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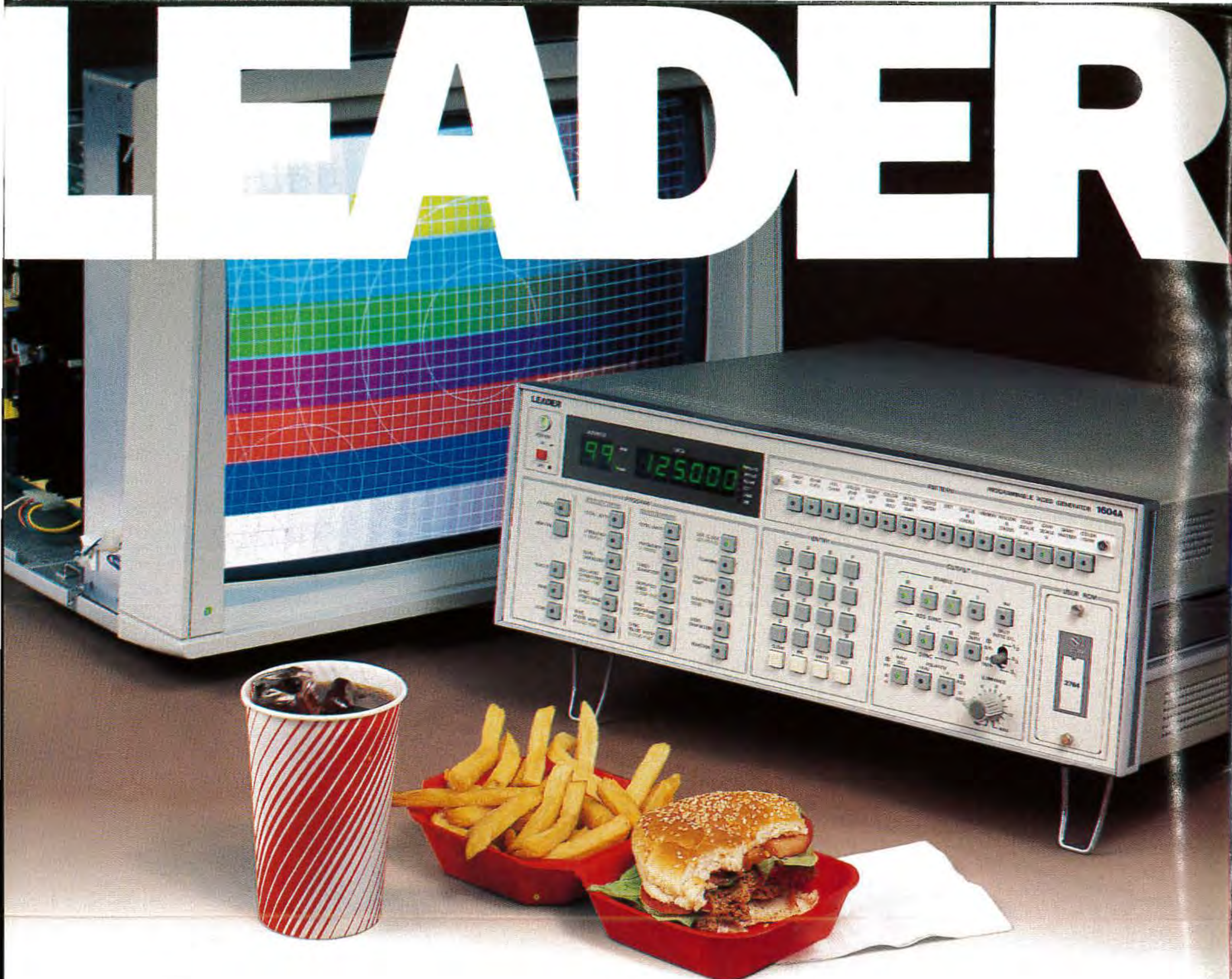
INFORMATION DISPLAY

March 1988
Vol. 4, No. 3

PS/2 graphics
Image processing primer
SID '88 preview



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Cover: Trailing mandrill image was created by raster copying at a speed of 12.5 million pixels per second using a Matrox PG2-1281 graphics processor. Image is displayed at a resolution of 1280 × 1084 on the Mitsubishi HG6905 monitor. *(page 6)*

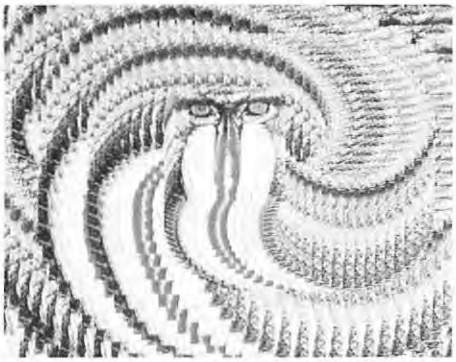

Photo: Matrox Electronic Systems

Next Month in Information Display

Image Science Issue

- DVI—digital video from a CD-ROM
- Displaying the Gospels
- The new ac plasma technology

References to early LCD work are misleading

In your November issue, you published an article by Thomas Credelle entitled "Recent Trends in Color Avionic LCDs," which has references to the early work on liquid crystals and active-matrix displays that misleadingly convey the impression that all the significant early work on active-matrix LCDs was carried out at RCA Laboratories.

His reference to Heilmeier's 1968 paper on dynamic-scattering LCDs is unobjectionable, but certainly the article should also have referred to the basic paper by Schadt and Helfrich (*Appl. Phys. Lett. 18*, 127, 1971), which is the first publication on the now universally used twisted-nematic principle.

Further, Mr. Credelle states: "To make high-resolution color LCDs, the active-matrix approach was proposed and demonstrated in the early 1970s," and gives as his reference a paper by Paul Weimer (*RCA Rev*, *32*, 251, 1971). If any of your readers follow up this reference, they will be surprised to find that Weimer's paper is entitled "Systems and Technologies for Solid-State Sensors" and contains not a single solitary reference to displays, LCDs, active matrix, or color!

—T. Peter Brody, President
Active Matrix Associates
Pittsburgh, Pennsylvania

The author replies—

In my article "Recent Trends in Color Avionic LCDs," I included a short list of references to indicate to the reader when TFT-LCD technology development began. It was not my intent to mislead the reader or give undue credit to RCA Laboratories.

Dr. Brody, who was one of the early pioneers of CdSe TFTs and TFT-LCDs, has correctly pointed out that the Heilmeier work was on dynamic-scattering LCDs and not on twisted-nematic LCDs, which were developed by Schadt and Helfrich three years later. It was the Heilmeier work that started the LCD development, however, so this is an appropriate reference to the beginnings of the LCD revolution.

Dr. Brody correctly points out that the Weimer reference is not the complete story on early TFT array development; the first published paper on TFTs was by Dr. Paul Weimer in 1962 ("The TFT—A New Thin-Film Transistor," *Proc. IRE, 50*, 1462, 1962). The paper referenced in my article was a review of the first *TFT arrays* (albeit for image sensors and not displays), the forerunner to all modern TFT-addressed LCDs. The concept for TFT-addressed LCDs was published in 1971 by B. Lechner et al. ("Liquid Crystal Matrix Displays," *Proc. IEEE, 59,* [11], Nov. 1971, p. 1566); the first operational TFT-LCD was described by A. Fischer et al. in 1972 (*IEEE/SID Conference Record*, Oct. 1972, p. 64).

—Thomas L. Credelle, Manager
Display Program
General Electric Corporate
Research and Development
Schenectady, New York

What is your opinion? ID*'s editors welcome letters from readers on specific articles or topics of general interest to the display community. Write to the Editor, Information Display, c/o Palisades Institute for Research Services, Inc., 201 Varick St., New York, NY 10014.*

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editorial

Those of us who live where it's been cold are looking forward to spring; those of you who don't are probably feeling pleased with your good judgment. But whether you see melting snow through your window or swaying palm trees, spring is the traditional season for looking forward and embarking on new initiatives. In this issue, we do a little of both.

