Official Monthly Publication of the Society for Information Display

INFORMATION DISPLAY

January 1995
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CRT ISSUE

The video channel
Making displays deliver
IDRC '94

Cover: At NIST's Video Processing Laboratory in Gaithersburg, Maryland, a tester uses an interactive knob to add scintillation-type noise to the video signal shown on a simulated LCD. By adjusting the noise level to the point where the tester can no longer tell the difference between "noise on" and "noise off," he is contributing to an enhanced understanding of human perception limits for display artifacts.

NIST

Next Month in Information Display

Flat-Panel Issue
- AR-Coated STN-LCDs
- The Other FPDs
- EL Display Technology
- Color Conference Report

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INFORMATION DISPLAY

JANUARY 1995
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editorial

The View from Japan: Aggressive

In the September 18, 1994 issue of William Coggshall's *Large-Screen Displays Industry Newsletter* (phone 415/948-3080), consultant William Bohannon (Manx Research; phone 619/735-9678, fax 619/735-8987) reported on some presentations from this year's Fine Process Technology Japan Conference. Since the official language of the conference is Japanese, Bohannon's translations provide some interesting insights. The following are some lightly edited excerpts from Bohannon's article, which are used with Bohannon's and Coggshall's kind permission.

In "The LCD Industry Enters a New Era," Toshiba's Mr. Kawanishi observed that LCDs are a key component today and will be even more important in the future as the Information Age really takes off. Although global competition is increasing, said Kawanishi, Japan will always retain at least an 80% market share.

But hardware leadership by itself is not enough. Success in the information-service era will require a tight integration of hardware and software. Japan is not a leader in software and the U.S. is not a leader in hardware, so closely cooperative global joint ventures are needed.

Kawanishi observed that current LCD yields are inadequate, but the actual numbers may be higher than some observers would anticipate. Most yields for TFT arrays, he said, are around 90% and most assembly yields are around 90%, which gives an overall yield of about 80%. NEC has a new factory called the "100 factory" because it is expected to be the first TFT-LCD factory to achieve 100% yield throughout.

The biggest material-cost component of a finished TFT-LCD is the color matrix filter (40%), followed by the LSI drivers and their required circuit board (36%). The way to solve these problems of low yield and high cost is to tie up the vendors of process equipment and LCD-component materials into vertical alliances of international companies. Mr. Kawanishi gave several examples illustrating how Toshiba has already made substantial progress in this direction.

In "Flat Panel Display Needs and Developments," Mr. Naono of the Nomura Research Institute discussed price trends for the leading flat-panel types, with the price of 10-in. color TFTs holding steady this year because of very strong demand. He showed that the market share of color STN is growing strongly because of the demand for color LCDs and the high price of TFTs. This will change when the price of TFTs comes down – that is, when the supply catches up with demand.

Naono showed that the "margin" – the percentage of the price of a computer that remains after the LCD's cost is accounted for – Taiwanese notebook manufacturers get for color STN notebooks is almost 70% but that the margin for color TFT notebooks is only 45%. According to Naono, the biggest contributor to the cost of the TFT-LCD is the size of the "mother glass" substrate used and the fringe area – the amount of glass left over – between the LCDs laid out on the mother glass.

Once LCD manufacturers use 500 x 600-mm substrate glass, and they can get six pieces of 10.4-in. LCD at a time or nine pieces of 9.4-in. LCD at a time, then the cost will really come down – or profits will be high. Naono estimated the

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the display continuum

The Burning Passion . . .

by Aris Silzars

No! No! Not <u>that</u> kind of burning passion. I'm sure that I will disappoint at least some of you, but the kind of burning passion I want to talk about in this month's column has something to do with bringing new display technologies to market. But, stay with me, this could still get interesting.

Let's look in on a new company with the intriguing name, New-Age Displays Inc. (Hopefully, this is not the name of a real company, since I just made it up to protect certain guilty parties – and maybe me from them.) This company was recently founded by two very capable engineers and a sales/marketing type with an excellent track record for building sales of new technology products. Also part of the founding team was their CFO (Chief Financial Officer), whose prior experience included financial responsibility for a business unit in a large corporation.

The founders left their previous corporate lives after developing a new display technology that, as often happens, did not fit the business portfolio of the large corporation. Of course, they were not told this until they had spent several years of intense effort developing a product based on the new technology. They were, however, able to persuade a Senior-VP to let them try to do something with this technology on their own, with the proviso that they agree to pay the corporation a modest royalty on future products using the technology and give it a 20% equity position in their new company.

Actually, this "support" came in quite handy when they went looking for start-up funds in the venture community. The venture folks looked at their technology and decided that it had lots of SIZZLE. (That's venture folk talk for a product that looks like it will grow in sales volume quickly so that the fund can do an early and highly profitable exit, that is, take the company public or sell it in less than 5 years.) This sizzle and the implied support of their well-respected corporate parent got them their first round of financing and they were on their way.

In their business plan, the founders had promised to have a product on the market in under 2 years. They knew they could do the engineering and product qualification in that time. And their customers would be ready to buy if they provided some prototype units for early qualification. So then, all they would have to do would be to put up a factory and go into volume production.

No big deal – just about everyone knows how to do that. First, you go out and buy an existing facility, then you hire some managers and operators, add some new equipment for the unique parts of the process, and with that accomplished get back to the real fun of designing the next generation of exciting new products.

For the next several months, it seemed these guys could do no wrong. They located an almost-new facility that had over half of the equipment they needed. (It was in the process of being shut down – the victim of another corporation's re-direction.) They even got lucky and found a manufacturing manager who was up on the latest techniques for Just-in-Time, Total Quality Management, Computer Integrated Manufacturing, and Material Resource Planning. To speed up the implementation process, they decided to help their new manufacturing manager (a few weeks before he arrived on the job) by hiring many of the opera-

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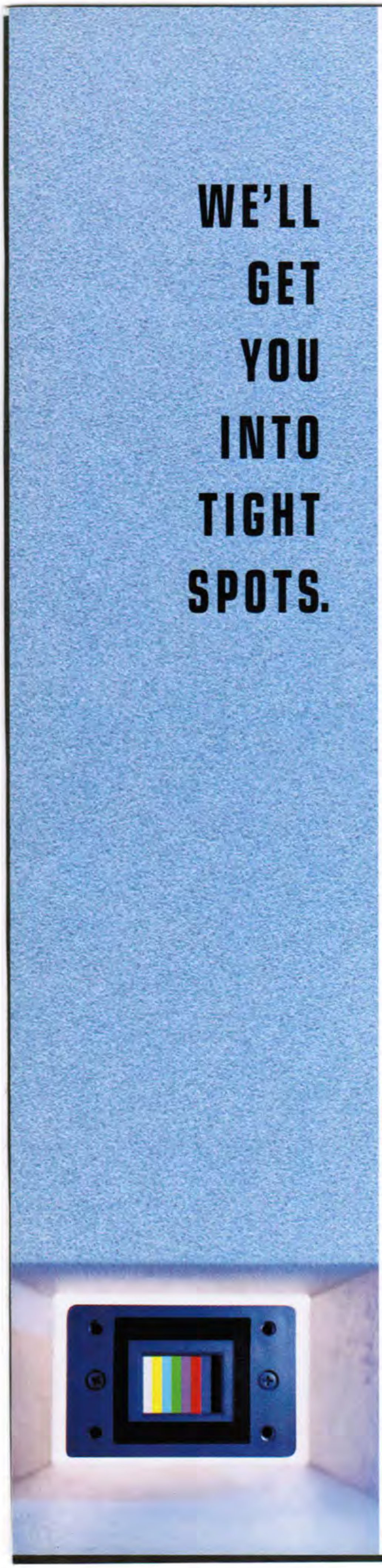

new products

Edited by Joan Gorman

Visual-inspection system

Eutecnics, Inc., Acton, Massachusetts, has introduced the ES-120, a system that performs automatic high-quality inspection of semiconductor chips and packages, hybrid circuits, SMT products, multichip modules, and flat-panel displays. Feature size and defect sensitivity are variable, ranging from 1 μm to 1 mm. Adaptive inspection and precision metrology guarantee the highest probability of defect detection. The system is capable of performing 50,000 inspections or measurements per minute. Unlike conventional bit-mapped inspection systems, Eutecnics' automatic optical-inspection concept utilizes object-based adaptive inspection for precise and correct defect detection and classification. In adaptive inspection, the level of inspection applied is an adaptive function of defect type. The ES-120 system hardware platform is modular, and designed to be configured rapidly and easily for a wide variety of cost-effective applications. Individual vision modules or complete systems are available. A similar strategy applies to software, where modular C code, developed for specific applications, can be ported to other products, with only minor modifications required.

Information: Alexander Kran, Eutecnics, Inc., 30 Nagog Park, Acton, MA 01720. 508/263-9998, fax 508/263-9942.

Circle no. 1

Hand-held photometer

Tektronix, Inc., Beaverton, Oregon, has announced the TekLumaColor™ II, an affordable hand-held high-performance photometer for applications including color matching and color balance for TV studios, TV manufacturing, display manufacturing and services, and CRT repair. When combined with the J1810 chromaticity head, the TekLumaColor™ makes real-time color measurements. It is calibrated to D6500 Kelvin for maximum accuracy and designed for the color coordinates of the 1931 CIE and 1976 CIE-UCS chromaticity systems. For immediate results, the TekLumaColor II/J1810 combination has an update speed of less than 0.5 s. The photometer can also use the full range of existing TekLumaColor heads. With the available single-sensor heads, it can perform any light measurement – luminance, illuminance, radiance, or irradiance. Features include a large, easily readable backlit display with metric or English readout selections. When used with the J1810 chromaticity head, the TekLumaColor II has a 10-channel memory for storing reference colors. RGB bar graphs assist with matching color displays to stored reference values for fast, easy color adjustments. It has full RS-232 control and can output light measurements in either RS-232 or analog format. All calibrations are traceable to the National Institute of Standards and Technology. TekLumaColor II is priced at $1995, and the J1810 at $1495.

Information: TekTools Electronic Measurement Instruments, Tektronix, Inc., P.O. Box 1520, Pittsfield, MA 01202. 1-800-426-2200.

Circle no. 2

Low-cost digital oscilloscope

Hitachi Denshi America, Ltd., Torrance, California, has introduced the VC-5410, a color LCD digital oscilloscope with a suggested user price of $1995, breaking the $2000 barrier for high-performance active-matrix color digital storage oscilloscopes (DSOs). The VC-5410 follows the introduction of the VC-5430 early in 1994, which broke the cost barrier for active-matrix color display technology in a field-portable DSO. The VC-5410 has a bandwidth of 20 MHz and two separate A/Ds operating at 15 MS/s. The VC-5400 series features a familiar scopelike interface for ease of use and advanced function keys to allow the user to autoset, print out, save, and recall front-panel set-ups and waveforms. The VC-5410 has a 2-kW record length, 4X longer than other portables on the market, and features 10 waveform and 10 front-panel memories. The VC-5410 performance and price make it appropriate for industrial control applications, mechanical applications, and those technologies involving the physical sciences. The analysis capability of the VC-5410 includes both waveform-parameter and cursor measurements. The VC-5400 series are the only field-portable DSOs at any price to feature both RS-232 and Centronics ports as standard for interfacing to a computer and direct connection to most supported printers.

Information: Richard Westle, Hitachi Denshi America, Ltd., 371 Van Ness Way, Suite 120, Torrance, CA 90501. 310/328-6116, fax 310/328-6252.

Circle no. 3

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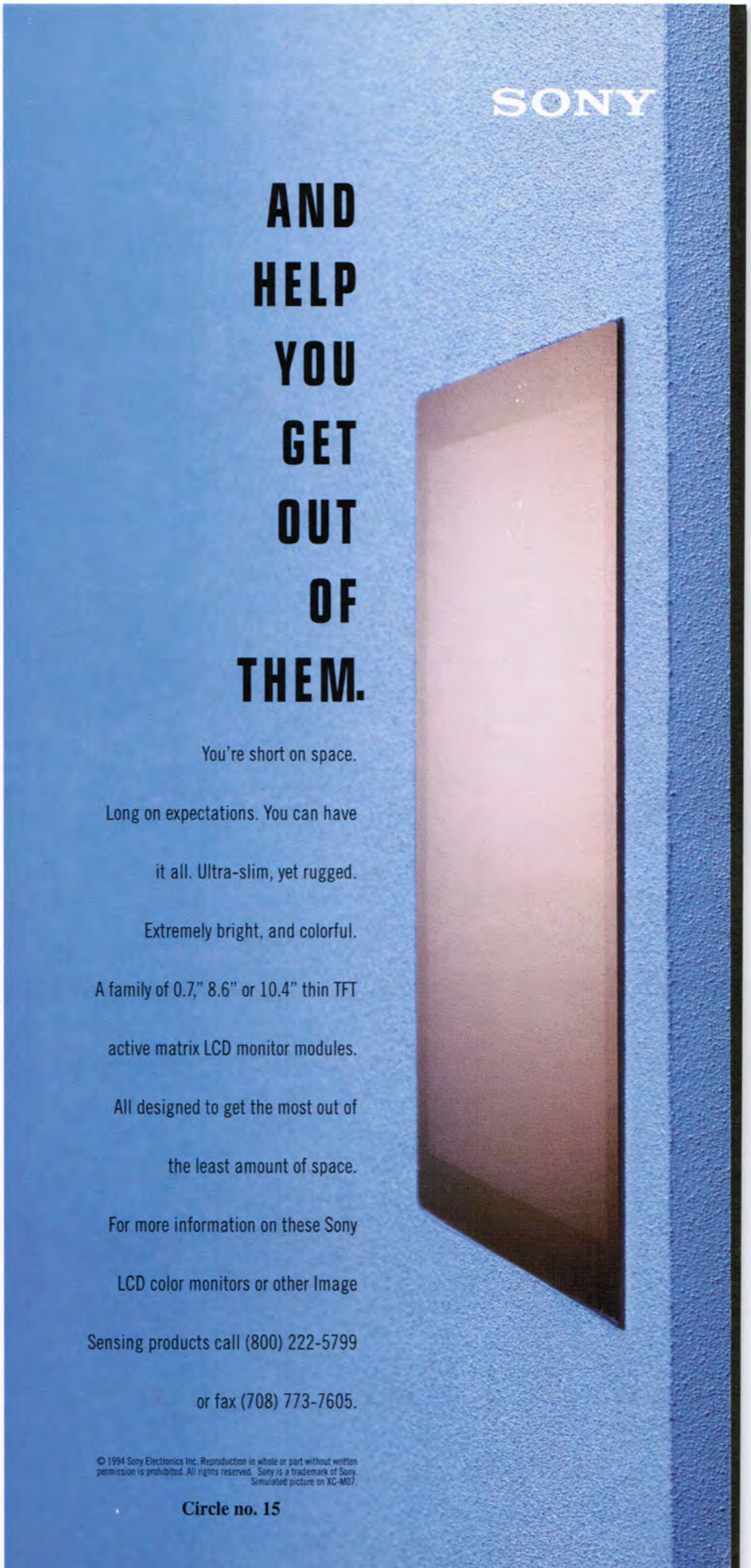

Circle no. 15

IC Technology and the Video Channel

Many CRT-driver designs still use discrete components, but they can't hold out against the IC onslaught forever.

by Hassan Karimian, Len Stencel, H. K. Chiu, Craig Wilson, and Tom Mills

INTEGRATED CIRCUIT (IC) TECHNOLOGY is used for nearly all pre-amplifier stages in the video channel of display monitors. But the other video-channel stage – the CRT driver – is still often assembled from discrete components.

