≡ Official Monthly Publication of the Society for Information Display

INFORMATION DISPLAY

January 1996
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MONITOR ISSUE

Self-Calibration
Automated Alignment
Color Specification
Japan Marathon

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COVER: Sharp exhibited the largest TFT-LCD to date at the Japan Electronics Show in Osaka last October 17–21, and briefly at LCD International in Yokohama the week before. The 28-in.-diagonal display is a tiling of two smaller displays bonded to a common piece of glass.

Credit: Ken Werner

Next Month in Information Display

Flat-Panel Issue
- CdSe-Based AMLCDs
- Ferroelectric LCDs
- Power-On Sequencing
- Color Conference Report
- SMAU '95 Report

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editorial

Living History

Last month, Ted Lucas retired as *Information Display*'s West Coast Advertising Representative at the premature age of 82. Ted's association with this magazine and with the Society for Information Display (SID) spans nearly 20 years.

In 1977, Ted joined SID, which was then a relatively small technical society still focused on the design and manufacture of cathode-ray tubes and their components, primarily in the United States. In 1978, Ted took over the editing of a Society newsletter called *Information Display*, the publication that ultimately evolved into this magazine. Since I started editing *Information Display* in 1987, Ted has been our energetic and effective sales rep on the West Coast, while simultaneously serving as a freelance technical writer for this and other publications. He is widely known and respected throughout the display community. Ted retires from a magazine with distinguished authors, dedicated readers, enthusiastic advertisers, and a worldwide reputation – a magazine that has expanded the number of its editorial pages twice in the past year.

Information Display's sponsoring organization, SID, is now an international society of nearly 4000 members in 19 chapters that is at the forefront of design, manufacturing, and applications in all display technologies all over the world.

During his career with *Information Display*, Ted has seen the display world transformed. Knowing Ted, I have no doubt he will continue to keep an eye on that world and the many friends he has made within it. He will be doing so from a wonderful observation point: the home he and his wife Joan recently completed in Newport, Oregon.

– Ken Werner

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INFORMATION DISPLAY

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the display continuum

The World's First Display Engineer ...

by Aris Silzars

"Welcome! Welcome! Please, come in.... Come in! I'm so glad to see you found us. Welcome to the '2001 Virtual Reality Experience.' I see from your request card that you would like to have a Customized Experience observing the world's very first display engineer at work. What an absolutely fascinating request! Well, as I'm sure you've heard, at '2001' here, no request is ever considered too challenging. I'm so sure that you will have your most interesting Event Experience ever.

"Please enter the booth here and we'll get you all set up.... Oh, dear me!... I seem to have forgotten to set up the machine.... Please, just give me a moment while I do a quick rewind to get you back to the right starting spot on the timeline. Ah, yes, here we go, back past TV ... movies ... photography ... impressionism ... the Renaissance ... past the Romans, Greeks, Egyptians.... Yes, yes, here we are.... Well, have a most pleasant journey. Good-bye for now."

And with that – my guide was gone. I was alone and not at all happy. I had come to learn about display technology, and now I was going to get a lesson on the history of the world. Darn, if I just knew how to shut this thing off, I could go ask for a refund.... But already before me and all around me the scene was changing. I was most definitely in the middle of the Dawn of Man – about 100,000 B.C., give or take a few centuries.

I had been told that '2001' would feel "like being there," and it did. I could feel the warmth of the glowing embers from the cooking fire and the coolness of the air in the cave. The visual and audio quality were near perfection. The air even had the faint odor of a not-too-sanitary lifestyle. I had to briefly remind myself that this was "just a movie." In addition to my invisible presence, there were two others in the cave: Ragoba, the artist, and his complementary mate, Maceyana.

Ragoba was creating what looked like the beginnings of a large mural on the cave wall. It was a scene depicting a recent successful hunt by his tribe. He seemed especially pleased because this day he was trying out some new pigments that he had recently discovered in the hill country. The new red was going on particularly well and seemed to cling to the rock surface much better. Maceyana did not look at all happy. She wouldn't have minded perhaps a few flower decorations on the wall, but this hunt scene stuff just looked terrible, and not only that, he was getting big splotches of color all over her newly cleaned floor. Why couldn't he be like the other men and just lie around a lot between hunts? Why did he have to spend all his spare time making a mess in their cave? And all those hikes up into the mountains to look for new colored powders. What had she done to deserve that? But Ragoba just kept grunting and working. And as the weeks went by, he produced quite a scene depicting people and animals, all in various poses and in lots of bright colors. This display of his tribe's success, he was sure, would last for a long time – maybe even several lifetimes.

I wanted to reach out and interact with Ragoba. I wanted to give him encouragement. I wanted to tell him that his work would last much longer than he could imagine. I wanted to tell Maceyana to be more patient and accepting of

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Self-Calibrating Monitors

Calibrating a monitor to obtain "true" color used to be a task for professionals, but smart monitors can now adjust their own color output.

by George Walter

CALIBRATION is the process of returning a piece of equipment to pre-determined specifications. There are several different ways of calibrating a monitor to meet targeted specifications. The most basic level is to set the monitor to a certain "white point," which is measured in Kelvins (K) – formerly degrees Kelvin. A white point is a certain combination of full red, green, and blue displayed on the monitor. A basic "calibrated monitor" can be set to any of the following white-point standards by its user:

- 5000K – a red-white that is used to simulate daylight.
- 6500K – broadcast lighting conditions.
- 9300K – a blue-white that is perceived as offering the highest contrast and is used for non-critical computer displays or consumer setting.

(For more information on color temperature, see the accompanying article by Peter Keller.)

To set the white point to any of the above standards, a monitor manufacturer can either adjust the output of the graphics card or vary the drives to the monitor itself. To adjust the graphics card, a "probe" is placed on the face of the monitor's cathode-ray tube (CRT) to read the luminous dots or stripes of red, green, and blue. A typical 24-bit graphics board displays a total of 256 levels each of red, green, and blue. The graphics board performs a digital-to-analog conversion (DAC), transforming these steps into the appropriate output voltage between 0 and 0.7 V.

When a monitor is set to the 9300K standard, maximum drive (0.7 V) is applied to the red, green, and blue electron guns. To achieve a color temperature of 5000K, the graphics card must reduce the output of green and blue, which decreases the total number of colors that can be displayed.

Another pitfall of this method is that it assumes the monitor is already displaying maximum red. If the monitor does not start with full red, the calibration is inaccurate and the total number of displayed colors is reduced even further. This method also cannot account for any drift in the graphics card or the monitor.

Old-Fashioned Calibration

Another method of calibrating a monitor is the old-fashioned way: manually adjusting the monitor while using a color-measuring light meter called a colorimeter. With this method, a technician places the colorimeter on the front of the CRT and adjusts the drives to the monitor until the colorimeter shows the appropriate white point. This method can be very accurate for one color temperature but is very inconvenient because it requires a specialist to come in, interrupt production, and manually calibrate each monitor each time the color drifts or the color temperature must be changed. In some cases, the monitor must be shipped to an outside facility for calibration. In addition, the manual method does not account for the drift of the graphics card.

Intelligent Calibration

A third – and more accurate and convenient – method involves the use of an "intelligent" microprocessor-based monitor with an integrated light probe. In this case, actual values, or presets, are stored within the monitor. These values take into consideration the total characteristics of the individual monitor, including phosphor coordinates, gamma, and light output. The values can be accurately measured in a controlled environment and stored for later use. The integrated light probe is then used to measure and evaluate the monitor's performance against the pre-registered values. The microprocessor then calculates what, if any, aspects of the display have changed.

Given the fact that a microprocessor-controlled monitor can easily be adjusted, the monitor can actually calibrate itself. The microprocessor can calculate the settings for each of the three guns to reach any given white point, and the probe can check these calculations to confirm the performance. This entire process can be done automatically. The only user effort is to place the probe on the face of the CRT.

Stability

In the process of calibration, regardless of the method used, stability of the monitor and the graphics card is essential. A CRT monitor – even a "digital" one – is an analog device that utilizes high voltage and generates considerable heat. These factors contribute to short-term drift. In fact, a monitor can drift by as much as 20% from the time it is first turned on to the time when it stabilizes some 15 min-

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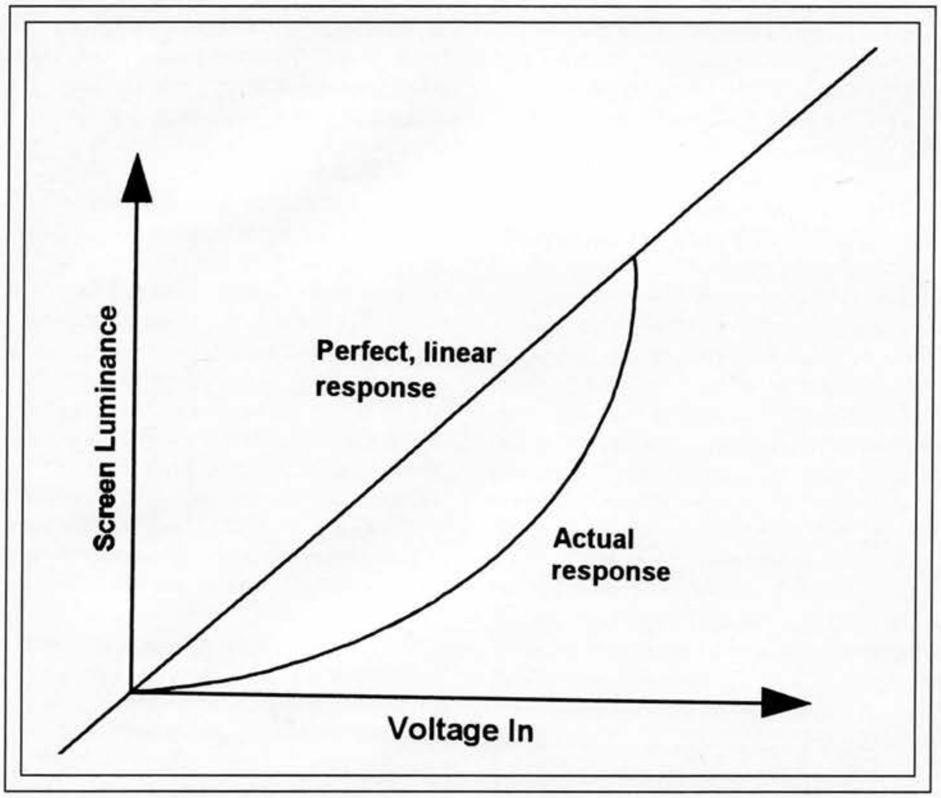

Fig. 1: The relationship between CRT drive voltage and screen luminance is usually not linear.

utes later. Without proper compensation, this drift can dramatically undermine calibration. Auto kinescope biasing (AKB) is an innovative compensation method developed by BARCO in which a circuit in the monitor samples a horizontal line of each gun to determine the red, green, and blue cutoffs – or black points. The sampling occurs during the vertical interval, so it is not apparent to the user. If the samples should begin to drift, the monitor corrects them.

Another way of minimizing short-term drift is to look at a "full drive" or "white level" during the vertical interval. Combined with AKB, auto white-point stabilization (AWS) creates a nearly perfect gray scale. But using AWS alone can only ensure balanced highlights. One can still lose shadow detail, where much important information may reside.

The BARCO 29-in. MegaCalibrator monitor is the only monitor on the market that can measure both its black and white levels. At BARCO, we believe that this provides the most accurate and stable color spectrum possible.

But creating a very stable and accurate monitor to achieve accurate images is not enough. We must also make sure that the graphics card is providing the correct levels. The graphics card has a look-up table (LUT) that takes digital steps from 0 (black) to 255 (full red, green, or blue) and converts them to analog values from 0.01 to 0.7 V that control the light output. Ideally, one would like to see a linear relationship between this input voltage and screen luminance (Fig. 1), but this is not usually the case. Compensation must therefore be applied – or built into the LUT – to obtain the desired linear relationship (Fig. 2).

When the match is made, the gray scale displayed on the monitor should appear nearly perfect, going from a "just black" bar on one side to a complete white bar on the other through a series of equally stepped gray bars. This is not easy. In fact, the best test of a color monitor is its ability to display a perfect gray scale because all three drives must be performing nearly to perfection for the resulting gray scale to be accurate.

If a monitor's whites and blacks look good, but in between there are hints of blue, red, or green, the monitor is imperfectly calibrated. In our view, the best way to integrate the performance of the monitor and the graphics card is with a microprocessor-based monitor. In such a system, the monitor acts like a "smart" peripheral – not like a "dumb" monitor that cannot communicate with its host and vice versa. A dumb monitor just receives input from the video card and displays it without feedback. In the smart mode, the monitor is hooked back to the host computer via a serial connection. With the correct control software, the monitor can talk directly to the host and tell it how the system is performing.

BARCO's Reference Calibrator and its corresponding Calibrator Talk software package is such a system. First, the monitor goes through a complete calibration independent of the graphics card or the host computer. Next, the monitor asks the graphics card, through the host computer, to provide certain inputs, including full red, green, and blue patches, as well as black points and several steps along the gamma curve. The monitor knows how these inputs should create the resulting outputs, which are measured with the light probe. If the output of the card has drifted, or is not linear, the probe will detect this and alert the host computer. If requested, the appropriate corrections can be made by either changing the drives inside the monitor or changing the LUT in the graphics card. By implementing this procedure, the end user calibrates not only the monitor but the entire display system.

The Value of a Calibrated Display

What is the purpose of a calibrated display, anyway? Well, for most people in the graphics world, the monitor is the midpoint in the working system. Images are either internally generated or scanned in. Next, the images are manipulated, or color corrected, proofed, and then sent to output. The monitor is the last stop before output. The closer the representation of the image on the monitor to the final output, the less rework required, which can be very expensive and time consuming.

Setting the Standards

Since a monitor is a device that creates colors by exciting phosphors, and final outputs in the graphic arts are typically made up of inks or dyes, perfect results can never be achieved.

Nonetheless, manufacturers continually try to achieve "near perfect" color on their displays. One of the biggest problems with color is that no two people perceive a color in exactly the same way. This creates the need to identify colors objectively.

Several standards have been created to assign numbers to colors. A few examples are Pantone, IT8 from Kodak, and the International CIE Lab system. The latter is a three-dimensional color space encompassing all colors and all luminance values. The "L" in Lab is the luminance value, which is measured on the vertical plane. The "a" and "b" are the corresponding locations on the horizontal plane. BARCO has developed a procedure that produces a display color-rendering index (DCRI) value that measures the absolute difference between the targeted color and the color being displayed on the screen.

An example of how this might work involves the use of a typical color workstation running Adobe Photoshop, with a Reference Calibrator and Calibrator Talk software. Choose a favorite image and display it on the screen. Use the Photoshop color picker and grab a color from the image. Open a box and fill it with the color. Photoshop will indicate the Lab values of this color as registered in the file. Calibrator Talk can now be opened to "measure" this color. Place the light probe on the patch and click on "measure." The monitor goes through a short routine that measures and displays the emitted Lab values of the patch. Now compare the two sets of numbers. A geometric equation quickly provides the absolute distance between the two colors. This is the DCRI value. A DCRI of 1 or less is considered undetectable by the human eye. A value of 3 or less is considered very acceptable. The average calibrated display produces a value between 5 and 10, and an uncalibrated display will range from 15 to greater than 25.

