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INFORMATION DISPLAY

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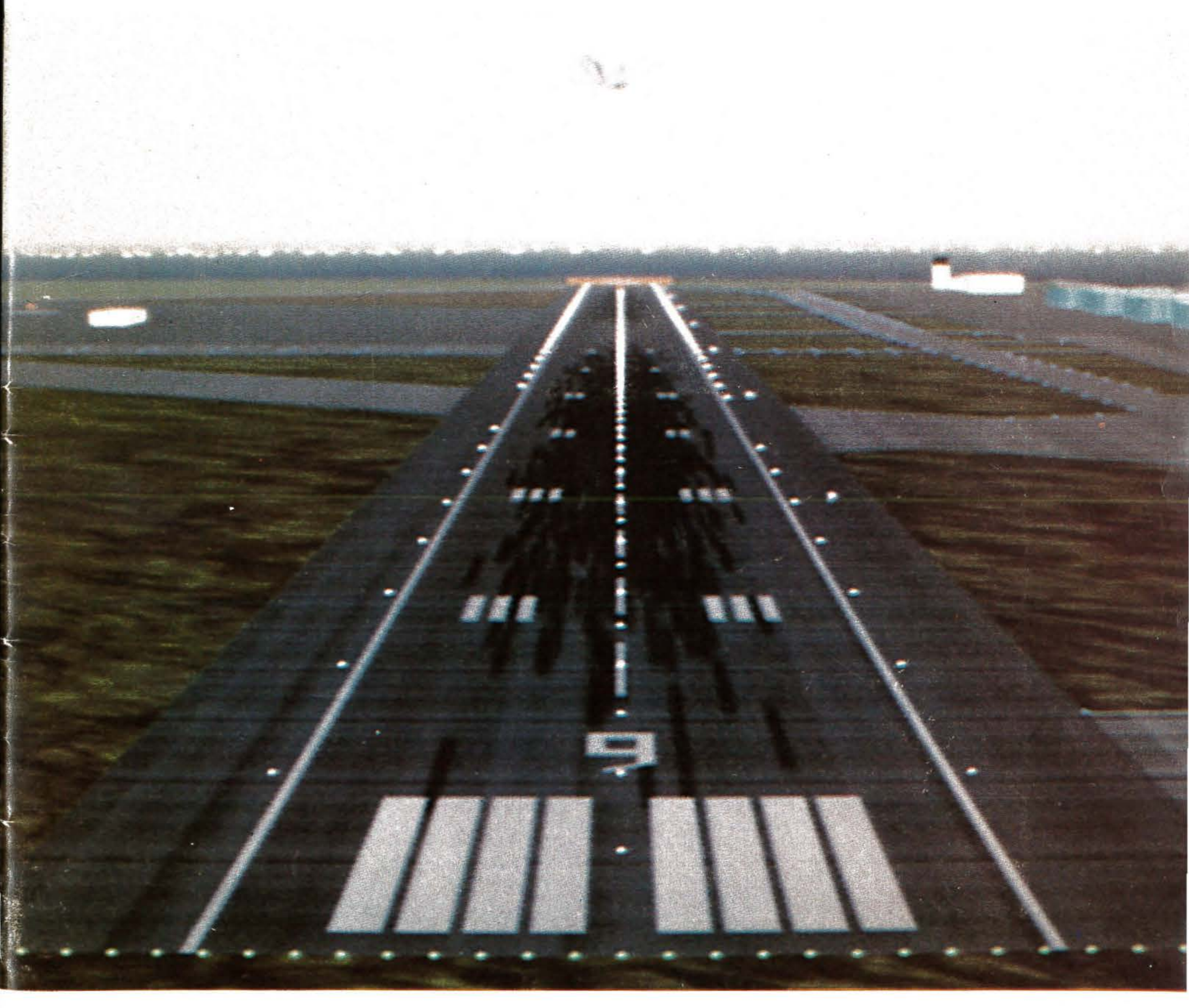

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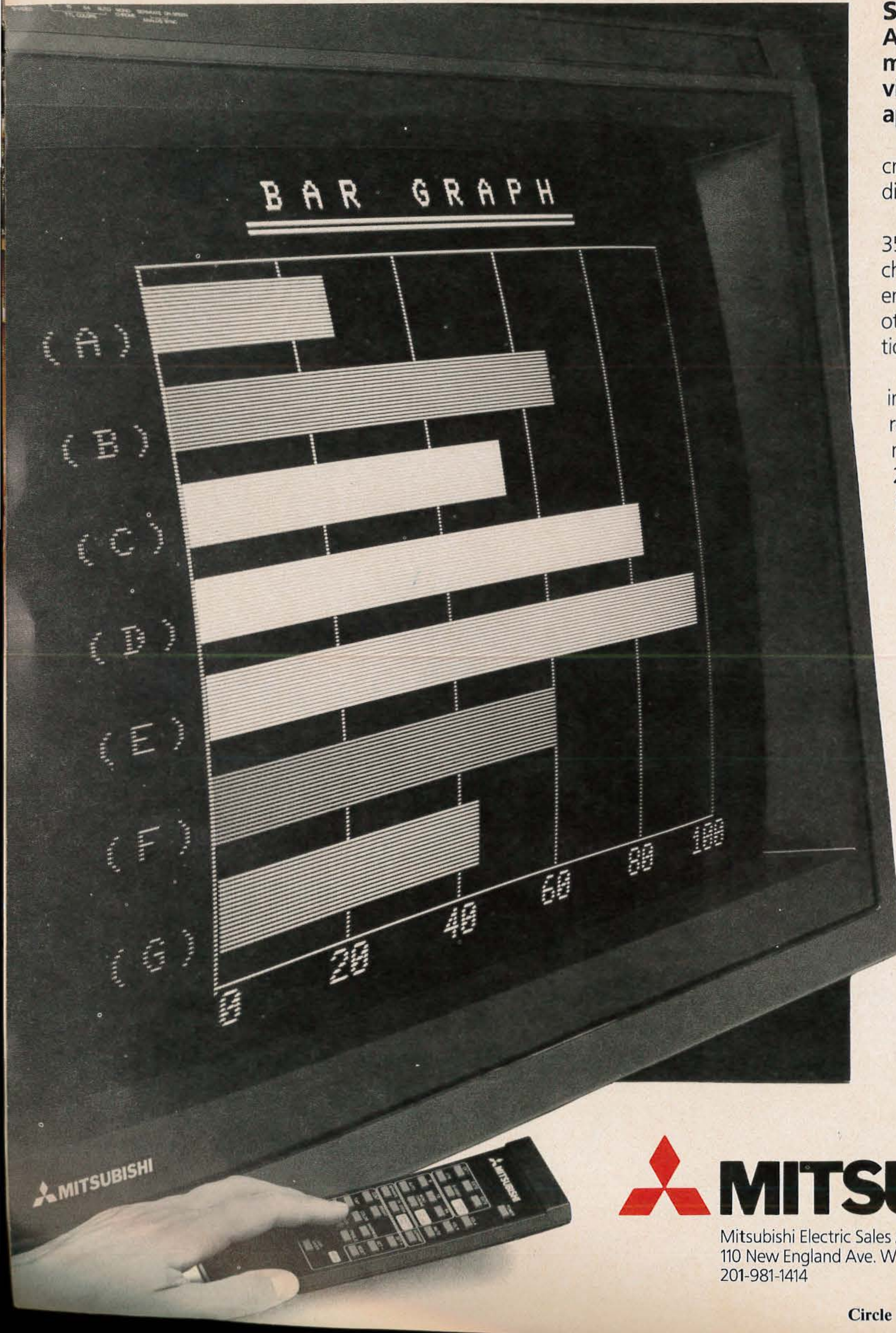

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INFORMATION DISPLAY

JANUARY 1988
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Cover: Elaborate flight simulators place an extra burden on the deflection amplifiers that drive them. Image is from the McDonnell Douglas Vital VII flight simulator. (page 8)

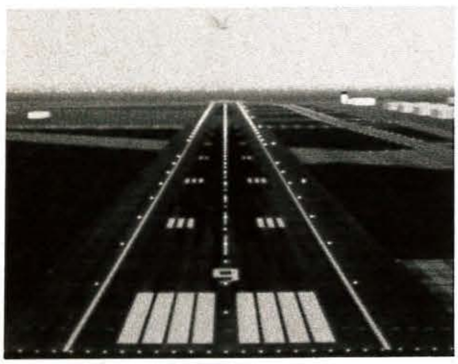

Photo: McDonnell Douglas Electronics

Next Month in Information Display

Special LCD Issue
- Active-matrix LCDs
- Automotive LCDs
- Eurodisplay '87 report

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INFORMATION DISPLAY

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editorial

This month we look at the problems encountered by two design teams working on very different high-performance displays. Al Pletz discusses the requirements for a high-performance deflection amplifier designed to drive CRT displays in aircraft simulators. Increasingly, the makers of these simulators are demanding displays that can show a raster presentation on one part of the screen and a calligraphic, or vector, presentation on another part of the same screen. The customer is always right, but how does the engineer design a deflection amp that does the job without consuming unreasonable amounts of power? Al tells all.

Brian Rosen and Stan Kriz tell of the trials and tribulations of bringing the world's highest-resolution commercial CRT monitor to market—and only one year later than planned. This monitor excited substantial comment at Electronic Imaging East '87, held in Boston last November.

And I describe a display with a 180° horizontal field of view, and the reasons its designers bothered. Those reasons are massive. The system of which the display is a part costs over $3 million, and it doesn't fly.

We also have a book review by Gerald Murch, and Howard Funk's column that identifies the essential articles you haven't read. Well, I haven't read them either. (There must be the nut of a New Year's resolution there somewhere, but I don't think I want to find it.)

—Kenneth I. Werner

Price reduction on video memories

Colorado Video, Inc., Boulder, CO, has reduced prices across the board up to 20% on its entire 490 series of video memories. These include single and multiple video frame stores, video subtractors, video scan converters, asynchronous video frame stores, and video multimemory recorders. In conjunction, Colorado Video announces the availability of an IBM PC interface package that offers a discount when an I/O module and a host adaptor are purchased together. The $1000 package also includes all necessary cabling, MS-DOS driver, and sample image processing program. For further information contact Cynthia Keen, Colorado Video, Inc., P.O. Box 928, Boulder, CO 80306. 303/530-9580.

