High-Resolution CRT-To-Film Printer:
CELCO MASTERPRINTER is a high resolution CRT-To-Film Precision Computer-accessed system utilizing digitized data from CELCO MASTERSCAN to produce production fonts.

MASTERPRINTER features automatic computer-control of CRT focus, optical focusing, lens selection and film positioning. High accuracy is obtained over 10" x 10" step and repeat X-Y tables. Automatic self-calibration and automatic exposure compensates for CRT aging, lens-selection and writing rate.

NEW 20, 35, & 60 volt X-Y Deflection Amplifiers.
Featuring NEW small-size and light weight, CELCO high-power X-Y Deflection Amplifiers provide 12 amps and 16 amps peak-to-peak and are designed for the highest accuracy and maximum stability applications, such as CRT Film Recorders and Flying Spot Scanners, Electron Beam Recording Equipment, Integrated Circuit Mask Generation, and Electron Beam Substrate Preparation.

Bandwidth for the MDA & MRDA 20 volt and 60 volt Amplifiers is greater than 2.5 MHz, and less than 300ns small signal step response with 10uH Yoke. The MDA & MRDA 35 volt Amplifier Bandwidth is greater than 2.5 MHz, and less than 350 ns small signal step response with 10uH Yoke.

Electrical specifications for the new CELCO Amplifiers also include 0.01% Linearity; Temperature Drift of less than 20uA/°C; Short Term Drift is less than 0.1mA, and Long Term Drift is less than 0.5mA.

The CELCO MRDA series of 20 volt, 35 volt, and 60 volt, 12 and 16 amp Amplifiers are offered with Regulated Quadru-Power Supplies, and are rack-mountable in standard 19" relay racks. Availability: 90 days.

Record on 70mm Film from 4600 Line CRT.
The CELCO DSC-III Photo Recorder provides new flexibility for satellite "Quick-Look" monitors, medical research, data reduction, and any application where a 0.0006" CRT light source (3" x 3" raster) can be used to advantage. Digitized photos, letter masters, X-rays, and data obtained in biological experiments can be operated on with CELCO's DSC-III 70mm Photo Recorder.

The CELCO DSC-III is fully integrated to accept digital and/or analogue inputs. All the necessary power supplies, electronics, and logic are included to operate this self-contained system.

The CELCO digitally controlled camera includes transport drive, lens, shutter and photomultiplier assembly which can be directly interfaced to TTL control lines from a computer. Film transport speeds are available from one second per frame, and faster. Features of the transport interfacing include pre-select for number of exposures, film advance, exposure counting, and single-frame exposure. Unique camera optics of the camera accomodate a variety of film transports and magazines.

CELCO's RG-116 Precision Dual Ramp Generator provides convenient selection of a wide range of recording or film reading applications.
Options include: Linearity to 0.05%, short term stability to 0.001%, long term stability to 0.0005%, MTF on film plane, metering, shades of grey required, brightness monitor, brightness limiting, loss of raster or scanner protection, film transport speeds, special interfacing, special lenses, video requirements, and CELCO software.

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Unique Large-Format Scanner:
MASTERSCAN from CELCO, now makes it posible to scan and digitize Large-format data and images (14 inches x 14 inches) for many different applications, such as X-Ray Scanning, Enhancement, Storage and Printing for Hospitals and Medical Centers; Clothing Pattern Digitization and Printing for numerical control production; or MASTERSCAN can be designed to digitize data at high-speed and high resolution to fit a customer's particular data requirements.

The MASTERSCAN System pictured is CELCO's unique solution for automating the production of Master Fonts for a manufacturer of Computer Typesetting Equipment.

Scanning a 16 million point area, MASTERSCAN calibrates itself and reduces an artwork master 14" x 14" to a digital record in 16 seconds.

Depending on your precision requirements, your MASTERSCAN System can be designed to produce 512, 1024, 2048, or 4096 line rasters on the CRT face. With 2048 line raster, the System provides 4096 resolvable dots per line.

CELCO Image Orthicon Assemblies
CELCO announces production of their newest line of Deflection Yokes for Image Dissector, Vidicon, Silicon Storage, SIT, and SEC tubes.

DQV series Yoke: designed for use with 2¼" diameter Image Dissector Tubes for Photo Typesetting, Digitizing, and Imaging applications where high resolution and linearity are of primary importance.

BQV series Vidicon Tube Assembly: for 1" neck diameter Round Mount, and TV Vidicons, the BQV is designed to minimize beam landing error.

CQV series High resolution Silicon Target Storage Tube Coil Assembly: for 1" neck diameters combine extreme field uniformity and high resolution design.

Information Display

BERNARD J. LECHNER EX
RCA LABORATORIES
PRINCETON, NJ 08540

DATA PROCESSING APPLICATIONS

The Official Journal of the Society For Information Display

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Our cover photo(s) is courtesy of Spectra Medical Systems Inc. While we have taken artistic liberties with the large photo, the small photos are representative of the actual system described on page six.

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DEPARTMENTS

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PRESIDENT'S MESSAGE

A petition of a group of active SID members to form the Japan chapter was accepted by the SID Executive Committee at its meeting on July 25, 1975. This marks a major milestone in the development of the Society.

Despite the international scope of SID's membership and the desires of some of our overseas members to form chapters, active local organizations have, until now, been limited to the continental United States. The pre-formation activities of the Japanese group, the number of its participants and the caliber of its membership virtually guarantee the development, growth and success of a viable, dynamic and creative chapter in Japan.

Under the able guidance of Dr. Sanai Mito and Mr. Toshio Inoguchi of Sharp Corporation, 35 SID members and 46 interested non-members participated in several meetings which led to chapter recognition.

The Japan Chapter has elected to assume a uniquely challenging and exceptionally valuable role in the international scientific community. In addition to the scientific and educational objectives shared by all SID chapters, this group is dedicated to improve communication between the scientists of Japan and their counterparts in the English speaking world. To this end, the chapter is establishing programs which will help Japanese speakers in the preparation and presentation of papers in the English language. Furthermore, due to the expense involved in bringing Japanese scientists to the United States, methods are being explored to permit presentation by proxy. This may be done using a speaker who will be in this country at the time or by means of recorded tapes. While details are still in the preliminary stages, the rate of progress and the dedication which the world has learned to associate with all Japanese undertakings guarantee that we will enjoy many more first class presentations describing Japanese developments.

Like U.S. chapters, the Japan Chapter will cater to the needs of the local scientific community. Consequently, the way it will be run, its activities and policies will be tailored to Japanese traditions and customs (SID's bylaws are sufficiently flexible to accommodate and encourage such diversity and, should we find them restricting, they can be changed). With the formation of the Japan Chapter we hope to see a substantial increase in technical interchange. The list of organizations, companies and universities represented by the founding group reads like a Who's Who in Japanese science. Many are household names with the American public; all are well known to practitioners of information display technology. Our journals, Information Display and the Proceedings of SID, and our symposia will be enriched by greater Japanese participation. On an individual basis, we hope that Japanese visitors to the United States will attend local chapter meetings and plan to contribute their thoughts on topics of common interest.

It is with genuine pleasure that I welcome the Japan Chapter to the Society for Information Display.

ROBERT C. KLEIN
President – SID

Color Terminal Applications: An Implementation Challenge?

By ROBERT P. YANDOW
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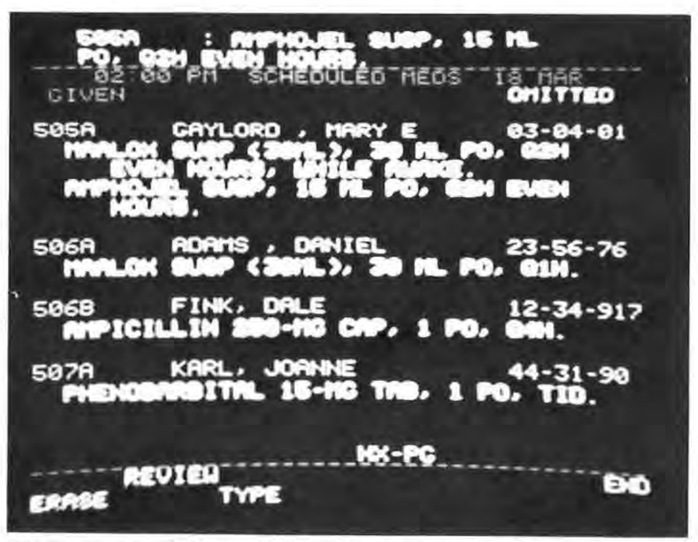
Where hospital personnel are using a Medical Information System (MIS), a color video terminal is proving to be useful in making a vast amount of data more comprehensible. But is it more effective than black and white? It is cost-effective? Will it help the user analyze the facts displayed, or confuse him?

The designers of Spectra Medical Systems' Spectra 2000 asked themselves these questions as the System was under development. The prime goal of the system is to make vast amounts of information readily available to the non-technical user. The Spectra 2000 Systems' designers chose to use Computer Communications Inc. (CCI) 4-color CRT displays at the user terminal simply to improve legibility. They were pleasantly surprised at the lack of software complications resulting from this decision.

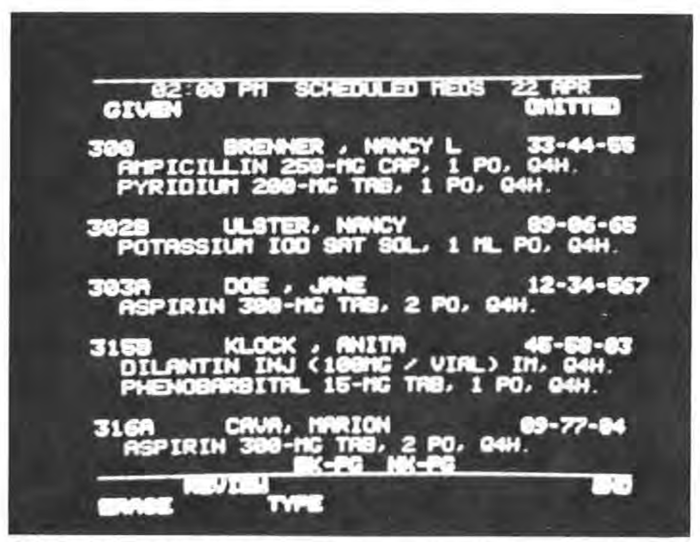
The Spectra MIS

The Spectra 2000 is a system designed to replace pencil-and-paper patient record keeping in the hospital. This MIS is built around an-on-line dedicated minicomputer installed on site. It offers the hospital a complete system of logging and retrieving information. In early tests, it has eliminated 70% of the time formerly needed to maintain Kardex files, track handwritten orders and keep patient charts updated. With its high speed CPU, the System handles the paperwork and frees nurses and doctors for patient care. The System provides an information processing capability for entry, storage and retrieval of medical data pertaining to the patient from admission through discharge. Loss of information is virtually eliminated.

The data stations, which include the 4-color CCI terminal and a printer, are located in key areas of the hospital (admitting, nursing stations, laboratory, pharmacy, radiology, etc.). They gather and dispense patient information, but only that portion



Medications which are due to be given at specific times appear in blue at their designated hour.



Once the medications are charted in the System by the user, they immediately appear in red which prohibits any other action until the medication is due again.

appropriate to each user's job responsibilities. His or her sign-on code tells the system what is appropriate. The system includes support for a previously all-manual hospital operation: Admit/Discharge/Transfer, permanent chart preparation, Nurse scheduling, current census, patient drug profiling as well as offering reference to an extensive drug interaction library.

System Components

Data General's 128K 16-bit Nova 840, located at the hospital, is the heart of the system using Alpha Data's fixed head disc (4 megabytes, 8.4ms average access) for non-resident programs and files requiring fast access and a Century moving head disc pack for large, less frequently used files. The operating system provides multi-programming; core, disc, and resource allocation capabilities.

The display component at the user interface terminal is CCI's 4-color CRT with a 960-character capability (24 x 40). The prime input device is CCI's lightpen which can cause system interrupts. A keyboard (alphanumeric, 64 ASCII characters) is a secondary input device. It allows the user access to the system by entering character code and thereby insures security of the data. The keyboard also allows free text entry. An electrostatic printer provides fast hard copy output at 600 1pm (800 cps). The memory at the data station provides 1024 character storage. The station transmits and receives data synchronously from the computer at a rate of 50,000 bits per second (6250 cps).

The Lightpen Led to Color

One of the initial decisions of the Spectra 2000 designers, from which the decision to use color evolved, was to use a lightpen at the data station. The lightpen provides ease and speed of operation, virtually eliminates typing, and is less likely to introduce errors into the System than other data entry schemes.