To consistently obtain values of less than 5, both the monitor and the system must be calibrated and the monitor characteristics entered into the system software package or color-management system. Adobe Photoshop, like most color-management systems, has the ability to accept unique values for phosphor coordinates as well as display gamma values that define the monitor's red, green, and blue luminance as a function of input voltages.

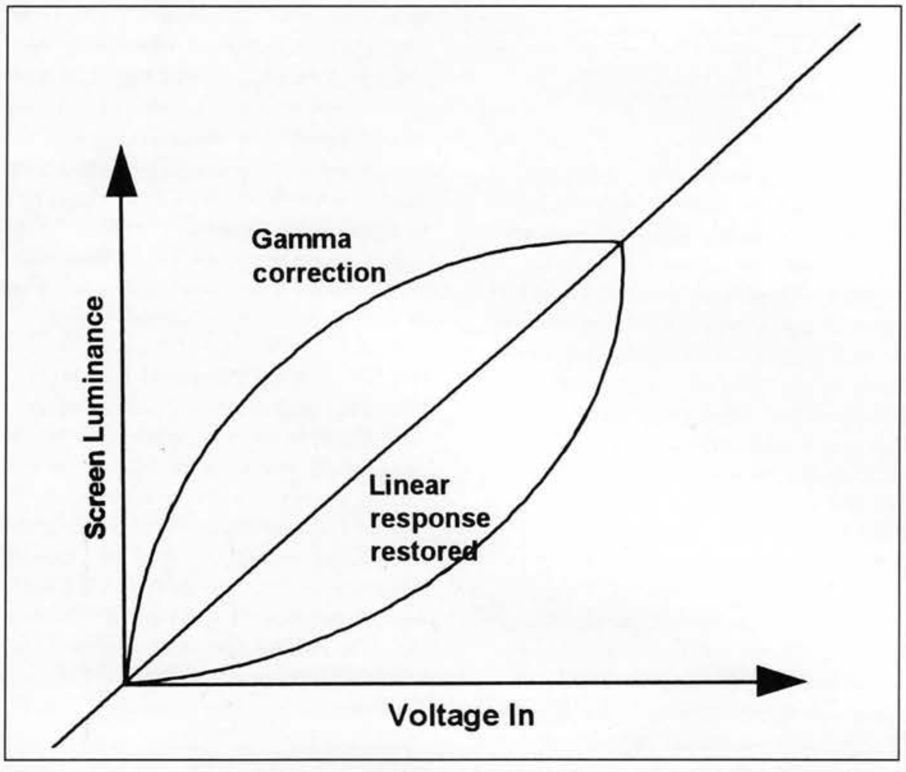

Fig. 2: It is possible to obtain the desired linear relationship between drive voltage and screen luminance by applying compensation – called gamma correction – or by building the compensation into the look-up table.

It's a Match

If all of these characteristics are taken into account and the whole system calibrated, the final output can be viewed on the monitor. When calibration reaches this level, the monitor becomes a true measurement device that permits electronic and remote proofing. To verify this, BARCO (in Atlanta) transferred a 20-Mbyte file over a phone line to a remote proofing station in New York. Colors were selected from both files and measured with sophisticated measurement equipment at both locations. The DCRI difference was less than 2. Both parties were viewing practically the same exact colors, which is the true value of a calibrated display.

Achieving accurate and predictable colors from a monitor is not an easy task, but there are now different methods at different cost levels that produce varying degrees of accuracy. With continuing advances in technology, the hardware and software are finally catching up to the demands of the outside world. ■

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.

Manufacturing Benefits of Microprocessor-Controlled Monitors

The automated systems used to align microprocessor-controlled monitors can generate a treasure trove of data – which is being ignored by most manufacturers.

by Craig Ridgely

THE USE OF MICROPROCESSORS in today's monitors has produced simplified designs and cost-reduced chassis and has facilitated multi-sync operation. From a manufacturing viewpoint, the most obvious benefit has probably been the introduction of automated CRT alignment in the manufacturing process. But most monitor manufacturers are overlooking the benefit resulting from automated alignment that is potentially the most significant.

Automated alignment provides substantial savings to monitor manufacturers through faster, more consistent, and less expensive alignment of CRTs. It also provides extensive alignment data for each monitor shipped, and this feature should be examined in more detail. Through proper analysis and implementation, vastly improved production yields are possible, along with higher-quality monitors that have longer "service-free" life spans in the field.

Automated alignment systems replace a sequence of variable manual adjustments with a repeatable digital process. They generally use one or more cameras and intelligent software to some degree. The monitor being aligned is placed in front of the camera, or vice versa. Then the relationship of the monitor to the camera is determined, either by fixturing or calculations, and measurements and adjustments are made through an RS232-type control loop to the monitor (Fig. 1).

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An Automated System

The benefits of automatic alignment systems can best be appreciated by looking at a representative system in some detail, and the MIMiCAM® system from Display Laboratories, Inc., has the advantage of being the system the author knows best.

The MIMiCAM® system uses a single camera and intelligent software that determines the physical relationship of the camera to the monitor being aligned, measures a test pattern displayed on the monitor, and communicates to the microprocessor in the monitor the adjustments needed to align the geometry. Adjustments are made as changes to DAC register values. Once all the adjustments are made, the register values are saved in the monitor's EEPROM – and, optionally, saved to the alignment system's hard disk along with other information.

The system performs complete compensation corrections – the alignment of the CRT after the yoke has been installed – in less than a minute. Prior to the inclusion of microprocessors in monitor designs, this task could have taken a technician an "order-of-magnitude" more time.

During each alignment, the monitor model number, ID string and/or serial number, and date and time of manufacture are usually available. Certainly, register values and other alignment parameters are available. All of this data can be collected quickly during the alignment process. Once collected, the data forms a unique profile or "fingerprint" of each monitor.

The MIMiCAM® system uses a script language that is responsible for much of its flexibility and power. One of the script-language functions defines the parameters of the data-collection facility. Essentially, the function opens a data file and defines a variable for each database field to be collected. The resulting database file is a comma-delimited

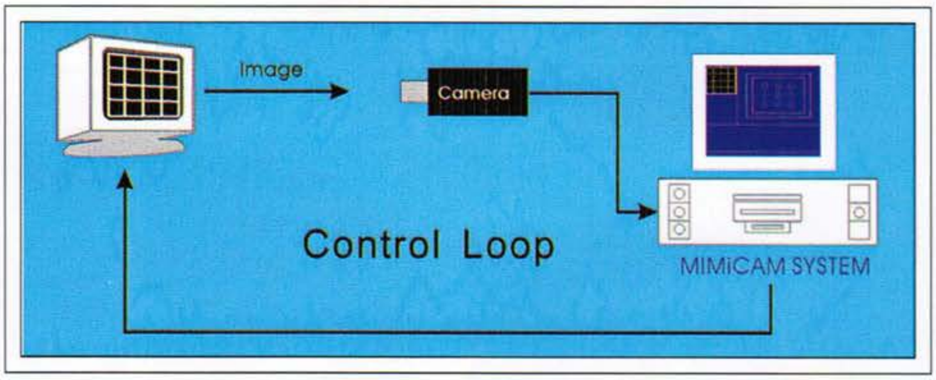

Fig. 1: Typical automated alignment control loop.

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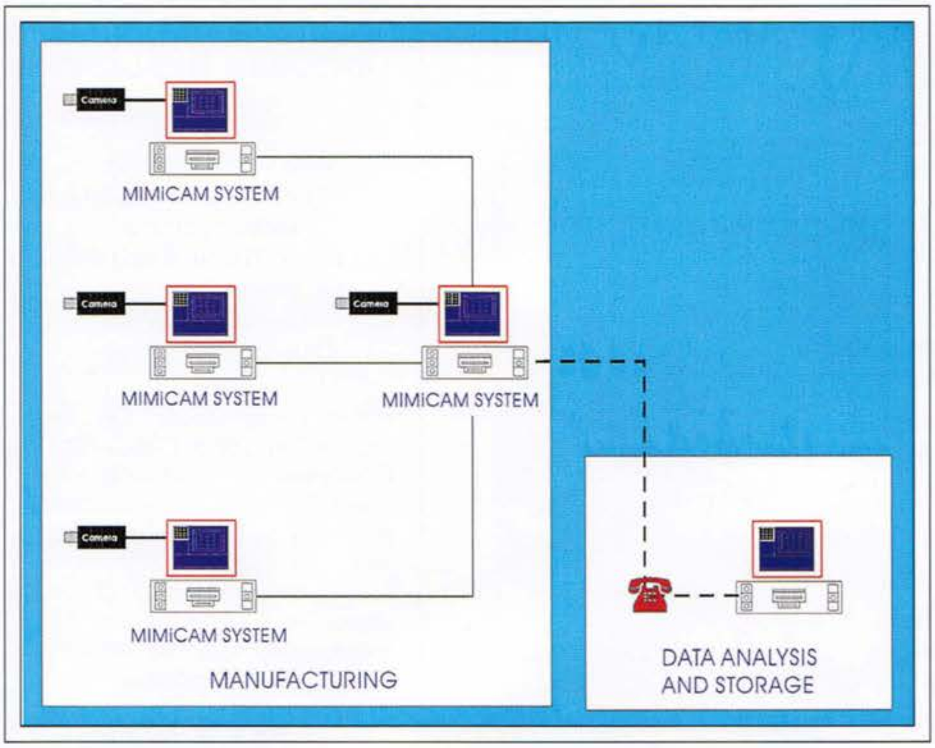

***Fig. 2:** Manufacturing network with data analysis.*

ASCII text file that can then be imported into any mainstream spreadsheet or database program.

Data Management

A typical monitor manufacturer can produce at least 500 monitors per shift per line. A manufacturer with several lines working two shifts could produce up to 5000 monitors per day. That might seem like an unmanageable number of monitors to "fingerprint." Consider, however, that the uncompressed ASCII data file for each monitor would be no larger than 0.5 kbytes. This represents about 2.5 Mbytes per day. At that rate, the annual raw-data collection on all monitor sizes and models would be approximately 0.5 Gbytes – certainly a small enough number to maintain on-line with today's hard drives.

Data collection could be organized on a size or model-by-model basis, rather than combining the data for all models, which would decrease the data-management issues. As databases are built, they could be archived to optical disk or tape for "near on-line" access.

To collect and manage all this data would require setting up a client/server relationship among the alignment systems on the various production lines and providing access to the stored data for manufacturing-data analysis (Fig. 2). Let's see how the analysis of this data – and the intelligent use and dissemination of the information gained from it – can increase the quality, reliability, and serviceability of microprocessor-controlled monitors.

Yield

Increasing production quantities through automation without enhancing quality-control processes simply increases the number of units being shipped with quality problems.

On the production line in real time, the alignment data can be used to screen for potential failures on a monitor-by-monitor basis. This can be done by setting alignment quality tolerances. These tolerances are not to be confused with the "+ or –" measurement specifications for geometry, but are rather the tolerance limits for the register settings that will achieve those specifications. For example, during alignment, a typical register value should fall within the middle 70–80% of that register's range. After alignment, a register value outside of that range might indicate a potential failure. Over time, analysis of register-tolerance variances would identify the relationships between register values and monitor failures. When such variances occur, the production-line controls could be set to flag the offending monitor for further investigation.

Quality and Reliability

Good-quality processes have feedback loops built into them. With the inclusion of feedback from the service centers and service depots on monitor-repair activity, more of the relationships between component or circuit failures and register-tolerance variations could be identified (Fig. 3). This would increase the probability of detecting potential failures *prior* to shipping units to the field. If this information were fed back to the responsible engineering organization for engineering changes, the overall quality standard for the monitors would be increased.

Serviceability

Service centers, by definition, suffer the penalty of their remote locations. They cannot share test-equipment resources with other service centers and generally cannot justify the cost of an automated alignment system. However, the cost of a modem or CD-ROM drive is affordable.

At service centers today, alignment of a repaired monitor is limited to what can be done with the available user controls. If a monitor requires more extensive alignment as part of its repair, it is generally shipped back to the factory or the manufacturer's service depot. This is an expensive proposition for the manufacturer (if the monitor is under warranty) or for the customer (if it isn't).

We need a cost-effective way to align a monitor to the same level of accuracy as when it was originally aligned at the factory. The simplest – and most cost-effective – way to achieve that end is simply to download into the monitor the original alignment specifications. If this information is available on hard disk, tape, or optical disk, a service technician could simply "dial up" the appropriate manufacturer's database of monitor profiles and download the original alignment values. (At the same time, the nature of the problem could

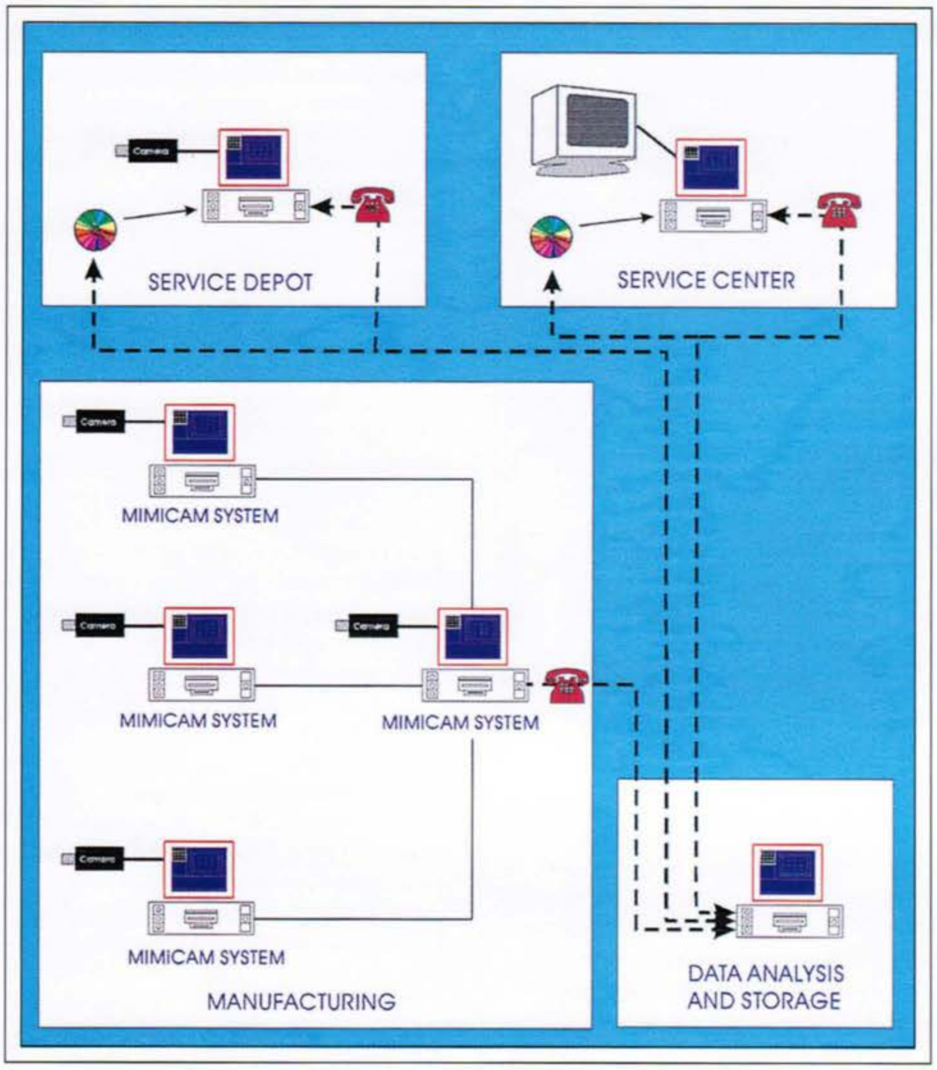

Fig. 3: Service center/depot feedback loop.

be described and repair/replace details logged for further analysis.) Alternatively, optical disks containing the databases could be distributed to service centers and depots. In that case, the technician would simply load the alignment values from a CD-ROM drive. In either case, if questionable results are obtained, the situation is certainly no worse than with our current system. It may be that the technician could then "tweak" the alignment by hand.