In pre-amps, cost/performance and the ability to add functionality economically tipped the balance away from discrete components about 1990. Among the advanced functions now included in existing IC video pre-amps are dc-controlled gain and offset. On-screen display (OSD) mixing and blanking and additional immunization to electrostatic discharge (ESD) have been incorporated in the latest generation of devices that will be available early in 1995.

But the cost/performance balance and the need for enhanced features have not decisively favored ICs for the CRT-driver stage, so here both IC and discrete design approaches are used. But as the functionality and performance of ICs continue to improve, and as the cost continues to drop, we believe that ICs will come to dominate the driver stage just as they now dominate the pre-amp stage. Although we – the authors of this article – work for a major vendor of CRT-driver ICs, our belief in their future is not simply a product of company loyalty. Rather, it is based on solid technical and financial factors.

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The Video Channel

The primary function of the video channel is to amplify the 0.7–1 V_{pp} input signal from the video source – usually a computer graphics card – to 30–50 V_{pp} at the CRT cathode. The first stage, the pre-amplifier, amplifies the signal to 2–4 V_{pp}, while the CRT driver provides the remainder of the needed gain. There are IC pre-amplifiers with bandwidths up to and beyond 200 MHz that meet the gain requirement. Since enough bandwidth is currently available, most design work is aimed at improving the ICs or adding functions to them.

The main challenge for CRT driver-stage designers is to provide high gain [typically 12–16 V/V – gain = output (voltage)/input (voltage) = V/V], a high-output-voltage swing, and adequate transient response, while keeping power dissipation and cost to a minimum. Designers must also keep their eyes on printed-circuit-board (PCB) size and overall weight, and they must control high-frequency emissions.

Pre-amplifiers. Triple-channel IC video pre-amps with bandwidths up to 130 MHz and single-channel IC pre-amps with bandwidths

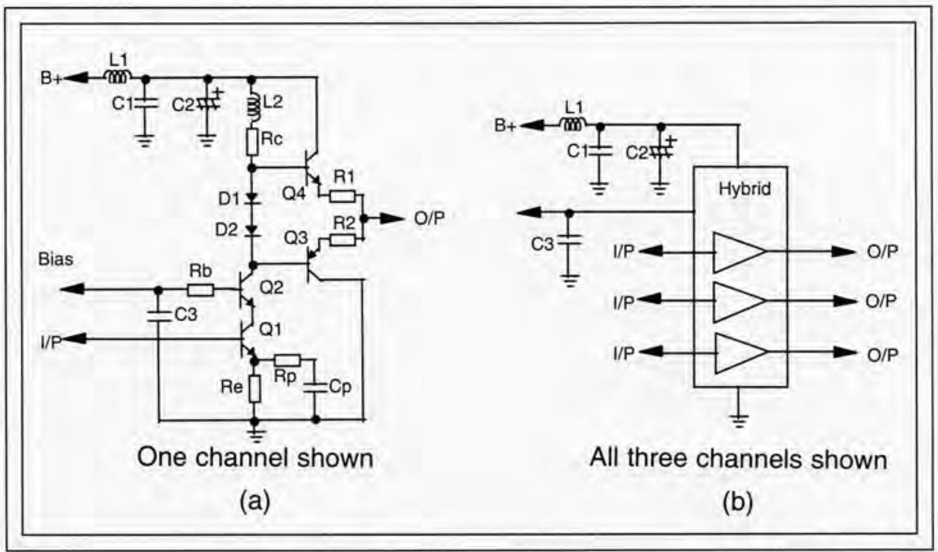

Fig. 1: *(a) Discrete cascode circuit with complementary emitter followers and inductive peaking. (b) Three-channel IC (cascode circuit with complementary emitter followers).*

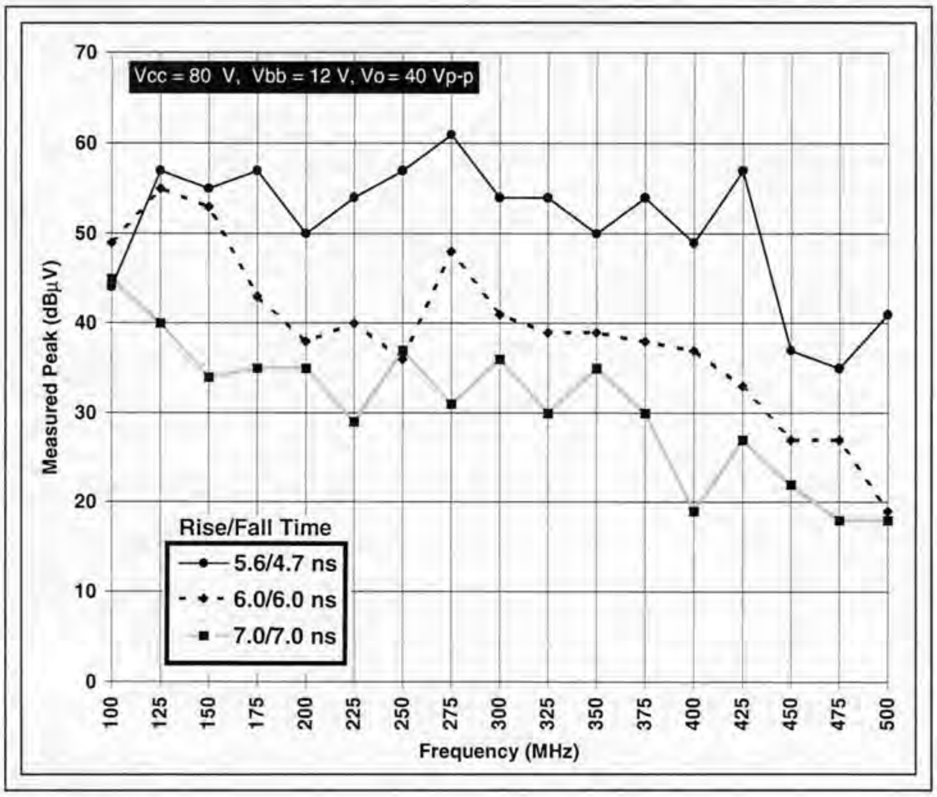

Fig. 2: A CRT driver's electromagnetic emissions vs. frequency for various rise and fall times.

up to 230 MHz are commercially available. Some provide voltage gains as high as 7 V/V and have output-swing capabilities of up to 7 V_{pp}, which exceeds the requirements for most applications. Many of these devices have advanced features that permit easy integration with monitor controls. DC-controlled contrast, drive, and black-level adjustments make computer control of video waveforms a reality. The desire for OSDs has prompted the addition of OSD mixers and blanking functions to the pre-amp ICs, features that will be available by early 1995.

In order to make their monitor designs more reliable and more rugged, many display manufacturers are improving the ESD immunity of their products. The International Electrotechnical Commission (IEC) 801-2 specifications call out ESD severity levels from 2 to 8 kV for the contact discharge test, and give equipment manufacturers the option to specify even higher levels. Semiconductor devices are typically specified at the 2-kV level, so IC manufacturers are looking for ways to enhance the ESD immunity of their pre-amplifiers. Enhancing the pre-amp's ESD immunity will allow display designers to reduce external circuitry.

CRT Drivers. Triple-channel IC CRT drivers with bandwidths up to 110 MHz and single-channel drivers up to 250 MHz are commercially available. Transistors that support discrete designs with bandwidths up to 110 MHz are also readily available. Two basic circuit topologies are used in IC-driver design: (1) the cascode circuit, usually with complementary emitter followers [Fig. 1(a)], and (2) the active-load closed-loop design. Discrete designs typically use the cascode circuit topology.

The cascode circuit requires two dc power-supply voltages while the closed-loop design requires one. The main advantages of the cascode circuit are higher input impedance and less susceptibility to thermal effects on the amplifier's transient response. The closed-loop design offers the advantage of a lower supply voltage and lower power dissipation, especially when a white background is used on the display.

The CRT driver is a high-speed high-output-voltage-swing amplifier specifically designed for driving a high-resistance and low-capacitance CRT cathode. The CRT cathode typically has a capacitance of 3–20 pF, and there is also an unavoidable stray capacitance consisting of the parasitic capacitance of the PCB; the capacitance of support circuitry such as arc-protection diodes, ac coupling/dc clamp, and spark gaps; and the capacitance of the CRT connector. The CRT driver's output pulse response is sensitive to the capacitive load connected to it, as well as to the inductance associated with the copper traces on the PCB. Excessive series inductance in the signal path will cause deterioration of the frequency and transient response.

The stray capacitance is far less in an IC CRT driver than in a discrete CRT driver because the IC amplifier is built on a very small substrate. Since the majority of the components of the driver stage are located in one package, the layout of the PCB is much simpler than in the discrete approach. In the discrete approach, the components are spread over the PCB, and it is hard to predict and control the stray effects on the overall system performance. Using the IC CRT driver is clearly easier than adjusting the positions of discrete components. That is why the IC approach is generally chosen for high-end monitors, where designing the driver amplifier is a particular challenge.

The clarity of a video display depends on the quality of the CRT as well as on the pulse response of the CRT driver. As the resolution of display monitors increases, it becomes increasingly difficult for a designer to obtain the same picture quality with a discrete design as with an IC design, given equal CRT quality. Discretes can match IC quality in applications having a pixel rate less than 110 MHz, but even in this regime IC CRT drivers can offer advantages – including reduced PCB size, lower component count, lower power consumption, and overall cost reduction.

Power Consumption

Because the smaller dimensions of IC technology relative to discrete components reduce the parasitic capacitance of the CRT driver, it permits the use of a larger collector load resistance in a cascode design. This translates to less power dissipation for an IC design that offers the same – or better – performance than

Table 1: Power Dissipation Comparison between Discrete and IC Driver Designs

	Discrete Cascode Amplifier	National Semiconductor LM2419 IC CRT driver
Collector resistor, R_c	733 Ω (3 × 2.2 kΩ in parallel)	1 kΩ
Emitter resistor, R_e	47 Ω	64 Ω
Supply voltage	+80 V	+80 V
Output dc level	+20 V	+20 V
Collector current	(80 - 20)/733 = 81.86 mA	(80 - 20)/1000 = 60 mA
Approximate power consumed (three channels)	80 × 0.08186 × 3 = 19.65 W	80 × 0.06 × 3 = 14.4 W

Note: The power consumed from the +12-V supply for biasing is assumed to be negligible, and the push-pull output stage is a class B amplifier.

Table 2: Cost Comparison of Discrete and IC Driver Designs for a 1024 × 768 Display

	Quantity		Cost	
Components	Discrete	IC	Discrete	IC
Transistors, diodes	18	---	$1.17	---
Passive components	36	4	$0.90	$0.07
PCB area	173 cm^2	144 cm^2	$5.19	$4.32
IC	---	1	---	$1.50
Total	55	6	$7.26	$5.89

Table 3: Summary of Discrete and IC CRT Drivers for Three Resolutions

Resolution		Performance t_r / t_f ns	Cost ($)	Size and weight	Emissions	Power (W)	Ease of manufacturing
IBM 8514A	discrete	11	7.26	big	medium low	14	difficult
	IC	11	5.89	small	low	12	easy
1024 × 768 72 Hz	discrete	6.7	8.08	big	medium high	19.6	difficult
	IC	6.7	7.89	small	medium	14.4	easy
1280 × 1024 60 Hz	discrete	4.7	11.34	huge	very high	26	very difficult
	IC	4.7	11.35	small	high	8	easy

Note: Information is for all three channels.

a discrete design. Further power reduction can be achieved by using a closed-loop IC design, as we have done in the National Semiconductor LM2427.

