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Message From The President

We start again

With this issue we resume publication of our official journal, **INFIORMATION DISPLAY**,which is now a joint effort of the Society for Information Display and of Benwill Publishing Corporation of Brookline, Massachusetts. We aim to make it informative and interesting to all who wish to be informed of the latest developments in the fast-moving field of information display. As in the past, **INFORMATION DISPLAY** will contrast with and complement its sister publication, the **PROCEEDINGS OF THE SOCIETY FOR INFORMATION DISPLAY**, a quarterly archival publication with a comprehensive review cycle and stringent technical referencing standards. Only SIDmembers and subscribing libraries receive our Proceedings.

If you are not a member of SID, you receive this issue of our journal as a complementary sample copy, sent with our expectation that information display may be included in your area of interest. If indeed it is, we urge you to join SID. A membership qualification is enclosed. If you are a member of SID, you receive this journal at no extra charge. **INFORMATION DISPLAY** is also available on a subscription basis.

Member or not, we welcome your comments and will be pleased to consider articles you may submit. Send all submissions to our Publications Chairman, Tom Curran, c/o the Society for Information Display, 654 North Sepulveda Blvd., Los Angeles, CA 90049.

Too much hardware?

The Society for Information Display was formed in 1962 as an interdisciplinary organization, encompassing display systems theory, psychological and physiological effects, and display system developments as well as display devices. Although a review of our recent Proceedings and Symposia Digests shows a balance in all of these areas, I'm told by some that we are getting a reputation as strictly a devices society, possibly to the detriment of those whose interests are primarily in software or systems.

Is that true? Have we changed over the years? You know, looks can be deceiving. Advertisers in our journal and exhibitors at our symposia are necessarily hardware oriented. Who ever thought tc run a software ad? It is true that our Program and Chapter Committee members tend to be hardware types. These committees depend on a hidden industry subsidy of travel, time, and support. I suspect that the people who control these subsidies feel that they are getting something for their money when it appears to relate to hardware. Thus, there is some tendency for SID to at least look like a hardware oriented society, and maybe, indeed, that is what we have become.

I would appreciate your opinion on this subject and any suggestions you may have for charting a different course. However, I'm not sure we can make any rapid changes. In some ways the Society is like a supertanker running at full speed with a volunteer crew (who most of the time are playing pinochle down below). But we can run up a flag on the bridge, signifying our intention to change course if that is required.

This journal is your forum to be heard on such subjects. Please drop me a note at the Society for Information Display. Or you may find it more convenient to contact one of the Chapter Officers, all of whom are listed on page 34.

Sincerely,

Erwin A. Ulbrich

Erwin A. Ulbrich, President-SID

NEWS

1977 SID International Symposium and Exhibition:

Worldwide Information Display Progress

Vernon J. Fowler, General Chairman SID 77
GTE Laboratories, Waltham, MA

John Flannery, Program Chairman, SID
Xerox Corporation, Webster, NY

Over 100 scientists, engineers and educators from here and overseas, including representatives from England, Germany, Switzerland, France, Japan, Holland and Canada, will present over 60 papers and participate in 16 day-evening sessions at the 1977 Society for Information Display International Symposium to be held April 19-21 in the Sheraton-Boston Hotel.

Invited and contributed efforts covering a broad scope of significant subjects have been programmed: plasma displays, systems and applications, integrated displays, video games, display design criteria, liquid crystal displays and materials, gas discharge, electroluminescence, 3-D displays, projection, image processing and medical display applications.

Dr. M. Tribus, Director of the Center for Advanced Engineering Study at the Massachusetts Institute of Technology will open the event with a keynote talk on Moving an Idea from R&D to the Marketplace. He will be followed by a pair of topical invited addresses on the system behind color TV display and the perfect TV picture by Donald Fink, formerly IEEE executive director, and W. David Wright of the University of London.

At the annual luncheon on Wednesday, April 20, Dr. Harold Edgerton, will deliver a talk on his recent expedition to photograph the Loch Ness monster. Many of the presentations will underscore circuitry and design improvements now contributing to the broadening popularity of information display technology. One paper will describe an addressing system for ac plasma panels using 32-line driver MOS ICs mounted on the edge of the display panel, affording improved alphanumeric applications. Another session will assess video games. Panelists will survey such current factors as the FCC rules on radiation and the burned image problems on the CRT caused by excessive brilliance when the games are in operation.

Also on the agenda are papers on twisted nematic liquid crystal developments affording better visibility and expanded applications; eventually they may replace some CRT uses. Another highlight area scheduled for comment is electroluminescence with four papers on the subject. One will be devoted to new dc EL blue, green and red displays offering striking results. Sessions on 3-D and projection displays will also discuss new trends including an advanced techniques for color helography.

The evening panels a traditional feature at SID, will include four sessions covering integrated display systems, CRT users (a workshop session) and the two subjects noted earlier: 3-D and video games.

Following the day sessions, author interviews will be held, enabling the speakers and attendees to chat about their papers in an informal atmosphere, within many cases, operational prototypes to illustrate further design features of their developments.

As in the past, all attendees will receive the annual DIGEST of TECHNICAL PAPERS, offering illustrated 800-1000 word condensations of all papers – keynote, invited and contributed. Additional copies will be available at the meeting and thereafter through the SID office in Los Angeles: $20.00 for members and $30.00 for nonmembers.

An exhibition with components, accessories and systems valued over $5-million will be held in a hall adjacent to the session rooms. This year's show will include operating models from Germany, England and France. The show will open on the first day at 10:00 A.M. and close at 5:30 P.M. On the following day, Wednesday, the doors will be opened at 9:00 A.M. and closed at 5:00 P.M., and on the final day, the hours will be 9:00 A.M. to 3:20 P.M., when the technical program is concluded.

Two-day Seminar on Information Display

The Symposium Seminar, sixth in a series held annually with East/West universities in juxtaposition with the SID International Symposia has been scheduled for Monday, April 18, and Friday, April 22, at the Sheraton Boston Hotel, Boston, Massachusetts. Cosponsored by the Architecture Machine Group, Massachusetts Institute of Technology, the two-day seminar will offer eight in-depth one and one-half hour tutorial presentations on a range of interesting and significant topics.

Nicholas P. Negroponte, Director of the Architecture Machine Group, MIT, will present a talk on television based computer graphics and its relationship to the future of personal computers. Robert D. Solomon, Professor of Electrical Engineering at Worcester Polytechnic Institute, will review colorimetry, the psychophysics of color vision, color reproduction and image coding to develop guidelines for color picture processing and graphics systems.

Commander Donald Schaff, U.S.

Navy Fleet Numerical Weather Center, Monterey, California, will discuss the problems in applying mini-computers in displays for graphics communications. A tutorial on the design of displays for severe environments will be presented by Gus Carroll, Project Engineer, Advanced Display Systems, Kaiser Aerospace & Electronics, Palo Alto, California.

Legibility criteria in the design, selection and evaluation of electronic data displays will be discussed by Donald A. Shurtleff, Senior Research Scientist, American Institutes for Research, Bedford, Massachusetts. The performance factors of the three basic color TV projection systems will be compared by Dr. William E. Good, Consultant, General Electric Company, Syracuse, New York.

William F. Schreiber, Professor of Electrical Engineering, MIT, will teach the use of a flat field configuration for cost-effectiveness in laser scanning systems. The final lecture by Donald E. Troxel, Associate Professor of Electrical Engineering, MIT, will be a presentation on the Electronic Darkroom, a minicomputer-based image processing system for new photos and facsimile pictures.

SID 77 Exhibitors

Aydin Controls • AEG-Telefunken Corp. • Ferranti Electric, Inc. • Display Components, Inc. • DuMont Electronics Corp. • Optical Coating Laboratory, Inc. • Rank Precision Industries, Ltd. • RCA Corporation • Ramtek Corp. • Raytheon Co. • Spellman High Voltage Electronics • Thomas Electronics • Syntronic Instrument • Venus Scientific • Washburn Laboratory • Watkins-Johnson • Westinghouse Electric. Industrial and Government Tube Division • Tektronix, Inc. • Media Systems, Inc. • Keltron Corp.

And here's some of what they'll be exhibiting:

Electrostatic focus instrument CRTs ■ High resolution large-screen display tubes ■ High brightness military display tubes ■ Flying-spot scanner tubes ■ High speed high resolution deflection amplifiers and yokes ■ Video storage equipment ■ Photosensitive devices and image tubes ■ Color penetration screen CRTs ■ ouble ended image storage tubes ■ Antireflection and conductive coating_ Laminated color filters ■ Broadband and narrowband filters ■ Liquid crystal displays designed for instrument clocks ■ Multidigit panel with 1/2" to 3/4" digit sizes ■ Color graphics and imagery display tubes ■ High voltage power supplies ■ Precision CRTs and allied circuits ■ Miniaturized power supplies ■ Projection, recording, computer display, radar-sonar-multisensor tubes and variety of CRTs and components.

Thin-Film Video Performance:

Pocket TV and pictures on the wall.

Real-time video performance on a thin-film transistorized electroluminescent (EL) panel no thicker than ordinary window glass has been successfully demonstrated at the Westinghouse Research Laboratories in Pittsburgh.

Dr. F.C. Luo of the Westinghouse Research Laboratories holds a developmental display.

"We have been investigating the real-time, grey-scale capabilities of our 6-by-6-inch, 20- and 30-lines-per-inch EL display panels," says Dr. T. P. Brody, head of the research group. "Our results, though preliminary, have far exceeded our original expectations. We have obtained good quality TV imagery with no visible smear, even for rapidly moving objects."

First announced in October, 1974, the 1/8-inch-thick display panel is primarily designed for digital, alphanumeric display – i.e., simple ON-OFF operation of the display elements in applications such as computer readouts and radar screens. However, since the microminiature thin-film transistors that control the brightness of the elements are also capable of grey-scale operation, Westinghouse researchers decided to attempt video inputs.

"The picture on our current panel," Dr. Brody says, "can be taken directly from any video-taped feed or commercial TV signal. It has excellent contrast and no problem with flicker. We can – and sometimes do – watch the afternoon soap operas on it." Nevertheless, Dr. Brody pointed out that they have quite a way to go before achieving line resolution and brightness comparable to present-day television receivers.

Westinghouse's thin-film transistorized panel, an enormous integrated circuit measuring six inches square, has 12,000 glowing picture elements in a 110 x 110 element format. Picture elements are phosphor dots that light up when electricity passes through them, similar to the phosphor dots on the inside face of a cathode ray tube.

Each element consists of two thin-film transistors, a storage capacitor and a phosphor overlay material. The transistorized matrix allows separate elements to be energized without activating others in the same row or column. Moving images are formed when a number of dots are triggered almost simultaneously across the entire screen, 30 times per second. The transistors also control the dots' brightness.

Dr. F. C. Luo, the scientist who built their 20- and 30-lpi panels, is now at work on a 3-3/4 x 5-inch display panel designed specifically for TV imaging. It will use a white phosphor rather than the green of the alphanumeric displays, will have 262 lines and will consist of over 80,000 elements. (A black-and-white screen with full TV resolution would require 250,000 elements, and a color screen would need three times that many.) Work is also in progress to increase the line density to 100 or to 128 lines per inch. The latter density is above the human eye's resolution limit and therefore appears continuous.

Dr. Brody pointed out that the major obstacle in developing a solidstate screen to a performance level comparable to present-day CRT's has been the problem of distributing the information to large numbers of picture points by some sort of wiring. No practical way of wiring 100,000 or more light emitting dots, one by one exists. Now, through thin-film transistor technology, the wiring is integrated into the panel itself. Leads on two sides of the panel feed signals to the thin-film circuit matrix, which then energizes the EL cells. The development of scanning and edge driver circuits, which can be simultaneously deposited onto the substrate along with the transistorized matrix, will further reduce the number of external leads from the present 220 to about 20. Continuous shading, rather than the eight levels of brightness now used, can be achieved through a modification of the drive electronics. Substantially better TV-type performance is expected from panels designed specifically for video display, Dr. Brody contends.

"Our 30 lines-per-inch digital panel weighs only a few ounces and consumes only 1 watt," Dr. Brody says. "We have produced on this panel legible letters in ambient illumination up to 10,000 footcandles, which is equivalent to direct sunshine at an elevation of 50,000 feet."

Among the work remaining to be done, Dr. Brody says, are improving the resolution, developing the thin-film driver circuitry, developing full color capability, and, most important, removing the few blemishes still visible on the screen.

"We already have phosphors in all the necessary colors," he says, "but a thin-film-transistorized, matrix-driven color TV panel would take several more years of concentrated effort."

However, Dr. Brody believes that the systematic development of thin-film transistor technology – without any further technological "breakthroughs" – could be the solution to the electronics industry's more than 20-year search for a solid-state equivalent of the bulky, high-voltage cathode ray tube. He emphasized that the present color TV tube has an extremely high level of performance and low cost, and said that an initial penetration of the flat TV screen into the consumer market is more likely to be in novel forms which are not accessible to the tube, such as a pocket set or a very large area, nonprojection, picture-on-the-wall system.