Cost and Benefit

The benefits to be derived from using this "free" data considerably outweigh the costs of setting up the manufacturing network and database-management system. Certainly, the quality-control feedback processing and engineering-change control procedures should already be in place.

There is a choice to be made between archiving databases to "near on-line" devices such as tape or optical libraries *vs.* maintaining them on hard disk. But distribution of optical disks has now become less costly than distributing diskettes.

All in all, the effective use of alignment data can improve a monitor manufacturer's yields, quality standards, and product reliability. ■

Basics of Display Color Specification

The numbers on a digital colorimeter look straightforward – but they can be misleading unless you understand some color-measurement basics.

by Peter A. Keller

CHROMATICITY (*i.e.*, color) specification and measurement are formidable subjects for many display designers and users. That's understandable. Color terminology is bewildering. To add to the difficulties, the concepts of photometry, radiometry, and spectroradiometry are thoroughly embedded in the terminology. What's more, this is not purely an engineering subject. The area is complicated by the elements of human visual perception that distort measurement linearities and the relationships of different colors under differing viewing conditions.

Fortunately, it is possible to discuss the terminology, concepts, pitfalls, and standards commonly encountered in flat-panel and CRT color specifications within the confines of a short article. We will make our job easier by deferring the similarly complex subject of hardcopy color specifications and matching to a future article. With that out of the way, let's take the can opener to the proverbial can of worms.

1931 CIE Chromaticity Chart

Display chromaticity is usually specified with one of two systems: the 1931 CIE system or the 1976 CIE-UCS system. Each has its own advantages – and faults. Fortunately, mea-

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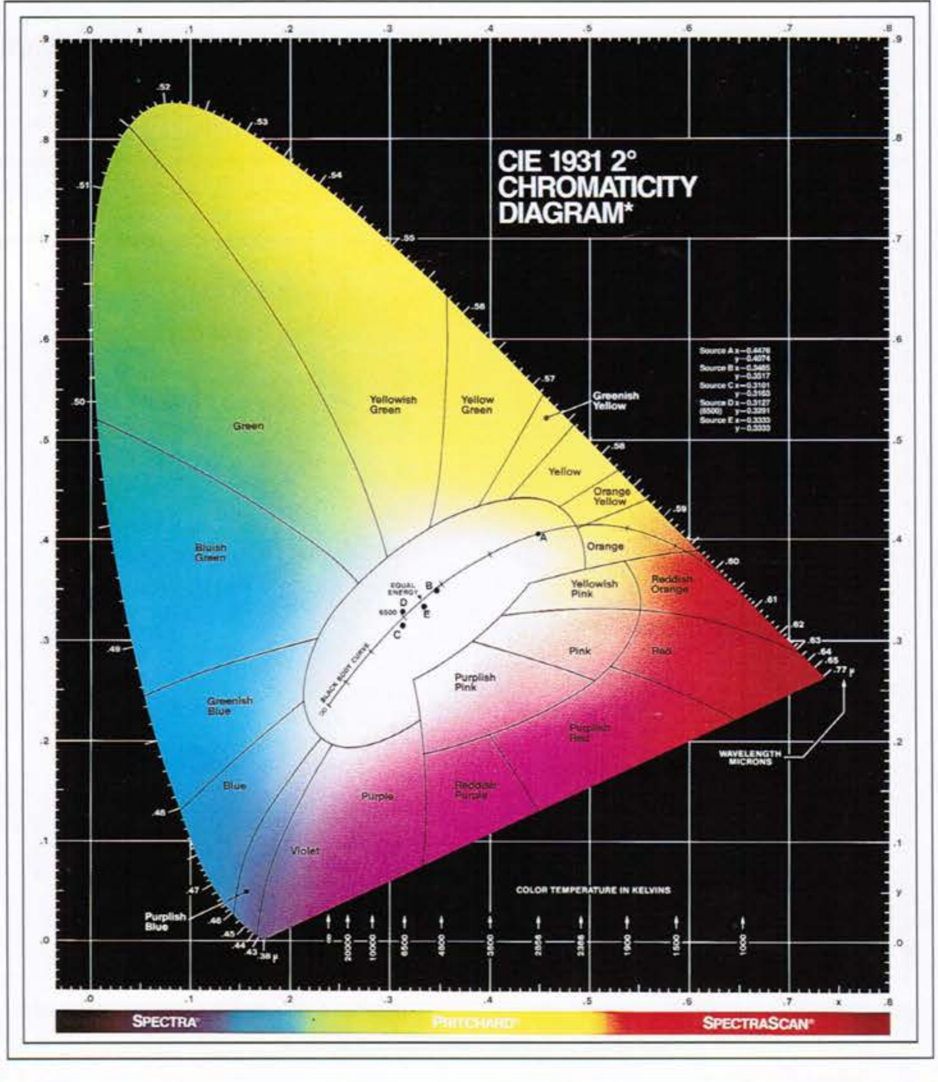

Fig. 1: *1931 CIE Chromaticity Diagram. (Photo courtesy of Photo Research.)*

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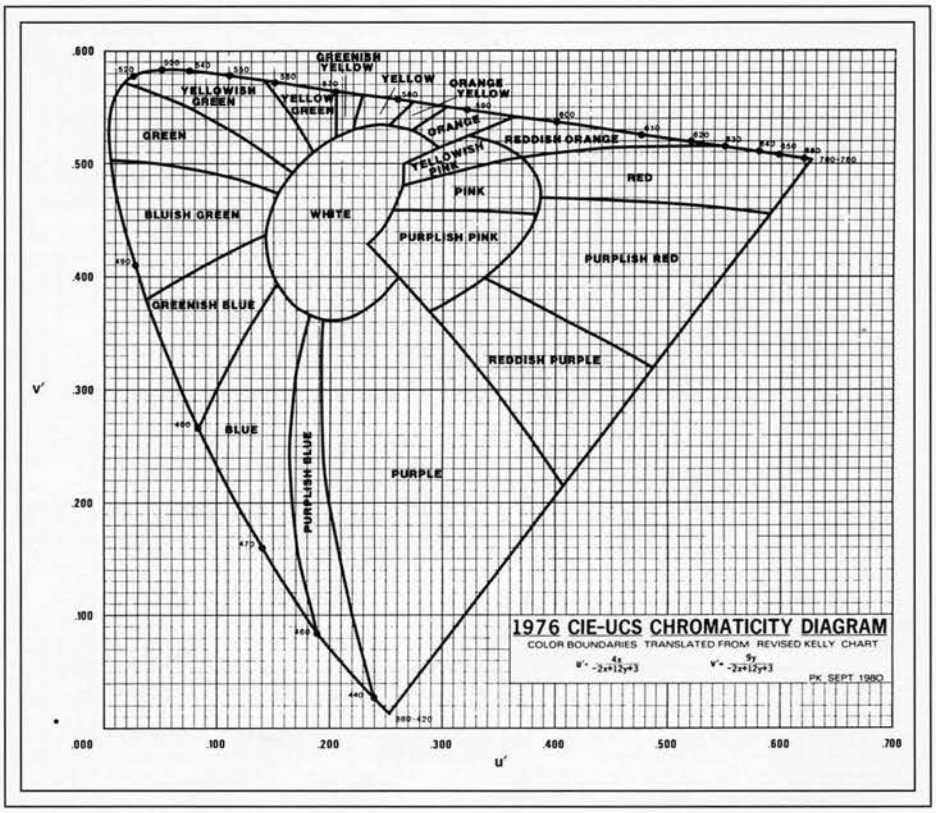

Fig. 2: 1976 CIE-UCS Chromaticity Diagram.

surements and specifications in either system can be converted to the other, often at the press of a button on the colorimeter or spectroradiometer used to take the measurements. At worst, you may have to use simple equations to perform the conversion (see the Appendix).

The 1931 CIE Chromaticity System was devised by the Commission Internationale de l'Eclairage (CIE), an international organization devoted to the specification of light and color. The 1931 CIE Chromaticity Chart allows any color that may be seen by the average human eye to be specified by a pair of coordinates x and y (Fig. 1). The color boundaries and names were added in 1943 by K. L. Kelly of the U.S. National Bureau of Standards (NBS) – now the National Institute of Standards and Technology (NIST), part of the U.S. Department of Commerce. In reality, the boundaries are not sharply defined but gradually blend. The boundary lines are approximations to help visualize the meaning of a pair of numerical coordinates. Color saturation or purity is greatest at the outer periphery of the chart, shifting to pastels and finally to neutral toward the center. Color mixtures, which are particularly applicable to color displays, are easily derived from the 1931 chart. The point representing a 50/50 mixture of a particular green and a particular red will lie exactly halfway on a straight line between the two points representing the original colors. The principal drawback of the 1931 system is that equal distances on the chart do not represent equal perceived color differences because of nonlinearities in the human eye.

1976 CIE-UCS Chromaticity Chart

The 1976 CIE-UCS (Uniform Chromaticity Scale) was developed to minimize the limitations of the 1931 system. The 1931 chart was squeezed and stretched via linear transformations (see the Appendix) so that equal perceived color differences are represented by approximately equal distances on the chart, while still allowing the color space to be displayed on a flat two-dimensional surface. The tradeoff is the system's inability to show the color that results from a mixture of two colors by a proportional distance along a straight line between them. The 1976 CIE-UCS chart uses u′ and v′ coordinates (Fig. 2). The symbols u′ and v′ were chosen to differentiate from the u and v coordinates of the similar but short-lived 1960 CIE-UCS system.

CIE Tristimulus Functions

Color measurement is based on three sets of data: the X, Y, and Z tristimulus values. (These are uppercase X and Y as opposed to the previous lowercase x and y.) The tristimulus values are three carefully prescribed spectral sensitivity curves that simulate the sensitivity of the average human eye receptors to red, green, and blue, respectively (Fig. 3). These may be measured using three separate detectors, each closely matched to the tristimulus functions in the case of the filter colorimeter, or computed by multiplying the measured intensities at each wavelength by the tristimulus functions for that wavelength and summing to determine the areas under the curves. The X, Y, and Z values are then summed and divided into the X value to determine x and divided into the Y value to determine y (see the Appendix).

Color Gamut

When excited individually, a display's three color primaries – red, green, and blue – may be measured and plotted on the chromaticity chart (either 1931 or 1976). The three resulting points form a triangle, and the display can only reproduce colors within this triangle (Fig. 4). When added to the light being emitted by a display, ambient light will dilute the color purity and give the display a "washed-out" appearance. The displayed color will be somewhere between that emitted by the display and the ambient illumination, depending on their intensities. This will reduce the overall size of the triangle formed by the color primaries and, hence, the range of colors (color gamut) that may be reproduced.

JND, JPD, and MPCD

The just-noticeable difference (JND) is used to denote the minimum perceptible difference between two closely spaced colors. This difference may vary considerably between different regions on the 1931 CIE Chromaticity Chart and – to a much lesser degree – on the 1976 CIE-UCS Chart. There will also be significant differences in distance with angle. Thus, 1 JND in one direction may be represented by 2 or more times the distance of 1 JND in the perpendicular direction. Plotting distances of 10 JNDs, for example, at various points on a chromaticity chart will result in a series of ellipses known as MacAdam ellipses (Fig. 5).

The JND is a good indication of how closely matched two displays must be if they are to be used in close proximity for critical applications. For applications in which displays are used in different locations, they need not be as closely matched because the eye's white reference point will adjust of its own accord to the combination of display white and the white of the surrounding lighting. Two displays adjusted to have exactly the same white reference will appear quite different when one is viewed under incandescent light and the other under fluorescent light or daylight.

Typically, a difference in the vector distance between any two sets of color coordinates of 0.002–0.006 in either system will be 1 JND. The just-perceptible difference (JPD) and, earlier, the minimum perceptible color difference (MPCD) have also been used for the same purpose.

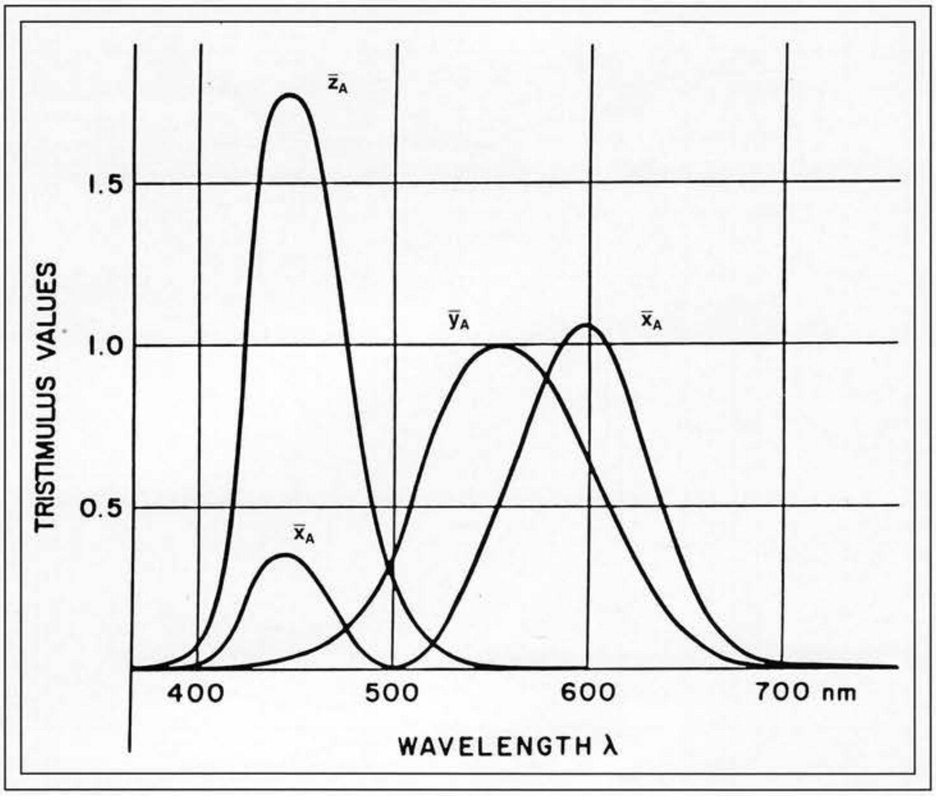

Fig. 3: Spectral response of the tristimulus functions.

Color Temperature

An object heated to any temperature above 650–800K will produce a broad-spectrum emission of light with a color that is related to its temperature. The color progresses from a very deep red through orange, yellow, white, and finally bluish-white as the temperature is increased. This path may be plotted on the chromaticity chart and is referred to as the Planckian locus (Fig. 6). Most natural light sources, such as stars, the sun, and fire, fall very close to the Planckian locus. Because human beings are familiar with natural light sources, engineers try to create displays and lamps that also fall close to the Planckian locus. Typical examples are the commonly accepted incandescent lamp near 2854K, the warm-white fluorescent lamp at 3000K, the cool-white fluorescent lamp at 4100K, daylight fluorescent lamps at 6500K, and trichromatic rare-earth phosphor fluorescent lamps at 3000, 4000, and 5000K. Other light sources, such as sodium and mercury lamps, that do not fall on the Planckian locus are used for their high visual efficiency – but not without considerable debate and complaints about their appearance.

