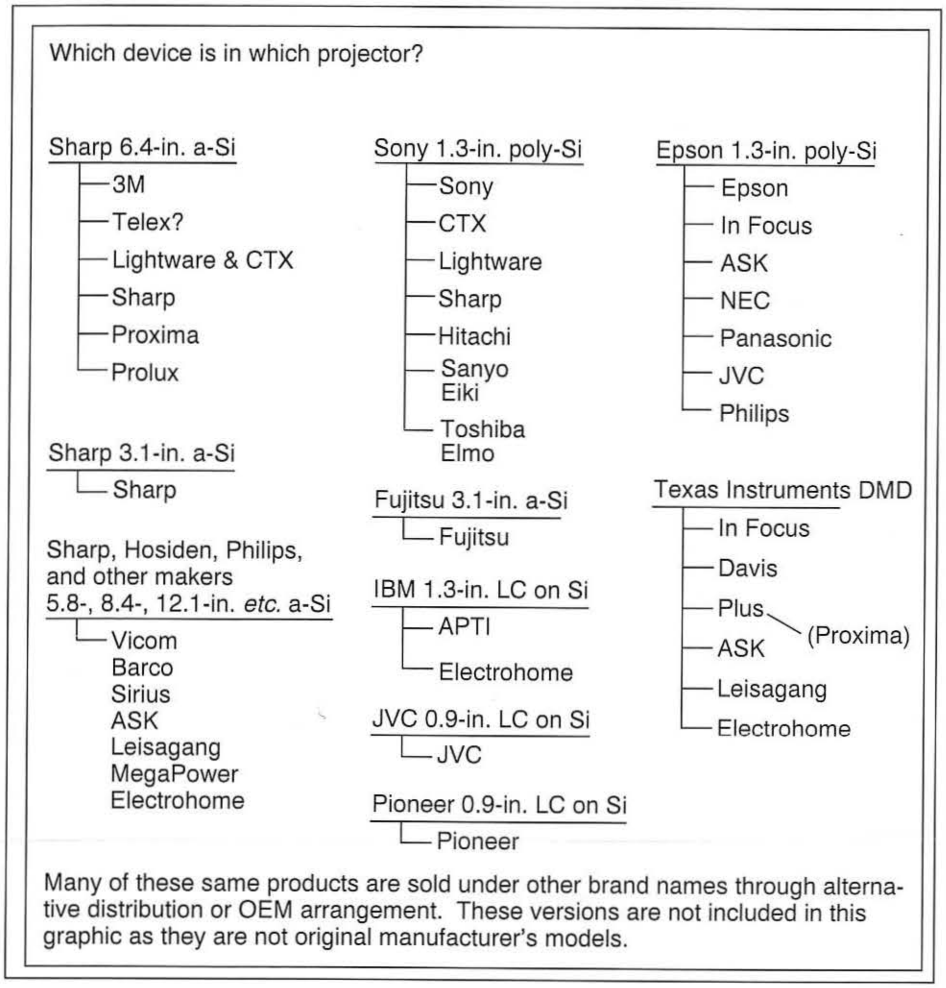

Fig. 3: *The network of relationships between panel manufacturers and the projector manufacturers that use those panels in their products has become complex and intertwined, as is shown by this sampling of panel and projector combinations.*

types of active-matrix liquid-crystal displays (AMCLDs) used in projection systems.

• **Amorphous-Silicon AMLCD (a-Si).** These panels are also referred to in some technical circles as amorphous-silicon, or a-Si, displays – the active-matrix liquid-crystal part is assumed. This technology is at the heart of most direct-view LCD panels, which are the mainstay of the laptop-computer and flat-panel desktop-monitor revolutions. Beginning with the first 9.4- and 10.4-in. VGA panels, notebook computers since 1990 have had excellent-quality color thin-film-transistor (TFT) screens. Nearly every computer buyer is familiar with the standards now being offered by the PC vendors, including XGA in 13.3-in.-diagonal format, SVGA in 12.1-in. formats, and recently a new 10.4-in. SVGA panel for the ultraportable notebook category. Incredible advances in manufacturing-process technology have now made possible 17-, 20-, and even 28-in.-diagonal displays for desktop-monitor applications.

Larger panels are relatively rare in projection-system applications; there are a few examples of 12-in. LCD panels used in luggable systems, but the majority of the a-Si LCDs used in projectors are considerably smaller. Most are 3-in.-diagonal panels – generally monochrome – with analog interface connections. Another excellent-quality display is the Philips thin-film-diode (TFD) panel, in 5.8-in.-diagonal size with 768 × 576 pixels. Because this panel is made with a type of hexagonal array, instead of a simple X-Y orthogonal matrix, the perceived resolution is much higher, and visual demonstrations of projectors using three of these LCDs have been given high marks for several years.

Another popular format is the 6.4-in.-diagonal color display, made by Sharp and NEC, in VGA and SVGA resolutions. This panel is more akin to a notebook-PC panel, having a similar digital interface and RGB color-stripe filters built in and intimately assembled with the liquid-crystal picture elements. These rely on the colored-filter approach described above, and so only a single panel is required to create a full-color image.

• **Polycrystalline-Silicon AMLCD (poly-Si).** These panels have become the *de facto* standard for the projection industry. Typical a-Si panels are made on master-glass sheet sizes approximately 500 mm square. In contrast, poly-Si devices are fabricated on quartz substrates using conventional IC-processing lines that are specially adapted to the task; the difference is that semiconductors are made on silicon wafers. Most panels are made on 6-in. quartz blanks, although some new production lines are built to handle 8-in. blanks. This larger blank size can increase production efficiency. In the same way that the very large master glass used for a-Si panels will support 6–40 projection panels per sheet, an 8-in. circular quartz blank can yield at least six and as many as 50 displays, depending on the display size. Unlike a-Si panels, that have diagonal dimensions measured in inches, poly-Si panels are measured in tenths of an inch.

The most popular size for poly-Si projector panels is 1.3 in.; this author believes that this size was chosen initially because it nearly perfectly matched the 35-mm slide-projector format, and it was initially believed that there would be some easy transition from slide-projection optics to "electronic slide projection" systems (Fig. 2). Interestingly, about the same time that Kodak introduced the first Epson-developed projector based on 1.3-in. poly-Si LCDs, Sharp Japan was introducing a TV-resolution projector based on 3.2-in. a-Si LCDs.

Already, the market appears to be moving toward even smaller panels. The next-generation 0.9-in. displays offer an advantage in that roughly twice as many panels can be produced per substrate, doubling the manufacturing capacity and cutting unit costs in half.

• **Low-Temperature-Polysilicon AMLCD (LTPS).** A new generation of panels is under development that promises the best qualities of both a-Si and poly-Si. The manufacturing process uses large glass substrates - such as 400 × 500 mm - with a-Si that has been deposited on their surface and then annealed. This approach offers the size and cost advantages of the older a-Si technology, but with the superior electrical characteristics - higher electron mobility - of the poly-Si-transistor arrays. For LTPS, peripheral driver circuits are usually incorporated on the same active-matrix substrate - as with poly-Si panels. This gives them additional cost and reliability advantages over the a-Si panels, where external edge (row and column) driver circuits must be bonded onto the edges of the glass display, requiring extra costs and processing steps.

The LTPS panels may also have higher aperture ratios than many a-Si panels, although many a-Si designs for projectors have already incorporated "super high aperture" technology. An increased aperture ratio means that more light will be transmitted by the panel, and, given the market emphasis on projector light output, manufacturers are always working to increase system light-transmission efficiency.

Another approach to enhancing the aperture ratio is to use microlens arrays. First employed by Sharp on their a-Si projection LCD panels and more recently applied to a variety of poly-Si panels, this approach typically increases the projection-system light output by 1.5-2.5 times. A significant number of new projectors can be expected to appear using this feature.

Emissive *vs.* Transmissive *vs.* Reflective

There are three fundamental ways to create an image. Emissive displays generate their own light, as is the case with the familiar cathode-ray-tube (CRT) displays, where electron beams cause phosphors to emit light. The revolution in display brightness occurred with the advent of light-valve technologies, which could work in either reflective or transmissive modes, but both offered the advantage of being able to apply a separate powerful light source. The a-Si and poly-Si LCD panels discussed to this point are transmissive devices, but there is a whole new group of semiconductor displays that are reflective devices.

This segment has burgeoned in recent years, and, frankly, there are too many different types of reflective devices to do an adequate job of explaining them all in this brief survey. At the risk of oversimplifying matters, here are two major categories for these devices.

- **Reflective LCD on Silicon (LCOS).** These displays have been talked about and worked on for decades, starting with the simple idea of mating silicon-chip production (large-scale semiconductor processes) with liquid-crystal materials and processing to achieve low-cost high-performance display devices. Only very recently has this dream come true. Today there are more than 20 companies now developing such devices for consumer applications. These products include handheld and personal viewing devices such as cellular phones, camcorders, virtual-reality head-mounted displays - and, most pertinent for this article's context, a range of projection systems. The optics for reflective projection systems are sufficiently different from those of transmissive systems so as to have been stumbling blocks in the early development stages of this new methodology. Also, there have been technical challenges to both IC and LC manufacturing processes to obtain adequate yields of reflective devices, but that appears to be changing for the better.

Most notably, there are three Japanese companies now making reflective LCDs with products on the market, and while none of these have replaced their transmissive cousins totally, they do have some nice advantages and may - in the future - become the more popular approach. The area where these devices truly excel is in high resolution. JVC has made a 1365 × 1024-dot device in a 0.9-in. format, which exceeds by far the number of dots per square centimeter of all commercially available projection devices on the market today. IBM Japan and Pioneer have also brought similar devices to market, and as many as two dozen more companies are working on alternative designs. It appears possible to gradually achieve higher resolutions in the future until a new physical limit is reached, probably having to do with the molecular limitations of the LC itself.

As an aside, there is also one transmissive version of LC-on-IC technology. Kopin has been pioneering the development of a process in which a display is created on a silicon wafer, and the display is subsequently transferred onto a glass substrate. The result incorporates the real benefits of the IC manufacturing process - high electron mobility and high resolution - while staying compatible with easier transmissive optical systems. Motorola has recently signed an agreement with Kopin, and this team is now offering microdisplays for handheld and head-mounted applications.

- **Reflective Integrated-Circuit Displays.** The most prominent of these newcomers is the DMD from Texas Instruments, which has become the imager of choice for many systems designers in 1998. Under the banner of Digital Light Processing (DLP), we find a wide variety of different projectors on the market today, including one- and two-chip designs using field-sequential-color modes of operation and several examples of stunning performance using three chips with conventional color-separation methodology. Systems can be found at both extremes: the high end (of brightness) and the low end (of weight).

Several new developments, such as the actuated mirror array (AMA) from Aura Systems (redesigned and recreated as the TMA from Daewoo) and the grating light valve (GLV) from Silicon Light Machines, hope to compete with DLP for a portion of the projection market.

One Chip *vs.* Three Panels

This year, the question is which is better: one chip (DMD) or three panels (poly-Si)? The jury is debating and there are excellent arguments on both sides. A lot has been written recently about these two modes of operation. The devil is in the details, as they say, and DMD has clearly taken hold as a viable reflective technology. Reflective LCD systems have about the same characteristics as poly-Si transmissive projectors, but higher resolutions and potentially better image quality due to the higher aperture ratio, which results in a smoother non-pixelated image. This is the subject of some debate because the contrast ratio of reflective projectors has not always been astounding, but in many other ways the DMD has demonstrated better image-quality characteristics than poly-Si.

Some poly-Si displayed images suffer from noticeable crosstalk, the kind of striping or ghosting artifacts that used to be the subject of much research in supertwisted-nematic (STN) and other passive-matrix driving techniques. Recent a-Si and many of the reflective devices are inherently less prone to such artifacts.

The speed of response of LC materials has always been an issue for fast-moving (video) images. This has been steadily improved, with thinner LC cell gaps and with vertical alignment modes as may be used in reflective panels. Some panels now even show image flickering because they respond too quickly! The single-chip DMD system, in field-sequential-color operation, has more than adequate response capability to allow three separate fields to be displayed (to show RGB full-color images) at rates above 70 or 80 Hz, where humans typically cannot perceive flickering sensations. In some situations, for some types of images, there can be a color break-up so that a sort of rainbow is noticed, but generally DMD systems produce stunning picture quality.

The DMD has shown steady improvements, such that sticky mirrors and other such defects are mostly eliminated. But because the DMD responds linearly (not logarithmically, with a specific gamma characteristic), the gradation of gray levels is not fine enough in the darkest range. This causes some occasional noticeable quantization or posterizing effects, which could be solved with higher native gray-level depth (*e.g.,* 10 bits instead of 8 bits), an improvement that reportedly is being pursued at TI.

Now, the issue of cost remains. The DMD can perhaps make a smaller and lighter projector (very important in the portable segment, where a 5-lb. product wins the awards over a 6-lb. contender), but the costs of the DMD and supporting DLP circuitry have been substantially higher than the costs of the roughly equivalent three poly-Si LCD panels. The optics costs for the LCD system are somewhat higher, but not to such an extent that the DMD approach would be chosen for a cost-sensitive product.

In practice, the choice of which panel or chip to use is not an easy one. For example, one area of particular interest and market growth is rear-projection systems. Here we still find CRTs in happy coexistence with a-Si and poly-Si LCD engines, and recently DMD one- and two-chip engines have also entered the fray. In the tiled rear-screen world (also called videowalls or projection cubes), it is not enough just to have excellent image quality. Good brightness and color uniformity is not only required within each display, but nearly perfect matching must be achieved from cube to cube. As a result, repeatability is a new critical display-system requirement. Even in this demanding arena, it is not easy to see a reason why any of these devices will become the majority solution, and the rapid pace of technical advances on all fronts makes it even more difficult to predict.

About the best we can do at present is to look at a snapshot of the current situation. As a matter of interest, we have compiled a chart (Fig. 3) that gives some answers to the question "Whose device is inside of whose projector?" We show it here with apologies in advance, since it cannot possibly be totally inclusive and there may be some glaring errors (which only letters to the editor will repair!).

Out of all this information, one conclusion is clear. The choice of an imaging device for a projection system is not easy to make, given the wide range of choices available on the market now and under development. If the recent past is prologue, we can expect the choices to become even harder, but along with the complex choices will come higher resolutions, better image quality, and faster response rates. The number and type of imaging devices will continually increase as new display technologies evolve. The foregoing summary is not intended to be a predictor of markets or trends, but rather a status report on the current commercial offerings.

Whichever device comes to the forefront next is bound to have superior image quality, just as the devices presently on the market are better, brighter, more uniform, and more beautiful than any that have come before. What's certain is that the trend is toward brighter projection systems with ever-higher resolutions and more perfect images. Keep those sunglasses and microscopes handy, we will be needing them! ■

The Hows and Whys of Computer-Video Interfacing

Analog RGB is the way most video and graphics are transmitted from computers to displays today – but saying that just begins the discussion.

by Gregory Maltz

ALMOST ANY IMAGE can be created on a computer. Charts and graphs, enhanced photos, slide presentations, animation, and video - it's all being done on computers with increasingly powerful processors and multimedia technology.

Unfortunately, when it comes to displaying these images for large audiences, computers fall short. Their monitors are too small to be viewed by more than a handful of people at a time, and their graphics cards are not ideal for use with other display devices. It's not easy to directly transfer charts, graphs, photos, slide presentations, animation, and video from a desktop computer to big-screen large-venue displays.

That is why computer-video interfaces are needed. Too often, interfaces are seen as the proverbial "black boxes" that sit between the computer and the display device (Fig. 1). Obviously there is nothing magical about what interfaces do, but to understand how they work requires a good knowledge of video signals, synchronization (sync) types, resolutions, and frequencies. Interfacing is also dependent on other elements of display devices, on computer-video technology such as ID bits, and on details as simple as the connectors and cables used to carry the signals.

Interfaces provide compatibility in three important ways. They allow video signals to run a lot farther than the standard 6 ft. from computer graphics card to monitor. They allow the video signal to be split to both a local monitor and to a projector or presentation display without loss in image quality on either device. And they provide the right connector for the right device; display devices rely on BNC connectors, but computers use either 15-pin HD, D-sub, or 13W3 connectors.

