DISPLAY BUSINESS ISSUE

Information DISPLAY

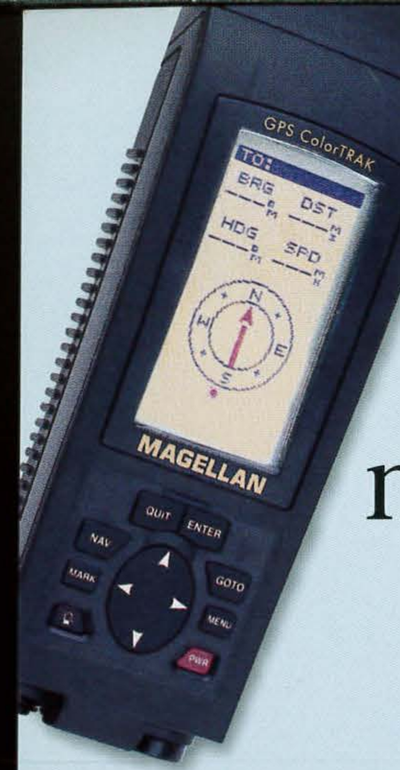
July 1998
Vol. 14, No. 7

SID

Official Monthly Publication of the Society for Information Display

As Flat Panels Invade the Desktop, Interface Chips Are As Important As the Panel

- **Bringing PDP Costs Down**
- **The New Monitor Market**
- **Making Good Measurements**
- **Company Profiles**
  Infinity Multimedia
  Lightware



The world plans, navigates, measures, monitors, plays, fishes, communicates, computes and displays with Optrex LCDs

And that's just the beginning.

The applications for LCDs keep growing and so does Optrex.
Why? Innovative engineering and design support, exceptional quality, and a nationwide distribution network. Our creative design approach allows you to develop new applications and enhance the performance of your existing products. Most importantly, it allows **you** to create the custom or semi-custom LCDs that

turn your bright ideas into reality.

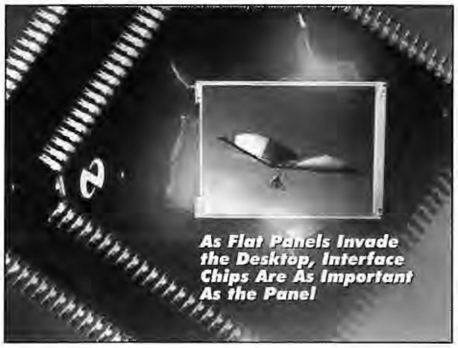
Our customers like that. You will, too.
For more information, call (734) 416-8500, or fax (734) 416-8520 today.

OPTREX AMERICA, INC.

44160 Plymouth Oaks Blvd. • Plymouth, MI 48170
(734) 416-8500 • FAX: (734) 416-8520
lcdinfo@optrexusa.com

Circle no. 1

COVER: National Semiconductor's forthcoming announcement, slated for late summer, of the first production LVDS chipset for SXGA-and-higher FPD monitors could help open a flat-panel market with exceptional growth potential. For more on LVDS, TMDS, and TTL interfaces, see our coverage beginning on p. 14.



Credit: National Semiconductor. Art direction and photography by Imagination, San Francisco, California.

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

Industry Directory Issue
- Directory of the Display Industry
- Errors in Ergonomic Standards
- Digital All the Way
- Adding Intelligence to FEDs
- CeBIT '98 Report

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: Erika Targum, 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.

Information DISPLAY

JULY 1998
VOL. 14, NO. 7

president's message

Changes and Opportunities at SID

by Tony Lowe

As the Society for Information Display's new President, I would like to communicate some recent news and tell you about changes we are making to improve the services SID provides to its members. We held our International Symposium, Seminar, and Exhibition in Anaheim in May. The comments I received were overwhelmingly that it was a very successful event. Our first ever Display Technology Showcase attracted huge interest. It enabled viewers to make side-by-side comparisons of many state-of-the-art displays. We plan to make it bigger and even better next year.

In mid-May we took action to move our International Headquarters to San Jose. Dee Dumont is our new Executive Director, and Jenny Needham the Executive Assistant. They are already working hard in the new location to bring you an improved range of services. We decided to keep the HQ in California because it is equidistant in time between Europe and Asia. This makes it possible for members anywhere in the world to make phone contact during working hours. Contact information is available on our Web site (www.sid.org) and elsewhere in this issue of *Information Display.*

Growing Internationally and Improving Communications

SID membership is growing. Current membership (pre-Symposium) and 1997-98 growth rates are: Americas (2830, +4.8%); Europe (830, +29%); and Asia (1100, +4.4%). Communicating with our members worldwide to provide them with display-related information and news is among the most important of the services SID provides. In addition to what we mail to you, we shall increasingly use our Web site as a primary means of communication.

From the Web site, you can now search the paper titles and authors from many of our recent conferences and download entire papers from the 1995 and 1996 Symposium Digests. By the time you read this, the 1998 Symposium Digest will be available on CD-ROM. Our aim for the future is to produce the CD-ROM in time for it to be distributed at the Symposium, but major cooperation from authors will be required if we are to succeed. Because the production time for the CD-ROM version of the Digest is currently longer than that for the print version, authors of next year's Symposium papers will have to submit their final papers strictly by the published deadline. Authors please note! Once we have achieved simultaneous publication of the CD-ROM and printed versions of the Symposium Digest we shall extend our electronic publishing activities.

Another new venture is in book publishing. *The Wiley-SID Series in Display Technology* is being undertaken jointly by SID and publisher John Wiley & Sons. The first two volumes, *Display Systems* and *Electronic Display Measurement,* were published last year. A third volume, *Projection Displays,* will be published later this year, and more volumes are in preparation. SID members may purchase these books at a substantial discount from SID HQ. Ordering details for these and all other SID publications can be found on the Web site. We are also extending the Web site facilities for reporting SID news and advertising technical meetings. Soon you will be able to click on any region, country, or chapter to discover its entire calendar of SID events. Much of this is already installed, with hot links to those chapters that have their own Web sites. You can already register for conferences and make purchases of publications on-line,

continued on page 39

Information DISPLAY

Editor: Kenneth I. Werner
Managing Editor: Jay Morreale
Administrative Editor: Ralph Nadell
Assistant Editor: Dian Mecca
Contributing Editors: Aris Silzars, Bryan Norris, Chuck McLaughlin, Joe Hallett
Advertising Manager: Jay Morreale
Director of Sales: Erika Targum

the display continuum

Due Diligence ...

by Aris Silzars

For Keith, Don, and Ralph, the walk across the tree-shaded parking lot back to their car had never seemed quite as pleasant. They had made this same walk at least a dozen times, but today the warm California sun felt especially inviting. The intricate shimmering patterns through the eucalyptus trees added to their vibrant mood. The afternoon coastal fog, in cool contrast, was beginning its usual creep over the mountains to the west. They were clearly in the best of spirits. Even Sarah, their conservative engineering VP, had to admit that the presentation had gone well.

What a difference from the previous dozen or so business-plan presentations they had made to other venture funds. Finally, they had found a venture company that seemed to have a genuine interest in the new display-technology company that they wanted to start. The turning point had been when the senior partner indicated that he wanted to take a very careful look at what they were proposing, followed by the suggestion that this venture fund could be the lead investor.

Getting a senior partner to show positive interest was one thing, but having him indicate that the fund would consider being the lead investor was truly in the breakthrough category. As they had by now learned, it was relatively easy to find funds that would be willing to participate as long as someone else would commit to take the role of the lead investor. In the lemming-like world of venture funds, it seemed that getting anyone to take that lead was the really tough challenge.

As they turned west onto Sand Hill Road and then took the quick entrance onto I-280 North, they continued their animated conversation about how finally, after a dozen tries, their presentation had hit home. During the half-hour drive to SFO, they reinforced each other by reprising all the insightful questions that had been asked and how well they had answered them. For once they were sure that there would be more discussions - all leading to getting their business funded and started at long last.

Life, for them, had not been much fun the last few months. The initial excitement of getting together and planning their new venture to develop an innovative desktop projector had been replaced by the frustration of making presentations that were politely received, then followed by equally polite but non-committal responses. They knew that they had written an excellent business plan around an innovative emissive-projector concept that would have a major impact on the PC-monitor business. However, after all this time, their families were getting concerned, and their wives were beginning to ask when they would get "real jobs." Sarah's husband was also starting to grumble about what he perceived as a high-risk and unnecessary career move on her part.

But finally ... just maybe ... all this hard work and the rejections from those other venture funds would come to a well-deserved and happy conclusion.

Sure enough, several days later, the expected phone call came. And what a great call it was. Not only was the venture fund interested, the call was from Senior Partner - the same one who had shown such positive interest during their presentation. He explained to them that the process going forward would be

continued on page 37

Society for Information Display
31 East Julian Street
San Jose, CA 95112
408/977-1013, fax -1531
e-mail: office@sid.org
http://www.sid.org

european views

New Display Technologies and the Venerable CRT

by Harm Tolner

The new display technologies are ever-more promising. Every year new display technologies are added, all with the aim of finally killing the CRT. What we see instead is that, for example, LCDs have created a new market: laptops. This new market has created the need for docking stations, resulting in increased sales of the good old CRT.

The next target for LCDs is the gradual replacement of the CRTs in these docking stations. For the standard sizes of 17 in. and smaller, the CRT will be difficult to replace, having a cost more than 10 times less than LCD panels. For large sizes (20–25 in.), however, LCDs can be attractive in the future.

A new reason for a gradual change to LCDs is that TFT-LCD monitor specs now offer better performance than the CRT in terms of resolution, brightness, contrast, and power consumption. Flatness is no longer the only unique feature of LCDs. Especially for multimedia use, LCDs can become attractive on the desktop.

In Japan it was expected that monitor applications would instantly eliminate the current overcapacity in TFT-LCD production. This did not happen because the CRT has one very important unique feature, *i.e.,* its performance/cost ratio.

The Asian financial crisis has stimulated Japanese companies to share their current LCD technology with other Asian countries. This will generate money that can be re-invested in innovation inside Japan so the Japanese companies can emerge revitalized from the new crisis in Asia. This is an old recipe that has been used before. This time, however, it will be interesting to see whether sufficient money can be generated to fund the next round.

It certainly is a difficult time for several Asian companies. Planned investment in, for example, CRT manufacturing in Europe and elsewhere has been put on hold by some of these companies. In the meantime, the CRT business of European companies like Philips Components and Thomson is flourishing. New CRT-manufacturing facilities have been built in China and elsewhere. A crew of Dutch equipment engineers recently finished a new Philips CRT factory in Hua Fei.

Field-emission systems are still the most promising displays I know of. Especially in the U.S.A., investors are lured into FED investments because of the technology's promise to replace the LCD. In Europe, Pixel (France) is gradually improving the state of the art.

It has always been clear, however, that high voltage (5 kV) is needed to obtain sufficient lifetime for color FEDs. The maximum Coulomb load of phosphors is well known and has been understood for many years. High voltages are difficult to combine with the spacers needed for larger display sizes. The flashover problems that result have long been downplayed, certainly to U.S. investors.

Anyone who is serious about a technology that uses vacuum support structures, with electrons flying around, should study the physics of hopping electrons, which was described in a special issue of the Philips Research Bulletin that was fully dedicated to the late ZEUS display.

Electroluminescent displays are also very promising, and are finding their own special niche market. Philips started a PLED pilot line in Heerlen, The Netherlands, for the manufacture of EL backlights, in cooperation with Hoechst. The major attraction, as in the case of FEDs, is the efficiency (5 lm/W), which

continued on page 31

calendar

Display Technology

5th Annual Flat Panel Display Strategic and Technical Symposium 1998. Sponsored by the University of Michigan (Center for Display Technology and Manufacturing) and the Metropolitan Detroit Chapter of the Society for Information Display. Contact: Robert Donofrio; 734/665-4266, fax -4211, e-mail: rldonofrio@aol.com
Sept 9-10, 1998 Ypsilanti, MI

9th International Workshop on Inorganic and Organic Electroluminescence (EL 98) and The Fourth International Conference on the Science and Technology of Display Phosphors. Sponsored by SID, PTCOE, DARPA, and the Oregon Center for Advanced Technology Education. Contact: Mark Goldfarb, Palisades Institute for Research Services, Inc., 201 Varick St., Suite 1006, New York, NY 10014; 212/620-3380, fax 212/620-3379.
Sept. 14-17, 1998 Bend, OR

The 18th International Display Research Conference (Asia Display '98). Sponsored by KPS and SID. Contact: Prof. S. Lim, Secretary General; +82-417-550-3542, fax +82-417-551-9229, e-mail: limsk@ns.dankook.ac.kr, Internet: http://tftlcd.kyunghee.ac.kr/idrc98.
Sept. 28-Oct. 1, 1998 Seoul, Korea

The 42nd Annual Meeting of the Human Factors and Ergonomics Society. Contact: HFES, P.O. Box 1369, Santa Monica, CA 90406-1369; 310/394-1811 or 310/394-9793, fax 310/394-2410.
Oct. 5-9, 1998 Chicago, IL

The Third Ibero-American Seminar on LCD Technology. Contact: Prof. Dr. José Otón, Univ. Politécnica de Madrid; +34-1-336-7340, fax -7319, e-mail: jmotón@tfo.upm.es.
Oct. 26–28, 1998 Madrid, Spain

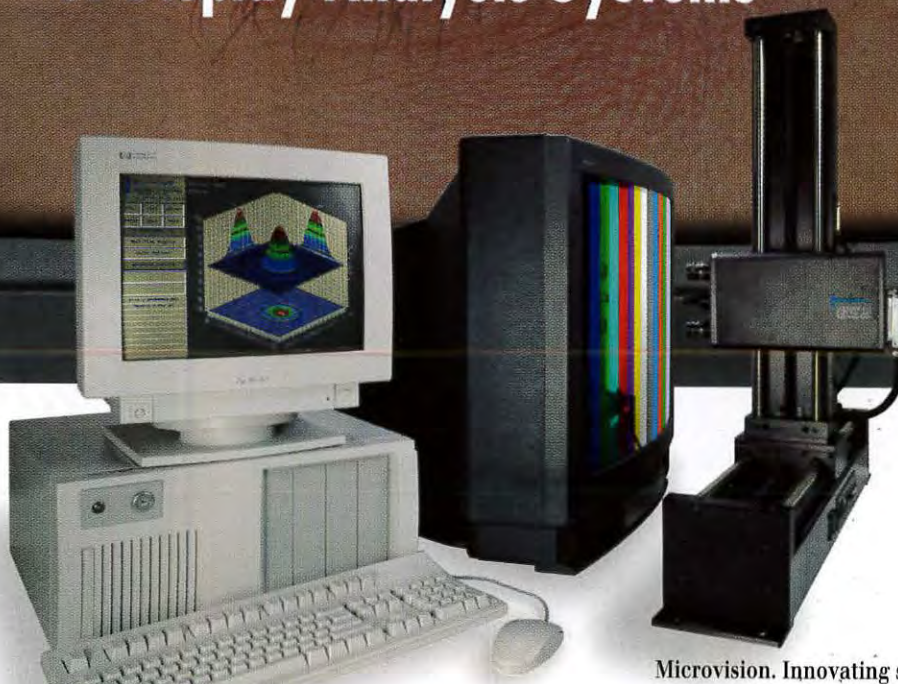
The Sixth Color Imaging Conference. Sponsored by IS&T and SID. Contact: IS&T, 7003 Kilworth Lane, Springfield, VA 22151; 703/642-9090, fax 703/642-9094, e-mail: info@imaging.org.
Nov. 17-20, 1998 Scottsdale, AZ

7th International Symposium on Advanced Display Technologies. Organized by the Belorussian and Ukrainian Chapters of the Society for Information Display in cooperation with the Belorussian Ministry of Education, Belorussian State Committee on Science and Technologies, the State University of Informatics and Radioelectronics, and the Scientific Production Corp. "INTEGRAL." Contact: Prof. A. Smirnov, tele/fax +375-17-239-88-58, e-mail: smirnov@display.rei.minsk.by.
Dec. 1-5, 1998 Minsk, Belarus ■

Check what you need in your display analysis system:

- ✓ flat panel tests
- ✓ CRT tests
- ✓ easy upgrades (hardware and software)
- ✓ standard for ISO, NIDL, and VESA testing
- ✓ optimized for fast, accurate, and automatic testing with many packaged test suites

If you checked all of the above, you have chosen the Microvision SS200 Family of Display Analysis Systems



With the SS200 family, you can precisely, automatically, and completely measure display performance—and that includes flat panels.