CRT displays have become loosely standardized at 9300K (coordinates of approximately x = 0.294 and y = 0.294) for home television and some computer displays and 6500K (referred to as D_{65} and having coordinates of x = 0.313 and y = 0.329) for television-studio monitors and critical display applications. A temperature of 6500K also corresponds to the appearance of natural daylight. Standardization of backlit liquid-crystal-display (LCD) color temperatures has not yet occurred, and manufacturers advertise miniature fluorescent lamps having color temperatures from at least 3000–6500K. Most readily available are those using standard warm-white (3000K), cool-white (4100K), and daylight (6500K) fluorescent-lamp phosphors, as well as narrow-band red, green, and blue phosphors.

The bluish-white color preference (at least in North America) of 9300 and 6500K is related to the similar human preference in laundry detergents. Detergent manufacturers have long added fluorescent "bluing" to their products to make clothes appear "cleaner" and "brighter." Otherwise, washed items would tend to look yellowish – "not clean" – under the comparatively low color temperature of incandescent lamps used in the home environment. Try looking at a freshly washed white shirt under long-wave ultraviolet light to see the effect of the bluing, or, better yet, look at some of the detergent itself. During the 1950s, Hoffman "Easy-Vision" with sepia-toned television receivers was a market failure. "Crisp, clean" pictures are preferred by the public.

Avoiding the CCT Trap

Since fluorescent lamps and display screens usually depend on mixtures of light emitted by two or three different phosphors – yellow and blue or red, green, and blue to produce white – they often emit light of a color near the Planckian locus but either above or below it. To determine what color temperature they approximate, a concept known as correlated color temperature (CCT) was devised. The

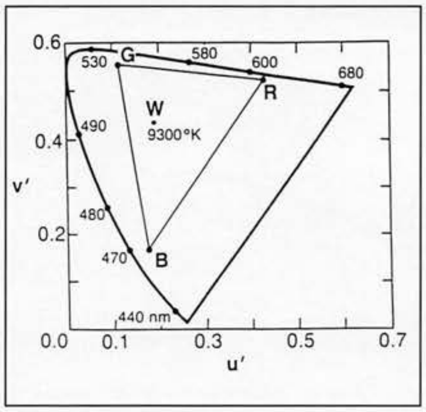

Fig. 4: Color gamut of typical red, green, and blue phosphor primaries plotted on the 1976 CIE-UCS chart. Any color within the triangle may be reproduced by controlling the relative excitations of the three phosphors.

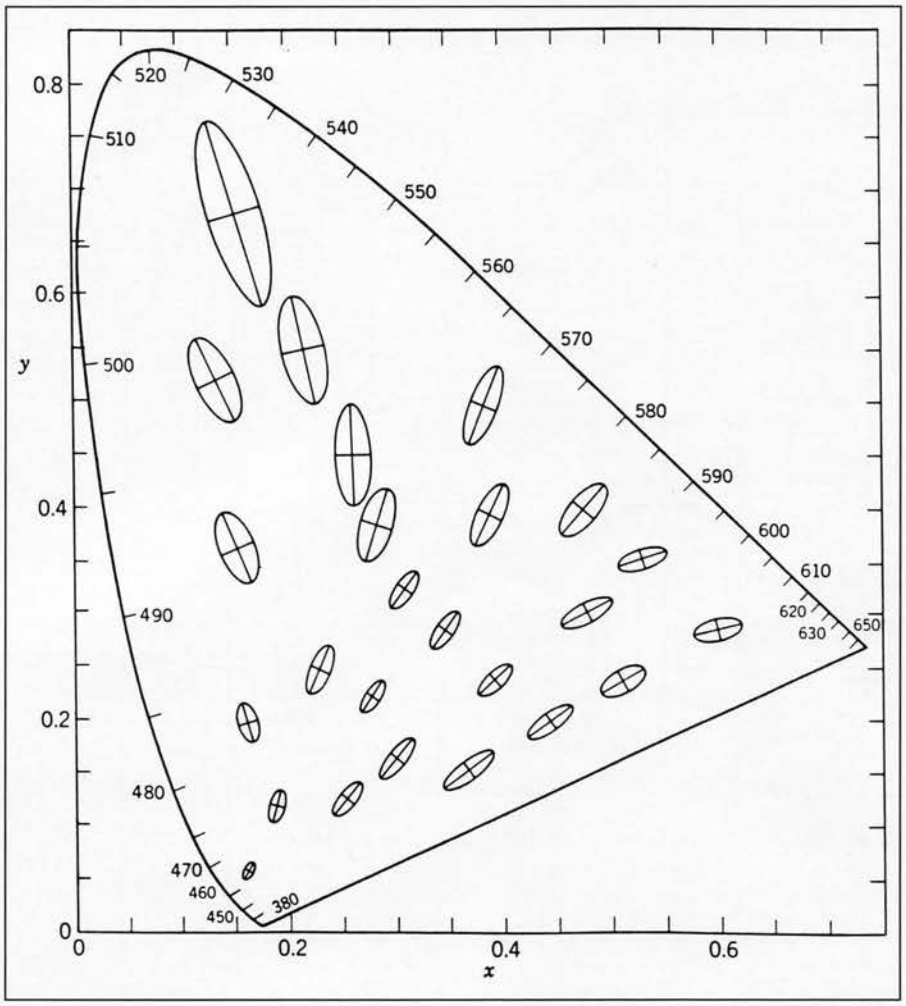

Fig. 5: MacAdam ellipses plotted on the 1931 CIE Chromaticity Diagram. For clarity, the ellipses are equal to 10 JNDs.

idea of CCT is based on a series of straight lines drawn perpendicular to the Planckian locus on the 1931 CIE chart (Fig. 7). A light source falling anywhere along one of these lines is said to have a correlated temperature equivalent to the point of its intersection with the Planckian locus.

It can therefore be misleading to depend on color temperature alone for specifying a display. A display adjusted to 6500K that happens to fall above the Planckian locus will have a decidedly greenish cast, especially at greater distances from the locus. Another display, also adjusted to 6500K but below the Planckian locus, will have a purplish tint. Yet the colorimeter says both displays are set to the manufacturer's specification of 6500K. If one of the displays had been misadjusted to 6300K – but both were on the Planckian locus – the displays could appear better matched than when they are both at 6500K but off the Planckian locus. To avoid this trap, always use the actual color coordinates of the desired color temperature at the point at which the correlated color-temperature line intersects the Planckian locus. Never rely on color temperature alone for anything other than an incandescent light source. Even that is subject to some error due to emissivity of the filament and colorimeter accuracy – but that is a subject in itself.

Color Tracking

"Color tracking" refers to the ability of a display to produce the same color at high and low drive levels and is a consideration particularly for CRT displays, since light output is a non-linear function of drive signals. Usually, two luminance levels are specified for tracking adjustments, and the white balance is adjusted to produce the same color coordinates for each luminance. Approximately 60–90 nits (20–30 fL) is usually specified for the highlight white point. For best accuracy with existing colorimeters, the low-light luminance should be selected to be about 15 nits (5 fL). This allows more accurate adjustment, and 15 nits is in a range where the eye is more apt to notice color errors. Ambient light will also have less effect on the measurements.

Published Standards

Many standards exist for the specification of display colors and measurement procedures. These include documents from ANSI, ASTM, CIE, EBU, EIA, EIAJ, SAE, SID, SMPTE, and others. (See the bibliography for some of the more pertinent ones.) Other display standards are in preparation as the state of the art advances, especially in the area of flat-panel displays, although flat-panel and CRT color measurement have much in common. After all, the correct and reproducible appearance of the display is the ultimate goal.

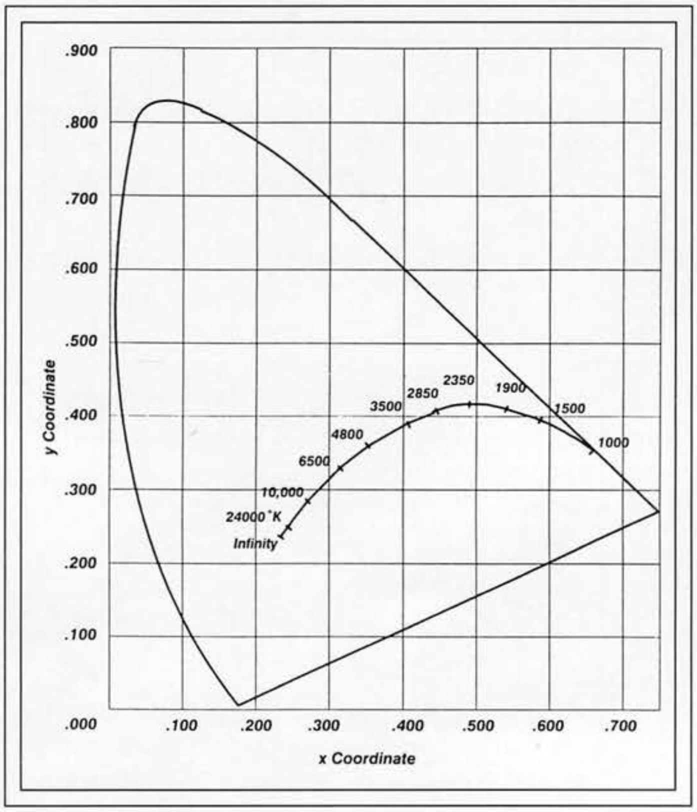

Fig. 6: Planckian locus plotted on the 1931 CIE Chromaticity Diagram.

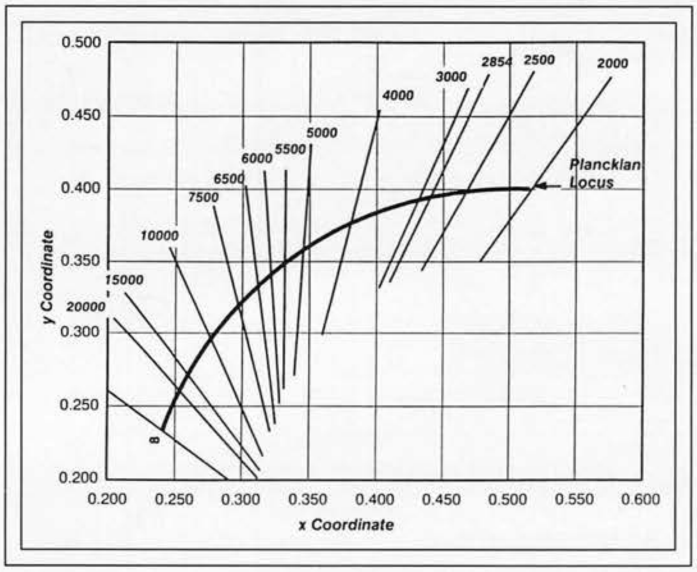

Fig. 7: Central portion of the 1931 CIE Chromaticity Diagram expanded to show the Planckian locus and correlated temperature (isotemperature) lines.

Appendix

Computation of x,y from X,Y,Z values:

$$x = \frac{X}{X+Y+Z} \qquad y = \frac{Y}{X+Y+Z}$$

Computation of u′,v′ from X,Y,Z values:

$$u' = \frac{4X}{X+15Y+3Z} \qquad v' = \frac{9Y}{X+15Y+3Z}$$

Computation of x,y from u′,v′ values:

$$x = \frac{6.75u'}{4.5u'-12v'+9} \qquad y = \frac{3v'}{4.5u'-12v'+9}$$

Computation of u′,v′ from x,y values:

$$u' = \frac{4x}{-2x+12y+3} \qquad v' = \frac{9y}{-2x+12y+3}$$

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Japan Marathon

In little more than a week in October, the energetic traveler could attend Asia Display, the International Display Workshops, LCD International, and the Japan Electronics Show.

by Ken Werner

Asia Display '95

The 1156 attendees of Asia Display '95, held October 16–18, 1995, in the "Music City" of Hamamatsu, Japan, had a choice of 229 technical papers and the opportunity to witness a startling advance in LCD technology.

The advance, described in two technical papers, is Hitachi's new in-plane-switching (IPS) TFT-LCD for which there was an impressive demonstration during the author-interview session. The display exhibited very natural colors and an incredibly wide viewing angle of over 120° on the horizontal axis. IPS places both pixel switch electrodes in the TFT plate instead of placing one electrode on the top plate. As a result, the electrodes do not have to be transparent, and they can be patterned along with the TFT source/drain and gate metallization layers, respectively. This eliminates all ITO from the display, along with two process steps. Japanese newspapers said the display would be available for sale in April, 1996, a report Hitachi representatives cheerfully quoted but would not confirm.

Asia Display is the renamed Japan Display, jointly sponsored by the Institute of Television Engineers of Japan and the Society for Information Display. In keeping with its new name and broadened orientation, Asia Display will now rotate among Asian countries with significant display industries. Seoul, Korea, will be the site for Asia Display '98. In his conference-opening remarks at the striking new ACT City convention center, Conference Chair Heiju Uchiike said the change marked a new era for the international display community.

The Commercial Context

Asia Display '95 took place during a period when serious oversupply is affecting the LCD industry. Portable-PC sales are flattening, LCD prices remain too high to generate a volume market for 10- and 11-in. LCD TVs, and the substantial new application for which the industry fervently hoped has not materialized. Hisao Ishii, President of ED Research, Tokyo, reports that since DRAMs are in short supply, companies that supply both LCDs and DRAMs are offering a package deal: "Buy my LCD and I'll sell you the DRAM for your computer along with it." Things are bad enough for there to be talk of a shake-out in the industry. The serious entry into the market of Samsung and LG Electronics – formerly Goldstar – of Korea is further complicating the situation. (Rumor had it that Compaq and Samsung were having serious discussions.)

But Asia Display is a research conference, and these dark thoughts rarely affected the comments of the speakers. Indeed, those speakers who took a sufficiently broad view were able to be quite cheerful.

In his keynote address, H. Mizuno, Senior Scientist at Matsushita and visiting professor

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Heiju Uchiike, Conference Chair for Asia Display '95, and Shigeo Mikoshiba, Program Chair for both Asia Display '95 and the International Display Workshops '95.

Ken Werner is the editor of Information Display.

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SID President Andy Lakatos (right) and Americas Regional VP Terry Nelson (far left) at the Asia Display '95 author interviews.

at Stanford University, presented his thoughtful definition of multimedia: the fusion of computer communications (CC) and digital audio and video (AV) in a display-based system. The technological fusion of these major threads exists now, but we need simple and ubiquitous tools and the graceful fusion of CC and AV in applications, he said. Mizuno had some predictions:

- Polysilicon TFT-LCDs with integrated drivers will be developed and will be followed by entire systems on glass.
- Plasma display panels (PDPs) will challenge projection CRTs in the 40-in.-and-over range when performance and power consumption improve.

Surveying the Industry

Ernst Lueder surveyed advances in AMLCDs and concluded that metal-insulator-metal (MIM) two-terminal devices are feasible replacements for TFTs up to XGA level, with quality equivalent to a-Si TFTs. When the MIMs are driven with a four-level drive, there is a cost advantage.