To demonstrate the power savings possible with IC designs, we compared two triple-channel cascode amplifiers of the same performance level, one designed with discrete transistors, the other an IC [Figs. 1(a) and 1(b)]. We assumed that a white flat field would be displayed with a 40-V_{pp} video signal required in each channel – the black level is 60 Vdc; the white level, 20 Vdc. The power consumption of the discrete approach is significantly higher than the IC approach (see Table 1).

Electromagnetic Emissions

The video channel is a major contributor to the emissions of a monitor. As resolution requirements increase, the faster video edge speeds increase the potential for electromagnetic emission. In many countries, these emissions are regulated by government agencies, and manufacturers must meet specific limits if they wish to market these products. Emissions are a function of edge speeds, pixel rates, voltage swings, and the physical layout of the system – which includes factors such as PCB trace lengths and loop areas. IC technology minimizes signal trace lengths, which reduces rf emissions relative to a discrete design with equivalent performance.

We measured the emissions of a triple-channel CRT driver in an anechoic chamber (Fig. 2). The antenna was located 3 m from the unit under test. All three channels were driven with a 25-MHz square wave from a single pulse generator, with the driver installed in a stand-alone test fixture. The input-signal amplitude was adjusted so that the output signal was 40 V_{pp}. The rise time (T_r) and fall time (T_f) of the input signal were adjusted so that the output signal T_r/T_f equaled the three values shown in the legend of Fig. 2, and the emissions were then measured and compared for the three cases. The physical system – including test fixture, power supplies, and pulse generator – was the same, so the measurements clearly demonstrate the potential effect of edge speed on emissions.

Weight

As the screen resolution of displays goes up, it becomes desirable to mount the video board directly on the CRT neck instead of wiring the output signals from a video amplifier board to the CRT socket. Doing this decreases the signal degradation caused by parasitic effects and helps control high-frequency emissions. However, the weight of the video circuit board becomes an issue when the board is going to be mounted on the CRT neck.

A discrete CRT driver uses small heat sinks but requires a larger PCB than an IC implementation and more components, including three large power resistors. On the other hand, an IC CRT driver has a smaller PCB and fewer components but requires a larger heat sink. The heat sink can be integrated with the EMI shield to distribute its weight across the video board and reduce cost. When everything is taken into account, an IC CRT driver will usually weigh less than a discrete implementation.

Manufacturability and Cost

The main factors that contribute to ease of manufacturing are component count, quality control, and labor cost. IC technology leads to a lower component count than discrete technology, which produces a variety of manufacturing-related benefits:

- Smaller PCB size for the whole video-amplifier system.
- Simpler vendor quality control and inventory control.
- Lower assembly cost than a discrete design manufactured with equal-cost labor.

We compared the cost of a video board for a 1024-pixel × 768-line display for the two design approaches. The first approach uses an IC for the pre-amplifier and a discrete CRT driver; the second uses ICs for both stages. The pre-amplifier cost is the same for both cases, so the overall cost difference is simply the cost difference between the discrete CRT driver and the IC CRT driver. As we calculate it, the advantage goes to the IC driver (see Table 2).

Today and Tomorrow

Today, IC technology dominates in the video channel's pre-amplifier stage, and will continue to do so as pre-amp performance and functionality become even better. In the CRT-driver stage, IC implementations have the edge in terms of cost, size, emissions, power dissipation, and manufacturability through XGA-level resolution (see Table 3).

At 1280 × 1024, however, the IC implementation still costs slightly more than the discrete implementation. But as display-performance requirements increase, as technology continues to progress, and as IC costs continue to drop, we believe that IC implementations of CRT drivers will come to dominate at all screen resolutions.

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Display Research Conference Thrives near Cannery Row

The largest IDRC ever held in the U.S. provides an intriguing look at the future of display technology.

by Ken Werner

IF THE ANNUAL SID SYMPOSIUM provides a look at current display technology, the most recent International Display Research Conference (IDRC '94) – held October 10–13 in Monterey, California, scene of John Steinbeck's classic novel *Cannery Row* – provides a glimpse of the future.

Attentive prognosticators could make much of the many reports of progress in active-matrix liquid-crystal displays (AMLCDs) with thin-film transistors (TFTs) made from polycrystalline silicon. Since polysilicon is a better-quality semiconductor material than the amorphous silicon used in most of today's AMLCDs, polysilicon transistors can be smaller, which allows the fabrication of displays that simultaneously have small diagonals – typically between 1 and 2 in. – and lots of pixels.

The authors of several papers strongly hinted that commercial projection products utilizing such displays are not far away. Steve Hix and In Focus Systems CEO John Harker did more than hint at a press conference held at IDRC October 12th to formally announce the creation of a new company called Sarif and the appointment of Hix as its CEO. Sarif is a joint venture of David Sarnoff Research Center and In Focus Systems to commercially produce projection-display engines using the polysilicon TFT-LCD technology developed by Sarnoff. Hix and Harker promised that an In Focus presentation projector and a Sarif-brand rear-projection workstation monitor using small polysilicon displays would be exhibited at Comdex '95.

Impressive amounts of work were also being reported in polymer-stabilized liquid crystals and plasma display panels (PDPs). Zvi Yaniv of Kent Display Systems said in conversation that Kent was currently making bistable polymer-stabilized LCDs and filling existing customer orders. A. Otsuka, speaking for a team from Fujitsu in an invited paper, said that Fujitsu's 21-in. color ac-plasma panel was now commercially available in the U.S. as well as in Japan, and that this version embodied advances that reduce power consumption and improve a luminous efficacy that was already among the better luminous efficacies reported. Twelve-hundred of these panels were recently sold to the New York Stock Exchange for displaying stock quotes. Mr. Otsuka promised that a plasma HDTV set would be available from Fujitsu in time for the 1997 introduction of HDTV programming in Japan.

The Society for Information Display (SID) issued a press release at the conference announcing that the United States Display Consortium (USDC) and Semiconductor Equipment and Materials International (SEMI) would be co-sponsoring major events at SID's Display Manufacturing Technology Conference being held January 31–February 2, 1995, in Santa Clara, California (DMTC '95).

Major press announcements are not usually made at research conferences, so the announcements from Sarif and SID served to highlight the growing importance of IDRC itself. Attendance at IDRC was impressively international – one could easily obtain the impression that the Asian and European contingents together outnumbered that from North America. Total registration was approximately 460, compared with 380 the last time IDRC was held in North America 3 years ago.

Now, let's get to specifics, with the understanding that space restraints demand I leave out far more than I include.

For AT&T, the Display's the Product

The keynote address, "Technology Creation and Conversion: Global Flat-Panel Display Manufacturing," by Lawrence C. Seifert, AT&T's Vice President for Global Manufacturing and Engineering, went substantially beyond what was promised in the printed abstract: "Commercial success in advanced products now requires traditional technology creation, such as in-house R&D, to be enhanced by including, for example, repatriation of technology where necessary."

Seifert went on to say that AT&T is not merely a service provider. It is also a global manufacturing company with 85% of its manufacturing capacity outside North America. The company makes system products for its own systems and those of other telecommunications companies, and terminal products for purchase by corporate and individual customers.

Communications is going wireless, which is part of AT&T's goal: "to deliver service to anyone anywhere – globally." Seifert referred to Nicholas Negroponte's comment that, historically, we got electronic communications backwards. We broadcast video through the

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Ken Werner is the editor of Information Display Magazine.

air and sent voice communications through wires. We are now in the process of getting it right by instituting: (1) cellular and other wireless systems for voice and low-rate data communications (like fax), and (2) a wired (or optical-fibered) infrastructure that provides two-way broadband communication.

Displays are an integral part of this vision, Seifert said. The home and office telephone of the future will be an inexpensive multimedia terminal plugged into the broadband network. AT&T's current concept for such a terminal is a TFT-LCD with chips around the display's periphery. These chips will not be limited to the display drivers, but will also include those for a 486-class processor, support chips, memory, disk controller, and LAN interface. The LCD is the chassis for the terminal, and most of the terminal's cost and size is in the display. "The display is the product."

Seifert said the wireless phone of the future will incorporate a low-power display and a touch panel for a "soft keypad" that appear only when needed. The display will be larger and have more resolution than current models, and could be used for sophisticated functions such as an integrated "touch-the-name-to-dial" personal Rolodex™.

"We believe that display technology is an enabling technology for our terminal business," but the price of TFT displays is not yet low enough. "In both our computer business and communication business, the display will be the product." And for the rest of this decade, the display will certainly be an LCD. AT&T is investing.

As far as national consortia are concerned, Seifert said, "We believe that consortia should be multinational. We've had limited success with [selling] that – but some success."

Workshops and Overviews

This year's IDRC had a new feature: preceding interactive workshops. The popularity of the workshops – nearly all IDRC registrants signed up for them – limited the actual interaction, but the philosophy remained intact. Generous question sessions were part of the schedule, and there was time at the end of the day for breakout discussions. The two simultaneous workshops – one on AMLCDs and one on display materials – contained only invited presentations, most of which had a survey or tutorial component.

The AMLCD workshop kicked off with K. Awane's survey of LCD research and business at Sharp Corporation. Sharp first got into LCDs to reduce the size, weight, and power consumption of its electronic calculators. In the 1980s, when display development seemed to hit a wall, the company developed its "spiral up" strategy of developing proprietary displays that would allow it to produce unique value-added products. The result? Sharp is now manufacturing ¥400 billion worth of LCDs annually, and the value is rising steadily.

A member of the audience asked, "Some people wonder if LCDs will be supplanted by other flat-panel technologies. What do you think?" Awane: "Sharp is developing new [LCD] products and applications." The implication was, I think, "You ain't seen nothin' yet."

AT&T's Webster Howard followed with a detailed talk. He convincingly argued that AMLCDs made with amorphous TFTs are strong products with substantial room for technical and performance improvements. Polysilicon TFT will not be able to match amorphous TFT's cost for 10-in. VGA and XGA displays. "Poly," said Howard, "will succeed only where amorphous can't work, such as applications demanding small displays with fine pitch." Not surprisingly, a lively discussion followed.

Bill Doane began the materials session with a talk on polymer-stabilized LCDs. Doane is from the Liquid Crystal Institute at Kent State University, which may be the world's leading center for academic research on this technology.

Later in the morning, S. Kobayashi, Y. Iimura, and M. Nishikawa of the Tokyo University of Agriculture and Technology presented "New Developments in Alignment Layers for Active-Matrix TN-LCDs." The paper described synthesized polyimide materials that simultaneously have a low curing temperature, produce good unidirectional LC alignment, generate the desired pretilt angle, and have an excellent voltage holding ratio.

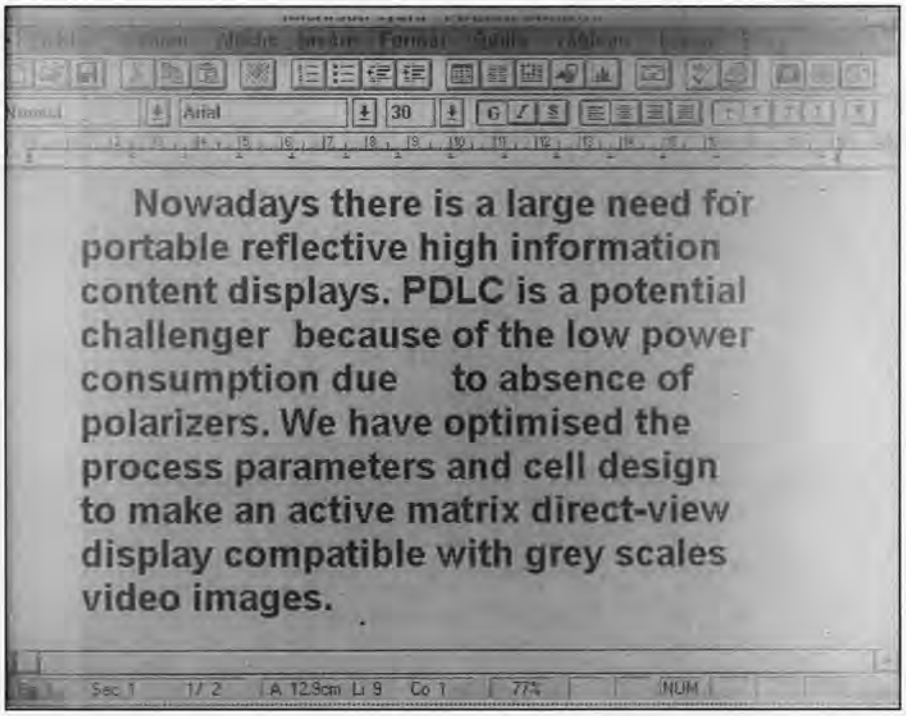


Fig. 1: Polymer-dispersed liquid-crystal (PDLC) technology is a candidate for portable reflective high-information-content displays. At the author interviews, a team from France Telecom demonstrated an active-matrix PDLC display with a 10:1 CR, 100-ms response, and a good viewing angle. (Photo courtesy of B. Vinouze, CNET Lannion, France Telecom.)

Going further and improving the viewing angle of color AMLCDs will require research into new materials and manufacturing processes for producing quartered-subpixel – super-multidomain – displays. The authors are pursuing that research.

In "Thin-Film-Diode Technology for High-Quality AMLCDs," A. G. Knapp of Philips Research Laboratory presented a paper also written by colleagues at Philips and Flat Panel Display (FPD) Company of Eindhoven, The Netherlands. The paper thoroughly reviewed work at Philips and FPD to develop thin-film diodes (TFDs) that, along with an appropriate addressing waveform, produce AMLCDs as good as those made with TFTs, but with a simpler process. FPD is producing displays with a 200:1 contrast ratio (CR), and advanced TFDs with large apertures for excellent luminance. The improved TFD process, which Philips calls TFD-R, requires only three photolithography steps. Photos of the TFD-R display were impressive.