Once the lightpen had been selected, the problem arose of how to keep the user from choosing certain fields of information and how to channel him to select the appropriate field. The solution was the then (1970) newly-introduced interactive color CRT from CCI. Color conventions were developed to guide the user. Data displayed on the CRT was organized into fields and each field was assigned a specific color. Red, green, blue, or yellow indicated a different information group and a different system response when selected by the lightpen. The color conventions were also designed to guide the user through the branching paths of the data presented to him and the hardware cost differential between black/white and color was only about 5%.

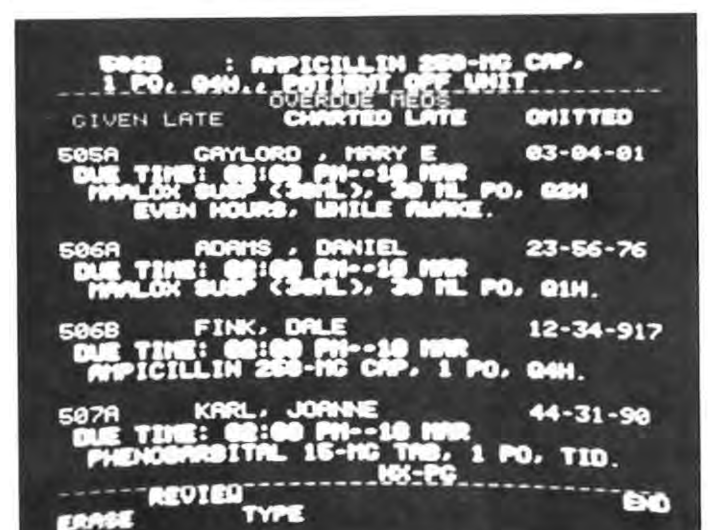
The Conventions

While using a station, the user is asked to view the data base as an inverted tree. As he proceeds through the tree, color indicates how far he can go. For example, selection of a green item indicates that particular field which will lead further into the system. It indicates the fields that will cause another display to be transmitted to the terminal. The user points the lightpen to the specific item he wishes to select, pushes an interrupt button located on the side of the lightpen and another display is presented. As he chooses further, the data becomes more specific, until he is led to the end of the branch where he will either enter the message into the data base or use it as a reference.

Blue items indicate information which can be entered into the data base. The user will choose a specific blue item (medication, dosage, diet, etc.) and that data will be updated in the patient's data base file (admission/discharge, admission data, nurse's orders, etc.). It becomes part of the changing data which is continually being retrieved and/or updated.

In charting medications, for example, the user will indicate whether the medication was given. In the case of medications such as narcotics, once the data is entered into the system the user can return to the display and view the last dose time charted in red. Each time the medication is charted, the red information is updated. Another use of red is in the bed availability function, where the user can see at a glance which beds are occupied (displayed in red and therefore unselectable) and which beds are available (displayed in blue and selectable).

Yellow items show general terminal operating functions. They are independent of the data being displayed. If the user selects a yellow field, a standard function will be executed (erase, sign-off, review, return, etc.).



When there are no charting actions, the medications appear in yellow indicating to the user that they are overdue for that hour.

Here the red beds indicate the bed is occupied; the blue beds are available. Transferring patients from bed to bed will change the blue bed to red and vice versa.

Display Modules

After the color conventions were established, the software development came surprisingly easy. It was built around three types of displays which offer a specific type of information in the appropriate colors.

The fixed display is generated off-line and formulated on disc as "read only" data. When it is called for, the data is read off the disc and transmitted to the terminal. There are over 3000 permanent displays in the System such as medication lists, Lab test lists, standard drug dosage, ward/bed identifications, as well as the reference material on drug interaction. Green, blue, or red information can be contained within any given fixed display, depending on its functions at the terminal.

The variable display is also already formulated on disc to be read and transmitted to the terminal. But it is designed to be updated at certain intervals. Ward patient listings and physician patient lists are examples of variable displays. The image on disc is updated whenever new information comes into the data base relating to a variable display.

The third display type, the dynamic display, is formulated at the moment it is requested. Data held in binary and ASCII forms are retrieved from the files, formulated into a display and transmitted . . . all in real time. Active orders for a patient, medications to be administered, are examples of data presented in dynamic displays.

As the designers of the Spectra 2000 explored the possibilities offered by color, it became clear to them that the benefits attained by the multi-color CCI display far outweighed the minor cost increase over black and white (5% for the hardware) and the minor additional development costs. In addition, the black and white alternatives for segregating information fields – blinking characters, underline, reverse background – necessitate virtually the same software capabilities yet do not offer the visual comprehension or aesthetic value of color.

Alternative uses of color were also explored. One idea was to use color geographically to indicate divide portions of the display screen. That was discarded as unnecessarily complicated for the user to remember. A fifth or even sixth color were also possible; research indicated that users would not remember their functions.

Which color to use?

The choice of colors was also significant. The CCI video display offered the complete spectrum. Spectra's designers specified four colors which would contrast best with each other and the background. The original deep blue available on the CCI CRT display was rejected as visually difficult. But in combination with the green, they obtained a bright blue that stood out well on the screen. The non-reactive display could have been either red or blue; the only requirement being that the wavelength of the color be on one end of the spectrum. The lightpen is set to react only to yellow, green and blue wavelengths.

The designers, continually aware of the human factor, made it visually easy by limiting the number of characters used in any display. Of the 960 character positions available on CCI's screen, an average of 400 positions are used on display.

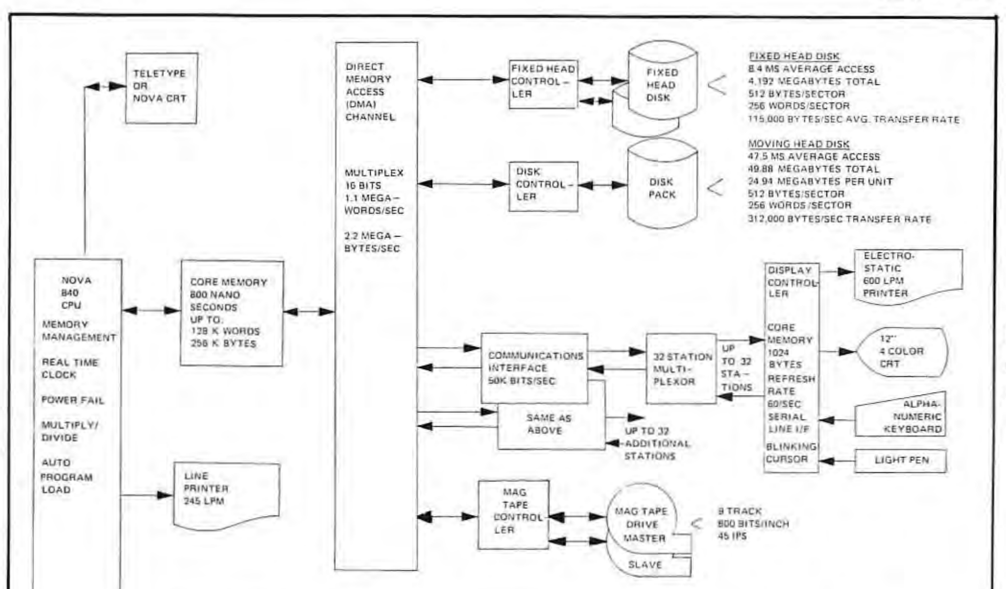
How does the user respond to a multi-color CRT display? The initial reaction is very positive; color is exciting and fun to play with. And people don't really grasp its full potential until well into the functions of the system. Color has simplified training enormously. Visual commands by color conventions are easy for the user to understand and assimilate. Once into the pattern, a user will expect a particular reaction from each color and easily respond.

Color at the Man-Machine Interface makes Sense.

Hardware configuring took only a few months. The preparation and debugging of all color related software for the system was completed in six months. Nurses who have worked with the Spectra MIS and with other black/white systems agree that color makes the information much more accessible.

And the ultimate justification of color terminals comes not from the minimal costs involved, but from what it can do for the user: help ease the use of automated systems. □

NOTE: Full color reproductions of the figures on the previous pages are shown on the front cover.



HARDWARE CONFIGURATION

It takes a lot of hardware to make this system work, and this is the block diagram of what is used.

grafix I: AN IMAGE PROCESSOR THAT READS HANDPRINTING...

By STEPHEN B. GREG
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Machine reading of hand printed letters and numbers has been the goal of several organizations for many years. There has been some success in reading machine printed material, but the reading of hand printed material was considered too difficult except for the limited range of zero through nine and a few letters. Now, a significant advancement has been achieved by Information International Inc. (III) of Culver City, CA. The entire upper case alphabet, numbers zero through nine, and some punctuation marks can be read with high accuracy and little training of the people who do the writing.

Performing this task requires a new combination of hardware and programming techniques. Much research was done in order to design this system. The results of this research was implemented partly in the hardware, and partly in the software.

The total system

Shown in Fig. 1 is the block diagram of the entire system, called GRAFIX I. Heart of the system's computation power is the Binary Image Processor (BIP), a general purpose image processor designed by III. Probably the most difficult concept to grasp about this system is the fact that the BIP is a general purpose computer oriented toward high-speed image processing computations. At first glance, because the BIP is only involved with image processing, it appears to fall into the general category of a "dedicated computer." This is not so because the BIP was designed to do a wide variety of jobs within the general area of image processing.

More about the BIP later. Additional major components of the system are a 36-bit general-purpose central processor, large core memory, a precision CRT film scanner, and standard console interactive operator computer peripherals.

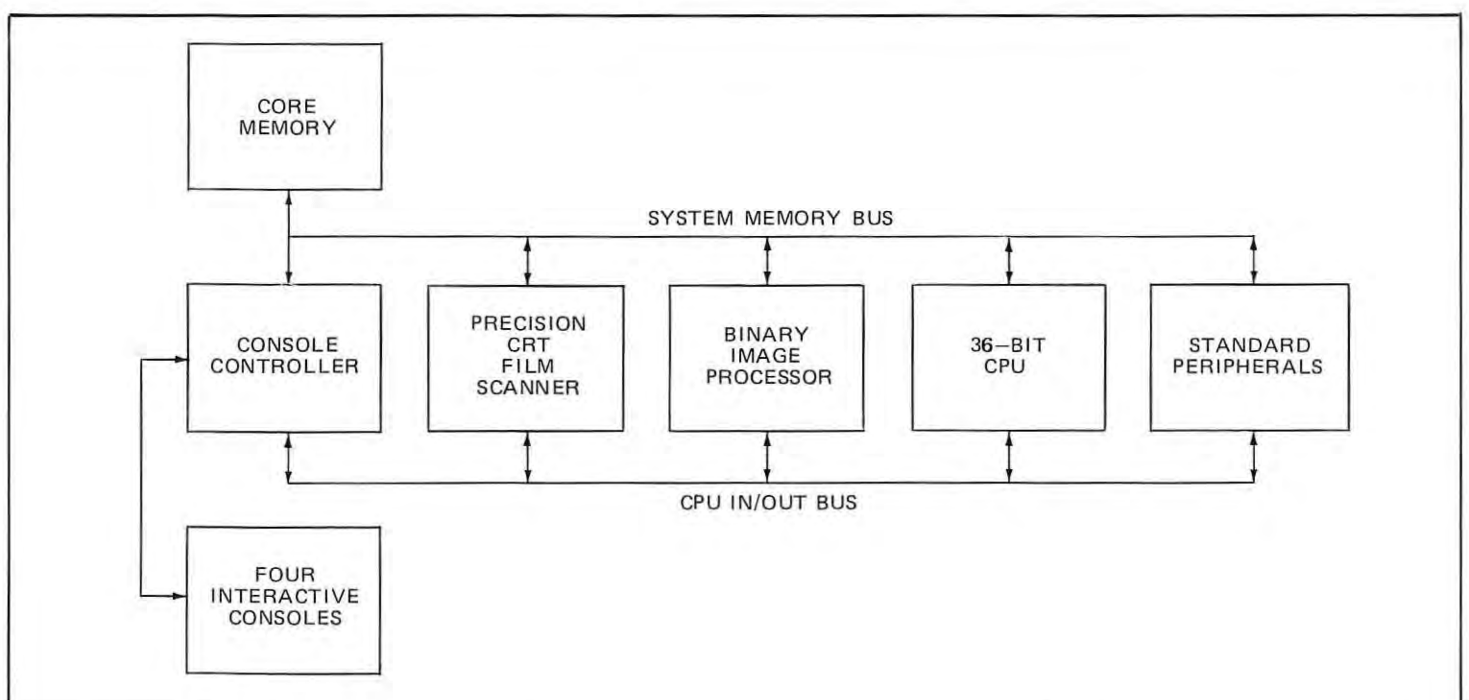


Figure 1 - GRAPHIX I block diagram looks like a conventional computer system at first glance. Power of the system derives from the large amount of computing power, both in the CPU and binary image processor (BIP).