Finlux and Hewlett-Packard sign supply agreement

Hewlett-Packard Co. has signed a three-year purchase agreement with Finlux, Inc., Cupertino, CA. Under the agreement, Finlux will supply its MD512.256 EL display to be incorporated into HP's 3082A Industrial Touch ruggedized display terminal for CIM environments. HP chose the Finlux display for its viewing contrast, compact size, and stable clear graphics.

SAIT awarded contract

SAI Technology (SAIT), San Diego, CA, a division of Science Applications International Corp., has recently been awarded a $1.5 million contract by Warner Robbins Air Logistic Command. SAIT will design and develop a replacement Horizontal Situation Indicator for use in the Air Force's KC-1354 aircraft. The design will replace the existing analog electromechanical design with new digital display technology. The first phase of the contract includes design and verification testing of an engineering model. The contract award allows the division to enhance its engineering capabilities and strongly positions it in a new area of avionic display. ■

Society for Information Display
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president's message

I wouldn't want to appear presumptuous by comparing SID and my office to the U.S. government and the office of its President. Nevertheless, I suspect Ronald Reagan is also spending some of his time between Christmas and New Year's preparing his State of the Union message next month. In the case of our society, the news, as I see it, is all good and we certainly don't need a once-a-year opportunity to explain away missed goals, failed programs, or disagreements in directions.

Our society remains strong and healthy, and it continues to grow steadily. In two weeks some 80 members of the program committee, all volunteers, will meet in Anaheim to arrange the final program for the SID '88 Symposium. Already we have received a record number of papers for this conference (158 at last count) and it promises to be a difficult task to select the best and newest papers for presentation at SID '88 (May 23–27 in Anaheim). Also, a record number of exhibitors are planning to display their products (73 companies will take 129 booths), leading to the safe prediction that this year's Symposium will again set new attendance records.

The number of sustaining members has also continued to grow steadily this year and it is a real pleasure for me to welcome the new members every month when they join; our total now stands at 114.

Not even the stock market crash this fall or the downward slide of the dollar seems to have affected us negatively. The policy instituted last winter of allowing chapters outside the United States to collect membership dues in local currency to be transmitted to the SID headquarters office has actually benefitted us in terms of U.S. dollars; we were lucky in this instance and it could have just as easily gone the other way. More importantly, however, this new policy, by making the dues payments simpler, seems to have encouraged more people to join SID; we now have some 315 members in Japan (a growth of 60% in one year) and some 104 members in the U.K. & Ireland Chapter.

Our newest chapters in Canada and Dayton are doing well and had very active programs in the past year. We expect to receive a petition for a new chapter in the Detroit area at the board of directors meeting in January. Andy Lakatos has worked hard with the local members in that area who initially proposed the new chapter.

Another major achievement this year is the publication of our new membership directory which is in the mail to all our members at the present time. It is a pleasure to acknowledge the tremendous efforts by Ron Feigenblatt in preparing this directory.

The board meeting in January will be my last as president, and the nominations committee is now at work preparing a new slate of officers for election in the spring. The transition to a new set of officers will happen quietly, smoothly, almost unnoticed from the outside, because of the unselfish support of our active members. I foresee strong leadership and many dynamic years ahead for our society.

—John A. van Raalte

High-performance deflection amplifiers

BY ALFRED PLETZ

THE ELABORATE real-time imagery required in advanced CRT display systems is placing an ever-increasing burden on the magnetic deflection amplifiers that drive these CRTs. Nowhere are the demands greater than in flight-simulator displays. Present trends in flight-simulation imagery require deflection amplifiers that have the dual capability of presenting images in calligraphic and highly linear raster modes.

Deflection amplifiers for calligraphic displays

Past and present flight simulators use calligraphic-mode CRT displays to generate the cockpit view of the outside world. A calligraphic CRT display creates an image by guiding the electron beam over the CRT's phosphor screen in any desired direction, much as a draftsman would draw with a pencil. Such displays are able to produce high screen brightness where desired by moving the electron beam very slowly (or, for very bright images, like runway strobe lights, keeping the beam stationary for the required amount of time).

Alfred Pletz is vice president and co-founder of Citronix, Inc., Carmichael, California, where he specializes in deflection amplifier design. Mr. Pletz received his B.S. degree in electronic engineering at the University of California at Berkeley in 1965 and his M.S.E.E. from Seattle University in 1968. Prior to joining Citronix, he was with CPS and Kaiser Electronics, where he designed CRT displays for military and commercial applications.

The calligraphic-mode displays are especially useful for producing nighttime images of cities and airport runways when a dual-phosphor beam-penetration CRT is used. The phosphor colors are usually red and green and are deposited one on top of the other. By changing the anode potential, one or the other or any combination of the two colors can be obtained.

Drawing the best possible images on these displays requires a deflection amplifier of great linearity, high current output, and high power dissipation. The amplifier must generate a linear write rate that will produce a sufficiently bright line or picture. In large dual-phosphor beam-penetration CRTs, the phosphors will not generally produce sufficient brightness at rates greater than 2 in./μsec; it is the phosphor that limits the write rate, not the amplifier.

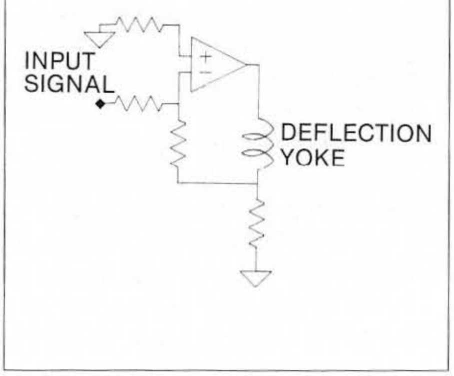


Fig. 1: A typical linear deflection amplifier for calligraphic displays.

Random jump-to times—the time it takes to jump from one point on the screen to another with the beam turned off—are less than write times because one can sacrifice linearity for speed. But the time is not very much less and poses no problem for deflection-amplifier design.

Small-signal bandwidth is an additional consideration. This determines how fast the linear write rate can be for a given visual reproduction of written characters. For instance, a sharp corner will be more rounded if the bandwidth is low.[1]

All of these design considerations result in a system that typically requires a yoke with an inductance of 30 μH and the ability to accommodate +/− 10 A. The maximum linear write rate should be on the order of 1.3 A/μsec and the random jump-to rate on the order of 1.6 A/μsec. The small-signal bandwidth must be greater than 1 MHz. All of this demands a linear power amplifier or deflection amplifier that has an open-loop gain of about 60 dB, an output swing of +/− 50 V at +/−10 A, and a full-power bandwidth of more than 1 MHz. The amplifier must be able to dissipate up to 500 W/axis. [See Figs. 1–3.]

Combined-format amplifiers

Increasingly, users want their simulators to show realistic daytime scenery, which is outside the capabilities of calligraphic displays. High-resolution raster displays, which produce realistic scenery, have drawbacks for cockpit simulators. They can not offer the brightness range of calligraphic displays, and many pilots object to the staircasing in raster displays of horizon lines that are only a few degrees

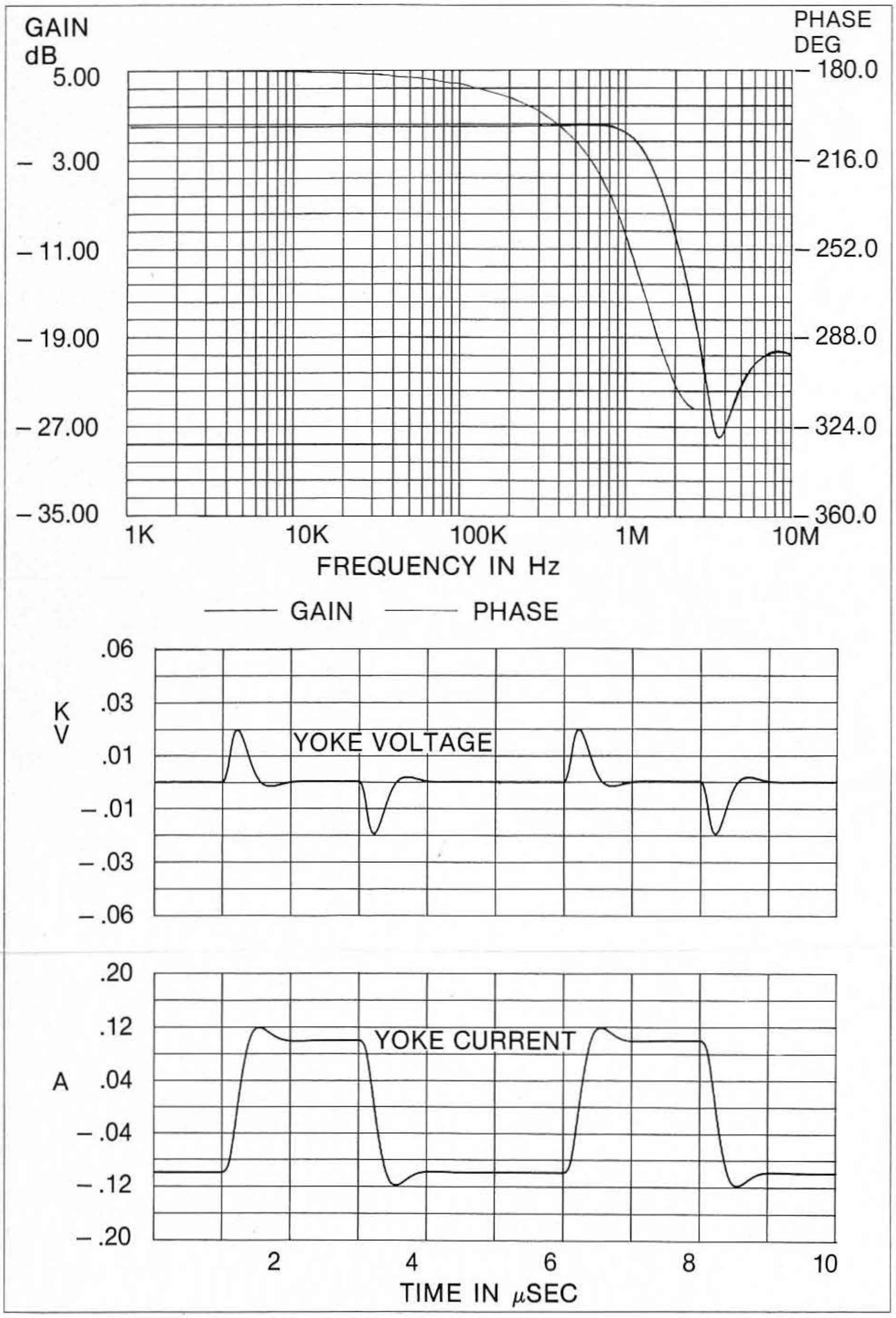


Fig. 2: The small-signal frequency response of a calligraphic deflection amplifier. This is the actual response of a Citronix CD-100-8 amplifier driving a 30-μH yoke.

from the horizontal.[2]

The solution is to combine the two types of display, but much higher performance is required from the deflection amplifier that produces calligraphic and raster formats in the same frame. When the amplifier is working in the calligraphic mode, no more is required of it than in a purely calligraphic application, but the situation changes for those portions of the frame utilizing a raster presentation.