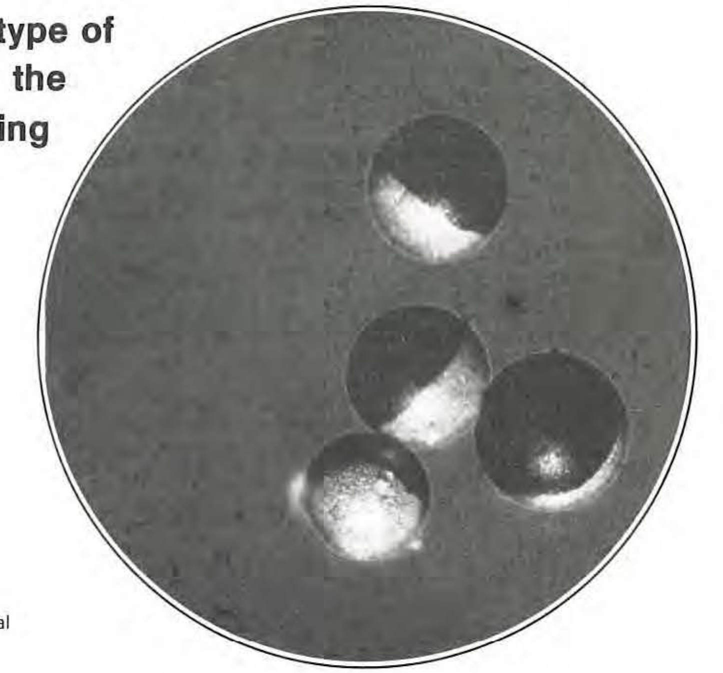
Multicolor Graphics

Complementing their line of monochromatic CRT monitors, KRATOS now offers Beam Penetration Phosphor multicolor display capability with resolution comparable to that of their black and white, random position, XYZ units. These monitors display characters, symbols and vectors in any of 4 standard colors which are selected by internally switching the CRT anode voltage. A fifth color is optional. Several standard models are available with screen sizes for 5" to 25" in both single chasis and dual chassis configurations. This allows for rack mounting of monitor and electronics or adaptation to the user's stylized console. Custom units are also available. KRATOS Display Division, 403 S. Raymond Ave., BIN 45 Pasadena, CA 91109.

A Magnetic Particles Display

Here's an update of a relatively new type of panel, matrix addressable display — the magnetic particles display: its operating principles, potential advantages and the results of recent research on its fabrication.

by Lawrence L. Lee
Magnavox Government & Industrial Electronics Company
Fort Wayne, IN



The magnetic particles display is a flat-panel, matrix-addressable display device. It forms images with a panel of free-rotating spherical particles each of which is a tiny permanent magnet, dark-colored in one hemisphere and light in the other. Thus, the amount of ambient light reflected by the particles is a function of the particles' orientations which is, in turn, controlled by a magnetic field. The magnetic field comes from a nearby not-so-permanent magnet array that functions as a memory. Sites in the memory can be selectively magnetized by currents through conductors imbedded in the display. Schematic sketches of the magnetic particles and the construction of the magnetic particles display are shown in Figures 1 and 2.

Matrix-addressing is possible – in a manner comparable to the switching of computer memory cores by coincident pulses of currents. The memory is first magnetized uniformly in one direction. It is coersive and can resist demagnetization by reverse fields below a certain threshold. Only stronger fields can reverse the direction of magnetization. Currents through the addressing conductors are designed to generate a reverse field below the threshold everywhere except at the selected site where the combined field-strength exceeds the threshold and the magnetization is locally reversed. Then the display will register a light spot against a dark background (or vice versa). Once the image is written into the memory, it will remain there until changed by further addressing. The memory is non-volatile and sustains stationary images without consuming any power. A more detailed analysis given in reference (1) shows that the scheme for matrix addressing and the non-volatile memory are also capable of giving a continuous grey-scale.

The magnetic particles display is in some respects similar to Ferranti-Packard's displays which also use rotatable multicolored magnets. An important difference is the size and shape of the magnets. Because they are spherical, the magnetic particles do not need to be pivoted for rotation, making it practical to use very large numbers of very small particles. Some particles are so small they cannot be resolved by the naked eye, offering the possibility of high-resolution displays. The memory can also be fabricated as one continuous sheet, so only the discreteness of the addressing grids of conductors ultimately limits resolution.

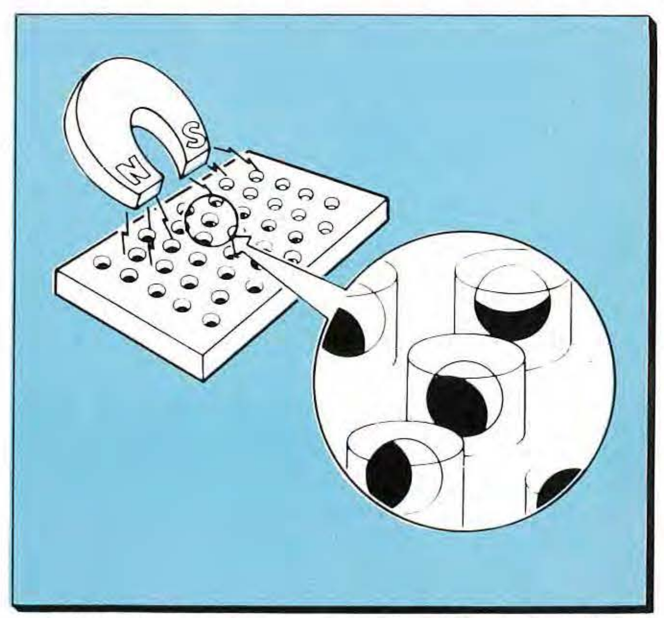


Fig 1 Principle of the magnetic particle display. Each spherical particle dark-colored in one hemisphere and light in the other is a tiny permanent magnet, free to rotate.

Table 1 lists the magnetic particles display's potential advantages. Most of them are direct results of the display's concept; the ones that are not suggested by the descriptions given above are observations from experiments described later.

Fabrication of the magnetic particles was reported in the SID International Symposium of May 1975 (2). These particles were made of polyethylene with powdered Strontium ferrite as a filler. They are naturally black; the light hemisphere is generated by applying a reflective metallic coating. Uniform spherical particles in sizes ranging between 20μm and 400μm have been made by generating droplets of the molten material (liquid polyethylene with the powdered ferrite in suspension) off the rim of a rapidly rotating toothed wheel and allowing them to solidify in-flight. These particles are then magnetized and metallized on one hemisphere. Two methods of metallization have produced satifactory results: in one method, aluminum was evaporated onto one side of the particles in vacuum; in the other method, silver is deposited onto the submerged hemisphere of particles on the surface of an electrodeless silvering bath. Circular photo shows a photomicrograph of some particles fabricated by the second method.

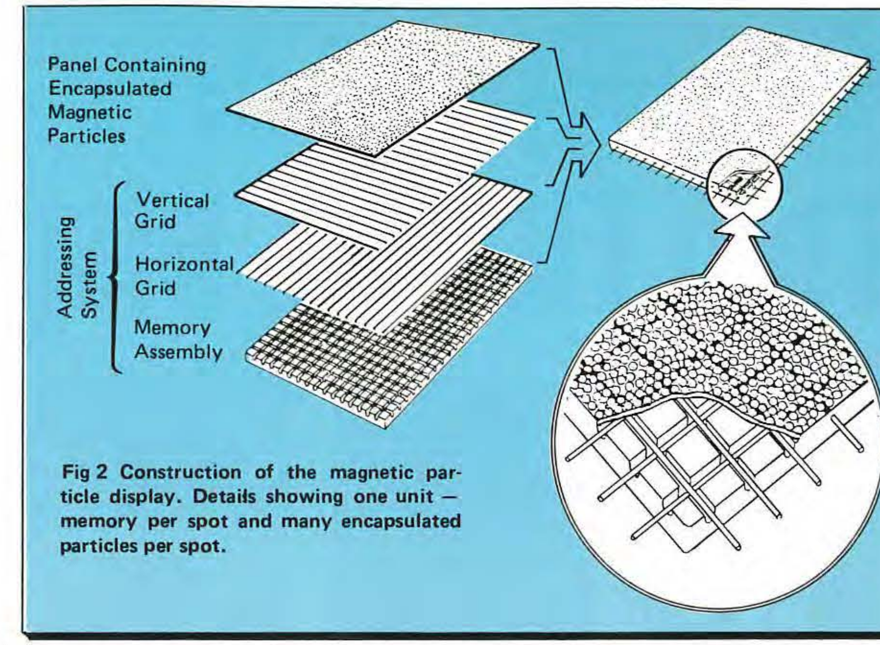


Fig 2 Construction of the magnetic particle display. Details showing one unit — memory per spot and many encapsulated particles per spot.

The magnetic particles displays described in (1) would be constructed with each particle encapsulated with a small amount of lubricant in its own transparent capsule, the capsules would then be cemented together to form the display panel. Encapsulation would enhance the display's sensitivity by diminishing the interaction among the particles. Some techniques for microencapsulations are described in (3). A small number of our magnetic particles have been microencapsulated; they were observed to have many times the sensitivity of the free particles (encapsulated particles were observed to respond to magnetic fields as weak as a few gauss) thus reaffirming the promise for high-sensitivity displays.

Table I Potential Advantages of the Magnetic Particles Display
Matrix addressable • Adequate contrast • Wide viewing angle • Good viewability under bright ambient illumination • Low power in some applications • Grey-scale capability compatible with memory • Low cost • Rugged and capable of surviving hostile environments • High resolution (ultimate resolution determined by the practical limit for fabricating fine grids of electrical conductors) • High write-in speed (determined by the time required to magnetize a site in the memory) • Low operating voltage (device is current-controlled) • Non-volatile memory (requires no power to sustain stationary images) • Flat panel

Lower sensitive displays were made by confining the free particles in thin (two-dimensional) cells of transparent materials. In some of these displays, the particles are surrounded by a transparent liquid lubricant; in others, the particles are dry. The displays without lubricants are generally less sensitive (probably because they have more friction), have lower contrast (because the blacks are not as black), but are more pleasing to look at (probably because the whites are whiter), and potentially usable over a wider temperature range (since they contain no liquid to boil or freeze). These displays were observed to generate clear images with wide viewing angles and contrast ratios up to 15; images do not "wash-out" even under high level of ambient illumination.

Seven-segment digital displays with one reversible magnet at each segment have also been constructed and satisfactorily operated. They were the first devices used for demonstrating the nonvolatility of the memory.

For an experimental verification of the method suggested in [1] for matrix-addressing, a 10 x 15 matrix was constructed and tested for performance. The results will be presented at the SID International Symposium, Apr. '77 [4].

Magnetic particles displays, which started as an interesting suggestion and exercise in theoretical study, have now received experimental support in all major areas of technology. Although more developments in each one of these areas is still needed, it appears most probable that the magnetic particles display, with so many potential advantages, will provide useful services for a wide range of applications.

References:

(1) L. Lee, "Magnetic Particles Display" Proc SID 16, 3, pp 177-184 (1975); also IEEE trans on Electron Devices ED-22, 9 pp 758-765.

(2) L. Lee, "Some Recent Advances on the Development of the Magnetic Particles Display." SID 1976 International Symposium, Beverly Hills, CA, May 1976; Digest of technical papers published.

(3) M. Gutcho, Capsule Technology & Microencapsulation, Noyes Data Corp, Park Ridge, NJ (1972).

(4) L. Lee, A Matrix-addressed Magnetic Particles Display, SID 1977 International Symposium, Boston, MA, April 1977.

Thin Film EL Displays



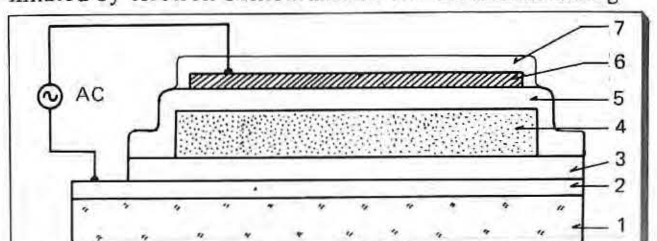
by Chuji Suzuki, Toshio Inoguchi and Sanai Mito
Central Research Lab.
Sharp Corporation
Tenri Nara, Japan

A number of studies on electroluminescent display devices have been pursued since G. Destriau[1] discovered its phenomena in 1936. Although these EL devices were manufactured industrially around 1960, their meagerness in brightness, efficiency and life appeared to be insurmountable. Thus, only a handful of people continued to research and develop EL devices and their applications.

In recent years[2], however, Sharp Corporation developed a stable, long life, high brightness thin film EL display device with a double insulating layer structure that gives evidence of greater potential for practical use of the EL display panels. This new type of EL device has inherent memory function applicable to graphic displays for computer terminal and still picture displays for videophone and television systems. Furthermore, the device shows photo polarization and photo relaxation effects by exposure of external light when suitable DC bias or zero bias is applied to the device, respectively. This attribute facilitates the use of a light pen or photographic projector for transcription and superposition of images on the panel. A thin film EL display device with a number of remarkable functions, and a variety of its applications will be introduced in this paper.

Basic Construction

The thin film EL display device has a basic three layered construction: an active EL layer sandwiched between two identical insulating layers which are useful in prolonging the life and enhancing the reliability of the device. Fig 1 illustrates the structure of the device. A plane glass substrate is first deposited with transparent conductive electrode made of In_2O_3. This electrode is chosen to be transparent for the displayed image on the EL layer to be visible through the glass substrate. An insulating layer of Y_2O_3 or Si_3N_4 having about 2000Å in thickness is then deposited over the transparent electrode. The active layer of ZnS doped only with Mn is formed over the first insulating layer by means of vacuum deposition, in which compound materials of phosphor contained in a crucible is directly heated and sublimated by electron bombardment. The second insulating layer which uses identical materials as the first insulator, is deposited over the active layer upon which a rear electrode layer of Al is formed. The thickness of the EL active layer and the second insulator are about 5000Å and 2000Å, respectively. Finally, silicon resin coated over the back electrode protects the device from humidity or graze.