Figure 2. GRAPHIX 1 Film Holder

All material to be scanned must first be filmed. The film is mounted in the GRAFIX 1 film scanner (a special design by III), so that processing may begin (Fig. 2).

In processing an individual handprinted (or other) character, three results are possible. A character may be identified correctly; it may be incorrectly identified (this type of error is called a "substitution"); or it may be "rejected", or not recognized at all. In the case of a rejected character, a stored picture of it is displayed on a CRT, together with its line of text for identification by an operator (Fig. 3).

The hardware

The BIP (Fig. 4) is the unique piece of hardware that allows the GRAFIX 1 system to achieve both extreme flexibility and high throughput speed. Built of medium-scale integrated circuits, the BIP contains a large amount of pipeline logic running synchronously at 40 MHz.

The BIP is unlike any general-purpose computer in its organization. As a general-purpose image processor, some of the tasks that can be performed are: conversion of image gray scale data into binary data; binary image enhancement; measurement of geometric image properties; image transformation or rotation; changing of image size; and comparison of an unknown binary image with a reference binary image.

High speed efficient operation in this serial processor is due to several facts. Primary among them is that in the BIP, loops are achieved through hardware, not software. Large amounts of data are handled in each instruction. For example, in most conventional general purpose computers, it takes many instructions to count the number of ones in a binary image (part of one recognition technique); the BIP has built-in circuits which accomplish this task in the execution of just one instruction. Original goals in designing the BIP were to create an image processor which would be both general enough to apply to new applications without hardware redesign, yet compact enough to be economically manufactured. The original design served was 1968-1970. Normally one would expect a first-of-its kind design of that period to be obsolescent by now. However, using it over a period of five years and on a number of different applications, its design goals have been met, and there are a large number of new applications suitable for the BIP.

The software

There are two main software modules used to process handprinting, which can be termed Acquisition and Recognition. Acquisition consists of: 1) finding page images on the microfilm; 2) finding any fiducials or registration marks on the pages; 3) finding the various data fields to be read; 4) scanning out these data fields and storing grey-scale pictures in core memory; 5) converting these pictures into binary images; 6) Finding each character in a data field and separating it from its neighbors, and 7) Normalizing any size variations occuring in the original character.

Recognition consists of two main modules, the filter and the verifier.

The filter is the first stage recognition to which every unknown character is presented. It operates by means of a feature extraction and restor-matching approach which proceeds in the same way no matter what the unknown character may be. The filter comes up with a "best guess" which is usually sufficient to recognize the unknown.

For certain difficult or ambiguous character shapes, the filter may fail to recognize, in which case the verifier is called. This is a set of heuristic programs, written by Dr. Arnold Griffith, which invoke a different procedure depending on what the filter's best guess was.

Figure 3 Technique for identifying "rejected" character.

Each individual verifier subroutine (there is one for A, another for B, etc.) fits the unknown binary image for the presence, absence, and position of certain geometric properties. Failure of any of these required properties to match results in rejection of the unknown. In this way a very low rate of misrecognition (or "substitution") is achieved. In fact a substitution can occur only if a) the filter makes an incorrect best guess, and b) the verifier incorrectly accepts the guess.

While the filter is quite fast, the accuracy would not be adequate for commercial applications; the verifiers are designed for very high accuracy but are relatively slow. Both modules used in conjunction achieve the required speed and accuracy.

Operating Conditions

The recognition system has been tested extensively on forms produced by several hundred clerks who were instructed to print neatly, to imitate a standard alphabet, and to print each

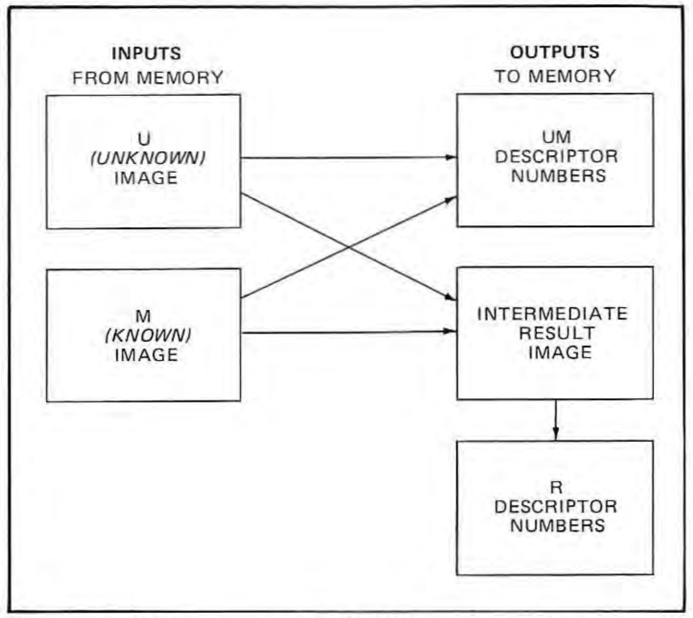


Figure 5 - Data mappings in the Binary Image Processor. In converting images to numbers as shown in Fig. 3, immediate result images are produced by the BIP, to be fed back in subsequently.

character on a grid of dots; but handprint is otherwise unconstrained. Very little practice was allowed before all the forms were filled in. The suggested constraints are really quite loose, the main effect being to improve general neatness, and not to restrict the style or "form" of printing. Whether reading a separate alpha or numeric data, reject rates are below 5% (on a character basis), and substitutions on the order of 0.1%. Mixed alphanumeric fields read just as accurately except for problem character pairs such as B-8, S-5, and G-6 (for which no special distinguishing styles or instructions were given). These pairs suffer from higher substitution rate; to help resolve these problems, GRAFIX I as a general-purpose computer can apply syntax rules, character statistics, and context information.

Among the significant character variations which can be tolerated by the GRAFIX-I hand print system are character size, line width and stroke density, skew to the right or left, all of the adjacent characters, line breaks, and variation in position of character strokes.

Diverse applications

This system has the potential for expansion into many fields because of its flexibility in rapid programming and novel hardware. Possible new uses include biomedical image processing, waveform digitizing, fingerprint analysis, metallurgical processing and robot research. ☐

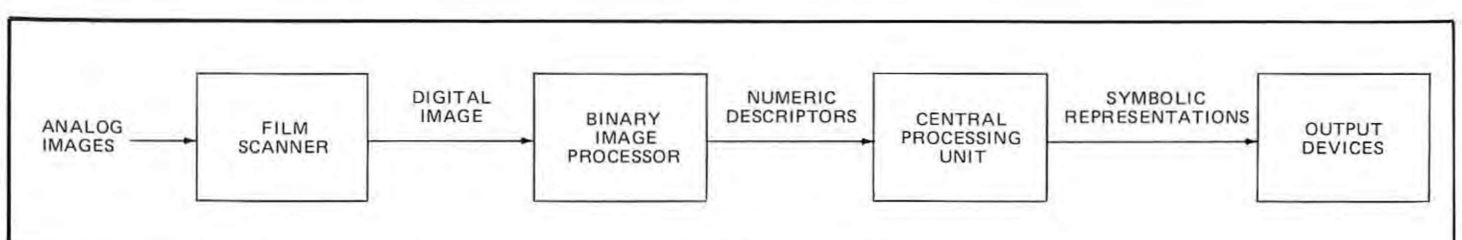


Figure 4 - Data transformations in GRAPHIX I takes place in each successive step, the original filtered image is analyzed to a further level, the final step being complete recognition of every character.

First Real-Time, All Attitude Tracking and Display System Provided in AMCR

The first real-time, all attitude tracking and display system in the world is now operational for the Navy and Marine Corps at U.S. Naval Air Station, Miramar, California and Marine Corps Air Station, Yuma, Arizona.

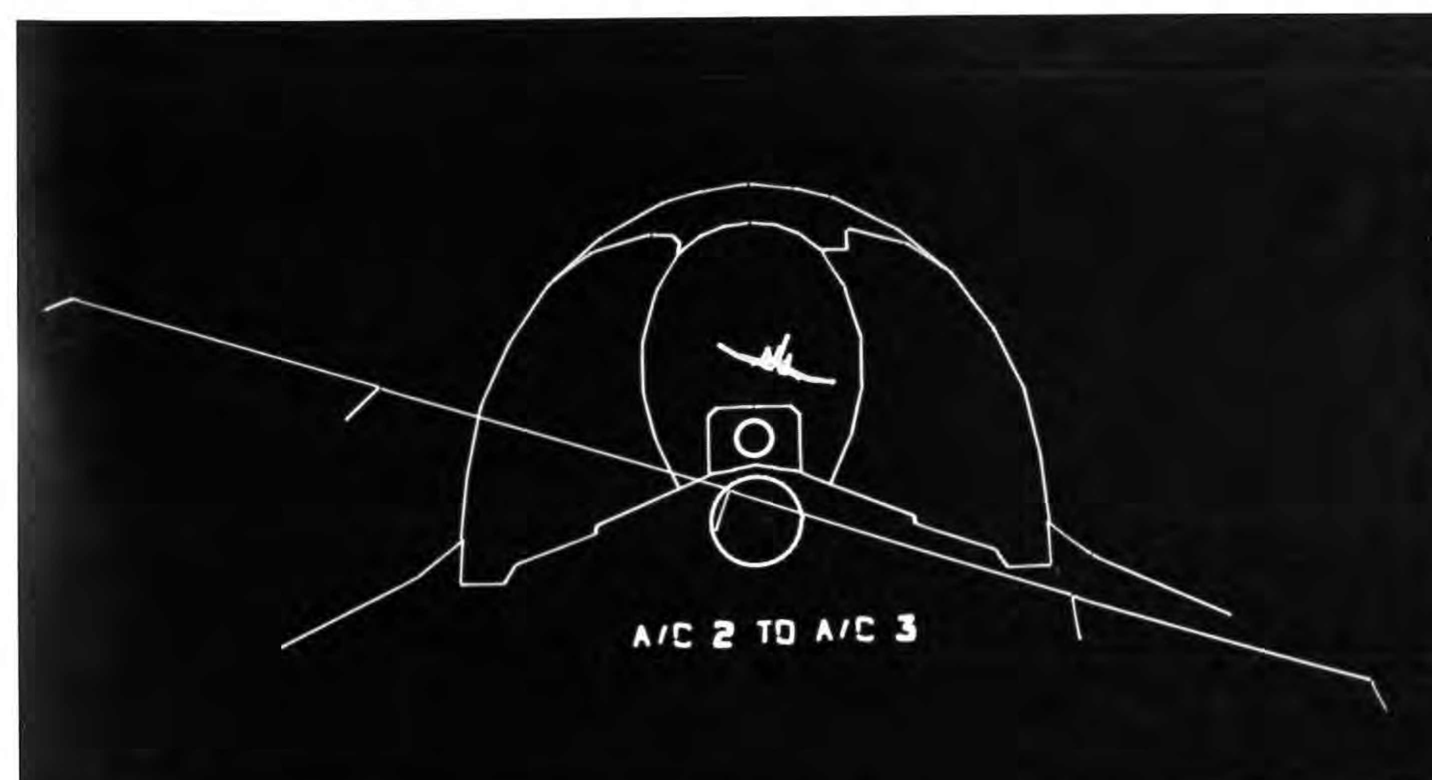
Though fighter aircraft have steadily improved over the years, providing pilots with combat training that is both realistic and safe has always been a problem. The Air Combat Maneuvering Range (ACMR), developed by Cubic Corporation, San Diego, for the Navy, is designed to teach pilots how to recognize when they are within range, to use their missiles effectively, how to arm and fire them, and how to develop techniques for evading enemy missiles, among other things.

ACMR is the result of three years of work by Cubic's Defense Systems Division. Providing a real-time perspective display of exactly what happens during a dogfight, the system monitors the maneuvers of training aircraft and simulates the flight of missiles. Maneuvers taking place in the air, along with critical flight path data such as speed and G load, are visually displayed in real time for a flight instructor on the ground to watch and evaluate. In one mode the pilots receive a tone telling them whether they are within the launch envelope of the missile. Verbally, the flight instructor tells them the results of their gunnery or evasive action. The encounter is also taped so pilots can benefit from an "instant replay" during their debriefing after each flight.

The system overcomes much of the expense and risk involved in dogfight training maneuvers. Before ACMR, fighter pilot trainees had the chance to fire only one or two missiles in training period. These were usually fired at expensive but generally unrealistic drones. With ACMR, realistic aerial combat training takes place using actual high performance aircraft as the simulated targets. Pilots fire dozens of simulated missiles at real tactical aircraft in flight.

The computer portion of the system consists of three XDS Sigma 5's, located at the Marine Corps Air Station, and one Sigma 3, located near the 700-square-mile aerial combat range where both Navy and Marine pilots practice dogfighting.