Polaroid's J. J. McCann pithily explained why display technology by itself can not solve the problem of making colors appear the same when we transfer images to different media and environments: "Colorimetry is pixel physics; color appearance is field psychophysics." The current generation of color-management systems are effectively solving the pixel physics problem. Now we need a better understanding of the perceptual psychology that will explain how the appearance of color fields is changed by the fields around them and by various illuminants.

M. Hirose of the University of Tokyo addressed the problem of creating virtual environments without having to deal with unmanageable amounts of data. His approach is the virtual dome, which permits the exploration of ways "to translate 2-D image sources to 3-D virtual experience."

In the poster session, Fujitsu described a multi-panel LCD projector display which uses short-throw rear projection from an array of 48 TFT-LCD panels onto a 1112 × 1964-mm screen – 2257 mm on the diagonal. The dot pitch is 0.4 mm, the contrast ratio (CR) is 50:1, the pixel dimensions are 4960 × 2790, and the power consumption is 5 kW to produce 50 lux.

Aura Systems and Daewoo Electronics described the status of their actuated mirror array (AMA). The AMA uses tiltable micromirrors like Texas Instruments' digital micromirror device (DMD), but the AMA uses piezolelectric instead of electrostatic actuators. Daewoo will introduce a 640 × 480 NTSC projector based on the device early in 1996. The projector will be compact and will fit into a 30 × 30-cm package.

Mission Impossible

Tom Williams of Industrial Light and Magic described the state of the art in computer animation for photorealistic simulation for cinema. He described the evolving sophistication of techniques used in *Jurassic Park, Caspar*, and *The Masque* – with appropriate film clips. Williams said that in the upcoming *Mission Impossible* with Tom Cruise, some segments of the film are completely computer generated except for Tom Cruise. This year, for the first time, it seems possible to computer-synthesize the actor himself, but that would also eliminate the actor's creative contribution. Besides, said Williams, actors are cheaper than the cost of synthesizing them!

In his invited paper on display systems for home multimedia, K. Yamamoto of Matsushita said the key words for home – as well as business – multimedia are digital, networked, and interactive. He sees the large home display of the future as producing 1000 lines and a luminance of 400 nits, being at least 40–50 in. on the diagonal, and costing $500! During the question period, consultant Larry Tannas commented that such a display would have to weigh at least 100 lbs. That means that sophisticated electronics would be costing $5/lb., which "would be difficult to achieve." Indeed, said Tannas, ten times that cost would be difficult to achieve. Yamamoto agreed, but said that as we enter the multimedia age we have to find ways of reducing price even as we improve quality, or our vision of the multimedia society will not come to pass.

In another invited paper, Larry Weber of Plasmaco surveyed the promise of color plasma displays. He commented that the global electronics industry has suddenly recognized the tremendous market potential of large-area color PDPs with large manufacturing commitments from major manufacturers: ¥60 billion from Fujitsu and ¥80 billion from NEC, for example. Weber said that LCDs have won the technology war in the 8–14-in. range. The marketing strategy for PDPs is to focus on the 20–30-in. workstation market and the 40–60-in. TV market. If LCDs push up to 20 in., PDP makers would probably not contest that segment but would concentrate on the larger sizes. Echoing an article by Peter Friedman in the October 1995 issue of *Information Display*, Weber said that the factory model for PDPs is not the LCD but the CRT, i.e., plants will cost $150–250 million, not $700 million or more. Weber noted that Plasmaco's PDP uses 70-V pulses to drive both columns and rows, so the panel can use standard EL drivers. It should eventually be possible to reduce this to 45 V, which would permit the use of STN drivers for a substantial cost savings. In the question period, Larry Tannas asked when Weber thought it would be possible to achieve a price of $100 per diagonal inch. Weber answered that he wanted to sell a 40-in. TV receiver in department stores for $2500, and he thought it would be possible to do that in 5 years. At that price, the market should be a million units per year, Weber said.

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The entrance to ACT Plaza, one part of Hamamatsu's ACT City, which also contained the conference center for Asia Display '95, the Okura ACT City Hotel, and a concert hall well-suited to Japan's "Music City."

Seiko-Epson announced the development of a 425°C polysilicon process and its application to 10.4-in. 800 × 600 TFT-LCDs. At this temperature, polysilicon displays can be fabricated on the relatively low-cost glass substrates currently used for STN displays.

Jim Scheussler of National Semiconductor presented a poster paper on behalf of VESA outlining the Flat-Panel Digital Interface (FPDI) standard. Scheussler reported "quite a bit" of interest, including interest from Japanese standards organizations.

Nippon Petrochemicals and Nippon Oil Co. demonstrated a retardation film made of a liquid-crystal polymer. The apparent retardation varies with the incident angle of light. The film looked impressive, permitting a horizontal viewing angle in excess of 100°. The film will be available for sampling early in 1996.

The Asian Powerhouse

In a special morning session, representatives of Asian countries summarized display R&D and industrial activities. Professor S-Q. Ding, standing in for L. Tong, said the People's Republic of China (PRC) was currently producing 20 million color picture tubes (CPTs) a year. In the PRC, 200 million families are potential buyers of color-TV receivers, so there is lots of room for expansion. There are more than 100 LED factories in the PRC, with LOTOP Corp. being the largest. R&D programs cover the popular FPD technologies, with AMLCD and monochrome PDP work being done at the National Flat Panel Research Center (NFPRC).

C. C. Chang, Chairman of Varitronix in Hong Kong, described the leading FPD companies in Hong Kong and commented that the only technology these companies are pursuing is LCDs. Virtually all manufacturing by Hong Kong controlled companies is done in the PRC, and these companies are responsible for 20% of all displays manufactured in the region (as of April, 1995). R&D is being done at the Hong Kong University of Science and Technology and, to a lesser extent, at the Chinese University of Hong Kong.

N. V. Madhusudana of the Liquid Crystal Laboratory at the Raman Research Institute in Bangalore commented that India still has an emerging economy, most research is still government-controlled, and there is not yet any strong effort in display R&D. There are efforts to develop TN-LCD technology for custom LCDs, and small companies are currently assembling modules. Color TV broadcasting has been greatly expanding, and CPTs are being manufactured. The market is a few hundred million U.S. dollars. There is still a good market for black-and-white television, and there is an active monochrome CRT industry.

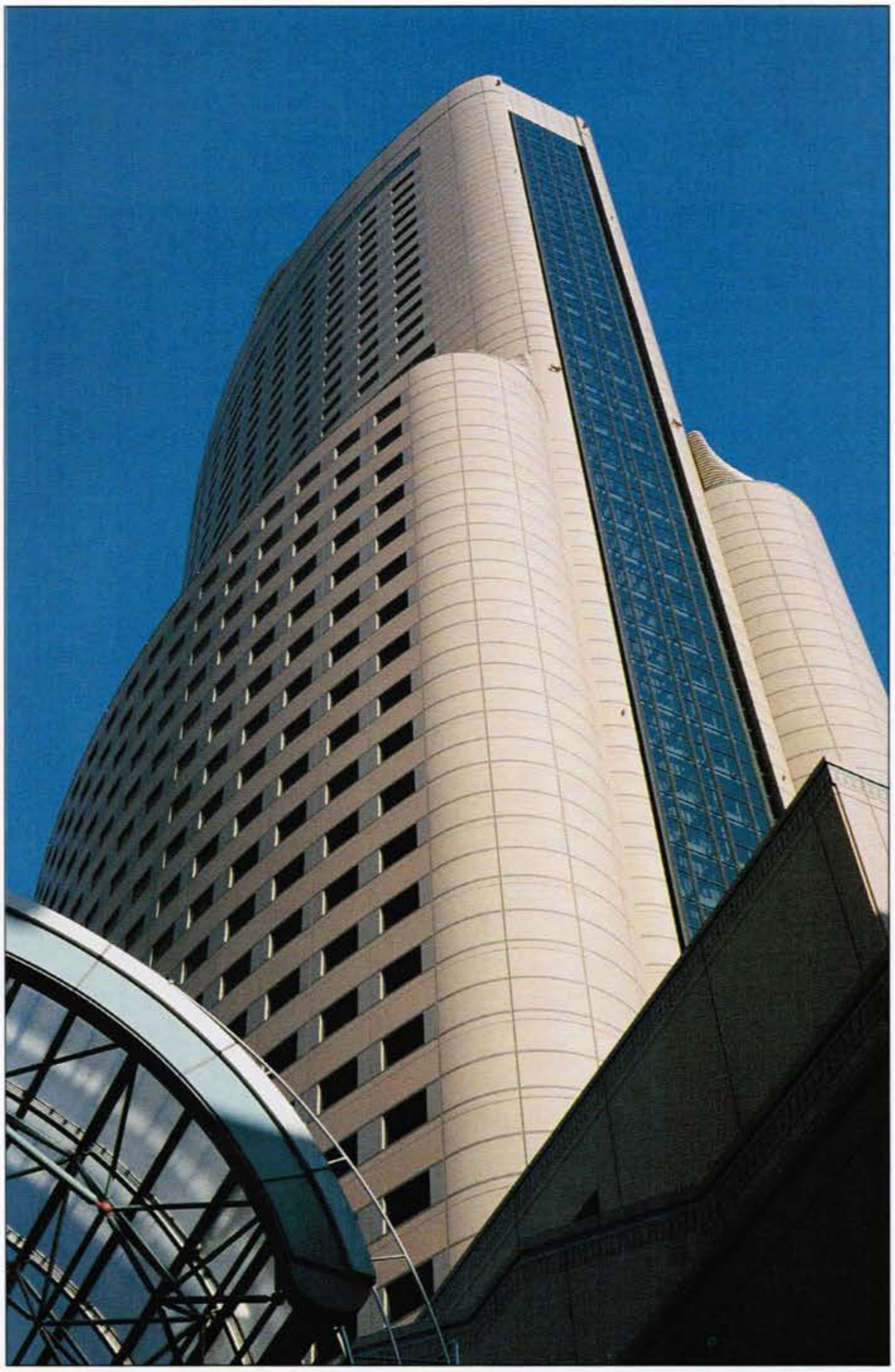
N. Naono of Nomura Research Institute in Japan said bluntly, "As production capacity [of LCDs] has increased faster than portable-PC production, some companies have suffered overcapacity," and "Korea, Taiwan, and other areas are taking a portion of the market from Japan." Naono presented a chart indicating that Japan's capacity for large-size color STN displays from existing production lines will be flat throughout 1996 at about 800,000 units per month, but new production lines will bring capacity to nearly 1.4 million panels per month by the end of the year. Naono stressed the importance of poly-Si TFTs to the industry.

Jin Jang of Kyung Hee University said that Korea maintains 24% of the world's CRT market, is getting into LCDs, and is doing R&D on other technologies. Hyundai, Samsung, and LG are doing large-scale LCD manufacturing but are inhibited by a still-limited equipment and materials infrastructure. Jang presented an interesting projection of Korea's contribution to the world's total LCD production (see Table 1).

Table 1: Korea's Share of World LCD Production

Year	1992	1995	2000	2005
Share (%)	2.7	4.7	20.0	34.0

According to Jimmy Chen of Chunghwa Picture Tubes, R&D in Taiwan is closely coupled to manufacturing. Most production is in CRTs, with LCDs under development. In 1994, Taiwan produced 11.3 million color display tubes (CDTs), 95% of them in the 14-in.-



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The Okura ACT City Hotel, Hamamatsu, was the headquarters hotel for Asia Display '95 and the International Display Workshops '95.

diagonal size. Philips and Chunghwa are the main manufacturers, while Yu-Tan is a serious start-up. Some low-end production is moving offshore. LCDs are being produced by Nan-Ya, Chunghwa, Unipac, and PrimeView.

Taiwanese companies have trouble hiring young people for CRT work. "Worldwide, young people seem to see CRTs as a sunset industry."

In an invited paper, T. Uchida and his colleagues at Tohoku University described a reflective color optically compensated bend (OCB)-mode display that uses an internal reflecting mirror and a front scattering film. The display requires only half the drive voltage of other OCB-mode displays and, like previously described OCB displays, has 10 times the speed of traditional STN displays. The new display is not bright yet, but the authors feel it has high-brightness potential.

S. Itoh and his associates at Futaba analyzed the state of the art of FED technology. While optimistic, they warned, "There is no royal road to developing LEDs." Areas that require further development are (1) the reduction in life expectancy resulting from adsorption and desorption of gases on the emitter surface with the gases coming from the anode, (2) the need for higher-efficiency phosphors if a luminance of greater than 300 cd/m^2 is desired, and (3) the development of a new blue phosphor material.

H. Hirai and his colleagues at Toshiba attempted to quantify a perennial question: How fast must a display be to adequately render motion pictures? They presented images on STN displays having different response times before a panel of observers and asked them to rate acceptability on a scale of 1–5, with 3 being just acceptable. They concluded that the bearable response time for displaying motion pictures is 185 ms [$t_{on} + t_{off}$ between ON (black) and OFF (white)] for animation, where full-on and full-off are primarily used, and 235 ms for moving images in which gray shades are used.

In the poster session, Noritake showed its rib-grid vacuum fluorescent device (VFD) that does away with the wire-mesh grid. The mesh is replaced by ribs surrounding the fluorescent area that are metallized on top. The result is a luminescence of up to 5000 cd/m^2 – double the maximum available from mesh-grid devices – and the elimination of the mesh pattern from illuminated areas. No new physics here, but as one analyst observed, "This is the kind of thing that makes money."

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A block away from the luxuries of ACT City, an Asia Display '95 attendee could see scenes more typical of everyday life in Hamamatsu.

3-D and VR

Sanyo described and demonstrated its new autostereoscopic (no-glasses) LCD Image Splitter Display. The display exhibits the left- and right-eye fields simultaneously and directs them to the appropriate eye. A 640 × 480 display therefore produces a 320 × 480 stereo image. The display was shown. It is effective when the viewer's head is positioned properly, and it is bright (the luminance is 350 cd/m^2).

A team from NHK, Sanyo, and Toppan Printing described an autostereoscopic 3-D Hi-Vision (16:9 high-definition) projection system that uses a double lenticular screen and an array of speakers with adjustable delays to create a sound image that tracks the 3-D visual image.

T. Kanade and his colleagues from Carnegie Mellon University described their work with virtualized (not virtual) reality. The team captures a visual event using several cameras. At playback, the viewer can select any "soft-camera" position (within a range) that he chooses, even if no physical camera was at that location.

International Display Workshops (IDW '95)

The International Display Workshops '95 immediately followed Asia Display '95. In the workshop on Advanced LCDs, M. K. Hatalis of Lehigh University commented that the development of lower-temperature poly-Si processes and new glass with a strain point over 650°C "removes the last barrier to using this technology in the manufacture of TFT-LCDs."

Two papers, one by P. J. Bos and his colleagues from Kent State and one by M. Suzuki and K. Sumiyoshi of NEC, agreed that several techniques – including dual-domain, multi-domain, less-than-90°-twist, pi-cell, and tilted homeotropic – offer wide-angle viewing for LCDs. The outstanding need is to make one or more of these techniques reliable and economical in production.

In the workshop on Field Emission Displays, J. C. M. Huang of the Industrial Technology Research Institute (ITRI), Taiwan, suggested that if LCDs were the display of the 80s, and TFT-LCDs are the displays of the 90s, perhaps FEDs will be the display of the first decade of the 21st century. Huang sees the compatibility of FED manufacturing with semiconductor processing techniques as very attractive, and he sees the manufacture of the bottom plate as now being less challenging than engineering the assembly and packaging of the entire display.