SS200

Complete turnkey system with computer, 6-axis positioner, monitor, software, and SS200 camera system. Automatically performs spatial and luminance measurements.

SS210

You can easily field upgrade to the more powerful SS210 package, which provides all SS200 functions, plus an integrated spectrometer for spectral analysis and color measurements. Includes response time measurement capability.

SS220

For flat panel testing, a field upgrade to the SS220 is easy. The SS220 provides spectrometer-based off-axis measurement, color analysis, color shift and luminance testing. Coupled with the SS210, this is the most comprehensive test system ever offered—at a fraction of the cost of individual test instruments. All tests are performed at NIST-traceable accuracy.

Circle no. 4

Microvision. Innovating since 1983.

If you checked all of the above and would like more information, call Microvision at (800) 931-3188.

MICROVISION

Dedicated to the Needs of the Display Industry

550 High St., Suite 108 / Auburn, CA 95603
Tel: (530) 888-8344 / Fax: (530) 888-8349
Toll Free: 1 (800) 931-3188
Email: microvsn.com
Web site: http://www.microvsn.com

International Reps:
Japan - ARGO CORP., 06 339 3366
Taiwan - SUPERLINK TECH., 02 705 7090
Korea - B & P INT'L, 02 546 1457

Why Do PDPs Cost So Much?

The best plasma displays look beautiful, but roll-out plans have been cut back because costs and prices are too high for consumer applications. Why are the manufacturing costs so high – and what is the industry doing about it?

by Kyung Y. Park

THE MARKET for large-screen displays is increasing, and the market for plasma-display panels (PDPs) will increase faster than the large-screen market overall. Stanford Resources projects that the average annual growth rate for PDPs will be 39% through the year 2003.

Although there are a variety of attractive commercial markets for PDPs, the initial prices are simply too high for consumer-television and home-multimedia applications. Current prices for a 42-in. television receiver/monitor are in the $10,000 range, and most analysts estimate that a substantial consumer market will not open up until prices fall to below - perhaps considerably below - $3000.

This makes many PDP market projections appear more like wish fulfillment than science. Sales depend on price, but predicted prices are often the prices one needs to justify the sales volume one wants rather than being based on a realistic manufacturing-cost model. But we have all seen what happens when prices are set independent of costs and the need for sensible margins, and no one wants to repeat that traumatic experience.

Samsung has constructed what we believe is a realistic estimate of the global PDP market (Fig. 1). Note that although the projected unit shipments rise steadily between the years 2000 and 2005, the market value of those shipments goes flat in 2002, indicating

Kyung Y. Park is Supervisor of the PDP Team at Samsung Display Devices Co., Ltd., Technology Division, San 24-1 Sungsung-Dong, Chonan City, Chungchongnam-Do 330-300, Korea; telephone +82-417-560-3710, fax +82-417-560-3725, e-mail: kypark@sdd.samsung.co.kr. This article was derived from the keynote address Dr. Park gave on January 21, 1998, at Display Works in San Jose, California.

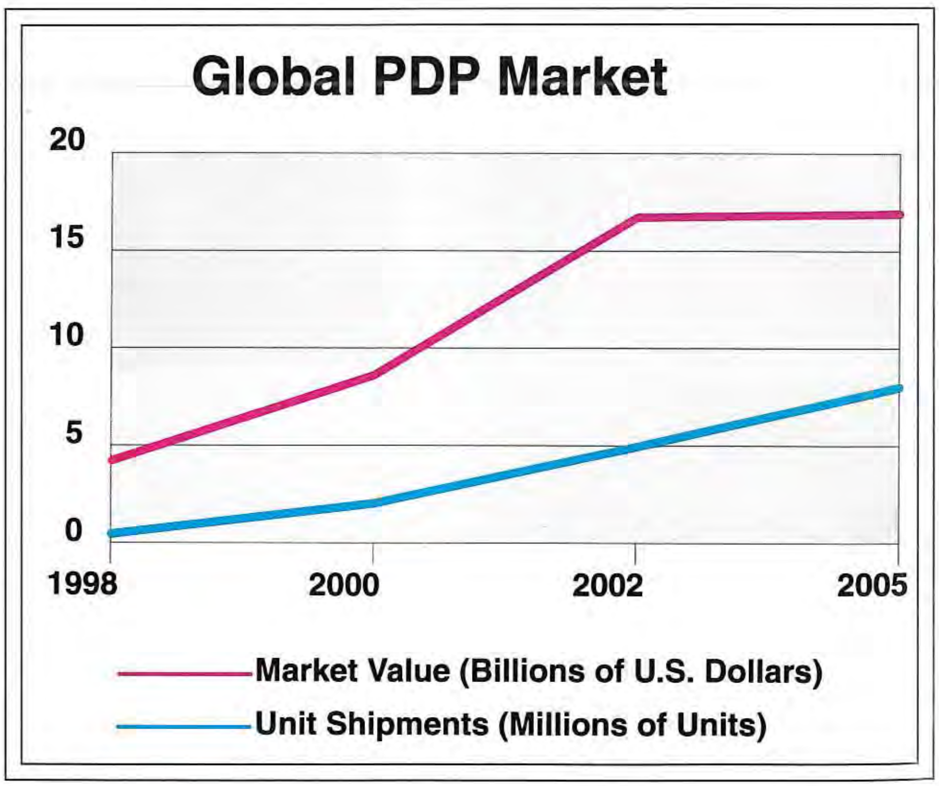


Fig. 1: The market for large-screen plasma-display panels is projected to increase rapidly over the next 5 years, with a sharp drop in unit price predicted for 2002. (Data: Samsung Display Devices)

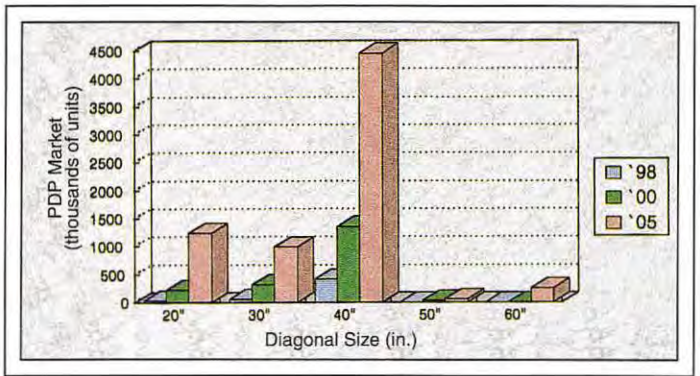


Fig. 2: Because price will remain a major issue, we see the dominant PDP size remaining the 40-in. class for TV and multimedia through 2005, but with substantial sales in smaller sizes for monitors. (Data: Samsung Display Devices)

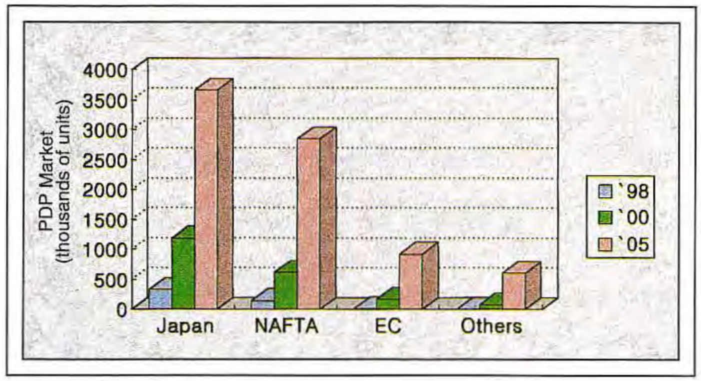


Fig. 3: The dominant market for large PDPs will continue to be Japan, which offers a less-price-sensitive consumer market than other regions. (Data: Samsung Display Devices)

sharply decreasing unit prices. Because price will remain a major issue, we see the dominant size being the 40-in. class for TV and multimedia, but with substantial sales in the 20- and 30-in. class for monitors and some compact entertainment applications (Fig. 2). Geographically, we see the dominant market being Japan, which offers a less-price-sensitive consumer market than other regions, followed by NAFTA, the EC, and all other markets (Fig. 3).

Cost, Cost, and Cost

Following the old saying in the American real-estate business that the three most important variables are location, location, and location, we can say that the future of the high-volume plasma television business will depend on cost, cost, and cost – despite glorious image quality and very attractive packaging. Although the PDP price forecast is steadily downward, other large-screen television technologies, such as CRT and LCD rear projection, will continue to have a cost advantage until after the turn of the century, according to widely accepted figures (Fig. 4).

But a close investigation of manufacturing-cost trends leads us to believe that the prices of all large-screen technologies (with the exception of direct-view LCD) will substantially converge by about 2003 when viewed from a cost-per-diagonal-inch perspective (Fig. 5). And the key to these projections is manufacturing cost.

We predict that 58% of the manufacturing cost of a PDP module in the year 2000 will go for materials, 27% for depreciation, and 10% for labor, with an additional 5% for miscellaneous items (Fig. 6). In our 1997 developmental panels, 53% of the materials cost was for the driving circuits and 27% was for the glass. In the mass-production panels we will produce in 2000, we expect the overall materials cost to be only a third of what it was in 1997, with 70% of the total going for driving circuits and 14% for the glass. (The remainder pays for assembly, MgO, phosphor, barrier ribs, the dielectric layer, and the electrodes.)

These predictions are encouraging, but what must be done to convert them into real-

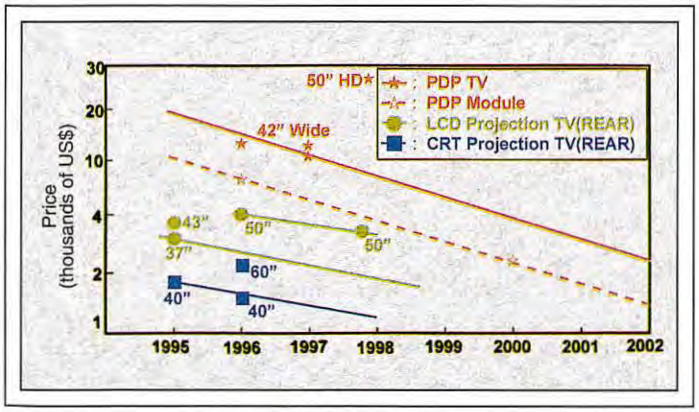


Fig. 4: For television, alternative large-screen technologies will continue to have a cost advantage over PDP until after the turn of the century. (Source: Flat Panel Display '98)

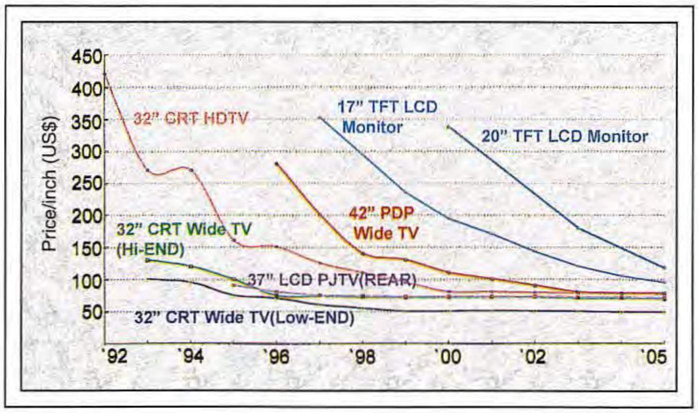


Fig. 5: An analysis of manufacturing-cost trends indicates that the prices of all large-screen technologies (with the exception of direct-view LCD) will substantially converge by about 2003. (Data: Samsung Display Devices)

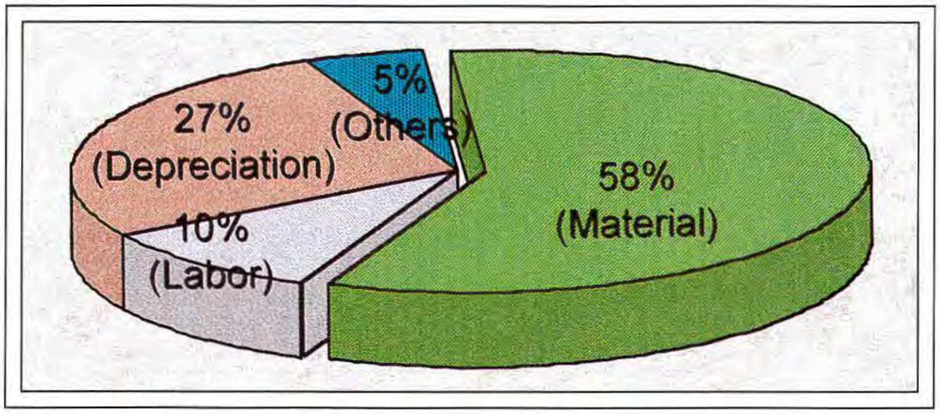


Fig. 6: Materials will account for nearly 60% of the manufacturing cost of a PDP module in the year 2000. (Data: Samsung Display Devices)

ity? Pushing the panel cost down in the real world requires a combination of volume manufacturing, process innovation, and materials minimization (Fig. 7). The predicted materials cost per sheet for a 42-in. panel must go from about \$480 in 2000 to about \$150 in 2010. To do this we must certainly minimize the amount of general materials (materials other than components) used, but approximately 60% of the materials cost is from electronic components. Techniques are currently being developed in Japan and in Korea to reduce the number of drivers and to improve the panel design so that lower-voltage drivers can be used. We must continue to support this work vigorously.

Plant and machinery costs (which appear as depreciation in Fig. 7) fall dramatically as manufacturing volume increases up to about 50,000 sheets per month (Fig. 8). But if we attain volume only by building more lines containing inefficient machines, we will not obtain the desired costs. We must develop manufacturing machinery that offers high throughput and low downtime to produce panels with very high yield. And we must reduce machinery costs, either through collaboration or by our own efforts.

The PDP in 2005

Our target for the selling price of a 42-in. PDP TV set in 2005 is \$2200, which implies a module cost of \$1250. (The \$2200 price is substantially less than our \$80-per-inch selling-price target for 2000.)

Compared to today's early versions, the PDP of 2005 must look very different - both to consumers and to manufacturing engineers. Luminous efficiency must increase from today's 1–1.5 lm/W to between 3 and 5 lm/W. Luminance must increase from today's 350 cd/m^2 to between 500 and 600 cd/m^2. Power consumption must be reduced from today's 300 W to about 150 W.

Combine these requirements with the manufacturing engineer's needs for simpler structures, easier fabrication, lower materials costs, and high yield and throughput, and it is clear that innovative designs/processes must be developed.