Display portions of the system are duplicated at both Yuma and Miramar. Navy pilots using the system are stationed at Miramar, where the Navy's Fighter Weapons School is located. Aircraft takeoff from Miramar, perform their combat maneuvers over the Arizona range, and then return to their California base while instructors watch the action on CRT display terminals at Miramar, Marine pilots, on the other hand, who are stationed at UCAS Yuma are monitored by their own instructors who watch the maneuvers on CRT displays in Yuma.



Simulated cockpit view.

View of the consol that includes two displays of the system.

The design challenge of ACMR was to create a system capable of displaying comprehensive, real-time information about four separate maneuvering aircraft. Software programming incorporates a "Kalman Filter" – a mathematical tool that takes all available raw data from several sources and provides an optimum, or best-estimate, solution. Major data inputs to the filter are range measurements from the tracking system, attitude and air sensor data from aircraft instrument pods hung on the aircraft, in place of a Standard Missile.

The optimum solution which the Kalman Filter provides is the position and attitude of each of the four aircraft at every 0.1 second, instant.

Data from each aircraft is transmitted by aircraft instrument pods. The pod is designed with the configuration of Sidewinder missiles so that no modifications are required to tactical aircraft.

Stored programs simulate missile performance after launching to indicate whether a pilot has scored a hit. The display actually presents an image of all aircraft in three dimensional perspective on CRTs. Streamers, or history trails, presented on the wing tips of the display image leave a tracing of each aircraft's maneuvers. Controls on the display console permit changing perspective on the screen so that the aircraft can be viewed from any angle. Also displayable is the action as seen through any pilot's canopy. This display shows an outline of the canopy and gunsite in the foreground with target aircraft viewed in the perspective the pilot sees.

Next to the display of the dogfight, another display screen identifies each pilot, and records the results every time a missile is launched. A third display provides critical data about each aircraft – such parameters as speed, angle of attack, and G load.

The ACMR system contains four major elements: the Tracking Instrumentation Subsystem (TIS), which consists of a high-speed phase-lock-loop ranging system; the Airborne Instrumentation System (AIS), which consists of a self contained five-inch diameter pod with an altitude reference unit, ranging transponder, data encoder, and weapons bus monitor; the Computation and Control Subsystem (CCS), which is a large multi-processor for real-time computation of aircraft position, aircraft attitude, accelerations, missile trajectory, flight safety predictions, and identification; the Display and Debriefing System (DDS), which consists of two sets of displays. Each display set includes a situation display, and alphanumeric display, and a status display. The situation display presents the relative range operation, using variable size and variable intensity for depth perception. The displayed aircraft vary in attitude, pitch, and roll as a function of AIS data. (Supporting analog and alphanumeric readouts on adjacent CRTs of flight, weapon system, and interactive parameters are also presented.)

Tracking and attitude data are produced in the system by multi-lateration by CW phase-shift measurement, augmented by inertial-platform-derived acceleration and angle measurements. Displays that accurately and realistically represent the engaged aircraft and all attitudes are comprised of a computer-drawn pseudo three dimensional display derived from digital values of the aircraft tracking. This display is presented on a 21-inch CRT. Figure 1 is a functional block diagram of the ACMR system.

The Display and Debriefing Subsystem is the primary man-machine interface. The DDS is designed specifically to translate information into a form that is easily assimilated by pilots – either instructors or students – and that is readily accepted by them as true and useful information. To accomplish this, the system was developed with the following characteristics:

1. The three dimensional graphics display has size and brightness cues engineered to provide a sense of depth.
2. Alarms are displayed at the top of the graphics display immediately upon detection of a safety hazard.
3. Displays of primary aircraft performance parameters are presented both as analog and numerics.
4. The DDS incorporates capabilities and controls for coordinate rotation, cockpit view, and scale change. These capabilities are available both in real-time and in replay for debriefing.

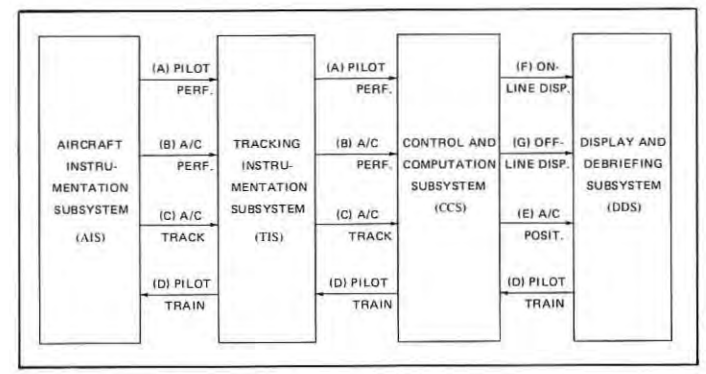


Fig. 1 ACMR Functional block diagram.

The DDS is contained in an air conditioned van connected to the CCS van by hardware or by microwave data link.

The live console within the DDS contains the main situation display CRT, which provides the 3D graphics, the 2D parametric display CRT, the control keyboard and the control panel. Three operating positions are provided at the console for the system operator, the ground instructor and the range control officer. The replay console, for its part, duplicates the live console control keyboard and control panel. A hard-copy printer is also included to provide a print of any picture displayed.

Control and Computation Subsystem software provides a common time base for the entire display system by accepting time information from the Tracking and Information Subsystem. This time information is used to determine the cyclical operations of the CCS and the time is made available to all display and debriefing subsystems. The CCS relays exercise data to all DDSs. The CCS itself responds to DDS-supplied fighter/target designations, hazard limit changes, and other exercise data to provide for correct sequencing of its programs and to perform pilot performance and hazard monitoring functions.

To accomplish the pilot performance and hazard monitoring functions, the CCS compares fighter and target positions, velocities, and accelerations against predetermined parameters. CCS also performs real-time operability tests and calibration, and monitors the status of ACMR equipment units by accepting equipment status messages from TIS and DDS and status information from its own computer and peripheral equipment.

The Display and Debriefing Subsystem incorporates a stand-alone program and overlay segment that operates in the system processor. The program controls all required data transfer, accepts and processes inputs and supplies outputs to each of its peripheral devices.

The display and debriefing program operates in a cyclic manner, performing all required functions, including data recording during the live operation, in a recurring period of 100 milliseconds. The DDS processor program interfaces directly with a disc operating software system and includes intereactive programs which are required to operate the input/output devices and displays scopes.

Cubic's Air Combat Maneuvering Range is now widely accepted by veteran combat pilots as a major step forward in dogfight training. New ranges are now being installed at an East Coast Navy location and, for the Air Force, at Nellis Air Force Base in Nevada.

As a contribution to the field of information display, ACMR represents what is probably the most detailed level of realism ever achieved in a real-time tracking and display system. As such, it provides a training and exercising tool that graphically presents the student with a demonstration, on his own terms, of the lessons to be learned. □

Standard missile configuration is used for instrumentation.

About the Author – George W. Eaton is Product Manager, ACMR and has complete authority and responsibility for performance of all contractual requirements of the Aircraft Combat Maneuvering Range systems and relation product lines.

Mr. Eaton has 23 years of engineering experience including Program Manager of the AN/PPS-15 at General Dynamics Electronics Division; Program Manager for AN/GSQ-160 CW/FM intrusion detectors, and as Program Manager of ATSR, was responsible for development, design, and installation of the applications technology satellite range and range-rate system for NASA Goddard. As an Electronics Engineer at RCA, Victor Division, in the advanced development group, he designed circuits using new tube types for application in VHF and UHF frequency bands.

Mr. Eaton received his BSEE from the University of Wyoming.

A Real-Time Optical Data Processing Device

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Coherent optical data processing (CODP) had its origins in the pioneering work of Abbe[1] and Porter[2] who first investigated the properties of image formation in coherent light. From the beginning, this field has been focused on the processing of two-dimensional arrays of data – primarily pictorial images and multichannel wide bandwidth electrical signals. Potentially, CODP, because of its inherent parallel organization, offers tremendous processing speed advantages over the electronic digital computer for certain important classes of problems (mathematical transforms, linear filtering and correlation, etc.). Although impressive experiments have been performed in the laboratory, very few operational CODP systems have emerged. One of the major reasons for this circumstance is that CODP can not be practiced in real-time. At present, CODP systems still rely on silver halide film both for inputting data and for performing the spatial filtering operation. Since silver halide film is usually processed off-line, the CODP system must be operated off-line. To make ODP an on-line process we require a device that can accept as an input an image formed either electrically or in noncoherent light, convert that image to a form where it can be picked up by a spatially coherent read-out light beam, and perform this process at TV (or faster) rates.

We describe here a new device using a liquid crystal as the electro-optic medium that offers great-promise for fulfilling the multitude of requirements demanded of a real-time input device for application to CODP. The new device is a special adaptation of the ac photoactivated liquid crystal light valve reported earlier.[3,4,5,6]. It represents a development of the original dc liquid crystal light valve which suffered from limited lifetime.[7] Basically, the device consists of a sandwich of thin films that photoelectrically control the optical birefringence of a thin ($\approx$2 um) liquid crystal layer. This thin layer and the liquid crystal alignment are critical in achieving the high performance capabilities which will be reported here. The device has high resolution ($>$100 ℓ/mm limiting resolution), high contrast ratio ($>$100:1), high speed: 10 msec on, 15 msec, off) and high input sensitivity ($\approx$0.3 ergs/cm^2 at the threshold). Moreover, it has several practical advantages. It is compact, uses low power, is inexpensive to manufacture, and can be operated with less than 10 V_{rms}. In this paper we describe the design, operation, structure of the device and the performance of a laboratory device.

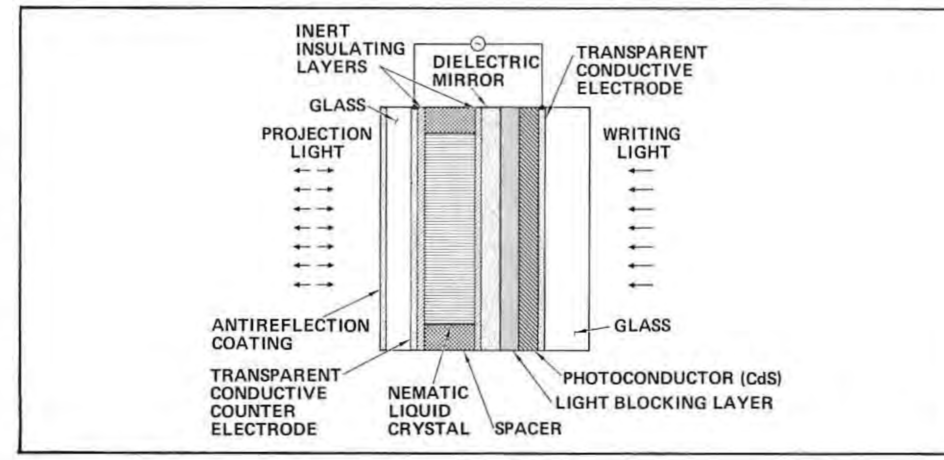

Figure 1. Schematic of the ac liquid crystal light valve.

Device Description and Operation

1. Description of Light Valve

The configuration of the reflection-mode ac light valve device is shown schematically in Fig. 1. The device consists of a number of continuous thin film layers sandwiched between two high quality optical glass* substrates. A low voltage audio frequency power supply is connected to the two outer, thin film indium-tin-oxide transparent electrodes and thus across the entire thin film sandwich. The cadmium sulfide photosensor film,[8] 15u thick, acts to sense the incoherent input light image. The dielectric mirror and the cadmium telluride light blocking layer separate the photosensor from the read-out light beam. The CdTe provides $\gtrsim$4 ND isolation between the photosensor and the read-out light. The dielectric mirror, consisting of alternate $\lambda/4$ films of high and low index materials, can be designed to provide greater than 90% reflectivity across the visible spectrum or can be tuned to reflect a specific region such as a single laser line. Two mirror systems that have been used are thermally evaporated ZnS/Na_3AlF_6 and sputtered TiO_2/SiO_2.

The combination of the light blocking layer and dielectric mirror is a fundamental design feature of the ac light valve. It enables simultaneous writing and reading of the device without regard to the spectral composition of the two light beams. Because of the insulating nature of the dielectric mirror, no dc current can flow, and thus ac operation is necessary.

Overcoating both the dielectric mirror and counter-electrode are sputter-deposited films of SiO_2. The films serve two purposes: The first is to provide a

*Schott BK 7a

surface in contact with the liquid crystal that is both chemically and electro-chemically inert. This configuration, along with the ac mode of operation, provides for long device lifetime. The second purpose is to provide a suitable surface for aligning the liquid crystal. We have found that ion beam etching of SiO_2 at an angle $<20^\circ$ with the surface provides highly uniform homogeneous (parallel) or twisted homogeneous ("twisted nematic") alignment. Also, with the use of the chemical bonding of aliphatic compounds to the ion beam etched surface[9] we can effect a unidirectional tilted homeotropic (perpendicular) alignment. These techniques give us a complete range of alignment modes to optimize the device electro-optic performance.