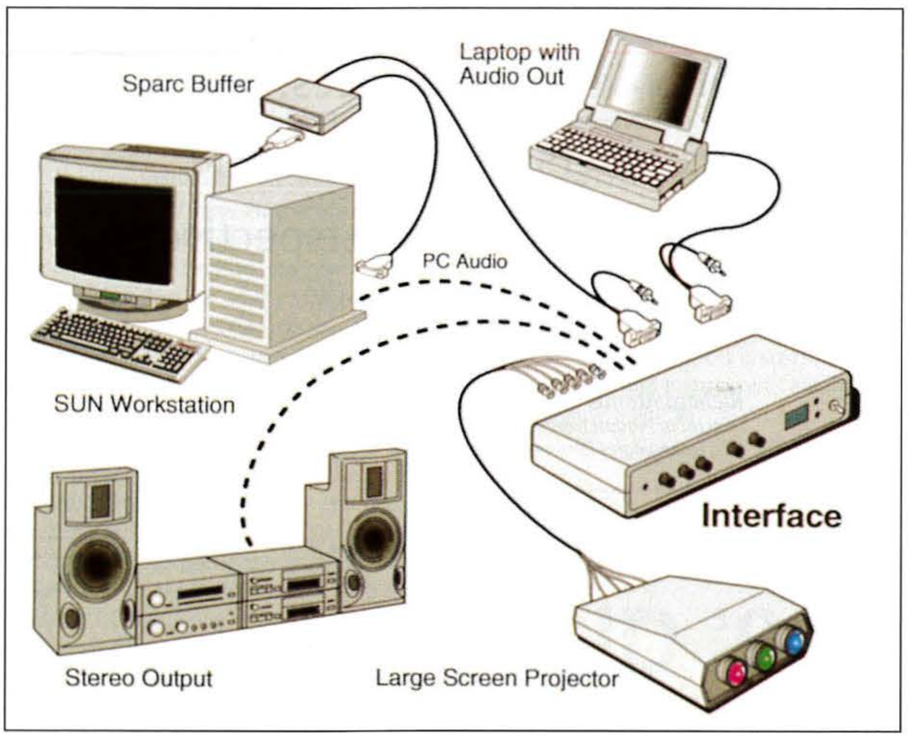

Fig. 1: *An interface is used to provide compatibility between computers and display devices, such as the Sun Workstation and a laptop connected to a large-screen projector. Some models can also provide audio interfacing as well.*

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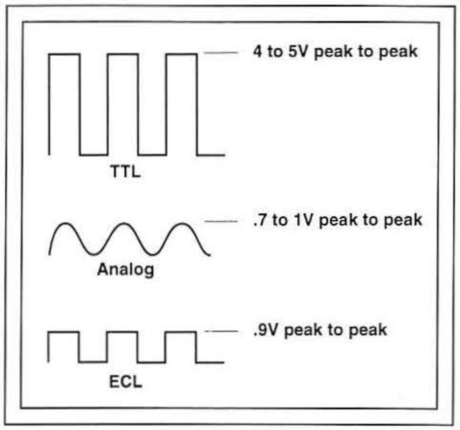

Fig. 2: *Analog signals have an infinite number of values, but digital signals, such as ECL and TTL, consist of changes or "pulses" that have a waveform corresponding to an ON and an OFF state.*

In doing so, interfaces provide compatibility with all other devices used in the system, such as switchers, line doublers, and distribution amplifiers.

Video Signals

Before we can understand what is entailed in translating computer video to a signal suitable for large-venue displays, we need to review the principles of a video signal. Basically, it is an electronic signal that produces a picture when inputted into a display device. This signal contains all the information concerning color, brightness, and sync. The sync information is conveyed as a series of timing pulses.

Unlike conventional TV signals, the signals generated by a typical computer-graphics adapter do not conform to rigid standards. They loosely correspond to varying resolutions and scan rates. And while conventional video signals are analog (though that is changing with the advent of HDTV), computer signals may be either analog or digital.

There are three kinds of computer-video signals: emitter coupled logic (ECL), transistor-transistor logic (TTL), and analog (Fig. 2). ECL signals use a video level of 0.9 V peak to peak (usually a negative voltage) for high to extremely high resolutions. Sun Microsystems monochrome workstations and Xerox 6085 and IBM 3477 machines all use ECL. Like all digital signals, ECL has only two possible states of waveform operation - ON or OFF - and has a distance limitation of 3–6 ft. of cable.

TTL, another digital signal, also has only ON and OFF states and a transmission distance limit of no more than 10 ft. It has a video level of 4–5 V peak to peak and is used with low-to-medium resolution levels like those used by CGA, EGA, Mac SE, and Mac classic computers.

Analog signals are by definition completely different from ECL and TTL because their waveforms have infinitely variable levels, not just ON or OFF. Almost all computers on the market today use analog signals. These signals have voltage levels of 0.7–1.0 V.

Video and Sync Formats

There is a lot of information in a typical color image, and the video-signal format is the physical means by which that information is transferred to the display. Any loss of the original information, or the introduction of unwanted additional information, can impact the image quality in terms of sharpness, color reproduction, or picture jitter. The ability of all devices to work with the video-signal format determines system integration and compatibility.

An analog format based on separate red, green, blue, horizontal-sync, and vertical-sync

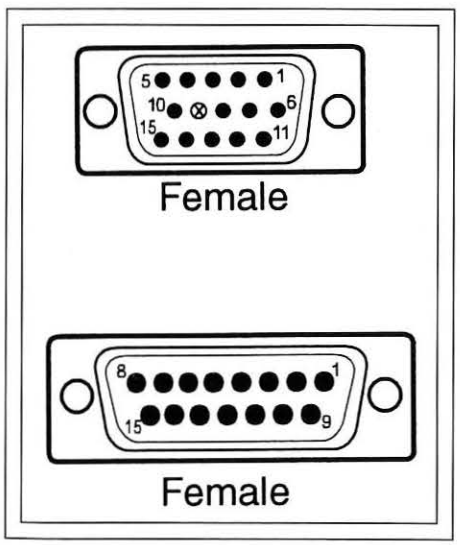

Fig. 3: *Although both PC "HD" (top) and Mac "D" (bottom) connectors use 15 pins, they are arranged in different configurations.*

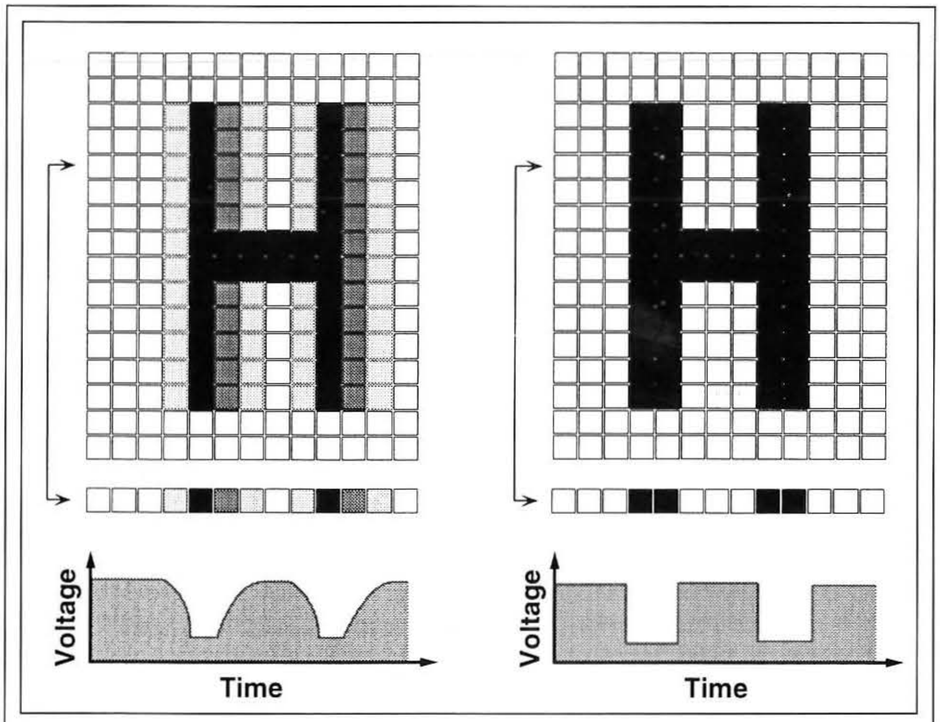

Fig. 4: *Inadequate bandwidth can result in loss of image quality (left) compared with sufficient bandwidth (right). The fuzzy pixels in the leading and trailing edges of the character are caused by gradual transitions between ON and OFF, while a sharp transition results in a crisp image.*

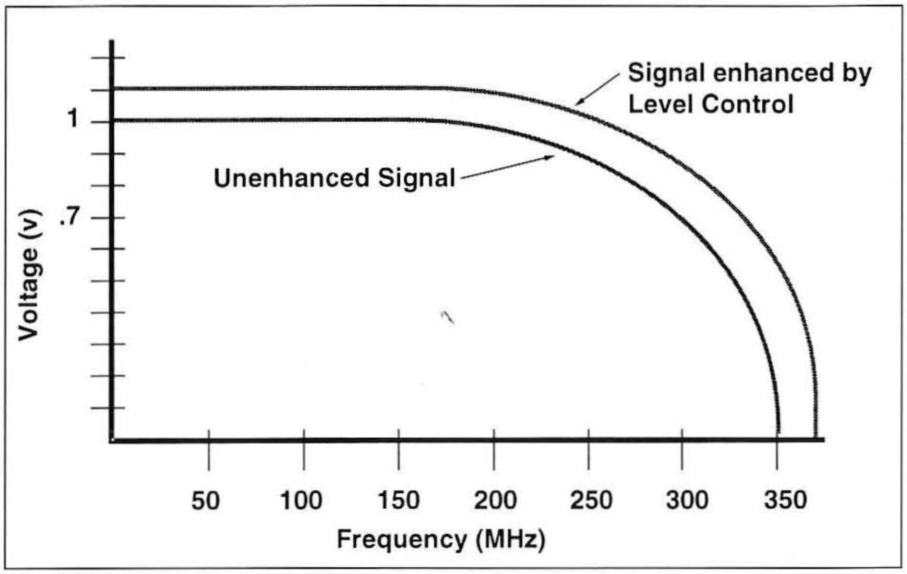

Fig. 5: Level or brightness control boosts the voltage of the entire video signal. This can compensate for loss of signal due to cable resistance over long runs. The goal of level control in an interface is to maintain signal resolution and integrity.

signals (RGBHV) is widely considered the best possible choice. All the basic elements of video are transferred individually, so no encoding or decoding is required. Moreover, computer-graphics adapters of VGA resolution or higher create RGBHV signals; it's just a matter of getting this format to the display device using the appropriate connectors.

RGBS is the next best format - one rung down on the video ladder (or video "food chain" as it is often referred to) from RGBHV. RGBS is the most common of the computer-video distribution formats. Instead of having their own separate signals, both the horizontal- and vertical-sync information is included in one composite wire (S). This approach can cause problems with some liquid-crystal displays (LCDs) and digital-light-processing (DLP) displays. Some line doublers and quadruplers use RGBS, which is why interfaces are sometimes needed when connecting line multipliers to digital displays.

RGsB is another commonly used signal that contains no separate sync conductor. All sync information is carried on the green channel along with the green-signal information. This format, a 0.3-V analog signal, is used by Sun Microsystems and in some Silicon Graphics computers. Many display devices - especially digital devices, such as LCDs, DLP projectors, and plasma panels - require RGBHV or RGBS formats, so an interface may be required to convert RGsB signals to RGBS or RGBHV.

Interfaces can also convert RsGsBs. This format is one step down from RGsB on the video food chain. RsGsBs signals contain sync in three separate wires, each of which also contains the R, G, or B signal. It is used in some Silicon Graphics machines and a few high-end specialty systems. RsGsBs is not nearly as universally accepted as the other formats we have talked about so far.

The only difference between these formats is the way sync information is handled. Before examining different types of sync formats within video signals, sync should be defined more precisely. This information provides a means of timing the video signals with pulses; by synchronizing the timing of different components of the image information, the imaging process occurs correctly and the desired image on the screen is obtained. This can have different implications, depending on the display device.

For CRT devices such as TV sets or computer monitors, timing pulses control the movement of the electron beam on the raster, signaling when the beam is to start drawing the next horizontal line and when it is to move back to the top of the screen to start creating the next image. This movement must be highly coordinated and precise within fractions of a microsecond; any error can result in a poor-quality image.

What does that mean in terms of interfacing? It means that the device receiving an RsGsBs or RGsB signal must perform what is called "sync stripping." This process converts the 0.3-V peak-to-peak analog-sync level to a TTL-level sync signal that is no longer carried in the R, G, or B channels but on its own H and V (or composite sync) wires. Some display devices can strip sync on their own, but others require an interface to produce a stable image.

Interfaces are also needed to adjust for differences in sync polarities. Sync polarities distinguish resolution modes, so it is essential that they be compatible between the computer and display device. Digital devices use polarities to determine the mode of VGA, for example. There are four possible modes of sync polarity: ++, −+, +−, and −−, where each polarity designation "+" or "−" corresponds to H and V, *e.g.*, −+ is a negative horizontal and positive vertical sync. Some devices cannot accept positive sync, so it is important for interfaces to have the capability to output only negative sync for these displays.

ID Bits and Termination

Interfaces serve another important purpose: to provide proper termination for computer sense lines. Many computers look for two types of termination: 75-Ω resistance of the local monitor load, providing video termination, and ID-bit termination for identification of the specific monitor type. Many computers will not even output a video signal unless both types of termination are present. The 75-Ω video termination of local monitors provides a load that absorbs the signal energy and prevents it from reflecting back to the source, where it could degrade the displayed image in the form of ghosting.

Correct termination is especially critical when using a computer with a large screen without a local computer monitor. Without proper termination, no ID bit may be detected by the computer and there may be an error at start-up. This may result in the computer's booting up at a minimum resolution or possibly failing to output any video signal at all.

ID bits are also called "mode" or "sense" lines. These lines are passed through either three or four pins on the video-output connector which are specifically reserved for monitor

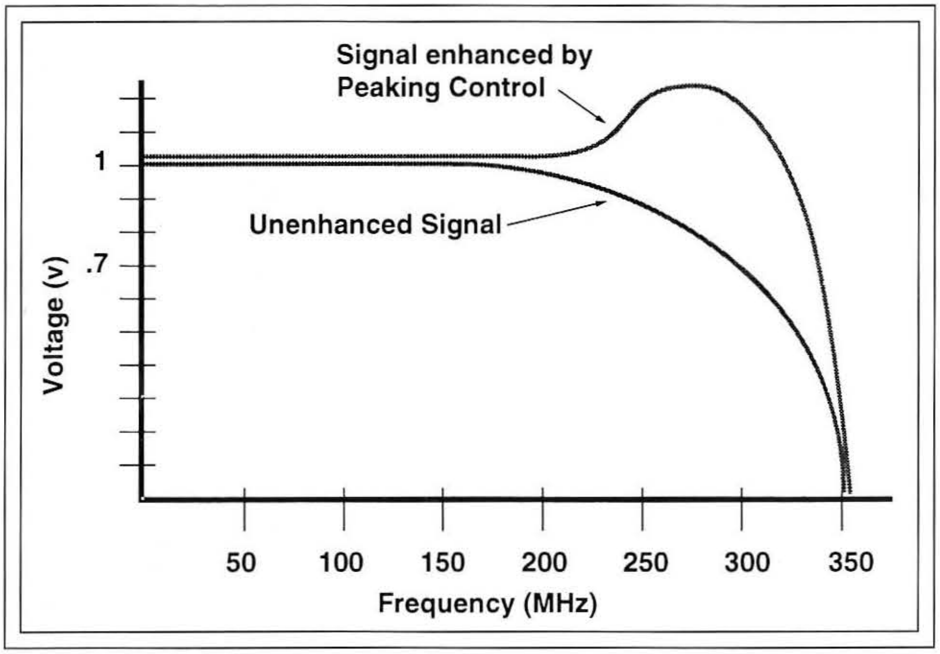

Fig. 6: Peaking or sharpness control increases the voltage at high frequencies, and is often used with long cable runs. This compensates for cable capacitance, which tends to clip the voltage at high frequencies, resulting in a fuzzy image.

identification. The computer also detects ground on certain pins and determines its output resolution, depending on which pins are grounded. When it comes to which pins carry this information (or, for that matter, the type of computer-video connector), there is little standardization among the various computer manufacturers.