1) Glass substrate 2) Transparent electrode (In_2O_3) 3) Insulating layer (Y_2O_3 or Si_3N_4) 4) Active layer (ZnS:Mn) 5) Insulating layer (Y_2O_3 or Si_3N_4) 6) Metal electrode (Al) 7) Protective coating (Silicon resin)

Fig 1 Schematic structure of the thin film EL device.

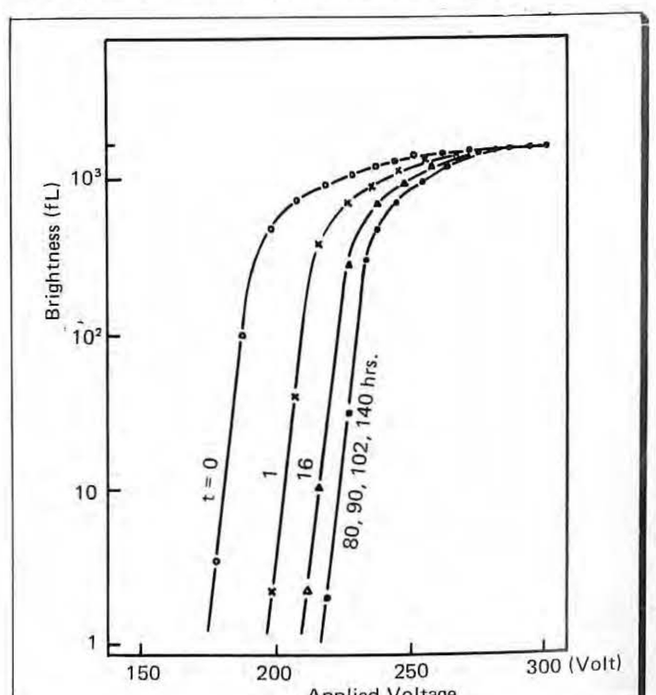


Fig 2 Brightness vs. applied voltage characteristic of the thin film EL panel.

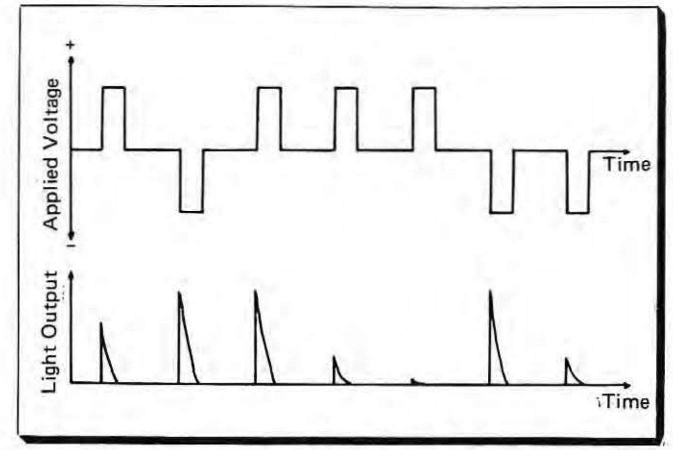


Fig 3 Schematic illustration of polarity effect on brightness of the T.F.E.L. panel.

Operating Characteristics

The sandwiched type thin film EL device described in Fig 1 is driven by an alternating electric field. The EL brightness versus the amplitude of the applied AC voltage characteristics are shown in Fig 2. Note that the brightness is extremely dependent on the applied voltage in the lower voltage region, and tends to saturate in the higher voltage region. Besides, this characteristic curve shifts toward the higher voltage side as time elapses, but it is not an indication of the degradation of the brightness. According to the result of its life test, no change in brightness is observed during an accumulated operation of over 2×10^4 hours at a constant operating voltage.

The EL device exhibits high brightness under an AC applied voltage with its typical saturation brightness around 1.5×10^3 fL at 5 KHz. Our experiments lead us to believe that such good performance is caused by internal polarization effect in the EL layer. Fig 3 shows the polarity effect on the brightness of the sandwiched type EL device. Reversing the polarity of the succeeding pulse increases the brightness remarkably. In contrast, when the polarity of the succeeding pulse is the same, the observed brightness is remarkably low. In other words, the internal residual polarization

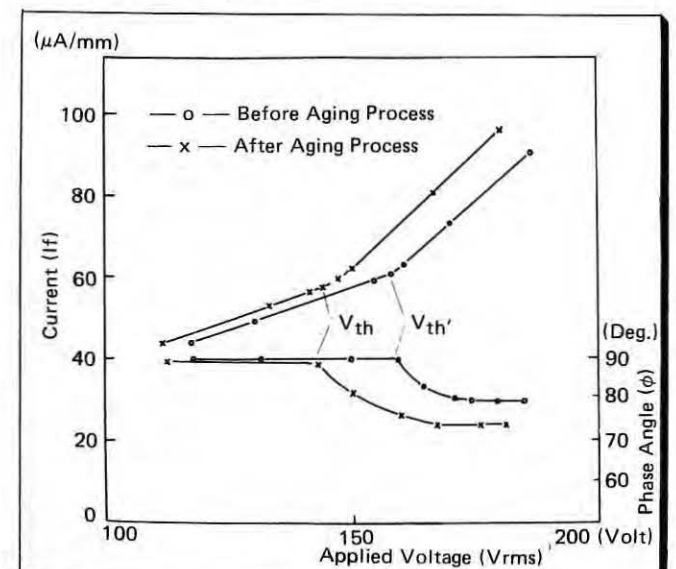


Fig 4 Fundamental frequency component of device current and its phase angle vs. voltage.

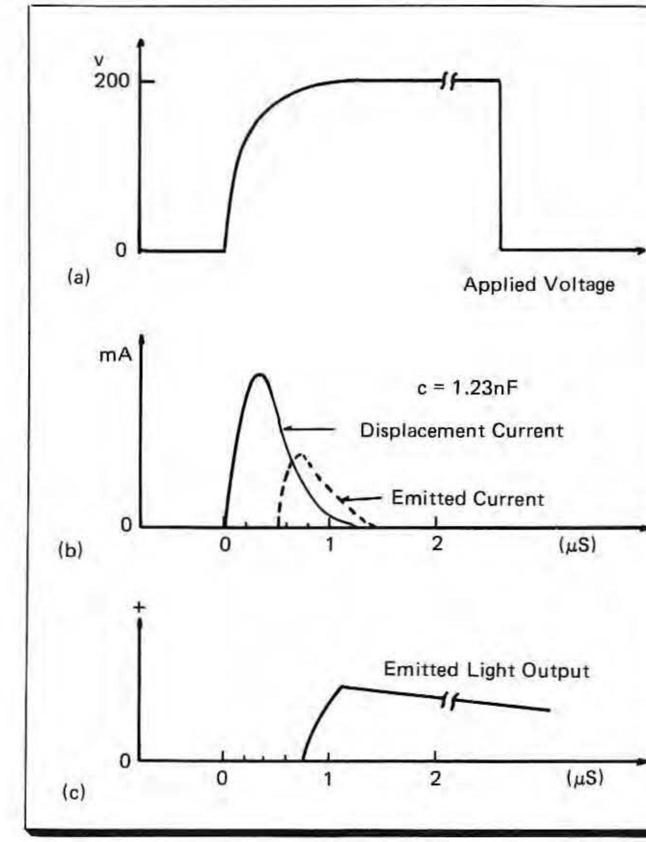


Fig 5 Wave form of applied voltage, displacement current. Emitted current and emitted light output observed with EL device.

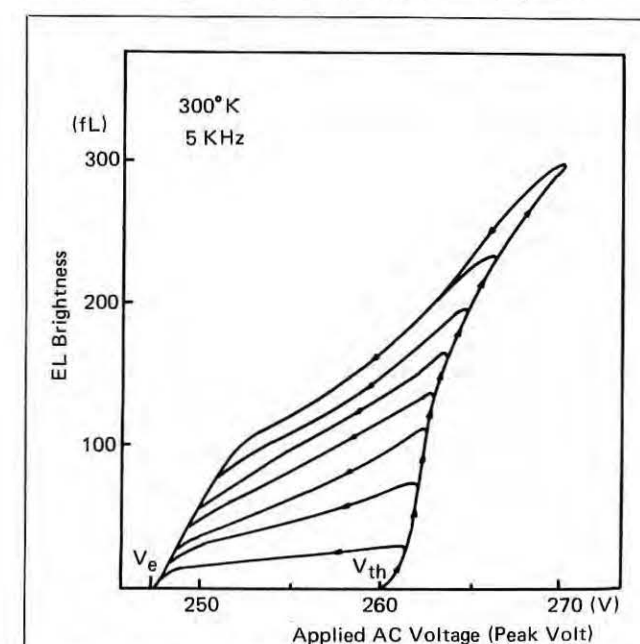


Fig 6 Hysteresis behavior observed in the EL brightness vs. voltage amplitude characteristics under square wave excitation.

of the former pulse is enforced by the added effect of the succeeding pulse voltage.

The current characteristics and the phase angle between the voltage and current versus the amplitude of the applied voltage, measured under the application of sinusoidal voltage of 1 KHz in frequency, is shown in Fig. 4. Here, the current (If) is the measured value of the fundamental frequency component. As is evident from Fig 4, in the lower voltage region, the current flowing through the device was mostly a pure displacement current which is attributed to inherent series capacitance of the individual layers in the sandwiched type structure. Within this region, light emission due to electroluminescence was not observed. The abrupt change in current and phase angle occurs at the threshold voltage of V_{th} causing an EL emission. In the higher voltage region beyond V_{th} or V_{th}', the abrupt increase in current exclusively determined by the capacitance of the insulating layers of the device, and the increased phase angle depends on the value of conductance in the EL layer.

If a single pulse voltage in the train of the AC driving pulses as illustrated in (a) of Fig 5 is applied between the metal and transparent electrodes, the displacement current and the pulsive polarization current flow into the device during a very short period of time as shown by the solid line and dotted line in (b) of Fig 5, respectively. Furthermore, as shown in (c) of Fig 5, the device emits a yellowish orange light having rapid rise time and suitable decay time. During the course of the improvement studies of the three layered EL device, we found that the device was endowed with inherent memory function when the doping content of Mn exceeds 5 wt % and the deposition of EL layer was controlled to a suitable thickness. The dependence of EL brightness on the applied voltage under square-wave excitation, traced on an X-Y recorder, is shown in Fig 6. Here, we observe a typical hysteresis behavior in the increasing and decreasing processes of the amplitude of the applied voltage. The figure shows that the V-B hysteresis loop varies continuously with respect to the applied voltage above Vth, rendering the operational points within the hysteresis loop.

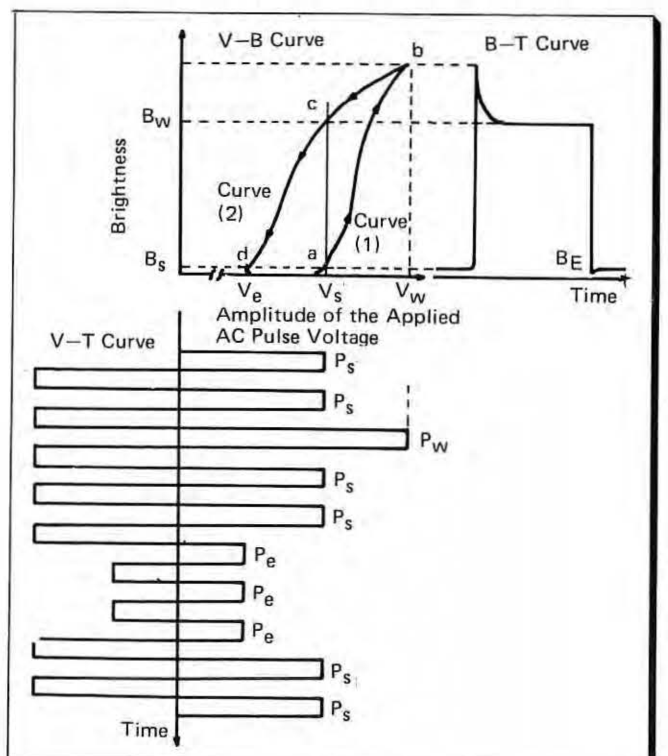


Fig 7 Diagrammatical representation of the memory operation in accordance with B-V hysteresis loop.

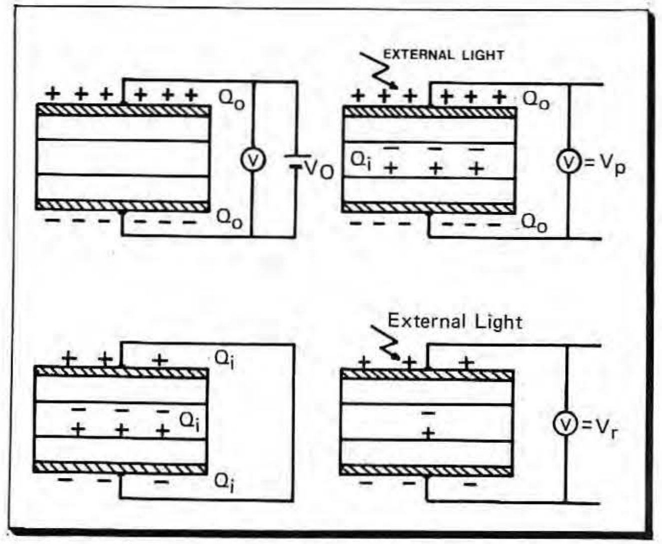


Fig 8 a) Voltage is applied in the dark (b) Formation of photo polarizatic (c) Internal polarization continues in the dark.