If a 10-in. FED is to have a lower power consumption than an equivalent LCD, it must have a phosphor efficiency of 5–10 lm/W, which requires more development, Huang said. On the positive side, at $20 the total driver cost for an FED is substantially less than that for an LCD. The reason for this is that, unlike LCD drivers, there is no need for FED drivers to reverse the polarity of the voltage they supply.

ITRI's Electronic Research and Service Organization (ERSO) is using monolayer surface coating of phosphors for their developmental FEDs instead of the 10-μm-thick multilayer coating that is typically used. Impressively, the result is four times the luminescence from the same beam energy.

ERSO plans to further develop FED core technology, then establish a domestic consortium, and then establish an international consortium. They anticipate pilot display production in 1998 or 1999. ERSO will sell FEDs for R&D and will make their simulation software and worldwide patent analyses available. There are yet some internal approvals to obtain, but Huang is hopeful that ERSO will institute an international training and research center.

Huang indicated that the Taiwanese technical establishment is well aware that it has built a powerful industry on imported technology. It would now like to give something back, and in its FED work believes it has something worth sharing.

In the workshop on LCD Color Filters, Takeo Sugiura of Toppan Printing Co. presented a detailed history of the technical development of color filters (CFs). He said that 1 million 10-in. color filters are manufactured each month for displays, most of them for PCs. Dr. Sugiura then went on to say, "The LCD market, which has depended too much on PCs, must be expanded to applications needing cheaper and lighter displays."

Ken Werner

The Japan Electronics Show '95 was held October 17–21, 1995, in the six halls of the Osaka Intex Exhibition Center. Intex is in a part of Osaka largely devoted to port facilities. The harbor and the skyline of downtown Osaka are in the background.

The Stereo Exhibit

IDW '95 contained an exhibit of stereo displays. Among them were lenticular autostereoscopic displays from Toppan Printing. These were high-impact, still-image, non-electronic displays for advertising and similar applications.

Sanyo demonstrated the LCD image-splitting display from Asia Display '95, saying the intended applications were personal amusement, medical imaging, 3-D car navigation, and home 3-D TV. The price will be ¥450,000 in the Japanese market only. Sanyo also showed a 16:9 32-in. CRT-based 3-D TV that processes 2-D images to create 3-D images. The system uses active glasses, and only moving images on the screen appear in 3-D. The system chooses which of the last six frames to use for synthesizing the 3-D, depending on image speed. The receiver can also be used in a conventional 2-D mode. The set is currently available for ¥380,000 in the Japanese market only.

Hibino's TriVision is a large desktop device into which the viewer looks through binocular-like lenses. The case protrudes so that speakers are near each of the viewer's ears when his eyes are at the binoculars. TriVision provides a high-intensity effect well suited to game playing.

Shimadzu's Aircraft Equipment Division showed a head-mounted stereo display using dual-projection CRTs. A visor provides a normal image when down, a see-through image when flipped up. The price is ¥2,800,000; ¥4,000,000 with head-motion sensor. For less demanding applications, Shimadzu was also selling an LCD-based VIM vision immersion unit for ¥680,000. Each of the two LCDs is 0.7 in. on the diagonal and contains 180,000 pixels. The unit is made by Kaiser Electrooptics in the U.S. for the Cue View game system.

Nissho Electronics was showing the VREX Cyberbook, a Mac Powerbook with passive glasses and custom software that produces left/right stereo separation on an alternate-line basis. "This may be the simplest stereo system," said Senior Staff Member Shigeaki Matsuura. The system is effective on still images; no software is available for moving images. VREX, a U.S. company located in Hawthorne, New York, is a subsidiary of Reveo that also makes stereo projection equipment.

LCD International '95

The week before Asia Display and IDW, Nikkei Business Publications ran LCD International '95 and the accompanying LCD Seminars at the Pacifico Yokohama convention center in Yokohama, the port city for Tokyo. In 1994, the seminars drew 2700 attendees. This year, the seminars included "A Practical Course in Panel Processes" to transfer production-technology information to younger engineers.

Although the exhibits focused on LCDs, materials, and manufacturing equipment, there was a small PDP section near the entrance containing three PDPs side by side. Mitsubishi's 640 × 480 20-in. color PDP had a luminance of 150 cd/m^2 and a sample price of ¥1 million. Mitsubishi's rep guessed that a U.S. version might be available for sampling in 1997.

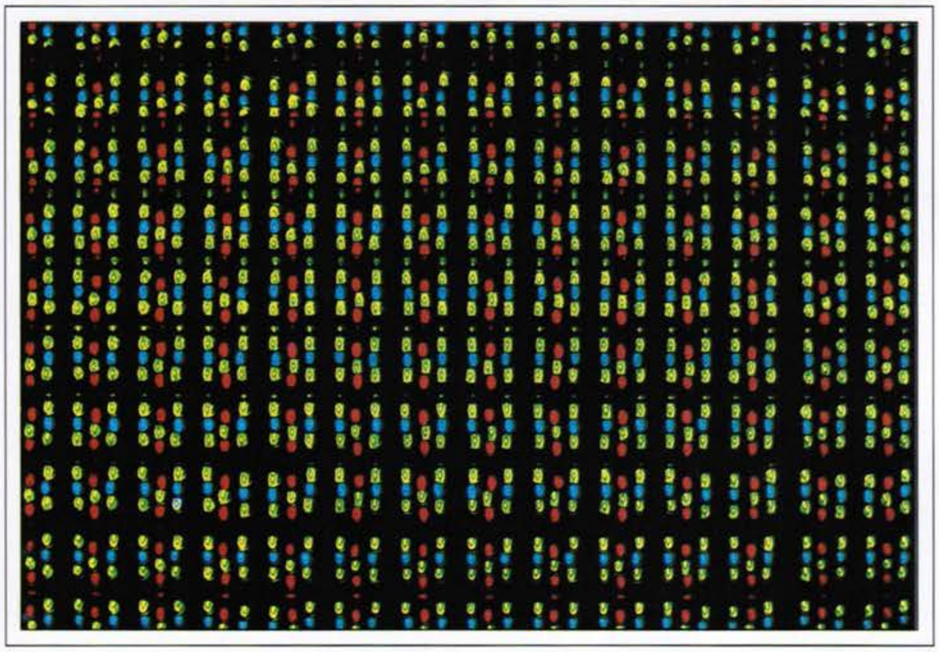
NEC's 640 × 480 33-in. RGB/NTSC color PDP benefitted not only from its larger size but also from its luminance of 200 cd/m^2 and its 30:1 contrast ratio – sampling now in Japan for ¥1 million and worldwide in 1996. Fujitsu had one of its 21-in. color PDPs running untended as a product-information terminal. Of the three displays, NEC's was the most striking.

On the strength of the extensive LCD exhibits mounted by Samsung and LG Electronics, there is a Korean national style in LCDs: high contrast with highly saturated colors. Samsung's exhibit touted the company's high aperture ratios and featured a handsome new 22-in. TFT-LCD prototype with a horizontal viewing angle subjectively better than 90°. Sampling might begin next year. The other displays ranged from a beautiful 14.2-in. 640 × 480 TFT display with 70% aperture ratio, 6-bit color, 100:1 CR, and 200 cd/m^2 through a variety of 10.4-, 11.8-, and 12.1-in. VGA, SVA, and XGA TFT-LCDs.

LG Electronics, Inc. (formerly GoldStar) was showing TFT-LCDs ranging from 5.6 in. (NTSC compatible) to 12.1 in. (XGA compatible).

Also showing LCDs were NEC, Toshiba, Panasonic, Sharp, Hitachi, Fujitsu, Epson, Casio, Torisan (Tottori Sanyo Display Division), Kyocera, and Hosiden.

Among Sharp's offerings was the "Gaia" XV-R43 16:9 rear projector using a filterless single-panel LCD system. The system produced a nice image, with perhaps a little smearing on fast motion. For critical viewers, the projected pixels might be too large. On Friday, the Gaia was replaced by a new 28-in. LCD! This unit, which was not quite what it seemed to be, was also shown at the Japan Electronics Show, and we'll describe it in more detail in that section. Sharp was also showing a nice 8.4-in. LCD TV mounted on a graceful pedestal. This is a nice unit, but it's



Ken Werner

The introduction of bright blue light-emitting diodes has made possible the introduction of full-color LED display modules, such as these from Panasonic. The green LEDs in the modules from all manufacturers were actually yellow-green, but pure bright greens are on the way.

hard to imagine that Sharp will sell a lot of them at ¥110,000 ($1100). The price is thought to be too high for the U.S. market, and Sharp will not market the unit in North America.

DNP (Dai Nippon Printing) was showing its range of photomasks. Rather than keeping stacks of handouts at the ready, DNP personnel guided potential customers (and even editors) to a modem-equipped laptop computer, and invited them to log onto DNP's World Wide Web site and print out whatever literature was of interest. The URL is http://www.dnp.co.jp/lcd/intro/intro_e.html. Toppan Printing was also showing matrix color filters (as used in Sharp LCDs), and Toray was showing its Toptical color filters for LCDs based on a polyimide/organic-pigment color system.

Photon Dynamics, California-based maker of automated test equipment for display manufacturers, had a booth staffed by Marketing and Communications Manager Tim Campbell. Campbell said that Japanese manufacturers were still buying equipment "despite the temporary oversupply" and that Photon Dynamics was finding new customers at LCD International '95 that they had not known about before.

3M had a large booth featuring BEF antireflection film and LCF film for improving the contrast of the crawling LED displays so popular in Japan. Ushio had a large exhibit of lamps, backlights, and inverters.

ED Research was exhibiting their research reports on the Japanese FPD manufacturing industry. English translations of some of these reports are jointly published by SID and Interlingua.

Fujioka Manufacturing Company was featuring its line of FPD manufacturing equipment, including a rubbing machine, dry spacer spraying machine, seal printing machine, and seal curing oven. M. Miyazaki, Director and General Manager of Fujioka's Sales Division, said the company's equipment is used in the U.S. by Three-Five Systems, AT&T, IBM T. J. Watson Research Center, and OIS Optical Imaging Systems.

Nagase and Co. was showing AlliedSignal's Spectra-Vue system for dramatically increasing the viewing angle of an LCD and Eldim's EZContrast contrast mapping system. AlliedSignal's Tom Credelle said his company was expanding its offerings because of the intense interest in 11.4-in. LCDs among Japanese manufacturers.

Ken Werner

The Japanese passion for wide-aspect-ratio television is affecting LCD product lines. Most manufacturers had at least one small or medium LCD with 16:9 aspect ratio for TV applications.

TMA, Palo Alto, California, was promoting Liquid, its software package for complete, physically based simulation of AMLCDs. The package, which can produce simulated output images as they would appear at different viewing angles, runs on Unix workstations.

Japan Electronics Show

Overlapping Asia Display and IDW, the Japan Electronics Show (JES '95) was held October 17–21 at the Intex Exhibit Center in Osaka. Although JES '95 had a large, bright, and noisy consumer component, five of the six halls at Intex were devoted to the selling of components and equipment to manufacturers.

Among the notable trends was a profusion of prototype color PDPs with diagonals from 21 to 40 in. There is no longer any question of whether Japan's large electronics companies will commit themselves to PDPs. The question is who will have the first product in each market segment.

Another trend was the wide availability of bright blue LEDs and full-color modules containing blue LEDs. Panasonic and Sharp, among others, had LED video displays to draw attention to the modules they were selling.

A remarkable transition is the replacement of 4:3 TVs with 16:9 "Panorama" sets that stretch a standard NTSC signal horizontally to fill the screen. These sets can also play videodisks recorded in 16:9 format. These

Ken Werner

sets are not all high end; many are 24-in.-diagonal sets selling for about ¥70,000 (about $700). Also being pushed are high-end high-definition Hi-Vision 16:9 sets whose signals are delivered by satellite. LCD manufacturers are not ignoring the 16:9 juggernaut. Several 16:9 LCDs were shown by various manufacturers.

The theme of JES '95 was "Discover Today's Multimedia!" In the industrial halls, this seemed to translate to a concentration on semiconductors for digital audio and video and on devices for exploiting the new super-density (SD) digital optical disks. The SD disks do seem to be an impressive way to store and play motion pictures with high-quality sound and video, and recordable versions were being discussed. Is this the beginning of the end of videotape?

Let's look at some of the booths at JES '95.

Philips was showing – for the first time? – its range of AMLCDs made at FPD Corp. in Eindhoven. These displays use two-terminal active elements that Philips insists on calling thin-film diodes (TFDs) but that the rest of the world calls MIMs.

Futaba was demonstrating many vacuum fluorescent devices (VFDs) in a variety of applications, including an add-on head-up display (HUD) for auto navigation systems that projects an arrow into the driver's field of view indicating which way to go at intersections. Also on display were duplex multicolor VFDs with color-dependent luminance of up to 2000 cd/m^2. These devices are the fruit of new developments in high-efficiency phosphors, Futaba said. Klaus Heynan, Assistant Manager of Product Engineering for Futaba (Europe) said Futaba did not intend to follow Noritake's lead and develop a rib-grid VFD, which has a fall-off in luminance at the edges of the luminous areas – a position that was refuted by Noritake's representative.

Noritake had its own extensive VFD exhibit, including the rib-grid device. The advantages Noritake claimed for the rib-grid VFD are dense and flexible patterning, high luminance, better resistance to vibration, and highly uniform luminance. Noritake says the rib-grid product will be slightly more expensive than traditional mesh-grid product at first, but will then attain parity.

Panasonic, Rodan, Sharp, Stanley, Kodenshu, Rohm, and probably some others I missed were showing full-color LED modules. Panasonic's modules contained five yellow, two blue, and two red LEDs for each color pixel. Panasonic put their blue LEDs in proprietary oval packages, with the blue LED chips coming from Toyo Togusay. Panasonic will sell you 16 × 16-pixel modules for ¥3 million. In addition to LEDs, Rodan was showing monochrome PDPs (but nothing large), and Stanley was showing a variety of small LCDs and backlights.

Panasonic's impressive booth included its new 40-in. 16:9 PDP for Hi-Vision. With 1344 × 800 pixels, 0.65-mm pixel pitch, a luminance of 150 cd/m^2, 150:1 contrast ratio, 24-bit color, and a 30,000-hour lifetime, this was a good-looking display. A 26-in. PDP had 896 × 512 pixels and shared the other specs of the 40-in. display. This display, probably in 28-in. form, is likely to be available for sampling in June '96.

Panasonic was showing a range of TFT- and STN-LCDs, including a 5.8-in. 16:9 400 × 234 TFT display for TV applications and a 15-in. full-color TFT-LCD module with 1152 × 900 pixels and 0.261-mm pixel pitch. There was also a projector with three 1.3-in. poly-Si LCD light valves, each having 310,000 pixels and 15% transmittance.

In the CRT arena, Panasonic is producing a Pure Flat (PF) 17-in. tension-mask tube with 0.24-mm pitch, 1280 × 1024 screen resolution, and 113-kHz horizontal deflection. Panasonic's Jim Masuda said the PF tube is a substantial improvement over Zenith's FTM. The slotted shadow mask and phosphor stripes provide better white uniformity than Zenith's dot-triad pattern, and Panasonic has designed a large custom yoke for the PF that permits multisync operation, something Zenith never implemented in an FTM tube, said Masuda. Samples of the PF tube are shipping now for $350, including the deflection yoke.