For example, Macintosh computers use a different connector and different pins for ID bits than Windows-based PCs; even though both PC and Mac connectors use 15 pins, they are arranged in different configurations (Fig. 3). In the case of an Apple computer, the ID bits are pins 4, 7, and 10. If pin 4 is shorted to ground internally in the Apple monitor, then at bootup the computer would determine that a 13-in. color monitor was hooked up to it.

ID-bit format differs from manufacturer to manufacturer, but the pin configurations tend to be consistent in all systems of a given brand. When one type of monitor is hooked up to a different type of computer using an adapter cable, however, problems may be encountered. The computer looks to the monitor for its ID-bit termination, but may not recognize a different brand of monitor. In order to function properly, a Mac-to-PC adapter – such as those manufactured by Extron Electronics – must have all the dip switches necessary to simulate monitor identification.

Many interfaces ignore ID-bit termination. Some offer a termination switch that provides video termination only. ID bits do not travel to the interface but pass directly to the monitor; ID bit is a protocol between a computer monitor and a computer only. For this reason, some interfaces provide termination adapters that connect to the local monitor. Other interfaces provide auto termination, which limits their compatibility to only one type of computer video because they will only terminate a specific range of frequencies.

Video Resolution and Frequency

Most computer-video systems produce a variety of specific resolutions and frequencies, so any given display device must be able to handle a range of signals. In order for these images to appear on the screen correctly, the display must have operating parameters that are compatible with the computer's signal.

Resolution refers to how many pixels are generated to create an image, and is expressed as the quantity of pixels running horizontally across the screen multiplied by how many horizontal lines are displayed. For example, 800 × 600 is a common computer resolution often referred to as SVGA. A display device that is not capable of displaying at least 480,000 pixels in a 4:3 aspect ratio will not be able to display such an image.

Frequency refers to how many times per second the image is created on the screen. The horizontal frequency defines how often the horizontal lines are drawn on the display device; at a frequency of 48.1 kHz, 48,100 lines are drawn in 1 sec. This means one line is drawn in 20.8 μsec. If the display device is unable to draw lines at this rate, it cannot produce a stable image at 48.1 kHz. The vertical scan frequency – also called the refresh rate – refers to how often the entire image is drawn, and is directly related to the horizontal frequency and the number of horizontal lines in the image.

Unfortunately, interfaces can do absolutely nothing about incompatibilities of this type. Interfaces can change formats, voltages, and polarities but they do not do anything to the resolution or frequency. To handle this type of problem, one must resort to a scan converter or similar device.

Video Bandwidth

Assuming an interface provides all the necessities to make a stable image on the display device, there is one other specification to consider: bandwidth. This is essentially a measure of the rate at which information must be transmitted to create the image. The bandwidth of a video source is determined by multiplying the total number of pixels (resolution) by the refresh rate, halving the product, and multiplying it by a factor of 3. For example, a laptop running 1024 × 768 video at 60 Hz would have a bandwidth calculated as follows:

$$[(1024 \times 768)(60 \text{ Hz})/2] \times 3 = 70.8 \text{ MHz}.$$

A component's specified bandwidth indicates the frequency range in which it will operate faithfully. If the bandwidth is not high enough, image information will be lost, possibly resulting in visible degradation of the image quality. So even if an interface provides all the other critical factors in getting the video signal to the display device, if it does not have sufficient bandwidth then the resulting picture may not be optimal.

The rule of thumb for component bandwidth is to use products that have a bandwidth at least two to three times greater than that of

Extron, Inc.

Fig. 7: A universal interface – such as Extron's RGB 202xi – is designed to be used with many types of computer signals and cabling. Some universal interfaces, including the RGB 202xi, are also good for solving sync problems.

the source. For example, if the computer has a video bandwidth of 100 MHz (-3 dB), it would be prudent to use an interface with at least 200 MHz (-3 dB) of video bandwidth. The interface should ideally have peaking and level controls to help compensate for bandwidth loss. Depending on factors including the system, the cable length, and the application the interface is being used in, this loss can be considerable. Generally, the more components used in the system, the greater the bandwidth loss.

What happens when proper bandwidth is not maintained in a system? For one thing, black-to-white transitions are lost to some degree (Fig. 4). There is also a loss in the high frequencies and a loss of vertical sharpness and detail. In other words, the video signal is compromised.

Connectors and Buffering

One of the major roles played by an interface is to connect the computer to both its local monitor and another display device. With different connectors for signal input (such as 15-pin VGA) and output (such as BNC coaxial connectors), an interface can physically match the computer connector to the display device.

In addition to this mechanical physical connection, an interface must also isolate, or buffer, a computer's local monitor from the presentation display so that proper termination is maintained. By buffering the computer from the local monitor, the interface prevents impedance mismatches so that the computer sees the expected 75-Ω impedance and outputs maximum power.

Of course, interfacing is not all about the computer. Interfaces also convert the video signal to a level acceptable to the display. Video-enhancement features on the interface, such as level and peaking controls, can improve the video signal and compensate for limitations of the presentation device. These controls also enable the use of longer cable runs so that the display can be located at a distance from the interface and the computer.

Level controls can be used to increase the signal voltage so that it can travel longer distances and withstand resistance in the system (Fig. 5). Some interfaces have a "step" level control that boosts the signal in increments. Others have a continuous control so the user can fine tune the level more precisely. In either case, the level is analogous to a brightness control, in which brightness increases as a function of voltage.

Peaking (or sharpness) control, on the other hand, is used to sharpen the edge of vertical lines of the picture. Peaking increases voltage only in the high-frequency range (Fig. 6), in contrast to a level control that boosts the voltage of the entire signal. Both of these controls can be used to compensate for signal loss like that of long cable runs or routing through multiple products. Although many other factors are involved, a simplified explanation is that peaking compensates for signal loss due to capacitance and level compensates for loss due to resistance.

Dedicated *versus* Universal

Interfaces can be divided into two groups: dedicated and universal. Dedicated interfaces work with only one computer or graphics-card type. For example, Extron's RGB 109 PLUS, a dedicated VGA, SVGA, XGA, VESA, and XGA-2 interface, includes a monitor breakout cable for connection to compatible monitors. Dedicated interfaces tend to have the highest bandwidth, work best in permanent installations, cost less, and are easier to use because they tend to have fewer controls and options than universal interfaces. Universal models are generally recommended for rental applications or if several different types of computers are intended for use with an interface.

Conversely, universal interfaces – such as Extron's RGB 202xi – are designed to be used with many types of computer signals (Fig. 7). They tend to have more controls than dedicated interfaces. This is necessary to allow users to select the type of cabling required since it can be used with many types of computer-video systems.

The RGB 202xi and some other universal interfaces are also good for solving sync problems due to the way they process sync. This is especially useful when routing video signals to various display devices, including plasma, DLP, CRT – and even LCD devices, which are notorious for sync incompatibilities. The RGB 202xi gets around these incompatibilities with an approach that Extron calls Digital Display Sync Processing (DDSP) technology, which also is available on several of Extron's other universal interfaces.

There are many more details about interfacing that are important to consider when purchasing a model. How will it be mounted? Will more than one computer be using the interface? If so, the interface should have the option to make connections at the front panel.

Just as one must carefully match the presentation device to the intended audience, the type of information to be displayed, and the physical environment where it will be used, one must consider a range of features when selecting an interface. These products cover a variety of choices; the computer can create powerful images to convey messages, but it takes the right interface to safely deliver the image information from the computer to the screen. ■

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Circle no. 14

How to Select a Flat-Panel Display

Selecting the best display for an application is a complicated and not entirely objective process, but here's a way to account for the important parameters while putting everybody's biases on the table.

by Tom Holzel

As MANUFACTURERS DISCOVER the advantages of incorporating flat-panel displays (FPDs) into more and more of their devices, it is becoming increasingly difficult to figure out which displays are best suited for them. Automobiles are moving from simple vacuum fluorescent displays (VFDs) to high-information-content active-matrix liquid-crystal displays (AMLCDs). Oscilloscopes are moving from monochrome line displays to shaded color displays. Even household appliances - which used to be satisfied with an on-off light - are beginning to adopt FPDs to advise users of the status of their inner workings.

With more new display technologies being offered, and even more promised, the choice of which flat panel to use can be quite bewildering. How can a system manufacturer decide?

Theoretically, a manufacturer should be able to decide which display to incorporate into his product merely by comparing specifications. But "specsmanship" - describing a product's virtues without even hinting at any faults - has reached the realm of high art. This makes comparison of specifications very difficult. And one can be seduced by appearances. A beautiful display that cannot stand the temperature range required by its host product cannot be considered, no matter how glamorous it makes the product look in a heated showroom.

Is there a quantitative method for comparing the important features of the various display technologies such that one can rank them for suitability to a specific task? We are about to describe such a method. The examples used here are for generic displays and generic applications, so the reader is warned to read with the aim of understanding the rationale of the model - and then applying it to his or her own version. *There is no such thing as a generic solution to a specific problem.* If an oscilloscope is being built, it will have specific attributes, such as whether or not it is rack-mounted, bench-seated, or now even handheld.

This specificity impacts, among other things, the value that must be placed on viewing angle. A rack-mounted oscilloscope requires the widest possible viewing angle; it may be mounted high or low in the rack, and will always be off center to the viewer. A portable oscilloscope can be swung around on the bench somewhat to reduce acute viewing angle, while a handheld unit will always be held directly facing the user. So, in this example, suitable display types would be a cathode-ray tube (CRT), an electroluminescent (EL) display, or a field-emitter display

Table 1: Relative Value of Display Characteristics
(Generic Values in Arbitrary Units)

	Low Cost	Brightness	Temperature	Speed	Viewing Angle	Picture Quality	Life	Low Power
STN	7	2	3	3	3	1	8	10
AMLCD	4	4	5	7	6	10	8	6
EL	2	3	10	10	10	5	10	2
FED	3	5	10	10	10	10	4	4

Table 2: Display Performance Requirements by Application

	Low Cost	Brightness	Temperature	Speed	Viewing Angle	Picture Quality	Life	Low Power
Oscilloscope	5	5	1	10	7	5	10	2
PDA	10	2	4	1	1	1	5	10
TV/Video	8	8	2	10	8	10	8	8
Laptop	7	3	3	5	1	10	5	6

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(FED) for the rack-mount, an AMLCD for the bench-mount, and possibly a supertwisted-nematic LCD (STN-LCD) for the handheld – with each subsequent display type exhibiting ever less viewing angle.

Of course, there are more factors to a display than its viewing angles. The marketing manager of each product line will have to determine all the specific display requirements of his or her electronic product. This evaluation will always be somewhat subjective, but at least it can be quantifiably subjective. (As one looks at the examples, one may be able to detect my biases.) Here is how a model can be created.

Table 1 is a rating system in arbitrary units of the comparative evaluation of different display characteristics. The STN-LCD is rated 7 in terms of its low cost, while EL is rated 2, *i.e.,* the EL is not as low in cost as the STN-LCD. Again, this is a generic model for illustrative purposes only. Versions of the displays in each category can be found that exceed the rankings used here. But when such a version is found, it may fall lower in other ratings.

Table 2 rates how important these same display characteristics are in the devices listed. A display in an oscilloscope need not be the cheapest, so we rate it a 5. But, as a consumer device, a personal-digital-assistant (PDA) display must be exceptionally inexpensive, thus the 10 rating. Now for the quantification.

Table 3 shows the product of each display type and each device. The STN's 7 rating on low cost multiplied by the 5 rating of the oscilloscope's price sensitivity equals a rating of 35.

The highest-rated display type for this application, given the above value system, is the EL. Its long life (oscilloscopes are often left on 24 hours a day) and fast response ("speed") are deciding factors in this example. If, however, a manufacturer wanted to include 8-bit gray scale, that would knock EL out of the box.

Low price and low power are the key elements to the STN's "winning" the PDA category, for which no amount of picture quality or viewing angle will compensate (Table 4).

For TV/video, a key element is the combination of picture quality and video speed (Table 5). Here the FED is the winner, with AMLCD creeping up, so the most accurate determination of actual specifications will be necessary to assure an accurate result.

The surprise of this exercise was the laptop result (Table 6). The author was sure the FED would be the winner, but, lo and behold, the AMLCD ekes out a victory here. This may be because the AMLCD is, in the final analysis, entirely driven by laptop needs, and its development reflects those needs. What are they? Indoor use (low ambient light and moderate temperatures); single-user (narrow viewing angle OK); high picture quality (resolution, in this case); and no real requirement for video speed.

Obviously, this model lacks the degree of sophistication a genuine utility analysis would require. Indeed, one could envision a linked spreadsheet in which each cell shown here is the sum of numerous sub-elements. Thus, the Picture Quality cell might be the result of a spreadsheet that rated color rendition, gray scale, and resolution.

The important thing is always to compare actual displays in actual products used in real-world settings. *Remember, there is no generic solution to anything.* ■

Table 3: Oscilloscope "Utility"

	Low Cost	Brightness	Temperature	Speed	Viewing Angle	Picture Quality	Life	Low Power	Total
STN	35	10	3	30	21	5	80	20	204
AMLCD	20	20	5	70	42	50	80	12	299
EL	**10**	**15**	**10**	**100**	**70**	**25**	**100**	**4**	**334**
FED	15	25	10	100	70	50	40	8	318

Table 4: PDA "Utility"

	Low Cost	Brightness	Temperature	Speed	Viewing Angle	Picture Quality	Life	Low Power	Total
STN	**70**	**4**	**12**	**3**	**3**	**1**	**40**	**100**	**233**
AMLCD	40	8	20	7	6	10	40	60	191
EL	20	6	40	10	10	5	50	20	161
FED	30	10	40	10	10	10	20	40	170

Table 5: TV/Video "Utility"

	Low Cost	Brightness	Temperature	Speed	Viewing Angle	Picture Quality	Life	Low Power	Total
STN	56	16	6	30	24	10	64	80	286
AMLCD	32	32	10	70	48	100	64	48	404
EL	16	24	20	100	80	50	80	16	386
FED	**24**	**40**	**20**	**100**	**80**	**100**	**32**	**32**	**428**

Table 6: Laptop "Utility"

	Low Cost	Brightness	Temperature	Speed	Viewing Angle	Picture Quality	Life	Low Power	Total
STN	49	6	9	15	3	10	40	60	192
AMLCD	**28**	**12**	**15**	**35**	**6**	**100**	**40**	**36**	**272**
EL	14	9	30	50	10	50	50	12	225
FED	21	15	30	50	10	100	20	24	270

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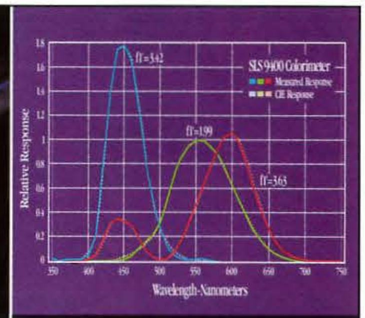

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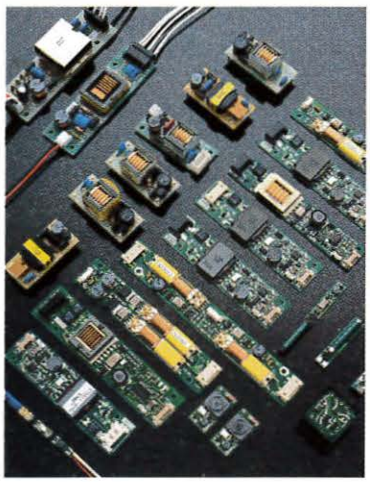

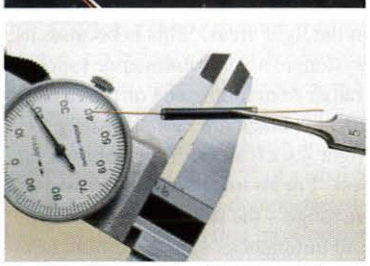

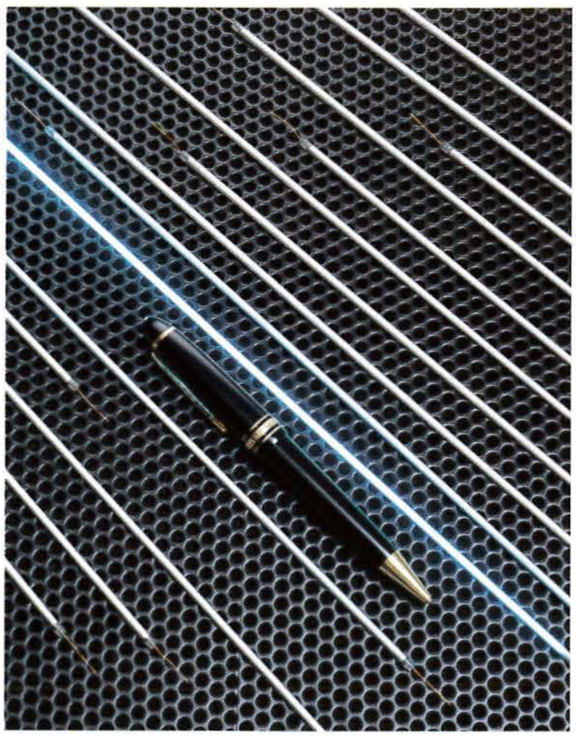

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Seeing Through Screen Reflection

Reflected light compromises image quality because it reduces image contrast – but a better understanding of reflected light is giving us new tools for improving the images we see.

by Michael H. Brill

IDEALLY, displays should be virtual "windows on the world," in which every visually accessible event in a scene is recorded and portrayed faithfully. But this ideal is compromised by screen reflection, the effects of which can be seen by turning on the lights in a dark room and watching the details vanish in the dark areas of a displayed image.