The deflection amplifier can easily accommodate the horizontal-line trace rate since, in most cases, it is less than the linear write rate. The problem arises in the horizontal retrace time, which can be less than 3 μsec in some high-resolution raster presentations. In a deflection system like the one described for calligraphic displays, a retrace yoke voltage of more than 250 V would be required. Increasing one of the horizontal supply voltages to 260 V would increase the maximum power dissipation to 2600 W. This change demands more complex circuitry, and greatly increases the cost.

A more efficient and cost-effective way of achieving fast retrace is to use a resonance flyback switch. Such a switch would remain on during the calligraphic mode and raster trace time. It would automatically open during the horizontal retrace [Fig. 4] to provide the required retrace speed [Fig. 5].

Linear raster deflection amplifiers

When a highly linear 1000-line raster format is required, the traditional resonance scan and retrace method can not be used. We can envy the efficiency of such a system, but geometry correction, offset control, and temperature stability are not possible with this system. In the three-color CRT projection system used in modern flight simulators, the image on the CRT must be predistorted for it to appear undistorted to the viewer at the designated eyepoint. This is necessary because of the optical path the image takes before it reaches the viewer. The images are usually projected from off-axis onto a curved screen.[3] To accommodate these requirements one can use the best parts of both deflection systems. For the horizontal axis one can use linear feedback control during the line trace time and resonance flyback during the retrace time. To save on power dissipation, a nonsymmetrical power supply can be used: a higher voltage power supply for the trace voltage side and the lowest possible voltage supply for the opposite side. In a 1000-line raster system with the same deflection yoke and current requirements as previously specified, the supply voltages can be +15 and −35 V. The deflection requirements for the vertical can be optimized with a larger yoke inductance of about 300 μH. This reduces the yoke current to about +/−3 A with a supply voltage of about +/−15 V to accommodate the horizontal signal components for geometry correction. These optimizations reduce power consumption and production costs. To present a 1000-line 2:1 interlaced raster, the power dissipation is 150 W for the horizontal axis and 30 W for the vertical axis [Fig. 6].

It is therefore practical to meet the new deflection requirements for CRT projected flight simulators by adapting the old flyback switch to the new generation of linear deflection amplifiers. This ap-

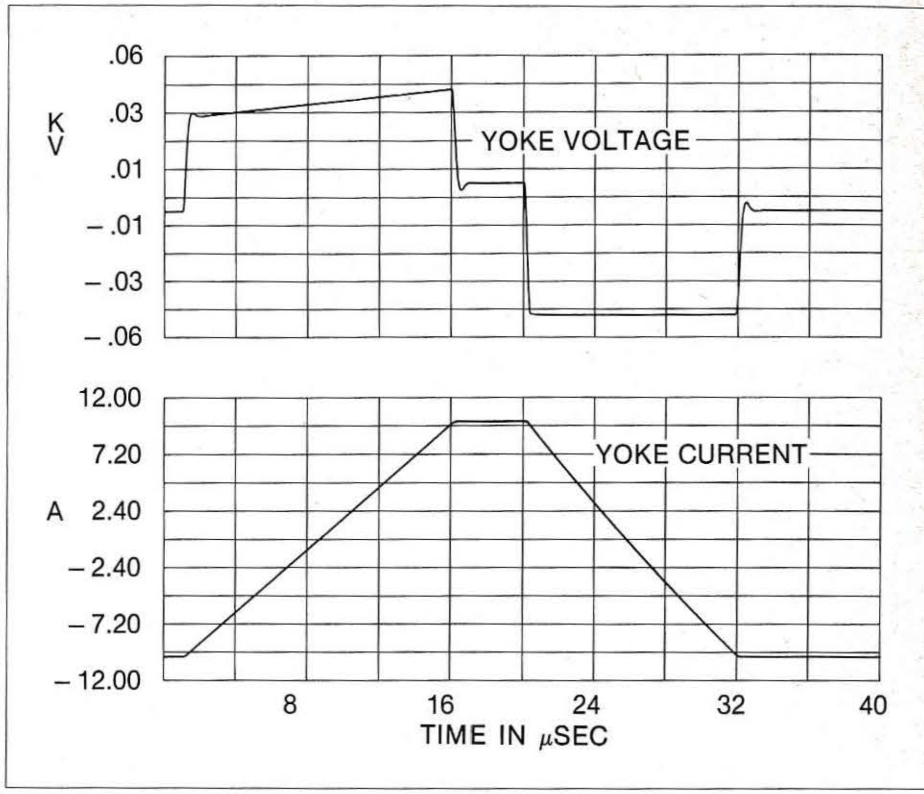


Fig. 3: Maximum linear trace (above) and slew rate (below) of the calligraphic deflection amplifier driving a 30-μH yoke.

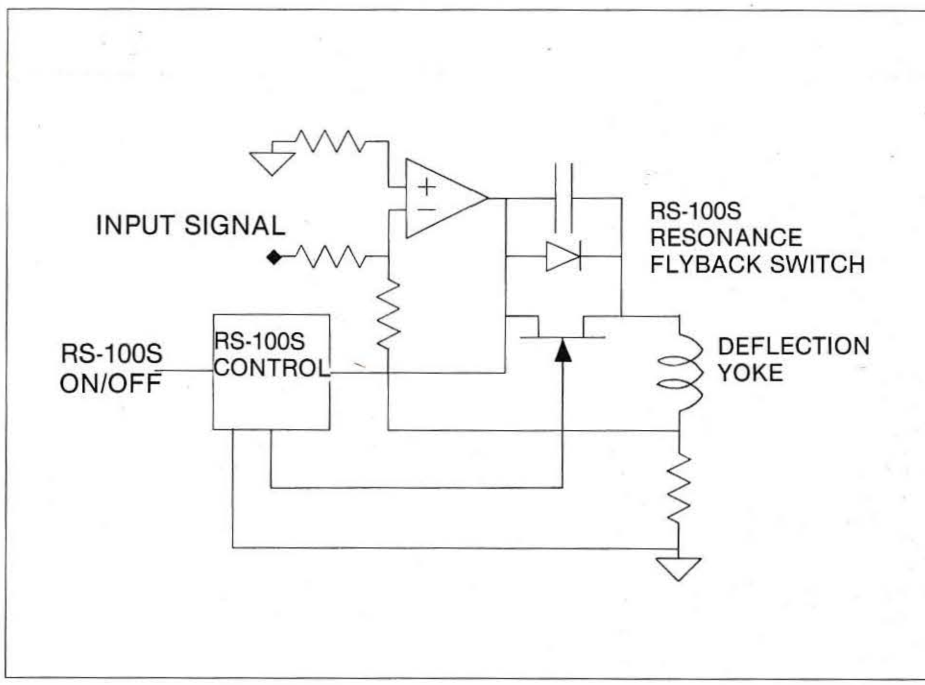


Fig. 4: Citronix CD-100-8 deflection amplifier modified with a resonance flyback switch for combined calligraphic and raster displays.

proach consumes more power than the all-resonance scan and retrace system, but it achieves direct linear control of the waveform.

Notes

[1]A. Pletz, "CRT Write Rate vs. Bandwidth Study," *Information Display* (July-

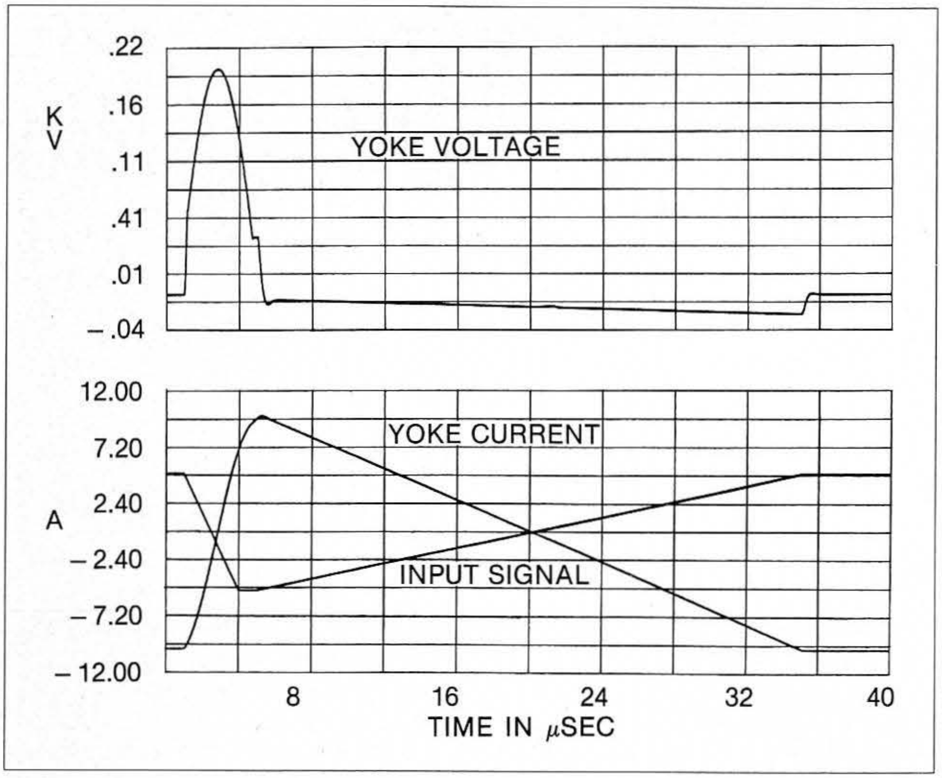


Fig. 5: Performance of the resonance flyback circuit driving a 30-μH yoke.