Fig 7 shows the diagrammatical representation of the memory operation in accordance with the V-B hysteresis loop. First of all, if a train of sustained pulses, Ps, of amplitude Vs are impressed continuously upon the device, the brightness is sustained at Bs which corresponds to point "a" on curve (1). Now, if a single writing pulse Pw, whose amplitude Vw is larger than Vs, is temporarily impressed during the Ps pulses, the resulting brightness settles at Bw that corresponds to point "c" on curve (2). If a train of erasing pulses, Pe, consisting of a few pulses whose amplitude is decreased from Vs to Ve are impressed, the EL device is restored to its initial state, Bs, where the brightness is faint. Switching on and off of the memory function is possible in such a manner.

More recently, we discovered a newly observed phenomena: the photo polarization and photo relaxation of the EL device. The three layered EL cell as shown in (a) of Fig 8 is placed in the dark while DC voltage, Vo, is applied to the electrodes. The electrodes are charged with electrostatic charge, Qo, as does a simple capacitor. The DC voltage source is removed after having charged the electrodes. The cell is then exposed to light through the glass substrate. The light excites electrons in the EL layer, to be displaced to the

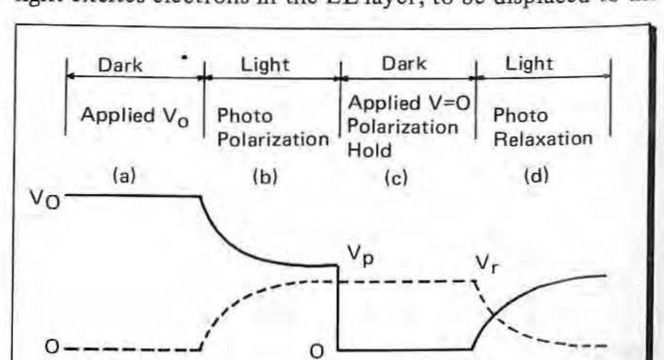


Fig 9 Process of photo polarization and relaxation.

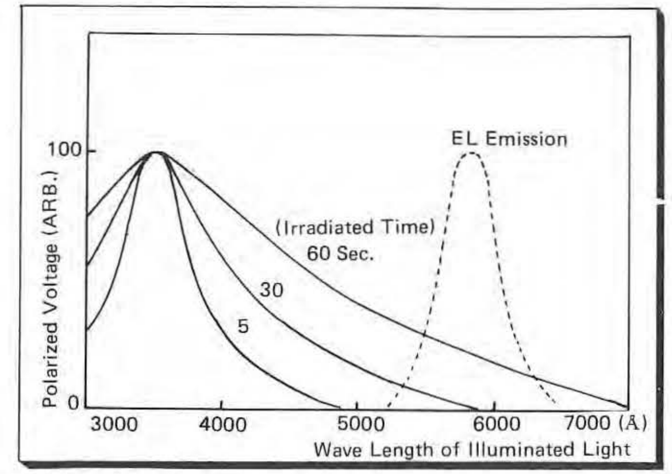


Fig 10 Polarized voltage versus wave length.

dielectric layer interface. This is the displaced internal charge, Qi, depicted in (b) of Fig 8 which is the photo polarization that takes place within the active layer. The electrode potential drops from Vo to Vp after completion of the photo polarization. The terminals are then short circuited to remove the charge on the electrodes as is shown in (c) of Fig 8. The polarized charge, Qi, created within the active layer remains for a few hours if the cell is kept in the dark. Opening the external circuit, exposing the cell to light again as shown in (d) of Fig 8 causes the polarized charge, Qi, within the active layer to relax, which in turn produces a residual potential of Vr between the electrodes.

Fig 9 shows the relationship of inter-electrode potential and polarized electric field during the photo-polarizing process and photo-relaxation process. The solid line represents the electrode potential and the dotted line the polarized electric field. We confirmed the wavelength dependence of photo polarization by the following experiment. To avoid thermal polarization, we immersed the cell in liquid nitrogen and applied a constant voltage of Vo, illuminating the cell with various monochromatic light. Fig 10 shows the relation between the polarized voltage, Vo, and the wavelength of illuminated light at Vo=10 volts. This experiment indicated that light of 3500Å wavelength offered enhanced polarization.

The polarized charge Qi caused by photo-polarization process is determined by the intensity of external light and the time of illumination. This charge remains polarized for a few hours, if the cell is kept in the dark. To convert this polarized charge into readable visible light, it is necessary to superpose a readout pulse upon the polarized field. In the experiment shown in Fig 11, the cell is illuminated with a tungsten lamp while it is being impressed with DC bias voltage Vd, whereby the polarization reaches completion within a few seconds. The reason why polarization is kept for 300 seconds in the figure is because it was necessary to observe the relation of the formation of polarization and the readout processes separately. Thereafter, if a reading pulse with opposite polarity to that of the DC bias voltage is impressed, the enhanced light output is observed as shown in (b) of Fig 11. On the other hand, if the DC voltage and the reading pulse have the same polarity, the effect of superposed internal polarization, being the difference between the two, would be decreased or offset. The relation between the peak value of light output vs. readout pulse voltage with the DC

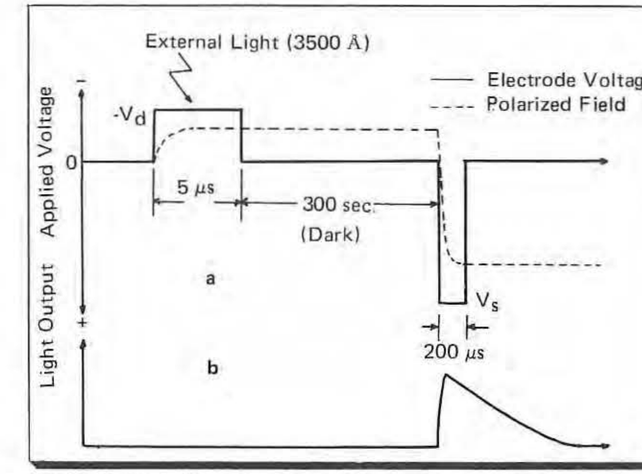


Fig 11 Enhanced superposition of the photo polarized field and the read out pulse (Vs).

bias of Vd as parameter, is illustrated in Fig 12. The readout pulse has a constant pulse width of 200 microseconds, and the output light is in arbitrary scales.

X-Y Matrix EL Display Panels

Fig 13 is an experimental matrix EL display panel with 48 mm x 36 mm picture size for television picture display. The electrodes of this panel consists of 120 column electrodes made of In_2O_3 transparent conductive layer and 90 row electrodes of Al. Each electrode is connected to the printed circuit board with copper wires as shown in Fig 13. Subsequently, we developed a large size EL matrix panel endowed with inherent memory function made of 320 x 240 dot elements displayable of 160mm x 120mm picture size for alpha-numerical character display. And more recently, we have fabricated a 240 x 160 element panel with memory made of 120mm x 90mm picture size for graphic and picture display.

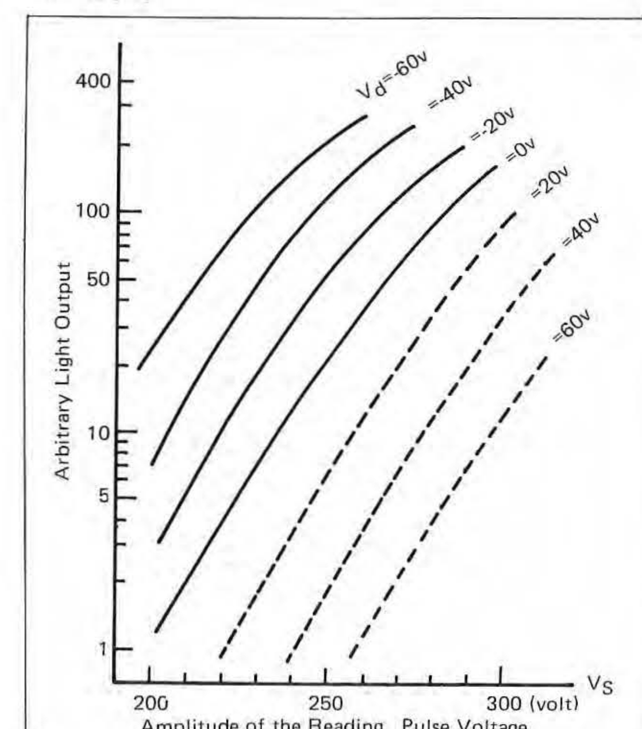


Fig 12 Sustain pulse voltage vs. light output characteristics.

Table 1

Number of Picture elements	108 x 81
Picture color	yellowish orange
Addressing	one line at a time out of every three lines
Driving pulse voltage	260 peak volts horizontal--------- 130V vertical ------------- 130V
Gray scale	8 grades
Brightness	maximum 60 fL at pulse width --- 100μS
Contrast ratio	50:1

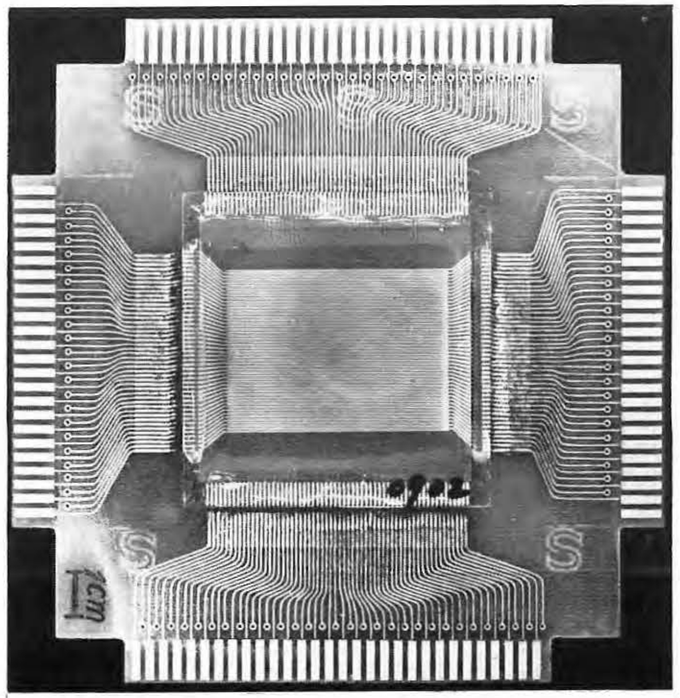


Fig 13 Experimental display panel

Fig 14 Reproduced TV picture.

Application to Picture Displays

As a first application of the EL matrix panels, we developed an imaging system for television picture display with 120 x 90 dot elements. The brightness of this panel depends not only on the driving pulse voltage, but also on the pulse width, thus making it possible to realize gray scale of brightness by modulating the duration of the pulse. The most important feature of this system is in the method of addressing of the AC operated panel. The TV video signal is converted into digital signals that correspond to one TV horizontal scanning line. Picture elements are stored into the memory units individually. These digital signals are converted further into the width of the driving pulses, which are imposed upon all the column electrodes of the panel at the same time. The scanning pulse is impressed upon the selected row electrode. The performance of this experimental TV imaging system is summarized in Table (1). A photograph of the reproduced TV picture on the experimental matrix panel is in Fig 14.

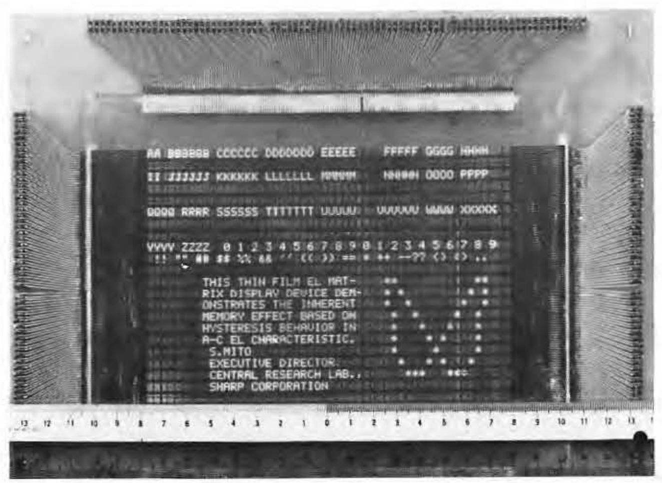


Fig 15 Photograph of experimental character display.

Fig 16 Photograph of experimental graphic display.

Fig 17 Photograph of picture display that results from exposure of positive photographic picture using a slide projector.