Reflections from a screen depend not only upon ambient light, but also upon the propensity of the screen to reflect this light - referred to as reflectance. In general, reflectance is a complicated function of lighting and viewing geometry, and also has wavelength dependence. This subtlety makes measurement and physical understanding of reflectance a challenge.

Kelley, Jones, and Germer[1] have developed a convincing model that divides reflectance into three components. This simplification opens the way to efficient measurements that separate the components and promise improvements in the visibility of images.

What Is Screen Reflection?

Kelley, Jones, and Germer[2] separate screen reflectance into three parts: specular, diffuse, and haze. Holding a pen-light near a screen in a dark room will show all the components. The specular reflection produces a clear image of the source which gets smaller as the pen-light is moved away but remains constant in luminance. The diffuse (Lambertian) reflection covers the whole screen, and captures none of the geometric features of the source, nor can one tell the direction of the source by moving one's head while looking at the screen. Finally, the haze reflection appears as a blurry image near where the specular reflection is seen, but the size of the haze ball increases and its luminance decreases as the light source is moved away from the screen.

Because display screens have two distinct surfaces (outer and inner), it is tempting to ascribe each of Kelley's reflection components to one of the surfaces: the specular component to the smooth first surface of the faceplate glass; the haze to the internal surface, which is roughened from irregular contact with the light-emitting elements (such as the phosphors); and the diffuse (Lambertian) contribution to the light-emitting elements themselves.

Although these ascriptions are accurate as far as they go, there is also a substantial haze component from the first surface of the faceplate. This can be seen by holding a pen-light at an angle and moving it away from the screen. The virtual image of the light gets smaller but stays just as luminous; there are also two diffuse balls of light (haze) that get larger and dimmer, each coming from one of the surfaces of the faceplate glass. Because of the thickness of the glass, the two haze components are displaced from one another.

One can understand the difference between specular reflection and haze purely on a geometric basis, without recourse to physical optics. We can idealize a reflecting surface as a set of flat reflecting mirrors - the "broken-mirror model."[3] Suppose there is a point source of light whose reflected image in the broken mirror is seen by the eye. If the facets of the broken mirror make images on the retina that are large compared with the eye's photoreceptor spacing, then each receptor tends to see a specular return from a single facet, and the eye as a whole sees a specular reflection. If the facet images are small compared to the receptor spacing, then each receptor sees light from more than one facet, and the result is a haze component of reflection. From this picture, the distance and image-forming characteristics of the haze and specular components can be readily reconstructed.

How Reflection Affects Screen Image

If an image is viewed on a display screen under substantial ambient illumination, the dark areas of the image appear more washed out than the light areas. This is because the visual system evaluates luminance ratios (contrasts) rather than luminance differences, and contrasts near black are more sensitive to added light - such as the light from screen reflection. For an image with a particular dynamic range - the ratio of maximum to minimum luminances - the minimum luminance must be set to a value greater than the

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__Robert Glittone__ and __John Leachtenauer__ of NIMA, and __Dennis Bechis, William Murray, Walter Paul, Jeff Johnson,__ and __Jeff Lubin__ of NIDL offered valuable technical help in the preparation of this article.

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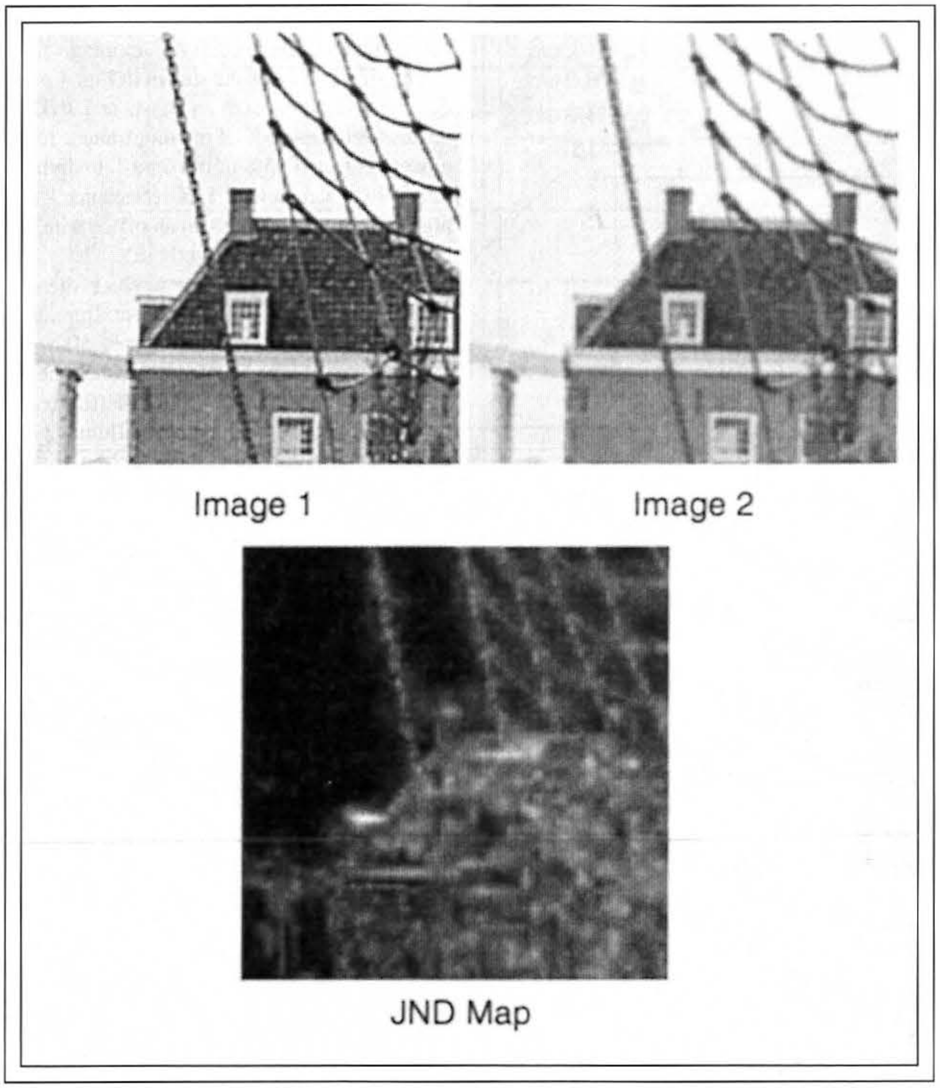


***Fig. 1:** Images 1 and 2 provide sample inputs to the Sarnoff JND Vision Model, which generates the accompanying output JND map. The unit of the map, 1 JND, is a visual stimulus difference seen by observers 75% of the time. The JND map is useful because it shows not only the magnitude, but also the position of noticeable differences between the two input images.*

expected ambient reflected light so that the lowest gray levels can still be discriminated from each other.

How much of a dynamic range would constitute a perfect "window on the world"? The answer is surprisingly large. Within a single image, small luminance differences can be discriminated within areas differing by factors from 10^4 to 10^5, so long as these areas are separated by more than about 5° of visual angle. This remarkable fact was demonstrated by J. J. Vos,[4] who concluded that intra-ocular light scatter, not retinal desensitization, reduces the visibility of dark image areas next to bright ones. E. F. Kelley[5] confirmed this with a demonstration that can easily be performed with a step wedge of neutral-density filters in front of a light box. If the light box is viewed in a dark room, all the steps in the wedge can be seen, from brightest to dimmest. Even the image of the lamp filament can be seen through the brightest part of the wedge.

These striking results depend on the fact that the eye has remarkably little intra-ocular scatter. This is because the optical elements in the eye are made of clear fluids of comparable refractive index - there is only one liquid/air interface, unlike that in a camera. Kelley noted that the eye is for this reason far superior to a camera in preserving image contrast - and also in revealing the loss of contrast that is due to screen reflection. The eye does not forgive what a measuring system may overlook.

Visual Contrast Sensitivity

How can visual sensitivity to contrast be quantified and measured? Typically, the core measurement is the contrast of a sine-wave pattern that can just barely be detected by human subjects. The sine-wave luminance pattern has the form

$$L(x,y) = L_0[1 + C_m \sin(2\pi f x)], \qquad (1)$$

where x and y are screen coordinates, L_0 is the mean luminance (in cd/m^2), f is the spatial frequency of the pattern, and C_m is the Michelson contrast. For any pattern (not just for sine waves), the Michelson contrast is defined as $C_m = (L_{max} - L_{min})/(L_{max} + L_{min})$, where L_{max} and L_{min} are the maximum and minimum luminances in the pattern. Using the sine-wave pattern, Van Nes and Bouman[6] found experimental values of just-detectable C_m for various values of L_0 and f.

The just-detectable contrast is described more generically as a just-noticeable difference (JND), and is predicted accurately by the Sarnoff JND Vision Model.[7] The Sarnoff model is a fast computational method for predicting the perceptual ratings that human subjects will assign to a degraded image relative to its nondegraded counterpart. The differences are quantified in units of the modeled human JND of local image contrast, and often presented in an output JND map (Fig. 1).

Predicted values from the Sarnoff model agree with the contrast-sensitivity data of Van Nes and Bouman over a wide range of luminances, and also over several spatial frequencies (4, 8, and 16 cycles/degree) of the sine-wave stimulus (Fig. 2).

Visual Impact of Screen Reflection

Low screen reflectance helps image visibility in any viewing environment. Even in a dark room, objects such as shirts and walls can be illuminated by the display and reflect light back onto the screen.

It might seem that the peak luminance of a display does not matter above 100 cd/m^2

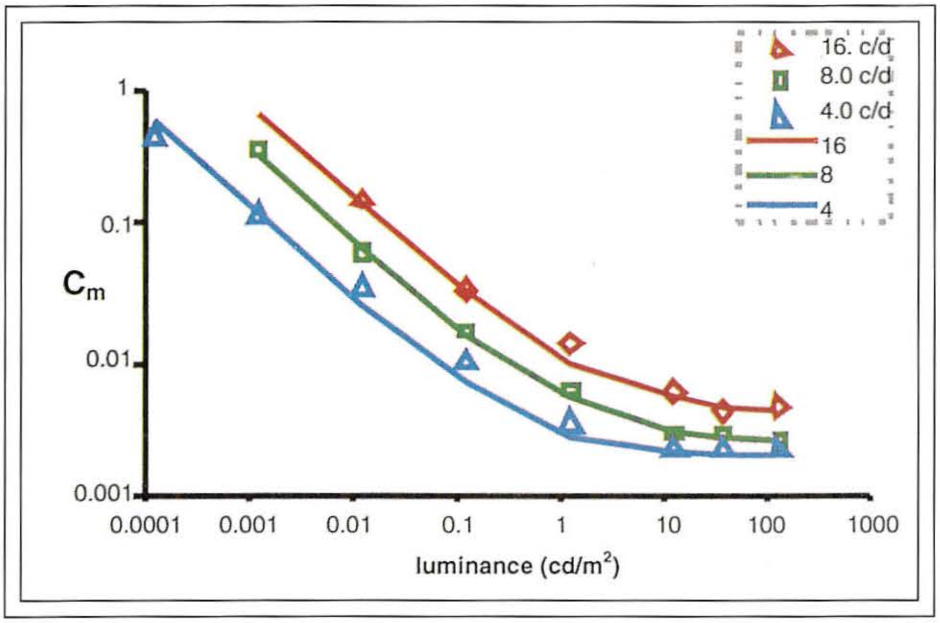


Fig. 2: The output of the JND model (solid curves) agrees with sine-wave contrast-detection data (point graphics). (Corrected from 2 to 3-mm pupil diameter.)

because the curves in Fig. 2 become horizontal at this value. But this is true only when the image activity is near the peak level. A typical image has significant information in the lowest 10% of its dynamic range, and this information - particularly fine spatial detail - is made more visible by increasing the peak luminance well above 100 cd/m^2.

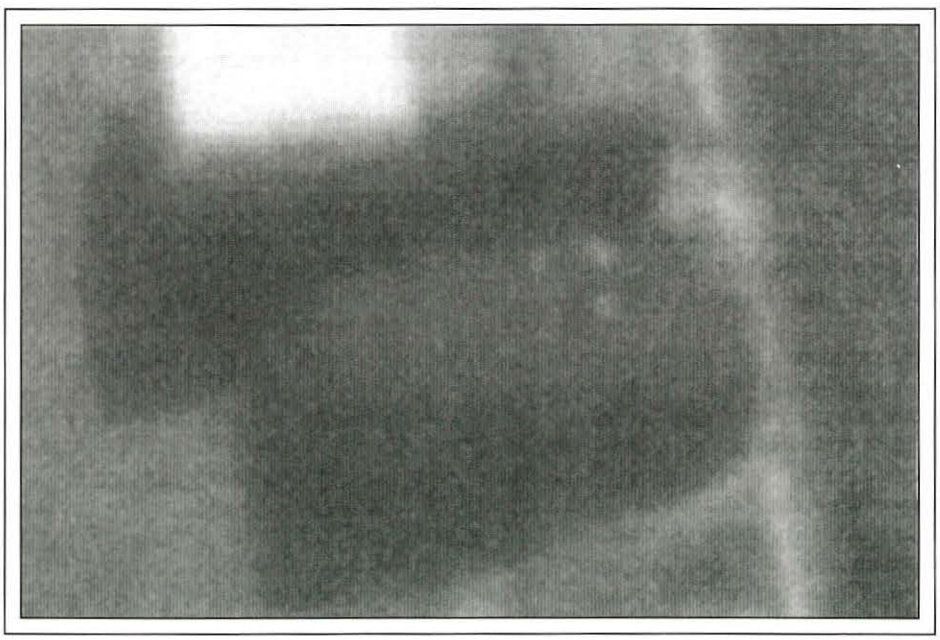
A recent simulation performed by the National Information Display Laboratory (NIDL) offers additional insight. The NIDL used the Sarnoff vision model to evaluate the conspicuousness of critical image features as seen with different display technologies. The features were chosen to be "typical but stressful," *i.e.*, subtle variations in the dark regions of the image (Fig. 3). The display technology - primarily black-level luminance, peak luminance, and spot size - was simulated, starting with an oversampled image. To evaluate the display, digital test images with and without critical features were processed into oversampled luminance maps, and then compared by the Sarnoff vision model to produce the JND metric. The larger the value of the metric, the more conspicuous the feature. In Fig. 3, the original image size was 180 × 120, the pixel size was 10 mils, and the assumed viewing distance was 7.2 in.

One can begin to estimate the effect of the black-level luminance - produced in part by screen reflectance - by a simple calculation. At zero black level, the luminance of the chosen feature in Fig. 3 varies from 8 to 11.6% of peak. This implies that the Michelson contrast of the feature is significantly reduced when the black level is increased to more than about 10% of the peak. This contrast reduction can impair the visibility of an image.