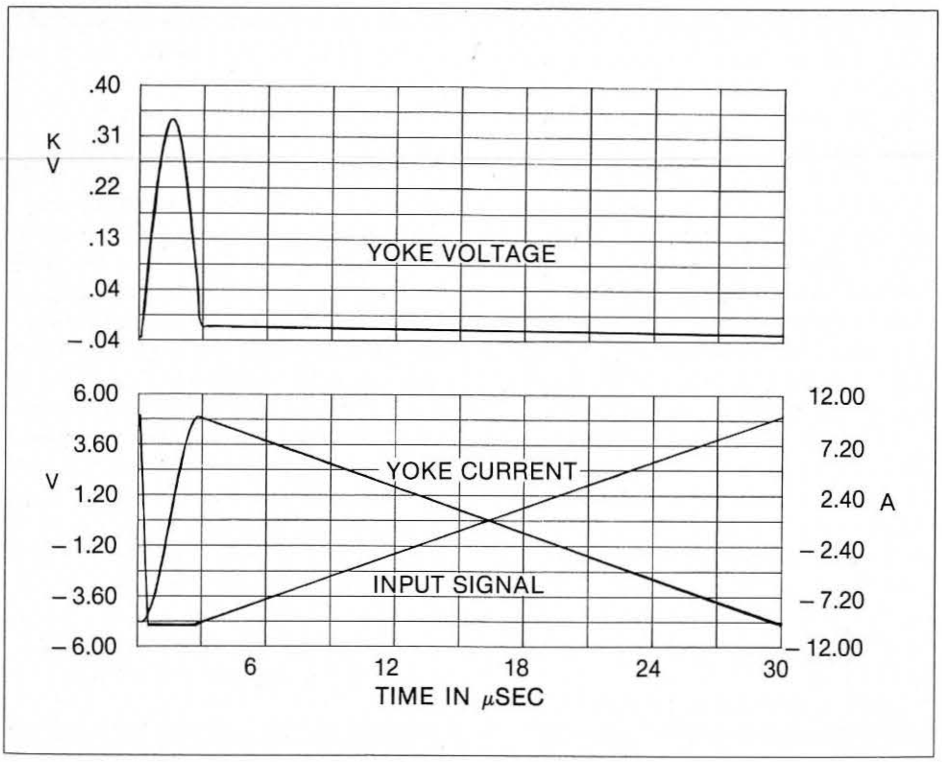


Fig. 6: Performance of an optimized raster deflection amplifier driving a 30-μH yoke.

August 1972).

[2]There are techniques for solving the horizontal staircasing problem in raster displays, but they are computationally expensive.

[3]G. Liapis, "Calligraphic and Raster Displays for Simulators," *Proceedings of the Society for Information Display,* Vol. 27, No. 4 (1986).■

Case study: developing a 3000-line interactive CRT display

BY BRIAN ROSEN AND STAN KRIZ

IMAGE QUALITY is one of the first things a user notices about an interactive display system, and his impression often forms a major part of his purchase decision. Perceived image quality primarily depends upon resolution because, in current interactive displays, resolution is usually the limiting parameter. These displays simply do not have enough resolution to be considered good in an absolute sense. Until display resolutions reach 1000 lines/in. or so, we can only say that quality is improving, not that it is excellent in an absolute sense.

It was in this context that the authors began developing an ultra-high-resolution monochrome display in 1983. By that time, 1000-line displays, with 64-kHz horizontal sweep rates and 100-MHz video rates, were relatively common in high-performance workstation applications. History indicated that display resolution was doubling roughly every five years and that by 1986, 2000-line displays would be available. We thought we could produce a display of 3000-line resolution. A few months of experimentation showed us that such performance was indeed possible [Fig. 1]. Actually, we changed the resolution specification shortly after we began. Instead of 3000-line resolution, the goal became 300-dpi resolution.

Brian Rosen is president and Stan Kriz is vice president of MegaScan Technology, Inc., Gibsonia, Pennsylvania, a company they cofounded in 1985. Mr. Kriz leads the monitor development team at MegaScan. Prior to starting MegaScan, the authors cofounded Perq Systems Corp., a pioneering manufacturer of workstations.

Lines per frame or dots per inch?

We did this for reasons that seemed obvious to us. The display industry has been confusing the world for decades by measuring resolution in lines per frame. Resolution is more properly measured in lines, dots, or pixels per inch (or millimeter). For constant viewing distance, dots per inch is what counts—but how many dots? We were impressed by the laser printer and we judged its quality as "good" on our absolute (though subjective) scale. We were even more impressed by the visible difference between early 240-dpi laser printers and the later generation of 300-dpi printers, even when toner and other marking engine improvements were considered. A 300-dpi CRT display would look like laser printer output.

With this in mind, we actually changed the precise number of scan lines on the display after we started exhibiting it. The display originally had 3276 scan lines but we had trouble explaining how the 300 dpi was calculated. We finally changed the resolution to 3300 scan lines and adjusted the height of the screen to exactly 11 in.

There is an additional advantage to 300 dpi besides the visible quality improvement. The changes in resolution when going from most displays to hard copy are hard to deal with. Having the display *exactly* the same resolution as the printer allows a dot-for-dot correlation between the screen and the paper. Since page scanners also run at 300 dpi—a fact we did not even consider when designing our display—documents can now be scanned, stored, displayed, and printed without modifying the raster representation.

Our display, which is now in production, has the following basic specifications:

$4096 \times 3300 \times 1$ displayed resolution
72-Hz noninterlaced refresh
19-in. CRT, 13.65×11.00 in. active area

CRT—the obvious choice

The problems in designing such a display were formidable. Although we reviewed all the obvious display technologies, we never seriously considered anything other than a CRT-based display. We are product designers, and we had a fixed time limit. We needed inexpensive technology that would not require process development in parallel with product development. We had done CRT monitor design before and were familiar with its problems. For similar reasons, we did not pursue multigun CRTs. We felt that we could achieve the performance levels we were seeking using conventional CRT technology, and that the cost of building a multigun CRT plus the complexity of the convergence mechanisms for multibeam designs would not yield a marketable product.

Having decided on CRTs, we started by designing 19-in. landscape-mounted horizontally swept displays. This flew in the face of tradition because increases in resolution usually first show up on short-scanned portrait-mounted CRTs, often in small bulb sizes. But our target markets were electronic publishing and CAD, both of which need lots of surface area. While

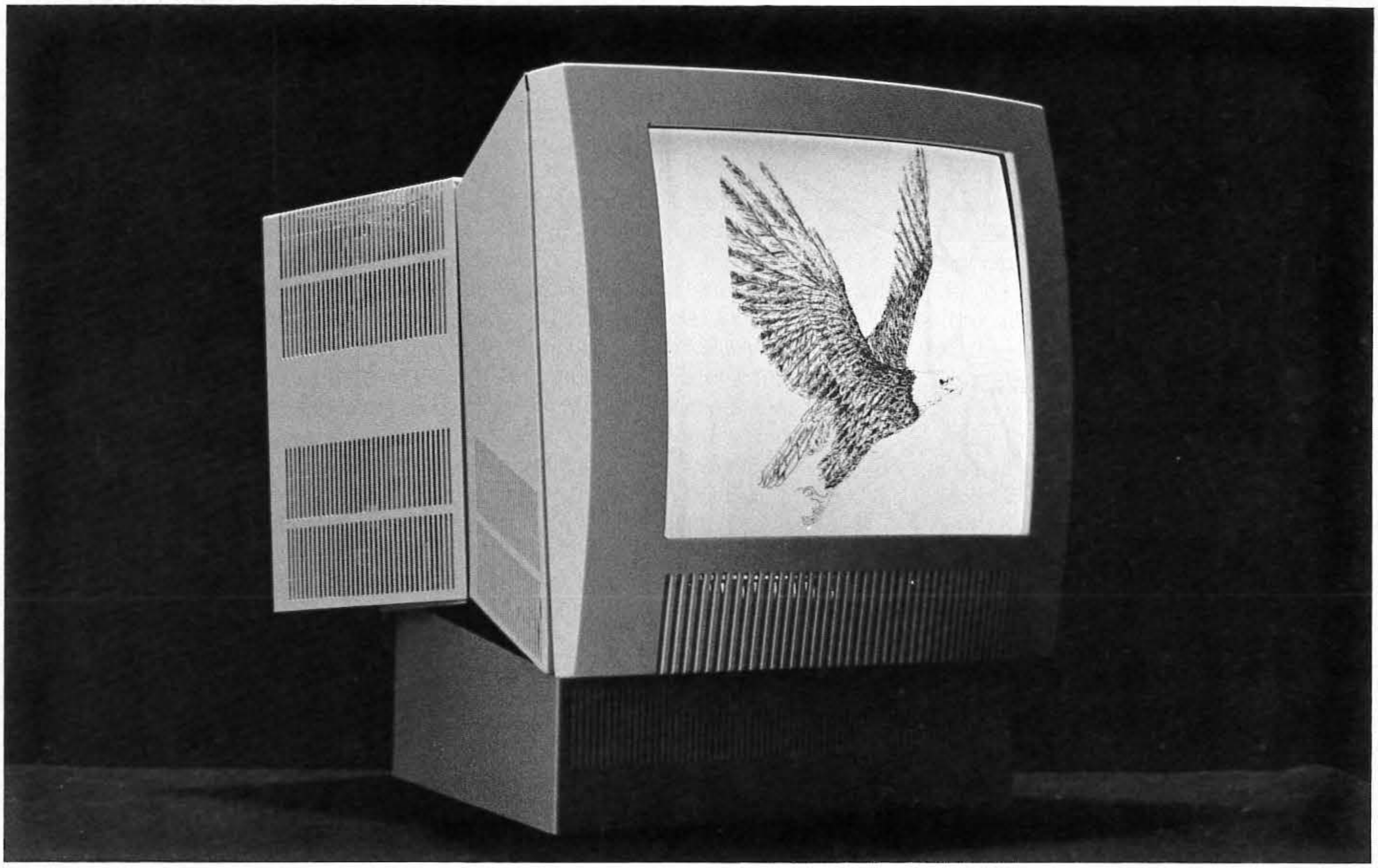


Fig. 1: The authors' 3300-line (300-dpi) interactive display is the highest resolution display commercially available. Its development presented interesting design problems.

we would have liked to start with color displays, we would have needed shadow-mask CRTs with 0.07-mm triad spacing, clearly not viable for mid-1980s production.