Scientists and engineers working on PDPs over the last 30 years have proved they can make impressive-looking panels, and the industry is now able to make panels that are attractive for commercial applications such as financial trading floors, sports bars, board rooms, and conference centers. Our next job is no less challenging: to develop the cost and manufacturing structures needed to support a high-volume PDP business. We can do that - and it won't take another 30 years. It can't. ■

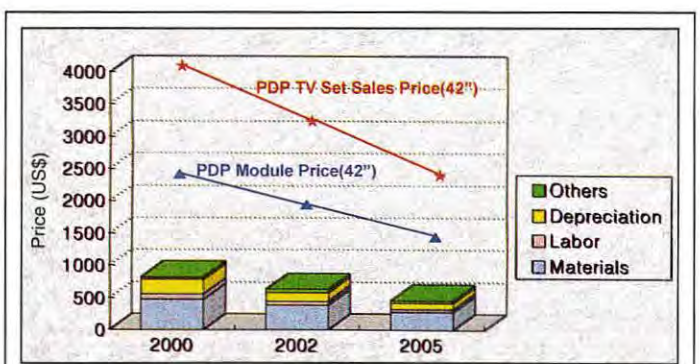


Fig. 7: Pushing panel cost down will require a combination of volume manufacturing, process innovation, and materials minimization. (Data: Samsung Display Devices)

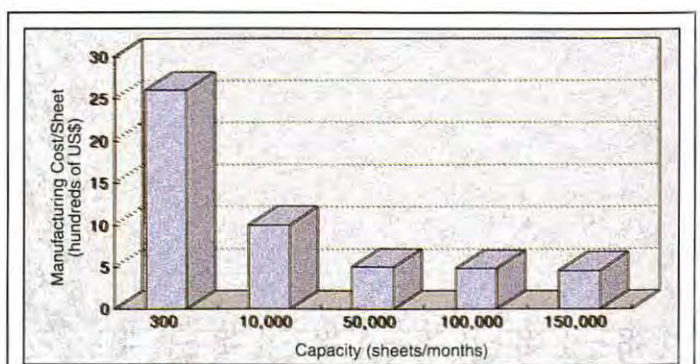


Fig. 8: Reducing manufacturing cost depends on mass production. (Data: Samsung Display Devices)

The New Monitor Market

National Semiconductor's forthcoming announcement, slated for late summer, of the first production LVDS chipset for SXGA-and-higher FPD monitors promises to open a market with exceptional growth potential over the next 5 years.

by Mitchell Abbey

DESPITE THE MANY INNOVATIONS that have made PCs more powerful and easier to use, monitors have remained substantially the same. PC users still have to deal with cathode-ray-tube (CRT) monitors that consume lots of power and take up lots of space.

But taking a lesson from notebook computers, desktop monitors are about to get thin (Fig. 1). Advances in flat-panel displays (FPDs) are enabling them to challenge CRTs in the desktop-PC market. And the advantages are clear: FPDs take only a fraction of the desk space required by CRTs, consume less power, and produce fewer emissions, while supporting the eye-catching graphics computer users expect.

As a result, the market for these thin, lightweight displays that hang on a wall or sit comfortably on the corner of a desk is developing rapidly, with increasing sales to a wide variety of resellers and retail outlets. But at this point users must be prepared to pay a premium to own one of these convenient displays because the cost of LCD panels is still quite high.

One of the reasons for high panel prices is the high image quality required for desktop monitors. While XGA screen resolution (1024 × 768) is now common for laptop displays, desktop users want SXGA (1280 × 1024) and UXGA (1600 × 1200). LCD panels with these screen resolutions in sizes suitable for the desktop are still expensive because manufacturers often get only one LCD panel per sheet of glass. Until new plants come on line, yields improve, and production reaches substantial levels, costs will remain high. Fortunately, the huge size of the

Mitchell Abbey is Strategic Product Marketing Manager, Interface Business Unit, National Semiconductor, Inc., P.O. Box 58090, M/S 82-585, Santa Clara, CA 95052-8090; telephone 408/721-4673, fax 408/245-9655.

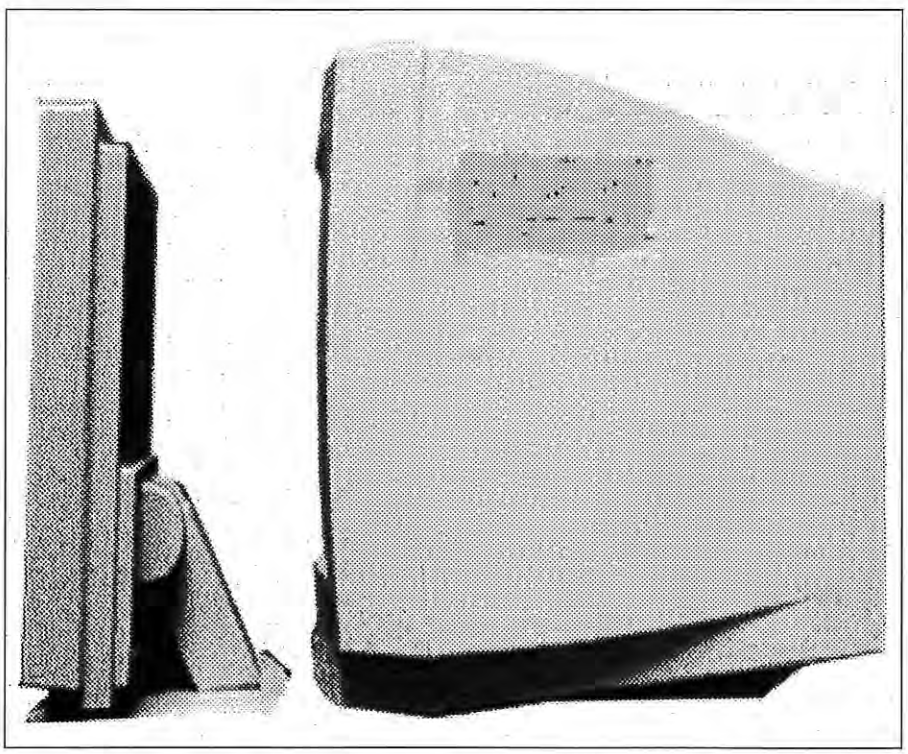


***Fig. 1:** Mainstream desktop monitors are about to get thin – if an economical interface is widely adopted by both the makers of host systems and the makers of FPD monitors.*

0362-0972/98/1407-014$1.00 + .00 © SID 1998

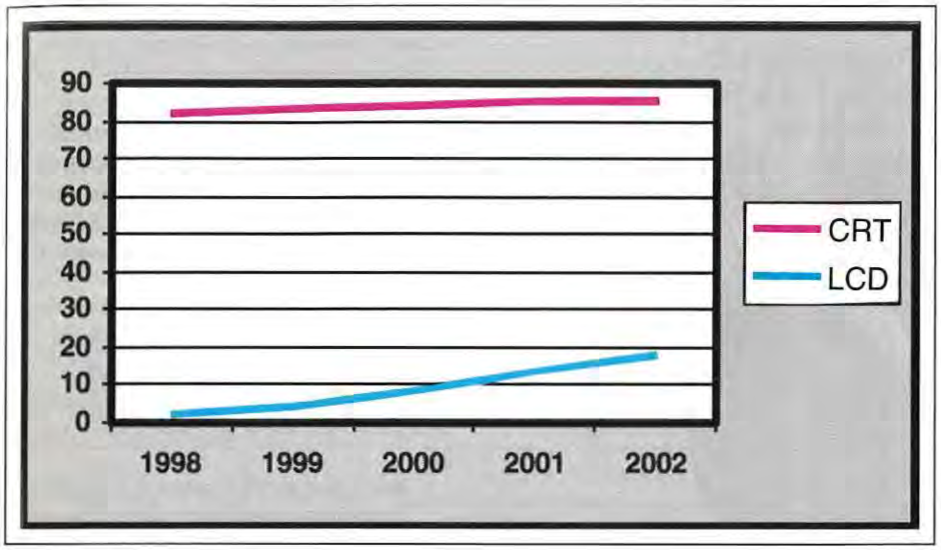


Fig. 2: Through the year 2002, the projected annual growth rate in global sales for LCD monitors is 18%; for CRT monitors, 5%. Figures are in millions of units. (Source: Stanford Resources, Inc.)

potential market promises to drive prices down quickly and speed acceptance - a process that may gather momentum by the end of 1998. Price reductions are also being accelerated by the current overcapacity among Asian LCD manufacturers.

How big is the market for FPD monitors? The worldwide market for active-matrix desktop monitors is expected to grow from approximately 0.73 million units shipped in 1997 to a projected 1.5 million units in 1998 and 8.9 million units in 2001 (Figs. 2 and 3). Those 8.9 million units constitute 8% of the total PC-monitor market; at $1200 apiece, that would be a substantial $10.7 billion market.

Driving Forces

Initial survey results from the *IDC Weekly Report (IDC)* point to an increased demand in 1998 for 17-in.-and-larger monitors in U.S. businesses. This news is probably not surprising. More interesting is the fact that the average extra cost a business is willing to pay for a larger monitor is $337. As PC systems decline in price from $2000 to $1200 and below, a premium of $337 becomes a steadily larger portion of the total systems cost. On the other hand, many users report that they are willing to pay 1.5 times the current CRT price to get an LCD monitor. And falling system prices may mean that users have more money to spend on a high-quality FPD monitor.

How fast will the new flat-panel market grow beyond 2001? It's hard to predict. The monitor market is a new entity that is emerging much like the computer-processor market, with similar time-to-market issues and ever-faster, newer, exciting technology. Once the flat-panel market starts growing, it could develop at a very fast pace, but it's hard to make detailed projections because of varying dynamics, such as fab capability, the global economy, and overall demand from end users.

Trends

At the beginning of 1998, the price for flat-panel monitors did not appear to be moving under $1000, a price point that is a key factor for demand. But the monitor business climate can change overnight and spin the direction of the market. For example, a Japanese company named Artwork recently announced that it will manufacture and market LCD monitors for around $860, according to a Japanese electronics publication, *Nikkei Microdevices.* This would be the lowest price point yet for a 14.1-in. LCD monitor, but current prices are considerably higher. When IBM cut prices on its LCD panels in April, a 14.1-in. monitor was discounted to $1499. Compaq Computer offered a 14.5-in. monitor in February for $1599.

Artwork said the low prices are possible because it will hand over its proprietary low-cost flat-panel technology to Korean manufacturer LG Electronics in exchange for the LCDs, *Nikkei* reported. The company also announced a 12.1-in. LCD for $540.

What Do the Customers Say?

The FPD-monitor business has attracted heavyweight players, including NEC, IBM, Compaq, Silicon Graphics, Sun, HP, and Dell. They are all indicating that the CRT's days may be truly numbered.

According to a study by *IDC,* Sony and NEC are the clear brand favorites in FPD monitors. The third favored "brand" turns out to be "don't know" at 18% overall. The top two vendors plus the "don't know" category accounted for 67% of the total survey sample. Based on the research, there is clearly room for each monitor and PC vendor in this market to re-examine its role in promoting brand recognition.

The biggest challenge to the acceptance of FPD monitors is price. Flat-panel monitors will not become commonplace until the price decreases, and manufacturing facilities are now ramping up to make that possible. But, in addition to cost considerations, there are technical hurdles that need to be overcome.

Interfacing Challenges

The latest interfacing challenge for FPDs is the move to high-resolution LCD panels, which are being considered for use in high-definition TV (HDTV), as well as automotive and consumer applications. Before FPD monitors can be brought into widespread use, we need to fill the need for a practical host-monitor interfacing method.

While the host-monitor interface issue seems simple on the surface, it involves some sophisticated technology. A high-resolution FPD using TTL/CMOS would require 52 wires across the interface, while LVDS needs only 10 wires, which makes the cable far less unwieldy and reduces costs. The high-speed signals on the wires in TTL can also create an electromagnetic-interference (EMI) nightmare.

To accommodate desktop FPD monitors, computer makers need an interfacing method that satisfies the same requirements as do the interfaces for laptop applications: high bandwidth with a reduced number of wires and minimal EMI. Reducing the number of wires is particularly important for desktop applications because users will have to deal with the cable between the host and monitor.

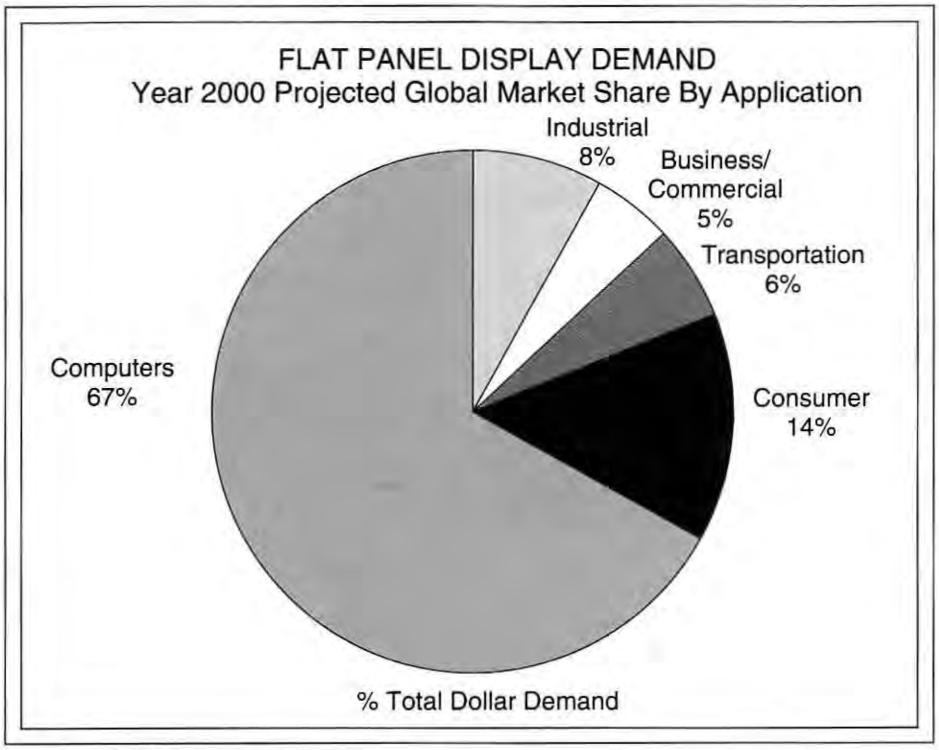


Fig. 3: Two-thirds of the flat-panel displays projected to be sold in the year 2000 will be used in – or with – PCs. (Source: Stanford Resources, Inc.)

The interfacing solutions used for CRT monitors are undesirable for FPDs. The interface would cost too much because the required analog-to-digital (A/D) and digital-to-analog (D/A) conversion circuits are expensive. (This is the approach that has been used with most of the first-generation FPD monitors, and is an important contributor to their high cost.) There are also reliability issues associated with transmitting and receiving high-frequency analog data.

The ability to interface with analog displays is, of course, incorporated in every desktop computer today, and it will take time to replace analog. As monitors come out with digital interfaces and manufacturers produce add-in cable interface boards at a reasonable price, host manufacturers will shift to digital or incorporate "universal" display controllers that can drive either digital or analog displays.

But during the transitional period, OEMs will some have pressing questions:

- Can a digital interface be bought in volume?
- Can it be bought at an affordable price?
- Is there a second source to support this interface?
- Is it an open standard?

Choosing a Digital Interface

Currently, there are two competing choices for the interface connection. The first is low-voltage differential signaling (LVDS) and the second is transition-minimized differential signaling (TMDS). LVDS is extensively used in notebook computers, and is embodied in the system called FPD-Link. It was relatively easy to carry the basic technology over to LVDS Display Interface (LDI) devices for the monitor market. LVDS is a true differential technology that requires only two signal conductors. LVDS chipsets are currently available and are manufactured by National Semiconductor.