Table 2

Number of characters	1248 character (52 character x 24 lines) one character consists of 5x7 dots
Color	yellowish orange
Sustain pulse voltage	420 volt (peak to peak)
Writing pulse voltage	280 volt (peak)
Erasing pulse voltage	370 volt (peak to peak)
Power source voltage	190 volt and 130 volt
Brightness	about 30 fL at 300 Hz sustain pulse frequency
Contrast ratio	10:1
Power consumption of sustain driver	about 10 watts

Application to Alpha-numerical Character Display

We also developed an alpha-numerical character display using a large size EL matrix panel with inherent memory. The 160mm x 120mm picture size panel has a large capacitance of about 0.3μF in comparison with other flat display panel such as plasma and powder type ELs. The usual driving system, therefore, consumes so much power that it is hardly possible to realize a compact character display. To cope with this situation, we devised a driving system in which an inductance is connected in series with the panel capacitance to form a serial LC resonant circuit. This display system employs this new electronics in the driver. Sustained pulses are applied to all the elements at the same time. "Writing" is done by superposing the writing pulse on the sustain pulses during the intermediate period between two pulses. "Erasing" is done by decreasing the amplitude of the sustain pulse below Ve as was illustrated in Fig 7. The experimental results of the character display are shown in Table (2). Fig 15 shows a photograph of the experimental character display.

Application to Graphic Display

Fig 16 illustrates our attempt to develop a graphic display with a 120mm x 90mm display size EL panel with 240 x 180 dot elements endowed with inherent memory; we successfully imprinted optical images directly upon the panel. Fig 17 is an example of a transcribed photographic picture from a 35mm slide projected on the panel.

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Authors Paul Peercy and Cecil Land check image resolution at new PFE device. New method of storing images in PLZT eliminates the need for photoconductive films on the ceramic.

Photoferroelectric Image Storage in PLZT Ceramics

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A new lead lanthanum zirconate titanate (PLZT) ceramic device uses a recently discovered photoferroelectric (PFE) effect to store high-resolution, high-contrast, nonvolatile images.[1] The PFE effect eliminates the need for photoconductive films which characterize all previous PLZT image storage devices.[2-8] The new image storage device consists simply of a thin flat plate of PLZT sandwhiched between two transparent electrodes. Image storage is achieved by exposing the image on a surface of the plate, using near-UV light at the band gap energy of 3.35 eV (3700Å), and, at the same time, switching the ferroelectric polarization through a portion of the the hysteresis loop.[9] Images are stored both as spatial distributions of light scattering centers in the bulk of the PLZT and as surface deformations which form a relief pattern of the image on the exposed surface. Both image storage phenomena are related to spatial distributions of ferroelectric domain orientations[9] introduced in the PLZT during the image storage process.

Stored images can be read out using either transmitted or reflected light. Transmitted light is scattered selectively so that the image can be viewed directly or projected onto a screen using a collimated light source and a Schlieren optical system to enhance the image contrast. For projection, the PFE device is placed in one focal plane of a converging lens and an aperture is located at the opposite focal point. Reconstruction of the stored image by reflected light utilizes the surface defromations on the storage surface. Collimated light is diffracted and scattered by the surface deformations so that the image can be projected onto a screen using Schlieren optics.[5] Reflectivity of the storage surface can be increased by depositing on the surface a dichroic film that transmits the near-UV write-in light and reflects the visible readout light.

Either total or selective erasure of stored images is accomplished by uniformly illuminating the area to be erased with near-UV light and simultaneously switching the ferroelectric polarization back to its initial state prior to image storage. Experiments have shown that erasure of the stored image can also be accomplished by heating the PFE device to the ferroelectric-penferroelectric phase transition temperature(T_t) at which all domain structure disappears.[10,11] For the PLZT 7/65/35 (7 at % La, 65/35 zirconium to titanium ratio) ceramics used in PFE devices, T_t is about 100°C.[10] Erasure by heating has also been achieved with I^2R heating obtained by passing a sheet current through one of the transparent electrodes of the PFE device.[11]

The presently known characteristics of the PFE device along with its attractive simplicity of fabrication suggest several potential applications. Temporary image storage and display is an important potential use. Various types of image and optical information processing are also suggested by device characteristics discussed later. Using scanning techniques to write-in and read out images could also accomplish transmission of high-resolution images over various types of communication channels.[12]

PFE Device Configuration

A major advantage of the PFE device over previous PLZT image storage devices is its simplicity.[1] The device consists of a polished plate (0.2 to 0.3 mm thick) of coarse-grained (grain size >3 μm), rhombohedral-phase PLZT ceramic[7] with low-resistance, transparent indium-tin oxide, $In_{2-x}Sn_xO_{3-y}$, (ITO) electrodes[13] sputter deposited on the two major surfaces as shown in Fig 1. The device shown in Fig 1 is designed for readout of the stored image using transmitted light. For image readout with reflected light, a dichroic film should be deposited on the ITO electrode surface exposed to write-in light. The dichroic film transmits the write-in light and reflects the readout light.

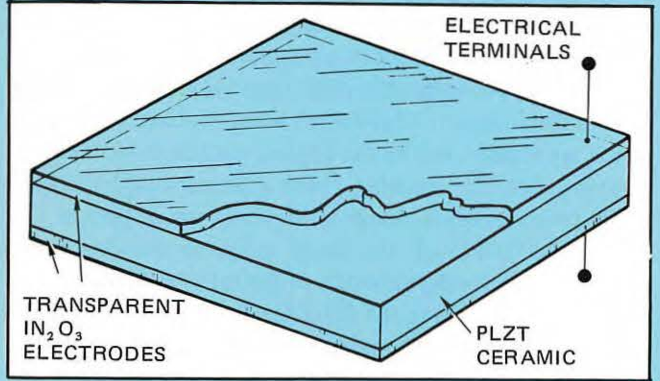

Fig 1 PFE device is designed for readout of the stored image using transmitted light. For image readout with reflected light, a dichroic film should be deposited on the ITO electrode surface exposed to write-in light. The dichroic film transmits the write-in light and reflects the readout light.

With transmitted readout light (scattering mode of operation), the maximum range of image contrast (exceeding 100:1) and maximum resolution (about 40 line pairs/mm) obtained to date were with a device using PLZT 7/65/35 with approximately 5 μm average grain size. ITO electrodes with low sheet resistivities of 2 to 3 ohms per square are used to minimize switching strains and allow fast switching speeds.

All previous PLZT image storage devices required a transparent photoconductive film deposited on one or both surfaces of the ceramic. These photoconducting films were then overcoated with transparent electrode(s).[2-8] In those PLZT ferroelectric-photoconductor (FE-PC) devices which use organic photoconductors (e.g., polyvinyl carbazole, PVK), image storage is inherently slow (1 to 10 seconds) because the conduction mechanism in PVK is a hopping process. Furthermore, the PVK is not uniformly transparent at all visible wavelengths which adds insertion loss and undesirable color in the device. Using sputter-deposited cadmium sulphide[14] or zinc-cadmium sulphide[13] photoconductive films achieves much faster image storage (e.g. 10 to 30 ms). These films usually have lower optical insertion losses than the PVK films, which makes them additionally attractive for most device applications. Unfortunately, CdS and ZnCdS films are technologically difficult to sputter with predictable and reproducible results. Difficulties and limitations imposed by photoconductive films emphasize the need for eliminating these films. PFE devices thus have an advantage over previous FE-PC image storage devices.

PFE Image Storage and Erasure Processes

Photoferroelectric PLZT ceramics are both photosensitive and ferroelectric. Visible light can photoexcite carriers from trapping centers in the band gap, and near-UV light at or near the band gap energy (3.35 eV or 3700 Å) can photoexcite carriers both from trapping centers in the band gap and across the band gap. Because they are ferroelectric, PLZT ceramics can be poled to a saturation remanent polarization by application of an electric field of sufficient magnitude. Their remanent polarization can be reversed or reoriented totally or incrementally by a properly oriented electric field.[9] These ferroelectric properties are illustrated by the polarization P versus electric field E hysteresis loop shown in Fig 2. The net polarization is zero in the virgin or thermally depoled state (A). Applying a negative electric field increases the polarization (negatively) until it saturates at the maximum applied field. Removing the field, poles the ceramic to negative saturation remanence (B). Remanent polarization can be switched incrementally through intermediate values, e.g., (C), (D) and (F), to positive saturation remanence at (B') by application of a positive electric field. In the PLZT compositions used for PFE image storage, the remanent polarization (See Fig 2) is directly related to corresponding ferroelectric domain orientations.

When a voltage is applied to the electrodes of a PFE device (Fig 1), the resulting electric field in the ceramic plate can be spatially modulated by exposing a surface of the device to band gap light of spatially nonuniform intensity. In areas illuminated by band gap light, the electric field is affected by the presence of photoexcited carriers; in the nonilluminated areas, the electric field is uniform. If the polarity of the applied voltage is such that the partially illuminated surface is negative with respect to the opposite surface, the electric field which produces domain switching in the illuminated areas will be greater than that in the dark areas. In this case, an applied voltage just large enough to switch the ferroelectric remanent polarization in the illuminated areas will produce substantially less polarization change in the dark areas. This selective domain switching results in spatial nonuniformity of the ferroelectric remanent polari-

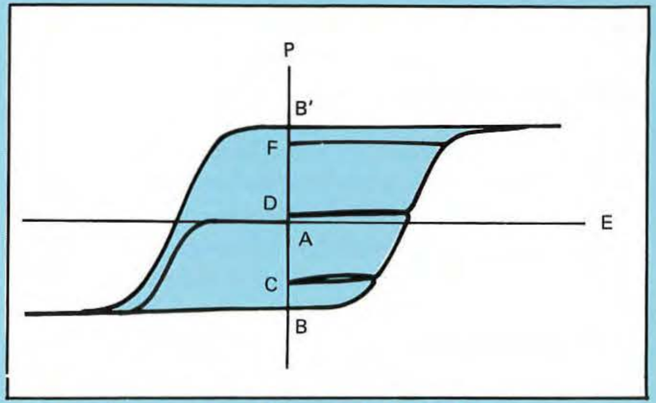

Fig 2 In the polarization (P) vs electric field (E) hysterisis lamp, the net polarization is zero in the virgin or thermally depoled state (A). Applying a negative electric field increases the polarization (negatively) until it saturates at the maximum aplied field. Removing the field, poles the ceramic to negative saturation remanence (B). Remanent polarization can be switched incrementally through intermediate values, e.g., (C), (D) and (F), to positive saturation remanence at (B') by application of a positive electric field.

zation and a corresponding spatial nonuniformity in the light scattering characteristics and surface deformation.

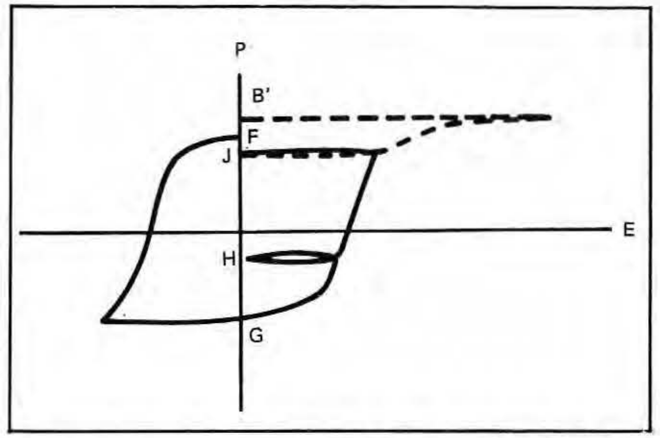

Fig 3 Note that the hysteresis loops of Figs. 2 and 3 are taken from actual data on the same PFE device while storing a photographic image, and the curves of Figs. 2 and 3 are reproduced with the same scale factor. The data of Figs. 2 and 3 show that the effective coercive field[9] during image storage was approximately 30% less than the coercive field measured from Fig. 2. Therefore, the presence of photoexcited carriers or space charge fields resulting from retrapping of photoexcited carriers caused a net average increase of the domain switching field of about 30% during image storage.

Fig 3 illustrates the actual image storage and erasure processes. The remanent polarization of the ceramic is first switched to a point near saturation remanence, e.g., (F) of Figs 2 and 3. An image is then exposed on one of the surfaces of the ceramic using band gap light with intensity ⩾15 mW/cm², and the ceramic polarization is switched from (F) to (G) as shown in Fig 3. The polarity of the voltage used to switch the remanent polarization from (F) to (G) should be such that the illuminated surface of the PFE device is negative with respect to the opposite surface. Experiments have shown that this arrangement produces both higher contrast and higher resolution in the stored image. The remanent polarization $P_{r(ex)}$ in the areas exposed to band gap light is switched by a significantly greater fraction of the total polarization than the remanent polarization $P_{r(d)}$ in the unexposed or dark areas of the image. If A is the total surface area of the PFE device, and ΔP_r is the effective net change in remanent polarization between points (F) and (G), then

$$\Delta P_r A = \Delta P_{r(ex)} A_{ex} + \Delta P_{r(d)} A_d .$$

A_{ex} is the area exposed to band gap light, and A_d is the dark area. As will be discussed in the next section, $\Delta P_{r(ex)}$ depends on the intensity of the band gap light.

After image storage (switching from (F) to (G) in Fig 3) the UV light is removed and the net polarization is switched to some point such as (H) in Fig 3 to obtain a high-contrast positive of the input image or to (J) to obtain a high-contrast negative of the input image. The net polarization may be subsequently switched from (J) to (H) through intermediate values to obtain various amounts of baseline subtraction and corresponding variations of gray and contrast.

It should be noted that the hysteresis loops of Figs 2 and 3 are taken from actual data on the same PFE device while storing a photographic image, and the curves of Figs 2 and 3 are reproduced with the same scale factor. The data of Figs 2 and 3 show that the effective coercive field[9] during image storage was approximately 30% less than the coercive field measured from Fig 2. Therefore, the presence of photoexcited carriers or space charge fields resulting from retrapping of photoexcited carriers caused a net average increase of the domain switching field of about 30% during image storage.