Although we were experienced display designers, we did not have any background designing CRTs themselves. Fortunately, Clinton Electronics, Rockville, Illinois, had begun the development of just the CRT we needed, using 19V90 glass (the same bottle used in most high-resolution 19-in. color CRTs). We were able to obtain some of Clinton's first prototypes to conduct our development.

Design problems

In most monochrome CRT displays, the spot size is about equal to the positioning accuracy of the sweep system. A typical 1280×1024 display on a 19-in. CRT has a 10-mil spot size matching its 100-dpi sweep. In most CRT typesetters, the beam is deliberately overlapped; that is, the beam diameter is larger than the positioning accuracy. Spot overlap is desirable when the observer can not resolve individual dots and when the width of features being drawn on the screen is greater than the diameter of the beam. A CRT's electron beam has approximately a Gaussian distribution of energy. When desired, overlap is usually considered ideal when the average energy of overlapped dots is uniform across a feature.

The Clinton CRT was originally intended for 2000-line systems and has a 5-mil spot diameter. We had to decide whether to search for a tube with a 3-mil spot size or use the Clinton tube. A nonoverlapped display renders small objects more precisely, while an overlapped display provides smoother edges.

Deciding which way to go involves aesthetic and philosophical considerations, and the best decision for a given set of applications is often not clear-cut. The case for a nonoverlapped system becomes stronger when the individual dots are clearly visible. We found that for most people, 3-mil dots aren't. (Some people can see a single 3-mil black dot on a white background at 27 in., but it's hard to find.) We therefore decided that spot overlap would be desirable on a 300-dpi display. The final design has the original 5-mil beam diameter and 3.3-mil positioning accuracy for a nearly ideal Kell factor of 67%. (It is also true that the tube existed, and 5 mils was the smallest beam diameter we could find in an inexpensive and readily reproducible design.)

Another early specification was a vertical refresh rate greater than 70-Hz noninterlaced. (Noninterlaced refresh is a requirement in our markets.) Although it has become acceptable to call 60-Hz noninterlaced displays "flicker-free," a large percentage of the population can see flicker at 60 Hz in peripheral vision when P4-type phosphors are used. A 19-in. CRT viewed at 27 in. covers more than central cone vision, and most people see some flicker. Raising the rate to over 70 Hz eliminates flicker, even peripheral vision flicker, for more than 95% of the population. We have confirmed this at trade shows—although most people do not perceive any flicker on our 72-Hz displays, we always find a few people out of a hundred who do.

Having set the resolution, the tube size, and the refresh rate, a quick calculation shows that we needed a quarter of a

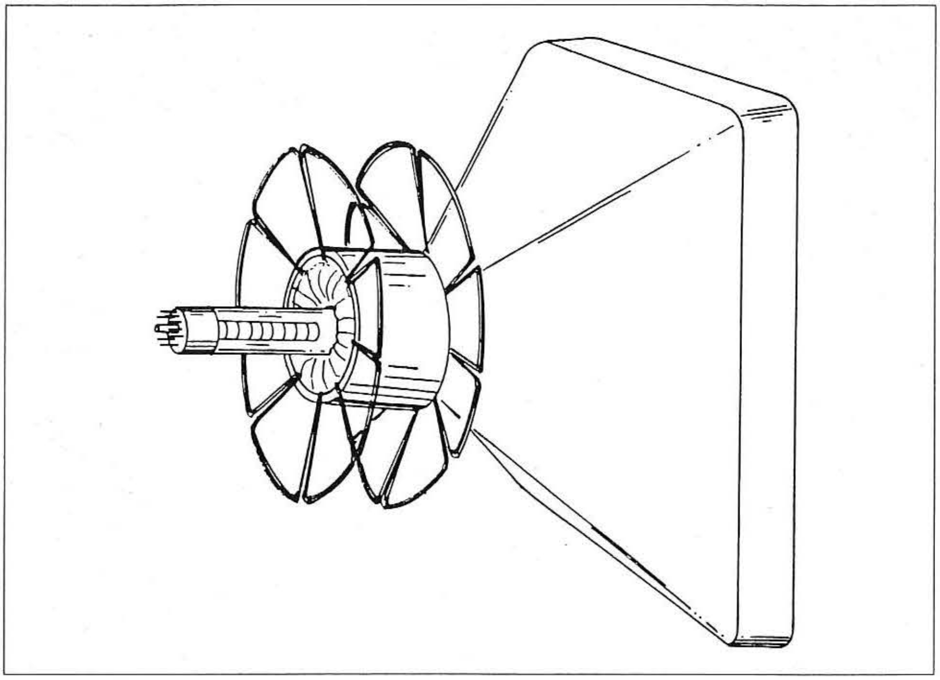


Fig. 2: A new technique for cooling the yoke was developed for the 3300-line display and has been patented. An extra winding interweaves with the deflection coil and acts as a heat radiator.

megacycle horizontal sweep rate. Using 5% vertical retrace overhead, 3300 scan lines at 72 Hz is about 250 kHz (our actual sweep rate is 244 kHz). The challenges of the horizontal sweep circuit are numerous.

Line-to-line positioning repeatability needs to be very small: we have found that we require less than one tenth of a pixel peak-to-peak jitter. In our system, this means less than 67 psec. Therefore, the horizontal oscillator needs to be a very-low-noise design. We chose to use an LC oscillator running at 1.25 MHz. The subsequent 5:1 division was helpful in the design of the low-voltage switching supply, which also runs at 250 kHz as opposed to some submultiple. If the low-voltage supply does not operate at the fundamental of the horizontal sweep rate, any ripple can easily cause displacements in sequential scan lines.

We chose to keep costs down and to contain the already high power dissipation in horizontal sweep circuitry by using a rather conventional resonant flyback design, although operating at 244 kHz. The monitor's horizontal period is 4.096 μsec and the retrace pulse is about 1.2 μsec, or 29%, with the blanking period 1.365 μsec.

The vertical waveform generator maintains linearity to much better than 1%, and no vertical linearity adjustment is needed. Because the screen has 3300 scan lines, the waveform generator and vertical amplifier must maintain much lower noise levels than the conventional single-chip vertical ICs that are now popular for display designs.

Although the circuit design for the deflection amplifiers is interesting, the hardest problem we faced in the deflection system was yoke cooling. We have worked hard to reduce the yoke losses to the lowest possible level, yet we are still dissipating a great deal of power in the yoke. New ferrites are being developed for the switching power supply industry and these will be useful for higher speed yoke designs. For the present, we are using conventional materials.

Minimizing noise

An early requirement was established that no fan, motor, or other noise-producing element was to be tolerated in the monitor. This requirement, which was steadfastly adhered to over many incarnations of the yoke design, lead us to a new patented technique for yoke cooling [Fig. 2]. The yoke includes an extra winding, interwoven with the deflection winding that loops in and out of the core. The loops extend away from the yoke for several inches. This winding acts as a heat sink, bringing the hot spot temperature of the yoke to less than 65°C above room ambient (not enclosure ambient) without disrupting the magnetic field.

The video amplifier also occupied a great part of our design time. The video data rate on our 4096 × 3300 monitor is 1.5 GHz, or 670 psec/pixel. At this frequency, the physical characteristics of the CRT become an integral part of the circuit. Reactance of the gun elements themselves is part of the final-stage video amp design.

The CRT base plug provides connections to all structures of the gun. We found it unnecessary to modify the basic tube design to provide special access to the grids.

The bi-potential gun in the CRT requires conventional 30-V drive, with which we get substantially more than the specified 45-fL light output on production monitors. The video amplifier design does not attempt to reproduce any harmonics of an alternating pixel video input. The fundamental is sufficient, especially with spot overlap, which seems to help here. Single-pixel dark vertical lines on a white background are quite visible on the screen.

Sending a signal to the video amplifier is often considered a problem, with differential delay distortion in the transmission line thought to be the underlying cause. Many designs for high-performance monitors have resorted to sending multisignal digital data to a neck-mounted video system, and some designs even have a DAC mounted on the neck. We have found that with 10 ft. of reasonable quality coaxial cable, our video generator sends satisfactory signals to the video amplifier using a composite sync, RS-170 style signal.

Meeting shielding requirements

Shielding issues figured prominently in the design and were among the most difficult problems to solve. Most OEM suppliers of monitors furnish their products on a flat plate, leaving to the customer the task of meeting safety and EMI regulatory requirements. We felt that the frequencies and power levels of our design would make this task unmanageable, so our standard product is delivered in a metal chassis meeting all safety and EMI limits.

The problems of heat dissipation and EMI radiation drove the mechanical design. The requirements were for the smallest envelope that would meet the goal of operation at 42°C ambient with convection cooling and would pass FCC and VDE EMI requirements. Mechanically, the video amplifier completely encases the video amp and the tube neck. The enclosure has separate chimney effect structures for the deflection boards, the yoke, and the video amplifier.

Two aspects of the video generator are also interesting. One is the generation of a serial data stream at 1.5 Gbits/sec. To accomplish this, we designed a serializer module that accepts 8 pixels in parallel at 188 MHz. The module multiplexes the pixels into a serial data stream, at 1.5 GHz, superimposes the sync signal, and drives the coax. The system accepts a low-frequency (47 MHz) clock to which it phase locks the 1.5-GHz oscillator. The phase detector circuit on the video clock has to be capable of discriminating very small phase changes to meet the jitter specifications of the monitor. The pixels are buffered on the module before multiplexing to reduce skew in the data. The final digital stage of the serializer is a gallium arsenide (GaAs) shift register running at 1.5 GHz. Changing to a GaAs component from a satisfactory silicon predecessor was done late in the design cycle when a price reduction made the GaAs cost effective.

The display controller

MegaScan manufactures display controllers for its monitors because the requirements for 300-dpi displays exceed the performance of commercial controller designs. Although the data rate is high, creating the refresh signal is not particularly difficult when the serializer module is used. Video RAM technology and the newly designed video shift register ICs have made the job easier. The frame buffer, while large at 12×10^6 pixels, is not difficult. What is difficult is writing to the frame buffer at a sufficient rate to make interactive displays really interactive. Raising the resolution from 100 to 300 dpi raised the number of pixels on the screen by a factor of 9. The update rate of the display generator must also increase by nearly an order of magnitude for the dynamic performance to remain where it was.