In a review of advances in phosphor materials, Professor Aron Vecht of the University of Greenwich, U.K., noted that the largest single category of display-related phosphor papers published this year was organic EL phosphors, and that organic EL had received a good deal of hype. Vecht warned that although some of this work is interesting, all the work is laboratory work and is a very long way from practical device fabrication. The second largest category is porous silicon (inorganic EL). He finds most of this work unconvincing.

Vecht concluded with an appeal for companies with proprietary experimental phosphor results to share them. Limited data is seriously impeding phosphor development, which is urgently needed. Vecht suggested that a brighter backlight could be produced by using a UV lamp and depositing an efficient phosphor on the back of the LCD itself.

In a standing-room-only session, Hiroyuki Ohshima of Seiko-Epson reviewed the status and prospects of polysilicon-TFT technology. Ohshima noted that low-temperature polysilicon adds a lot of value: competitive cost, high aperture ratio, and the possibility of integrating advanced functions such as drivers and controllers. TFTs can be on the pixels or placed on the periphery, and the technology is easy to integrate on existing fab lines. A low-temperature polysilicon TFT has essentially the same characteristics as a high-temperature TFT – except that it has *lower* leakage current. One problem with low-temperature processing has been transistor-to-transistor variation, but this has been sharply reduced with a two-step annealing process. Ohshima concluded that high-temperature polysilicon will tend toward high-resolution compact LCD applications, while developers are positioning low-temperature polysilicon as the replacement for a-Si TFT-LCDs and as the technology that will carry LCDs into broad new areas of application.

The first TFT-LCDs were made with cadmium selenide (CdSe), which has long been out of favor because of long-term instability and difficulty in maintaining the proper balance of cadmium and selenium during film deposition. In "Fabrication of CdSe TFTs and Implementation of Integrated Drivers with Polycrystalline TFTs," Professor Ernst Lueder reported that his group at the University of Stuttgart has solved these problems, and has fabricated a 140,000-pixel panel with a low-temperature fabrication process to prove the point. Professor Lueder's conclusion: "For LC panels with integrated drivers, CdSe TFTs offer an economic solution. However, if drivers are realized by ICs, a-Si TFTs are preferable, due to their ease of fabrication, for a less demanding application."

Jack Salerno of Kopin Corp. reviewed his company's process for fabricating single-crystal-silicon TFT arrays using traditional silicon processing and then transferring them to glass substrates to make AMLCDs. Salerno said the company's goal is to fabricate displays with 10,000 pixels/in.

Bill Doane of Kent State University's Liquid Crystal Institute reviewed "Stabilized and Modified Cholesteric Liquid Crystals for Reflective Displays." The first of these were polymer-dispersed liquid crystals (PDLCs), in which LC "bubbles" were contained within a polymer matrix. Recent developments at Kent State have reduced the amount of polymer needed and have permitted power-off gray-scale memory. "Finally," says Doane, "for the first time, cholesteric direct-view displays are entering the manufacturing stage through the efforts of Kent Display Systems."

Planar's Chris King reviewed electroluminescent (EL) display technology, culminating in a description of the quarter-VGA full-color EL display Planar will introduce as a commercial product early in 1995. King later described the display in more detail in a technical paper after demonstrating it at the author interviews, where it drew a favorable response from observers for its improved blue/white chromaticity and increased luminance.

Mizuhiro Tani and Takeo Sugiura of Toppan Printing Company reviewed the technology of color filters (CFs) for LCDs, and observed that dyed-polymer CFs are being replaced by CFs using pigment-dispersed techniques. Reduced costs, increased productivity, and increased production volume are urgently needed. In the future, it is likely that printing and electrodeposition processes will lower the cost of CFs for high-quality displays. The price target for 10-in. CFs is ¥5000 in 1996.

Peter Friedman of Photonics looked at large color PDPs from a materials perspective. If PDPs are fabricated like CRTs instead of being process-dominated like LCDs, their cost will primarily be determined by their material content. Friedman explored the implications for materials-selection and fabrication strategies, and outlined the expected performance. In response to a question from the audience, Friedman said, "You'll see \$2000–\$4000 40-in. displays by the end of the 1990s."

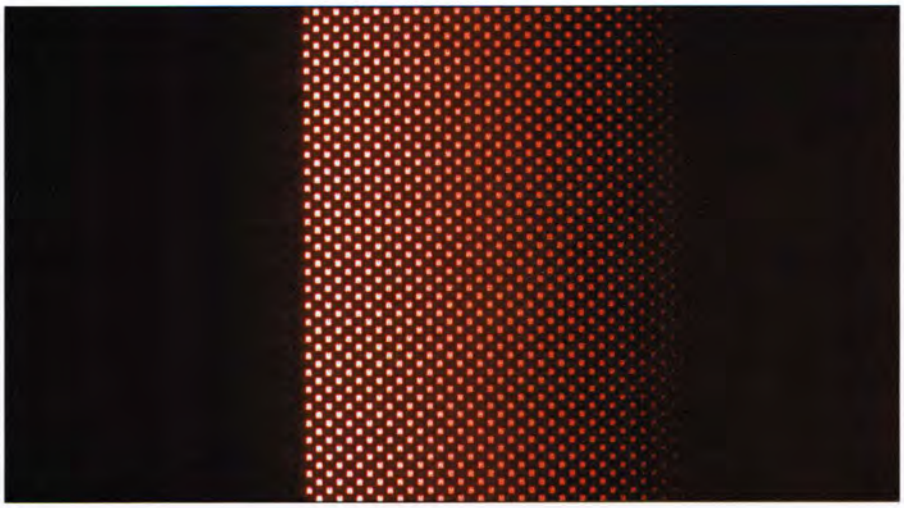
The Technical Sessions

In three different papers, authors from Hitachi, Giant Electronics Technology Corp., Philips Research Laboratories, XMR, and Xerox PARC described low-temperature polysilicon-TFT processes. The Hitachi/Giant team predicted 20-in. polysilicon TFT-LCDs with integrated drivers.

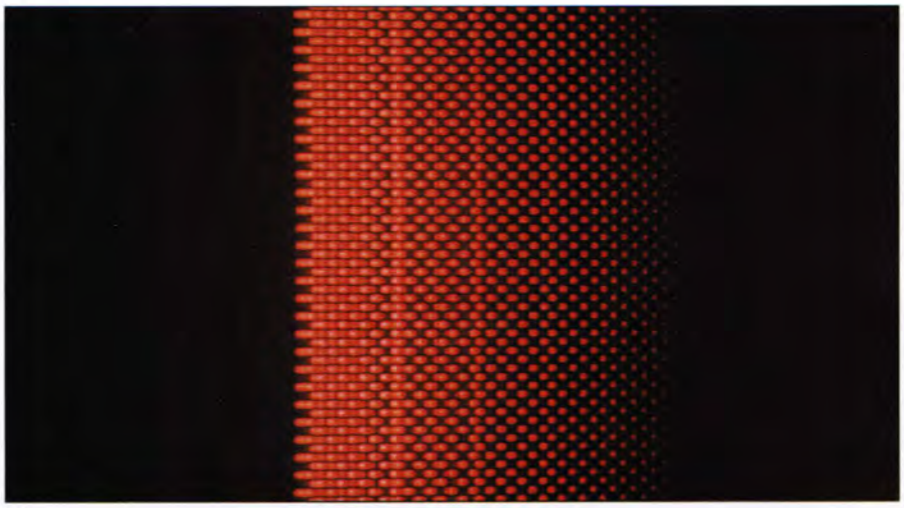
A group from Shipley and Rohm and Haas compared the processes for preparing RGB color filters with traditional dyes and the new pigment-dispersed photoresists. Y. Inoue and his colleagues from NHK reported on a new blue EL device made with a cerium-doped strontium thiogallate phosphor film.

A group from MCTC and SI Diamond reported work in a paper entitled, "Optimization of Amorphic Diamond™ for Diode Field-Emission Displays." Knowledgeable members of the audience characterized the work as an early effort to characterize the film and get a handle on the deposition process. The meat of the paper is that in films created with laser ablation, "films grown with higher laser power density lead to lower emission thresh-

Fig. 2: A new category of contour noise arises when moving images are shown on matrix displays – such as PDPs – that use pulse-width or pulse-number modulation within a field to express gray levels. The effect is illustrated by showing (a) a stationary image on a display that is itself stationary, (b) moving to the left, and (c) moving to the right. The effect can be minimized by changes in level coding. (Photos courtesy of Professor Shigeo Mikoshiba, The University of Electro-Communications, Tokyo.)



(a)



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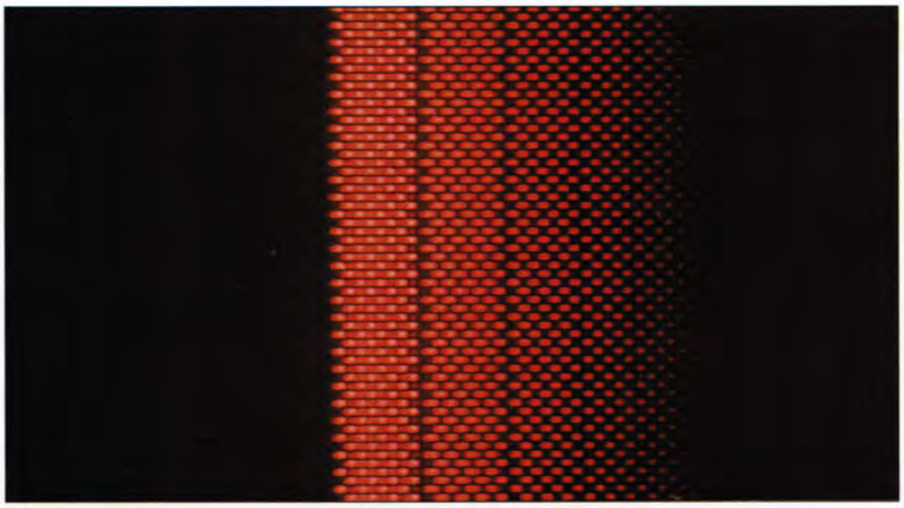

(c)

old fields." A 50 × 50-pixel test array showed substantial pixel-to-pixel variation, but there was no long-term drift over 20 hours of dc operation.

The entire conference contained only two papers on CRTs: one on a new dispenser cathode containing Y_2O_3 from H. Nakanishi and his colleagues at Tokyo Cathode Laboratory; the other on narrow-elliptical-aperture technology (NEAT) electron guns for color display tubes with 24.3-mm necks. Power consumption of the NEAT gun matches that of normal guns for mini-neck tubes, while focus characteristics are as good as those in large-neck tubes. The authors are S. Shirai and a substantial group of co-authors from Hitachi.

Active-Matrix Materials and Devices

In "A 9.5-in. TFT-LCD with an Ultra-High-Aperture-Ratio Pixel Structure," T. Kitizawa and his co-workers at Toshiba described a high-brightness (or more energy-efficient) display with a 70% aperture ratio, a cell transmission of 7.5%, and a contrast ratio greater than 200. N. Hirano and his colleagues at NEC presented "A 33-cm-Diagonal High-Resolution Multi-Color TFT-LCD with Fully Self-Aligned a-Si:H TFTs." The self-aligned TFTs are fabricated with an ion-implantation step. "We believe the technology we have introduced here will be extremely valuable in the attempt to produce larger-size and higher-resolution TFT-LCDs, such as those of 30-, 40-, and 50-cm-diagonal display size."

Speaking for a list of authors so long it seemed to include much of the engineering staffs of Philips Research Laboratories (Eindhoven, The Netherlands, and Redhill, U.K.) and the Flat Panel Display Co. (Eindhoven), W.J.A.M. Hartmann presented "TFD-R:

Improved Stable Two-Terminal Devices for State-of-the-Art AMLCDs," which provided another look at the TFD technology described more generally in the workshop. As a result of the developments described in the paper, "the complete performance parameters for TFD-R AMLCDs can match and even surpass TFT displays."

Jennifer Gille (Western Aerospace Laboratories), Russell Martin (Xerox PARC), and James Larimer (NASA/Ames Research Center) explored the implications of a recently performed perceptual study for economical display design in "Spatial Resolution, Gray-Scale, and Error-Diffusion Tradeoffs: Impact on Display System Design." The study, verified with human testing, was based on predictions of the VIDEOS Sarnoff Human Vision Model. The results can guide display designers to the most cost-effective display they can build, given the cost of gray levels and resolution in a given technology.

K. Meinstein and M. Callahan of Crystal Semiconductor Corporation reported on the development of two low-voltage 6-bit signal drivers for TFT-LCD panels that are reportedly the smallest in the world. Two papers, one by D. Straub and his colleagues at the Laboratory for Flat-Panel Displays at the University of Stuttgart and one by M. Quinn and P. Migliorato at the Cambridge University (U.K.) Engineering Department, reported on different polysilicon-TFT device models. Each group claimed improved circuit simulation with its model.

Projection

In an invited address, Ed Stupp of Philips Laboratories surveyed the elements of projection technology. Neglecting very-expensive very-high-luminance systems, current professional systems are predominantly front-projection CRT, with a few three-panel LCD light-valve systems. Consumer systems are predominantly rear-projection CRT. At present, LCD systems are too expensive and pass too little light for most applications, but developments such as polysilicon TFTs and more efficient polarization schemes will change that. In the end, image quality with LCD projectors will exceed that of CRT projectors, Stupp said. Rear-projected high-resolution images, regardless of the device producing them, will probably require a screen technology other than today's double lenticular screens.