TMDS is a licensed technology that is sold under the name PanelLink and can be purchased from Silicon Image. PanelLink formed the basis of the VESA digital interface standard but has not yet been incorporated in many shipping FPD monitors. Some early adopters had concerns about the technology's apparent susceptibility to damage from electrostatic discharge, and found that extensive shielding is required to meet EMI regulations. TMDS is not a true differential technology because it requires three wires: two signal wires with a common ground wire. Despite the relatively slow start of TMDS, many monitor makers plan to offer their OEM customers a choice of LVDS or TMDS in the future.

Technology and Market Needs

The market is demanding increased pixel counts from its FPD monitors, and this is increasing the urgency for an advanced interfacing method. There are three reasons for this:

- Increasing screen resolution expands the bandwidth requirement between the computer and the screen by the square of the number of pixels.
- The resulting higher clock rates generate more EMI.
- The FPD's requirements for higher addressability lead to wider conventional cable/connector interfaces, which are impractical. With conventional TTL technology, the XGA screens commonly used in laptops would require a 52-wire interface with heavy shielding to meet FCC EMI regulations.

These problems are solved by National Semiconductor's LVDS system, which also generates very little noise and minimizes susceptibility to crosstalk by using a differential data-transmission scheme. Differential transmission uses two wires with opposite voltage swings instead of the one wire used in single-ended methods. The advantage of the differential approach is that common-mode noise does not tend to couple onto the two wires with their opposite voltage swings and is thus rejected by the receivers. The receivers respond only to differential voltages - voltage differences between the two wires - which represent data signals.

Because differential technologies such as LVDS reduce concerns about noise, they can use lower signal voltage swings. This is a crucial advantage because it is impossible to raise data rates and lower power consumption without using low-voltage swings. Specifically, LVDS uses a differential voltage swing of only 300 mV (typical) - less than half the voltage swing of pseudo emitter-coupled logic (PECL) and 10 times lower than traditional TTL/CMOS levels. In addition, LVDS's

TMDS and LVDS: An Integrator's View

Most LCD monitors currently in production use LVDS, but just about every vendor is on the verge of coming out with a TMDS monitor or they have one in development.

TMDS has been adopted as the VESA standard, and it seems to make more sense overall in terms of transmission, but we have little data on its EMI performance to date. However, LVDS is not delivering the EMI performance originally expected. In fact, we see no improvement in EMI performance with LVDS compared to straight digital (TTL). However, LVDS does permit a longer transmission cable than TTL, and it reduces the visible noise on the screen compared to TTL.

Second sources are available for LVDS. In addition to National Semiconductor, there are Texas Instruments and a fairly new Japanese company called THine, both of which make LVDS chips that are pin-compatible with National's. Although all these chips are nominally the same, they each have individual characteristics. In our experience, the National Semiconductor chip generates unanticipated noise when the input video signal is in particular frequency bands, while THine's chip produces the least noise of the three.

What's our choice of technologies? Dolch Computer Systems implements both LVDS and TMDS on all of our interface boards, and we populate each board depending on what the panel expects. But for our rugged industrial monitors, the ultimate solution will probably be FDDI, VESA's fiber-optic interface.

- Hassan Karimian
Director of Display Technology
Dolch Computer Systems, Inc.
Fremont, California

CMOS current-mode driver design greatly reduces quiescent power-supply requirements and noise generation.

National Semiconductor's recently announced LDI chipset is the first production chipset specifically designed for flat panels with resolutions of SXGA and above. The company sees this as an emerging market with potential for exceptional growth over the next 5 years. As digital monitors become commonplace, new features will improve the performance of the flat monitors and make them superior to current CRT-based monitors.

National Semiconductor's existing LVDS interface devices work for cable lengths as long as 5 m, which is more than sufficient for current desktop applications. Some people in the industry have overlooked LVDS as an interfacing method for desktop LCD monitors because of the potential need for a longer cable drive. For longer cable lengths - up to 10 m - the interface needs to account for additional factors such as dc balance and cable deskew.

LVDS Display-Interface Chips

To provide a digital interface for high-resolution FPD monitors, National Semiconductor is packaging LVDS technology in LDI chips. The CMOS LDI transmitter and receiver chips support SVGA (800 × 600), XGA (1024 × 768), SXGA (1280 × 1024), and UXGA (1600 × 1200) screen resolutions in desktop displays with CRT or LCD timing.

By taking advantage of these chips, designers obtain a ready-made interface that leverages LVDS to reduce power consumption, EMI, and the number of connecting wires compared to conventional technologies. The chips are suitable for use with AMLCD and double-supertwisted-nematic (DSTN) monitors, forming the interface between the desktop host's graphical-user-interface (GUI) display controller and the LCD's timing-control application-specific integrated circuit (ASIC).

The new chips include a 3-V 112-MHz shift clock that supports bandwidths as high as 672 Mbytes/sec. This data rate, combined with a dual-pixel-per-clock technique, enables the chips to handle UXGA resolutions. At the same time, the 345-mV LVDS swing minimizes EMI. To enable the interface to work over long cables, the chips include cable deskew, pre-emphasis, and dc balance. The receiver chip also provides a 50% output clock to simplify interfacing to the display's timing controller. The chips are fully backward-compatible to existing FPD-Link products. The LDIs are slated for release in late July, 1998. ■

What's Behind Good Display Measurements?

If our measurements can't be trusted, we can't know for sure which design changes or control adjustments are really making things better. This is the first article in a series from the U.S. National Institute of Standards and Technology.

by Edward F. Kelley

HOW MANY LUMINANCE MEASUREMENTS do we need to make to feel comfortable with the result? What do we do if the checkerboard pattern on the screen appears to the eye to have more contrast than we are measuring? Which do we believe: the instrument or our eyes?

How can we be comfortable with the calibration of our instrumentation? We can measure voltages to better than 0.1% with inexpensive voltmeters, so why can't we do the same with luminance meters?

When we deal with display measurements, there can be many questions that confront and even confuse us. Good display metrology is not based upon the mere purchase of a good instrument; it depends also upon how we use that instrument and how we approach the measurement process. There are a few things we should keep in mind as we make measurements on our displays. These involve our implementation of the measurement and our expectations of the results.

Trust Your Eye

People who work in the display industry may sometimes get the impression that the eye is not very good at what it does. Many experiments are performed to determine the limitations of the eye so that better vision models can be developed. If we are not careful, we might focus on the limitations and come to think less of the eye than we should.

For example, we might hear someone say, "You don't need more than 100:1 contrast to render a scene. It's all the eye can reasonably see anyway." Is that true for all situations? It might be true for this particular example - provided the measurements were made correctly.

The capability of the eye can be demonstrated by the following experiment. A dark, transparent neutral-density film (NDF), ideally with 50% attenuation or more (density of 0.3), should be used. This material, similar to the plastic film people put on car windows, can be obtained at an art-supply store or an automobile-parts store. A stepped neutral-density target is made by cutting up the film and overlaying strips on clear glass or plastic, with a small displacement for each layer. The target is placed over a quasi-uniform light source, but it doesn't have to be as sophisti-

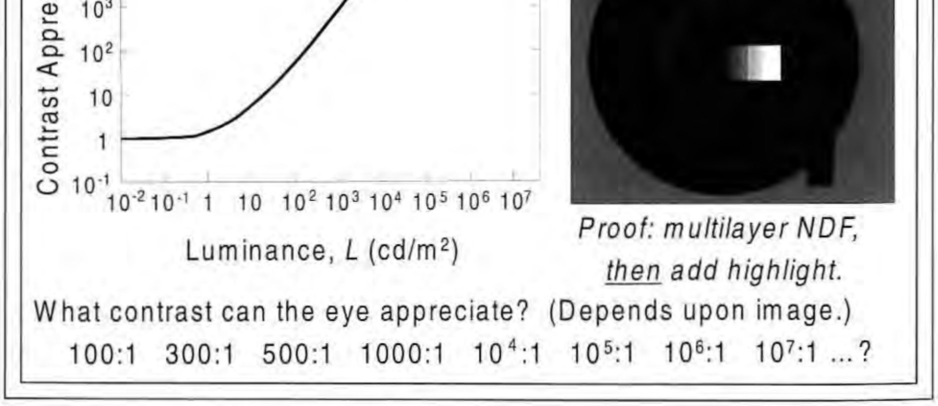


Fig. 1: The eye can appreciate more contrast than many people realize.

***Edward F. Kelley** is a physicist at the U.S. National Institute of Standards and Technology (NIST), Bldg. 225, Room A53, Gaithersburg, MD 20899; telephone 301/975-3842, fax 301/926-3534, e-mail: kelley@eeel.nist.gov.*

0362-0972/98/1407-018$1.00 + .00 © SID 1998

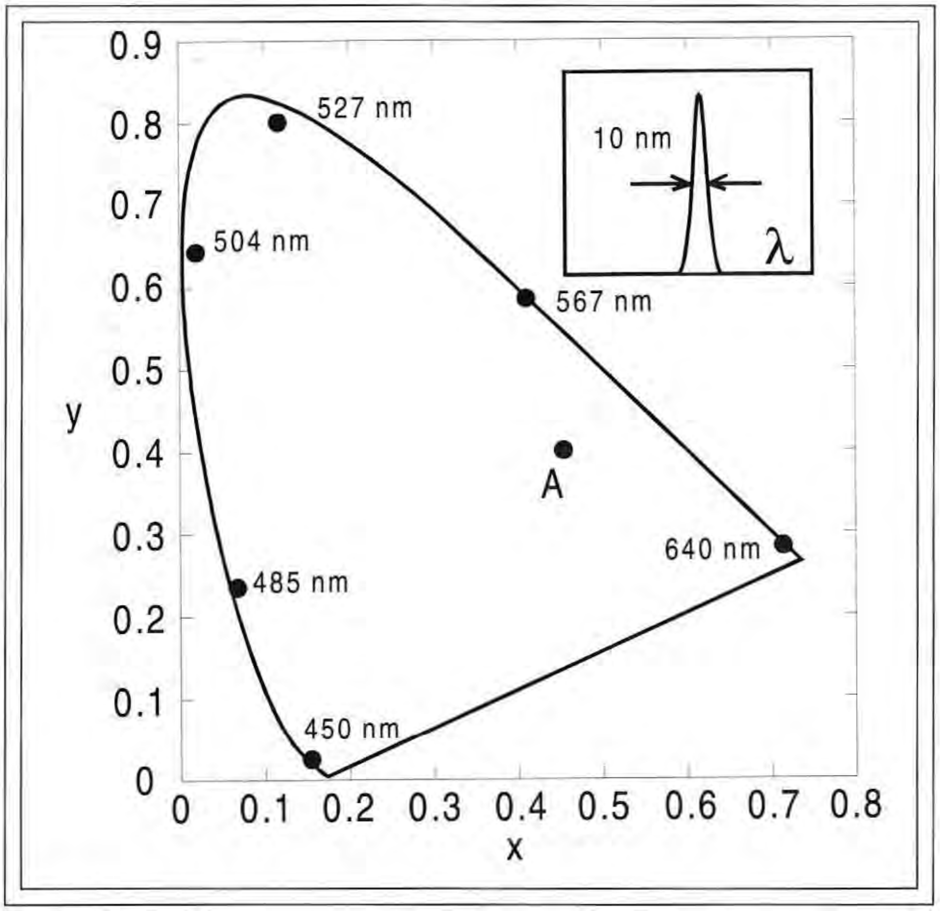


Fig. 2: Color measurements are shown for interference filters with 10-nm bandwidths at various wavelengths in the CIE 1931 color space. CIE illuminant-A is shown.

cated as the integrating sphere shown in Fig. 1. Black tape is used to mask off all light except that which comes through the target. A contrast of about 1000:1 is found 10 steps from clear, assuming a 50% transmission; 65,000:1 is about 16 steps from clear.

How many steps can be seen as close as 0.2-0.3 m away? Those who think the eye is "bad", are going to be surprised! Most people have little difficulty seeing 65,000:1. When a flashlight with a bare exposed bulb is moved into the field of view, as shown in Fig. 1, many people will still be able to see the entire target. But the little filament will appear much brighter than the brightest step in the target. That is extreme contrast! The eye is fairly well designed after all.

If we put that target on a light table (of the kind used for viewing slides) so that it is surrounded by white light, we won't be able to see nearly the same contrast. The amount of contrast the eye can appreciate depends upon the solid angle of the dark area. Thus, we may not be able to appreciate more contrast than 25:1 for a very small black letter on a white surface, but we can appreciate much more contrast in a large dark scene, such as a rainy night on a city street - or the target we made from ND film.

The eye can indeed be trusted in many ways. When setting up a measurement, we must look at what the instrument is seeing - not through the viewfinder, but from the vantage point of the lens of the instrument. (Those of us who need to wear glasses are at a disadvantage here because the glare they introduce reduces scene contrast.) During luminance measurements of a black screen, the eye will catch spurious reflections - such as reflections of instrument lights or other illuminated objects in the room - that might be missed when looking through the viewfinder.

Great Expectations

We may spend a lot of money on a spectroradiometer or colorimeter and be surprised to find the specifications state a ±4% measurement uncertainty. Why is there such a large uncertainty when we typically find voltmeters with ±0.1% relative measurement uncertainties?

The problem is not with the instrument, but rather with finding a light source that can be calibrated well enough to provide an accurate fundamental starting point. The best that can be done today is approximately 0.5% for the combined relative standard uncertainty of the luminance measured by a national standards laboratory such as the U.S. National Institute of Standards and Technology (NIST). This number includes all the contributions toward the uncertainty in the measurement in a root-sum-of-squares (RSS) method of combining uncertainty components.[1] A national standards laboratory will then express this result as an expanded uncertainty with a coverage factor of 2 for an approximate 95% level of confidence in the result. (This is the new terminology for a "two-sigma" uncertainty.[2,3]) We thus have a starting relative expanded uncertainty of about 1% for any kind of calibration of light, such as the luminous flux of a lamp or the luminance of the exit port of an integrating sphere. That is the best that an equipment manufacturer has to work with.

Therefore, a manufacturer that assumes his incoming lamp was not damaged or changed by handling during shipping starts with the 1% relative expanded uncertainty. Using an RSS of component uncertainties, he then factors in his own uncertainty estimates, and perhaps comes up with a combined standard uncertainty of 2% - the old terminology would be a "one-sigma" uncertainty. To provide a 95% confidence in the result, he expands it to 4%, and there we are.

As we try to understand the manufacturer's specifications, we need to know how he determined his uncertainty, based as it was on the transfer standards as calibrated by a particular national standards laboratory. If the manufacturer states, "the relative expanded uncertainty with a coverage factor of 2 is 4%," then there is some idea of how it was determined. But if the statement is, "the accuracy is ±2%," we don't know what was done to establish that uncertainty. We do not, for example, know what coverage factor was used. Did the manufacturer use 1% for the uncertainty of the pri-

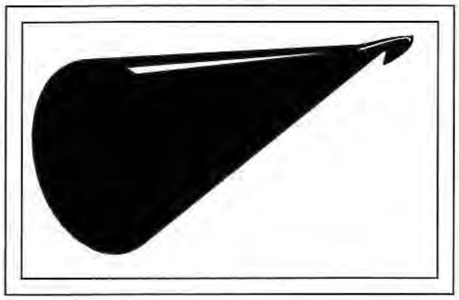


Fig. 3: A light trap constructed from glossy black plastic can serve as an absolute-black reference.

mary calibration of his chosen national standards laboratory? Did he use 0.5%, thereby removing the coverage factor of 2 from the national-standards-laboratory calibration in order to use the equivalent of one standard deviation?