The simulation results shown in Fig. 4 predict the visual impact in JND, where 1 JND means "detected 75% of the time" and 2 JND means "detected 95% of the time." Imagine a Lambertian screen with 15% reflectance - a high but common value - in an office with an illumination of 70 fC (brightly lit). The reflected luminance from the screen is then 10.5 fL, or 36 cd/m^2. This ambient illumination will produce the visual response of the lowest curve in Fig. 4. However, when the screen reflectance is reduced to 5% (for example, by a faceplate) and the room illumination is reduced threefold (for example, by a window shade), the visual sensitivity follows the middle curve. Finally, if the window shade is completely closed so as to further reduce the light by a factor of 10, no visual impairment is experienced due to the ambient light, as can be seen from the top curve. It is imperative, therefore, that softcopy displays for image exploitation be utilized in environments with the lowest possible ambient illumination.

Managing Screen Reflection

When one has no control over ambient illumination, one can reduce the reflection by decreasing the screen reflectance through an absorptive faceplate. A faceplate absorbs the



NIDL

Fig. 3: This sub-image is of a flatbed truck. The "typical-but-stressful" feature to be detected is the boundary between the cab and flat bed on the dark truck.

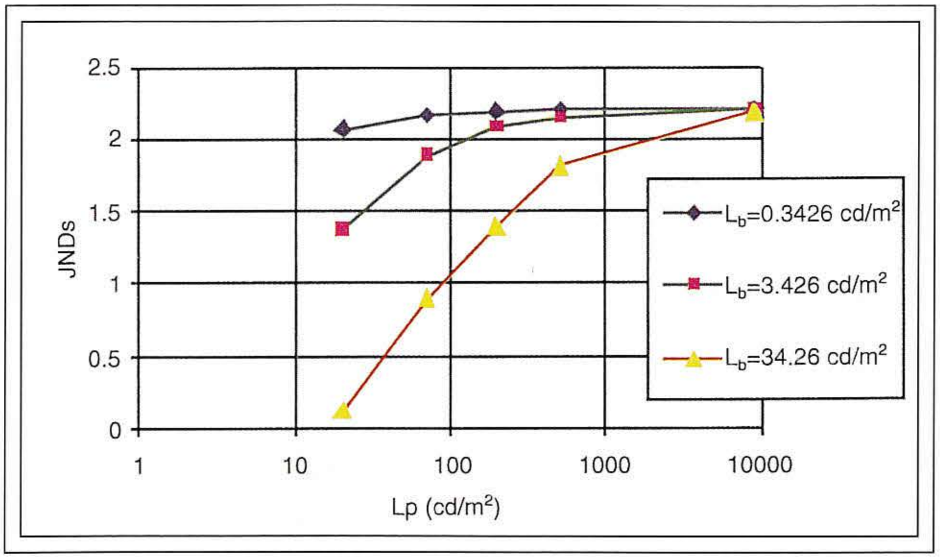


Fig. 4: *The effect of peak luminance (L_p) and black luminance (L_b) on visibility of feature is shown. The spot size is held constant at 10 mils.*

light from the screen only once on the way to the viewer, but absorbs light from the outside twice – once on the way in and once on the way out. Of course, there are limits to the advantage conferred by increasing the absorption of the faceplate:

- ***Vision-imposed limit.*** Vision is less sensitive at lower light levels, especially to fine spatial detail. If the faceplate absorption is very high, key information in an image will not be perceived if its luminance range is lower than the threshold at which the human visual system is unimpaired, about 30 cd/m^2.
- ***Reflected light that does not pass through the plate.*** There is a luminance floor set by ambient light that undergoes first-surface reflection from the faceplate. This light is unaffected by the faceplate absorption, competes with the light from the phosphors, and reduces dynamic range. Antireflection coatings on the faceplate can reduce this unwanted light considerably (from about 4% to 0.25–0.5%), but it is never absent.

Assuming that the screen is lit from all angles, the transmittance T_p of a neutral-density (gray) faceplate giving the maximum image contrast can be shown to be

$$T_p = (R_p/R_S)^{0.5}, \qquad (2)$$

where R_p is the reflectance of the faceplate and R_S is the reflectance of the screen without the faceplate. Thus, if $R_S = 0.4$ and $R_p = 0.004$, then $T_p = 0.1$, and there is a contrast advantage in decreasing transmittance until it becomes less than 0.1. Since a typical faceplate has a transmittance of 30–40%, its transmittance could be decreased for further contrast advantage.

As Kelley has noted, it may further help the reflection problem to roughen the screen surface, turning specular reflection into haze. Because the specular component of reflection is usually quite strong, this measure reduces the "worst-case" reflection from the screen. But it will work only if the screen surface is close enough to the light-emitting elements to preserve image resolution. Since liquid-crystal displays (LCDs) have thinner screens than CRTs, they may be better suited to the screen-roughening solution. A thin screen is an advantage because light from the emitter does not have much space to spread before it encounters the rough surface. The effect of screen thickness can be seen by looking through a piece of wax paper at an LCD screen, moving the paper closer to the screen, and noting that the image is finally seen when the paper touches the screen.

Another way of dealing with screen reflection is to alter the gray-scale map on the tone response curve. This may be unsatisfactory for the same reason that zooming isn't always the answer to resolution problems – it may just increase the time to find something in an image. And it surely does not give a good illusion of a "window on the world."

Finally, it should be remembered that, other things being equal, increased display brightness always helps.

Conclusion

Screen reflection is visually important because reflected light reduces image contrast. Three ways of mitigating the effect of screen reflection are to increase screen luminance, to darken the viewing environment, and to use an intelligently designed absorptive faceplate. Reducing screen reflectance is a hard problem, but significant advances have been made. Although our more-than-four-decade visual dynamic range precludes displays from being true "windows on the world," a lot can be done in that direction.

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Success in Seoul

A reflective chip from Daewoo, impressive PDP prototypes, high-contrast phosphors, beautiful LCDs, and a top-notch program drew 950 people to Korea's first Asia Display.

by Ken Werner

THE UNSEASONABLE typhoon-generated rains that fell during most of Asia Display, held September 28 to October 1, 1998, at the Sheraton Walker Hill Hotel in Seoul, Korea, could have been viewed as a metaphor for Korea's present economic difficulties. But few of the people at Korea's first International Display Research Conference seemed metaphorically inclined, and the mood - particularly once the extent of the conference's success became clear - was unabashedly upbeat.

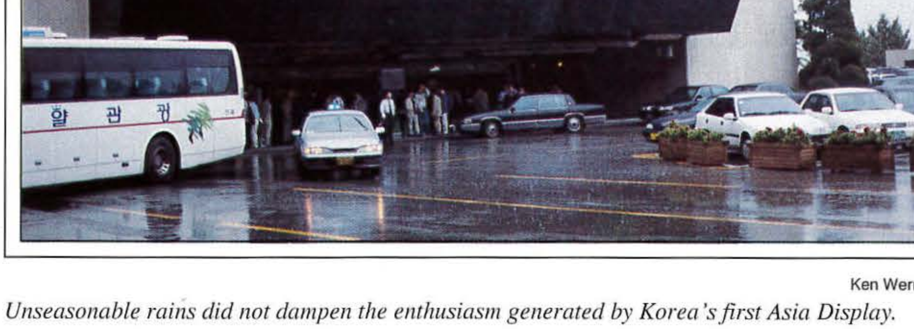
Despite the rain, which dropped a record 300+ mm on a southern Korean city, external events supported a certain optimism.

- A large parade, fortunately coinciding with a break in the weather, celebrated the 50th anniversary of the founding of the South Korean military forces.
- South Korean President Kim Dae-jung announced that the legislative package required to implement Korea's economic recovery was in place and only required passage by the legislature. He predicted a return to economic growth by the second half of 1999.
- Korea's Chaebols - powerful family-owned manufacturing groups - reversed a plan to hire an American consulting company to determine who should run the merged companies they are being forced to form by the Government as part of the IMF agreement. Instead, the Chaebols committed to reaching agreements themselves by the Government-mandated deadline.
- The Chusok holiday - Korea's Thanksgiving - began shortly after the close of Asia Display. This lent a festive air to events - even if holiday shopping was sharply off. (On the day after the conference closed, a smiling highway toll collector was wearing a traditional Korean dress in anticipation of the holiday.)

Perhaps most significant for the conference itself, this first Asia Display to be held in Korea drew the support of the entire Korean display community, from CEOs to students. It was easy to get the feeling that during the course of the conference, organized by the Korea Chapter of the Society for Information Display (SID) and the Korean Physical Society (KPS), the Korean display community was gaining a new sense of itself as a significant force on the world stage, above and beyond the activities of individual companies.

A PDP TV for $2000?

The Monday workshops preceding Asia Display '98 proper (also known as the 18th International Display Research Conference) included workshops on liquid-crystal materials, active-matrix liquid-crystal displays



Ken Werner

Unseasonable rains did not dampen the enthusiasm generated by Korea's first Asia Display.

Ken Werner is Editor of Information Display Magazine.

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Ken Werner

The 40-in. VGA PDP that LG Electronics showed at Asia Display had a 400:1 contrast ratio and a luminance of 350 nits, and was showing a movie without noticeable artifacts.

(AMLCDs), field-emission displays (FEDs), plasma-display panels (PDPs), and phosphors.

The PDP workshop kicked off with a presentation entitled "Recent Advances of PDP Drive Techniques" by Shigeo Mikoshiba of The University of Electro-Communications, Tokyo, Japan. Mikoshiba identified the primary goals for plasma television as a 100:1 bright-room contrast and a cost of \$2000 for a 50-in. TV receiver. These goals are set by the performance of rear-projection CRT-based TV receivers. The quality of the PDP TV image has gotten better, said Mikoshiba. When price parity is achieved, people will buy plasma in quantity. The cost-reduction requirement is severe, but it must be accomplished, and the primary approach is reducing driver cost. Approaches include lowering operating voltages, lowering peak current, and reducing the number of scan drivers by using AND logic (along the lines pioneered by Larry Weber). Overall, driver cost can be reduced by modifying drive techniques. "We have glorious opportunities," said Mikoshiba.

Mikoshiba quickly described Fujitsu's recently announced Alternative Lighting of Surfaces (ALiS) method. Reminiscent of CRT interlacing, ALiS lights up the odd lines of the display first, then the even ones, which results in higher luminance and luminous efficiency, says Fujitsu. It was ALiS that generated some lively questions and answers following Mikoshiba's presentation, since it was not initially clear how ALiS produced the results claimed for it. Session moderator Larry Weber said an ALiS display he had seen looked good, but he suspected that the improved luminance came from a higher sustain frequency and that there was no increase in luminous efficiency.

Jean-Pierre Boeuf and his colleagues from the Université Paul Sabatier, Toulouse, France, in "Modeling as a Tool for Plasma Display Optimization," indicated how the team's two-dimensional plasma-simulation software can be used to analyze and improve the performance of real PDPs. Among their conclusions was that modeling indicates that too much energy goes into the plasma ions and not enough into the electrons for maximum efficiency. If the balance can be adjusted through cell geometry and changes in driving, panel efficiency could be improved.

Shinji Morozumi of Hosiden & Philips Display Corporation, Hyogo, Japan, discussed the challenge of making LCDs for the growing flat-panel-monitor (FPM) market. The market for FPMs is expected to grow to 15 million units per year in 2003, he said, when the cost performance of FPMs will finally catch up with CRTs. One of the things that has permitted LCD screen sizes to grow, he said, is the remarkable reduction in defect density over the last 10 years. The density has dropped two orders of magnitude to about 0.001 defects/cm^2.

N. D. Young and his colleagues from Philips Research Labs, Redhill, Surrey, U.K., described the low-temperature polysilicon on polymer technology they have developed for

Samsung Electronics showed an impressive 13.3-in. XGA reflective panel in a notebook computer. The application showed a newsletter with windowed video. The panel's response time is 20–40 ms and the contrast ratio between 10:1 and 12:1. Commercial availability is targeted for mid-1999.

Ken Werner

Students were encouraged to attend Asia Display, which they did in impressive numbers.

making plastic LCDs and sensors. They use a 275°C process on polyimide, but since polyimide has an orange color, this is only suitable for reflective displays. For transmissive displays, they use polyethersulfone (PES), which requires a 200°C process. The characteristics of TFTs produced at 200°C is adequate for active-matrix applications, say the authors, although the leakage current is a factor of 10 higher than desired. Applications for "plastic LCD" technology include personal digital assistants (PDAs), palmtop PCs, phones, electronic tags, fingerprint scanners, flexible electronics on foil, supersmart cards, and lightweight displays (one-fifth the weight of a similar display on a glass substrate).

In "A Super-High-Image-Quality Multi-Domain Vertical Alignment LCD," T. Sasaki and his colleagues from Fujitsu, Ltd., Kawasaki, Japan, describe a vertical-alignment-mode LCD that has high contrast ratio (CR), fast optical response, and low light leakage. Even with one optical domain per subpixel, this architecture has a larger viewing angle than a conventional TN display. To this, Fujitsu has added a new technology it calls Automatic Domain Formation (ADF). With ADF, pyramidal structures are photolithographically formed on the "insides" of two plates that form the LCD cells. When properly positioned, these protrusions "automatically" form four domains without rubbing. The viewing angle is 160° or more in all directions (CR greater than 10), with a maximum of 300:1 or more. The switching speed is less than 20 msec for all modes except black to gray, where it is approximately 80 msec. Fujitsu developed the multidomain vertical-alignment (MVA) LCD for desktop-monitor applications.

Korea's Road to Success

Yoon-Woo Lee, President and CEO of the Semiconductor Division of Samsung Electronics Co., Kyungki-Do, Korea, kicked off the main conference with his keynote address, "An Economic and Business Perspective of the Korean Display Industry." Lee pulled no punches, stating directly that the Korean display industry was in crisis because of Korea's weak economic situation and rapid profit shrinkage. His solution was aggressive: "Now is the time to invest in advanced technologies and create new FPD applications beyond the volume production of mid-range products in order to capture the high-end market in FPDs."

Lee noted the rapid growth of Korean LCD production over the last 4 years, which now accounts for 10% of the world market (compared to Japan's 73%). In CRT production, Korea leads Japan, although production is declining. "PDPs will take off after the year 2000," he said, and "displays will proliferate in the 21st century."

A challenge is that the investment efficiency for TFT displays is much poorer (at 3.7) than for ICs (at 1.56). He defined investment efficiency as the ratio of first-year sales to investment required for break-even.

To be successful, Lee said, the Korean industry must

- Maintain an optimum level of manufacturing capacity, *i.e.,* be a stable supplier.
- Provide system makers with total solutions.
- Be a catalyst for innovation.
- Participate in global cooperation.

"The future of the Korean industry is bright," said Lee, "if it focuses on value instead of volume."

The Plenary Session and Technical Program

In the first of two invited addresses following the keynote address, Shunsuke Kobayashi of the Science University of Tokyo in Yamaguchi, Japan, described the fabrication of a polymer-stabilized ferroelectric LCD (PS-FLCD) that is free of zigzag defects, and uses a special Nissan polyimide. The display has a CR of 230:1, a response time of 40 μsec, gray-scale capability, wide viewing angle, and a high resolution of 400 lines/mm. The colorimetry still needs work. Kobayashi believes this technology will be very important for the multimedia network era that is rapidly approaching. ("Rapidly approaching" is particularly well defined in Japan, where every home in the country is scheduled to be connected to a national optical-fiber network by 2005.)

Larry Weber of Plasmaco/Matsushita, Highland, New York, U.S.A., led off the second invited address, "Plasma Display Device Challenges," by saying, "While the ac plasma display is straightforward to manufacture, it is a challenging and fascinating device to understand." The presentation answered the question "How did we achieve the breakthrough of the 21-in. PDP shown at Asia Display in Hamamatsu?" A central characteristic of this display was its superior dark-room CR. Weber hoped this case study would provide insight for a road to the future, which must include better device characterization.

The problem that Weber set out to solve was that, although the on-value of the wall voltage in a PDP cell was uniquely defined, the off-state voltage could have many values within a band. As a result, it was impossible to have a well-defined electro-optic curve. The paper describes Plasmaco's efforts at "wall-voltage engineering," which produced a positive-resistance discharge - something that plasmas are not normally known for - and a well-defined electro-optic curve that permitted the design of a PDP having a much better CR than existing designs. The version of the paper printed in the Asia Display digest goes through the wall-voltage-engineering process in detail.