Yukio Takahashi and his colleagues at NTT described a 6-Mpixel LCD projection system that optically interleaves pixels from four 720 × 480-pixel LCD projectors. The projector achieves a resolution of 1600 TV lines (H) by 1800 TV lines (V).

Toshikazu Maekawa and his co-authors from Sony described a 1.35-in. LCD panel with polysilicon TFTs and 1068 × 480 pixels. Built-in functions include image reversing and switchable 16:9 and 4:3 aspect ratios. Resolution is 600 TV lines (H) by 450 TV lines (V). The authors "believe that this LCD panel will lead to small-size high-resolution front/rear projectors."

In a paper presented by Tsutomu Hashizume, a group from Seiko-Epson described a 1.3-in. polysilicon TFT-LCD with a 14-μm pixel pitch and integrated single data driver.

H. Hamada and his associates at Sharp's Liquid Crystal Labs described a single-panel projection system that does away with the mosaic color filter. The system "has been developed using a planar microlens array and a special configuration of dichroic mirrors. The dichroic mirrors are stacked in a nonparallel arrangement, they split a white light beam into three primary-color (RGB) beams, and these beams are projected upon a single monochrome TFT-LCD from different incident angles, respectively. Each microlens, which is associated with every three subpixels (RGB), converges RGB beams into corresponding sub-pixel apertures. The screen brightness [is more than three times brighter than] the previously developed single-panel LC projector using a microlens array with a mosaic color filter."

Emissive Displays

Henry Gray of the Naval Research Laboratory kicked off the last day of the conference with a typically bravura presentation of new understanding of field-emitter displays (FEDs) and new developments in FED design. Gray discussed the inherently high luminous efficacy of FEDs, as well as new designs that minimize unnecessary capacitance between the gate and microtip – the primary non-productive energy-consuming mechanism. He also stated his suspicion that diamond films supply atomically sharp emission "tips" that are not fundamentally different from conventional microtips. If this suspicion is correct, said Gray, it means that the diamond-film FED is the only "bed-of-nails" FED that works.

In "Field-Emission Characteristic Requirements for Field-Emission Displays," Chenggang Xie of MCTC reported calculations indicating that "with improvements, especially in tip density and emission area, this technology will be capable of satisfying contrast and luminance requirements of high-quality flat-panel displays" to the XGA level.

In "Long-Life Color DC-PDP with Transparent Cathode," NHK's Y. Motoyama and J. Koikes described a near-doubling of luminous efficacy to 0.51 lum/W by using a transparent ITO cathode. The panel uses a reflective phosphor screen and a resistor-in-cell structure. A lifetime of over 30,000 hours has been confirmed.

LCDs

The final afternoon of the technical sessions consisted of two LCD sessions. They were kicked off with a paper from France Telecom, presented by B. Vinouze, which reported an active-matrix PDLC panel. To quote the authors, "there is a large need for portable reflective high-information-content displays. PDLC is a potential challenger because of the low power consumption due to the absence of polarizers. We have optimized the process parameters and cell design to make an active direct-view display compatible with gray-scale video images." With a CR of 10:1, 100-ms response, and a good viewing angle, the panel was impressive for a reflective display when shown at the author interviews (Fig. 1).

Designers of PDLCs have been making bistable devices with less and less polymer gel – now well under 1% – in the mix. In a paper presented by B.-G. Wu, a group from Advanced Display Systems and the University of Texas at Arlington reported the first display exhibiting zero-field multistability (for gray scale) without any polymer-gel additive at all.

In "Polymer-Stabilized SBE Devices," D. S. Fredly and his colleagues at Kent State's Liquid Crystal Institute reported that by adding polymer dopant to STN displays, they could increase the twist from 240 to 270° without stripe formation. Driving voltage is also reduced. In a paper presented by T. Hashimoto, a group from Stanley, Dainippon,

Fig. 3: A solid-state volumetric display can be based on upconversion in rare-earth-doped heavy-metal fluoride glass. When two infrared photons of different frequencies elevate an electron through two quantum states, the electron can fall back to its original state with the emission of one visible photon. The sources of the exciting photons are two lasers, and a voxel – volumetric pixel – is created wherever the two laser beams intersect. (Photo courtesy of Elizabeth Downing, Stanford University.)

and Tokyo University described a fabrication process for polymer-stabilized amorphous TN-LCDs that does not require rubbing of the stabilizing surfaces.

Poster Session

The Tuesday afternoon Poster Session provided some particularly interesting nuggets. Here are a few.

T. Masuda, T. Yamaguchi, and S. Mikoshiba's multimedia poster paper effectively demonstrated a new category of contour noise that has been observed when moving images are shown on matrix displays – such as PDPs – that use pulse-width or pulse-number modulation within a field to express gray levels (Fig. 2). The noise originates when a temporal non-uniformity of light emission is translated into a spatial non-uniformity by the image's motion. "The noise can be reduced by sub-dividing the light-emitting periods of the major bits."

E. A. Downing and L. Hesselink at Stanford University's EE Dept. and R. M. Macfarlane at IBM Almaden described and showed photos and a video of a solid-state 3D volumetric display (Fig. 3). (Hesselink is also working on volumetric data storage.) The display medium is a rare-earth-doped heavy-metal fluoride glass. The mechanism is "upconversion," in which two infrared photons of different frequencies elevate an electron through two quantum states. The electron then falls back to its original state, emitting one visible photon. The sources of the exciting photons are two lasers. A voxel – volumetric pixel – is created wherever the two laser beams intersect. The images displayed were simple Lissajous-like patterns. Elizabeth Downing, the presenter, said that being non-crystalline, the glass is easy to fabricate, even in large pieces.

Akihiko Kanemoto and a group from Ricoh described and demonstrated a prism array sheet for enhancing the backscattering, and hence the luminance, of PDLCDs. It can also be used to reduce the driving voltage because the film allows strong backscattering even with a thin PDLC film.

Ichiro Fukuda and a group from Kanazawa Institute of Technology and Tohoku University proposed an achromatic reflective STN-LCD using only one polarizer. Numerical analysis predicts several solution sets that produce achromatic images with high luminance and CR. All of these solutions require a retardation film. A reflectance of 49% and a CR of 12:1 were predicted using a practical polarizer.

The development of a new fluorescent lamp for LCD backlighting that combines high luminance and long lifetime was described by F. Sato and a team from Noritake and ISE Electronics. The combination was attributed to a new cesium-impregnated sintered metal cathode. A luminance of 22,000 cd/m^2 and a lifetime of 20,000 hours were reported in a lamp with a diameter of 5.8 mm.

Nader M. Kalkhoren and his co-authors at Spire Corp. described the display possibilities of porous silicon that emits visible light. Spire has prepared porous silicon layers that have strong visible photoluminescence and has demonstrated electroluminescence in bulk crystalline silicon. The company recently demonstrated electrically induced visible luminescence in porous polycrystalline silicon. A photoluminescent wafer was shown.

A complete record of the conference can be found in *The Conference Record of the 1994 International Display Research Conference* (Society for Information Display, 1526 Brookhollow Drive, Suite 82, Santa Ana, CA 92705-5421; 714/545-1526, fax -1547. ■

Making Displays Deliver a Full Measure*

NIST wants to use its sophisticated laboratories to help you get high-quality displays to market faster.

by Herbert S. Bennett, Charles Fenimore, Bruce F. Field, and Edward F. Kelley

HIGH-RESOLUTION DISPLAYS are essential for market acceptance of advanced video systems and for sophisticated exploitation of "the information age." Developing and manufacturing such displays will require advanced measurement capabilities. This is a subject that interests us greatly at the National Institute of Standards and Technology (NIST), where the development of measurement standards and their application to industrial competitiveness have long been a central part of our mission.

Unfortunately, a recent NIST assessment of the measurement capabilities needed for video technology found that there is little metrological basis for the video-quality measurements that are typically made where video is generated, processed, or displayed.[1] Currently, measures of video and display quality are poorly defined and are affected by the optical properties of cameras, by the details of mathematical algorithms, by the electronic circuitry used to process video information, and by the electro-optical properties of display devices. The industry's capabilities in real-time video and display-quality measurements are limited because it is hard to visualize theoretical video-processing constructions without manufacturing specialized hardware. The video supercomputer at NIST – which we will describe shortly – solves this problem by directly displaying signal-processing constructions for video.

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Note

Additional NIST contacts are **Jonathan E. Hardis** for information on absolute luminance standards for FPDs; telephone 301/975-2372, fax 301/840-8551, and **Mark Williamson** for information on the Flat Panel Display Interface Laboratory; telephone 301/975-3160, fax 301/216-1369.

NIST

Fig. 1: *The Video Processing Laboratory at NIST, Gaithersburg, Maryland, is built around the Princeton Engine that was developed by David Sarnoff Research Center. The lab is available to members of the display community for appropriate projects.*

Fig. 2: The Princeton Engine has a split-screen mode that permits an original video signal to be shown on the left side of a CRT and processed video on the right side. Here, the right side shows image degradation in a transmissive LCD caused by resistance in the interconnections between TFTs horizontally across the simulated display.

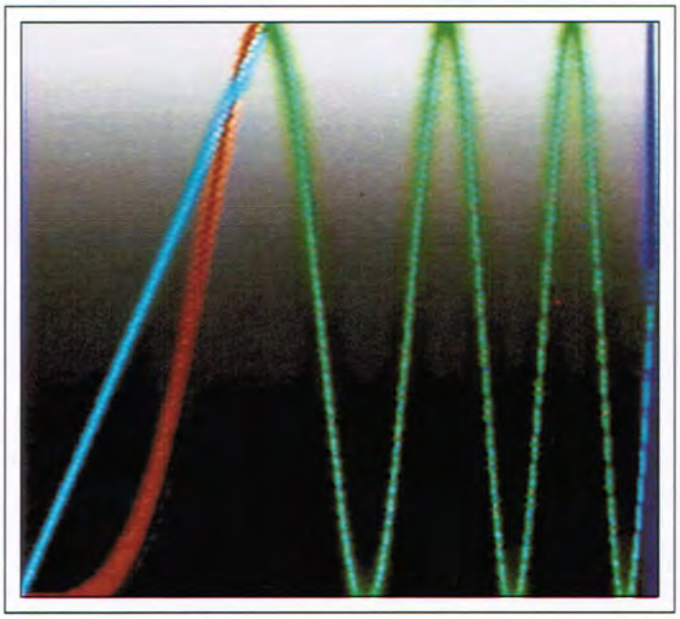


Fig. 4: This video output from the Princeton Engine shows the video processed by a linear system (left) and the video as it would appear on a model FPD (right). Superimposed on the right half is the transmission curve for the model pixel, which relates the pixel's light output (vertical axis) to the voltage applied to the pixel (horizontal axis). The straight cyan line gives the transmission curve for a linear system. The curve for the model pixel is in red.

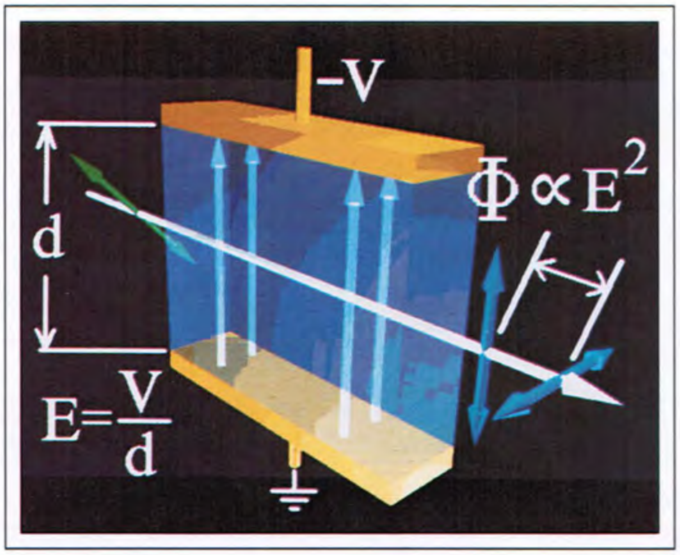


Fig. 3: This schematic of a generic pixel for a transmissive display shows the electro-optical characteristics that are used as input parameters for the simulation model. The quantities are the electric field (E), the voltage (V), the distance between pixel electrodes (d), and the phase angle (Φ) between the parallel and perpendicular components of the light that is being transmitted through the pixel.

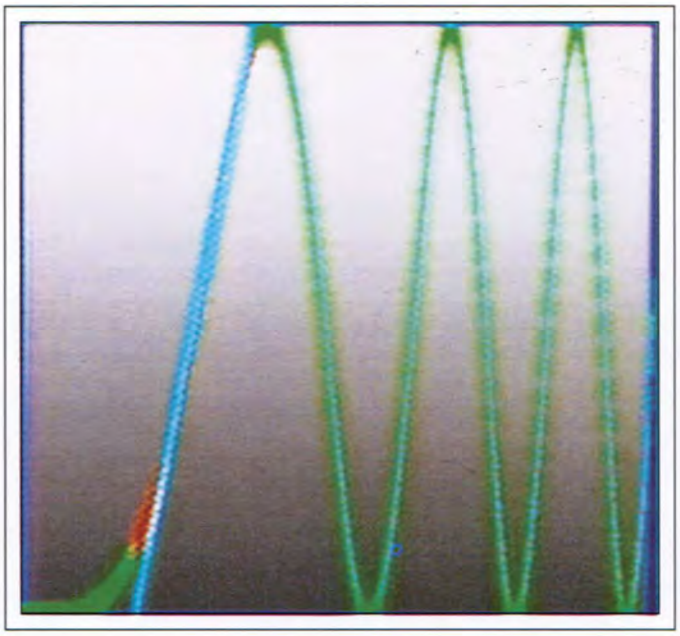


Fig. 5: The modeled FPD's video output comes closer to matching the original if we can exploit a more linear region of the transmission curve.