Alps was showing its nice mouse-replacing digitizing panel in build-in and add-on versions and a range of STN-LCDs. The VGA-level STN displays are new. Alps will sell a high-contrast 10.4-in. VGA display with 40:1 CR for $350 if you buy 5000 per month. Yoshihiro Nagura, Alps' marketing manager for LCDs, said, "We will compete on price."

Sharp was showing its full range of LCDs, including a 17.7-in. XGA STN module and the 28-in. VGA LCD first shown in Yokohama. This unit is made by tiling two smaller displays by bonding them to a single piece of 28-in. glass. The pixel pitch is 0.88 mm. In Yokohama, a Sharp spokesperson assured consultant William Bohannon that this display was indeed manufacturable in quantity.

Casio was showing its "personal multimedia" products and its line of LCDs, including a 9.4-in. RC-STN VGA liquid-crystal module.

There was also a 960 × 640 monochrome STN for viewing a full page vertically (if not at full size), as used on Casio's Darwin personal word processor (PWP).

Fujitsu was featuring its by-now familiar 21-in. PDP, which it calls "Plasmavision." One trick was putting one of the PDPs behind a picture frame as a changeable photo-on-the-wall. This was surprisingly effective when viewed from 8 to 10 ft. away.

Pioneer showed its new prototype 40-in. 4:3 AC-PDP with a luminance of 350 cd/m^2, a 150:1 CR, full color, and a luminous efficiency of 1.2 lm/W. A final version of the display will be available in early 1997 in a Pioneer TV receiver which is estimated to cost ¥400,000.

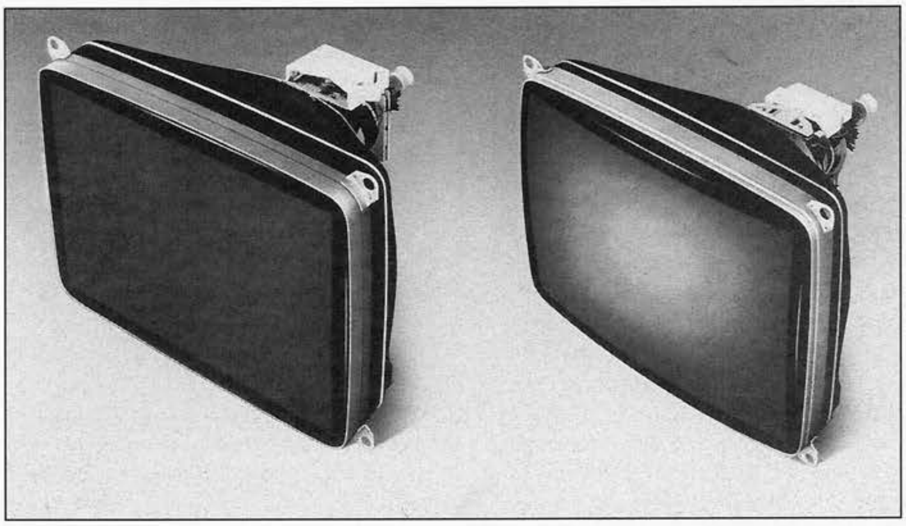
Hitachi was showing its range of LCDs, but not the in-plane switching LCD shown at Asia Display. Included was a 1-in. poly-Si monochrome module with 300,000 dots and a 1.4-in. color module with 345,000 dots.

NEC showed its range of TFT-LCDs, many with multiple scanning, and the nice 33-in. PDP seen at Yokohama.

Texas Instruments was demonstrating its Digital Light Processing® (DLP®) engine, which looked good rear-projected at about a 6-ft. diagonal – big enough for real cinematic effect. TI was sharing the booth with Nokia, which had a very nice prototype rear-projection SVGA monitor using the DLP® engine. Nokia's Göran Wahlberg and TI's Chris Tapsfield were quick to point out the prototype's imperfections and to indicate that correcting them was not a problem. There will be two products: a commercial VGA/SVGA projector and a consumer NTSC/VGA/SVGA projector. TI has one source of cold-discharge metal-halide lamps having a lifetime of 10,000 hours, and these are 100-W lamps. The lamps have relatively weak output in the red, so the Nokia projector will use two DMDs, one for blue and green and one full-time for red.

Tapsfield said it was his understanding that Japanese companies were having trouble getting beyond VGA resolution with small poly-Si TFT-LCD light valves. As a result, he said, there was intense interest in the TI/Nokia product at JES.

Toshiba showed a reflective 95-gram VGA 7.2-in. monochrome TFD-LCD module with 0.4-W power consumption and up to 16 gray levels. The unit, with a small spotlight supplementing the ambient illumination, looked good for a reflective LCD. The company was also showing its range of mostly TFT-LCD modules up to a stunning 16:9 HDTV display with a 15.5-in. diagonal, 1920 × 1035 pixels, 6-bit color, 20-ms response, and wide viewing angle. Toshiba representatives would not comment on availability. Photonics Imaging President Peter Friedman commented that, with close to 2 million color pixels having 18 bits of color depth, the Toshiba panel now seems to be the world's highest-information-content FPD.



Matsushita Electronics Corp.

Filling the gap left by Zenith's discontinuance of its flat-tension-mask (FTM) CRT, Panasonic began to promote its "perfectly flat" (PF) CRT to OEMs. (The PF tube is on the left; a conventional Panasonic tube is on the right.)

Within its wide range of small-to-medium LCD modules, Epson was showing a 6.3-in. "simple matrix" – that is, passive matrix – monochrome LCD with 50:1 CR and a 4-ms response time! The display utilizes a bistable TN (or BTN) mode and a variation on active addressing.

Epson's rep seemed very proud of the company's ELP-3000 "multimedia" projector that uses three of the company's 3.1-in. monochrome VGA projection LCDs. The projector has 50% of projector sales in Japan, is apparently price-competitive at ¥898,000, and is certainly bright at 250 lm. However, after the novelty wears off, it seems to me that VGA projectors are a stop-gap measure that necessarily offer an image quality we no longer tolerate on the desk-top. The SVGA version of the ELP-3000 is possibly 2 years away, said the rep.

Among Sanyo's offerings were a 2.4-in. VGA poly-Si TFT-LCD module apparently made with a 600°C poly process. Samples are available now. The little TVs containing these modules, which looked very much like a product, were for demonstration only.

In the consumer electronics hall, Sony was showing its Plasmatron, the plasma-addressed LCD (PALCD) using PALCD technology licensed from Tektronix. The 24-in.-diagonal 16:9 display had nice color saturation and contrast. Sony's literature discussed using the technology for 20–50-in. hang-on-the-wall TV. PALCD clearly works, but there are those who question its ability to be cost-competitive. Sharing Sony's area with the Plasmatron was a very cost-competitive and very impressive rear-projection LCD. The Flight 037 uses three of Sony's 1.35-in. 510,000-dot poly-Si "SIPOLIX" (Sony Integrated Polysilicon Liquid Xtal) light valves that are compatible with both 16:9 and 4:3 aspect ratios. The light valves are good for 600 TV lines (horizontal) and have 16.5% transmittance. The Flight 037 exhibits very-good-looking video without the oversized pixels we have come to expect from projection LCDs. Even more impressive, the Flight 037 is available now at a list price of ¥330,000 ($3300). ■

continued from page 4

this evolving talent. I wanted them both to know that the world would look back in appreciation of their efforts. But the scene was already fading, and it was time to move on.

The next stop on my Virtual Reality Experience journey revealed itself as Egypt around 2000 B.C. Clearly, progress had been made, and the artwork on the walls of the tombs I was touring was more colorful and refined. The details were also much better. Nevertheless, the scenes definitely still had a two-dimensional look. It appears that the Egyptians couldn't quite figure out how to render real objects on a flat surface without having them look, well, flat. When they wanted to add depth, they either carved statues or put artworks on buildings and monuments that had relief to them – so now they could do 3-D and a sort of two-and-a-half-D. The Romans in the 1st century B.C. and the Etruscans around 700 B.C. really got the 3-D statue-carving process down to a "fine art." Their statues started to look like they could spring to life at any moment, like naked bodies with a heavy layer of talcum powder. Once again, the scene faded, and the next stop on my journey was fast approaching. Would we finally get to REAL displays – you know – the electronic kind?

Well, I hardly thought the High Renaissance in Italy around the early 1500s qualified. On the other hand, there was Leonardo Da Vinci creating the Last Supper and the Mona Lisa and Michelangelo doing the ceiling of the Sistine chapel. Leonardo certainly had an engineering side to him. And he did a rather fine job of capturing the feeling of three-dimensional objects on a two-dimensional surface. Could we perhaps make a legitimate claim that he was one of the early display engineers? And Michelangelo's Sistine chapel ceiling would certainly qualify as a high-pixel-count display. The Pope of that day must have been one great salesman to talk him into painting while lying on his back way up in the air on rickety scaffolding when he didn't even like to paint. Mikey actually wanted to do 3-D stuff. You know, statues and such.

While thus still mesmerized, pondering the Sistine chapel and the incredible number of "pixels" that Michelangelo put on that ceiling, I felt myself pulled forward in time to the era of the impressionists. These folks began to see that feelings could be conveyed on the painted canvas in ways that were not precise copies of particular objects. They began to understand how the eye and brain perceive light and color and integrate holistically. Georges Seurat took this concept to its limit in the 1880s when he did a series of technically challenging paintings using small patches of color that look remarkably like the pixels in a color CRT. If he did this today, no one would be much interested. But he did these paintings *before* CRTs or LCDs or plasma panels! As we now know, those pixels blend into beautiful images and are every bit as effective in conveying the overall scene as are more detailed and more "realistic" brush strokes.

Once again, my scene began to shift, but now there was also a strange feeling like accelerating and turning at the same time – a speeding up combined with the crossing of a branchpoint in the continuum. I was heading into a new direction, and art was diverging off into a different realm – one that looked a bit confusing. Although not yet sure where my own path was leading, I was glad that my experience would not include an extensive presentation of the contemporary arts.

Of course! I should have known! The branchpoint in the continuum was the invention of photography, which came about in 1822. Aha! finally some real technology. From 1839, with the Paris introduction of the daguerreotype, the world of information display would forever be dramatically altered. Now it would be possible for more and more people to capture that special "Moment-in-Time." It would no longer be necessary to be a trained artist to create a likeness of reality.

And one would be able to duplicate the artwork if desired for wider distribution. Of course, the invention of the printing press had earlier provided a capability for making multiple copies of text or of an illustration. However, the process of engraving the printing plate for an illustration was a difficult and time-consuming one and thus reserved for special and limited applications.

Now, as I approached the threshold of the 20th century, into my view came photography's close companion – motion pictures. Then came color … and radio … and then TV … and color TV … and then computers … and digital signal processing … and then …

Are we doing great or what? Poor Ragoba. Poor Leonardo. Poor Seurat. If only they had had access to the latest technology.

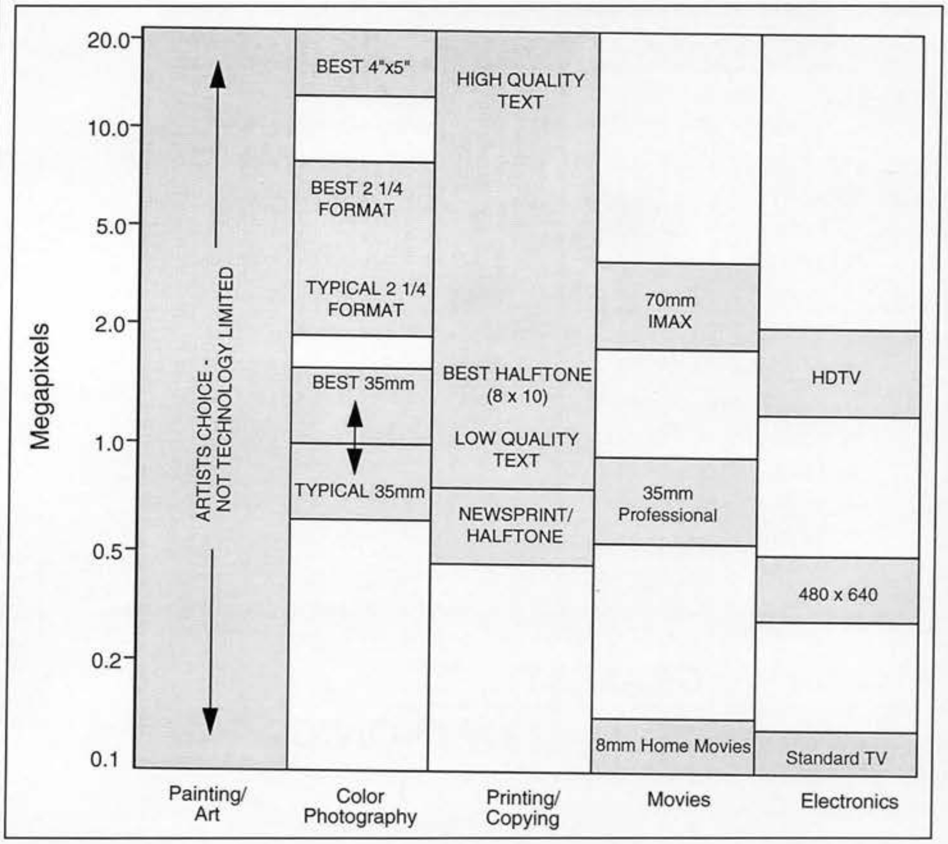
It's so easy to succumb to smugness. Let's get humble for a moment. When is the last time you saw a really inspirational work of art on a computer screen? And how many pixels would it take to do an accurate reproduction of the ceiling of the Sistine chapel? In fact, if all you have ever done is push around a mouse on a pad, let's see you do a really classy cave painting. Photography, film, and electronics have certainly done something highly useful, but maybe it's not what we think.

Our modern photographic and electronic displays cannot reproduce the pixels or color gamut of even a mediocre work of art – not even a cave painting. Some progress! More like 100,000 years of stagnation. Where we have, in fact, added capability is in doing things with displays that traditional art media could not and cannot do. **The traditional artist can create a spectacular work – with many more pixels and with a far richer color gamut than is possible with electronics or photography – but that work is not easily reproducible, imbued with motion, quickly and easily disseminated, or available for further creative modification while retaining the original.** That's what electronics and photography have allowed us to do. And, along with that, they have incidentally created their own unique art forms.

And thus we come to the end of our journey. This traveler at least, having been properly humbled by the accomplishments of past centuries, wishes to pay his respects. Ragoba, I salute you and all of your soulmates who have travelled before us and who struggled so mightily to get us to where we are today. You created displays that have uplifted our spirits and guided us to ever greater accomplishments. You overcame the limitations of the media and created new capabilities. Ragoba, my friend, you were indeed the first display engineer.

As a new feature in this month's column (which may never be repeated) we have added two tables: the first to further elucidate the statements of the above paragraphs, the second as an initial try to quantify the pixel capabilities of the various media.