Before we can really understand what the manufacturer's uncertainty claims mean, we have to know how he determined them. As implied in the previous paragraph, one manufacturer might say "4%" and another "2%," and they could mean the same thing! Without knowing exactly how the uncertainty was established, we really don't know much about the uncertainty statement. Most of the time we would assume an expanded uncertainty using a coverage factor of 2, but we still need to know how the manufacturer handled the component uncertainties - including the uncertainty of the calibration in his national standards laboratory. One company might be very conservative; another might be less conservative.

Confidence in Contrast

When measuring contrast, we must contend with some additional problems. Let's assume a 4% relative expanded uncertainty. We want to estimate the uncertainty of a full-screen contrast measurement of the ratio of the white luminance to the black luminance. Removing the coverage factor of 2, we start with our luminance measurements at 2% relative uncertainty, which reflects an expectation of one standard deviation. That may be true for the white-luminance result, but what about the black luminance?

With black, there may be added problems, including noise, instrument linearity, round-off errors, digitization resolution, or readout error. This is especially true if we are near the limits of usability of the instrument, and that can happen with modern high-contrast displays. If our display has a full-screen contrast of 250:1 and we measure a white luminance of 100 cd/m^2, then the black luminance will be 0.4 cd/m^2. If the instrument measurement uncertainty at low levels were an additional 0.05 cd/m^2, then - in addition to the 2% calibration relative uncertainty - we would have a 12.5% relative uncertainty (0.05/0.4). When we combine these according to the RSS method, we obtain a dark-measurement relative uncertainty of 12.7% for the black luminance. (We'll retain the third significant figure to keep track of the calculation and eliminate it in the final result.)

But this is only one component of uncertainty. The relative uncertainty of the white luminance is still 2%. Combining the relative black and white uncertainties by the RSS method results in an overall relative combined standard uncertainty in the contrast measurement of 12.8%. In other words, the primary source of error for the contrast measurement is in the black measurement.

At this point, we are dealing with a 68% confidence - an expected "one-sigma" standard deviation. The relative expanded uncertainty with a coverage factor of 2 is 26% - with a confidence of 95% - and that is a large error. Since we haven't accounted for any repeatability yet, our uncertainty estimate may be low. (Repeatability is the standard deviation of repeated measurement results taken in a short period of time. It would be combined with the other uncertainties using the RSS method.)

All of this has to do with our expectations of the instrumentation. If we understand the sources of error and how those errors propagate, then we will not be alarmed unnecessarily when disagreements occur. For example, we will no longer be expecting the uncertainty of a contrast measurement to necessarily be the same as the calibration uncertainty of our instrument.

Other factors can contribute to the introduction of errors in making a luminance measurement. Complications arise with any lenses that might be used. The measured luminance can change with focus, aperture size, polarization, size of source, alignment, and other parameters.[4] Although the manufacturer selects a lens that minimizes these, they are not totally eliminated and will therefore contribute to the uncertainty of the instrument.

An interesting situation arises from the large uncertainty associated with luminance measurements. The repeatability of the instrument may be smaller by a factor of 5-10 than its measurement uncertainty, but, without verifying this, people often rely on a single measurement instead of taking a number of measurements and averaging the results. A single measurement is appropriate only after we have convinced ourselves that with the meter-display combination being used, the repeatability is, indeed, small. Only then can we make other measurements under similar circumstances using only one measurement result.

Looking for Errors

People generally don't think in terms of diagnostics - looking for possible sources of error - as they make display measurements. But diagnostics help us to reveal serious problems as well as help us to feel comfortable with the measurement results we obtain. For example, suppose a colorimeter is calibrated against a CIE illuminant-A source to have a relative expanded uncertainty with a coverage factor of 2-4% for luminance measurements, and an expanded uncertainty with a coverage factor of 2 for the chromaticity coordinates 0.002. That calibration is good for only one point in the color space - and may be good for only one luminance value.

If we want to use the colorimeter for saturated colors, can we assume those uncertainties will carry over? If we're not sure, we should consider diagnostics. Narrow-band interference filters that sample the visible spectrum - 400-700 nm (Fig. 2) - are readily available. Careful measurements should be made to determine how close the color of the filtered light comes to the spectrum locus in the color space. If the chromaticity coordinates fall near the locus, then we will feel comfortable using the instrument all over the color space. If the colors fall far away from the locus or significantly outside the color space, then we know that we will have to make corrections in order to use the instrument on highly saturated colors.[5]

Making a measurement of the contrast of a checkerboard pattern provides another example. How much veiling glare corrupts the black measurement because of stray light from the white areas of the screen - even if the instrument has a flare-free lens? Diagnostics should be used to be sure that the instrument is working properly: A small black patch the same size as the checkerboard rect angle - which is called a replica mask - is placed over one of the black rectangles. Let us suppose the replica mask looks obviously darker to the eye than the other checkerboard rectangles. However, if the black patch and the black checkerboard rectangle have almost the same luminance, then there is a veiling-glare problem with the instrument that needs to be corrected. Provided the area to be measured is not small, a glossy cone mask may be used to provide a more reliable measurement.[6]

There is a simple diagnostic tool called a light trap (Fig. 3) that provides an "absolute" black in any scene. The light trap can be made by rolling black glossy plastic into a narrow cone (like an ice-cream cone) and securing it in that shape with tape or glue. The apex of the cone should be bent around upon itself to eliminate any reflective dimple at the point of the apex. This cone can be very small or rather large. It is very black inside, and not much can be seen (except dust). It should be used as a diagnostic tool for a reference black when dealing with veiling glare. But we cannot arbitrarily subtract the cone-trap black result from other black-measurement results to correct for glare because the amount of glare depends upon the size of the black area. For this, we need a replica mask or a cone mask.

The veiling-glare problem is not limited to luminance corruption; it can also mix colors.

Don't Trust Anyone

While it is tempting to trust what others conclude and measure, a healthy skepticism is recommended. If we can't measure it ourselves, or verify it in some way, then how can we be sure that the other person measured it correctly? Suppose a claim is made that a certain display has a contrast of 250:1, and the display is advertised as being better than all other displays in its class.

A skeptic would ask how the contrast was measured. Are the contrasts of the other displays measured the same way? If something like a checkerboard pattern was used, was an accounting of veiling glare made in the measurements? Did the other manufacturers account for glare? Were any adjustments made to enhance the contrast? Was the display measured under its normal operating and viewing conditions, or were the settings changed for the black and white measurements separately to deliberately increase the contrast?

There is a dangerous argument that is frequently made: If the eye doesn't see it, why worry about measuring it so carefully? But what does the eye actually see? Are we to base our evaluations of what the eye sees upon good metrology or sloppy metrology? It is clearly safer to make a good measurement. The issue is separating the physics from the psychophysics so that our vision models and display measurements rest solidly on a bedrock of good metrology.

A little skepticism can go a long way in preventing misconceptions from creeping into the conclusions that may be drawn from inadequate display metrology. But it is not only the methods that are suspect; we must also regard our equipment with suspicion.

If we send off a luminance meter to be calibrated, do we assume it is calibrated when we get it back? Many would not hesitate to say yes, but suppose the meter was dropped in handling and was no longer calibrated. We wouldn't have any idea that such a thing had happened unless we had duplicate methods of checking any resulting changes.

Another meter would help, especially if there was a history of the relative performance of both meters. But suppose that, in addition to the two luminance meters, we had a well-designed and carefully cared for integrating-sphere light source, with a photopic photodiode monitor connected to a microammeter, to make relative luminance measurements. Then we would have three different ways to monitor any changes. If a history of the relative performance of all three instruments has been maintained, we will be able to spot any anomalous behavior. Now the comfort zone is increased because of the redundancy.

Be Suspicious

If we have an uneasy feeling that there is something wrong with our measurements, we are probably right. When we find that everything is going perfectly while taking test measurements, there is probably something wrong. There are multitudes of details that are never written down in a procedure, and these often amount to the application of common sense gained from experience.

The intuition that has developed from years of working with equipment can serve us well. We must not be afraid to listen to those nagging doubts. There is a certain amount of agonizing that seems to be required in order to develop any good measurement. For example, someone with little experience might never think about cleaning the front surface of a lens - which must be done carefully, by the way - but after he has taken a few weeks of bad data because of a dirty lens, he is not likely to forget it. Checking the lens to see if it is too dirty might even become an almost unconscious act. The same is true of developing a sensitivity to veiling glare. Once someone has had to trash months of data because of failure to account for glare, he will never forget to think about it before recording that final data.

Documenting Too Little – or Too Much

The idea that to be "Dr. Science" we have to write everything down in detail may provide us with a lot of useless documentation and no time remaining to do the job correctly. Invariably, in this author's experience, the first attempt at making a difficult measurement is less than encouraging. After set up, we should try to get to the final measurement result as fast as we can, holding the documentation down to a minimum, if any at all. We probably don't have any idea of what's really going to happen.

By taking some data, we get a feel for how things are working. Are our expectations being met? Do we understand what is happening with the equipment? Generally, we will realize something is wrong. Then we can go back and more carefully configure the apparatus and refine our procedure. At this point, the data might start to make some sense, but there may still be problems.

Finally, by the third or fourth time we delve into the problem, we begin to figure out what is happening. The data start to make sense and we understand where the errors previously obtained were coming from. Now we can settle down to take some useful data - and now is the time to make a thorough documentation so that we can recreate the proper method and apparatus configuration. Unfortunately, we are usually in such a hurry at this point that we neglect to document our measurement. This, too, should be avoided.

The Bottom Line

The preceding comments may ruffle some feathers. It seems that nobody wants to say these things, although we have all experienced them. The bottom line is that good metrology is more than a good instrument. Some good metrologists have made rather remarkable measurements using what others would consider to be equipment that is inadequate for the task. Other people have made terrible measurements using good equipment. In the end, metrology is more an attitude than a set of procedures - an attitude of skepticism.[7]

References

[1]Yoshihiro Ohno, *Photometric Calibrations* (NIST Special Publication 250-37, U.S. Department of Commerce, National Institute of Standards and Technology, July 1997). Presents the details of how calibrations are made in photometry and describes the subtleties of instrumentation use, with a complete uncertainty analysis.

[2]Barry N. Taylor and Chris E. Kuyatt, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results" (NIST Technical Note 1297, 1994 edition). Based on the *ISO Guide to the Expression of Uncertainty in Measurement* (International Organization for Standardization, 1995).

[3]Barry N. Taylor, *Guide for the Use of the International System of Units (SI)* (NIST Special Publication 811, 1995 edition).

[4]CIE Publication No. 69, "Methods of Characterizing Illuminance and Luminance Meters."

[5]P. A. Boynton, Y. Ohno, and E. F. Kelley, "Interference-Filter Characterization of Spectroradiometers and Colorimeters," *SID Intl. Symp. Digest Tech. Papers* **27,** 207-210 (1996).

[6]P. A. Boynton and E. F. Kelley, "Accurate Contrast-Ratio Measurements Using a Cone Mask," *SID Intl. Symp. Digest Tech. Papers* **28,** 823-826 (1997).

[7]The discussions on uncertainty and diagnostics in this article are addressed - along with much more - in the Video Electronics Standards Association (VESA) Flat Panel Display Measurements Standard (FPDM) that was scheduled for release in May 1998. ■

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.

Pioneering the Right Technology at the Right Time

Identifying the market opportunity for a truly portable LCD projector was easy; quickly developing the technology to exploit that opportunity was the achievement that put Lightware on the map.

by Paul White

IN 1995, a "portable" LCD projector weighed about 15 or 20 lbs. and cost about $8500. While a few salespeople, trainers, and corporate presenters were using these new projectors, the bulk of the market was not. Both weight and cost were barriers to entry. It just wasn't that easy to take a projector on the road. These early LCD projectors didn't fit in overhead bins on airplanes, and sending them as checked baggage was far too risky. They were a burden to hand-carry.

The young LCD-projector industry was mainly focused on very high image brightness, to the exclusion of other features. No one was addressing portability or a lower price point, features that were necessary for wide acceptance.

A group of engineers and industry leaders believed they could build a smaller, better projector. They also believed that once the technology opened up new markets, higher production volume would enable them to lower costs.

They quickly backed up their idea with informal market research. Their interviews with potential end users - mobile presenters or "road warriors" - confirmed the need for reliable, portable, affordable technology. These road warriors needed to carry a laptop computer and a projector in the same case, and fit that case in an airplane's overhead bin. This requirement limited the projector's weight to under 10 lbs.

The company had to grow fast. Lightware's founders knew that whoever brought

Paul White is President of Comp View, Inc., 10035 SW Artic Dr., Beaverton, OR 97005; telephone 503/641-8439, fax 503/626-8439; Web site: www.compview.com. Comp View is a major reseller of LCD projection systems.

Lightware, Inc.

Fig. 1: *In the VP100, Lightware accomplished what no company had done before: put an amorphous LCD panel into a 9-lb. package and get more than 250 ANSI lumens out of it.*

0362-0972/98/1407-024$1.00 + .00 © SID 1998

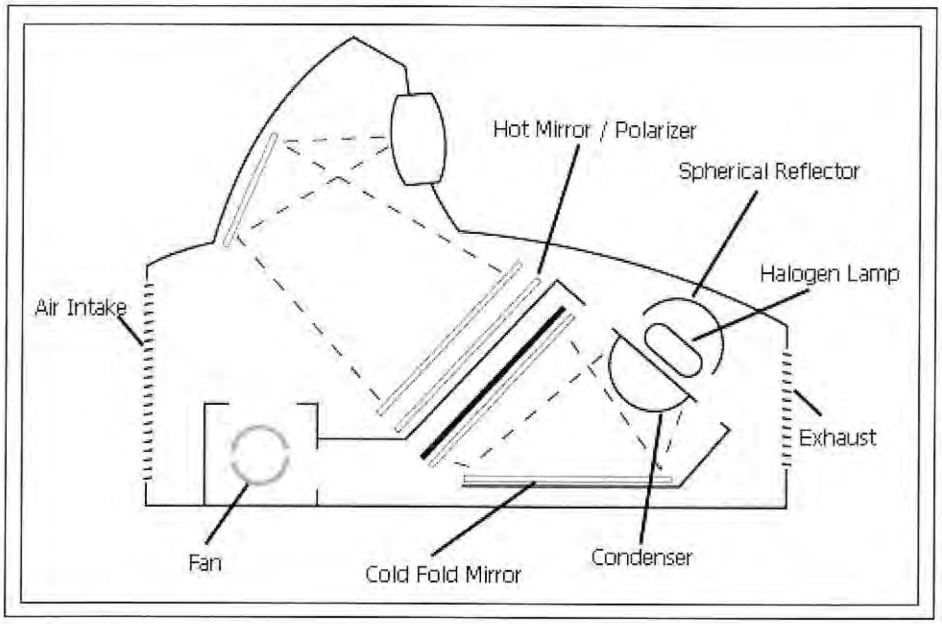


Fig. 2: The VP100 relied on innovative compact packaging to break then-existing barriers of weight and size.

out the first truly portable projector would gain a tremendous share of an expanding market. Time was truly of the essence.

Lightware's team set out to accomplish what no one had done before: put an amorphous LCD panel into a 9-lb. package and get more than 250 ANSI lumens out of it (Fig. 1). How did they manage to take an established technology and put it into a cutting-edge, award-winning design?

Building a Company on Display Integration

Arlie Conner, Lightware's Chief Technologist, has always been an innovative designer. From his research and development work with InFocus Systems, as well as his independent design consulting, he felt sure it was possible to combine existing LCD technology with an ultra-portable design. Conner and David Booth, Lightware's other engineering virtuoso, overcame one obstacle after another.

"The design challenges were pretty daunting," recalls Conner. "First, put a power-intensive lamp, an imaging device, and a projection lens into a small package. At the same time, you need to manage the heat and light leakages and still have room for a bunch of cables in the carrying case. The lamp power supply itself can weigh 4 lbs." The design innovations in Lightware's first product included a patented optics pathway, a high-efficiency ventilation system, and a compact, rugged body design. Put together, these innovations made a breakthrough product for mobile presenting: Lightware's VP100 (Fig. 2).