Table 1: Measurement Needs for Flat-Panel Displays

Category	Measured Quantity
Materials characterization	Defect density Resistivity Flatness Birefringence Carrier mobility Refractive index Absorption coefficient
Manufacturing yield	Defect density Chemical identification Layer thickness Layer uniformity
Display performance	Pixel response time Gray-scale linearity Brightness Contrast ratio Field of view Resolution for color uniformity Resolution for intensity Aliasing Fixed-pattern noise artifacts Color and brightness non-uniformity
Interfacing to computers	Figures of merit for resource allocation Semiconductor memory CPU time

NIST's assessment also found that improved measurements are needed to assist industry in meeting its challenges, particularly improvements in materials characterization, yield, display performance, and display/computer interfacing. The technical requirements for manufacturing active-matrix liquid-crystal displays (AMLCDs), plasma display panels (PDPs), and electroluminescent (EL) displays are major challenges that give rise to a number of measurement and standards needs (Table 1). A specific example is the set of technical concerns and priorities for AMLCDs expressed by display manufacturers at a 1993 meeting of the Display Working Group of the Photonics Materials Workshop (Table 2).

NIST has initiated new internal programs on video technology to address some of the measurement needs identified in its assessment. These needs are as follows:

- The assessment of display performance.
- Display tests that are technology-independent.
- The automation of display measurements.
- The interfacing of displays with computers.

NIST is developing a measurement-technology program for advanced imaging systems, and is creating three new laboratories to provide measurements of display performance. These laboratories are the Video Processing Laboratory, the Display Measurement Laboratory, and the Flat Panel Display Interface Laboratory.

One goal of this program is to help develop a common specification language for display-performance characteristics. Such a language is needed by both manufacturers and users to conveniently assess a display's suitability for a given task. Since this NIST program is technology neutral, it is well-positioned to provide assistance in the development of standards and measurement practices that do not favor any single display technology.

Video Processing Laboratory

The Video Processing Laboratory is built around the Princeton Engine video supercomputer, which is used for a variety of video-processing applications such as assessing display performance (Fig. 1).[2,3] This massively parallel, single-instruction, multiple-data computer – developed by the David Sarnoff Research Center as a research tool – accepts multiple video signals as input, processes the video information in real time, and flexibly outputs multiple video signals. The machine has six video inputs and seven video outputs with programmable horizontal and vertical scan rates. Its plug-in cards accept (or produce) either analog or digital video.

Each scan line from a video image is digitized into 1024 pixels in real time. The entire line of pixels is processed simultaneously by 1024 processors in parallel that run the same calculation or program for each pixel. This massive parallelism permits the machine to output processed video synchronously before the next line of the image becomes input. The result is real-time video processing of virtually any video input. We can simulate on a standard high-quality CRT graphics monitor the video output that would appear, for example, on an LCD.

With the Princeton Engine, we can measure the performance of compression-decompression algorithms, and we can simulate display characteristics with analytical or empirical data that describe the performance of pixels in the display. In one of the Princeton Engine's modes, we can use a split-screen technique to display the original video on the left side of a CRT, while we display the same image after video processing on the right side (Fig. 2). Because the Princeton Engine can reliably simulate the performance of proposed designs without the need to make an actual display or have the simulation algorithms embodied in chips first, the time for manufacturing design can be shortened.

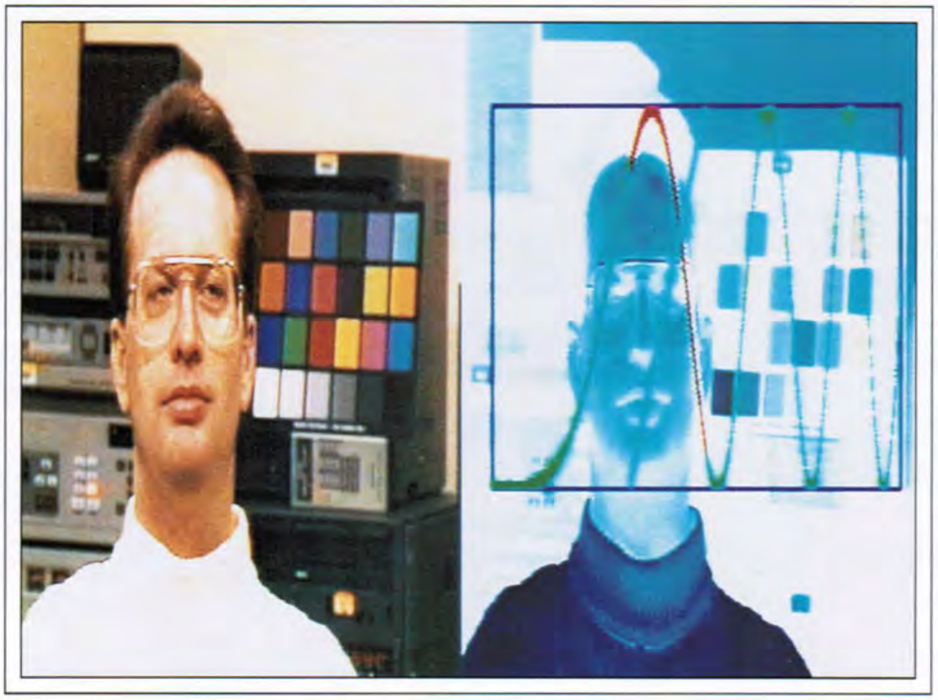
Overall, the capabilities of the Video Processing Laboratory include (1) real-time processing of video images, (2) real-time modeling of display characteristics, (3) video-quality metrics, and (4) visual-perception testing.

In one application, we have used the Princeton Engine to perform real-time modeling of flat-panel display (FPD) characteristics on a CRT. These characteristics include "seeing" – before the display is manufactured – the effect of resistance in the interconnections to the transistors that drive the pixels, the extent of "crosstalk" among neighboring pixels, the color balance, and changes in the displayed image with viewing angle. We used the appropriate electro-optical properties of the pixels as the input parameters for modeling a transmissive FPD (Fig. 3). The detailed relationships among these parameters, the viewing angle, and the path length of the transmitted light depend on the specific electro-optical effect being exploited in the display.

The transmission curve for the model pixel relates the pixel's light output (vertical axis) to the voltage applied to the pixel (horizontal axis) (Fig. 4). The straight cyan line gives the transmission curve for a linear system. It varies from black to white and operates over the same range in voltage as that for the model pixel's transmission curve, shown in red.

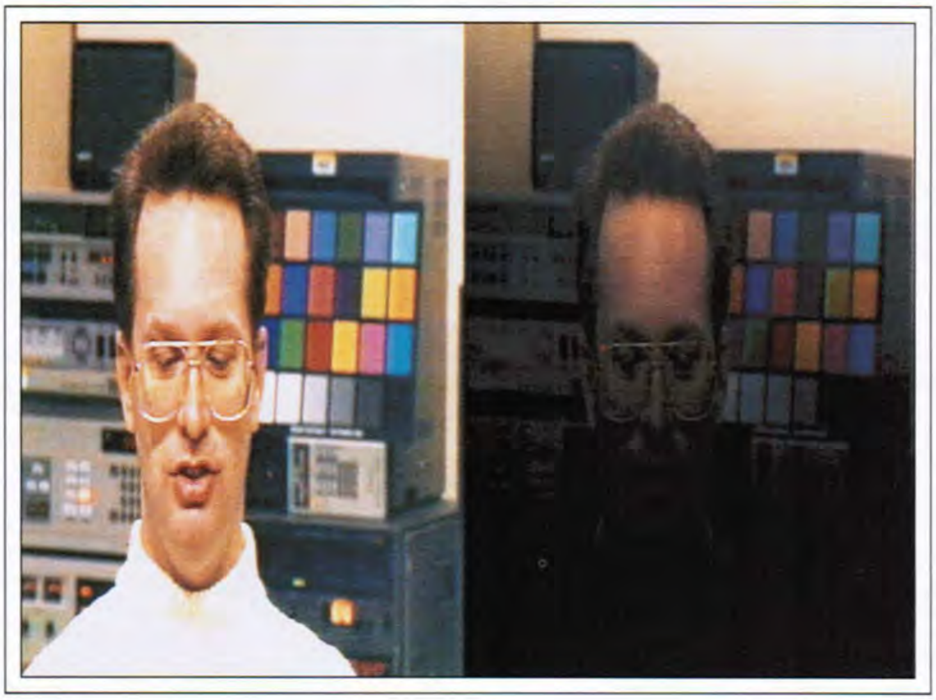
Table 2: Technical Concerns in the Manufacture of AMLCDs

Concern	Priority	Cost/Yield Impact	Performance Impact	Measurement Needs/Issues
Substrate particle inspection for uncoated, coated, and patterned layers	High	Primary	Secondary	Defect density, chemical identification, and index of refraction
Less-expensive color filters with less absorption of light	High	Primary	Secondary	Transmission efficiency
Process materials development for active matrices	High	Secondary	Primary	Fast in-situ measurements of process parameters such as deposition rates, thickness, and chemical stoichiometry; statistical process control; and reduced processing time
New liquid crystals for reflective-mode operation (long-term and high-risk challenge)	High		Primary	Pixel response time, gray-scale linearity, viewing angle, resolution, birefringence, and layer thickness
Substrate cleaning	Medium	Primary		Surface density of contaminants
Resist and polyimide coatings	Medium	Primary		Speed of application, amount that is waste, layer uniformity, and thickness in real time
Alignment layer	Medium	Secondary	Primary	Relative rubbing speeds, pressure, spacing between ridges, cross section of ridges, and uniformity of these quantities across large areas
Packaging	Medium	Secondary	Primary	Crosstalk among drivers, speed with which rows and columns may be addressed, pitch, viscosity of liquid crystal with temperature, and thickness and size of substrates



NIST

Fig. 6: Video output from the Princeton Engine that shows a false negative-like image at large viewing angles. This is equivalent to operating a display with a range of input voltages that spans both sides of the transmission curve's first maximum.



NIST

Fig. 7: Video output from the Princeton Engine that shows image degradation caused by resistance in interconnections to TFTs vertically down the model display.

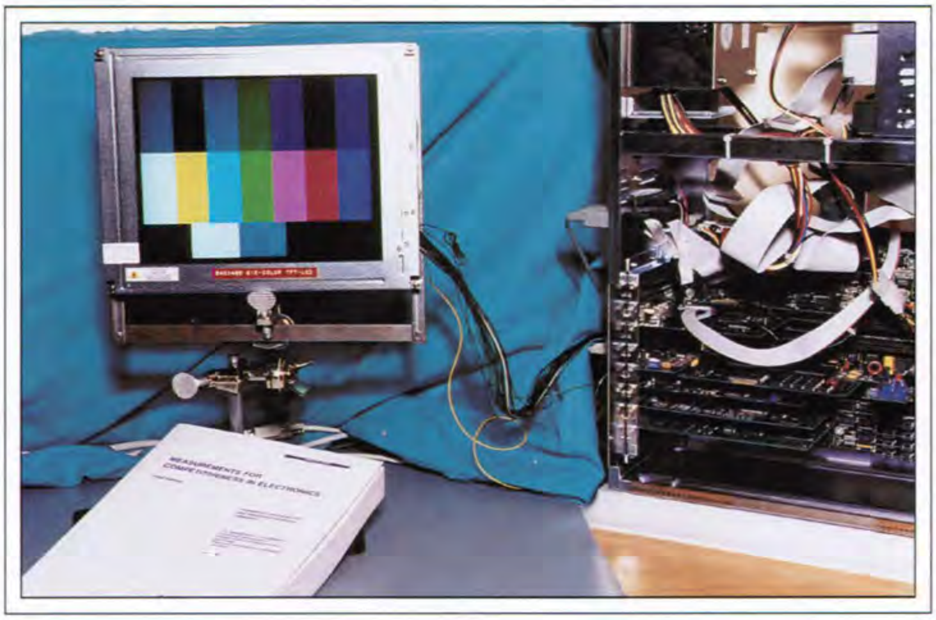
For a given electro-optical effect, changes in the viewing angle produce effective changes in the operating region on the transmission curve. In the modeled display, increased contrast and a concomitant loss of detail would occur in the dark and bright portions of an image. Many of the grays of the original are mapped into the darks. This is consistent with the overlayed graphic. By adjusting the voltage range, for example, to exploit a more linear region of the model transmission curve, we can better match the original gray scale (Fig. 5).

False-negative images – a major objectionable feature of electro-optical displays – occurs when the portion of the transmission curve that is used exploits both sides of the first maximum (Fig. 6). Another concern is the resistance across and down the screen in the interconnections to the transistors driving the pixels. This causes a degradation in the voltage signal as a function of position on the screen (Figs. 2 and 7). These simulations are for a transmissive display, but the Princeton Engine can also be used to model emissive and reflective displays in real time.

Display Measurement Laboratory

We are also assembling a photometric and colorimetric testing laboratory for completed FPDs – that is, displays with pixel drivers – to provide tests that are traceable to absolute units and correlated with the limits of human visual perception. This Display Measurement Laboratory, which is adjacent to the Princeton Engine, will provide a flexible environment capable of addressing a large variety of display-quality measurements. The laboratory can be used for radiometric, photometric, and colorimetric calibrations, and for ambient-light characterization. This laboratory will also serve as a testbed for combining robotic and automated systems to measure quickly signals sent to displays and light received from displays.