After the liquid crystal layer, the counterelectrode and liquid crystal spacer complete the light valve structure. The spacer is fabricated by sputtering SiO_2, or thermally depositing Al_2O_3, in the form of a border around the device aperture on the counterelectrode. In this way we have accurately defined liquid crystal layer thicknesses from 1 to 6 um. The counterelectrode glass is 1/2" thick to minimize distortion when the cell is mounted in a holder. It is given a "10-5 reticle quality" polish with both surfaces flat to $\lambda/10$ and parallel to <0.5 um across the aperture. These tolerances are crucial in optical data processing applications in order to preserve the flatness of the laser read-out beam wavefront. The substrate films are also deposited on 1/2 inch thick glass. We can maintain the flatness of the substrate to $<\lambda/4$ across the aperture.

Finally an antireflection coating is deposited on the outer surface of the counterelectrode to minimize the contrast of interference fringes caused by multiple reflections between the dielectric mirror and counterelectrode surfaces. In addition, the indium-tin oxide film on the inner surface of the counterelectrode is deposited to an optical thickness of $\lambda/2$ (0.33 um for He-Ne Laser use) to provide optical matching between the liquid crystal and the glass. These techniques reduce the reflection of both surfaces of the counterelectrode to < 1%.

2. Operation

The principle of operation of the light valve is straightforward. The ac voltage across the device is divided between the thin-film substrate which includes the photosensor, light blocking layer and the liquid crystal layer. The substrate is designed so that in the absence of imaging illumination most of the voltage falls across the photosensor. This maintains the liquid crystal layer below its threshold for electro-optic activation. When imaging light in the spectral range from 520 to 550 nm illuminates the Cds photosensor, the impedance of the film becomes lower and additional voltage is switched to the liquid crystal, thereby activating the liquid crystal electro-optic effect. Image resolution is maintained by the very high ratio of transverse to longitudinal impedance exhibited by the component films of the device.

The response time of the photosensor for values of imaging light of approximately 100 uW/cm^2 is on the order of 10 msec. Our present goal in designing the light valve has been to provide a liquid crystal configuration with response time fast enough so that the photosensor limits the composite response of the light valve.

Liquid Crystal Considerations

1. Liquid Crystal Considerations

ferent electro-optic effects: Dynamic scattering,[10] and two field effects – optical birefringence[11] and the twisted nematic effect.[12] In choosing an effect for the incoherent-to-coherent light valve, we discarded dynamic scattering and selected the field effect approach. The principal reason for this choice is that dynamic scattering is characterized by turbulence of the liquid crystal that introduces an unacceptably high level of spatial noise on the coherent read-out beam. Moreover, it is difficult to obtain high contrast (wide dynamic range) with the dynamic scattering effect. The field effect mode is not burdened by these liabilities.

The particular field effect modes that could be used in a device of this type include the birefringent effect with perpendicularly aligned liquid crystals, the birefringent effect with parallel aligned liquid crystals, and the twisted nematic effect. Of these three possibilities, the homeotropically aligned materials exhibit relatively slow response time, and the homogeneously aligned material yields low contrast and excessive sensitivity to variations in the thickness of the liquid crystal layer. The twisted nematic effect, on the other hand, combines the best features of the two birefringent modes. These are very low transmission in the off-state; relative freedom from background non-uniformity caused by thickness variations; and fast time response. For these reasons we have chosen to implement the light valve with the twisted nematic effect.

The liquid crystal we have chosen for use in this configuration is cyanobiphenyl nematic mixture. This liquid crystal combines chemical stability with a high positive dielectric anisotropy ($E_{11} - E_{1} \doteq 10$) and a high birefringence ($\Delta n_{max} = 0.23$). The positive anisotropy is necessary for use with parallel or twisted nematic alignment. Moreover, the high anisotropy provides low operating voltages and this high birefringence coefficient allows high optical retardation even in the thin liquid crystal layers which are necessary for fast response times. Because the response of the liquid crystal varies as the square of the thickness there is a significant advantage in making the liquid crystal thinner to improve the response time.

2. The Hybrid Field Effect Mode

Although we use a twisted nematic configuration, it is not the 90° twist generally reported in the literature.[12] We cannot use the 90° twist configuration because the device operates in the reflection mode, and it is impractical to incorporate a polarizer between the liquid crystal and the dielectric mirror. Therefore, we place both polarizer and analyzer on the same side of the liquid crystal layer. With this arrangement, the 90° twisted nematic effect does not modulate the intensity of the light beam effectively.[13] As a result, we developed a hybrid field effect mode of operation – one that uses the 45° twisted nematic effect[13] in the off-state and the pure optical birefringence effect of the liquid crystal in the on-state.

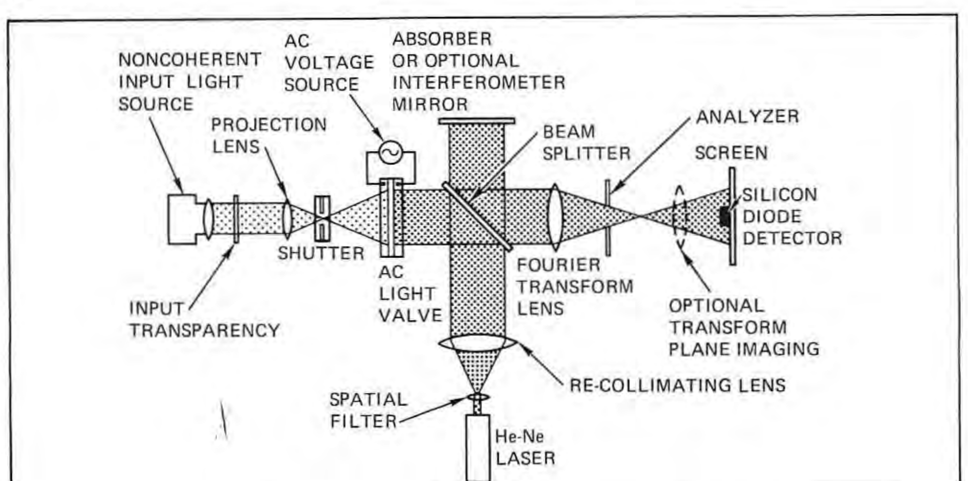

Figure 2. Schematic of the coherent optical data processing system facility.

Light Valve Performance

Next we will consider the actual experimental performance of a hybrid field effect laboratory light valve. The measurements were made in a ODP test bench shown in Fig. 2 using a linearly polarized 18 mW HeNe laser for the coherent source. We will report here measurements of the sensitometry, MTF, response time, and Fourier Transform plane characteristics of the device.

Sensitometry

The sensitometry curve shown in Fig. 3 is that of a typical light valve designed for application to coherent optical data processing. As can be seen from the figure, the threshold sensitivity occurs at about 3.3 uW/cm^2. If we use the value 10 msec for the excitation time response (see below) we find that the threshold exposure for the device is 0.33 ergs/cm^2. Typically we operate the device at voltages such that $\sim$ 100 uW/cm^2 of input intensity produces full contrast. For this device the contast measured was 90:1 at the exposure levels of 10 ergs/cm^2.

The gray scale content of the output can also be derived from this curve. If we use the standard sensitometric definition of a gray scale of 0.15 ND per step, we find that the output contains nine shades of gray. A photograph that demonstrates the grayscale performance of the device is shown in Fig. 4.

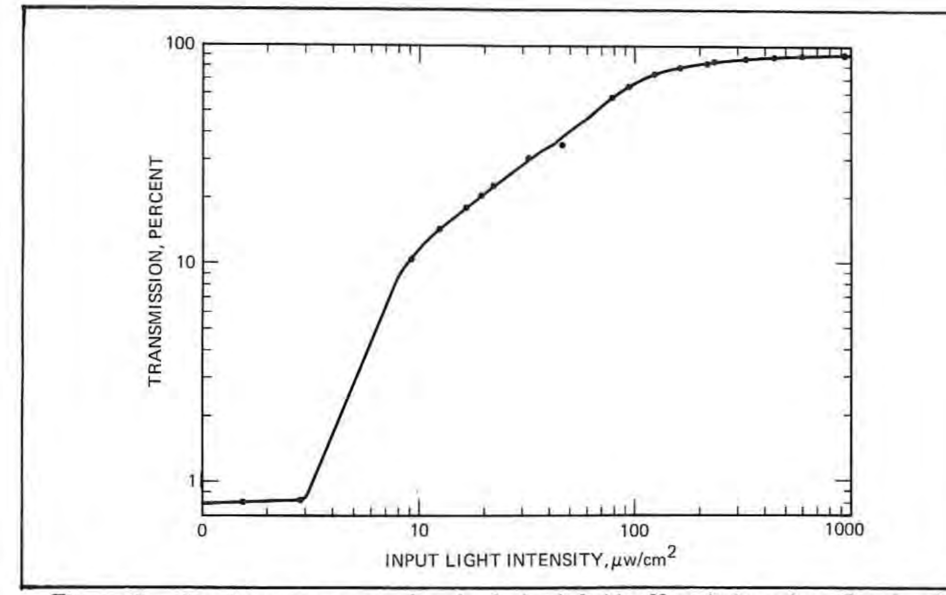

Figure 3. Sensitometry curve for the hybrid field effect light valve: Graph of percent transmission versus input light intensity.

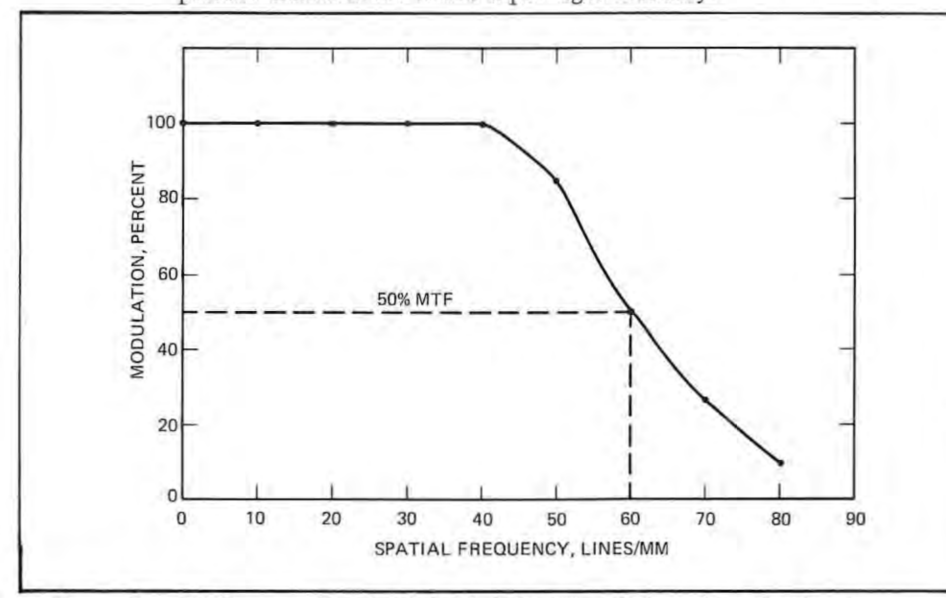

Figure 5. MTF curve for the hybrid field effect light valve: Graph of percent modulation versus spatial frequency.

Figure 4. Gray scale image in coherent light projected by light valve.

MTF Measurements

The MTF measurements were made using a Sayce Resolution Chart transparency to input a continuously varying spatial frequency line pattern to the light valve. The light valve and projection optics project the line pattern to the screen with magnification of 50X to 70X. The projected line pattern is then mechanically scanned with a photodiode detector that has a 500u diameter aperture. The limiting spatial frequency response of this system used in this mode is 140 lines/mm.

A typical MTF curve for the light valve is shown in Fig. 5. From the definition of the MTF, the 50% modulation point corresponds to a contrast ratio of 3:1. As can be seen from the figure, the resolution at 50% MTF is 60 lines/mm. This is the so-called TV resolution capability of the light valve. Thus a device with a one inch aperture can resolve 1500 TV lines. Referring again to the figure, we see that light valve limiting resolution is in excess of 100 lines/mm.