Our new initiative stems from the increasing difficulty we face in treating display hardware independently of the communications, computing, graphics, and imaging systems of which it is a part. In fact, we do not believe we would be serving you well if we tried to maintain a rigid separation. Therefore, we plan to increase coverage of imaging and graphics, particularly, in forthcoming issues of *Information Display*. This month, we try to bring some order to the welter of de facto graphics standards established for IBM-compatible personal computers. We do this both for its own sake and to provide the background for answering a current question. How significant an improvement is the VGA graphics of IBM's new PS/2 family of personal computers, and is it good enough for engineering and graphic workstation applications? There is an obvious connection to display design, and the article touches on it.

For those who regard the field of imaging as a bewildering profusion of add-in boards performing incomprehensible functions, we present a very brief introduction to imaging basics. We will get more sophisticated as time goes on and as you tell us what aspects of these fields you would like us to cover in particular depth.

The look forward is to the week of May 23 in Anaheim, California, where the Society for Information Display will hold what promises to be its largest international technical symposium since the society was founded. Our third article previews the symposium's technical highlights.

—Kenneth I. Werner

PS/2 graphics: fight or switch?

BY SUSAN VERRECCHIA

When IBM introduced the PS/2 line of personal computers in April 1987, the advantages cited for the models 50 and 60 over their PC-AT predecessor and the new Intel 80386-based model 80 were a new internal microchannel bus tailored for multiprocessing, the new OS/2 operating system, and improved graphics with the new standard video graphics array (VGA).

Few people doubt that OS/2 will become a popular operating system, but it is so new that we've yet to see applications programs designed to run under it. Without OS/2, the microchannel bus's reputed advantages are not evident, and some of IBM's competitors question that bus's performance versus alternative approaches. That leaves the VGA graphics as the PS/2's greatest distinguishing feature for the near term.

How does VGA stack up against the preceding PC graphics standards that now compete with it? With third-party manufacturers currently building VGA chips and boards for ATs, is upgrading an AT to VGA standards attractive for people who need VGA quality? Finally, is VGA itself adequate for professional engineering, graphics, and imaging applications, and what can add-on graphics boards provide in the way of better-than-VGA levels of quality?

Early standards

The history of PC graphics "standards" is short but complicated. Today's de facto standards originated when IBM unveiled the personal computer in 1981. Two video modes were available on separate add-in boards. Users interested in graphics purchased an IBM color graphics adapter (CGA) card and an IBM color monitor. Those doing accounting and other numeric or text applications generally bought a monochrome system that included a monochrome display adapter (MDA) card and a monochrome monitor.

In the early 1980s, PC graphics referred almost exclusively to games. What developed into the CGA standard was originally intended for home and game use, rather than business use, and that explains many of its shortcomings. CGA operates in two resolution modes – graphics and text-only. Text-only mode provides a resolution of 640 × 200 and two colors, from a palette of 16. The graphics mode offers two groups of four colors each, at a resolution of 320 × 200. The CGA's 8 × 8 character box gives text and numerical data a grainy appearance, reducing character legibility.

The MDA solution provides a text-only resolution of 720 × 348 and does not generate graphics. The monochrome system has gained more popularity than the color system, largely because of its lower cost and greater text legibility. The MDA's character box is 9 × 14 compared to the CGA's 8 × 8. With more pixels to work with, the basic character cell can be more dense, making it more readable.

Hercules standard

Hercules Computer Technology addressed the limitations of CGA and MDA and fulfilled the requirements of Lotus 1-2-3 by introducing a monochrome system that provides text and graphics resolutions of 720 × 348 on monochrome displays. Users of the IBM monochrome display adapter had only to replace their MDA card with a Hercules card to obtain a previously unavailable 720 × 348 graphics resolution. The reasonable resolution and low cost of the Hercules card and compatible monochrome monitors were (and still are) appealing to a wide variety of users. The original Hercules card can be obtained for $249.

EGA standard

In 1984, IBM responded to the demand for higher-resolution graphics and more colors with the enhanced graphics adapter (EGA).

To maintain compatibility with original CGA programs and monitors, the IBM enhanced graphics adapter can drive a monitor at either the CGA horizontal scan rate of 15.75 kHz or an enhanced scan rate of 21.85 kHz. EGA supports 12 video modes whose availability depends upon the amount of memory installed on the board. The display's sharpness of detail is directly related to the technical capabilities of the monitor and the graphics adapter.

The best results are obtained from an EGA card that contains 128K memory and an enhanced graphics display (or equivalent) that can generate *mode 16* and provide a 640 × 350 image in 16 colors, from a palette of 64. Text and data characters are formed in a matrix of 8 × 14 pixels for greater readability than is available from CGA's 8 × 8 character matrix.

Susan Verrecchia is marketing promotions coordinator at Matrox Electronic Systems, Dorval, Quebec, Canada.

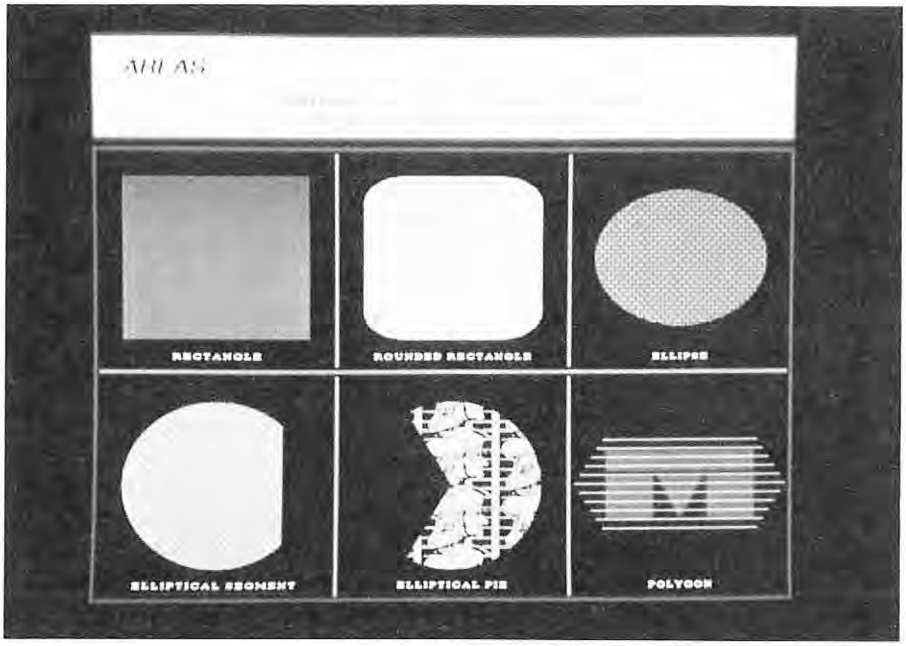


Photo: Matrox Electronic Systems

Fig. 1: Most standard graphics adapters for IBM and compatible personal computers, including VGA, are "dumb" frame buffers. More money can buy an "intelligent" graphics processor that executes graphics primitives on board, resulting in greater speed and less load on the central processor. A few of the area primitives that can be drawn by the Matrox PG2-1281 are shown above. Two hundred fifty-six colors can be displayed simultaneously from a palette of 16.7 million.

The popularity of EGA has stimulated third-party development of EGA-compatible boards, most of which contain the Chips and Technologies four chip set. This chip set offers CGA and MDA emulation, as does IBM's EGA card, and also provides Hercules graphics emulation. These compatible boards generally contain a minimum of 128K, enabling a user to get 16 colors from the high-resolution mode 16 and to use a 512-character set in text modes. EGA board prices range from $300 to $600.

During the past two years, *enhanced EGA* or *EGA plus* boards have appeared. These boards offer higher resolution and better text readability than standard EGA boards. The development of these video adapters was spurred by the introduction of multiscan monitors, which can automatically adjust their horizontal scan rate over a wide range to match the rate of the adapter card. Multiscan monitors can handle CGA, EGA, PGC, and sometimes VGA adapters in both digital (TTL) and analog modes, making it unnecessary to purchase a separate monitor that is compatible with each video adapter's scan rate.