Where possible, display-technology-neutral photometric and colorimetric tests will be used. If necessary, such tests will be developed. Tests can be performed on transmissive panels with and without a backlight, on emissive panels, and on projection systems. The purpose of the laboratory is to demonstrate proof-of-concept for measurement practices that will be applied to limited production runs or limited numbers of samples. Thus, in



NIST

Fig. 8: An AMLCD under test in the FPD Interface Laboratory at NIST, Gaithersburg, Maryland.

designing the laboratory, we emphasized versatility rather than raw production speed.

Key elements of this laboratory include an automated five-axis display positioner within a 1.9-m surround sphere with controlled illumination and temperature monitoring, spectroradiometers, colorimeters, and luminance-calibration sources. Other key elements include a charge-coupled-device (CCD) imager attached to a long-distance microscope, programmable video-signal sources (test generators, computer display adapters, and videotape and disk recorders), video-signal monitors, and laboratory computers to control the apparatus and to log and analyze data.

These systems can provide comparative measurements among panels, and among pixels within a panel, and reference them to absolute luminance standards.

FPD Interface Laboratory

NIST is also assembling a laboratory to achieve interoperability and flexibility between FPDs and computers. In order to accomplish this, it will be necessary to develop logical electrical and mechanical standards for interfacing FPDs to computers. NIST is coordinating efforts to develop voluntary industry standards in this area.

Research is also being conducted on interface architectures for connecting FPDs to advanced computers and on performance measures for these interfaces. As can be seen in Fig. 8, there are currently no logical electrical or mechanical standards for connecting FPDs to computers. This lack of standards has led to difficulties in integrating FPDs into computer systems, and has prolonged the development of plug-and-play products.

External Programs

In addition to its internal programs on displays, NIST has an external program, the Advanced Technology Program (ATP), that funds companies to do precompetitive and generic research in many technologies. Funding decisions are made strictly on a competitive basis through submitted proposals that are evaluated for technical and business merit in response to ATP solicitations. The ATP has made several awards that are related directly or indirectly to display technologies. These include:

- The American Display Consortium to develop automated inspection and repair technology, interconnections, packaging, and patterning technology.
- The American Scaled-Electronics Consortium to develop multi-film module technology and fabricate flat-panel displays with on-board drivers and logic on a glass substrate.
- FED Corp. to develop field-emitter displays.
- Hercules, Inc., to improve optically controlled alignment materials.
- Cree Research to advance SiC crystal growth, epitaxial deposition, and doping processes for power electronics and blue light-emitting diodes.
- Thomas Electronics, Inc., to develop flat fluorescent light sources.
- Philips Laboratories to develop microminiature light-source technology.

For information on ATP awards that relate directly to displays, send a fax to Thomas Leedy at 301/926-9524. To receive a Proposer's Kit for responding to ATP solicitations, call 1-800-ATP-FUND.

Conclusions

NIST will support the display industry in developing flat-panel video-quality measurements and standards by modeling displays, performing photometric and calorimetric testing, interfacing displays and computers, and providing funds for pre-competitive and generic research on FPD manufacturing.

A necessary but not sufficient condition for displays to deliver a full measure will be internationally accepted measurement techniques for manufacturing and for characterizing displays, and consistent sets of interoperable, extensible, and compatible standards and protocols that can be used for many applications throughout the global village.

Notes

*This article is a contribution of the National Institute of Standards and Technology, not subject to copyright. Certain materials, computers, and equipment are identified in this paper in order to specify the procedures adequately. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials, computers, and equipment so identified are necessarily the best available for the purpose.

[1]National Institute of Standards and Technology. "Measurements for Competitiveness in Electronics," Chap. 11 in: *Video. National Institute of Standards and Technology Inter-*

nal Report NISTIR No. 4583 (NIST, Gaithersburg, Maryland, April 1993), pp. 339-378. Chapter 11 contains a more complete assessment of the technical challenges and measurement needs faced by the display industry than contained in this summary. Readers may obtain copies of NISTIR 4583 by sending a fax to H. S. Bennett at 301/975-4091.

[2]B. F. Field and C. Fenimore, "Video Processing with the Princeton Engine at NIST," in: *National Institute of Standards and Technology Technical Note 1288* (NIST, Gaithersburg, Maryland, August 1991), 51 pp.

[3]D. Chin, J. Passe, F. Benard, H. Taylor, and S. Knight, "The Princeton Engine: A Real-Time Video System Simulator," *IEEE Trans. Consumer Electron.* **34**, No. 2, 285-297 (May 1988). ■

display continuum

continued from page 4

tors and managers of this existing facility. They were quite puzzled when their new manager expressed concern instead of gratitude upon being told what a great favor they had done for him. Why was he "fussing"? Couldn't he see how they had substantially shortened the time to get the factory operational?

For Bob, the new manufacturing manager, manufacturing was his life – it was his ***burning passion***. He kept up on all the latest techniques, and had an excellent track record. He looked forward to this opportunity to bring a new technology into successful volume production. He was, however, uneasy that the founders viewed his task with such lack of enthusiasm and seemed to hold his position in such low regard. Oh well, he would just have to prove his value as he made his contribution.

The first signs of trouble came just 2 months later. Bob had been trying to implement a complex thin-film coating process that was the key to making the new display product meet its gray-scale uniformity spec. It had been done successfully in the lab, but when Bob looked into it, he found that even the most senior lab technicians could only get the process to work when everything was "just right." The demo display currently being shown to customers had been carefully selected as the best from more than a dozen attempts. In Bob's opinion, there was no way to transfer this touchy process into a manufacturing environment.

Before he joined the company, Bob had carefully read the business plan, so he was well aware of the planned selling price for the product. From past experience, he knew he should put a high priority on establishing manufacturing costs based on the preliminary throughput and yield results. His first-pass calculations left him shaken. How could the founders have promised a selling price that was well below the expected ***variable*** cost of manufacturing? If he added his fixed costs and the company's overhead, the product would have to be priced at least five times higher.

Needless to say, he quickly became the least popular member of the management team. If he was so darn capable, why wasn't he fixing these problems instead of complaining about them? The final ugly scene occurred when Bob tried to tell the founders that the people retained from the previous business would require far more training than had been planned. He had found that key groups, such as the people in the machining area, had never worked in a demand-scheduled factory and had no idea of the principles behind just-in-time manufacturing and/or total quality management. While pretending to go along with the new systems, they were either ignoring them or subverting them by keeping secret "stashes" of safety stocks and using the informal methods of work assignments they had always used. As a result, his quality measures were in a shambles, he had no idea of the real yield numbers at each process step, and he couldn't tell which part of the process needed improvement the most.

This problem was especially serious because not only were these people ***unable*** to perform in this new environment, they were ***unwilling*** to do so. ***Unable and willing*** he could fix by training, but ***unable and unwilling***, he knew, usually meant dismissal or (at least) a move to a different organization.

Can you think of anything else that Bob could have done to make himself more "popular"? He had told the founders that their technology couldn't be made manufacturable. His estimates showed that they would have to price their product much higher than customers wanted to pay. And, in his considered opinion, the factory they had acquired with such ease wasn't such a great deal after all, since it would take much longer and cost a great deal more to start up. (Perhaps you will think back on this story the next time you read a flashy press announcement about a start-up having just acquired someone's existing facility and expecting to be in volume production in just a few months.)

Bob's exit from New-Age Displays, Inc., was only a precursor to what happened a year and a half later, when the venture fund managers decided that what this company really needed was some "experienced managers" to turn it around.

> ***Getting technology to market requires a Burning Passion and unwavering dedication to making a product manufacturable at a competitive cost.***
>
> ***Technology, Market Understanding, and Manufacturing are the three success fundamentals of any profitable high-tech business. The failure of any one spells the failure of all.***

The growing importance of displays as the "Windows into the Information Age" and the desire within the United States to improve its world share of display-manufacturing capability are creating a need for engineering and management talent ***passionately dedicated to manufacturing***. Japan, followed by Taiwan and Korea, recognized this need some years ago and undertook the training of engineers and scientists specializing in this area. The results of this dedication are today self-evident.

Manufacturing is a discipline intolerant of shortcuts. Throughput improvements, yield increases, and cost reductions are accomplished in methodical and carefully structured steps. For the U.S. to get to world-class status in display manufacturing, it may have to borrow talent from its semiconductor and automotive industries to fill the gap. Is there enough to go around?

For a number of years now, my personal ***burning passion*** has been "taking technologies to market." For me, that means discovering new market opportunities and meeting them with manufacturable products. Thus, I am always searching among my display industry colleagues for those with an interest in manufacturing. So far, here in my U.S. home, I'm feeling a bit lonely.

However, I will look to meet many of you, from all parts of the world, on January 31 at the Display Manufacturing Technology Conference (DMTC) in Santa Clara, California. It's an event that should become ***the*** opportunity to learn the latest in what is happening in display-manufacturing technology worldwide. This year's addition of product exhibits will make the DMTC an even more special occasion.

To begin this month's industry news segment, **In Focus Systems, Inc.**, and the **David Sarnoff Research Center** made it official at the International Display Research Conference in Monterey, California, by announcing the formation of **Sarif, Inc**. At a reception for the press and interested conference attendees (who filled the room to capacity and spilled into the hallway), they announced that the new company would produce and commercialize polysilicon active-matrix flat-panel displays and projection systems. As previously mentioned in this column, the new company will be headed by **Steven R. Hix**, who will serve as Chairman and CEO. At the heart of this new venture is the active-matrix polysilicon technology that the Sarnoff Center has researched and developed over the last 10 years with more than $35 million invested, including funding from **ARPA**, the **Wright Aeronautical Laboratory**, the **National Information Display Laboratory**, and a number of private companies. Among the dignitaries at this event were **John Harker**, President and CEO of In Focus Systems, and **Curt Carlson**, Vice President of Sarnoff's Information Systems Research Division, the laboratory that developed the polysilicon technology.

Plasmaco, Inc., of Highland, New York, has announced a major restructuring of its operations as a first step towards enabling the company to pursue the commercialization of its recently demonstrated full-color FPD. The total financing, which included debt restructuring and new equity, exceeded $6 million. The new equity financing was led by **Atlantic Venture Group, Inc.**, a New York City based merchant banking firm, together with a group of new shareholders. **Stephen E. Globus**, Chairman of Globus Growth Group, Inc., will become the Chairman of Plasmaco, with **John J. Antretter**, the President of Atlantic Ventures, assuming the positions of Acting CEO and Director. **Larry F. Weber**, a founder of Plasmaco in 1987, was named President and a Director of the company. **Donald F. Neville**, Vice President of Atlantic Ventures, was named CFO, and **Michael J. Sprague** was elected Vice President.

Licensing agreements have been signed by **Tektronix, Inc.**, of Wilsonville, Oregon, with two Asian companies for Tek's patented liquid-crystal pi-cell technology. The Tek-developed technology, which includes both color-shutter and stereoscopic displays, has been used in products sold by several Tektronix instrument divisions, as well as a growing number of outside industrial, medical, and consumer-product suppliers. The new licenses, granted to **Delta Electronics, Inc.**, of Taipei, Taiwan, and **Vikay Industrial Ltd.** of Singapore, represent an attempt at further expansion for the pi-cell LCD implementation. Both Delta and Vikay will be working closely with Tektronix to provide a migration path for Tektronix's existing customer base. Vikay has established a new company called **Nu Vision Technologies, Inc.**, in Beaverton, Oregon, which will focus exclusively on marketing and engineering pi-cell-based shutters for the industrial and consumer display markets. The Display Products group at Tektronix was shut down effective October 28, 1994.

Chomerics, Inc., of Woburn, Massachusetts, has been acquired by the **Parker Hannifin Corporation** from **W. R. Grace & Co.** Chomerics is the world's largest manufacturer of EMI shielding materials and thermal interface products. The company also has facilities in Hudson, New Hampshire, and Marlow, U.K. Chomerics will operate as a division of the **Parker Seal Group**. Parker Seal is headquartered in Irvine, California, and provides many types of industrial and commercial sealing devices and related products.

As always, contributions to and comments about this column are most welcome. I can be reached by phone at 609/734-2949, by fax at 609/734-2127, and by e-mail at aris_silzars @maca.sarnoff.com. If you prefer the mail, please send your information to Aris Silzars, Contributing Editor, Information Display, c/o Jay Morreale, Palisades Institute for Research Services, Inc., 201 Varick Street, Suite 1006, New York, NY 10014. ■

Please send new product releases or news items to Joan Gorman, Departments Editor, Information Display, c/o Palisades Institute for Research Services, Inc., 201 Varick Street, New York, NY 10014.

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VGA-driven plug-in TFT-LCD

Computer Dynamics, Greer, South Carolina, has introduced the VAMP-XGA, the first 1024 × 768 color TFT-LCD that can be driven directly from a PC's standard VGA/SVGA analog signal. As a complete plug-in package for OEMs, the VAMP-XGA includes an 11.8-in. brilliant color LCD, an optional resistive touch screen, all driver electronics, an easily mounted 14.5 × 10.5 × 3.5-in. metal frame, and RS-232 cabling for the touch-screen and display controls. Applications include financial-information display, statistical process control, and data-acquisition applications, medical instrumentation, and mapping systems. The VAMP-XGA is priced at $7645 (OEM quantity) for the 11.8-in. color TFT-LCD and touch screen. Delivery is stock to 30 days.

Information: Sales Department, Computer Dynamics, 107 S. Main Street, Greer, SC 29650. 803/877-8700, fax 803/879-2030.