For single-bit-per-pixel displays, the two primitive operations performed by a display controller are the RasterOp or BitBlt algorithm, which is a rectangular bit-copying operation, and the line-drawing algorithm. Current designs achieve RasterOp rates of $10\text{–}30 \times 10^6$ pixels/sec, while line-drawing rates are typically $1\text{–}3 \times 10^6$ pixels/sec. We have designed a set of gate arrays, using 8000-gate 1.5-μm CMOS technology, which performs RasterOp at $88\text{–}133 \times 10^6$ pixels/sec, and draws lines at 32×10^6 pixels/sec. We are able to achieve these rates by operating on patches of 8 pixels wide by 8 scan lines high in parallel. These 8×8 patches of pixels can be read or written to the frame buffer in a single cycle. RasterOp and line drawing operate at memory rates.

The controller includes a frame buffer of 2 or 4 Mbyte of video RAM, the gate arrays, a 68020 microprocessor, and a fiber-optic link. The link connects the controller, housed in the base of the monitor, to the host interface board. It runs at 100×10^6 bits/sec. Host interface boards for a variety of popular computer busses are available. We have thus far been unable to design a housing for the controller that does not require a fan blowing air across the memory and logic for operation at 42°C ambient, at an acceptable cost. Although we buried the fan in the middle of the monitor base, we were unsuccessful in making the system totally silent.

Putting it all together

The project was completed with two teams, one for the monitor and one for the display. The monitor team had one principal designer and one additional analog engineer who was added halfway through the project. A three-person controller design team produced the gate arrays from an architectural description to working silicon in 17 months using a Daisy PC/AT-based CAE system. The arrays all worked the first time, despite the fact that none of the hardware engineers had prior ASIC experience.

It took us a year longer than we anticipated to produce the display system, from our original investigations to manufactured product. When we started in 1983, we had anticipated a 1985 launch with 1986 production. We have, however, produced a product that meets or exceeds all of its original specifications. ■

Displaying the high seas

BY KENNETH WERNER

"ALL ENGINES STOP," says the nervous U.S. Coast Guard cadet. He is participating in a training exercise, and this is the first time he's had command of a ship's bridge. The 1000-ton cutter slowly and silently loses speed in the twilight. Harbor lights appear against the evening sky. The cadet anxiously sweeps his eyes from left to right over a full 180° and back again, keeping track of surrounding harbor traffic and the approaching dock.

The dock now looms close on the starboard bow. The cutter is traveling too fast. "Left full rudder," shouts the cadet, and the helmsman spins the wheel. The cutter slowly turns from the dock—too late.

But the expected jar of ship against dock doesn't come. There is no splintering of dock planking, no screeching of tortured metal. The cutter's "bridge" is not a bridge at all, but an elaborate $3.6-million simulator designed and built by Ship Analytics of North Stonington, Connecticut. All of the controls and instruments of the Coast Guard's two largest cutters are approximately where they would be on a real bridge, and all are actual units. But instead of controlling and monitoring real engines and a real rudder, they are connected to a sophisticated computer simulation running on a Digital Equipment Corporation VAX 750.

Ship simulators—compute quickly, move slowly

A hydrodynamic model of the ship being simulated is part of the software, so at the Maritime Training and Research Center in Toledo, Ohio, or at the Harry Lundeberg School of Seamanship in Piney Point, Maryland, loading different software can change the simulator's behavior from that of a ponderous 500,000-deadweight-ton supertanker to that of a small high-powered tug. At the U.S. Coast Guard Academy in New London, Connecticut (the site of our simulated docking accident), the medium-endurance 270-ft. Bear-Class cutter and the high-endurance 378-ft. Secretary-Class cutter are simulated.

The hydrodynamic model also incorporates the effects of wind, currents, tides, and for river navigation, the suction of nearby banks. The results of the model's calculations are seen through the simulated "windows" on the bridge—seven of them in Ship Analytic's "standard" top-of-the-line simulator called Pilotship. Since each window displays a 26° horizontal field of view, the total field is slightly more than 180°. In current models, the image for each window is generated by an unmodified Arcturus red-green-blue video projection unit. Each unit projects onto the back of a ground-glass screen. It is this image, seen from the front of the screen, that appears through the bridge window. The seven images are carefully coordinated, and the result is a sweeping panoramic display [Fig. 1].

In addition to the bow of the ship being simulated (the "ownship"), 2000–3000 objects can be simulated and displayed in real time. These objects include other ships, aids to navigation, docks and port facilities, geographical features such as islands and points of land, and architectural features such as church steeples—one of the mainstays of coastal piloting.

Water, water, everywhere

A 360° simulation is maintained. As the ownship is "turned," the windows apparently pan across an existing scene. In fact, if space and finances permit, the system can be expanded to provide a 360° field of view. Specific harbors and waterways can be simulated for pilot training.

The images have a typical high-resolution computer-graphics appearance. Each has a resolution of 1024 × 1024 and is displayed at 60-Hz noninterlaced. The size of the projected image varies from installation to installation. In one current project, each of the seven displays is 6 × 6 ft. Output to CRT monitors is possible for classroom exercises and for lower cost versions of the simlator. Although the display is updated every one sixtieth of a second, the graphic simulation requires about 2 seconds to respond to rudder and engine speed changes—essentially real time for shiphandling.

The origin of all this graphic activity is the host computer, which contains the hydrodynamic model and the interactive scenario that plays out on the bridge windows. In earlier versions of the Ship Analytics simulator (including the one at the Coast Guard Academy) the host is a VAX 750; in later versions it is a MicroVAX 2. The host computer drives two visual processors, also MicroVAXes in the current model. The visual processors control one General Electric Graphicon 1700 S image processor for

Kenneth Werner is the editor of Information Display.

Fig. 1: Part of the view from the "bridge" of a shiphandling simulator. The full display spans seven "windows" with a 182° horizontal field of view. The display changes in response to inputs from the bridge controls, takes into account wind, currents, tides, and the programmed characteristics of the ship being simulated.

each window display, and this sends the appropriate images to its video projector or CRT monitor.

The host computer also supplies the signals to the various bridge instruments: compass, rate-of-turn indicator, anemometer, fathometer, rudder-angle indicator, engine-order telegraph, etc. It can also present a radar display driver with a plot-position display of the same situation presented on the visual display.

An automatic data and control unit reads the inputs from the bridge controls and feeds them to the host computer, which correlates the data with the hydrodynamic model and the programmed environmental parameters such as wind and tide. This generates appropriate changes in the simulated speed and heading of the ownship, the instrument readings, and the visual and radar displays. Mechanical casualties, such as the loss of an engine or rudder, can also be simulated.

The institutions using the simulators seem happy with them. Lieutenant Christine Quedens, chief instructor for the Coast Guard's simulator, told *Information Display* the simulator is extremely effective in teaching cadets to anticipate course and speed changes long in advance—necessary to accommodate the great momentum of a large ship. And experienced Coast Guard officers who have used the simulator for refresher courses before returning to sea after a period of shore duty have reportedly been impressed.

Sophisticated modeling and computer control are at the heart of this simulator, but its unique "feel" is clearly the result of its panoramic display. And that display results from the imaginative use of familiar display hardware and sophisticated visual processors. ■

The dock looms close to starboard. "Left full rudder," shouts the cadet and the helmsman spins the wheel—too late. But the expected jar doesn't come. The cutter's "bridge" is not a bridge at all, but an elaborate $3.6-million simulator.

Vision

by David Marr
397 pp. New York: W.H. Freeman and Co.
$23.95 paper.

Reviewed by GERALD M. MURCH

In our fast-paced high-tech world, the insights, events, and discoveries of five years ago are about as newsworthy as pre-Copernican theories of astronomy. Why, then, in 1988 print a review of a scientific work written in 1980? Either the reviewer was very late with his assignement, or— as is clearly the case with David Marr's *Vision*—the book was published years before its time. Sadly, when science catches up to Marr, the opportunity for dialogue will be gone; the author of this challenging work died before it was published, his life cut short by leukemia at the age of 34.

In *Vision,* Marr develops a concept that has appeared from time to time in the history of visual science as an untestable model—the idea that vision is an active, not a passive, process. Perceptual psychologists such as Fred Attneave and James J. Gibson have suspected that vision is more than the passive infringement of light on a complex receptive system. The reason is that our visual system seems expressly designed to extract meaningful information about the external world from the array of light presented to it. But it was Marr who took the information extracting idea one step further and turned an interesting concept into a testable hypothesis. His unorthodox vision of vision will continue to challenge designers of imaging and display systems for years to come.

Marr's perspective on the visual process was shaped by his background in computer science and artificial intelligence. The distinction between what a computer program does and how it does it has never been taken seriously, but it is this fundamental distinction that makes artificial intelligence a plausibility and points the way to a new approach to perception. Knowing how a computer is put together is very different from understanding the nature of computation. Similarly, says Marr, vision can only be understood as a *process.* The neurophysiology of the visual system must be seen in the context of the information extracting process of perceiving. There are three levels to any information processing task, whether it is performed by a computer or by the human eye and brain:

1. Computational theory (What is the goal of the computation?)
2. Representation (How can the computational theory be implemented?)
3. Hardware (How can the representation be physically realized?)

For Marr, this analysis dictates a process view of vision: "The nature of the computations that underlie perception depends more upon the computational problems that have to be solved than upon the particular hardware in which their solutions are implemented." More simply: "Trying to understand perception by studying only neurons is like trying to understand bird flight by studying only feathers."

In the 1950s and 1960s, visual scientists searched for neural cells that responded to specific events in the environment. The assumption was that feature detectors responded to the fundamental building blocks of perception. Thus, edges and shapes were detected and recognized by matching them to stored representation. This approach raised a hope in the emerging AI community that a similar set of properly coded detectors could form the basis of pattern recognition machines. Yet the effort proved overly optimistic, since so much of perception depends upon context: the same circular shape can represent many different things. Furthermore, an enormous memory would be required against which the features could be matched for recognition. These failures, in turn, led scientists to doubt that human vision functioned in the assumed manner. After all, human memory is also limited.

Marr draws a lesson from this history: that the visual system has its own *goal* in processing external events. The goal is not to detect features and match them to stored representation; the goal is to extract useful information about the outside world. A frog's visual system is tuned to "seeing" small edible moving objects. A fly detector need not be postulated.