Illuminating the originally exposed surface of the PFE device with band gap light of uniform intensity (about 15 mW/cm²), and switching the net remanent polarization to saturation remanence at (B') – as shown by the dashed lines of Fig 3 – erases the stored image.

PFE Image Storage and Erasure Mechanisms

As stated in the preceding section, a voltage applied to the electrodes of a PFE device produces an electric field in the PLZT ceramic which can be spatially modulated by exposing a surface of the device to band gap light of spatially non-uniform intensity. Absorbed photons in PLZT grains at or near the surface of illuminated areas photoexcite carriers which are transported by the applied electric field to new trapping sites. The resulting charge separation within these grains produces space charge fields (E_{SC}) which oppose the applied field (E_A). The charge redistribution gives rise to an effective spatial variation of the internal domain switching fields (E_I) in the illuminated areas.

Fig 4 illustrates schematically the PFE image storage mechanism. Fig 4 represents a portion of a cross section of a PFE device, including the ceramic grain structure with grain dimensions greatly exaggerated for the purpose of illustration. At the beginning of the image storage process illustrated in Fig 3, a portion of the PFE device surface is illuminated with band gap light as shown in Fig 4. A voltage of the polarity indicated in Fig 4 is applied to the ITO electrodes. Photoexcited carriers in the grain layers near the surface exposed to UV radiation are transported by the applied field to new trapping sites within the grains or at the grain boundaries. Fig 4 shows charge separation in only one grain layer, but, depending on the nature of the absorption characteristics of PLZT[15] and the presence of longer wavelength illumination, absorption and carrier photoexcitation may occur over several grain layers, beginning at the illuminated suface. The space charge fields E_{SC} oppose the applied field E_A in the absorbing grains. Since the charge separation depends on the electric field within these grains, the maximum attainable value of E_{SC} is equal to $-E_A$. The net effect of compensation of E_A by E_{SC} in the absorbing grains is that the applied voltage V_A is dropped across the the nonabsorbing grains beneath the illuminated area, which results in an increased electric field E_I. If the thickness of the ceramic plates is t and the thickness of the absorbing layer is t_A, then in the limit of $E_{SC}=-E_A$.

$$E_I = V_A/(t - t_A).$$

Since $E_A = V_A/t$, it is obvious that $E_I > E_A$. The field E_I causes domains to switch at lower applied voltage than E_A the field in the dark area of the ceramic. The result – nonuniform localized domain switching – is essential to the image storage process.

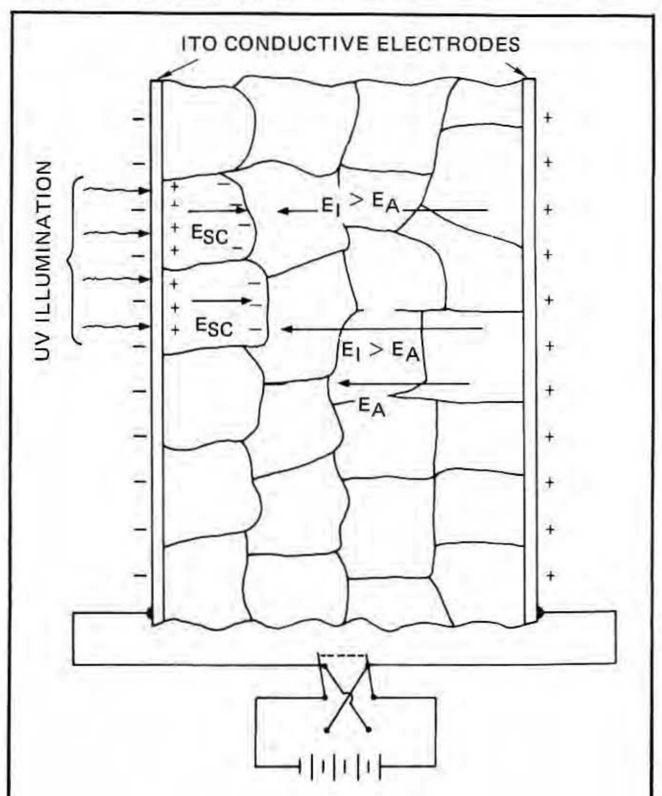

Fig 4 Schematic of a portion of a cross section of a PFE device, includes the ceramic grain structure with grain dimensions greatly exaggerated for the purpose of illustration.

Assuming that the quantum efficiency is uniform over the surface of the ceramic plate, the number of photocarriers excited in any illuminated area depends approximately linearly on the localized intensity of the band gap radiation. It follows, therefore, that the magnitude of the localized space charge fields E_{SC} and, hence, the localized domain switching field E_I depend approximately linearly on the intensity of the band gap radiation provided $|E_{SC}| < |E_A|$ in the absorbing grains. This intensity dependence of E_I is responsible for the apparently linear gray scale reproduction in stored photographic images.

Other physical mechanisms have been suggested[16] to explain nonuniform domain switching during image storage. These mechanisms involve both photoconductivity and photoassisted domain switching. Glass, et al.,[17] have reported the presence of both photoconductive and photovoltaic effects at wavelengths of 4500 Å and less for a PLZT 8/65/35 composition. Further study of PFE image storage mechanisms will probably reveal that all the physical effects enumerated above contribute in varying degrees to the image storage capabilities of PLZT.

The erasure process described in the preceding section frefrequently requires more light energy than the storage process. Rouchon, et al.,[18] report that erasure of photoinduced changes in refractive index in PLZT 9/65/35 requires four times the storage light energy density. We also find that images stored for a number of days are more difficult to erase than those stored for only a few hours. Better understanding of the storage mechanism will undoubtedly lead to more efficient erasure processes. At present, the erasure mechanism is thought to consist of photoexcitation of carriers and subsequent recombination of electron-hole pairs to restore the original polarization state of the ceramic prior to image storage.

Light Scattering Associated with PFE Image Storage

Images are stored in PFE devices as spatial distributions of scattering centers in the bulk of the PLZT and as surface deformations which form a relief pattern of the image on the exposed surface. Light scattering in coarse-grained, rhombohedral-phase PLZT ceramics varies with the magnitude of the remanent polarization P_r measured parallel to the light propagation direction.[1,4,7] thus, from a practical standpoint, the transmittance or insertion loss of a PLZT plate measured by a fixed-aperture detector depends on the remanent polarization of the PLZT. Also, P_R is the saturation remanent polarization after application of an electric field E_S equal to three times the coercive field E_C, i.e., $E_S = 3E_C$. Points (A) through (G) on the insertion loss curve of Fig 5 correspond approximately to similarly designated points on Figs 2 and 3, except that the sense of the polarization axis is reversed in Fig 5. From the discussion of manent polarization of the PLZT. Fig 5 shows the insertion loss in dB plotted as a function of the normalized remanent polarization P_r/P_R for a PLZT 7/65/35 ceramic plate. Note that insertion loss in dB can be divided by 10 to obtain optical density. Also, P_R is the saturation remanent polarization after application of an electric field E_S equal to three times the coercive field E_C, i.e., $E_S=3E_C$. Points (A) through (G) on the insertion loss curve of Fig 5 correspond approximately to similarly designated points on Figs 2 and 3, except that the sense of the polarization axis is reversed in Fig 5. From the discussion of the image storage an erasure processes relating to Figs 2 and 3, you can determine the associated optical insertion losses from Fig 5. For examlple, if a positive of an input image is stored as a spatial distribution of scattering states between (B) and (D), it can be converted to a negative by simply switching the remanent polarization states so that they are distributed between (D) and (B'). In this example, localized areas with an original insertion loss at (D) would be switched to (B'), and areas originally at (B) would be switched to (D). This illustrates how positive-to-negative image conversion occurs and how you can obtain baseline substraction to control the contrast of the stored image by switching to intermediate polarization states, an important capability of PFE devices for contrast enhancement and image processing. (Continued on page 26)

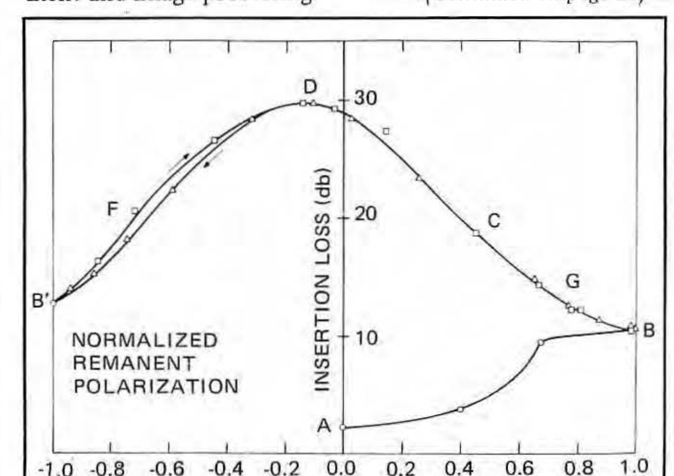

Fig 5 Insertion loss in dB plotted as a function of the normalized remanent polarization P_r/P_R for a PLZT 7/65/35 ceramic plate. Note that insertion loss in dB can be divided by 10 to obtain optical density.

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THICK FILM NICKEL CONDUCTORS FOR DC GAS DISCHARGE DISPLAYS

Air fireable conductor/dielectric system simplifies production

TABLE I*

Base-Plate Processing Steps for 8 to 16 Character Displays

Step	Optoelectronic Compositions	Function	Processing
1	Silver conductor	Edge inter-connect	Print (325 mesh) halfway under glass seal area, dry, fire at 570-600°C peak.
2	Nickel conductor	Segment inter-connect	Same as above. Silver and nickel prints may be cofired.
3	Black dielectric	Cross-over	Print (200 mesh), dry.
4	Black dielectric	Cross-over	Same as above. Fire at 570-600°C peak.
5	Nickel conductor	Segment	Print (325 mesh), fire at 570-600°C peak.
6	Black dielectric	Contrast	Print (200 mesh), fire at 570-600°C peak.

*Values apply for DuPont Compositions

TABLE II*

Physical and Electrical Properties of Thick-Film Dielectrics for DC Plasma Displays

Property	Crossover Dielectric Composition	Contrast Dielectric Composition
Color	Charcoal, Gray-black	Black
Finish	Matte	Matte
Fired thickness	1.5-1.8 mils	1.5-1.8 mils
Insulation resistance at 100 VDC	$>10^{11}$ ohms	$>10^{10}$ ohms
Breakdown voltage		
AC	>500	>500
DC	>900	>900

*Values apply for DuPont compositions

Since the development of the Nixie tube in 1955, DC (direct current) plasma displays have been well known and widely used. Planar format versions of these displays have provided an opportunity and incentive for the use of thick-film materials to produce numeric and alphanumeric display panels. Manufacturers initially fabricated planar numeric displays from thick-film nickel and dielectric compositions, which they fired on ceramic substrates at relatively high (850-1000°C) temperatures in inert or reducing atmospheres.

In recent years, plasma display producers have adopted soda-lime glass to support the transparent tin oxide on face plates. A soda-lime cathode-supporting substrate, in addition to its cost advantage over ceramic, provides a perfect thermal match for the face plate.

To fit the requirements of display manufacturers, DuPont offers a low-firing, nickel-conductor composition, #9530, processable on soda-lime glass to form cathodes. It also makes available compatible dielectric and silver compositions for the air fireable nickel metallization. Of special significance, firing in a conventional air-flow belt furnace eliminates the need for atmosphere control, as explained by F.K. Patterson, S.M. Marcus and R.J. Bacher, Electronic Materials Div., Photo Products Dept., DuPont Co., Wilmington, Delaware.

nickel metallization on glass substrates

The sheet resistivity of the nickel metallization for display applications varies as a function of film thickness, firing temperature and time at peak temperature. In a recommended firing cycle for the conductor on soda-lime glass substrates, the peak temperature stays at 580°C, although peak temperatures up to 600° are permissable.

In addition, the resistance drops with increasing firing temperature. With a firing temperature of 560-600°C, the sheet resistivity falls well within the requirements of a nickel cathode for DC plasma displays, typically ⩽100 milliohms/square (Fig 1).

Fabrication of a DC plasma panel using thick-film techniques requires multiple firing steps. Of great importance the air-fireable nickel metallization, subjected to several firing steps, must not degenerate under these conditions. Degeneration increases sheet resistivity, accompanied by severe oxidation of the nickel surface, which would necessitate a supplemental firing in a reducing atmosphere or other steps to provide a clean surface for glow discharge.

For all cases described in Fig 2, the sheet resistivity decreases with increasing time at peak temperature. The change of resistance with time at peak becomes greatest for the lowest peak firing temperature. These curves demonstrate that the electrical characteristics do not degrade, but, rather, improve with increased firing times.