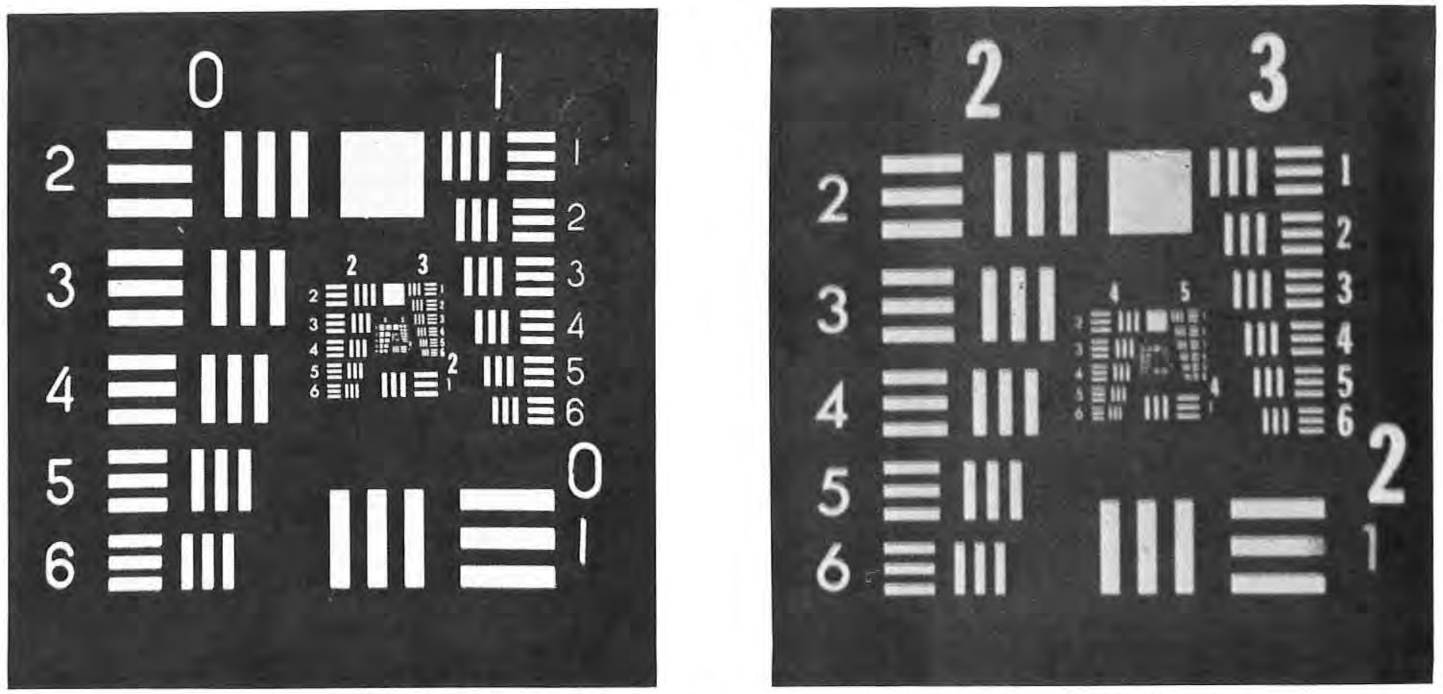

Figure 6. Photographs of Air Force resolution chart images read-out from the light valve: (a) Complete image; (b) Magnified view of central portion of the chart.

To demonstrate this resolution capability pictorially, we show in Fig. 6a an Air Force resolution chart image that is projected from the light valve to a screen and is then photographed from the screen. The photograph shows the uniformity of the contrast and the overall sharpness of the image. Fig. 6b shows a magnified view of the central section of the resolution chart. From this latter photo one can read the limiting resolution to be the group 5-6 which corresponds to 114 lines/mm.

Time Response

Light valve time response measurements were also made for different input light pulse durations. This is shown in Fig. 7a-d. As can be seen from the figure, the rise time is approximately 10 msec and the decay time is about 15 msec. These fast times are attributable to the thinness of the liquid crystal layer that we use in the device. Note also that these response times are essentially independent of the duration of the light pulse. It can be seen in Fig. 7d that the fast response time is preserved, even at very low input light levels. A full contrast response is achieved with an excitation of 24 erg/cm^2 (60 uW/cm^2 x 40 ms) and a rise time of about 10 ms.

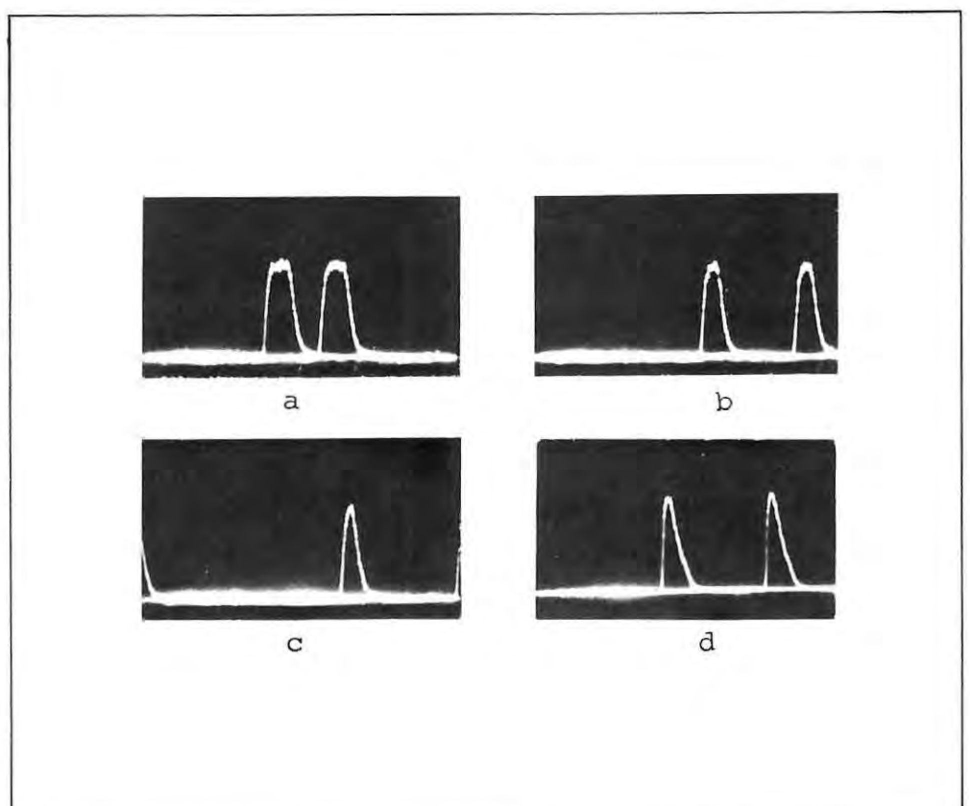

Figure 7. Time response measurements of the hybrid field effect light valve. In Fig. a), b) and c) the input light intensity is 350 uW/cm^2. In d) the input intensity is 60 uW/cm^2. In a) and d) the light pulse duration is 40 msec. In b) it is 23 msec, and in c) 18 msec. Scope trace is 50 mse/cm, throughout. Light valve voltage is 5.4 V_{rms} at 10 kHz.

Fourier Transform Plane

In Fig. 8 we present a photograph of the spatial Fourier transform generated by imaging a Ronchi Ruling of 24 lines/mm onto the light valve and reading-out the light valve with the 6328Å He-Ne laser light. In this photo, the very low Fourier Plane noise and the high resolution capability of the light valve are clearly demonstrated. The irregularity of the diffracted spots was caused in part from the poor quality optics that are used, and in part by the 1-3/4 wavelength curvature of the particular light valve measured.

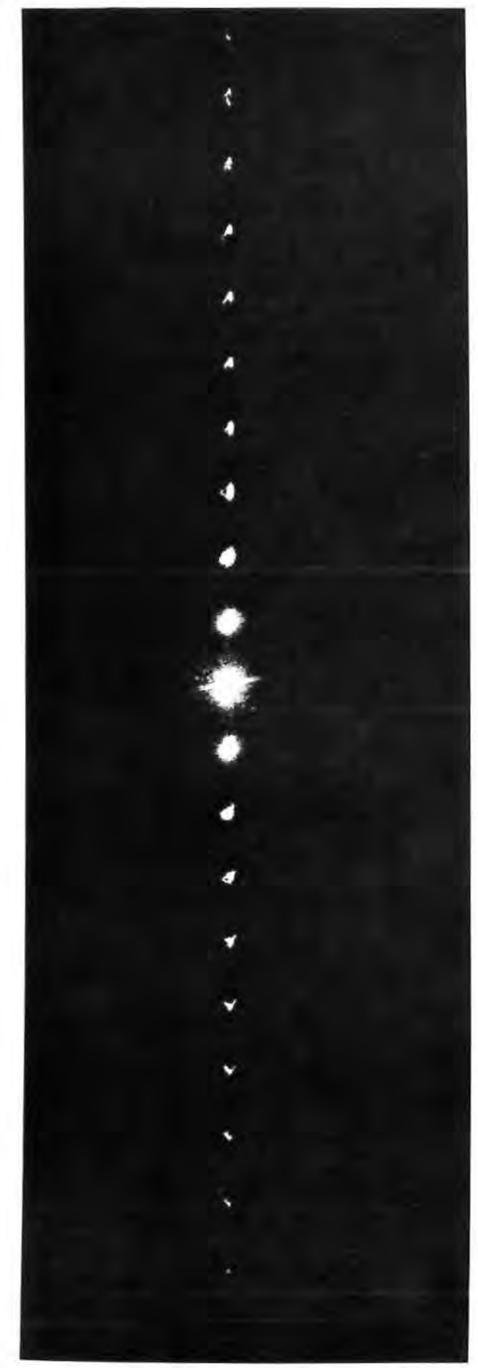

Figure 8. Photograph of the spatial Fourtier transform plane with a 24 line/mm Ronchi ruling imaged into the light valve.

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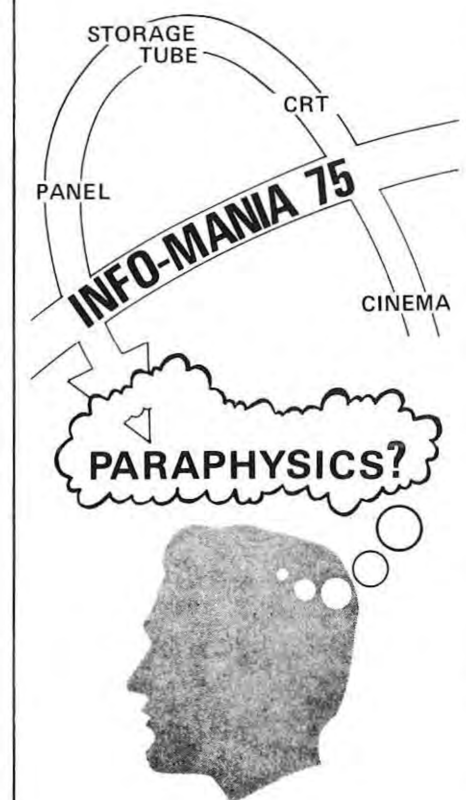

FALL – 1975

TECHNICAL MEETING

INFO-MANIA '75

The Los Angeles Chaper of the Society for Information Display is planning a one-day fall technical seminar to be held on Thursday, 6 November 1975, at the Americana Hotel near Los Angeles International Airport. Morning and afternoon technical sessions will be devoted to display devices, applications, and systems.

Mr. Lucian Biberman of the Institute for Defense Analysis will be the Keynote Speaker of the session. Dr. Henry Christiansen of Brigham Young University will be the luncheon speaker.

A wide variety of interesting and provocative technical papers were received by the Technical Seminar Committee in response to a Call for Papers issued several months ago. The committee has selected seven of the more than 20 technical papers received for presentation at this seminar.

Papers selected (and authors) for the seminar are:

1. "Factors Influencing Operation Interaction with Dynamic Air Defense Displays," C.J. Davis, U.S. Army, Human Engineering Laboratories, Aberdeen, MD.
2. "An Advanced Charactron Shaped Beam Tube for Computer Displays," Dan J. Heflinger, Stomberg Datagraphic Co., San Diego, CA.
3. "Software for Real Time 3D Displays," Richard Fryer, U.S. Naval Weapons Center, China Lake, CA.
4. "Storage Camera Tube with Non-Destructive Readout," Leon S. Yaggy, Hughes Aircraft Company, Carlsbad, Ca.
5. "Holographic Collimator/Combiner Element for a Head Up Display," Anson Au, Hughes Research Laboratories, Malibu, CA.
6. "Liquid Crystal Light Valve – Large Screen Display," Don Sprotbery, Hughes Aircraft Company, Fullerton, Ca.
7. "An Application of Electronic Display Techniques to Motion Picture Production," Peter Vlahos, Association of Motion Picture and Television Producers, Inc.

For further details contact Bill Hoffman, General Chairman, telephone 213/391-0711, ext. 4268.

Summary of Performance

In Table I a summary is given of the present performance of the hybrid field effect light valve. The table shows the high level of performance, particularly the combination of high resolution, contrast and sensitivity available simultaneously. The low operating voltage is also a distinct practical advantage in terms of prolonged device lifetime and ease of operation. The goals for future development include improving fabrication techniques and photosensor response so that a "tuned" liquid crystal thickness of 1.37 um (for 632.8 nm operation) can be uitlized. This will allow device response of <10 milliseconds.