> *"Trying to understand perception by studying only neurons is like trying to understand bird flight by studying only feathers."*
> *—David Marr*

The extraction process occurs, according to Marr, via structured seeing *modules.* The random-dot stereograms of Bela Julesz demonstrate the way a 3D module works. Each eye sees an identical pattern of random black-and-white squares. On one pattern, a central segment is shifted by a prescribed number of dots. This produces the illusion of a square floating in space above a background. No meaning is assigned and nothing is recognized except depth. Marr's visual modules can be likened to mathematical symbols which we can manipulate to perform certain tasks. Just as arabic numerals facilitate multiplication and roman numerals inhibit it, so visual modules can either facilitate or inhibit the process of information extraction. Marr sees the modules, or symbols, as patterns of light intensity falling on the retina, where are translated into neural representations to become the computational stuff of vision.

The visual system's first task is to create a *primal sketch* of an event. Particular calculations performed at this point impose constraints upon vision. In color perception, for example, images are analyzed for the amount of red or green or the amount of yellow or blue they contain. An image can be seen as a combination of the two color channels but not as a combination of colors within the same channel. Therefore, we can perceive greenish yellow but not reddish green. The primal sketch model, states Marr, also explains why we can easily recognize

Gerald M. Murch directs the activities of the user interface research group at Tektronix, Inc., in Beaverton, Oregon. His current work emphasizes the visual and cognitive interface to displays.

rudimentary line drawings that contain only a few key elements of a complex object or event. Such simple drawings are rough sketches much like the primal sketches "drawn" by our visual system.

From the primal sketch, Marr suggests, the brain develops a *2 1/2 D sketch.* Numerous independent visual modules capture the 3D nature, shape, motion, and shading of the event, giving structure and location to the primal sketch. Again, specific constraints dictate the nature of the resulting perceptual experience. An example is the principle of *rigidity.* A square is projected onto a viewing screen and its sides systematically lengthened and shortened. Of the two possible visual experiences—a square changing in size versus a rigid square moving towards and away from the viewer—the latter is uniformly perceived.

The information contained in the 2 1/2 D sketch forms the basis for the final 3D perceptual experience. It is only at this stage, says Marr, that past experience is brought to bear to evoke a recognition or to confirm the lack of one.

The view of vision described by Marr offers a strong challenge to the passive feature detector model. It suggests numerous preprogrammed processing modes designed to help us extract the visual information we need to survive in our world. By explaining the specific constraints imposed upon the visual system and describing the modules that direct and select information, Marr's work gives direction to the designer of display systems. Perhaps Marr's greatest contribution, though, is in giving us a general framework (perhaps even a theory) of vision. So much of today's vision research is so specifically focused that the broader implications are lost. David Marr asks us to focus on the whole forest and not just on a specific tree. ■

have you read . . . ?

Compiled by HOWARD L. FUNK
IBM CORP.

"PLZT Electrooptic Materials and Applications—A Review," G.H. Haertling, *Ferroelectrics* (U.K.), Vol. 75, No. 1-2 (September 1987), pp. 25-55. *PLZT, the old-reliable for spatial light modulators, shutters, and filters, is reviewed.*

"Evidence for Field-Assisted Thermal Emission of Holes from Deep Mobility Gap States in Amorphous Semiconductors from Xerographic Dark Discharge Measurements," S.O. Kasap, M. Baxendale, and C. Juhasz, *Journal of Applied Physics,* Vol. 62, No. 1 (July 1987), pp. 171-173. *Good agreement is shown between experiments with amorphous Se-Te and a depletion discharge model for the dark decay of the surface potential.*

"A Photoconductor for Laser Printers," R.B. Champ, *Proceedings of SPIE International Society of Optical Engineers,* Vol. 759 (1987), pp. 40-46. *A photoconductor used in an IBM laser printer is characterized.*

"Matching Photoreceptor Response to State-of-the-Art Exposure Sources," M. Lutz, *Proceedings of SPIE International Society of Optical Engineers,* Vol. 759 (1987), pp. 35-39. *Various light sources and shutters are discussed.*

"Transparent Conductive Coatings for Electrophotographic and Electrostatic Imaging," I. Ritchie and J.B. Fenn, Jr., *Proceedings of SPIE International Society of Optical Engineers,* Vol. 759 (1987), pp. 30-34. *Metallic and oxide coatings compared.*

"Hard Copy Market Overview (Color Hard Copy," P.R. Testan, *Proceedings of SPIE International Society of Optical Engineers,* Vol. 759 (1987), pp. 54-61. *The title tells it all. By CAP, a well-known consulting firm.*

"Light Emitting Diode Array Electrophotographic Printers," E. Norman-Wilson, *Information Media & Technology* (U.K.), Vol. 20, No. 3 (May 1987), pp. 115-119. *TCOP (total-cost-of-printing) figures are developed for four popular light-bar printers.*

"Engineering Workstation: Some Thoughts on Its Future Form," P.F. Arthur, *Computer Aided Design,* Vol. 17, No. 3 (April 1985), pp. 115-116. *A requirements statement.*

"System Timing Sets Microprocessor Performance." R. Schopmeyer, *Computer Aided Design,* Vol. 26, No. 6 (March 15, 1987), pp. 67-70. *To cache or not to cache. The author, from Convergent Technologies, discusses this question for an 80286-based system.*

"CAE Station Uses Real Chips to Simulate VLSI-Based Systems," L.C. Widdoes, Jr., and W.C. Harding, *Electronic Design,* Vol. 32 No. 6 (March 1984), pp. 167-172, 174, 176. *Using a computer-aided engineering workstation for VLSI simulation.*

"The LCD Race in Europe Gets Hot," J.L. Schenker, *Electronics* (October 1, 1987), p. 36. *Thomson-CSF, General Electric, Olivetti, Philips are mentioned. Excellent table projects sales in units and dollars by market sector for 1987 and 1991.*

"Realization of a Large-Area Electroluminescent Display with Matrix Addressing for Full Video," E. Schlam et al., *Proceedings of the Society for Information Display: Selected Papers from the 1986 SID International Symposium,* Vol. 28, No. 1 (1987), pp. 31-35. *Our own Elliott Schlam describes a 512 × 640 video EL panel.*

"Ferroelectric Liquid Crystal Display Capable of Video Line Address Times," M.F. Bone et al., *Displays: Technology and Applications* (U.K.), Vol. 8 No. 3 (July 1987), pp. 115-118. *Multiplexing ferroelectric LCDs.*

"Using LEDs in Large Area Displays," T. Klein, *New Electronics,* Vol. 20, No. 8 (April 14, 1987), pp. 44-45. *A review of the state of the art.* ■

High-resolution matrix display

Finlux, Inc., introduces the Finlux MD640.400, a new high-resolution electroluminescent matrix display designed for high-end personal computers and instruments, factory terminals, and process controllers. Crisp stable flicker-free images in yellow are produced by a subwavelength-thin light-emitting EL phosphor layer. The Finlux EL display supports both high-quality text—from 25 lines of 80 characters—and detailed high-resolution graphics. It has square pixels at 12-mil pitch, equivalent to 83 lines/in. The solid-state EL panel and electronic board containing the drive and controlling electronics are assembled into a package

less than 0.5 in. thick. The package connects to a DC-DC converter, which can be mounted directly on the back of the display or close to the display. Connections between the display and the power supply are made through a flat ribbon cable. To assure reliability, the EL panel is produced with a proprietary atomic layer epitaxy (ALE) process developed by Lohja Corp. of Finland. Prototypes of the new product are available, and production shipments are scheduled to begin in the first quarter of 1988. Initial sample price, including the DC-DC converter, is $1650.

For further information contact Ismo V. Linden, Finlux Inc., 20395 Pacifica Dr., Ste. 109, Cupertino, CA 95014. 408/725-1972.

Circle no. 9

UV exposure systems

Optical Radiation Corp. announces a new family of high-technology collimated light-exposure systems for the printed-circuit-board fabrication industry. The Opti-Beam^R 7000 Series product line includes an entire family of UV photoexposure systems ranging from manual two-drawer hard vacuum-type trays to optional high-production soft-contact trays. In addition, systems are available that provide complete automatic load-unload operation, as well as machines that can accommodate registration cameras for precise phototool alignment. The Opti-Beam^R 7000 product line will accept film phototools with a 24 × 24 in. (610 × 610 mm) standard format; 18 × 24 in. (460 × 610 mm) or 24 × 30 in. (610 × 762 mm) formats are available. Precision optics and ORC's proprietary collimated light source provide for superior edge quality and image definition. This highly collimated UV light energy focused onto the photosensitive resist or solder mask

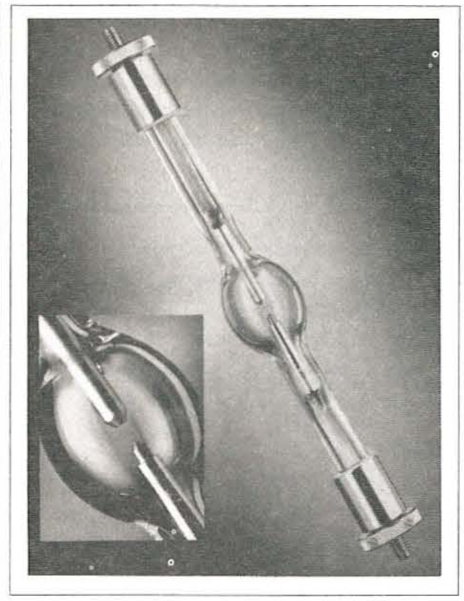
utilizes ORC's 5-kW short arc lamp light source. This highly concentrated collimated light energy allows fast exposures for cost-effective high production.

For further information contact Don Van Arnam, Optical Radiation Corp., 1300 Optical Dr., Azusa, CA 91702. 818/969-3344.

Circle no. 11

Short arc lamp

Optical Radiation Corp. introduces an ultra-stable 150-W xenon short arc lamp. Lamp performance is up to 10 times more stable and provides users with a lifetime up to four times industry standard. This light source is ideally suited for those applications where arc stability and lumen



maintenance are essential. The lamp is currently available in two different 150-W configurations, and the company plans to introduce 75- and 300-W configurations soon.

For further information contact Robert Fleming, Optical Radiation Corp., Lamp Div., 1300 Optical Dr., Azusa, CA 91702. 818/969-3344.