Circle no. 4

Color VGA ac plasma display

Thomson Tubes Electroniques, Velizy, France, has introduced the TH 7675B, a 512-color VGA ac plasma display panel. This 640 × 480-dot display has an RGB color-pixel pitch of 0.4 mm, resulting in a 13-in. diagonal. The white area brightness is 50 cd/m^2. The TH 7675B combines RGB-phosphor color and the inherent qualities of ac plasma flat-screen technology, which include ruggedness and a stable flicker-free high-contrast image with a viewing angle of over 160°. Options include the power-supply unit, coupler board, and touch-input device. The flat-screen panel is designed for an enhanced temperature range from –10 to +60°C. It is primarily intended for industrial data processing and ruggedized military applications.

Information: Thomson Tubes Electroniques, BP 121, F-78148 Velizy Cedex, France. 33-1-30-70-36-45, fax -50.

Circle no. 5

Sunlight-readable VGA monitor

Lucas Control Systems Products, Deeco™ Systems, Hayward, California, has introduced the ST1230-SR, a sunlight-readable VGA monitor built to withstand the demands of outdoor or industrial use. Features include a backlit transflective LCD with 640 × 480 resolution and a 1:1 pixel aspect ratio. The ST1230-SR is 100% VGA-compatible and utilizes a proprietary infrared touch system with mouse emulation. The monitor is designed for round-the-clock viewing under harsh ambient-light conditions, particularly in direct sunlight or where bright lights are present. External knobs fine-tune contrast and backlight brightness. Encased in a rugged cast-aluminum enclosure, the monitor is fully enclosed and sealed to meet NEMA 4 & 12 (IP65) standards. It can be located up to 300 ft. from a PC without modification or the use of external line drivers when connected by coaxial cables. Ultrathin by VGA-monitor standards, the ST1230-SR measures 12.72 in. (323 mm) high, 13.47 in. (342 mm) wide, and 5 in. (127 mm) deep, and weighs 26 lbs. (11.8 kg). The viewing- and touch-area dimensions are 7.71 in. (196 mm) wide by 5.8 in. (147 mm) high. Operating temperatures range from 0 to 45°C and humidity from 0 to 100%. Pricing for the ST1230-SR is $4180 in volume quantities. Delivery is 90 days ARO.

Information: Melissa May, Lucas Control Systems Products, Deeco Systems™, 31047 Genstar Road, Hayward, CA 94544-7831. 510/471-4700, 1-800-376-1154 in USA and Canada, fax 510/489-3500.

Circle no. 6

Small color TFT-LCD monitors

AND, a division of William J. Purdy Co., Burlingame, California, has introduced the AND-TFT-4 and the AND-TFT-5, 4- and 5-in. color TFT monitors. The 4-in. monitor has outline dimensions of 128.5 cm (W) × 102.8 cm (H) × 25.2 cm (D) and a pixel number (RGB trio) of 220 × 160. The input signal is PAL/NTSC compatible analog RGB (0.7 Vp-p) with composite sync. The unit requires a single +12-V power supply. The 5-in. monitor has outline dimensions of 145.2 cm (W) × 92.4 cm (H) × 33.0 cm (D) and a pixel number (RGB trio) of 234 × 240. The input signal is NTSC composite (1.0 Vp-p) signal and analog RGB (0.7 Vp-p) interface. It requires a single +9.5-V power supply. Both units are full-color LCDs employing thin-film transistor (TFT) technology, with a contrast ratio of 50:1 and luminance of 250 cd/m^2. Modules also have CCFL backlight with on-board power supply. The AND-TFT-4 and AND-TFT-5 are suitable for various applications such as portable television, medical, avionics, and automotive instrumentation, and portable test and measurement equipment.

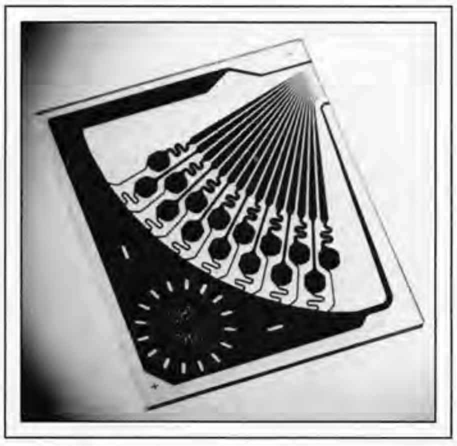
Information: AND, 770 Airport Blvd., Burlingame, CA 94010. 415/347-9916, fax 415/340-1670.

Circle no. 7

Micro-etchable glass

Schott Glass Technologies, Inc., Duryea, Pennsylvania, has introduced FOTURAN®, micro-etchable photosensitive glass designed for micro-optics, integrated optics, electronics, medicine, biotechnology, and communications. Unlike ceramics, it is pore-free, its breaking strength is considerably higher than silicon, its temperature stability and chemical resistance are much higher than those of plastics, and, compared to metals, it features better corrosion resistance and lower thermal conductivity while offering the advantage of electrical isolation. FOTURAN® glass is available in a wide variety of dimensions and geometries. For components, the minimum achievable hole or slot size is 0.025 ± 0.005 mm and maximum hole density is 10,000 holes/cm^2. For high-temperature applications, it can be converted to a brown glass ceramic by special heat-treatment and processing procedures.

Information: Schott Glass Technologies, Inc., 400 York Avenue, Duryea, PA 18642. 717/457-7485, fax -6960.



Circle no. 8

Hi-res multi-sweep monitors

Image Systems Corp., Hopkins, Minnesota, has introduced the M21L2KHBMAX 21-in. (landscape) and the M21P2KHBMAX 21-in. (portrait) Hi-Res Multi-Sweep™ (HRMS™) gray-scale monitors with 100-fL nominal brightness. The 90° long-life dispenser-cathode CRT provides excellent performance and high brightness, with little degradation over the life of the monitor, and has a contrast-enhancing anti-reflective anti-static faceplate. These monitors are ideal for medical imaging and other applications requiring up to 5,000,000 pixels of resolution coupled with high brightness. The HRMS™ circuitry allows the monitor to scan from 85 to 170 kHz and from 55 to 80 Hz for a flexible flicker-free display of up to 2048×2560 high-resolution portrait or 2560×2048 landscape. The suggested list price of the monitors is $6000. OEM and systems-integrator discounts are available.

Information: Image Systems Corp., 11595 K-Tel Drive, Hopkins, MN 55343. 612/935-1171, fax 612/935-1386.

Circle no. 9

AR coating for plastics

Balzers, Ltd., Balzers, Liechtenstein, has introduced GEDOLIN, a broadband, multilayer anti-reflection coating particularly suited for transparent plastic substrates, with best results on polycarbonate. GEDOLIN has been field-proven in instrument cover panels in heavy road vehicles and in aerospace applications, providing a glare-free view of panel instruments. It has also found widespread use as an anti-reflection coating in certain optical systems chosen for their light weight and resistance to breakage. GEDOLIN can also be applied to pre-hardcoated plastic substrates, giving good adhesion values and high resistance to environmental influences.

Information: G. Becker, Balzers, Ltd., FL-9496 Balzers, Principality of Liechtenstein. 49-67-22-7-07-28, fax -61.

Circle no. 10

Miniature power supply

American High Voltage Corp., El Cajon, California, has announced a new low-cost regulated 5-W miniature high-voltage power-supply series packaged in 3 in.^{3} and designed to withstand extremes of shock, thermal shock, vibration, and acceleration in accordance with MIL-STD-810. Applications include capacitor charging, xenon tubes, geiger counters, piezo devices, and avalanche-diode systems. Electrical characteristics include voltage input, $12 \text{ V} \pm 2$ Vdc; voltage output, 5 models covering an output range from 100-1200 Vdc; power output, 5 W; current input, 100 mA (no load) and 600 mA (full load); ripple, 1%; and regulation, 0.1% (line and load). The dimensions are $1.5 \times 2.5 \times 0.8$ in., with an operating temperature range of –20 to +85°C.

Information: Gerry Krebs, Sales Manager, American High Voltage, 1957-A Friendship Drive, El Cajon, CA 92020. 619/258-5804, fax -6816.

Circle no. 11 ■

editorial

continued from page 2

prices of "10-in. type" – a loose designation for LCDs in the range of 9.4–10.4 in. – color TFT-LCDs built in first-, second-, and third-generation factories. Today's price (first generation) is about $800. In 1996, when second-generation factories come on line, the price will be about $550. Third-generation factories, which should come on line about 1999, should be able to produce such a display for an OEM price of less than $400.

And with that, we will leave Mr. Bohannon's very interesting translation.

– Ken Werner

To participate as an exhibitor at DMTC '95 in Santa Clara, please call Erika Suresky, Exhibit Manager, Palisades Institute for Research Services, Inc., at 212/620-3375, fax -3379.

book review

Digital Halftoning

by Robert Ulichney
362 pages
MIT Press, Cambridge, Massachusetts, 1987
Price: $50.00

Reviewed by THEOPHANO MITSA

Although published in 1987, *Digital Halftoning* by Robert Ulichney is still the only reference book for the reader interested in the principles of digital halftoning, or "spatial dithering," which is the method of rendering the illusion of continuous-tone pictures on displays that are capable of producing only binary picture elements. Given the recent proliferation of binary-output devices such as laser printers and fax machines, digital halftoning is becoming an issue of increasing importance in the electronic-imaging industry.

At the beginning of the book, Ulichney presents the fundamentals of digital halftoning, providing a comprehensive catalog of the most widely used halftoning techniques, which are organized by computational complexity and according to the nature of the dots produced, dispersed, or clustered. The techniques are analyzed either in the spatial domain or frequency domain, although there is an emphasis on analysis in the spatial domain. The book also emphasizes the development of halftoning algorithms that best match the specific parameters of different target display devices, particularly for nonstandard grid geometries.

Chapter 1 discusses the basic operations of an image-rendering system. In Chapter 2, the parameters of the Physical Reconstruction System are described, and a new aspect-ratio immunity argument in favor of hexagonal grids is developed. The best measure of the virtues of a halftone algorithm is its ability to render areas of uniform gray. Chapter 3 presents tools for the Fourier analysis of binary patterns produced by different halftoning techniques. Introduced are "exposure plots" of composite Fourier transforms which present insight into the nature of periodic binary patterns, and "radially averaged power spectra," along with a measure of anisotropy to provide a mechanism for studying aperiodic patterns.

In Chapter 4, dithering with white noise is investigated. Although devoting a whole chapter to white-noise dithering seems rather unnecessary at first, Ulichney points out that this is done for historical reasons and to provide a means to check the validity of the introduced metrics of radially averaged power spectrum and anisotropy. The topic of Chapters 5, 6, and 7 is ordered dither. In Chapter 5, clustered-dot dither techniques are discussed, while in Chapter 6 dispersed-dot dither techniques are considered. In Chapter 7, a solution to providing symmetrically ordered dither patterns for any unidirectional resolution is presented.

Chapter 8 presents the very popular error-diffusion algorithm, and it is one of the most important chapters in the book, as it presents the concept of "blue noise." This provides an excellent means of explaining the visually pleasing properties of the binary patterns produced by neighborhood operations. Error diffusion with perturbation is also introduced in Chapter 8 and its performance analyzed via anisotropy and radially averaged power-spectrum plots. A brief discussion of other neighborhood processes and of multibit and color displays is provided in Chapter 9.

In general, the book is well-written and provides a thorough analysis of the most widely used halftoning techniques from a theoretical point of view, while also investigating some important practical issues such as tackling different grid geometries. Since *Digital Halftoning* was published in 1987, significant advances have been made in the field for both black-and-white and color displays. Since digital halftoning is such an important topic, and this is the only book in the area, up-to-date books that include the most recent advances in halftoning would be welcome in the field. ■

Theophano Mitsa is Professor of Electrical and Computer Engineering at the University of Iowa, Iowa City, Iowa.

letters

To the Editor:

In the SID show report entitled, "The Way to San Jose," [on page 34] of the September issue, a mistake was made. You aptly described our polarizing ink, LCD color filters, and stereoscopic 3D display technology, but you gave credit to Advanced Backlighting. Our company name is Reveo, Inc., located in Hawthorne, New York. Please inform the readers of this error.

– Edwin J. Hill
V.P. Advanced Programs
Reveo, Inc.
Hawthorne, New York

We regret the error in crediting Reveo's interesting technology.

– Editor

To the Editor:

Your article, "The Way to San Jose," which appeared in your September 1994 issue, mentioned [on page 34] the BARCO Graph-X Wall and stated that "Atlanta is planning to use the system for highway traffic control for the 1996 Olympics." It should have said that Atlanta is planning to use a multi-screen system for highway traffic control for the 1996 Olympics. Although BARCO will be among the bidders, the city of Atlanta has not decided which multi-screen display it will use.

– Luc Fabry
Marketing &
Communications Manager
BARCO Chromatics
Tucker, Georgia

To the Editor:

Thank you for the kind review of *Color in Electronic Displays*, edited by Heino Widdel and myself, in the September issue of *Information Display*. Unfortunately, the price shown for the book in that review ($104.95) is incorrect. The price in the U.S. and Canada is $85; elsewhere, $102.

– David L. Post
Armstrong Laboratory
Wright-Patterson AFB, Ohio

sustaining members

Ad-Vance Magnetics, Inc.
AEG Corp.
Arconium Specialty Alloys
Babcock Display Products
Brewer Science, Inc.
Canon, Inc.
Capetronic USA (HK), Inc.
Celco
Cherry Electrical Products
Chunghwa Picture Tubes, Ltd.
Clinton Electronics Corp.
Corning Inc.
Corning Japan K.K.
Dale Electronics, Inc.
David Sarnoff Research Center
Diagnostic/Retrieval Systems, Inc.
Dickey-John Corp.
DISCOM/Display Components, Inc.
EG&G Gamma Scientific
Electro-Plasma, Inc.
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