These multiscan monitors have various resolution capabilities. The NEC MultiSync can display up to 800 × 560 pixels and the Sony Multiscan up to 900 × 600. Eventually, multiscan monitors capable of displaying resolutions up to 1280 × 1024 and higher will become available, enabling high-end graphics processors to utilize their graphic resolution abilities.

Vendors of video adaptors soon realized that it wasn't too difficult to produce an EGA board that could achieve a higher resolution than the standard 640 × 350. Consequently, users can purchase enhanced EGA boards that are EGA 640 × 350 compatible and can also display graphics and text resolutions of 640 × 480. Some enhanced EGA adapters can display 742 × 410 pixels and others as many as 800 × 600 pixels. These enhanced EGA boards, however, require customized drivers for the relatively limited number of software applications supporting 640 × 480. The majority of programs, which do not support the higher resolution, operate at standard EGA resolution.

In addition to higher resolution, enhanced EGA boards offer improved text capabilities over EGA boards because their character cells contain as many as 9 × 14 pixels versus EGA's 8 × 14. They can also display either more columns, more rows, or more of each, making the boards extremely useful for word-processing and spreadsheet applications.

Although enhanced EGA cards have distinct differences, including prices ranging from $395 to $795, they all have several features in common. They all contain 256K bytes of video random access memory (RAM) and can emulate CGA, MDA, and Hercules; they all offer 640 × 480 resolution in addition to the standard 640 × 350 modes, in 16 colors; and they all can operate on a multiple-scan-rate monitor.

PGA standard

The year 1984 also saw the introduction of the professional graphics adapter (PGA), designed and manufactured for IBM by Vermont Microsystems to satisfy the needs of high-end graphics users.

The PGA, commonly referred to as the PGC, is an "intelligent" board that performs some graphics functions on board. It is capable of providing a 640 × 480 graphics resolution and 256 colors from a color palette of 4096. But the modest video improvements relative to EGA combined with the several-thousand-dollar price tag for board and compatible monitor have sharply limited its use.

PS/2 standards

IBM's PS/2 series has contributed a new set of graphics standards to the video industry because these computers contain graphics adapters as standard motherboard features. These video adapters have a graphics resolution of 640 × 480 pixels and text-mode character boxes of 8 × 16 or 9 × 16. The adapters and monitors use analog signals and can generate 64 values for each of the red, green, and blue primaries for a color palette of 262,144 colors, of which 256 can be simultaneously displayed. Unfortunately for users, the improved color and resolution capabilities offered by the PS/2 series are virtually unsupported by applications programs and will remain so for some time to come.

IBM's low-end models 25 and 30, based on the Intel 8086 microprocessor, do not contain the microchannel bus and can be seen as faster replacements for the old PC-XT. They contain the multicolor graphics adapter (MCGA), which emulates the two graphics modes of CGA and provides two others: 300 × 200 resolution with 256 colors or 640 × 480 with two colors. In text mode, the MCGA offers 16 colors and an 8 × 16 character box. MCGA does not offer EGA com-

Table 1: PS/2 Models

	Model 25	Model 30	Model 50	Model 60	Model 80
Base price*	$1150	$1695	$3595	$5295	$6995
Bus architecture	XT	XT	MCA	MCA	MCA
Processor	8086 8 MHz	8086 8 MHz	80286 10 MHz	80286 10 MHz	80386 16 MHz 20 MHz
Number of available expansion slots	2- 8-bit	3- 8-bit	3- 16-bit	7- 16-bit	4- 16-bit 3- 32-bit
Video modes	CGA MCGA	CGA MCGA	MDA CGA EGA VGA 8514A	MDA CGA EGA VGA 8514A	MDA CGA EGA VGA 8514A
OS/2 compatibility	No	No	Yes	Yes	Yes
Monitor compatibility	8503 8512	8503 8512	8503 8512 8513 8514	8503 8512 8513 8514	8503 8512 8513 8514

*Monitors are not included in base price of computers.

patibility and, until vendors offer specially modified versions, MCGA users can only obtain CGA resolution. Two IBM analog monitors are available to run MCGA graphics: the 8503 monochrome monitor ($250) and the 8514 color monitor ($595).

The Intel 80286-based models 50 and 60 and the 80386-based model 80 contain a VGA video adapter on the motherboard. VGA can run applications designed for the previous video modes if they follow the rules of IBM's basic input-output system (BIOS). With its horizontal scan rate of 31.5 kHz, VGA adds new color modes: a resolution of 640 × 480 in 16 colors and 320 × 200 in 256 colors.

The new adapter is expected to broaden the use of color in mainstream business applications, such as spreadsheets, and replace EGA as the dominant graphics standard in the PC market. Dataquest predicts that IBM's VGA chip shipments will rise from 1.2 million units in 1987 to 3.1 million in 1989. During the same time, EGA chip shipments are expected to fall steadily from 1.1 million to 150,000 units per year.

Waiting for OS/2

The improved color and resolution capabilities of VGA figure prominently in the design of MS-OS/2 (Microsoft Operating System 2), the operating system for the 80286- and 80386-based PS/2 computers. MS-OS/2 supports multitasking and networking capabilities, and will eventually include a graphical windowing environment called the Presentation Manager. When new applications software appears, much of it will take advantage of the VGA's graphics capabilities. But the first version of OS/2, without the Presentation Manager, was not shipped until December, so it will be a while before applications software taking full advantage of OS/2 is available. It is not necessary to buy a PS/2 computer to take advantage of OS/2 and VGA. Zenith and Compaq, among other companies, are releasing their own licensed versions of OS/2 that will run on their 10-MHz 80286-based computers containing 5 Mbytes of memory. These versions, like IBM's, will not immediately include a graphical windowing environment, but it is likely that future releases for 80286- and 80386-based computers will contain a compatible windowing interface. These OS/2 versions are expected to accommodate the graphics and resolution capabilities of add-on VGA boards.

Table 2: Standard Graphics and Text Modes

Board	Mode	Type	Resolution	Colors	Rows × Cols.	Char. Box
MDA	0, 1	Text	720 × 348	Monochrome	25 × 80	9 × 14
CGA	0, 1	Text	320 × 200	16	25 × 40	8 × 8
	2, 3	Text	640 × 200	16	25 × 80	8 × 8
	4, 5	Graphics	320 × 200	4 (two palettes)		
	6	Graphics	640 × 200	2 (foreground selectable)		
Hercules	7	Text	720 × 348	Monochrome	25 × 80	9 × 14
	15	Graphics	720 × 348	Monochrome		
EGA	0, 1	Text	320 × 350	16/64	25 × 40	8 × 14
	2, 3	Text	640 × 350	16/64	25 × 80	8 × 14
	7	Text	720 × 350	Monochrome	25 × 80	8 × 14
	4, 5	Graphics	320 × 200	4/64		
	6	Graphics	640 × 200	2/64		
	13	Graphics	320 × 350	16/64		
	14	Graphics	640 × 200	16/64		
	15	Graphics	640 × 350	Monochrome		
	16	Graphics	640 × 350	16/64		
MCGA	0, 1	Text	320 × 400	16/262, 144	25 × 40	8 × 16
	2, 3	Text	640 × 400	16/262, 144	25 × 80	8 × 16
	4, 5	Graphics	320 × 200	4/262, 144		
	6	Graphics	640 × 200	2/262, 144		
	17	Graphics	640 × 480	2/262, 144		
	19	Graphics	320 × 200	256/262, 144		
VGA	0, 1	Text	320 × 400	16/262, 144	25 × 40	9 × 16
	2, 3	Text	720 × 400	16/262, 144	25 × 80	9 × 16
	7	Text	720 × 400	Monochrome	25 × 80	9 × 16
	4, 5	Graphics	320 × 200	4/262, 144		
	6	Graphics	640 × 200	2/262, 144		
	13	Graphics	320 × 200	16/262, 144		
	14	Graphics	640 × 200	16/262, 144		
	15	Graphics	640 × 350	Monochrome		
	16	Graphics	640 × 350	16/262, 144		
	17	Graphics	640 × 480	2/262, 144		
	18	Graphics	640 × 480	16/262, 144		
	19	Graphics	320 × 200	256/262, 144		

Third-party manufacturers may even provide drivers for popular applications software, so existing versions of these programs can take advantage of VGA-level graphics or higher-level graphics capabilities that their boards may offer.