Tatsuo Uchida of Tohoku University, Sendai, Japan, began the Advanced and Reflective LCDs session with "Advanced Liquid-Crystal Displays." He observed that LCD viewing-angle problems have been effectively addressed with the halftone method, multi-domain structures, and compensation using discotic LC films. Now, a new generation of innovative displays - in-plane switching (IPS), automatic domain formation (ADF), optically compensated bend (OCB) cells, axially symmetrically aligned microcell (ASM) mode, vertical-alignment mode, and dual-domain-like VA (DDVA) mode - are attaining symmetrical wide viewing angles and high contrast.

Uchida's group is focusing on field-sequential-color LCDs (FSC-LCDs) using OCB mode and reflective color displays using a variant of OCB referred to as the R-OCB mode. The latter display has high reflectance (60–70%), fast response suitable for video (t_{on} = 1 ms; t_{off} = 6 ms), wide viewing angle, and an excellent CR of more than 50:1 in a typical room environment. The display is "almost as bright as paper," said Uchida.

Ken Werner

Two hostesses in traditional costume greet visitors to the Ch'angdŏkgung Palace, a Korean cultural treasure and leading Seoul tourist attraction.

During the question period, Alan Mosley, Technical Director of MicroPix Technologies, U.K., asked about the speed required of the colored backlights in FSC OCB displays. Uchida answered that the turn-on time should be about 0.1 msec, which current cold-cathode fluorescent tubes (CCFTs) can do, but that the current turn-off time of around 3 msec is far too long. Therefore, work needs to be done on developing fluorescent-lamp phosphors with significantly shorter decay times.

Lest anyone think that all interest is focused on flat-panel displays, Sony's Makato Maeda led off the CRT Technologies session with "What Is the Future of the CRT?" This was not a market projection, but a roadmap for the technological developments that will keep the CRT competitive for years to come.

The first characteristic Maeda discussed was a flat face, which Maeda said would dominate CRTs in the future. (In North America, shortly after Asia Display ended, Sony's Graphic Display Group began a serious campaign to publicize Sony's completely flat-screen FD Trinitron technology.) A flat-faced CRT tends to have greater raster distortion and worse convergence than a conventional CRT, and a flat mask can begin vibrating more easily. There are approaches to solving these problems, but it sounded like the FD tube (and its competitors) would be premium products for some time to come.

It is clearly important to decrease the depth of CRTs. The structure of Aiken's flat tube of 1951 was too complicated for practical use, said Maeda, but Sluyterman's recent proposal of a CRT with two necks (and two guns and two yokes) and half the depth is much simpler. It's also more expensive. How much will people pay for thinness? Also on Maeda's agenda were lower power consumption, recyclability, a 16:9 aspect ratio, and lower-cost TV tubes that maintain better focus (for alphanumeric content) at high beam current.

Computer monitors will have to provide 200 dpi in the next few years. This will require new ways of fabricating fine screens that use a shorter wavelength than current UV techniques, and an economical way of making a finer-pitch mask.

"Obviously," said Maeda in the written version of his presentation, "these problems can not be solved all together overnight, but we're committed to solving them one after another."

Don Carkner of Westaim's Advanced Display Technologies Division, Alberta, Canada, described the company's refocused thick-dielectric EL (TDEL) technology in a paper in the Display Systems session. Westaim originally aimed this technology at rugged, small, low-resolution alphanumeric and graphic display modules, but now feels the technology can compete with color plasma for fairly high-resolution large-screen displays - at a much lower cost. The company has also given the technology a new name, Solid-State Display (SSD), because of the belief that the world perceives EL technology development as having stalled, said CEO Michael Goldstein. An 8.7-in. prototype was scheduled to be exhibited at Stanford Resources' Flat Information Displays Conference in early December in Monterey, California, and a 17-in. prototype is scheduled for limited demonstration in early February.

Predicting Display Markets

In a Special Session on Display Markets on Tuesday evening, Joe Castellano of Stanford Resources, San Jose, California, U.S.A., reviewed his company's latest market projections. "The worldwide FPD-component market continues to grow rapidly and will reach $26 billion in 2004 from $14 billion in 1998," said Castellano. In 2004, the largest market segment for flat panels will still be computers, with a 52% share. "LCDs will dominate the FPD market with a share of over 84% in 2004. Desktop monitors using flat panels will begin to seriously replace CRT types in the middle of the next decade."

Fred Kahn of Kahn International, Palo Alto, California, U.S.A., looked at the projector market for 2004, predicting an average growth rate of 12.3%. CRT rear projectors dominate the market today, he said, but by 2003, more than half of the projectors sold will be front-projection LCD units or chip based. He projected an $11 billion market overall in 2003 and a $20 billion market in 2010.

Kahn predicted that luminous efficiency would rise to a minimum of 20 lm/W by 2003, and might rise as high as 70 lm/W - a prediction that elicited some dubious comments following his presentation.

Professor M. Y. Huh of Sung Kyun Kwan University, Seoul, Korea, had been caught in the rain and traffic, so his talk was rescheduled on the fly to follow Kahn's. Huh presented an interesting chart showing that Korean Government support for FPD research in 1997 roughly matched that of 1996 (at about 11 billion won) despite the Asian economic crisis, and that it was expected to rise to 19 billion won in 1998.

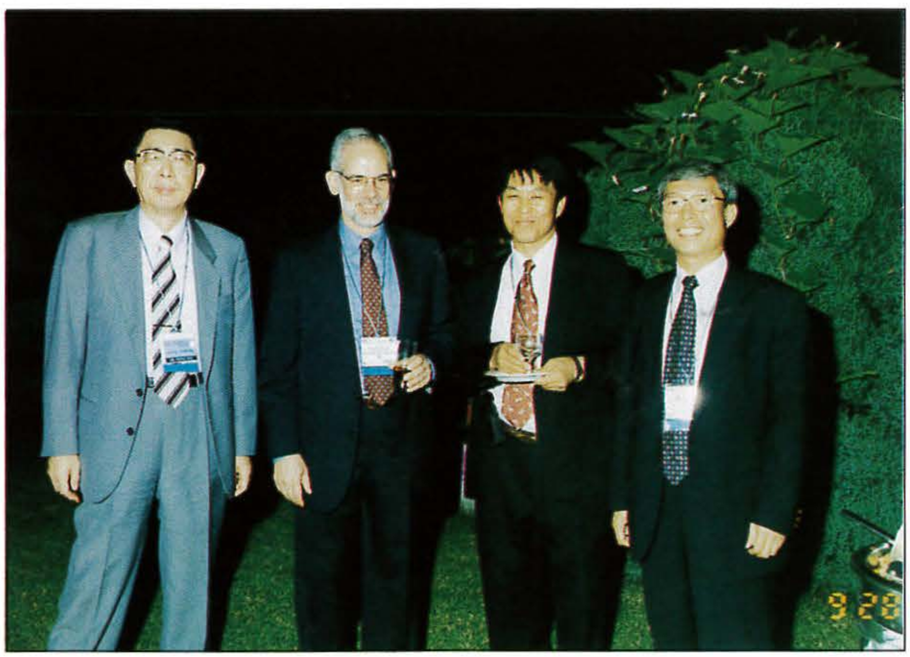
Finally, J. H. Gros of PixTech, Montpellier, France, filling in for F. G. Courreges, answered a question from *Information Display* by saying that PixTech was shooting for FED sales of $100 million in 2000. "That's what we need to break even," he said.

Walking the Show Floor

SEMI Korea worked with SID and KPS to mount an accompanying exhibit with approximately 35 participants. Although the show was fairly small, the main exhibitors mounted booths worthy of a much larger show, and there was a surprising amount to see.

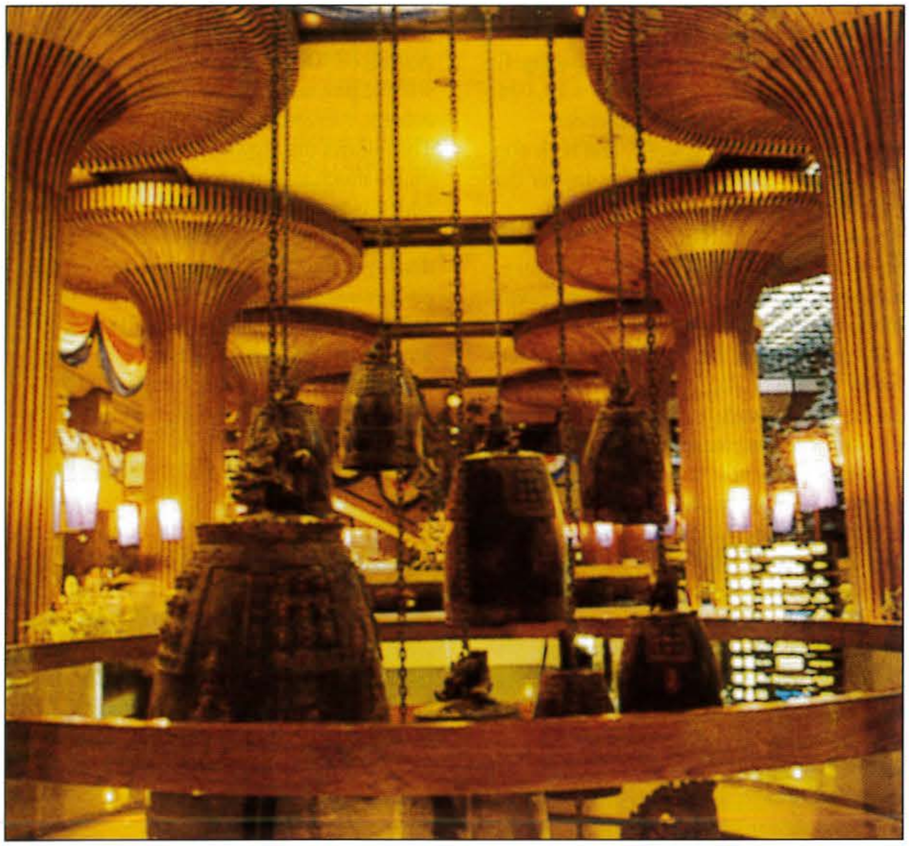
Daewoo Electronics Co., Seoul, Korea, showed the Actuated Mirror Array (AMA) reflective projection chip on which it has been working for the last 5 years. The basic concept is along the lines of Texas Instruments' DMD chip in that the pixels are formed by tilting mirrors, but Daewoo mounts each mirror on micromachined thin-film PZT piezoelectric cantilevers that tilt the mirror linearly with applied voltage. The light reflected from each mirror is blocked by an optical stop when no voltage is applied. As the applied voltage and tilt angle increase, more of the light is directed through the transparent portion of the stop. The AMA thus produces analog gray scale, which the DMD does not. This permits the use of less expensive driving circuitry and packaging, Daewoo said in an invited paper that led off the Display System session. Sang-Gook Kim, the senior author of that paper, will also be an invited speaker at SID '99 in San Jose, California, U.S.A..

The prototype chip has 300,000 micromirrors (VGA format), each of which is 97 μm square. An engine based on this chip produces 5000 ANSI lumens with a 1-kW xenon lamp, says Daewoo, and demonstrated the impressive brightness in the Mugunghwa Ballroom prior to the conference banquet. The large ballroom was packed for the



Sheraton Walker Hill Hotel

Enjoying themselves at an Asia Display reception were C. C. Lee (KAIST), Asia Display Conference Chair; Ken Werner; M. H. Oh (KIST), Asia Display Executive Committee Chair; and S. Lim (Dankook Univ.), Asia Display Secretary General.



Sheraton Walker Hill Hotel

Traditional bronze bells form the centerpiece of the main lobby in the Sheraton Walker Hill Hotel in Seoul, Korea, site of Asia Display '98.

demonstration, which generated substantial excitement. Daewoo Electronics Company's President and CEO J. B. Chun, who hosted the event, was clearly pleased.

Daewoo Senior Research Engineer Kyu-Ho Hwang told *Information Display* that the prototype chip measures 4 in. A production XGA chip will have mirrors that are 50 μm square on a 2.1-in. chip, and will be available in the first half of 1999. A production SXGA 3-in. chip will be available in the second half of 1999. The engine demonstrated at Asia Display used a three-chip design, but the mirrors respond at up to 40 kHz, more than fast enough for field-sequential color. A sign in Daewoo's booth called the AMA "the brightest display device in the world." That's gilding the lily, but the AMA is impressive.

Samsung Display Devices (SDD), Seoul, Korea, was showing off its technical prowess, starting with a "Dynaflat" CRT that has a faceplate that is truly flat on the outside but has a curved inner surface. Dynaflat tubes will be made in 17- and 19-in. data-grade versions and in a 29-in. entertainment-grade version. The 19-in. version is a UXGA device with a 0.26-mm pitch. The 29-in. tube was on display and looked good - almost LCD-like.

SDD was also demonstrating its ProLCD LCD-simulation program and its ProGun 3D electron-gun simulation program, both of which were for internal use only. Hsing-Yao (Jimmy) Chen of Chunghwa Picture Tubes, Taiwan, a noted gun designer himself, said he was very impressed with ProGun 3D: "It is now the best electron optics program in existence, with some features that exceed Sarnoff's Beam 3D. I'm amazed."

SDD was also showing off a high-contrast phosphor with improvements in binder adsorption that prevented pigment agglomeration. The phosphor also had high pigment concentration, and "nano-sized" grains that offered high contrast (low reflectivity) and extended color gamut. Two otherwise identical monitors contained tubes with the new phosphor and a conventional phosphor, and the improvement was obvious. Chungwha's Jimmy Chen called the phosphor a solid development, perhaps the major CRT-related development at the meeting. SDD is making 30–40% of their mid-range and high-end tubes with the new phosphor, and will move to 100% when supplies permit. (Samsung uses 20 grams of phosphor per tube, and the company is currently consuming four tons of the new phosphor per month.) Tubes with the new phosphor are being sold for the same price as those with the old phosphor.

SDD also presented its first-generation 42-in. PDP prototype, with a 400:1 dark-room CR. In the ambient of the exhibit hall, the display subjectively had very high contrast, and presented good-looking still images. Motion artifacts were visible, which Kyung Y. Park, PDP Team Supervisor, immediately acknowledged. Solutions were being implemented, he said. The panel should be available starting in January '99 in a limited quantity and in quantities of hundreds of panels per month starting mid-year.

A developmental reflective STN-LCD with 4096 colors and 10:1 CR looked quite good sitting under a spotlight, as did reflective monochrome plastic-film LCDs (PFLCDs) in 4.2-in. quarter-VGA and 5.9-in. half-VGA versions. SDD wants to go to color plastic LCDs for PDA applications.

In a different room ***Samsung Electronics Co.,*** Kyunghi-Do, Korea, mounted a separate exhibit. (Is it my imagination, or do these two Samsung companies make a special effort *not* to cooperate?) Included was a 30-in. TFT-LCD, the world's largest built on a single sheet of glass, said Samsung. The specifications are 1600 × 1200 pixels, 200:1 CR, 200 nits, less than 40-msec response time at 25°C, and a viewing angle of 60° (V) and 100° (H). This very nice display had a surprisingly glossy surface. I was told that the designers did not want to compromise resolution with an anti-reflection treatment on a display that is intended for HDTV, CAD/CAM monitors, and ATC. There was a 21.3-in. UXGA panel with similar specs.

Samsung's more mainstream panels were impressive. SXGA TFT panels in 18.1- and 17-in. sizes with wide viewing angle (160°), 250:1 CR, and 200 nits looked beautiful showing still images; the colors were saturated and contrast excellent.

A 15-in. XGA TFT-LCD used patterned domain-divided VA with optimized fringe field to produce a ±170° viewing angle, less than 40-msec response, 300-nits luminance, and 500:1 CR! There was also a 15-in. XGA TFT with LVDS interface for mega-notebooks that was billed as the largest available screen for notebook PCs.

Among Samsung's other offerings were an impressive 13.3-in. XGA reflective panel in a notebook computer showing a word-processing application with Korean Han-gul text and windowed video (response time, 20–40 msec; CR between 10:1 and 12:1). Samsung has a mid-1999 target for commercial availability.