In addition to overcoming the challenges posed by lighter design, the new projector offered other features that surprised and delighted customers. The VP100's lamp housing, for instance, allows presenters to change bulbs during a presentation, an industry first. The VP100's "pop-and-play" lens keeps the overall design of the projector compact and portable, and protects the lens at the same time.

The Lightware team knew that superior features and an innovative design wouldn't help them if they missed the opportunity to be first to market with a sub-10-lb projector. To ramp up very rapidly, Lightware found in CTX Opto a manufacturing partner to produce its breakthrough design reliably and quickly.

Success

Lightware's 9.25-lb. VP100 projector set the benchmark for lightness in the projection industry. As the first company to fill the mobile-presentation niche with a bright, portable, affordable projector, Lightware shaped an emerging market when it launched the product in 1996.

The response was tremendous. The VP100 garnered *PC Magazine*'s Editors' Choice Award for LCD projectors, a huge coup for a start-up company's initial product. Audio-visual reseller and dealer channels came on board, impressed by how well the VP100 resonated with customers. Then, end users validated the technology choice with their checkbooks.

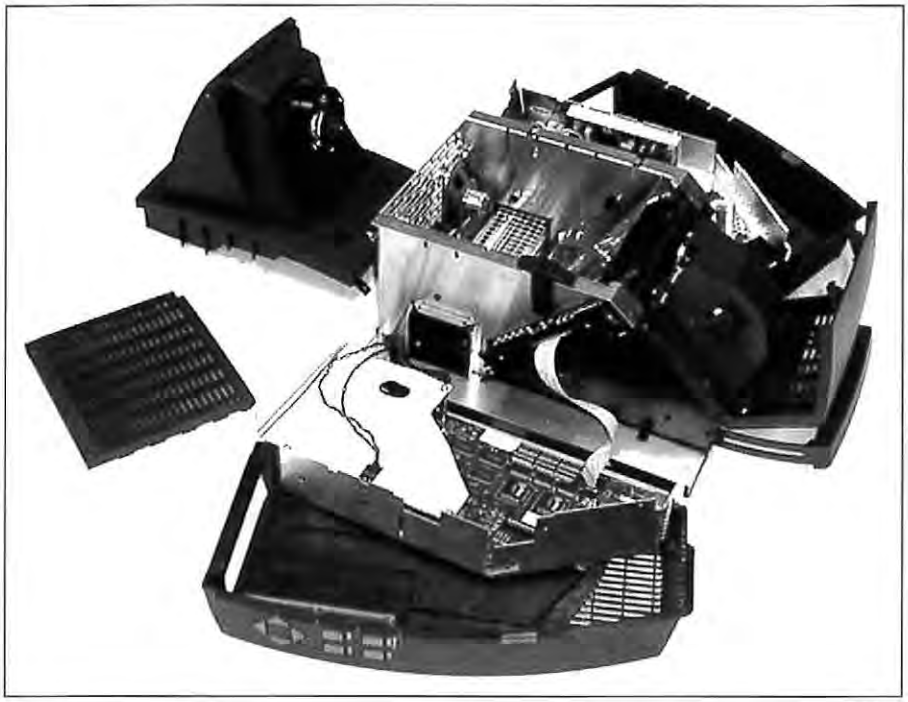
The company grew dramatically in its first year, and launched a second product based on the same form factor, the SVGA-resolution VP800. The VP800 met customers' growing need for higher brightness and true 800 × 600-pixel format.

In 1997, Lightware launched the MVP800, the first ultra-portable projector with a metal-halide bulb – and another engineering breakthrough for the team of Conner and Booth (Fig. 3). "When we were designing the VP100, we opted for the smaller, lighter halogen lamp and power supply. With additional design innovations for the MVP800 – including a mounting scheme for the metal-halide lamp that incorporated a smaller reflector while maintaining good efficiency, evolutionary changes in the power-supply design, and better routing of cooling air – we overcame the weight factor of the metal-halide lamp, which has the advantage of giving a brighter projected image with a bluer white. The modification wound up adding about a quarter pound to the unit and required specialized engineering to put the larger lamp power supply into our uniquely shaped box," said Booth.

Affordability

Other projector makers followed Lightware's lead into the booming market for portable and ultra-portable projectors. So, Lightware took another bold step, dropping the price of its VP800 to $2999. This move made the VP800 the most affordable high-performance unit on the market, essentially the first "personal projector." Suddenly the projector market broadened significantly – and got a lot less crowded. Lightware's sales spiked.

In November and December of 1997, Lightware took the third-rank spot in overall market share. More importantly, the price drop of the VP800 made this technology available to a whole new range of customers, including small office, home office (SOHO) users, schools, government agencies, and large-scale fleet sales.



Lightware, Inc.

Fig. 3: In 1997, Lightware launched the MVP800, the first ultra-portable projector with a metal-halide bulb, and did so in the VP100's compact package. The modification added about a quarter pound and required specialized engineering to put the larger lamp power supply into the uniquely shaped case.

Growing Pains

While Lightware's is unequivocally a success story, that success has not come easily. The company went through a major reorganization in leadership in 1996, bringing a new executive team on board. The transition from struggling start-up to a company managing nearly overwhelming success was not a simple one.

Lightware experienced many of the manufacturing and supply-and-demand challenges that every company goes through. At first, there were too many orders and not enough projectors. Then the pendulum swung and there were too many projectors and too few orders. Then orders caught up again and supply lagged. It's a familiar story.

Now Lightware has mastered these challenges. Its team focuses on bringing powerful, affordable technology to the broadest range of consumers. As they expanded the portables market, Lightware's staff grew tremendously, as did sales.

What Do We Do Next?

Lightware continues to look to the future and evaluate technologies as they appear on the horizon. But each new technology has to pass Lightware's "affordable, durable, proven" test. When Lightware's market requires a specific technology – such as XGA resolution – the company meets that need.

Lightware is currently launching its L-1020 projector, an XGA unit that is the company's first departure from the VP form factor. As with the VP line, the L-1020 is designed to take advantage of technology that is proven, yet effective and appropriate to the needs of consumers.

While DLP (digital light processing) is an interesting and, in some cases, effective display innovation, it has yet to pass the Lightware technology test. Will you see a DLP-based product from Lightware in the future? Perhaps ... when the market need is clear and the technology makes sense in the context of end users' needs.

What does the future hold for Lightware? "Let's dream a little," says Conner. "If we could get the right-sized LCD or a high-efficiency light valve that would allow us to wrap about a gallon of optical parts into a take-out box, that would be a good start.

"Then imagine a compact lamp power supply no larger than a box of Altoids, and you start to get the idea of the next level of portability. The imaging device would have to generate color without much loss and be highly efficient, wasting little light, so that it could use a lamp that requires only about 100 W.

"If you can create a small light-emitting semiconductor in each color with reasonable cost, then a pocket-sized projector is possible." ■

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.

Riding Moore to Market … in 3-D

A young company is combining an innovative technology with big-time alliances and its faith in Moore's law to produce an affordable autostereoscopic projection display.

by Peter Canepa

THE MARKET HAS BEEN CLAMORING for a cost-effective autostereoscopic display for some time. Arcade-game companies, kiosk manufacturers, and others are seeking a way to display real 3-D images that can be viewed without any special eyewear or head tracking.

Infinity Multimedia, working with Cambridge-based ASD Ltd. and Litton Industries, has developed a second-generation prototype of a practical display that time-multiplexes multiple perspective views of computer-generated 3-D images and live-action 3-D video. This unique time-multiplexing technology opens significant applications opportunities relative to other autostereoscopic approaches.

The Cambridge Method

The Infinity Multimedia 3-D display is based on the Cambridge autostereoscopic method invented and patented by Dr. Adrian Travis of the University of Cambridge. This system is time-multiplexed in that an image of each point of view of a scene is displayed sequentially on a projection CRT at high speed. A transfer lens projects the image from the CRT onto a Fresnel lens, which is the "screen" for the viewer (Fig. 1).

Within the transfer lens is an LCD "directional" shutter that opens and closes columns – which are either opaque or transparent. As shown in the figure, the Fresnel lens focuses the light traveling through each column to produce the view zone, or "window." If images are put up on the CRT for each view and the proper column of the shutter is made transparent in synchronization with the correct view, then the viewer will see a different image in each window. The dashed lines show how the viewer sees the entire CRT image with each eye through the third and subsequently the fourth column of the directional shutter. On the next cycle, the next column of the directional shutter would open and the correct image would be put on the CRT to be seen in the next window.

Current prototypes of the autostereoscopic display use monochrome projection CRTs, which are bright and efficient. Color is produced by adding another component in the light path, a color shutter. In the example shown, instead of putting up seven views on the CRT and sequencing the directional shutter to produce the seven viewing zones, 21 views are put up on the CRT in sequence to produce the seven color views. First, the color shutter is red, and seven views of the red parts of the images are put on the CRT in sequence; then the color shutter is sequenced to green, then blue, during which time the correct seven views are sequenced. Therefore, each window gets one red, one blue, and one green view of the CRT in each complete video cycle. As far as the viewer is concerned, a different full-color view is presented in each zone at all times. We are currently demonstrating a 25-in.-diagonal prototype of this configuration.

The width of each viewing zone must be small enough to provide a different view for each eye. The more views produced, the larger is the overall viewing area in which the viewer can see 3-D. The smaller each indi-

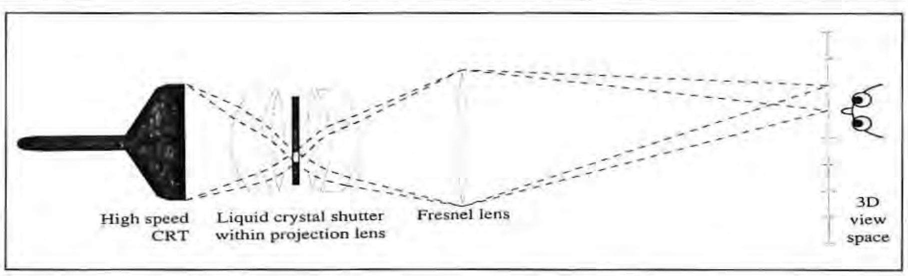


Fig. 1: In the Cambridge autostereoscopic method, the image is time-multiplexed, with the image of each point of view for a scene displayed sequentially at high speed on a CRT. Within the transfer lens (close to the CRT) is an LCD directional shutter that opens and closes columns (makes them transparent or opaque).

Peter Canepa is Chief Technology Officer of Infinity Multimedia International, Inc., 14225 Ventura Blvd., Sherman Oaks, CA 91423; telephone 818/981-4950, fax 818/501-6224, e-mail: infin3D@aol.com, Web site: www.infinitymultimedia.com.

0362-0972/98/1407-028$1.00 + .00 © SID 1998

Infinity Multimedia

Fig. 2: In one possible arcade application, the player sits in his or her seat, fingers on the controls, and competes in a three-dimensional environment.

vidual viewing zone is, the smoother the transition from one view to the next when the viewer moves his head left or right.

The overall width of the viewing area is the number of views times the width of each individual viewing zone. In the 25-in. prototype, each individual viewing zone is 22 mm wide. Four small CRTs (100 mm) are combined to produce 28 of these zones, providing an overall viewing-area width of approximately 620 mm. This "multiview" viewing area provides a considerable degree of motion parallax, adding to the stereo 3-D effect and allowing "look-around" of objects. The depth of the viewing area is considerably greater than the width.

A new prototype with a 50-in. screen is under construction. It differs from the 25-in. prototype in that three monochrome CRTs are combined via dichroic mirrors to provide one projected beam. The viewing zones are produced by the directional shutter, as in the 25-in., but the screen is a concave mirror instead of a Fresnel lens.

Storing the Images

The computing system – or image storage system – simply needs to feed the video at a multiple of the normal video rate. For computing multiview images in real time (for games and simulations), the computer calculates the state vector (the location, size, shape, and texture of all the objects in the scene) for each frame, and then sends this vector to multiple fast 3-D rendering chips that render the multiple views in real time. These are buffered to video random access memory (VRAM) and read out as video by a high-speed digital-to-analog converter (DAC).

For pre-rendered movies or rides, the animation or live-action movie can be stored on a disk array in compressed digital form and fed to a buffer and fast DAC. Each view of the same scene is very similar to its neighbor, which makes two levels of compression possible. One level is across the views (3-D compression), and the other one is in time (such as MPEG or motion JPEG). As a result, 28 views of 3-D does not require 28 times the storage space or transmission bandwidth of a 2-D display. According to current estimates, multiview compression will limit the additional storage space or bandwidth to approximately twice or three times that needed for 2-D of the same resolution. Perceptronics, a California-based small business, Infinity Multimedia, and Litton are working together under an SBIR grant to develop efficient networking of multiview images over low-bandwidth lines.

At the moment, the processing power required for Cambridge-method multiview displays is too great for consumer applications. But the rate of change in processor speed continues to follow Moore's law, doubling every 18 months or so, and the rate of change in graphics-chip computational speed is on an even steeper path. The number of polygons per second throughput for graphics chips is currently doubling in less than 12 months. The combination of these two factors will provide affordable computational power for high-volume consumer applications in another year or two at the latest.

Performance

The current 25-in. prototype produces 28 different points of view, with a screen resolution of 512 × 384 full-color pixels. The screen luminance is 70 fL, with a contrast ratio of about 100:1. The prototype is driven by standard high-speed PCs, with multiple Glint 500TX graphics chips. The next prototype is being designed to have a screen luminance greater than 120 fL. A computer architecture developed specifically for efficient computation of multiview images will be ready when the 50-in. VGA-resolution prototype display is completed in late 1998.

The ability to drive CRTs faster is a key R&D task in the evolution of this technology.

Faster CRT scanning allows more views per CRT and higher resolution. Continued increases in resolution are planned throughout the development process.

Design to Market

Our marketing studies indicate that the best high-volume applications for the first production models of the multiview display will be arcade video games, "film rides," and advertising kiosks (Fig. 2).

The arcade market has had negative growth for the past few years because home PCs are now so powerful that there is not enough difference between the home and arcade experiences for game players to be enticed into the arcades. The totally new experience of autostereoscopic 3-D will provide new types of game play and an experience players cannot get at home.

But this opportunity comes with its own set of challenges. Most of the high-end games in arcades and location-based entertainment centers require significantly larger screens than earlier games did. This is the reason that Infinity Multimedia is working toward a 50-in. production display for the arcade market. We anticipate that an affordable autostereoscopic display will find many other uses in industrial, medical, and other markets.

A year after entry into the arcade and other public-venue markets mentioned above, Infinity Multimedia plans to produce a smaller-screen monitor for attachment to a standard PC. We intend these units to be much lower in cost than the larger units, and we plan to design and market them with a specialized graphics card which will plug into a standard PC. This combination will allow home users to play games and compute in real 3-D without glasses.

Development, Marketing, and Distribution

Infinity Multimedia has the worldwide exclusive rights to the Cambridge multiview technology for the consumer and entertainment markets. Litton, Infinity Multimedia's strategic partner, has the rights for the defense and aerospace markets. The two companies are working together with ASD, an R&D company in Cambridge, U.K., to develop the prototypes and prepare for production. We are planning for full-scale OEM production to be provided by a world-class high-volume display manufacturer, which has yet to be chosen. Full-scale production of the first models is planned for late 1999.