Enhanced graphics on small machines

Although OS/2 was designed with VGA in mind, VGA does not require OS/2. In fact, IBM has announced the VGA Personal System/2 Display Adaptor to provide VGA capabilities for the existing base of IBM PCs. This adapter will generally be slower than the motherboard VGA since it employs an 8-bit bus for compatibility with PC systems and low-end PS/2 systems, not the 16-bit bus of the higher-end PS/2 systems.

Third-party vendors have been quick to take advantage of the market opportunity that VGA offers. Paradise and Tseng Labs, among others, have developed VGA-compatible products for both OEMs and end users. Many vendors have chosen the VGA "functional equivalency" approach to avoid infringing upon IBM's chip design. They will probably offer enhancements like additional display modes, more on-screen colors, and special-application drivers to provide added value at prices competitive with the IBM PS/2 display adapter's price of $599.

It should be noted that current third-party VGA adapters for non-PS/2 machines are not perfect clones of the VGA hardware registers built into the PS/2 models 50, 60, and 80. Even IBM does not claim that its VGA display adapter is completely compatible with the motherboard VGA.

For operational compatibility, however, an adapter must communicate with the BIOS exactly as does IBM's VGA. For those boards that do not, special drivers will be required to write to the BIOS. There is some dispute among vendors over the necessity of complete hardware register compatibility. Video 7 and Quadram, for example, feel that 100% hardware register compatibility is impossible without the reverse engineering of IBM's original chip sets. Thomas Van Overbeek of Paradise, however, feels that there will be an enormous temptation for software developers to write directly to the hardware instead of to the BIOS because writing to the BIOS tends to slow applications down. Paradise, as a result, is planning a board that will be 100% compatible with the IBM VGA display adapter and close to completely compatible with the models 50, 60, and 80 VGA.

Does VGA a workstation make?

VGA offers increased resolution and more colors, but its highest resolution, 640 × 480 (which some enhanced EGA boards also display), is too low for the complex drawings required by high-level computer-aided design (CAD) applications. Moreover, the VGA's performance in its high-resolution mode tends to be sluggish because central prcessing unit (CPU) access to video RAM is slow. Since VGA, like EGA and CGA, is a "dumb" frame buffer and cannot execute drawing primitives (like line and polygon algorithms) on board, these functions must be executed by the CPU [Fig. 1]. This means that the CPU cannot do anything else while graphics commands are being executed. Complex drawings could tie up the processor, creating throughput bottlenecks and degrading overall system performance. IBM has attempted to address these performance deficiencies with an add-in graphics controller, the 8514A display adapter. The 8514A, intended for desktop publishing and low-end CAD applications, is an "intelligent" graphics processor that is capable of a noninterlaced display resolution of 640 × 480 in 256 colors and an interlaced display resolution of 1024 × 768 in 16 colors or 1024 × 1024 in 256 colors. (Additional 4-bit-plane upgrade is optional.)

The 8514A is compatible with all four IBM monitors, but only the 8514 color monitor (at a price of $1550) can display the 8514A's higher resolutions.

Competition at the high end

An early competitor for the 8514A is the Control Systems Artist 10/16 VGA. The Control Systems board, which supprts the PS/2 models 60 and 80, costs $2995, more than twice the IBM 8514A display adapter, which lists for $1290 (or $1560 with the 8-bit-plane option). It provides a 1024 × 768 noninterlaced display and a 1024 × 1024 interlaced display. It has 1 Mbyte of graphics memory and can exhibit 16 colors from a palette of 4096. The Artist 10/16 VGA, which incorporates the Hitachi ACRTC processor, can draw 20-pixel-long vectors at a rate of 65,000 per second.

Users who need higher graphics capability than the 8514A provides can choose an add-on board such as the

PG2-1281 from Matrox. The PG2-1281 is a high-resolution graphics controller that performs for PS/2 microchannel-based systems the same functions the company's PG-1281 board performs for AT-compatible 80286- and 80386-based machines. The high resolution and speed capabilities of the PG-1281 and PG2-1281 put them in the professional graphics workstation league. The PG2-1281 provides a 1280 × 1024 noninterlaced display with 256 colors from palettes of 4096 or 16.7 million. The board is based on the Texas Instruments TMS34010 processor and adds custom gate arrays for speeds of 12.5 million bit-block transfers (BITBLT) per second and 100,000 2D vectors per second. The PG2-1281 also contains an onboard display list, eliminating the time required to load the series of commands needed to perform functions, like PAN and ZOOM, across the bus interface to the board for processing. Consequently, the redraw time of an image is lessened. The PG2-1281 provides a single-screen solution by enabling PS/2 VGA data to be displayed on the same high-resolution monitor. The PG2-1281 offers several options: virtual device interface (VDI) and color graphics interface (CGI) drivers and a special autocad driver. At $3495, the PG2-1281 is not inexpensive, but an architect, engineer, or designer who does a lot of redrawing can more than double his or her productivity with this kind of board. The ability to display a CAD image that is nearly as sharp as a pen-and-paper image can significantly reduce operator fatigue and make presentation documents affordable at the early stages of the design process.

Mitsubishi, RCA, Philips, Sony and Hitachi, among others, produce analog monitors capable of displaying the PG2-1281's resolution of 1280 × 1024.

The next stage

IBM's introduction of the PS/2 series has stimulated many users to reevaluate the capabilities of their present personal computers, without necessarily concluding they should buy PS/2s.

If the processing power of a current PC or AT is adequate and the single task orientation of MS-DOS is suitable, enhanced graphics ability can be had simply by adding an appropriate add-on graphics board (either from IBM or a third party) and a monitor compatible with that board. Those purchasing a third-party VGA board should ensure that it is software compatible with IBM's BIOS, or if not, that special drivers are provided. It is a rare third-party VGA manufacturer that does not have a few bugs to iron out before its board runs smoothly.

If multitasking is needed, OS/2 will be available for properly configured AT clones and the growing number of 80386 machines.

Buying an 80286 or 80386 PS/2 from IBM has decided advantages: the user receives the motherboard VGA; has the immediate option of acquiring the only version of OS/2 available right now; is put in line for the first version of OS/2 to include the Presentation Manager; and is eligible for IBM service and support.

But for some professional graphics and engineering applications, even VGA quality may not be enough. Then an investigation of available professional-quality graphics boards is needed. ■

A very brief digital image processing primer

BY BRUCE MACKIE

DIGITAL image processing (DIP) consists of collecting data from a relatively harsh environment known as the analog domain (the world we live in), converting it to the more stable and predictable digital domain (where computer circuitry resides), manipulating the data digitally, and reconverting it to an analog image. During this process, the usual profusion of information in the analog source is selectively reduced to the minimum required for effective decision making.

Applied DIP is the direct result of mathematical shortcuts developed prior to the digital-computing era and updated during the 1960s and 1970s. The integrated-circuit technology of the 1980s made it possible to construct DIP engines that were so cost effective that DIP is now becoming mass marketable, and a variety of imaging companies are implementing the technology.

One engine per task

Typically, once an image has been acquired, it is subjected to a series of algorithms before the processed data can be presented to a computer for decisions. Not long ago, a large general-purpose computer would be programmed to implement each of these algorithms. Now, single-board special-purpose computers, or compute engines, are available for each of the common algorithms. For a given application, a user need only select those boards required to implement the necessary algorithms. The preprocessed data, which constitutes a greatly reduced data set, is then presented to a general-purpose computer for analysis. Often, the image-processing boards are designed to fit into available slots in the general-purpose computer, though the image-processing system sometimes requires a separate chassis.