Three-Five Systems, Tempe, Arizona, U.S.A., was showing its LcaD and LciD displays, but General Manager Dwight Nordstrom said that most of the interest was in the company's microdisplays, which he didn't bring. ***Colorado Microdisplay (CMD),*** Boulder, Colorado, showed its 0.47-in. SVGA LCOS FSC microdisplay, announced the availability of a developer's kit, and "pre-announced" an agreement with Planar by which Planar would distribute CMD's displays for military, POS, transportation, industrial, and ruggedized applications. (The official announcement was to be made on the following Monday.) CMD was showing their displays in a variety of headset prototypes.

LG Electronics, Seoul, Korea, was showing two PDPs: a 40-in. 400:1-CR 350-nit 640 × 480 panel that was showing a fast-moving movie without noticeable artifacts, and a 50-in. 1360 × 760 100:1-CR 280-nit panel that was showing one of the old, slow-moving Sony MUSE videos. There were a couple of horizontal line defects and a few pixel defects on the 50-in., but that's not significant at this stage of development. The images were beautiful and beautifully detailed. HDTV at 720 lines progressive (720p) would clearly be an attractive format on PDP-based TV receivers.

LG Electronics was also showing a broad range of LCDs. Among them was a 12.1-in. XGA panel made with laser-annealed low-temperature poly-Si (LTPS) at 400°C. The panel featured integrated drivers, 262,000 colors, and a five-mask process. This compares to the eight- or nine-mask process used by Sanyo, said LG's Young-Ok Kim.

There was also a 14.1-in. XGA multi-domain panel using UV alignment with ±140° viewing angle, 200:1 CR, and 250-nit luminance that will be available in Q1 '99.

LG Senior Research Engineer Kyeong-Jin Kim seemed particularly proud of a 14.1-in. XGA panel that combined high-speed response, wide viewing angle, and high contrast, all at the same time (specs: greater than 160° viewing angle, less than 30-msec response time, 300:1 CR, and 250 nits). This very nice "Ultra Wide VA" (UVA) display showed clean video with no smearing (available in Q3 '99).

There was also a 14.1-in. XGA notebook-display prototype that produced 150 nits from less than 4 W, thanks to an 80.4% aperture ratio. Engineering samples were expected by the turn of the year – "ahead of Hyundai and Samsung," said Kim. Finally, LG had a 15-in. SXGA mega-notebook LCD with a very narrow frame designed to fit in notebooks now taking a 14.1-in. display, thanks in part to a patented side-mounting mechanism.

Hyundai Electronics Industries, Kyoungki, Korea, also showed an extensive range of LCDs, including a 15-in. XGA monitor panel using the company's recently announced Fringe Field Switching, which seems to be a refinement of IPS. The panel looked lovely showing still images. Its specifications are ±170° viewing angle, 5.2% light transmission, 30,000-hour four-CCFL backlight, TTL dual-port signal IF, 200 nits, 250:1 CR, 20 W, and a $t_{on} + t_{off}$ of 60 msec. Production starts in Q1 '99.

There was also a nice, although more conventional, 18.1-in. SXGA monitor panel, and 12.1-in. SVGA, 13.3-in. XGA, and 14.1-in. XGA panels for notebook use.

Genesis Microchip, Ontario, Canada, was showing customer LCD monitors using the company's scaling engine under the "imengine" branding program, much as they had at INFOCOMM in June. The exhibited products came from Samsung, Apple, DICON, LG Electronics, Sony, KCI, and Philips.

Kumho Electric, Inc., Korea, and ***Shin Pyung Co., Ltd.,*** Korea, were exhibiting their CCFL backlight systems. Each company can supply about 20,000 units per month.

In what amounted to an extended author interview in the author-interview area, ***IBM T. J. Watson Research Center,*** Yorktown Heights, New York, U.S.A. and ***IBM Japan Ltd.,*** Tokyo, Japan, showed their beautiful 16.3-in. 2560 × 2048 Quad SXGA (QSXGA) TFT-LCD with 6-bit color, which was described in a paper with 34 authors in the Advanced AMLCD session. The display, which IBM says has the highest information content ever shown, has 200 pixels per inch. This allows the viewer to relate to the screen image much as if it were a printed page, which is very different from viewing a typical 80-ppi display. What is surprising about this display is that the TFTs are made from amorphous silicon.

When subpixels get this small (42 × 126 μm), something's got to give. What gives here is the aperture ratio, which is 27.3%. Nevertheless, the total power consumption of the panel is less than 75 W, about half that consumed by a 17-in. CRT monitor running in SXGA mode, says IBM.

Hisanori Kinoshita of IBM Japan said they hoped to have units for sale by the end of 1999. Paul Grier of IBM T. J. Watson Research Center responded carefully to an inquiry about price from *Information Display* by saying the cost should be between that of a good 20-in. CRT graphic-arts monitor and Sony's 20 × 20-in. monitor, but closer to the former. The initial target markets will be CAD and command and control, followed by the graphic arts, he said.

A Flowering of Korean Display Culture

Asia Display '98 turned out to be both a great success and a celebration of the Korean display industry. Overall attendance was about 950, of which 300 were from outside Korea. The efforts of Conference Chair C. Lee, Executive Chair M. H. Oh, Program Co-Chairs J. H. Souk and J. Jang, and Secretary General S. Lim were widely acknowledged, and were warmly praised by SID President Tony Lowe and other members of the SID Board of Directors. Even the details worked, such as a performance of traditional Korean music at the Conference Banquet by extremely skilled students in traditional costume, and a CD-ROM of the conference digest that was ready for distribution along with the paper version. ■

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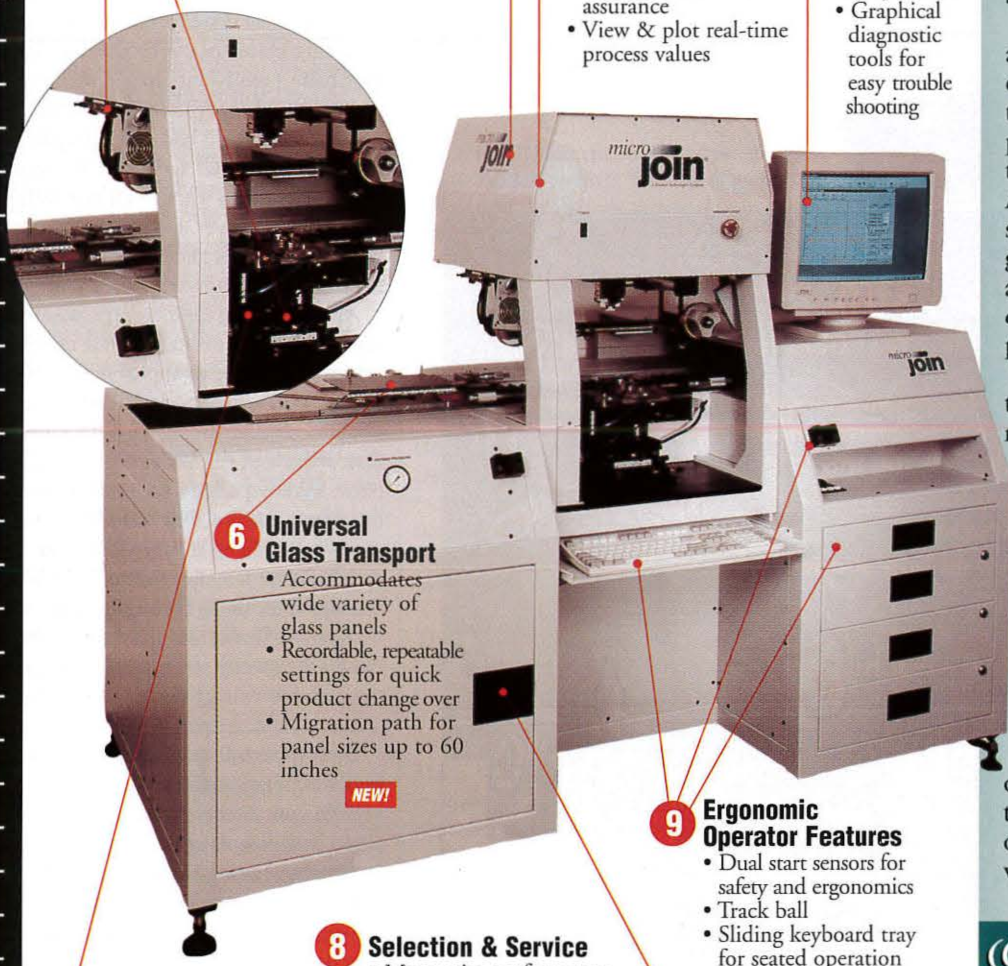

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that had all the appearances of having been crossbred between that VW Beetle and the SUVs of that era.

The family's first stop that evening was for a casual dinner at a popular drive-in offering the typical menu of custom-made burgers with a long list of ingredients, a variety of drinks, including all the shakes, floats, and sodas known to mankind, and a variety of other menu choices for those with more sophisticated or substantial appetites. Their server took their order, entering it via a portable remote terminal, and within ten minutes returned with the tray holding their meals. The tray was placed onto their partly lowered driver-side window - just as drive-in restaurants have done for the last 70 or 80 years. Jeff and Diane always found it interesting how these park-while-you-eat drive-in restaurants had made such a comeback over the past 20 years, while the drive-through fast-food chains so popular at the turn of the century had all but disappeared. When they were younger, they had seen movies about how teenagers used drive-in restaurants as popular gathering places in the 1950s and 1960s, but they hadn't really anticipated that they, as adults, would enjoy them as much as they now did. Maybe it had something to do with the kids being at an age where the more traditional restaurants weren't all that well suited for them. However, looking at the other cars, people of all ages and all group sizes seemed to be similarly enjoying their evening out.

After finishing their meal, it was time to take in the main event, a movie carefully selected by Diane to appeal both to them and to their kids - they hoped. Earlier that afternoon Diane had already called a number of their friends to get movie recommendations. Now, as they pulled into the drive-in theater, they were asked if they needed an audio-receive module or if they would like to use their own car's audio system. Almost everyone opted for using their own audio systems, with only a few of the older cars - those without high-capacity storage cells - plugging into the variable-voltage power sources provided at every parking spot.

Even though Diane was pretty sure that the kids would enjoy the movie and stay in the vehicle with their parents, she had come prepared with a back-up strategy. If the movie became too boring for them, the kids could go to the nearby game arcade and play the newest virtual-reality games while Mom and Dad watched the movie. Of course, she and Jeff also enjoyed many of these games, but tonight, they would most likely stick with the movie.

The sun had just set and dusk was deepening. Although there were still the vestiges of daylight and wispy red bands of clouds glowing near the horizon, the movie started right on schedule. The images flashing from the huge screen before them had a brilliance and resolution so compelling they couldn't help but be drawn to them. Even Jeff, the engineer, was impressed. This was the latest in large-screen display technology and it really was spectacular. The screen was large, it was bright, and its HDTV-like resolution provided about the same picture quality as the IMAX theaters of 20 years before. Of course, even conventional theaters no longer used film. The conversion to electronic distribution had had a difficult beginning and had taken some time to catch on, but film had finally been eliminated around 2010.

Quite unexpectedly, Jeff thought of something that put such a big grin on his face that Diane immediately asked, "OK, what's so funny?" "Well, I just remembered my first job out of college. Remember that display company that I went to work for? Remember the one trying to develop field-emission displays for laptop and desktop applications? I just can't help wondering what some of their investors are thinking today, now that they can see where field-emission technology finally achieved its biggest success. Isn't it great to be able to watch a movie on such a large display screen at night and then to know that all day tomorrow this theater will be making money showing ads to the shoppers going in and out of the shopping mall next door? What a neat business. And all of this because of a display technology that is bright enough for both night and day use and that can be electronically oriented to serve two sets of customers. This thing makes money 24 hours a day!" Jeff was getting excited. Diane just nodded her agreement. This discussion was starting to sound too much like work.

As a result of Diane's careful checking, the movie turned out to be better than they had expected. Even the kids stayed in the car with them. Being in their own vehicle, they didn't disturb anyone else with their occasional conversations, and the surround-sound system in their car was just as impressive as the ones in theaters. All in all, Jeff had to admit that it was turning out to be a very nice evening. Staying at home has its advantages, but spending an evening with the family, while being entertained and fed in such a convenient manner, had its own satisfactions as well. The next day, driving to work, Jeff was especially aware of all the sunlight-readable displays vying for his attention. He could see that display technology had certainly made the world a brighter and more colorful place.

calendar

Display Technology

Display Works 99: Display Manufacturing Technology Conference. Co-sponsored by SID, SEMI, and USDC. Contact: Mark Goldfarb, Palisades Institute for Research Services, Inc.; 212/460-8090 x202, fax -5460, e-mail: mgoldfar@newyork.palisades.org.
Feb. 2–5, 1999 San Jose, CA

Asia Region Society for Information Display Symposium & Workshop. Co-sponsored by SID Asia Region, SID Japan Chapter, IEICE, ITE, SID Korea Chapter, SID Hong Kong Chapter, SID Beijing Chapter, SID Taipei Chapter. Contact: SID Taipei Chapter Office; +886-3-5720409, fax -5737681, e-mail: hpshieh@cc.nctu.edu.tw.
Mar. 17–19, 1999 Hsinchu, Taiwan

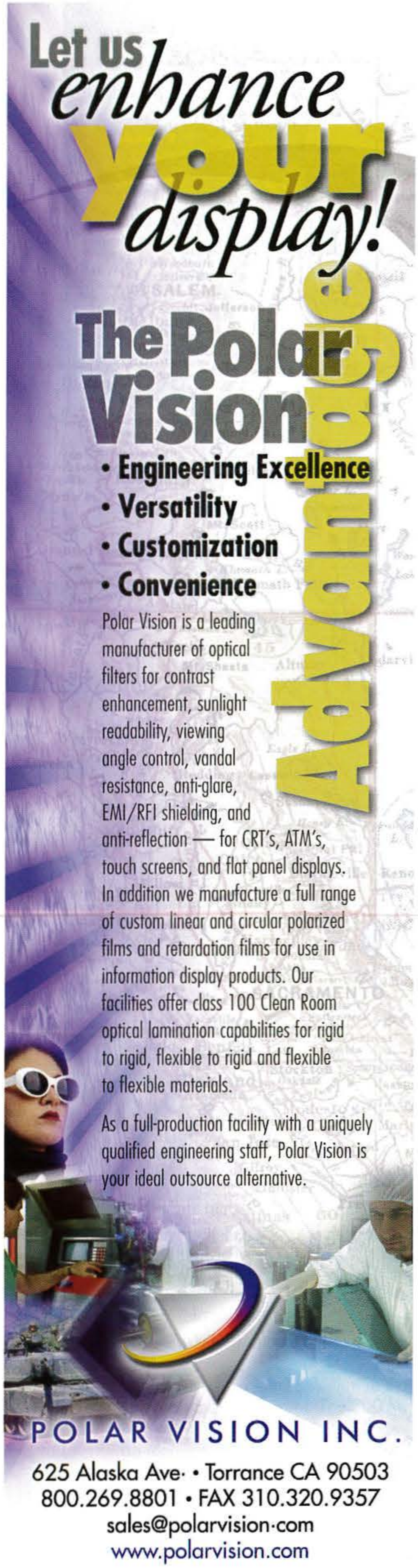
The 1999 SID International Symposium, Seminar & Exhibition (SID '99). Sponsored by SID. Contact: Mark Goldfarb, Palisades Institute for Research Services, Inc., 411 Lafayette St., New York, NY 10003; 212/460-8090 x202, fax -5460, e-mail: mgoldfar@newyork.palisades.org.
May 16–21, 1999 San Jose, CA

The 7th International Conference on Ferroelectric Liquid Crystals (FLC '99). Contact: Prof. Wolfgang Haase, Condensed Matter Research Group, Institute of Physical Chemistry, Darmstadt University of Technology, Petersenstraβe 20, D-64287 Darmstadt, Germany; +49-61-51-16-33-98, fax -49-24, e-mail: flc99@tu-darmstadt.de, http://flc99.tu.darmstadt.de.
Aug. 29–Sept. 3, 1999 Darmstadt, Germany

The 19th International Display Research Conference (EuroDisplay '99). Sponsored by SID and in cooperation with ITG. Contact: Dipl.-Ing. Rupert Rompel, VDE Verband Deutscher Elektrotechniker e.V., Stresemannallee 15, D-60596 Frankfurt am Main; +49-69-6308-381, fax +49-69-9631-5213, e-mail: 100145-67@compuserve.com.
Sept. 6–9, 1999 Berlin, Germany

The Fifth International Conference on the Science and Technology of Display Phosphors. Sponsored by SID, PTCOE, and DARPA. Contact: Mark Goldfarb, Palisades Institute for Research Services, Inc., 411 Lafayette St., New York, NY 10003; 212/460-8090 x203, fax -5460, e-mail: mgoldfar@newyork.palisades.org.
Nov. 8–10, 1999 San Diego, CA

The Sixth International Color Imaging Conference. Sponsored by IS&T and SID. Contact: IS&T, 7003 Kilworth Lane, Springfield, VA 22151; 703/642-9090, fax -9094, e-mail: info@imaging.org.
Nov. 16–19, 1999 Scottsdale, AZ



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display continuum

Should you have entertaining ideas of your own that you would like to share with me, I can be reached by e-mail at silzars@ibm.net, by phone at 425/557-8850, by fax at 425/557-8983, and by paper-based displays at 22513 S.E. 47th Place, Issaquah, WA 98029. ■

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Since 1962, a professional worldwide interdisciplinary society committed to the advancement of information display.

letters to the editor

To the Editor:

I would like to call your readers' attention to an error. The photograph on page 14 in the September 1998 issue shows DRL's Emissive Micro-Display prototype, which uses vacuum fluorescent on silicon technology (or VFOS, as coined by David Lieberman in *EE Times*). The photo is incorrectly identified as a Colorado Microdisplay device. As pioneers not only in a new product category, but also in a new display technology, DRL would prefer that the credit for our achievements does not go to one of our competitors!