Preliminary measurements have also been started on CODP applications such as level slicing, filtering, contrast reversal, and edge enhancement. These experiments and the light valve performance indicate that the liquid crystal light valve can play an important role in real-time CODP.

Acknowledgements

The authors would like to acknowledge the contributions of Dr. H.L. Garvin, K. Robinson, P. G. Reif and C. P. Hoberg to the fabrication of the light valves.

TABLE I

Summary of Hybrid Field Effect Light Valve Performance

Aperture Size	1 in.^{2}
Sensitivity (Full Contrast)	160 uW/cm^2 at 525 nm
Resolution	60 lines/mm at 50% MTF
Contrast	> 100:1
Grayscales	9
Speed	
Excitation (0 to 90%)	10 msec
Excitation (100% to 10%)	15 msec
Projection Light Throughput	> 100 mW/cm^2
Reflectivity	>90%
Optical Quality	< 2 wavelength curvature at 6328 Å
Voltage	6 V_{rms} at 10 kHz

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Electrostatic Impactless Printing and Plotting

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The word electrostatic implies the use of electrical charges as a means of producing an image on a substrate. I am told that the first man to produce images on a substrate which could be retrieved visually using the elctrostatic technique was Galvani. He did it by selectively charging the surface of a dielectric plate using a stylus, and then developing the image by dusting it with carbon particles. In the last few years, this technique has been improved to the point where excellent hardcopy printout is now produced daily by commercially available devices. But first, let us examine some fundamentals.

The electrostatic writing process involves two steps before the image is visible. It does not exhibit instant visibility. A piece of paper which is conductive (and this can be done by either adding salts or conductive polymers when the paper is manufactured) is coated with a very thin layer of nonconductive material or a dielectric. The selective charging of the paper is accomplished by placing a stylus in contact with the dielectric side of the paper and then supporting the paper with another electrode, thus establishing electric fields through the dielectric, with some transfer of charge between the dielectric and the stylus. When the stylus is removed, the portion of the dielectric which touched it is now charged electrically (Figure 1).

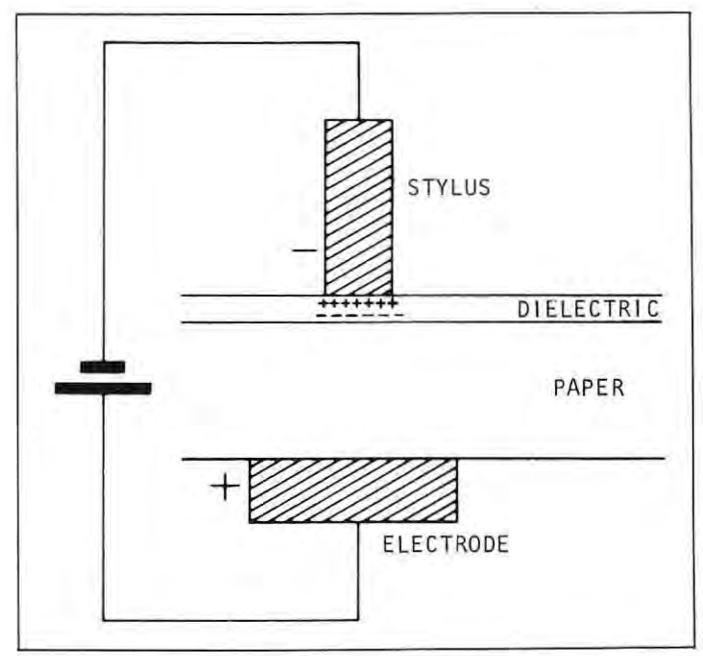


Figure 1. This charging process of paper is what makes electrostatic printing possible.

The establishment of an electrical potential at the back of the paper can be done by capacitive coupling through the front of the paper which is coated with dielectric, or by placing an actual electrode at the back of the paper.

Incidentally, the fundamental difference between the methods of writing by the three companies who are manufacturing commercial devices is that, in two instances, an electrode is placed at the back of the paper, while the third firm has chosen to capacitively couple to the paper by placing the electrodes on each side of the stylus array and on the dielectric side of the paper.

In this discussion, I am not going to include an analysis of the movement of the charges or the physics of electrostatic writing. Instead, I will mention some empirical results which we have found, and other information which we have assembled on how other companies in the field have achieved results to date.

As I noted, one can charge the surface of a dielectric coated paper but that charge is totally invisible. It can be rendered visible by developing this latent image with a dry or liquid toner.

The typical toner consists of charged particles of a contrasting color to the substrate which are attracted and stick electrically on the charged areas, thus imparting to them the color of the particles. In the case of a dry toner, the materials used are similar to those used in the xerographic process. Each particle has a coating of paraffin and, after they have been attracted and positioned on the charged area, the substrate is heated to a temperature required to melt the coating, thus permanently attaching the particles to the surface.

If liquid tone is used, the particles are in a colloidal suspension, in which resins have been added, so that when the toner dries the image is permanently fixed on the substrate. There are many companies which manufacture dry and liquid toner. The toners vary in their ability to produce high contrast images and the rate at which they dry. The fact is that electrostatic images developed by these toners have excellent archival qualities and the contract of the image does not change with time.

Now, let us examine the design of a typical electrostatic printer or plotter. I will concentrate on the details involved in actually writing the image and not on the logic circuits which are used to process the signals which are eventually applied to the writing head. Consider Figure 2, where the typical arrangement is shown. The paper supply consists of a receptacle where fan-fold or roll paper can be stored. The paper is normally drawn by a drive roller which is connected to a stepper Motor. The motion of the paper is naturally incremental. In Figure 2,

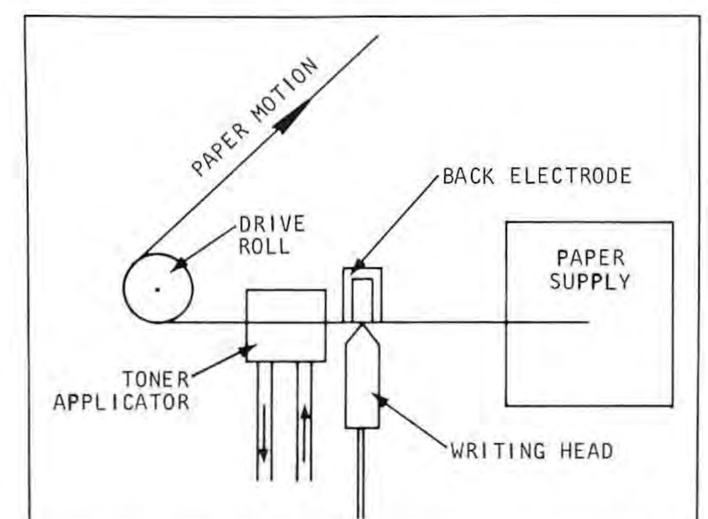


Figure 2. This is a typical arrangement of an electrostatic printer where the dielectric side of the paper is face down and the writing head deposits charges on the dielectric surface.

the dielectric side of the paper is down and the writing head is depositing the charges on the surface of the dielectric. It continues through the toner applicator and emerges for viewing.

There are different means of placing the charges on the dielectric and different methods of applying the toner. These are processes which are continuously under development and have varied through time. If the voltage on every nib has to be fluctuated up and down in order to write, this implies that the machine will have to have as many driving circuits as nibs in the writing head.

Early versions of the machine were designed according to this principle. In later models, a physical phenomenon was used in order to minimize the number of drivers necessary to write across the page.

Shown in Figure 3 is an elementary presentation of a curve

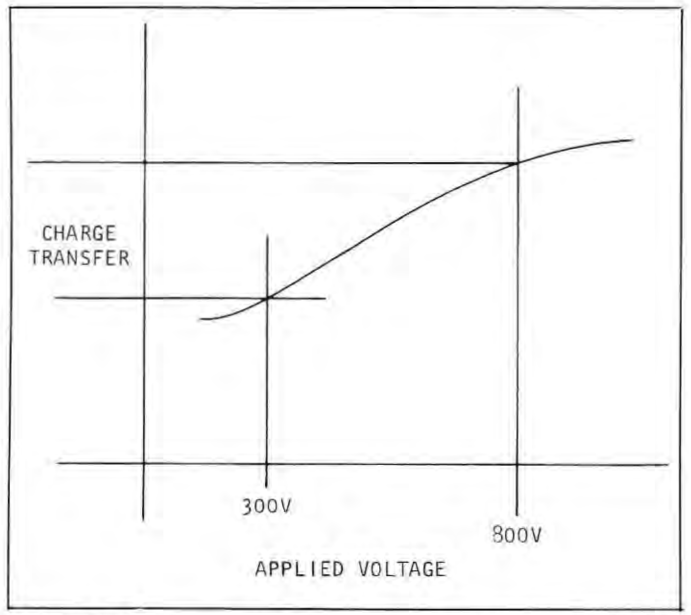


Figure 3. Voltage — charge curve indicates charge required to develop an adequate image.

which varies according to certain conditions. The important thing here is the charge which is required to be transferred before any adequate development of the image can be accomplished. Voltage increases rapidly between 300-800 volts. It is a minimum at 300 and a maximum around 800. This makes it possible to use a scheme, such as the one shown in Figure 4, to reduce the number of drives used.

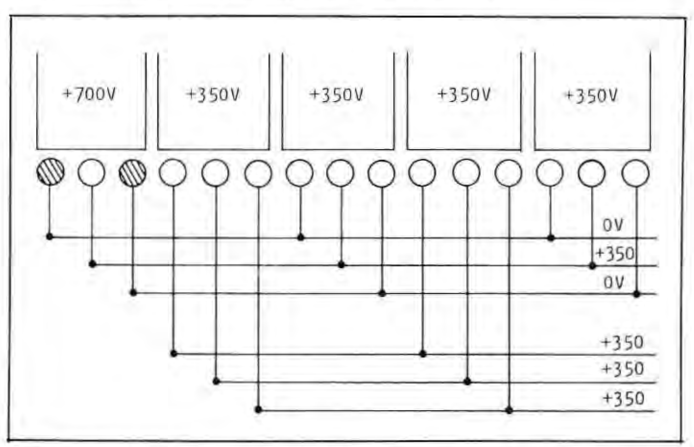


Figure 4. By using segmented back-up electrodes, the number of drives can be reduced. In this configuration, nibs 1, 7, and 13 are addressed at the same time, but conditions conducive to writing are present only where the back-up electrode is at plus 700 volts.

Here the back-up electrode is segmented and the voltage can be applied in sequence so that the proper conditions exist sequentially for writing across the page. As shown in the figure, the 1, 7, 13, and so on nibs are connected together and can be addressed at the same time. However, conditions conductive to writing will be present only where the back-up electrode is at plus 700 volts versus 350 volts. Elsewhere the writing is not visible.

Most electrostatic machines perform in two modes, the printing and the plotting modes. In the printing mode, information is received in 8-bit ASCII and through appropriate hardware character generation, the voltages applied on the writing head write the characters in a matrix form. Figure 5 shows an

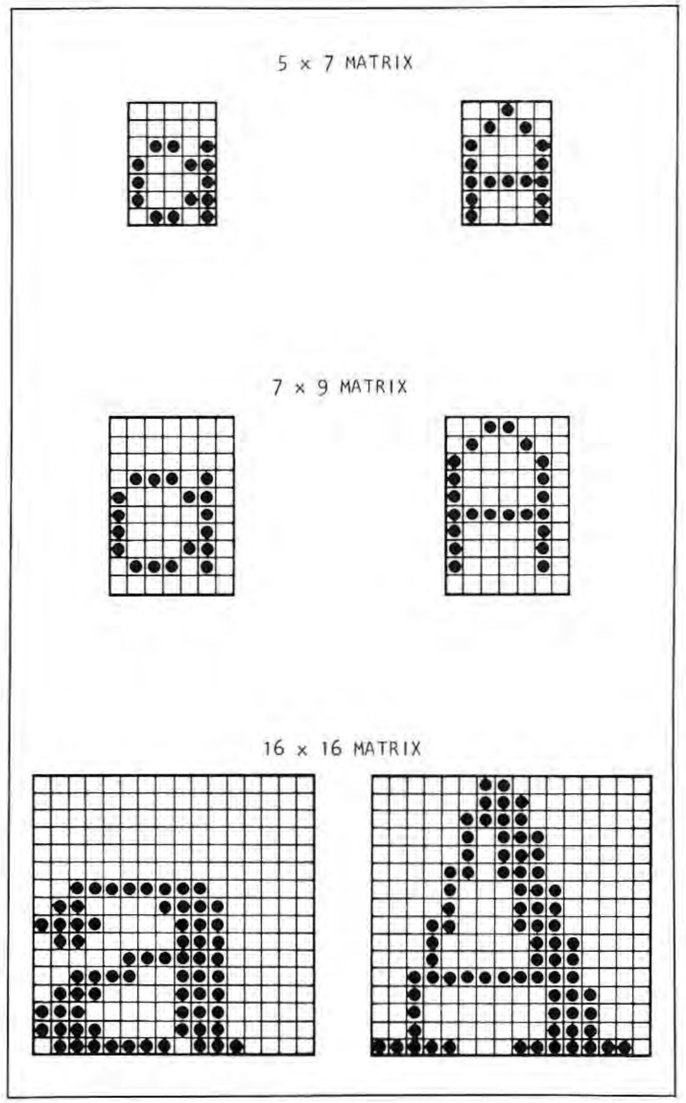


Figure 5. The size of the dot Matrix will determine the apparent resolution of the characters as shown.

elementary view as to how characters will appear containing different resolutions. It is commonly known that matrix produced characters contain a dot structure with white spaces between the dots. This is usually the result of writing with an "in-line" array. The white spaces between the dots are there primarily as a result of the spaces between the nibs. A way of removing the white spaces between the dots, thus making the writing appear as a continuous line, is accomplished by using a dual array. In this case, the information is appropriately buffered and delayed so that continuous lines are formed.