Image processing incorporates three types of operations. Quality enhancements are manipulations of an image's brightness characteristics, including contrast, dynamic range, and spatial distribution. Image transformations such as rotation, zooming, panning, and warping are usually included in this category. Analysis is the derivation of numerical values that characterize aspects of the image. Coding is the representation of an image in a particular way—often the way that requires the minimum amount of information.

Quality enhancements

When the edges of objects interest us [as in Fig. 1], we can utilize the mathematical technique of spatial filtering to enhance the edges.

One kind of spatial filtering, finite impulse response (FIR) filtering—specifically D FIR filtering (convolution)—replaces the brightness value of a pixel with a weighted average of the values of the pixels surrounding it. When performed on each pixel in an image, convolutions can produce dramatic and highly useful transformations. Moreover, the same convolution algorithm can produce varying results when used with different convolution kernels—the sets of weighting factors that multiply the pixel values in the convolution. The Nyquist dx gradient kernel [Fig. 5a], for example, is a "horizontal edge filter." When applied to the image of Fig. 1, it suppresses horizontal edges [Fig. 2]. The Nyquist dy gradient [Fig. 5b] does the same for vertical edges [Fig. 3], as does the Nyquist diagonal gradient [Fig. 5c] for northwest edges [Fig. 4]. (A similar filter suppresses northeast edges.)

Analysis

Images are analyzed to derive useful image characteristics. Dramatic changes in average brightness, for instance, could signal the need for scaling the input image's dynamic range to keep it within system capabilities. Some image processing boards derive a brightness histogram of the incoming image [Fig. 6a] and perform a histogram equalization on that captured image [Fig. 6b].

Coding

Coding can be the most important stage of image preprocessing when final analysis is performed with a computer using the traditional Von Neuman architecture. It is at this stage, after all of the enhancement and analysis processes have been performed, that the image is reduced to a minimum descriptive set.

Filtering an image to reduce noise, scaling it to a predictable dynamic range, and spatially enhancing potential key features are generally intermediate steps on the way to a greater end. If that end is to analyze images with a general-purpose computer, those images must have extractable features.

Bruce Mackie is director of sales and marketing for Datacube, Inc., of Peabody, Massachusetts. He has a B.S.E.E. degree from the University of Rhode Island.

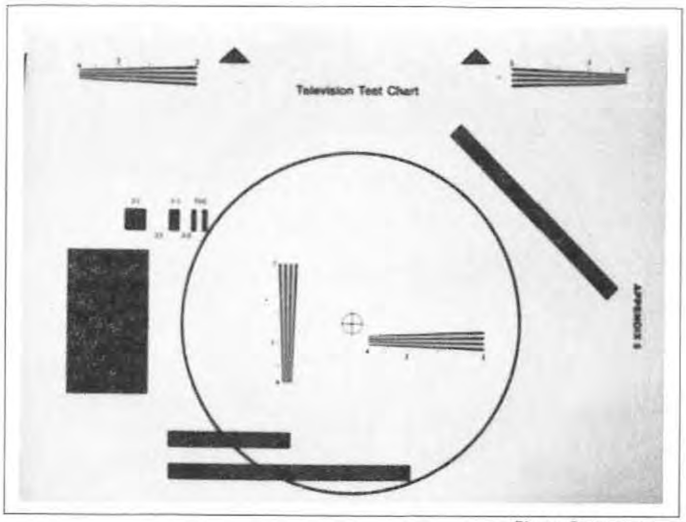


Photo: Datacube, Inc.

Fig. 1: An original test image prior to processing.

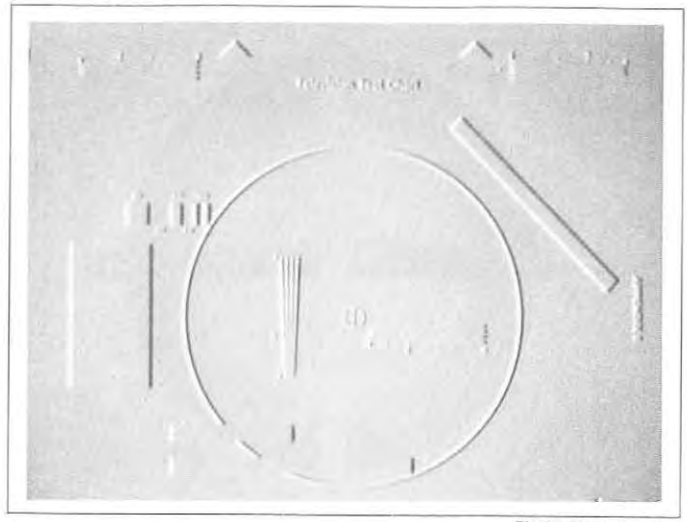


Photo: Datacube, Inc.

Fig. 2: The image of Fig. 1 after processing with the horizontal edge filter of Fig. 5a.

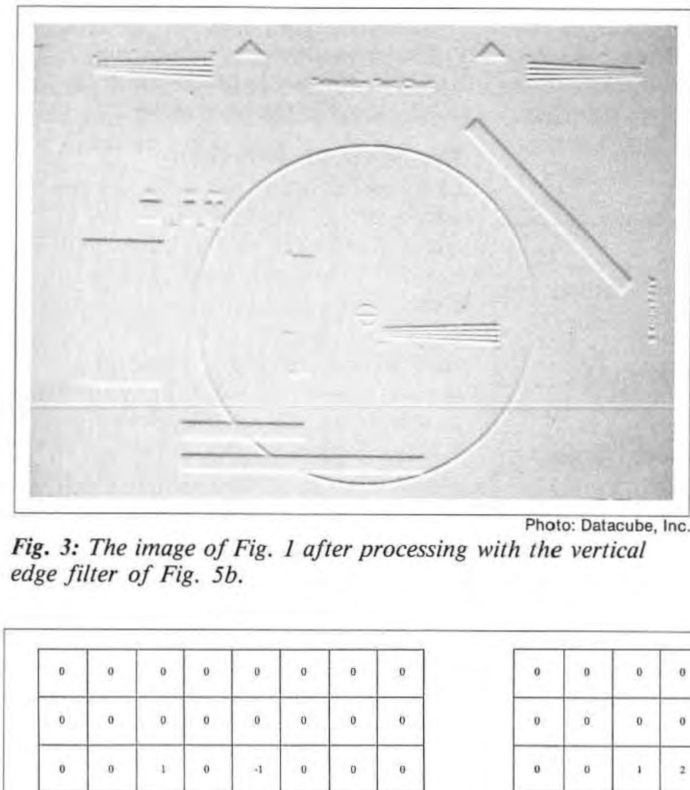


Photo: Datacube, Inc.

Fig. 3: The image of Fig. 1 after processing with the vertical edge filter of Fig. 5b.

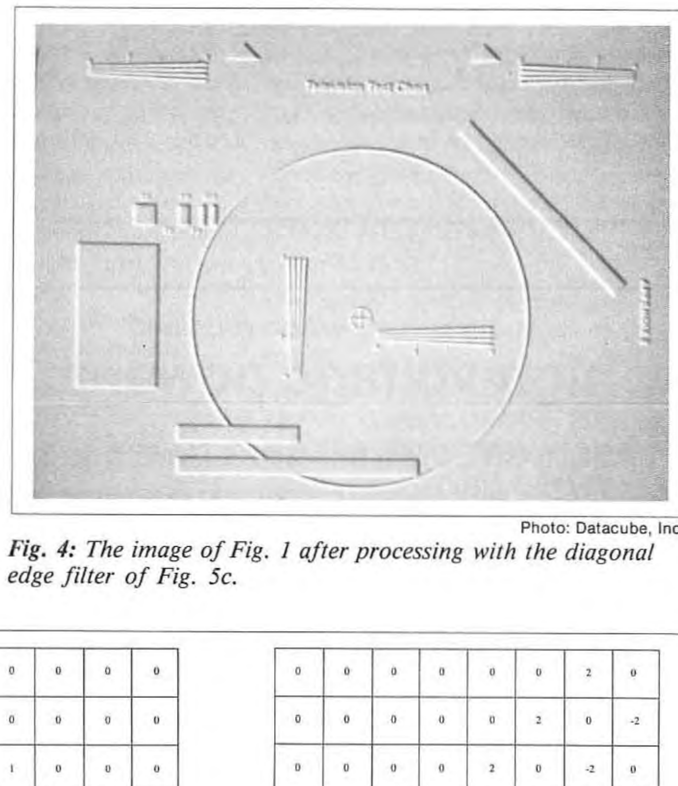


Photo: Datacube, Inc.