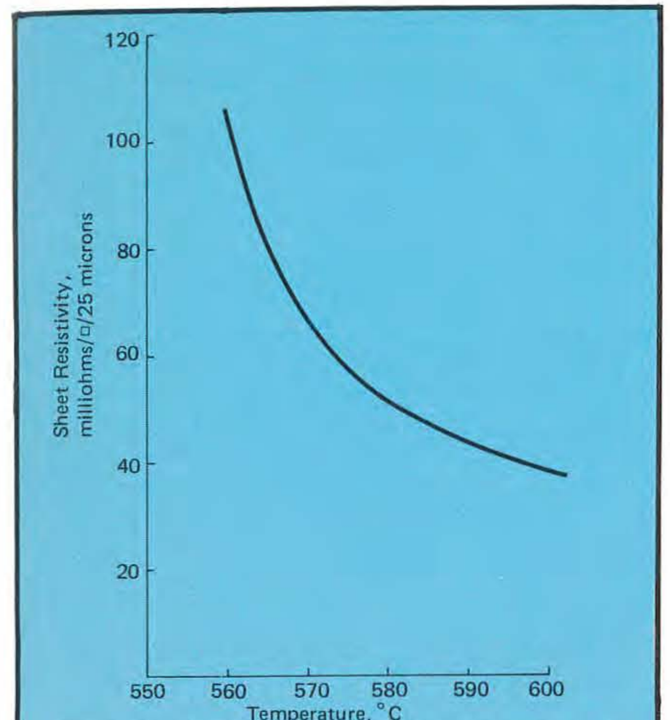

Fig 1 Sheet resistivity vs. peak firing temperature (10 minutes at peak) for 9530 nickel composition.

fabricating an all-glass panel dc plasma display

Using this air-fireable nickel conductor composition and its companion dielectric compositions (9740 and 9741) simplifies the processing of DC plasma displays on soda-lime glass substrates. Since soda-lime substrates are readily available and easily cut to size, the display manufacturers can fabricate a wide variety of shapes and configurations. The following information discusses typical processing steps for the base plates in a seven-bar segment numeric display for calculators with 8 to 16 and 2 to 4 characters.

8 to 16 Character Display

As shown in Table I, the initial step deposits, by means of a 200- or 325 mesh screen, silver 7713 metallization on the glass substrate to serve as the edge interconnect pattern. The film undergoes drying by normal techniques used in thick-film technology. Nickel conductor composition 9530 is then printed and dried in the same manner. Subsequent steps may fire the prints separately or cofire them through a conventional air-flow belt furnace with a 10-to 15-minute dwell at peak temperature between 570° and 600°C.

After this operation come two prints of a black, matte crossover dielectric composition over the metallization. Dielectric 9740 insulates the subsequent segment cathode pattern from the interconnect metallization. The performance characteristics of the crossover dielectric composition appear in Table II. High insulation resistance, good via resolution and absence of pinholes in the fired film to eliminate shorting represent the most important features.

Application of the dielectric usually involves a two-print, dry, operation followed by firing through the previously described profile. The fourth printing step puts down the nickel metallization for each of the seven segments. Rheology of the paste formulation optimizes via filling and ohmic contact with the buried interconnect pattern after firing. The metallization also goes through a firing operation as described before.

The final printing step for the base plate deposits a black, matte-contrasting dielectric that sharply outlines the cathode segments and provides a pleasing contrast to the orange neon glow of the discharge. Electrical and physical characteristics of the contrasting dielectric developed for this function appear in Table II. In most cases display makers can use the crossover and contrasting dielectrics interchangeably, although the electrical requirements for the crossover are more stringent because of the closer conductor spacing.

2 to 4 character display:

For a limited number of characters as in a clock display, a two-step printing operation works well. In such cases, the nickel metallization serves as both an interconnecting and segment pattern. A single print of a contrasting dielectric layer outlines the segments.

final assembly:

Production workers align the base plate with a soda-lime glass face plate containing a pre-etched transparent anode, usually of tin or indium oxide. A solder glass or crystallizable solder glass is then dispensed on both plates and over the overlap of the silver and nickel metallizations with a sandwiched glass spacer; then firing joins the plates.

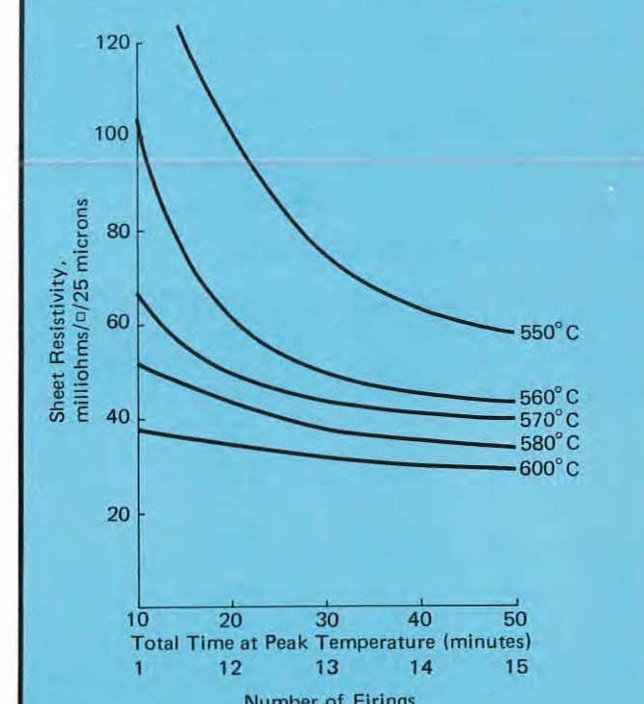

Fig 2 Sheet resistivity vs. total time at peak temperature from multiple firings for 9530 nickel composition.

For reasons of cost, reliability, and process simplification, producers of planar displays have replaced ceramic substrates with relatively inexpensive and readily available soda-lime glass substrates and may convert from controlled atmosphere to conventional air-flow furnaces by adopting the air-fireable "Nicyl"® nickel conductor/dielectric system.

For more information, contact E. I. Dupont De Nemours & Co. Inc., Wilmington, DE 19898.

Fig 6 Image illustrates the gray-scale capability of the PFE device.

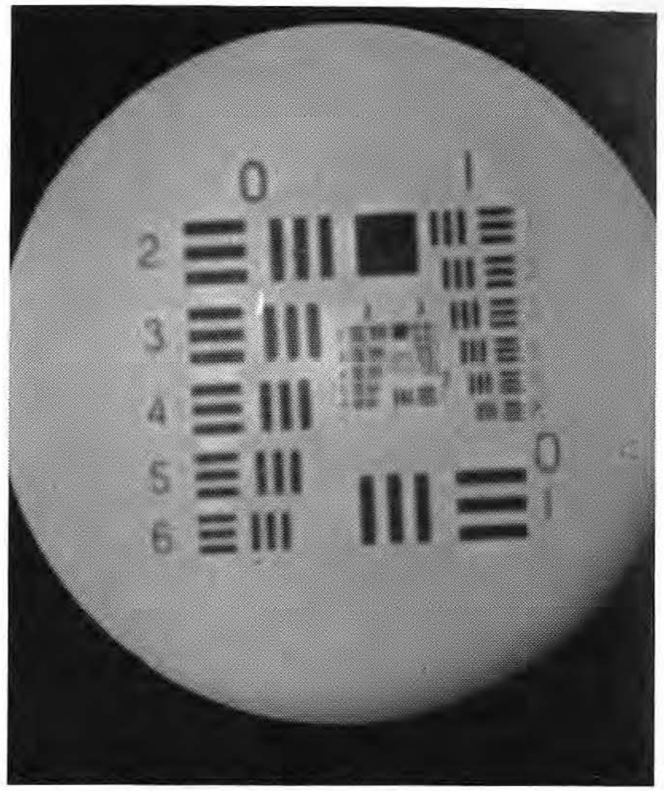

Fig 7 Image illustrates its resolution capability.

(Continued from page 23)

The variation of light scattering with changes in remanent polarization is useful only in devices which use transmitted light to view or project the stored image. Reflective mode devices employ a similar variation of surface strain with changes in remanent polarization to store images as spatial variations of surface deformations.[5,7]

Image Display Using the Scattering Effect

Fig.6 shows two photographic images stored using a PFE dedevice with a 0.25 mm thick PLZT 7/65/35 ceramic plate. The images were projected onto Polaroid color film through a Schlieren optical system with an effective angular aperture of about 5° using visible light transmitted by the PFE device. The images were stored using light from a Hg-vapor lamp of about 50 mW/cm^2 intensity and 700 Å bandwith centered at the 3650 Å Hg line. Similar image storage has been obtained with light of about 15 mW/cm^2 intensity and 200 Å bandwith centered at the 3650 Å Hg line. Maximum contrast of the stored images is about 20 dB, and maximum resolution is between 30 and 40 line pairs/mm. Because the images were photographed on Polaroid color film, the apparent contrast and resolution in the reproductions of Figs 6 and 7 are considerably less than in the ceramic plate.

The images of Figs 6 and 7 can also be viewed or projected by light reflected from the surface exposed to the UV storage light. Indentations or deformations in the locally switched areas of the exposed surface form a relief pattern which can be used to diffract light reflected from this surface and reconstruct the image using Schlieren optics.[5]

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PRODUCTS

Automated Displays Reduce Flight Test Time

Computer-driven graphic display systems that enable ground based engineers to analyze "live" information telemetered from in-flight aircraft are helping engineers at McDonnell Douglas Corporation to reduce overall flight test times.

The graphic display systems, developed by Sanders Associates, Inc., are part of McDonnell Douglas' automated system which has been used for more than 6 years to support test flights of the DC-10 and DC-9 Series aircraft, the A-4 attack plane and the new YC-15 aircraft.

Using the graphic systems, engineers can select telemetered information from the ground computers and display it on 20-inch television-like screens in easy to read graphs and scales. By controlling and monitoring experimental flight operations, ground based engineers can respond to the displayed information while the aircraft is still aloft.

McDonnell Douglas test engineers, observing the data, can immediately advise the flight crew whether a particular movement is successful and whether to proceed with the next manuever in the flight plan. Previous systems required days to determine the success of a particular flight.

Ground based operations

An engineering test pilot, normally assigned as test controller in the center during every telemetered flight, is in constant voice contact with the plane's crew via the microwave-tracking station link and can monitor all phases of the test operation on his own CRT display. The pilot-controller coordinates the flight crew's actions with the real-time data on aircraft performance appearing on his screen to refine and perfect each test procedure as it happens. Thus, the test controller, the test director and the pilot in the air work together to extract maximum information from every hour of the flight.

The new system greatly reduces repetition of tests that yield inconclusive data on the first effort – a costly factor in previous flight development programs. From a four hour test flight, three engineers working two hours can obtain the information and flight objectives. Before the automated system the same data required 4 or 5 days.

Graphic display operation

Using light pens, pushbutton controls and typewriter keyboards coupled to the CRT and computer units, McDonnell Douglas engineers direct the computer in building a complete graphic presentation of data on the CRT screen from a particular phase of testing.

In seconds, the automated system sketches out a basic test report format pre-programmed into the computer's memory discs. The operator then calls up the specific information required and directs the computer to process it into the desired format.

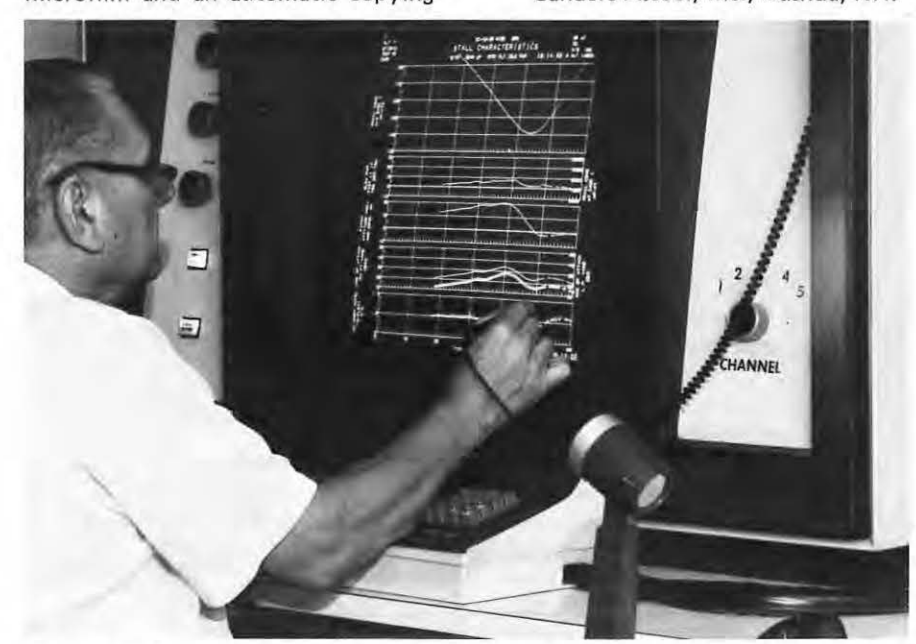
When all the necessary data appears on the screen – for example, as a plot of time, airspeed and flight control positions – the engineer pushes a pair of buttons on his control board. Within seconds the entire display is permanently recorded on microfilm and an automatic copying machine produces a paper copy as well. The hard copy and microfilm recording machines are also part of the Sanders system. The computers also can perform the final analysis of data from another flight while a flight is underway, using information stored by the airborne tape recorders and delivered to the control center after landing.

Airborne segment

Airborne computers process the data from instruments such as strain gauges, pressure sensors and temperature sensors for immediate display to engineers on boards. At the same time, the information is transmitted via a telemetry system to the ground where computers translate the telemetry impulses into useful form for display at the rate of 7200 wps.

The DC-10's airborne system is primarily digital with secondary AM-FM recording capability. One unit telemeters 400 channels simultaneously, while additional units on board the test aircraft allow almost 1600 parameters to be recorded during a single flight.

Sanders Assoc., Inc., Nashua, NH.



Computer driven graphic display systems enable engineers to select telemetered information from the ground computers and display it on 20-inch television-like screens in easy to read graphs and scales. By controlling and monitoring experimental flight operations, ground based engineers can respond to the displayed information while the aircraft is still aloft.