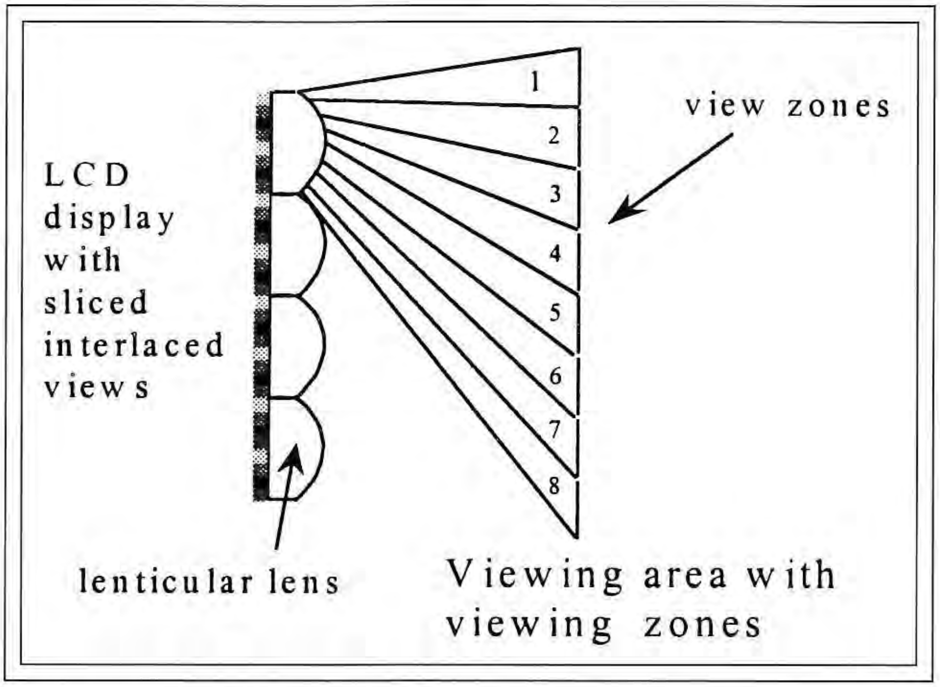


Fig. 3: Many competing autostereoscopic systems use cylindrical lenticular lenslets in front of groups of pixel columns. Each column in a group corresponds to a different point of view for what would be a single column of pixels in a 2-D display.

Alliances are being formed with various leading international companies for marketing and distribution of the 3-D displays. Mitsubishi Corporation, which is an investor in Infinity Multimedia, has marketing and distribution rights in Japan. Thomson Entertainment (U.K.) is working with Infinity to adapt the 3-D display to future motion-base "film-ride" products. (A motion base moves the seat or the entire simulator in synchronization with the film ride or simulation.) The company plans to continue to add additional alliances by market segment and geographical territory throughout 1998 and early 1999. Marketing and distributing through alliances with large established companies will allow Infinity Multimedia to efficiently address the market for autostereoscopic displays, which is projected to be worth a billion dollars at the turn of the century.

Where's the Competition?

Most of the other autostereoscopic technologies under development use one form or another of spatial multiplexing of images. Multiple points of view - usually two, but sometimes more - are generated and displayed on an LCD or rear-projection screen. What is common to these approaches is that all of the points of view are put on the display at the same time, and some form of optical system is used to restrict the viewer's eyes to seeing only the correct view for each eye.

Most systems use cylindrical lenticular lenslets in front of groups of pixel columns. The groups are organized so that each column in a group corresponds to a different point of view for what would be a single column of pixels in a 2-D display (Fig. 3). Other systems use parallax barriers to effectively block out what would be the wrong view for each eye. Systems along these lines have been demonstrated, usually with two views, but sometimes with up to four or six views per display.

The common problem with these spatially multiplexed displays is that the user's head must be in exactly the right position to view the display. It depends on the size of the display and the specific method of separating the views for each eye, but in most cases the viewer must also be precisely located at a certain distance from the display. A few inches closer or farther back from the optimal distance and the viewer sees disturbing artifacts.

Another approach is to display complete multiple views of a scene on the same LCD. A system with seven views, each with its own lens projecting onto a specially engineered Fresnel and lenticular screen has been demonstrated. This system does not suffer from the precise-head-location problem, but it does require LCDs with extremely high pixel density to provide adequate resolution for each view.

Another company has developed a system using two projectors for each viewer. Each projector provides one view of a stereo scene, and a head-tracking system physically moves the projectors to ensure that, even if the viewer moves his head, he still sees the left image with his left eye and the right image with his right eye.

Another display has been developed using two LCD panels, one for each view. They are at 90° from each other, with a half-silvered mirror between them. This technique produces a good picture for one viewer, but image size is limited to the size of the LCD. Here, too, head tracking must be used to keep the correct view in front of each eye.

Various developers have produced volumetric autostereoscopic displays using rotating mirrors or helixes, mirrors that are large relative to the image size, or very small special glass blocks. Among other drawbacks, volumetric displays do not provide a realistic video image because they lack occlusion - to some extent the viewer sees through an object to elements behind it that would be occluded in normal 3-D vision.

Video holography, such as the version being developed at MIT, shows promise, but the computational and pixel requirements for a high-resolution picture are so great that it will be many years before this approach will generate a practical and affordable display.

We have therefore concluded that time-multiplexed, multiview, autostereoscopic displays will be the best solution for a variety of 3-D applications. ■

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.

european views

continued from page 6

increases battery lifetime for PDAs and GSM systems. Matrix EL displays are also being developed, especially in Cambridge.

Projection systems complement the range of CRTs at large screen sizes. But CRT-based rear-projection systems have never appealed to the European public because the systems are bulky, have very poor viewing angle, and have limited resolution. With the advent of LCD-based projection systems, this might change. The resolution is much better than for the CRT, and recently, the new Philips short-arc lamp has had a major impact, permitting more compact systems. The short arc length (1.3 mm) results in compact designs, with system efficiencies of up to 8 lm/W. This is even better than for a CRT. Using a 120-W lamp, more than 800 lm can be projected on the screen.

All of this was explained at the special meeting on projection systems organized by the SID Mid-Europe Chapter and held on March 19-20 in Ghent, Belgium. During the factory excursion at BARCO, the leader in professional projection systems, the company gave an impressive demonstration of what sheer power can do.

Yet, for home-theatre applications, the currently used screen gains of 5-10 are far too high for comfortable family viewing. More power will be needed to put out more lumens in all directions. Since I am a physicist, this makes me feel that the world is still okay. After all, an increase in brightness requires energy.

Two technologies compete with rear-projection systems: PALC and PDP. Plasma-addressed liquid-crystal (PALC) technology is a very good candidate, if daylight contrast and a brightness equal to that of the CRT is required. The display was invented by Tom Buzak when he was at Tektronix. Philips, Sony, and Sharp now have a joint development group in Mizunami, Japan, for 42-in. panels. For all parties involved, it is a unique learning experience, and it clearly shows how the strengths of European and Japanese companies can complement each other.

Plasma-display panels (PDPs) are much further along on the learning curve. They have the longest track record as a promising candidate to replace the CRT. It strikes me that the ac-panel structure today is not very different from that of about 20 years ago. Even the MgO layer was already there, for memory purposes. Only the driving system was considered to be too difficult for TV applications.

The parallel with the LCD is striking: Japanese companies have continuously improved the display. PDP technology now has evolved so far that brightness, contrast, and lifetime are at the level required for home-theatre applications. In Europe both Thomson and Philips are active in this area. Two bottlenecks remain: efficacy and cost. Promising results have been achieved recently by us, with an efficacy (for green) of 3.3 lm/W.

The costs of PDP and PALC today are such that they can be afforded only by the happy few. There is a strong determination worldwide to reduce the cost to the level of $3000 for the end user within the next 5 years. Then the dream of large flat displays on the wall will finally be fulfilled, creating a theatre at home. But then again, isn't that what we said 5 years ago?

***Harm Tolner** is Technology Strategy Manager, Large Flat Displays, Philips Components BV, Eindhoven, The Netherlands; telephone +31-40-278-8359, fax +31-40-278-3100; e-mail Harm.Tolner@nl.cis.philips.com.* ■

SID Conference Calendar

Next Show!

5th Annual Flat-Panel Display Strategic and Technical Symposium

JOIN US IN YPSILANTI TO FIND OUT WHAT'S NEW IN VEHICULAR DISPLAYS AND TO HEAR WHERE THE U.S. FPD INDUSTRY IS HEADED.

- FPD Strategy, Markets, and Technology
- Business Issues – Government and Industry
- Emerging Flat-Panel Technologies
- Applications – Microdisplays, Backlighting
- Status and Prospects of Vehicular Displays
- Technical and Poster Sessions

9 SEPTEMBER 98

5th Annual Flat-Panel Display Strategic and Technical Symposium 1998

YPSILANTI, MICHIGAN
SEPTEMBER 9 – 10, 1998

• Two-day event jointly sponsored by the University of Michigan (Center for Display Technology and Manufacturing) and the Metropolitan Detroit Chapter of the Society for Information Display

14 SEPTEMBER 98

Fourth International Conference on the Science and Technology of Display Phosphors

BEND, OREGON
SEPTEMBER 14–17, 1998

• An international conference on the future prospects of phosphors for:
- ELDs – FEDs
- CRTs – Plasma Displays
- PL Devices – LC Backlights

28 SEPTEMBER 98

18th International Display Research Conference (Asia Display '98)

SEOUL, KOREA
SEPT. 28 – OCT. 1, 1998

• An international conference on display research and development aspects of:
- Display Fundamentals, Display Devices,
- Hard Copy & Storage, Input Systems,
- Integrated Devices and Applications,
- Image and Signal Processing,
- Color Perception, Human Factors

17 NOVEMBER 98

Sixth Color Imaging Conference: Color Science, Systems & Applications

SCOTTSDALE, ARIZONA
NOVEMBER 17 – 20, 1998

• An international multidisciplinary forum for dialogue on:
- Creation and capture of Color Images
- Color Image reproduction and interchange
- Co-sponsored with IS&T.

For additional information:
Dee Dumont
Society for Information Display
31 East Julian Street
San Jose, CA 95112
408/977-1013, fax - 1531
www.sid.org

SID

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

Circle no. 13

Circle no. 14

SOCIETY FOR INFORMATION DISPLAY NEWS

Asiana Offers Low Air Fares to Asia Display

Asiana Airline, which has been designated as the official airline for Asia Display '98, is offering low rates to Seoul from North America and Europe. In addition to the typical 45% discount available to general customers, Asiana Airline is offering Asia Display attendees a special 10% discount on either economy class or first class air fare if you arrive in Seoul between September 19 to October 1, 1998, via Asiana Airline.

Reservations and tickets are available through an Asiana Airline Ticketing Office or any travel agency anywhere in the world. Call the Asiana Ticketing Office in your area or send e-mail to birdy@asiana.co.kr for the special rates available from your departing city. A simple form, which is included in the Asia Display Advance Program and is also available from the conference organizers, must be filled out to obtain the special fare.

Sample rates (economy class):

NYC/SEL R/T $1365 $751 (45% discount)
$614 (55% discount for Asia Display)
LAX/SEL R/T $1045 $575 (45% discount)
$470 (55% discount for Asia Display)
SEA/SEL R/T $1045 $523 (50% discount)
$418 (60% discount for Asia Display)

If there are 10 or more attendees from your area, please contact your local Asiana Ticketing office to receive the cheapest discounted group rate. Please send e-mail to birdy@asiana.co.kr for more information.

Asia Display in Korea

Asia Display '98, the first Asia Display conference to be held outside Japan, will be held September 28 to October 1, 1998, at the Sheraton Walker-Hill Hotel in Seoul, Korea. Asia Display '98 is a vertically integrated international opportunity expected to draw over 1500 attendees from around the world. The event is sponsored by the Korea Chapter of the Society for Information Display and the Korean Physical Society. SEMI Korea is managing the exhibition.

You can present your research results at Asia Display '98, share the most recent achievements in information display research and development, explore market opportunities, and interact with industry people. You can also exhibit your products and view state-of-the-art display technologies at the vendor exhibition, which will include information displays, production equipment, materials, and components.

Asia Display '98 will enable you to keep abreast of the growing flat-panel-display (FPD) technologies and industries in Korea. The global FPD market will be US$15.2 billion in 1998 and it will grow to US$21.5 billion in the year 2000. A healthy portion of this market increase will be due to the plans of Korean and other Asian companies to make multi-billion dollar investments in the information-display industry within the next few years.

Technical Program

Conference topics include Active Matrix LCDs, Applications, Applied Vision/Human Factors/3D Displays, CRTs, Display Manufacturing, Display Measurement, Display Systems, Plasma Display Panels, Electroluminescent Displays, Field Emission Displays, Large Area Displays, and Liquid Crystal Technology.

Asia Display '98 also offers a series of technical workshops given by experts in the field of information displays. The workshops will be held on Monday, September 28, 1998, and will cover AMLCDs/LCs, FEDs, PDPs, and Phosphors.

Keynote and invited addresses will be given by Mr. Y. W. Lee, President of Semiconductor Business, Samsung Electronics, Co., Ltd.; Dr. S. Kobayashi, Professor, Science University of Tokyo in Yamaguchi; and Dr. Larry F. Weber, President, Plasmaco.

The schedule for Asia Display '98 is as follows:

Workshop	Sept. 28
Reception	Sept. 28
Technical Conference	Sept. 29 - Oct. 1
Vendor Exhibition	Sept. 29 - Oct. 1
Exhibitors' Reception	Sept. 29
Banquet	Sept. 30

Hotel and Travel Information

Visitors to Asia Display '98 will be able to enjoy very nice hotels, meals, transportation, and shopping because the value of the U.S. dollar has increased more than 50% since last year. The Sheraton Walker-Hill Hotel in Seoul, Korea is the conference site (+82-2-453-0121, fax +82-2-452-6867, e-mail: hotel@pretty.walkerhill.co.kr.) It sits on attractive wooded lakeside grounds outside Seoul. There are several other hotels, such as Lotte World Hotel, Han Kang Hotel, and Olympic Parktel, near the conference site, and there will be special discounted room rates for the 18th IDRC.

Access to the hotel is easy. From Kimpo International Airport, Korean Air Limousine Buses leave for the Sheraton Walker-Hill Hotel every 15 minutes. Free shuttle buses between the Sheraton Walker-Hill Hotel and the Kwangnaru subway station (Line 5) are provided all through the year. Please e-mail to idrc@ns.dankook.ac.kr for more information.

Tours and Activities

One of Korea's TFT-LCD manufacturers has promised to open its TFT-LCD development line to Asia Display attendees. The reservation for the industry tour will be made at the registration desk during the conference.

The weather in Korea during early autumn is mild, and the countryside is beautiful. There will be several social and spouses' programs, such as a city tour and shopping at Itaewon and Namdaemoon. There are also many activities prepared by Kim's Travel Services Co., Ltd., including tours to a traditional ceramics-making villiage and a Korean Folk Village, and night cruise on a Han River Pleasure-Boat, with Korean dishes and a tradional Korean dance performed on board. The night view along the Han River is memorable.

For more-extended trips, there is a three-day tour of the beautiful and unspoiled Cheju Island, and a two-day excursion of the ancient buildings and temple of Kyongju, the "Museum without walls," which was the capital of the Shilla Kingdom for a thousand years. You will feel the history of Korea by just walking in the city of Kyongju.

Information

For general information, contact S. Lim, Secretary General, Dankook University; +82-2-709-2979, fax +82-2-792-5857, e-mail: idrc@ns.dankook.ac.kr.

For Technical Conference and Workshop information, contact Jin Jang, Program Co-chair, Kyung Hee University; +82-2-961-0270, fax +82-2-968-6924, e-mail: jjang@nms.kyunghee.ac.kr.