Fig. 4: The image of Fig. 1 after processing with the diagonal edge filter of Fig. 5c.

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	1	0	-1	0	0	0
0	0	2	0	-2	0	0	0
0	0	1	0	-1	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

(a)

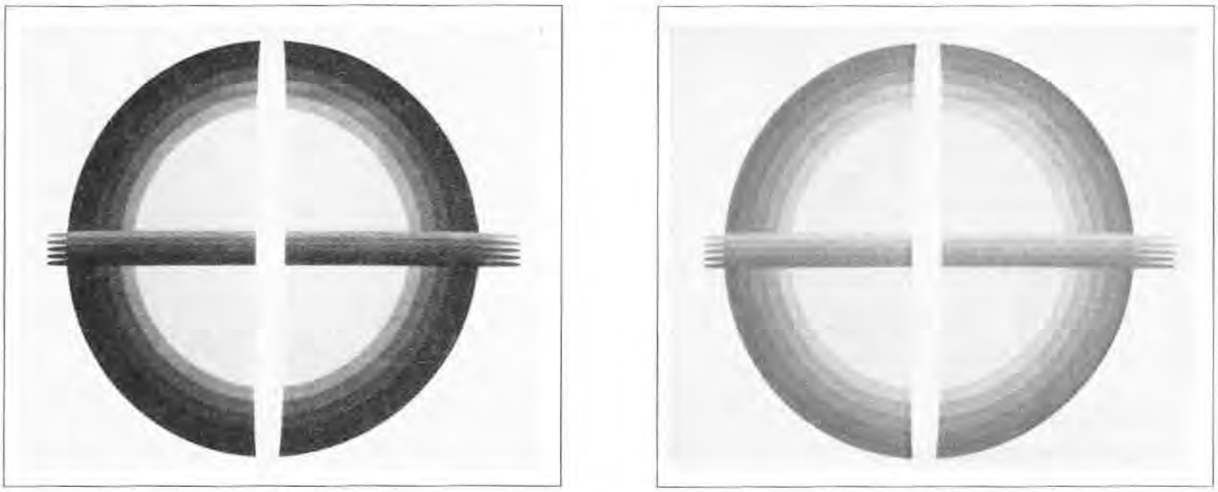
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	1	2	1	0	0	0
0	0	0	0	0	0	0	0
0	0	-1	-2	-1	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

(b)

0	0	0	0	0	0	2	0
0	0	0	0	0	2	0	-2
0	0	0	0	2	0	-2	0
0	0	0	2	0	-2	0	0
0	0	2	0	-2	0	0	0
0	2	0	-2	0	0	0	0
2	0	-2	0	0	0	0	0
0	-2	0	0	0	0	0	0

(c)

***Fig. 5:** The Nyquist 8 × 8 dx gradient (a) is a convolution kernel that filters horizontal edges out of an image when used in an appropriate convolution algorithm. Applying this kernel to Fig. 1 produced the image in Fig. 2. The Nyquist 8 × 8 dy gradient (b) filters vertical edges out of an image. When Fig. 1 is the input, Fig. 3 is the result. The Nyquist 8 × 8 diagonal gradient (c) filters northwest edges out of an image (see Fig. 4 for the result).*



(a) (b)

Photo: Datacube, Inc.

Fig. 6: "Histogram equalization" scales the dynamic range of an input image (a) to an image having a predictable range of values (b).

In some metrology applications, for instance, the host computer must determine whether a particular image classifies as an object that should be measured. A "feature list extraction" can provide the two-dimensional addresses of all pixels in the image having a particular gray-scale value. This address listing can be used to determine the object's shape and, therefore, whether to proceed with detailed measurement calculations.

The power of dedication

Each stage of image processing can consume a lot of computing power. For instance, performing an 8×8 convolution on a 512×512 pixel image, as was done in each of our edge-suppression examples, requires on the order of $64 \times 512 \times 512$, or 17 million, operations. Datacube's 64-point convolving board, the VFIR MK II, will do this and other kinds of finite impulse response filtering in one or two dimensions at a continuous rate of 640 million integer operations (multiply-accumulates) per second. Doing this with a Von Neuman-type computer programmed for the task requires a supercomputer that costs roughly a million dollars—130 times the $7800 price of a VFIR MK II. Clearly, it is now far more cost-effective to use special-purpose compute engines for the common digital image-processing functions and to devote the flexibility of the general-purpose computer to those functions that require it. This approach allows systems based on large computers to be faster and more cost effective, and it permits capable image processing systems to be based on host computers as small as an IBM PC-AT or compatible.

Notes

[1]*Digital Image Processing* by Gregory A. Baxus (Englewood Cliffs, N.J.: Prentice-Hall, 1984) is an excellent introductory textbook. ■

SID '88 preview

SID '88, THE 1988 International Symposium, Seminar, and Exhibition of the Society for Information Display, will be held May 23-27 at the Disneyland Hotel in Anaheim, California.

SID '88 will feature 20 technical sessions running concurrently on Tuesday, Wednesday, and Thursday (May 24–26); the largest exhibit of display manufacturers in SID's history (129 booths); and a two-day seminar which will be presented on Monday and Friday of the conference week (May 23 and May 27).

The SID '88 seminar will have two parallel sessions of six lectures each and will begin with a common session for all registrants, "Overview of Display Technology," presented by Walter F. Goede of Northrop. Leading scientists and engineers representing industry, academia, and government from the United States, Europe, and Asia will provide both tutorial and timely information on the following topics: Human Interface Design, Display Measurement, Anti-Aliasing and Image Quality, Input Devices, Printing and Desktop Publishing, Workstation Architecture, TFT and LCD Active Matrix, LCDs with High Information Content, Color Emissive Flat Panels (Electroluminescent and Plasma), Large-Screen and Projection Displays, High-Definition Television (HDTV), and the CRT: Present and Future.

Revolutionary concepts of control and display will be the challenge given to display designers by the keynote, Dr. Thomas A. Furness of the Armstrong Aerospace Medical Research Laboratory at Wright-Patterson Air Force Base in his address, "Harnessing Virtual Space." Arthur Kaiman, director of digital products research at the David Sarnoff Research Center, will define, explain, and demonstrate "Digital Video Interactive" technology in his keynote presentation. DVI is a new technology that combines in one system, under the control of a personal computer, the capabilities of a computer graphics system, a video system, and an audio system.

Off-the-record informal panel discussions have been scheduled for Tuesday evening (May 24). For SID '88 this popular feature will include three parallel sessions: Stereoscopic Viewing Systems, LCD Reliability, and CRT Measurement.

From a record number of submissions, 107 papers were selected by the SID '88 program committee for presentation this year. Each presentation of 20 minutes is followed by a 5-minute interval for questions to the speaker. At the end of each day, the SID-pioneered hour-long author interview sessions provide an opportunity for in-depth discussions and demonstrations.

For SID '88, the distribution of technical sessions is as follows: four on human factors; three on active-matrix LCDs; two each on printing, CRTs, and large-screen systems. Other sessions are on workstations, electroluminescence, automotive and airborne displays, 3D displays, and other flat-panel technologies. Five of the six papers in the plasma display session are about color.

The SID '88 advance program, to be distributed in March, will include a brief description of each of the technical papers. The following is a sampling of papers from each technical session.