PRODUCTS

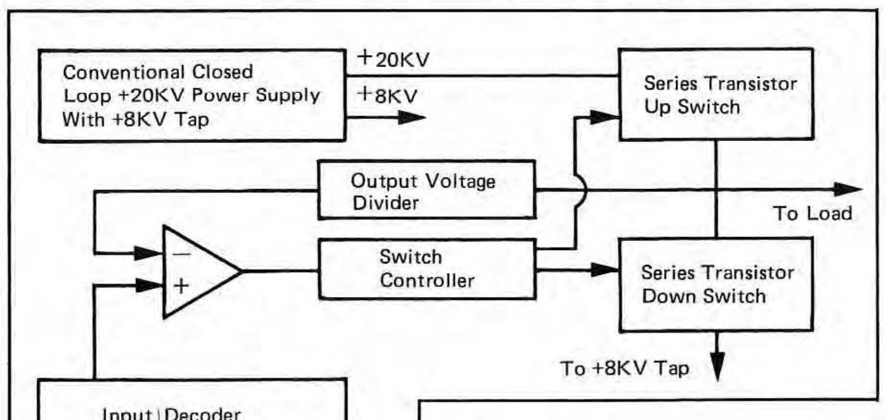
Screen Voltage Supply

10KV to 18KV in Four Adjustable Steps

In 1972, Venus Scientific engineers realized that with the introduction of multilayer phosphor screens, a multicolor, single gun CRT could be fabricated for use as a display tube. The problem with this tube was the inavailability of a high voltage power supply that would supply the screen voltage to the CRT, and would allow the user to randomly change it at speeds consistent with a low flicker display system.

Simply stated, the circuit design problem was to provide a high voltage power supply whose output voltage could range from 10,000 Vdc to 18,000 Vdc with a slew rate of 100 volts/microsecond and at a frequency of at least 60 Hz. The load on the power supply would be a CRT, which can be characterized as a large capacitor (700 pf) in parallel with a current sink. A second requirement was that the unit be all transistorized, including whatever means to be used as the output switch.

Many schemes were evaluated that would perform this function, but most of them were discarded since they did not meet all of the design goals. The first scheme involved the seriesing of multiple high voltage power supplies and switching the output via a multiple number of series strings of transistors from each power supply to the output. One of the switches would be closed at a time



High voltage operational amplifier is composed of a conventional closed loop +20KV power supply with an 8KV tap, a series transistor up switch, an output voltage divider, a differential amplifier and a switch controller. The +20KV power supply acts as the raw power source and the up switch charges up the load until the output of the voltage divider is equal to the analog output of the decoder/digital to analog converter. At this point the switch controller modulates the current supplied to the load through the up switch to maintain the output voltage.

Designed for use with the latest beam penetration color CRTs, the CS-18 supply produces switched anode voltages from 10KV to 18KV in four fully adjustable steps. According to Venus, the unit, with a volume of only 180 cubic inches and input power requirement of only 56 watts, delivers pulse rates of 480 steps per second with transition times of less than 150 microseconds into a load capacity of 750 pico farads.

thus connecting the load to a successively higher output voltage. This scheme was discarded as both the number of levels was fixed for a given design, the output was not capable of random selection and each of the levels was not adjustable. Other similar schemes were investigated using switches to switch the output voltage where evaluated and discarded for similar reasons.

Thus the problem was still there: how to change the output voltage to a large capacitive load rapidly? The scheme finally selected was to configure a high voltage operational amplifier with an output swing capability of 10,000 volts. This amplifier is driven by a precision analog input which represents the desired output voltage. The analog input voltage is derived from the digital input selection lines by an input decoder and an adjustable digital to analog converter. The block diagram details its operation.

When the output of the decoder/digital to analog converter decreases (see block diagram), corresponding to a lower output voltage, the switch controller turns the up switch off and turns the down switch on. The load then discharges through the down switch toward the 8KV tap on the +20KV power supply until voltage out of the divider is equal to the new voltage out of the decoder/digital to analog converter. At this point, output voltage regulation is again achieved by modulating the up switch.

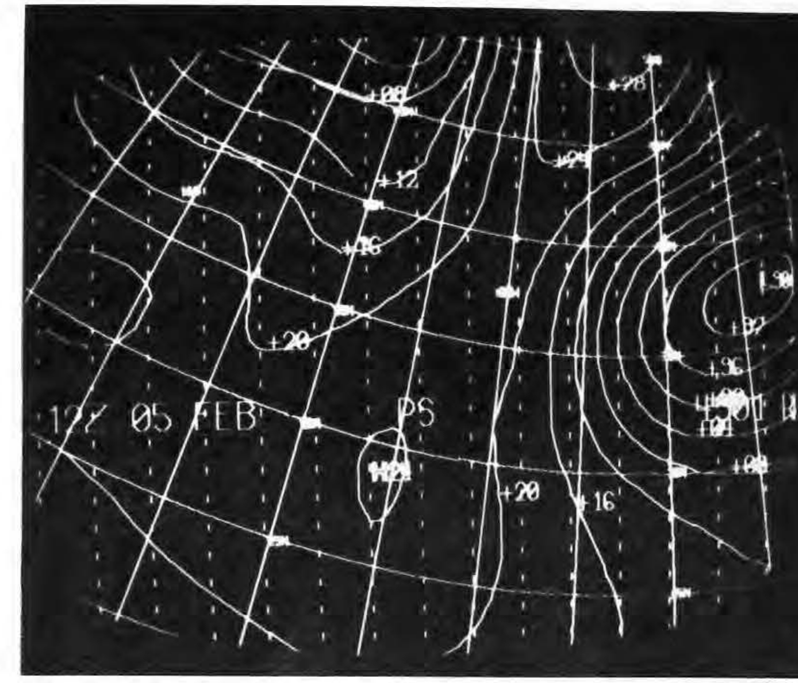
Major problems associated with this scheme were loop stability over a wide range of load capacity, the design of the output voltage divider and the mechanization of the switch controller. Since the load on the system was primarily capacitive and the switch controller was configured as an amplitude controlled oscillator, the open loop gain has three major poles. They are the load pole, the controller pole, and the differential amplifier pole. The placement of compensating zeros in the feedback divider to provide stable operation was achieved after much analysis and testing. The end result was an operational amplifier with a closed loop gain of 69db with a three db point at 13 KHz. System stability was achieved by placing a zero just prior to crossing the zero db axis and a compensating pole just after.

The completed system delivers a slew rate of greater than 100 volts/microsecond and has a settling time of less than 75 microseconds – well within original design goals. Venus Scientific Inc., 399 Smith Street, Farmingdale, New York 11735 (516) 293-4100.

Digital Raster Graphics Display

Genisco Computers of Irvine, California, a division of Genisco Technology Corporation, announces the immediate availability of a 1024 x 1024 digital raster graphics display system, named the GCT-1024. Its ultra-high resolution takes the "stair-step" appearance out of raster displays to minimize distortion and provide greater density detail.

According to William Huber, Marketing Vice-President for Genisco Computers, "This is the first time that a complete high-performance, 1024 x 1024 digital graphics display system has been available on a production-run basis. It's also the first system of such magnitude to be priced at under $20,000 (in volume quantities). It includes a unique and proprietary discrete microprocessor that provides instruction times as fast as 150 nanoseconds and 51 mnemonic instructions for increased user programming flexibility. Genisco Computers, 17805-D Sky Park Circle Drive, Irvine, CA 92714 (714) 556-4916.



Digital raster graphics display, Model GCT-1024, offered at under $20,000 (in volume quantities) includes a proprietary discrete microprocessor that provides instruction cycle times as fast as 150 ns and up to 51 nmemonic instructions. A number of options and accessories like a "joystick", an up-to-64 function "keyboard", graphic tables and cursors enhance the system's usage flexibility. Applications include functions like Command and Control Process Simulation, Automatic Data Reduction, Computer-Aided Design, Mapping, War Gaming, and Crystallography in such diverse fields as Textiles, Medical, Architecture, Industrial Design, and Control Equipment.

PRODUCTS

Plasma Display Terminal

In militarized tactical computer terminal by Librascope Division of Singer, 8½" square plasma panel display is used in either text or graphics mode. In the graphics mode, dynamic information is positioned in accurate scale on a standard field map inserted behind the transparent plasma panel. Voice and digital data are transmitted or received by radio or direct wire. Built in microprocessor permits stand-alone operation and acts as controller for external peripheral devices such as a printer/plotter. The keyboard is an integral part of the case and folds up to form a water tight cover. Cooling is accomplished without the use of fans. The terminal operates directly from 28 VDC vehicular power. Singer-Librascope, Aerospace & Marine Systems Group, 833 Sonora Avenue, Glendale, CA 91201.

Programmable Alpha-Numeric Display

A programmable 32-character alphanumeric display module permits selection of an unlimited number of different characters and symbols for display in a 5x7 format on the 32-character capacity panel. A 64-character repertoire version uses a pair of PROM's for easy programming of any desired character set. If desired, the PROM's can be reprogrammed as desired to display any new combination of letters, symbols or numbers after their initial programming. This feature is of interest for new product prototyping and for a large number of OEM applications requiring flexibility in information readout.

The unit can also be used with a 128-character repertoire by populating the display module with 64 "standard" characters in a metal-masked ROM plus an additional 64 "custom" character set generated by the two PROM's.

The 32-character gas discharge panels display characters 0.2"H x 0.14"W in a 5x7 dot matrix. Characters are uniform in size and present a high-contrast, steady neon-orange glow and are easily readable at distances up to 15 feet.

Price is $172.00 in quantities of 1K; delivery is from stock. ROM's or PROM's are not included in the price of the module. Burroughs Corporation, Electronic Components Div., P. O. Box 1226, Plainfield, NJ 07061

Miniature Cathode Ray Tubes

The 04A/117 is the latest in the Ferranti line of microspot Cathode Ray Tubes. It is suitable for hand-held TV camera viewfinders and other applications requiring a small rectangular picture. It is designed as a direct view tube, with possibly a simple magnifying lens, but with the high optical quality faceplate, it can also be used in an optical system.

Useful screen area is 32 x 21 mm and line width at center is typically 25 micrometers. Overall length is 125 mm (5") and with a 14 mm diameter neck for deflection coils. Weight is 50 grams.

Also available now is the 02C/117 which is a reduced weight and size version of the one inch 02B/97. This tube has a useful screen area 19mm in diameter. It is complete with deflection coil and is encapsulated in a mumetal shield. Overall dimensions are 27 mm maximum diameter and 100 mm (4") maximum length. Weight excluding leads is 90 g. Line width at center is 20 micrometer typical.

Designed to military specifications, both tubes can be obtained with fiber optic faceplates. Ferranti Electric, Inc., E. Bethpage Rd., Plainview, NY 11803

3-D Graphic Display Modules

An 8-page brochure describes 3-D display capabilities and configurations possible with 15 basic analog graphic building block modules: basic principles, block circuit diagrams, how to mix graphics and alphanumerics, micro-computer buffer/interface, vector generators, video-to-analog converter and universal 3-D image generator. Photographs illustrate 3-D image generation by modules that provide options and characteristics such as mono-cular-binocular selection, magnification, focal field, interposition, movement parallax, perspective, 3-D plotting and image rotation. Optical Electronics, Inc., P.O. Box 11140, Tucson, Arizona 85734.

Large Display Counter/Ratemeter

Industrial counter/ratemeter's extra large display — 3-inch high digits — makes possible remote monitoring of machine speeds of production rates by operators and supervisors under circumstances where the standard sized display of the usual industrial counter would be difficult or impossible to observe. Count rates as high as 60,000 counts per minute can be fed into a variety of electro-mechanical and electronic sensors. Housed in a black anodized cabinet 14" w X 9" h X 2" d, it operates from 115 VAC at 10 VA. Price is $233.00 in 25 unit orders. Vorne Industries, Inc., 5023 West Belmont, Chicago, IL 60641.

Low-Cost Modular Video A/D Converter

Claimed to be the first low-cost modular A/D Converter designed primarily for video digitization, Computer Labs Model MATV-0811 converts high band-width video signals to parallel digital format with eight bit accuracy at random or periodic word rates of DC through 11 MHz. The MATV-0811 is designed for color television digitization at rates through three times the NTSC color subcarrier frequency (10.74 MHz). This unit is a metal encased module measuring 5.5" by 4.38" by 0.85", and contains internal 30 ps track-and-hold, encoder, TTL compatible parallel output data latch and all required timing. The analog input is the industry standard one volt at 75 ohms. The encode command input is TTL compatible with an input impedance of 75 ohms. Power requirements are less than eight watts when the A/D is operated from ±12V, +5V, and -5.2V, although it may be operated with any analog supply voltage between ±12V and ±15V. With a relative accuracy of ±0.2% of full-scale (±½ LSB), for step function inputs, it will achieve eight bit accuracy within 50 ns. While intended for color TV applications, the MATV-0811 is appliable to radar, medical, or other video systems. Also available is Model MATV-0808, which has essentially the same operational specs as the MATV-0811, except that the upper encode frequency is limited to 8 MHz. Delivery: stock to six weeks ARO. Prices are FOB Greensboro, NC as follows: MATV-0811 (Qty 1-4), $1,150; MATV-0808 (Qty 1-4), $995. Computer Labs Inc., 505 Edwardia Dr., Greensboro, NC 27409

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