– *David C. Guo*
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Display Research Laboratories, Inc.
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Los Altos, CA 94024
650/969-3670
fax: 650/969-3769
e-mail: dguo251359@aol.com

To the Editor:

In the December issue of Information Display, I published an article describing the need for, and difficulties in acquiring, flat-panel displays for military systems. In it, I attempted to present to your readers a very positive picture of a systematic approach to FPD acquisition for military aircraft.

The article summarized a comprehensive military evaluation of a mature form of FPD technology, the large-area LCD from Nippon Electric Corporation. We tested the integration of this LCD by seven different suppliers and found "a wide range of performance and operator preference among these units, despite the fact that all used the same LCD glass." Following a summary of our results, we concluded that, "... the NEC 2000 glass – as offered by some suppliers ... was indeed qualified to replace on-board CRTs [in U.S. Navy maritime patrol and surveillance aircraft]."

The logical process of finding a mature technology, verifying it will meet military needs, drafting a performance-based acquisition specification, and initiating an open competition and a multi-platform buy of these displays was completed in a very short time (for the military) – less than nine months.

Unfortunately, due to the military attitudes and acquisition practices roundly criticized in the article, the final elements in the logical sequence (open competition and multi-platform buy) will not occur in this display acquisition. The EP-3E aircraft managers have already proceeded with an independent buy of some 170 units plus spares in a sole-source acquisition, using some $800K of Congressional plus-up funding. I am not even certain that the remaining P-3 platform variations targeted for the combined buy will actually execute according to the plan.

I thought it important to let your readers know that I did not intentionally lead them astray in thinking that one military service had improved the acquisition process, as mandated by Congress. I honestly thought we had. But, despite our best intentions and efforts, we have utterly failed to achieve even the first of the necessary requirements for improved acquisition stated in that article. That is: "Begin effective inter- and intra-service collaboration."

On a more positive note, the initial products of that sole source supplier will be delivered for testing to the premiere U.S. Navy test and evaluation center, Patuxent River. I intend to be a part of the test team. If the product has not improved significantly beyond what we saw back in February of last year, there may yet be a full and open competition for display replacements on the EP-3E aircraft. I remain confident that the fleet sailors will ultimately receive the best, most cost-effective product which we, as a nation and as a Navy engineering support infrastructure, can deliver.

– *Ken Sola*
Citizen, Taxpayer,
Fleet Guardian

P. S. This issue will be revisited in a paper and at the Rugged Displays Roundtable discussion at Display Works 99, to be held the first week in February in San Jose, California. ■

Please send new product releases or news items to Information Display, c/o Palisades Institute for Research Services, Inc., 411 Lafayette Street, 2nd Floor, New York, NY 10003.

editorial

continued from page 2

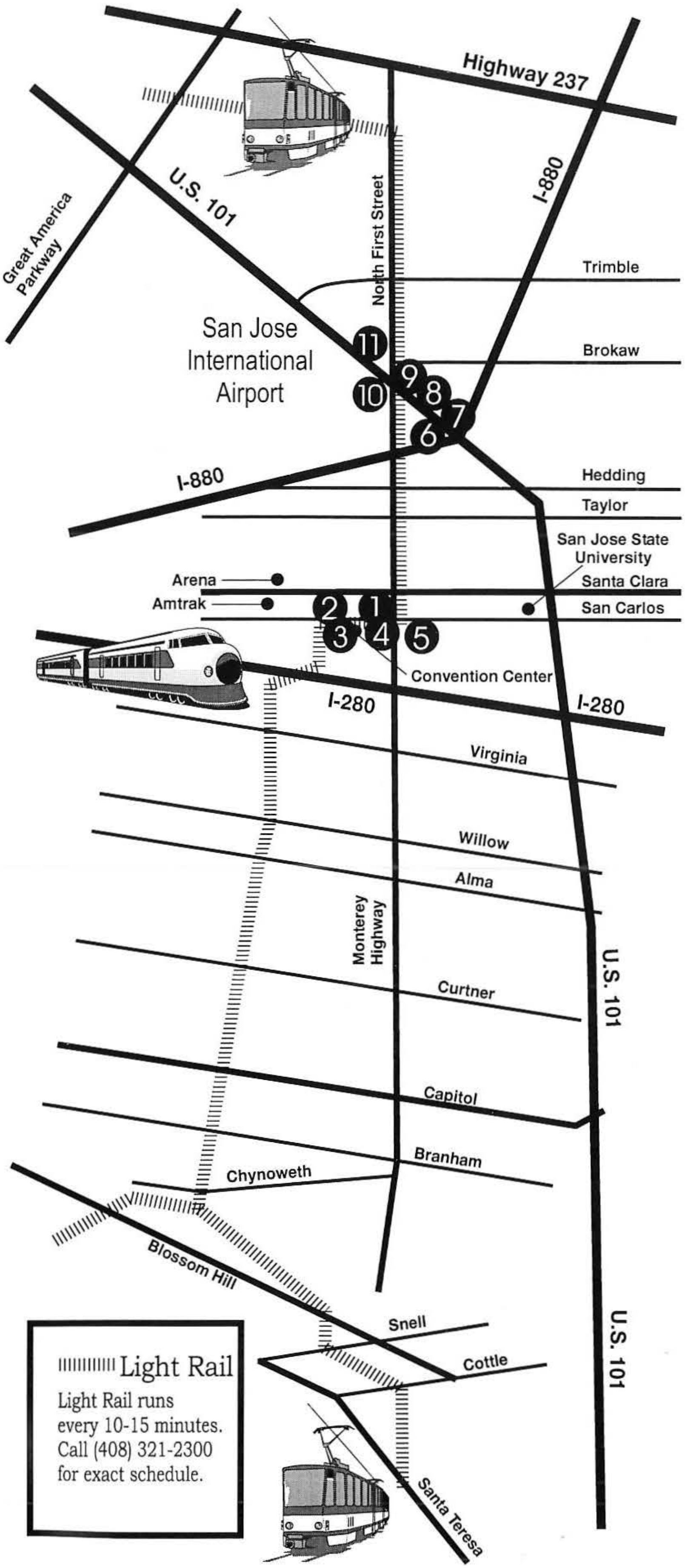
developmental panel – it was being worked on by several spirited technicians as I viewed it – but, as best I could tell in the laboratory's subdued lighting, the panel appeared bright and contrasty.

At the Asia Display exhibits, as reported elsewhere in this issue, SDD was also showing prototypes of a color reflective LCD and two plastic-substrate reflective monochrome LCDs, a unique approach to flat-screen CRTs, and an impressive new high-contrast CRT phosphor, as well as both electron-beam and LCD simulation software for internal use.

Perhaps SDD's engineers have been drinking from Admiral Yi's well, which is not far from Chonan City, and perhaps my somewhat mystical interpretation is not so far off the mark after all. In any case, it is clear that SDD and its major Korean competitors have attained world-class stature, not only in the quality of the displays they are building, but in a new spirit of innovative design and engineering – an area in which many Koreans thought themselves to be outclassed only a few years ago.

– 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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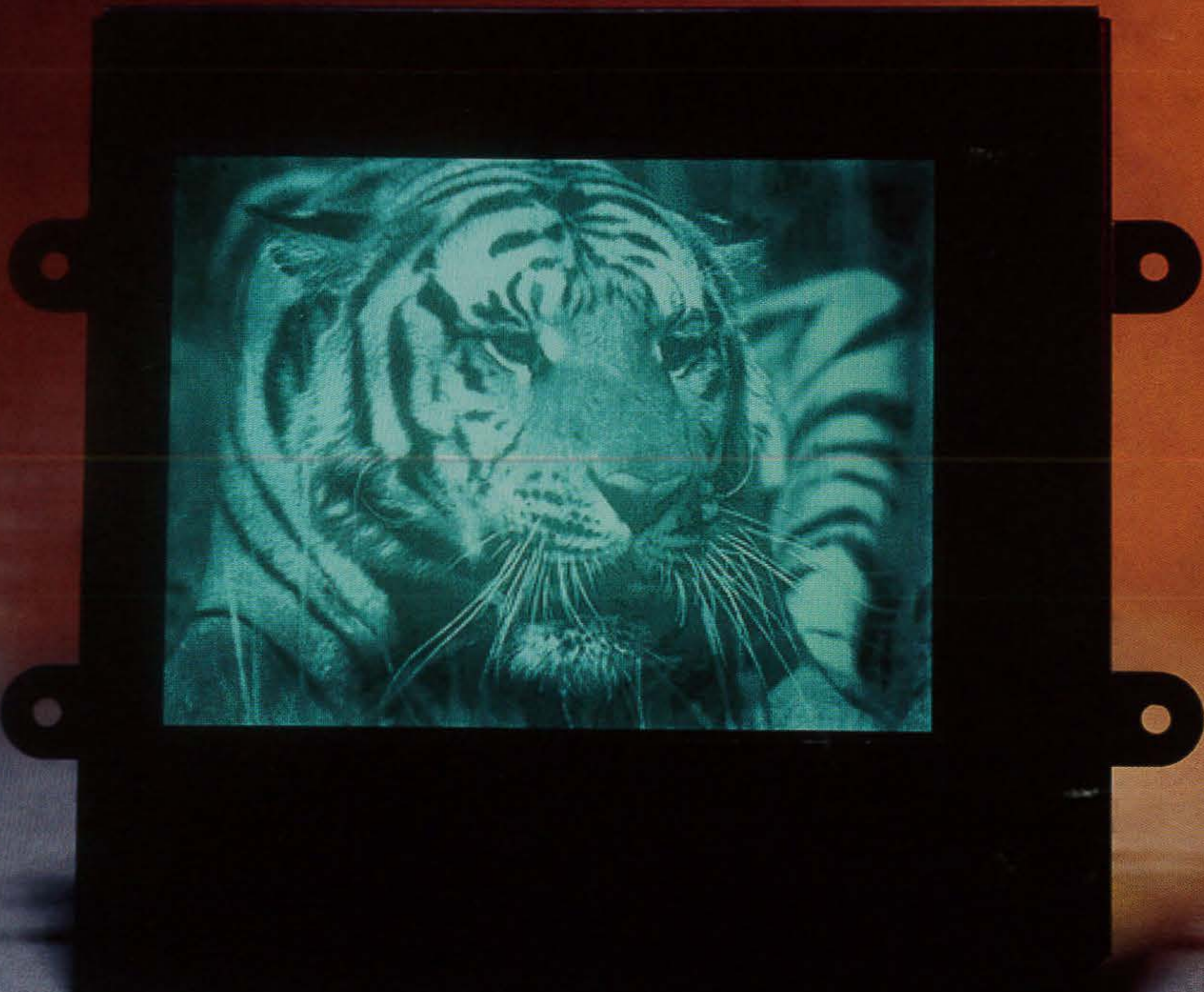

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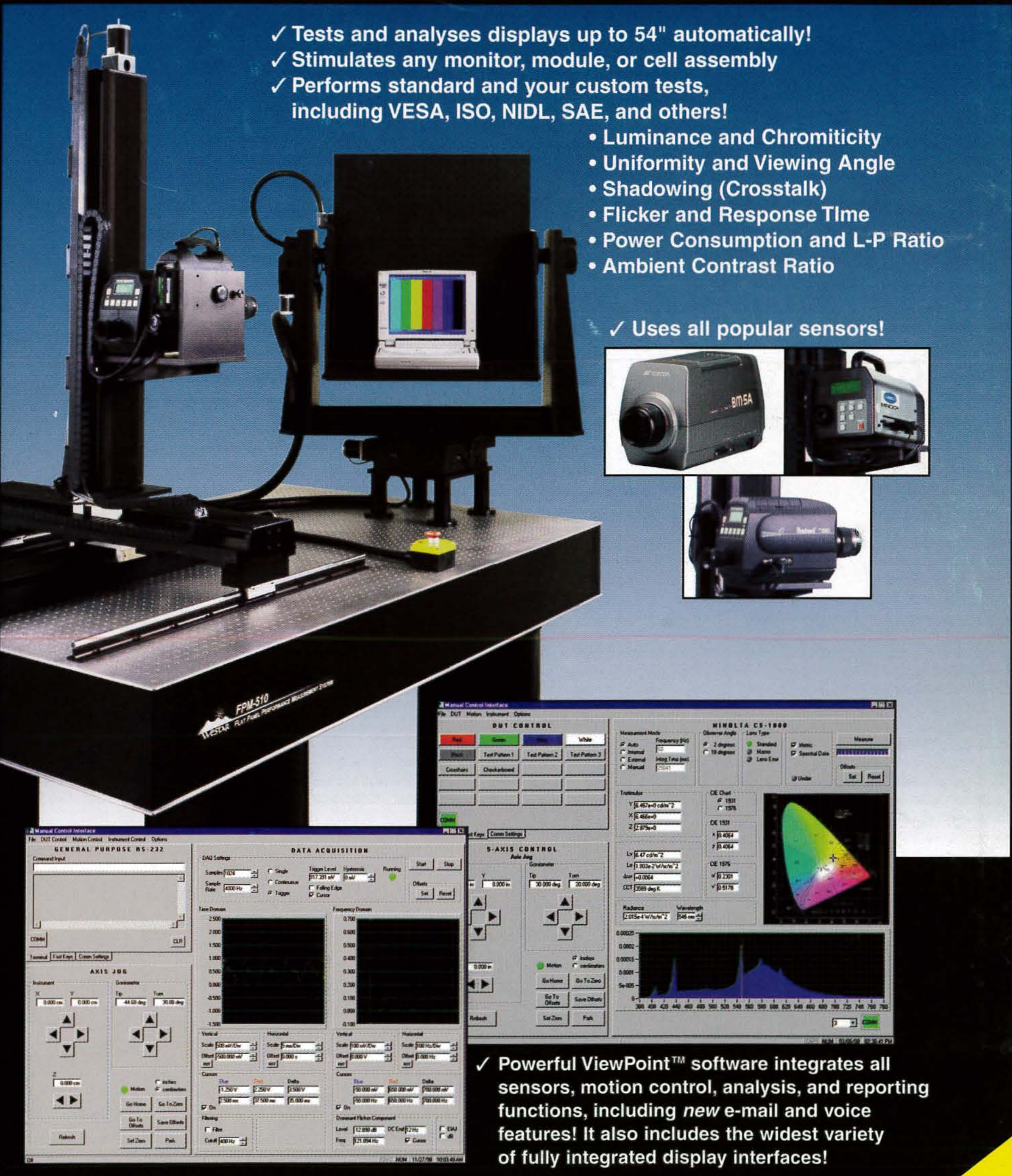

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