- *A 1,000,000-pixel color TFT-LCD* measuring 6¼ x 6¼ in. will be described by D.E. Castleberry and G.E. Possin of General Electric's Corporate Research & Development. The authors will explain the device design, repair method, and the gray-scale drive electronics of the most complex TFT-LCD yet disclosed. (paper 13.1)

- *The special emphasis on vehicular displays* in SID '87 has carried over to SID '88 as exemplified by "The Display System for an Express-Turbine Concept Vehicle." This paper by E.J. Elkins and D.J. Brandt of Delco Electronics will describe the design and implementation of a CRT-based primary display for a Chevrolet test vehicle. Both hardware and software aspects will be included. (paper 10.3)

- *"Fabrication Techniques for a 20-in. Color Plasma Panel"* by T. Katoh et al. of the NHK Science and Technical Research Laboratories was motivated by the desire to demonstrate a thin light large-screen display for home use in HDTV systems. (paper 9.1)

- *Three of the active-matrix LCD* papers on color are "A 10-in.-Diagonal High-Resolution Active-Matrix Color LCD Module" [$(640 \times 3) \times 450$ pixels] by K. Niki et al. from Mitsubishi (paper 17.4); "High-Resolution Full-Color LCDs Addressed by Double-Layered Gate-Insulator a-Si TFTs" (480×640 pixels) by M. Katayama et al. of Sharp, which reports on improved stability and a redundant TFT-array design (paper 17.1); and "Multicolor Display Using a Double-Layered Supertwisted Nematic LCD" by

N. Kimura et al. of Sharp, which discloses a prototype color LCD display of 200 × (384 × 3) pixels with a contrast ratio better than 15:1 (paper 5.4).

•*H. Oshima and his collegues* at Seiko Epson will describe a technique to minimize parasitic capacitance in a large-area LCD in their paper, "9.5-in. Poly-Si TFT-LCD with New Transistor Configuration." (paper 21.4) "A 960 × 240 Pixel Multicolor Supertwisted Nematic Display" by K. Sawada et al. of Asahi Glass presents the design of a 9-in. multiplexed display. (paper 5.5)

•*Liquid crystals find application* not only in displays but in printers as well. A scanned color printing system for producing 512 × 480 pixel continuous-tone color images on special papers is explained in "Electronic Color Printing with a Liquid-Crystal Light Modulator on Low-Sensitivity Photographic Materials" by the AT&T Bell Laboratories team of R.V. Kollarits, D.C. Gibbon, and W.H. Ninke. (paper 11.1)

• *A paper by Ph.D. candidate* Peter C. Berdelle-Hilge of the Technical University of Munich is one of seven student-authored presentations. His "Study of the Electrodynamic Effect in a Transducer for the Ejection of Ink Droplets" will describe the use of a model and simulation to design a more effective mechanism. (paper 15.3)

•*The thermal behavior* of the composite structure of a resistive heater in a thermal ink-jet printhead is investigated by M. Tirumula and F. Lee of IBM in their "Thermal Analysis of Thermal Ink-Jet Heater Structure." Results reveal some important information on spatial temperature time history, peak temperatures, heat flux magnitudes and distribution, and cooling times for different material sets and configurations. (paper 15.1)

•*A 3D system* capable of producing a brightness of 240 fL on a 50-in.-diagonal screen is described by M. Muro et al. of the Univeristy of Tokyo in "Brightness Amplifying 3D TV Projection System with a Copper Laser." (paper 7.2)

•*Tektronix engineers* P. Bos, T. Haven, and L. Virgin will talk about the design considerations for a 3D video system using liquid-crystal shutters with a CRT in their presentation "High-Performance 3D Viewing System Using Passive Glasses." (paper 23.1)

•*Comparisons of spatial quality* and overall quality of images produced by the RGBG quad, RGB diagonal, and RGB triad are presented by a team of Honeywell researchers (F. Gomer et al.) in "A Perceptual Basis for Comparing Pixel Selection Algorithms for Binary Color Matrix Displays." (paper 22.4)

•*M. Green and P. Lyon* of Evans & Sutherland will show how "A User-Friendly Computer-Human Interface for Aligning and Edge Matching Multichannel Projector Systems" may be achieved through the use of menu-oriented software. (paper 7.6)

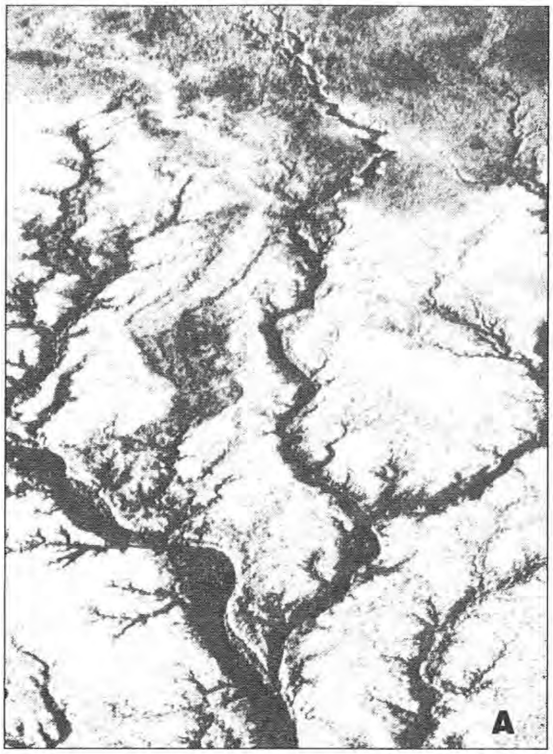
•*Companion papers,* "The Interference Filter Projection TV CRT" (L. Vriens et al.) and "Optical Aspects of the Interference Filter Projection CRT" (J.A. Clarke et al.) from Philips Research Laboratories, give design considerations for a rear-projection system using dielectric interference filters which lead to a 50% gain in brightness along with better saturation and a reduction in chromatic aberration. (papers 12.1 and 12.2)

•*The design of graphic benchmarks* to probe specific functional responses is presented along with the results on four commercial workstation products in "Graphic Benchmarks for Real-Time C^3 Applications" by J.L. Conway and J.R. Leger of The MITRE Corp. (paper 19.1)

•*In the session on I/O,* L. Tanne and R. Marsden, both students at the University of Alberta (Canada), will describe a functional prototype of a system to provide a more efficient method of communicating for nonverbal individuals. Their paper "Display-Enhanced Speech Prosthesis" will describe a M68000-based system using a flat-panel backlit LCD display. (paper 14.2) ■

CALL FOR PAPERS: EL-88

Fourth International Workshop on Electroluminescence. October 11–14, Tottori, Japan. Topics of interest include: basic physics of luminescence; materials, processing technology, and characterization; color EL; thin-film EL panels; and powder EL panels. Send three copies of a two-page abstract, double-spaced, including full mailing address of author, to: Dr. Masaru Yoshida, Central Research Laboratories, Sharp Corp., Ichinomoto, Tenri, Nara 632, Japan. Deadline for abstracts: May 31



Delta or Aorta? Which is Which?

No problem here because both of these images were processed on Raytheon's new TDU-850 Thermal Display Unit.

The TDU-850 is the only thermal recorder to display true grey levels (not mere halftone representations) at such high speeds and resolutions. Utilizing 203 dots per inch, the unit offers 64 grey levels and can provide 256 grey levels through the use of super pixels. The TDU-850 is your assurance of high quality images. Standard units about $5,000. (Slightly higher overseas). RS-170 video and IEEE-488 computer interfaces are available.

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Raytheon

A. Satellite view of river delta. **B.** Arterial angiogram.

Note: These began as continuous tone images which were processed in black and grey by a TDU-850. The TDU-850 images, however, had to be converted to conventional halftones in order to be shown in this magazine. Thus the high quality of the original TDU-850 images have been obscured. For true results ask to see a demonstration.