For information on the Asia Display '98 Exhibition, contact H. C. Kim, SEMI Korea; +82-2-551-3041, fax +82-2-551-3406, e-mail: hkim@semi.org or semikorea@semi.org, Web site: http://tftlcd.kyunghee.ac.kr/idrc98. ■

continued from page 4

pretty routine. The fund would assign someone to do their "due diligence." This was always done so that the fund could show their investors how careful and thorough they had been and how well the investors' money was being managed. Senior Partner assured them that he had every expectation that once this process was complete, their proposal would be approved and their venture funded, subject of course to the successful negotiation of equity positions and valuation of their company. He even described which other funds he would solicit to join in the total investment package.

Keith, Don, and Sarah were feeling on top of the world. Only Ralph seemed a bit uneasy. The previous weekend he had talked to a neighbor who was a financial type and who had told him that the venture funds had some high expectations regarding the percentage of the company they would want and were very unbending regarding how companies were valued. They had already heard that anything less than 40% ownership by the lead venture fund would not be accepted. However, the most disturbing concern was that the management team would end up with no more than 20% of the company, even during this initial round of financing. Clearly, the investors would control their company from day one. Ralph wasn't at all sure that he liked a deal in which he had no more job security than an employee in a typical corporation, and in which the venture partners could dictate how the company was going to be run, and by whom. However, the others assured him that they would be so important to the technology and the new product development that they would be viewed as indispensable.

In any case, they would always have their stock. If the company was a success, they would get their financial rewards no matter what. Nevertheless, Ralph was still uncomfortable. He had done some reading on various ways that stocks could be devalued and diluted by those in control. He was beginning to feel real nervous that their great idea was going to end up making someone else rich. Yet, he could not come up with a better solution. With some remaining reservations, he decided to stay with the team.

For the due-diligence process, Senior Partner appointed a young, very energetic, and very recent MBA graduate. A few days later they were introduced to Howard III. Howard had been awarded his MBA degree from one of the top East Coast business schools and clearly intended to make a name for himself in the high-tech business world. Thus, Howard's immediate goal in life was to show Senior Partner just how capable he could be. By golly, his due-diligence process would be the best ever done by any junior partner. And since Senior Partner had already indicated that he was interested in funding this deal, there was even more justification to do superb work.

The business plan that Keith, Don, Ralph, and Sarah had put together was really already quite good. They had studied Rich and Gumpert's book on writing business plans (highly recommended), and they had incorporated additional data and answered all the questions put to them in their previous presentations – except for the ones that were clearly off the wall and didn't deserve an answer. But enthusiastic young Howard III saw this as just a good starting point.

The first request from Howard was for them to produce a spot-and-dot chart showing just how their new product would fit in with existing technologies and other new technologies that might be under development by others. Howard wanted them to produce a plot of screen sizes and prices for the particular markets they would be addressing. Although they had already covered all this in their business plan, they did not want to seem uncooperative, and thus spent several days re-casting their data into several spot-and-dot charts, with the sizes of the spots/dots representing market sizes for the various applications. Five minutes after they had faxed these to Howard, the phone rang and Howard expressed his obvious enthusiasm with the quality of their work. Since Howard seemed so pleased, they certainly weren't going to be the ones to tell him that all this data had come straight out of their business plan.

A few days later came yet another call from Howard. He'd been thinking that they should take a look at their technology's benefits as compared to other approaches. Would they put together some "spider diagrams" comparing all display technologies? Howard went on to give them a business-school-style lecture on how one makes a spider diagram by looking at six or more important criteria and putting them on a radiating diagram so that the best features are on the outer boundary of the spider web.

The team decided that they had better start dividing up what was now becoming a significant effort. Ralph was the first to show a bit of frustration with what seemed like useless activity to him. Not only that, he was beginning to worry that every time they provided something, if it missed the mark or didn't meet Howard's expectations, the whole effort could come to an untimely end. Nevertheless, he couldn't come up with any polite way to refuse these requests. Reluctantly they proceeded with their task.

The next request came after another few days had passed. Since most of their products were planned for sale to OEM customers, could they get letters of endorsement from at least four and preferably six of these customers? Would the OEMs actually buy this new computer-monitor projection display for incorporation into their products? And in what quantities, and on what time scale?

"You've got to be kidding!" was the team's unspoken response. Here they were developing a new product with proprietary features that they didn't want anyone to know about, and they were supposed to get letters of endorsement from customers to whom they weren't yet prepared to describe their technological breakthrough.

For several hours they sat glumly around the conference table assessing their options. Ralph was ready to toss in the towel. Sarah thought they should call Howard back and explain how ridiculous his request really was. However, Keith and Don had talked to a few of their friends who had gotten venture money and had been assured that this all was still within the expected routine. In spite of their reluctance, and the feeling that they were now just playing a meaningless game, they were coming to the conclusion that with all the effort they had already put in they should somehow try to comply with this – hopefully final – request.

Sarah was the first to offer up the idea that what they should do is to develop a very generic specification, contact people who they already knew, and impose on these friendships by asking them to sign a non-committal letter that Sarah would put in front of them. She would even vary the wording from letter to letter so that each one would appear to have been created by the signer. Could they think of four or five individuals in well-known companies who would do that for them? It was a stretch, but they finally came up with five names. One name was a bit doubtful, but the remaining four sounded pretty good.

The letters were written, the phone calls were made, and the agreements were cajoled. More days went by. They had now been working with Howard for nearly a month, and it would be at least another week before this last request would be satisfied. The lack of income was really becoming painful for them. They had expected that by now they would already be funded. The strain on their families was getting worse. Don told the others that he would have to begin to look for a job if something positive didn't happen in the next week or two at most.

While they were waiting for the endorsement letters to be returned, Howard continued to bombard them with requests for additional explanations and data regarding their plan.

Then one morning, Keith mentioned that he had had a call from a colleague that the venture fund was checking their personal references. The others soon were getting similar feedback from their friends and former business associates. Well, finally it appeared that they were nearing the end of the due-diligence process.

A few more weeks dragged by. At long last, Howard called to say that Senior Partner would be in town on Wednesday and was ready to meet with them. In fact, he would like to schedule the meeting over dinner at a prestigious and very expensive restaurant.

Well, while it wasn't yet a fait accompli, they were finally going to have the chance to negotiate the deal. After all the work and the weeks of waiting, they had to keep reassuring themselves that they would try not to give in too easily. But they knew that by now they were ready to take almost any offer. They just wanted to get their company started and show the world their great new product. Also, by now, they realized that their skills were much better suited to building the business than they were to raising money.

The few days until Wednesday evening seemed like an eternity. They were clearly nervous as they were shown to the corner table. Howard was already there waiting for them. A few minutes later Senior Partner made his entrance and greeted them with warmth and enthusiasm. Howard was beaming like a proud parent. They ordered a round of drinks and made the usual pleasantries about airplane travel, rush-hour traffic, and the latest stock-market activities.

Then it happened. Senior Partner's voice took on a more formal tone, "I met earlier this afternoon with one of the other venture funds you had talked to some time ago. Fred is a good friend of mine. He said he had briefly looked at your deal and decided that he didn't really like it. I respect Fred a lot. I know we've put you through a lot of effort, but I've decided that we're going to pass as well. You have a good plan and all the due diligence came up great, but I'm just not sure about this deal in light of Fred's comments. Oh, by the way, Howard, I meant to tell you earlier, but it slipped my mind." Howard suddenly took on the look of a deer staring into the headlights of an oncoming Mack truck.

Keith, Don, Ralph, and Sarah just sat there. What could they say? What was there to say? Just then the waiter brought their expensive appetizers. But how does one eat with a dry mouth and a churning stomach? Keith felt that any second he just might throw up. Senior Partner didn't seem much concerned. "Well, look, let's not let any of this spoil a great meal. After my busy day, I'm ready to relax with a good dinner and a few drinks. Hey, the least I can do is buy you all a nice dinner."

What to do? Walk out? Cause a confrontation? Get sick? All seemed like great options. However, Ralph was the first to recover his composure with something at least borderline constructive. "Well, we're clearly disappointed that you have come to this conclusion, and we really think that you are missing a great opportunity by not funding us, but given that you have already made up your mind, perhaps we could spend the rest of our evening learning more about the venture business and the kind of deals that are attractive to the venture community."

And having survived the "train wreck," what a useful evening it turned out to be. The emotional shock actually made the learning experience more memorable.

The first thing they learned, which they had already begun to suspect, was that the venture funds are good for certain kinds of deals and not others. And perhaps theirs was one of those that was in the "other" category.

Senior Partner told them, "Venture funds must have deals that will create companies that can be taken public or sold in three to five years. They must grow quickly and be large enough to merit the attention of the partners. They must have lots of 'sizzle.'

"The venture companies are great at providing additional management talent and large amounts of funding in the \$10–50 million range or even larger when needed to create rapid business growth. They are not effective with smaller and more modestly positioned businesses, especially if they have a founding team that already has start-up experience."

According to Senior Partner, the problem he was having with this deal was that they were only proposing to have a \$50 million company in 5 years, and they had such a tightly knit team that the venture companies would have a difficult time giving them guidance or bringing in additional talent. Keith was really frustrated by this last comment. "But if you agree that we already have the right skill set, then isn't that exactly what will create the greatest opportunity for business success?"

"Well, yes," agreed Senior Partner. "It just may not allow us the flexibility in coming up with an effective exit strategy. You're interested in building a great display company. Our interest is in making money – as much as possible and as quickly as possible."

"But, isn't a \$50 million company that has several hundred employees and makes a good profit a great success?" argued Don.

"Well, of course it is. It's just not the kind of business we can fund," responded Senior Partner. "We need something with a much bigger upside potential, and for that we are willing to take greater risks."

And so it came to pass that not long after this fateful dinner, Don made contact with a private investor who was looking for exactly the modest-sized opportunity that this team represented. They were able to negotiate a deal which allowed them to keep control of their company. Sure, it would take a bit longer to grow to the size that the venture funds expected, but they would have fun doing it and they would be able to decide when and under what conditions to take on the growth investment they knew that eventually their success would drive them into accepting. But by then, it would still be their business and their choice to make.

Most important, they had learned that the greatest asset to any new business is not the technology but the people. They were a

continued on page 39

president's message

continued from page 6

and we are working to make this process easier. We have a secure server, so you can use your credit card without fear that your number will be accessed by a cyber-pirate.

On the Web site, you will also find a list of SID committees. They do the real work of the Society. The Long Range Planning Committee, chaired by Jean-Noel Perbet, addresses the Society's long-term strategy for growth and service to members. The Chapter Formation and Membership committees, chaired respectively by Heiju Uchiike and John Parker, help members form new chapters and then address their individual membership needs. The Academic Committee, chaired by Chris Summers, looks at ways to increase university involvement in SID activities and provides support to students for travel to our major conferences.

The Communications Committee, chaired by John Rupp, who is working closely with our Webmaster, Howard Funk, will now focus on the Internet as an increasingly important means of communication. Finally, the Honors and Awards Committee, chaired by Andy Lakatos, chooses the recipients of the Society's major awards each year. Many of you may not realize that any member of SID may nominate a candidate for an award and that you can do this directly on the Web site.

These key committees have members from each region to ensure that they address the differing needs of members from all parts of the world. Soon you will find the names of all the committee members with their e-mail and other contact information on the Web site. Please help to improve the effectiveness of these committees by making contact with them, telling them about your needs, and giving them your views about the future of the Society.

Since *Information Display* is read by many people who are not SID members, I would like to encourage those of you who are not yet members to join SID and take advantage of all our services. We are a worldwide resource for everybody who is involved in display technology, from research and development to manufacturing, marketing, integration, and display-containing products.

I will provide periodic updates on progress in future editions of *ID*. Remember, you can help us to develop SID in the way you want.

Anthony C. Lowe is the new President of SID, as well as a member of the IBM Academy of Technology and Manager of Advanced Display Technology, IBM Personal Systems Group, Greenock, Scotland; +44 (0)1475-893-938, fax +44 (0)1475-895277, e-mail: tonylowe@uk.ibm.com. ■

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.

display continuum

continued from page 38

strong team and they had demonstrated their compatibility and common vision in bad times as well as good. They knew that they could count on each other and overcome whatever obstacles might come their way.

And that, perhaps, may be the topic for a future column.

In the meantime, if you would like to share any of your business-related experiences, you may send me an e-mail at silzars@ibm.net, or a fax at 425/557-8983, or call me at 425/557-8850. And believe it or not, some of you still send me really interesting stuff by mail. That can be accomplished by way of 22513 S.E. 47th Place, Issaquah, WA 98029. ■

sustaining members

Acer Display Technologies
Ad-Vance Magnetics, Inc.
Advance Reproductions Corp.
Arconium
autronic - Melchers GmbH
Brewer Science, Inc.
Brimar Ltd.
Cherry Electrical Products
Chunghwa Picture Tubes, Ltd.
Clinton Electronics Corp.
Colorado MicroDisplay, Inc.
Corning Japan K.K.
Crystaloid LCDs
Display Laboratories
DisplaySearch
Displaytech, Inc.
Dolch Computer Systems
DNP Denmark
Earth Computer Technologies
Electronic Designs, Inc.
Electro-Plasma, Inc.
Electronic Designs, Inc.
Emco Electronics Ltd.
Endicott Research Group, Inc.
ERSO/ITRI
FED Corp.
F-P Electronics
Futaba Corp.
Hewlett-Packard Co.
Hitachi, Ltd.
Imaging & Sensing Technology
Incom, Inc.
Infodex, Inc.
Instrument Systems
Interface Products, Inc.
Interstate Electronics Corp.
ISE Electronics Corp.
Kent Display Systems
Lexel Imaging Systems, Inc.
LinFinity Microelectronics, Inc.
Micron Display Technology, Inc.
Mitsubishi Electric Corp.
Mitsubishi Electronics America
Motorola FPD Division
NEC Corp., Japan
Nippon Seiki Co., Ltd.
OIS Optical Imaging Systems, Inc.
OKI Electric Industry Co., Ltd.
Optical Coating Lab., Inc.
Optrex America, Inc.
Phosphor Technology Ltd.
Photo Research
Pilkington Micronics Ltd.
Pix Electronics, Inc.
Planar Standish, Inc.
Planar Systems, Inc.
Plasmaco, Inc.
Polar Vision, Inc.
Polytronix, Inc.
Q.C. Optics, Inc.
Quantum Data Inc.
RF Power Products
ROLIC Liquid Crystals R&D Co.
Sarnoff Corp.
Semiconductor Systems, Inc.
Sharp Corp. - Japan
Sony Corp./Corporate Research Labs
Stanford Resources, Inc.
Supertex, Inc.
Syntronic Instruments, Inc.
TDK Corp.
TEAM Systems
Techneglas, Inc.
Teledyne Electronic Technologies
Thomas Electronics, Inc.
Three-Five Systems, Inc.
Toshiba America
Ultra Electronics Command & Control Systems
ULVAC Technologies, Inc.
Unipac Optoelectronics Corp.
Universal Display Corp.
Ushio America, Inc.
Viratec Thin Films Inc.
Vishay-Dale Electronics, Inc.
Westar Corp.
WINTEK Corp.
XCITEK, Inc.
XMR, Inc.

index to advertisers

Business and Editorial Offices
Palisades Institute for Research Services, Inc.
411 Lafayette Street, 2nd Floor
New York, NY 10003
Jay Morreale, Managing Editor
212/460-8090 x212 Fax: 212/460-5460

Sales Office
Palisades Institute for Research Services, Inc.
411 Lafayette Street, 2nd Floor
New York, NY 10003
Erika Targum, Director of Sales
212/460-8090 x211 Fax: 212/460-5460


LCaD activedrive
STOCK
ORDER
TRACK
REVIEW
THREE-FIVE SYSTEMS
PWR
CTL
E