Circle no. 12

Image processing workstation

Perceptics Corp. announces the NuVision image processing workstation and software for the Apple Macintosh II. Each Smart Memory module contains a dedicated digital signal processor (DSP) on board with the frame buffer, which

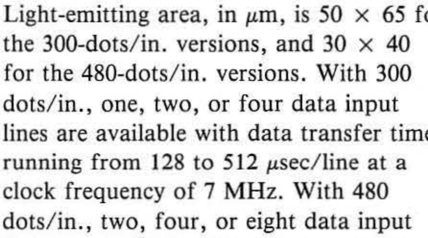
Circle no. 13

automatically increases processing power along with memory size. The architecture decouples acquisition, display, and processing functions, allowing speeds in excess of standard video rates. NuVision features flicker-free 1280 × 1024 24-bit true-color display; a pixel processor for real-time video arithmetic/logic and histogram computations; and an Apple Macintosh II workstation providing friendly user interface, image scanning, printing, and networking.

For further information contact Mary Ann Herrick, Perceptics Corp., 725 Pellissippi Pkwy., P.O. Box 22991, Knoxville, TN 37933-0991. 615/966-9200.
Circle no. 14

High-speed LED printhead

Rohm Corp's new RLH3012 and RLH4812 LED printheads offer 12-in. print widths; run at 300 and 480 dots/in., respectively; and feature high-speed imaging, vibration sensitivity, and consistent dot size and placement. LED bar length is 5.41 mm at 300 dots/in., and 6.77 mm at 480 dots/in. Emission intensity is 5.0 μW/steradian at 5 mA forward current. A selected resistor sets emission intensity to the desired level. The emission intensity dispersion variation is ±15% or ±30% in the 300 dots/in. version, and ±30% for the 480 dots/in. models. Two power connectors provide better power distribution. The printheads focus each element at a specific location, and an optional self-focusing lens is available to provide the desired focus point. Light wavelength is set at 660 ± 10 nm with a spectral width of 20 nm at half power points.



Light-emitting area, in μm, is 50 × 65 for the 300-dots/in. versions, and 30 × 40 for the 480-dots/in. versions. With 300 dots/in., one, two, or four data input lines are available with data transfer times running from 128 to 512 μsec/line at a clock frequency of 7 MHz. With 480 dots/in., two, four, or eight data input lines are available with data transfer times running from 100 to 400 μsec/line at a clock frequency of 7 MHz.

For further information contact Rohm Corp., P.O. Box 19515, 8 Whatney, Irvine, CA, 92718. 714/855-2131.
Circle no. 15

Gold-plated LCD pin terminals

Hamlin, Inc., has developed a gold-plated pin terminal for LCDs. The terminals accommodate military, airframe, and other applications where gold-plated termination is critical. The gold is Type I, grade C, class 0, and conforms to MILSPEC G45204. The gold is plated to a thickness of 0.000030 in. over a 0.000050–0.000100-in. nickel base. The precious-metal terminals can be supplied on all Hamlin standard and most custom DIL/SIL pinned LCDs.

For further information contact Walter Bruenger, LCD Div., Marketing Manager, Hamlin Inc., Lake and Grove Sts., Lake Mills, WI 53551. 414/648-2361.
Circle no. 19

Circle no. 21

Software design aid for thin films

Sound Decisions announces its new Multilayer Interference Program (MIP) software. The program was written to be used as an aid in the design or specification of multilayer coatings and the interpretation of ellipsometric data. It solves the electromagnetic boundary value problem to compute the reflection, transmission, absorption, and polarization properties of multilayer thin films with as many as 50 layers. The program can be used with or without a math co-processor (8087, 80287), and its graphics operate with either the IBM or Hercules monochrome graphics cards. It requires approximately 160K of memory for execution.

The data input screens and editing features make the program extremely user friendly. The program provides a spreadsheet-style data entry format that makes it very easy to construct and edit a multilayer structure and to specify tables of output data to be calculated. Output data files are written in a form suitable for importation into spreadsheet programs for further calculations or graphical presentations. Price is $134.

For further information contact Sound Decisions, 6646 Clearhaven Circle, Dallas, TX 75252-4020. 214/404-9445.
Circle no. 20

Editor's Note: This program will be reviewed in a forthcoming issue of ID. *We encourage software developers and publishers to notify us of new packages relating to display design and evaluation for listing in our new software section and to submit copies of software to be considered for review.* ■

Bay Area Chapter

SID Bay Area Chapter members welcomed **Gene Adam** of **McDonnell Douglas** to their October 27 chapter meeting. Mr. Adam's presentation, "Fighter Cockpits: Automating the Office," focused on military cockpit display technology.

Three-dimensional display technology was the focus of the November 19 meeting. Three speakers from StereoGraphics Corp. gave a demonstration of a stereoscopic TV system. StereoGraphics president **Lenny Lipton** spoke about the "Fundamentals of Stereoscopics and Multiplexer Technology." Vice president **Larry Meyer** and manager of electro-optics **Art Berman** gave presentations on "The Electronics and the Electro-optics of a Stereoscopic TV System."

Los Angeles Chapter

The June 24 SID Los Angeles Chapter meeting was a group effort by **Gerry Gabel, Lisa MacKenzie,** and others from **Pixar Co.** The team demonstrated and discussed the Pixar Image Computer (PIC).

Mid-Atlantic Chapter

"Current Trends in LCD Technology" was another group effort, this time from **IBM** at the November 10 meeting of the SID Mid-Atlantic Chapter. **Webster Howard** stressed the increasing impact of LCDs. **Hiap L. Ong** discussed LC material breakthroughs, particularly in supertwisted nematics. **Kei-Hsuing Yang** reviewed ferroelectric LCD advances and important papers from the First International Symposium on Ferroelectric LCs.

Minneapolis-St. Paul Chapter

Tom Petschauer, vice president of **Printware, Inc.,** hosted the SID Minneapolis-St. Paul Chapter's October 23 meeting. Chapter members toured and witnessed a demonstration of Printware's facilities.

Upcoming meetings and speakers include:

Jan. 22. Tom Werner
Feb. 26. Bob Shurson
Mar. 26. Richard Jamieson
Apr. 23. Vernon Born
May 21. George Huard

UK and Ireland Chapter

On November 10 the SID UK and Ireland Chapter elected the following officers for 1987-1988: **Neil Bartlett,** chairman; **Harry Ellis,** vice chairman and meetings organizer; **Derek Washington,** secretary and newsletter editor; and **Barbara Needham,** treasurer. The chapter also elected the following committee members: **Laurie Allard,** meetings registrar; **Stephen Elmer,** membership secretary; **Daphne Lamport,** committee secretary; and **David Marshall** and **Ian Shanks,** committee members.

The February 18 chapter meeting on "Hard Copy" will include the following topics: xerography, thermal transfer, film from computer, laser printing, military applications, newspaper applications, and hardware.

Upcoming meetings include (revised schedule):

Feb. 18. "Hard Copy"
Mar. 21. "Display Industry"
Mar. 29-30. "Color in Information Technology and Visual Displays" (joint meeting with the Institute of Electronic and Radio Engineers)
May-June. "High-Information Content" (joint meeting with IEE)
July 18-19. Annual general meeting, "LCDs for TV"
Oct.-Nov. "Military and Civilian Vehicle Displays" ■

calendar

January

Second International Conference on Computer Workstations. Patrick Mantey, 335A Applied Science Bldg., Dept. of Computer Engineering, Univ. of Calif. at Santa Cruz, Santa Cruz, CA 95064.
Jan. 31–Feb. 3 Santa Clara, CA

Medical Imaging II. SPIE, P.O. Box 10, Bellingham, WA 98227-0010. 206/676-3290.
Jan. 31–Feb. 5 Newport Beach, CA

February

1988 SCS Multiconference. Simulation Councils, Inc., P.O. Box 17900, San Diego, CA 92117-7900. 619/277-3888.
Feb. 3–5 San Diego, CA

The International Conference on Technology Management. Tarek M. Khalil, Chair, Dept. of Industrial Engineering, Univ. of Miami, P.O. Box 248294, Coral Gables, FL 33124. 305/284-2344.
Feb. 17–19 Miami, FL

Fourth Annual Computer Graphics New York. Exhibition Marketing and Management, Inc., 8300 Greensboro Dr., Suite 1110, Mc Lean, VA 22102. 703/893-4545.
Feb. 22–24 New York, NY

Flat Panel and CRT Display Technologies—Short Course. UCLA Extension, P.O. Box 24901, Los Angeles, CA 90024. 213/825-1047.
Feb. 22–26 Los Angeles, CA

March

Hannover Fair CeBIT '88. Hannover Fairs USA Inc., 103 Carnegie Center, P.O. Box 7066, Princeton, NJ 08540. 609/987-1202.
Mar. 16–23 Hannover, W. Germany

NCGA '88. Bob Cramblitt or Nancy Flower, National Computer Graphics Assn., 2722 Merrilee Dr., Suite 200, Fairfax, VA 22031. 703/698-9600.
Mar. 20–24 Anaheim, CA

Fourth International Congress on Advances in Non-Impact Printing Technologies. SPSE, 7003 Kilworth La., Springfield, VA 22151. 703/642-9090.
Mar. 20–25 New Orleans, LA

India Computer Graphics. Tara S. Ganguli, Technology and Research Associates, 5 Lindsay St., Calcutta 700087, India. (033) 29-9420.
Mar. 22–25 New Delhi, India

World Congress on Computing/Interface '88. The Interface Group, Inc., 300 First Ave., Needham, MA 02194. 617/449-6600.
Mar. 28–31 Chicago, IL

Second International Conference on Color in Information Technology and Visual Displays. Conference Secretariat, IERE, 99 Gower St., London WC1E 6AZ, U.K. 44-1-388-3071.
Mar. 29–30 Surrey, England

Call for Papers

"Toward the 21st Century's Television," short paper contest sponsored by the Institute of Television Engineers of Japan. The contest's sponsors hope to encourage young scientists and engineers to think about the year 2000; therefore, the contest is limited to applicants under 40. Papers should focus on future devices and technological trends in television engineering. Best and Outstanding Paper Awards of $3000 and $1000 will be given at the ITE National Convention, July 1988, in Tokyo, Japan. Manuscripts should have "Toward the 21st Century's Television" as the title and the author's paper topic as the subtitle. Include full author name; birth date; nationality; affiliation and related work field; and complete work address with telephone, telex, and facsimile numbers. Papers can be up to 2000 words in length; should be typewritten, double-spaced, on A4 paper; and may include figures and tables. Send two copies to 35th Anniversary, ITE Short Paper Contest, the Institute of Television Engineers of Japan, Kikai-shinkou Building, 3-5-8 Shibakouen, Minatoku, Tokyo 105, Japan.
Deadline: March 15 ■

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