Circle no. 11

1988 ISCC/SID Joint Meeting

CRT to Hard Copy in Color

May 9–10, 1988
Sheraton Inner Harbor Hotel
Baltimore, Maryland

General Chairman
Nick Hale, President
Hale Color Consultants, Inc.
Phoenix, MD

Program Chairman
Lawrence E. Tannas, Jr., President
Tannas Electronics
Orange, CA

Within sight of the *USS Constellation* in Baltimore's inner harbor, the Inter-Society Color Council (ISCC) and the Society for Information Display (SID) will hold their first joint meeting May 9–10. The conference is entitled "CRT to Hard Copy in Color." At a dinner Tuesday evening, SID will explore the reinstatement of its Washington, DC, Chapter.

Monday Afternoon, May 9
Hard-Copy Technology

Session Chairperson: Lawrence E. Tannas, Jr., *Tannas Electronics, Orange, CA*

Co-Chairperson: Justin J. Rennilson, *Advanced Retro Technology, La Mesa, CA*

Problems and Standards (Invited Paper)
Warren L. (Dusty) Rhodes, *ChromaTech, Inc., Altadena, CA*

Color and the Hard-Copy Printer
Ross N. Mills, *IBM Corp., Boulder, CO*

A Colorimetric Halftoning Algorithm for Four-Color Printers
Peter G. Engeldrum, *Imcotek, Inc., Bloomfield, CT*
Peter A. Zuber, *Colorocs Corp., Norcross, GA*

Algorithms for Fast Color Correction
A.W. Paeth, *Univ. of Waterloo, Waterloo, Ontario, Canada*

Color Representation in Page Description Languages
Robert Buckley, Mary Ann Dvonch, Paul Roetling, *Xerox Webster Research Center, Webster, NY*

Tuesday Morning, May 10
CRT Technology

Session Chairperson: Gerald M. Murch, *Tektronix, Inc., Beaverton, OR*

Co-Chairperson: William J. Lloyd, *Hewlett-Packard Laboratories, Palo Alto, CA*

Fidelity and Consistency of Color in a CRT
Gus F. Carroll, Carroll Consulting Co., Los Gatos, CA

Characterization of CRT and Hard-Copy Devices: Theory
William B. Cowan, *National Research Council, Ottawa, Ontario, Canada*

Characterization of CRT and Hard-Copy Devices: Instrumentation
Justin J. Rennilson, *Advanced Retro Technology, La Mesa, CA*

The Colorimetric Calibration of a CRT Imaging System for Color Appearances Research
Ricardo J. Motta, *Hewlett-Packard Laboratories, Palo Alto, CA*
Roy S. Berns, *Rochester Institute of Technology, Rochester, NY*

An Evaluation of Methods for Producing Specific Colors on CRTs
David L. Post, Christopher S. Calhoun, *AAMRL/HEA, Wright-Patterson Air Force Base, OH*

Tuesday Afternoon, May 10
CRT to Hard Copy

Session Chairperson: Gary K. Starkweather, *Xerox PARC, Palo Alto, CA*

Co-Chairperson: Ross N. Mills, *IBM Corp., Boulder, CO*

A Matrix Color Correction Scheme for Color Electronic Printers
Gary K. Starkweather, *Xerox PARC, Palo Alto, CA*

Optimizing the Principles of Digital Color Reproduction on the Basis of Visual Assessment of Reproduced Images
Pekka Laihanen, *Helsinki Univ. of Technology, Espoo, Finland*

Tektronix HVC: A Uniform Perceptual Color System for Display Users
Joann M. Taylor, Gerald M. Murch, Paul A. McManus, *Tektronix, Inc., Beaverton, OR*

Printing Computer Graphics Imagery
Maureen C. Stone, *Xerox PARC, Palo Alto, CA*

CRT to Print: An Empirical Procedure
Mik Lamming, *Xerox PARC, Palo Alto, CA*
Warren Rhodes, *ChromaTech, Inc., Altadena, CA*

Poster Session

Session Chairperson: Paula J. Alessi, *Eastman Kodak Co., Rochester, NY*

Tuesday Evening, May 10
SID Dinner to Reinstitute the Washington, DC, Chapter

For dinner reservations, call SID Headquarters Office Manager, Bettye Burdett, 213/305-1502. For conference registration forms, call Dr. Norman Burningham, 716/477-7466.

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Circle no. 14

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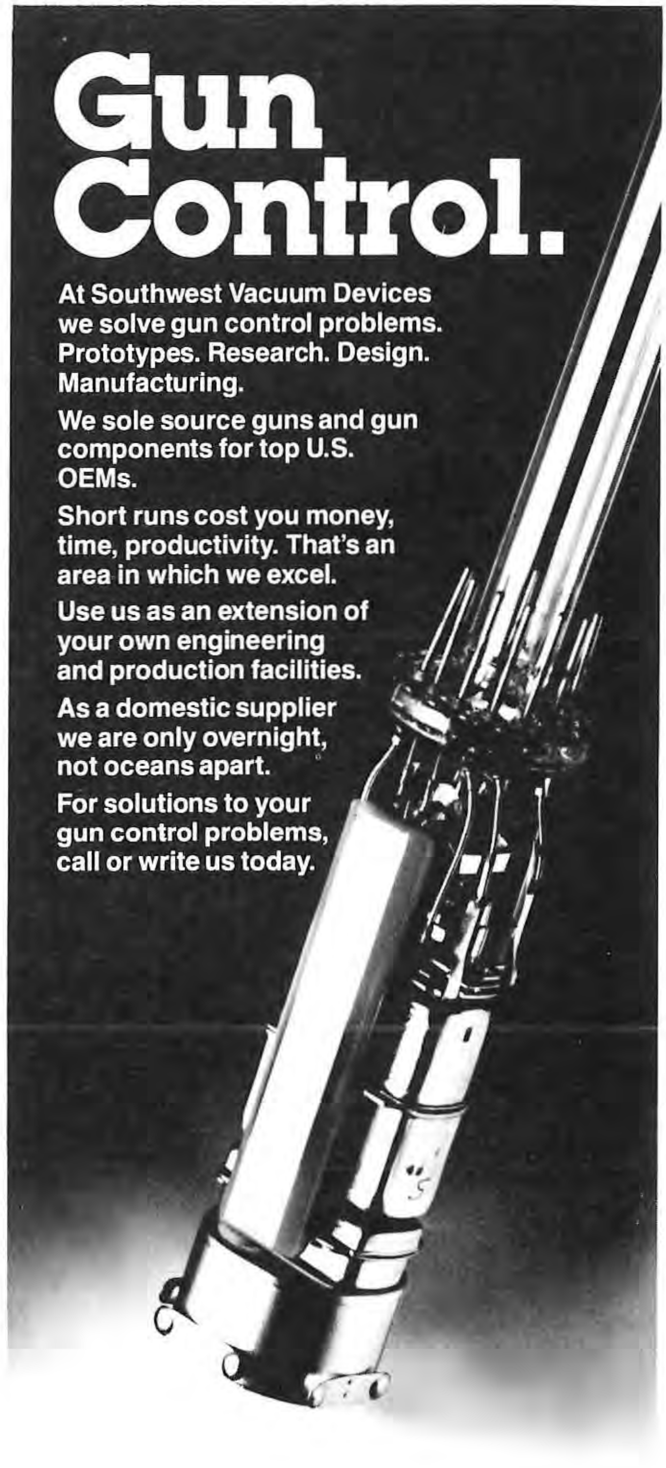
Circle no. 15



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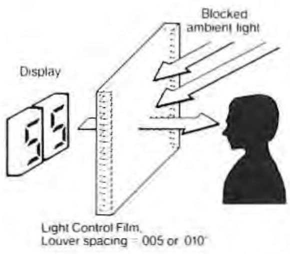

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Circle no. 18

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Circle no. 19

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"Seeing the Big Picture with the New LCD Screens," J. Olivas, *Classroom Computer Learning*, Vol. 8, No. 2 (October 1987), pp. 32–37. *Review of many LCD projectors.*

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