	Still ←			*→ Motion*	
	Painting/Art	*Photography*	*Printing/Copying*	*Movies*	*Electronics*
Create	Skilled artists and pigments	Anyone can capture a "Moment-in-Time"	Creation–<u>NOT</u> The Objective	Anyone can do it – but mostly for commercial applications	Anyone can, and does capture "Segments of Life"
Reproduce	Same as above (No gain in Efficiency)	Hours → Minutes	Books = Weeks Copying = Seconds	Hours → Weeks	Seconds
Disseminate	Transport to location	Transport/mail	Book stores Copy machines	Ship to theater	Speed of light
Manipulate	Re-do by artist	Limited to skilled techs	Not an intended capability	Only by skilled techs	Easy and doesn't destroy original



The industry news this month is influenced by my recent attendance at Asia Display '95, which took place in mid-October. **Ken Werner** has assembled an excellent overview of both this conference and the Japan Electronics Show, which appears in another part of this issue. On the Saturday and Sunday preceding the Asia Display conference, the Executive Committee and the Board of Directors of the SID met in all-day sessions to review the status and plan the future activities of the Society. What was particularly impressive was the level of participation at both of these meetings. It's a measure of just how international SID has become. The Executive Committee was in full attendance minus one. The Board of Directors was well above the number needed for a quorum. In fact, the only missing representatives were from a few of the U.S. chapters. Overall, the Society is very healthy financially, and membership is at an all-time high.

Fujitsu Microelectronics, Inc., San Jose, California, has signed **Science Applications International Corp.**, San Diego, California, as a value-added reseller of its 21-in. color plasma display panel. SAIC will analyze specific applications areas and customize the plasma panels for integration into such areas as military mobile command and control systems. **Roger Johnson**, a long-time participant in SID activities, was instrumental in arranging this relationship because of his long-standing relationship with Fujitsu and his past extensive work with plasma-panel technology. SAIC will be the exclusive value-added reseller for the color plasma flat-panel display in military market applications. However, Fujitsu plans to name other value-added resellers to sell the product in other vertical market applications.

Electrohome Ltd. has acquired **Display Technologies, Inc.** (DTI), Rochester, New York. DTI is a manufacturer of high-resolution monochromatic displays. DTI will operate as a part of Electrohome's Electronics Group, joining the existing Display and Projection Systems divisions.

A consortium of companies led by **Raytheon Electronic Systems** and **Texas Instruments** has been awarded a $25 million ARPA cost-sharing contract to develop technology leading to a new generation of field-emission displays. Other consortium partners are **Georgia Tech, Lockheed-Sanders, MRS Technology, EG&G Power Systems,** and **Sandia National Laboratories.**

SI Diamond Technology, Inc., Houston, Texas, has announced that they have completed the assembly and testing of the first 5-in. prototype based on their diamond field-emission technology. This follows on the earlier demonstration of a 1-in. prototype and demonstrates the ability to scale the process to larger display sizes. The display prototype measures 3 × 4 in. and produces a monochrome image with a resolution of 320 × 240, with 80 lines per inch, equivalent to that found on a 10-in. VGA screen.

Crystallume, Santa Clara, California, and **Electronic Designs, Inc.,** Westborough, Massachusetts, have announced plans to merge the two companies, with Crystallume expecting to purchase EDI for about $13 million. EDI packages and sells memory devices and AMLCDs and has sales of about $30 million annually. Crystallume is a publicly held company with annual sales of about $3.5 million. Although smaller, Crystallume became the acquiring company because it was desired that the new merged company also be publicly held. The addition of Crystallume's diamond films technology to EDI's existing display capability could result in some new development work on FEDs.

Lam Research Corporation, Fremont, California, has appointed Richard Lovgren to the position of vice president, general counsel, and corporate secretary, reporting to Henk Evenhuis, Lam's chief financial officer. The company also announced the promotion of **Julie Chubb** to vice president and treasurer, also reporting to Henk Evenhuis. Julie is a long-time Lam employee and has seen the company through its initial public offering in 1984 and through three subsequent public equity offerings. Lam's products are focused on etch and deposition processing equipment.

To actively participate in the information age, you can reach me by e-mail at asilzars@sarnoff.com, by fax at 609/734-2127, by telephone at 609/734-2924, or if you do not wish to be in the information age, by mail through Jay Morreale at Palisades Institute, Suite 1006, 201 Varick Street, New York, NY 10014. By the way, there will be a special "reward" for those readers who note the mystical significance of the names 'Ragoba' and 'Maceyana.' ■

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.

Edited by JOAN GORMAN

Goggles and headsets made obsolete

RPI Entertainment, San Francisco, California, has begun sales of the Spectral-Active™ Display System that provides full-color 3-D stereoscopic images without a headset or glasses. A display pad projects different virtual-reality images to each eye via a proprietary electro-optical array. Spectral-Active™ displays are only sold as an integrated component in RPI Entertainment's game, ride, and visualization systems and are custom-engineered for each client. They can be modified and upgraded an infinite number of times.

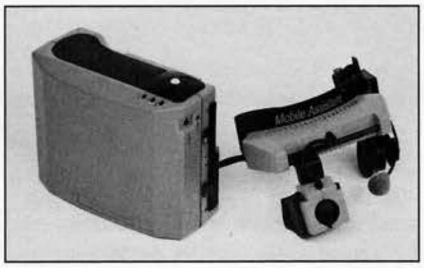
Information: RPI Entertainment, 274 Brannan Street, San Francisco, CA 94107. 415/495-4460, fax 415/512-1131.

Circle no. 1

Wearable computer

Computer Products & Services, Inc. (CPSI), Fairfax, Virginia, has introduced The Mobile Assistant™, a wearable computer featuring a canteen-sized 486 PC worn on a user's belt, a lithium ion battery pack, a head-mounted display, and a voice interface. The hands-free computing environment features voice-activated data input or call-up of schematics or videos, allowing the user to simultaneously perform other tasks. The Mobile Assistant™ runs under DOS, Windows™, and UNIX and includes a built-in voice-recognition engine. A voice-activated Mobile Inspection™ package designed to let non-technical users develop custom applications is available as an option. The head-mounted system, manufactured by Kopin Corp., features a monochrome VGA-display image that appears to float at about arm's length. The image is overlaid onto the outside world, allowing both images to been seen clearly. A full-color VGA-display upgrade is expected by the summer of 1996. Optional PCMCIA cards are available for wireless communications, GPS location, or video conferencing. The entire system weighs about 5 lbs. and sells for $10,000–13,000.

Information: Carol Covin, CPSI, 12701 Fair Lakes Circle, Fairfax, VA 22033. 703/631-6925, fax -6734.



Circle no. 2

Pricing for digital camcorder

Matsushita Consumer Electronics Co., Secaucus, New Jersey, which in August, 1995, introduced the first digital videocassette (DV Cassette) camcorder, announced pricing for the Panasonic PV-DV1000: a suggested retail price of $4199.95, with a suggested minimum price of $3999.95. Panasonic will offer blank tape in both 30- and 60-min lengths, with the 30-min AY-DVM30EA carrying a suggested retail price of $11.99 and a 60-min AY-DVM60EA for $13.99. The PV-DV1000 and blank DV Cassette tapes are marketed in the U.S. by MCEC.

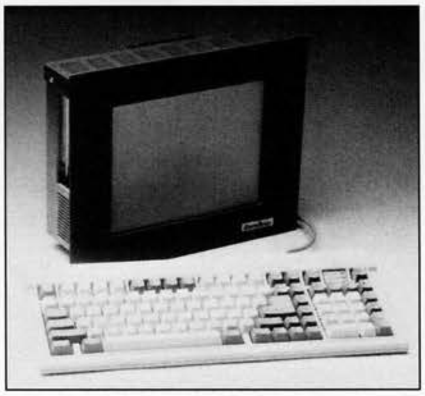
Information: Matsushita Consumer Electronics Co., One Panasonic Way, Secaucus, NJ 07094.

Circle no. 3

Color LCD industrial PC

Densitron Corp., Torrance, California, has introduced the DT59, the first industrial computer to feature a color LCD, touch screen, and integrated LAN adapter in a NEMA-4 industrial housing for under $4000. The DT59 provides a rugged, expandable, 486-based display and control system designed for applications including factory automation, process control, data acquisition, gaming, kiosks, medical equipment, point of sale, and security systems. The DT59 measures 13 (W) × 4 (D) × 10.2 (H) in., with a diagonal screen size of 10.3 in. providing 480 × 640 VGA resolution. This new industrial PC is easily upgraded to Pentium level and will support up to 32 MB of system memory. Two RS232 serial ports and a parallel port are standard, along with connections for an external keyboard, mouse, and floppy-disk drive. The standard configuration incorporates a 270-MB hard disk, with additional data-storage options available. The industrial-grade case, sealed to NEMA-4 at the front, makes the unit ideal for panel-mounted applications in hostile environments. Options include the selection of display technology, processor, and memory configuration. The price for the unit is under $4000 for the standard configuration in quantities higher than 100. Delivery is 12 weeks ARO, depending on configuration.

Information: Craig Stapleton, Densitron, 3425 W. Lomita Blvd., Torrance, CA 90505. 310/530-3530, fax 310/534-8419.



Circle no. 4

AMLCD for industrial applications

Flat Panel Display (FPD) Co., Eindhoven, The Netherlands, a joint venture between Philips, Thomson, Sagem, and Merck, has introduced the LDH102T-31, an active-matrix LCD module featuring a new integrated meander backlighting system that dramatically increases screen brightness, making it ideal for applications in bright surroundings. A dimmable backlighting feature allows it to be used in darkened environments. The module offers full VGA resolution (640 × 480 pixels) on a 10.4-in.-diagonal screen, and its 24-bit electronics can display up to 16.7 million colors. The LDH102T-31's backlighting system, a co-development with Philips' Lighting Division, offers high brightness (typically 250 cd/m^2 at peak white), low power consumption, and lifetimes of 40,000 hours. The module's operating temperature range extends from –5 to 55°C.

Information: Philips Components, Marketing Communications, Bldg. BAE-1, 5600 MD, Eindhoven, The Netherlands. +31-40-72-27-90, fax +31-40-72-45-47.
Circle no. 5

Microchip inverters

Durel Corp., Chandler, Arizona, has introduced the DUREL D310 and D350, two new chip inverters for use with electroluminescent (EL) lamp designs. The new inverters, specifically designed for use with DUREL® 3 EL lamps, are up to ten times smaller and half as expensive as the conventional transformer-based inverters which they are intended to replace. The lamp drivers are switch-mode IC drivers for EL backlighting systems used in watches, pagers, and cellular-phone keypads. The D350 driver can be specified for use in quartz/analog and digital-watch applications and in cellular phone keypads, while the D310 provides adequate power for use in pagers and cellular phones. Both driver types have microprocessor interfaces which enable dimming and power-down features. The inverters are available in SOIC 14 packages as bare die or in custom packages.

Information: Durel Corp., 2225 West Chandler Blvd., Chandler, AZ 85224. 602/917-6000, fax 602/917-6049.
Circle no. 6

High-definition virtual reality

RGB Spectrum, Alameda, California, has announced the SynchroMaster™ 100HD scan converter, an enhanced version of the SynchroMaster 100 which is currently being used in virtual-reality applications. The 100HD adds compatibility with HDTV signals. The SynchroMaster 100 can convert the normal RGB parallel signals from computer workstations or scene generators to the serial signals used by high-end virtual-reality displays. The 100HD can convert HDTV signals to field-sequential color. The SynchroMaster 100 models offer bi-directional capability, so they can also convert field-sequential color signals to normal RGB for display on standard computer monitors, or in the case of the 100HD, to HDTV signals for display on HDTV screens.

Information: RGB Spectrum, 950 Marina Village Parkway, Alameda, CA 94501. 510/814-7000, fax 510/814-7026.

Circle no. 7

Flat-panel CRT replacements

Computer Dynamics, Greenville, South Carolina, has introduced VAMP-HiBrites, color LCD systems designed for high-ambient-light conditions that plug directly into any standard VGA analog output. These bright flat-panel replacements are offered with active-matrix TFT and dual-scan passive-matrix screens, with a choice of infrared, resistive, or guided-acoustic-wave touch screens. The complete plug-in package for OEMs includes the display, touch screen, easy-to-mount metal frame, RS-232 touch-screen cabling, and touch-screen controls. The VAMP-HiBrite-P combines enhanced brightness (150 nits) and a wide viewing angle (50°) with dual-scan passive technology. The 10.4-in. display is capable of 512 colors and rated for 0–40°C. This display is the first to offer field-replaceable backlights. The side-edge-type CCFT tubes can be removed and easily replaced. The VAMP-HiBrite-A features a 10.4-in. active-matrix TFT display capable of 262,144 true colors and is rated at 120 nits, an 80-ms response time, and a 0–50°C operating-temperature range. Two low-reflection CCFT backlights and higher color saturation techniques have been incorporated. Pricing for the VAMP-HiBrite-P is $2226 (in quantities of 50 with resistive touch screens), with delivery from stock to 30 days. A free 84-page "Designer's Guide to Flat-Panel Computers, Flat-Panel Monitors, and Single-Board Computers" is available.

Information: Computer Dynamics, 7640 Pelham Road, Greenville, SC 29615. 803/627-8800, fax 803/675-0106, e-mail: sales@cdynamics.com.

Circle no. 8

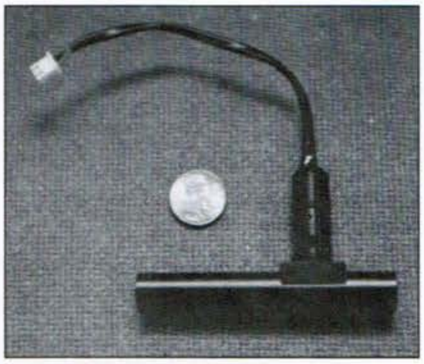
Compact vision system

Seiwa Optical of Tokyo, Tokyo, Japan, has introduced the world's smallest video optics system. The Compact Vision Mini MPL/MBL series is a line of compact high-resolution CCD cameras available with high-quality objective lenses. With an outer diameter of only 12 mm, the compact vision system fits into almost any available space. The unit has many applications including machine vision, inspection probes, robotics, and auto-

Circle no. 32

positioning and alignment. The Compact Vision Mini System offers a low-profile design (12–17-mm diameter), long working distance (56–111 mm), high-resolution (410,000 pixels) CCD camera, and various objectives (0.25× to 8×) with several illuminator options.

Information: Sal Cortorillo, Optro-Mechanics U.S.A. Corp., One Blue Hill Plaza, Suite 815, Pearl River, NY 10965. 1-800-890-3333, 914/620-1999, fax 914/620-1950.



Circle no. 9

Software analyzes AMLCDs

Technology Modeling Associates (TMA), Inc., Palo Alto, California, has introduced Liquid 1.0, a software system capable of modeling an entire flat-panel display. Liquid simulates the TFT, LCC, interconnect, and optical effects, and displays the results of the analysis as a "simulated image" on the computer workstation. The new tool allows designers to anticipate the tradeoffs that must be made because of the complicated interactions between the various components comprising LCD panels. Liquid's "Optical Analysis" window contains a polar plot of contrast ratio as a function of viewing angle as well as the electro-optic curve for the device. The contrast ratio is greatest near the plot's center, which corresponds to normal incidence viewing. While contrast is lost moving away from the center, it is not lost uniformly in all directions. The best display will be the one with the largest circle in the polar plot, corresponding to the largest viewing angle. Another approach to this problem involves viewing "simulated images" from various viewing angles. As the viewing angle increases, contrast is lost and the image turns gray. Liquid 1.0 lists for $105,000.

Information: Milan Lazich, Technology Modeling Associates, Inc., 3950 Fabian Way, Palo Alto, CA 94303-4605. 415/856-8862, fax 415/856-8860.

Circle no. 10 ■

Circle no. 33

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Capetronic Computer USA (HK), Inc.
Celco
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