In the plot mode, the machines can receive either serial or parallel streams of data, and one line at a time is drawn on the paper. This is known as scan plotting as contrasted to vector plotting where the paper can go forward and backward with respect to the recording stylus.

Most electrostatic machines employ liquid toner. The different ways of applying toner always involve the circulation of the toner from the supply to the toner applicator and back to the supply. The drying process can use either air or vacuum. Electrostatic machines in general exhibit some peculiarities compared to typical impact machines, which in some cases made them preferable, but in other cases inadequate for the production of certain results. Following is a list of features pertaining to machines using the electrostatic writing technique:

1. Except for the toner pump and the paper drive, there are no moving parts in the writing process.
2. The paper which is used is coated with a dielectric, and presently is three to five times more expensive than plain paper. It also exhibits limitations regarding the temperature and humidity where it is stored once the box has been opened. To date, there are many manufacturers of electrostatic paper.
3. It is an indirect writing process. There is a definite delay between the writing and seeing of the image. Although this is not a problem at high speeds, in the case where a short message is written and has to be seen immediately, it may present a problem. There is also a need to develop the image shortly after it is written, and for this reason such machines are not usually suitable for operations where single lines are written and the paper does not move forward for a considerable length of time. In that case, the charge will leak and the image will eventually be lost.
4. If the machine stops for an extended period of time in one spot and the image has already been recorded, it will overdevelop and be blacker than the rest, or if there is no recording at all and the toner is not removed, a dark area across the page will be seen.
5. Except for one isolated instance of a machine in Japan producing two simultaneous copies, this technique is not suited for making simultaneous copies.
6. Since there is no impact, the machines are extremely quiet. As a matter of fact, probably quieter than the computer itself.
7. Since there are no moving parts in the writing process and the writing can be done in very short time (microseconds), the machines are capable of very high printing speeds.
8. The use of a sectioned recording head makes it possible to produce very versatile hardcopy. Different fonts in alphanumerics interspersed with graphics can be done easily.
9. The presence of relatively few mechanical parts renders the machine extremely reliable and very easy to repair. Most failures in the field are semiconductor components which can easily be changed. Even preventive maintenance is not frequently required.
10. Using staggered arrays and very fine nibs, resolutions exceeding 200 per inch can be accomplished. This produces very high-quality, high-contrast writing.
11. The technique can be extended to wider and wider machines since the problem of increasing the size of the writing head is apparently not a serious one.
12. With the appropriate software which is now available, an electrostatic printer/plotter can be plug-to-plug compatible with an impact printer and pen plotter in many applications.

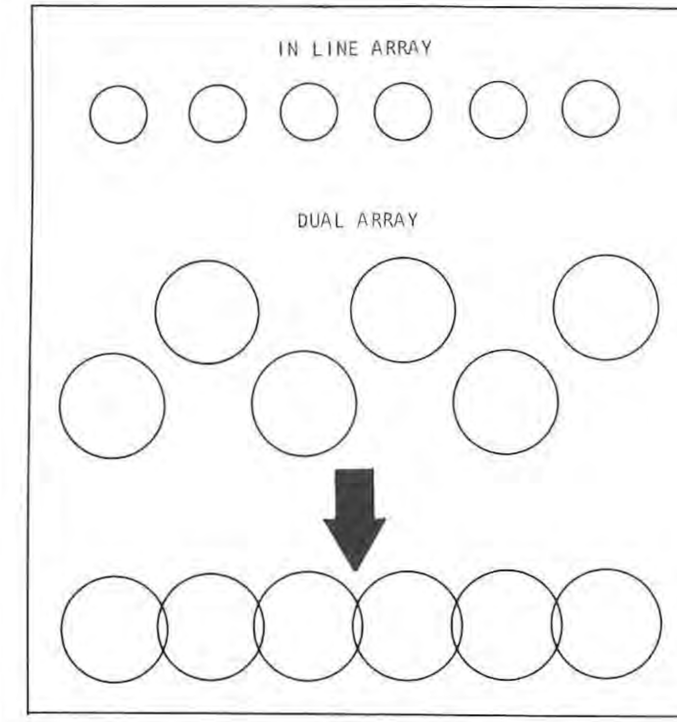


Figure 6. By using a dual array, the white spaces between dots is eliminated, making the lines appear to be continuous.

It is estimated that there are presently over 2500 electrostatic devices in the field. It is a fact that printers with plotting capability and plotters outsell straight printers by two to one. This is because the presence of the plotting capability is very unique in this sort of device. Most of the machines are used with mini-computers and off-line with some large computers. This is primarily due to the ease of interfacing and the fact that the need for lower priced high-speed machines is more apparent in mini-computer installations, where the main frames are less expensive.

Typical uses are in government, industrial, and scientific areas. Within these areas, there are some applications where machines using the electrostatic technique have been used extensively. These are the application of electrostatic printer/plotters in the retrieval of seismic data, in oil exploration, and the use of printers, particularly high-resolution machines, in the printing and publishing industry where they are used as proofers.

Government applications include mil spec machines, retrieval of information generated in space exploration, weather mapping, graphics in flight simulation, and others. Industrial applications include process control, medical results, chemical analysis, data logging, and others. Scientific applications include medical research, accelerator generated atomic data, and display of other research information. □

SID

NEW PRODUCTS

RECORDING STORAGE TUBES FEATURE ENHANCED RESOLUTION

A new series of single-ended recording storage tubes featuring improved resolutions makes use of electromagnetic focusing and deflection, and have non-destructive readout and excellent gray-scale capabilities. Three sizes are available: 1", 1-1/2" and 2".

The 1" tube, designated TME 1238 A, replaces the TME 1238. General characteristics remain unchanged, so the tubes are electrically and mechanically interchangeable. However, the orthogonal read-write resolution at 50% modulation has been increased from 800 to 1000 TV lines/diameter. This value can even be boosted to 1400 TV lines/diameter by operating the tube in the high-voltage mode at the expense of a slight degradation in image uniformity. Limiting resolution is 2000 TV line/diameter.

The 1-1/2" tube, designated TME 1239 A, replaces the TME 1239, with which it is completely interchangeable. The orthogonal read-write resolution at 50% modulation has been raised to 1500 TV lines/dia, and high voltage operation will yield 1900 TV lines/dia. Limiting resolution is 2700 TV lines/dia.

The 2" tube, TH 8803, is a new addition to the line. It features an orthogonal read-write resolution at 50% modulation of 2700 TV lines/dia, with a limiting resolution of 4300 TV lines/dia.

Applications for these tubes include TV frame-freeze, slow-scan TV, data recording and storage, scan conversion and integration of low-level video signals. Because of its extremely high resolution the TH 8803 is particularly suitable for any application involving the reproduction of very fine details, such as the production of hard copy from incoming electrical signals or storage of several television quality pictures.

Thomson – CSF
38, rue Vauthier
92100 Boulogne-Billoncourt
Paris, France

Circle Readers Service No. 100

IMAGE DISSECTOR DEFLECTION–FOCUS ASSEMBLY

CELCO's DV4102 DEFLECTION-FOCUS ASSEMBLY is designed for use with 2-1/4" diameter Image Dissector Tubes such as the ITT F4052/F4052RP and EMR Model #575.

High resolution and low geometric distortion are achieved through careful application of electro-optical design principles developed at CELCO. Electrical parameters are chosen for compatibility with deflection driver amplifiers and focus current sources.

Both single-ended and push-pull deflection coils can be provided, with a wide range of inductances available.

For those applications where conventional response times are not sufficient, special models are available with recovery times as low as 20 microseconds to 0.1%.

Standard models are supplied with high-permeability integral magnetic shielding and cushioned tube support clamp. Special variations can be provided as required for 2-1/4" as well as for other tube sizes. Delivery time is six weeks.

CELCO
Edson Ryder
70 Constantine Drive
Mahwah, NJ 07430

Circle Readers Service Card No. 101

LOW COST REFRESH MEMORY SYSTEM

This random access refresh memory system permits real-time scan conversion such as from radar PPI to TV raster. Memory organization is modular with the basic building block consisting of 65,536 bits on 4" x 6" printed circuit card. These modules are combined to provide increased capacity as required. Addressing and control logic are provided by a separate control module. Cost is 0.5 to 0.9 cents per bit and speed is up to 20 MHz. Interfaces are TTL compatible and power required is +5 and –12 VDC.

DLI's memory system consists of three basic modules. They consist of a memory module with 16 - 4K RAM chips assembled in a 65K x 1 bit array and the memory control module which controls the read/write and refresh functions of the memory (also provides the interfacing between the system input and output lines), and the raster timing module, the latter provides the system clock and all timing signals. It includes the pixel and line counters and frame and line sync generation circuitry. The raster dimensions and sync patterns are all derived through ROM decoding, thus allowing flexibility in generating both standard and non-standard rasters.

The simplest memory system configuration would consist of one each of the basic modules and might be a display of 256 horizontal by 256 vertical points with one bit of dynamic range. By adding memory modules, the horizontal (X) or vertical (Y) size or dynamic range (Z axis) can be increased.

Development Laboratories, Inc.
2920 Olympic Blvd.
Santa Monica, CA 90404

Circle Readers Service No. 102

CRT TERMINAL WITH BUILT-IN MASS STORAGE

With 220,000 bytes of built-in mass storage, the newest Hewlett-Packard CRT terminal can perform on a stand-alone basis many operations normally requiring connection to a computer. Two fully-integrated tape transports, using the newly-developed miniature version of the 3M data cartridge, provide enough data storage for a day's work at the keyboard. For data entry, forms can be stored on one mini-cartridge and selectively retrieved in seconds. Program preparation, editing, tape copying, and tape-to-printer operations are all within the stand-alone abilities of the microprocessor-controlled 2644A.

Protected fields, video high-lighting, and elaborate editing capabilities make it easy to enter data from the keyboard to the display and to verify the data entered. The data then may be stored on a second mini-cartridge by pushing a single button. Later, full mini-cartridges of data can be batch-transmitted to a computer system. The 2644A includes a range of micro-programmed instructions sufficient to exercise all its data-handling capabilities.

Single keys execute the most common tape data transfer commands. Touching any "File" button, f_1 through f_8, automatically calls up the appropriate one of the first 8 files on a cartridge. "Read" and "Record" are single-button functions.

Two prefix keys speed operations. Input/output functions are quickly assigned by first touching the green prefix key, then the appropriate input and output device keys. Data path architecture of the 2644A is generalized so data may be moved readily among any of the station's functional units, between cartridge tapes, from the keyboard, to or from the display's semiconductor memory, to a printer, to or from the RS232C data communications interface.

A gold key is the prefix for quick access to extended operations. For example, "Gold Key + find file key + file-number + cartridge ident key" calls up any of 255 files at search speed (60 ips). File records may vary in length from 1 to 256 bytes, stored in ASCII or binary format.

The 2644A has a high-resolution 5" by 10" display. Within the enhanced display, 1920 characters can be presented in a 24-line by 80-column format. A 9 x 15 dot character cell shows large characters accurately, removes ambiguity and relieves operator fatigue. Inverse video (black on white), blinking, half-bright, and underlining may be employed in all their possible 16 combinations. The 2644A can display multiple character sets. A 128-character Roman set, including lower

case and displayable control characters, can be used along with as many as three additional character sets. A math-symbol set is available, and a line drawing set which can be used to generate the user's entry data forms on the 2644A display.

Full editing capability is provided to correct data before transmission or recording. Standard features include character and line insert and delete, cursor sensing and positioning, programmable protected fields for forms, off-screen solid-state-memory storage with scrolling and page-select, tabulation, 8 special-function keys for user-defined routines, and a positional memory lock.

The new 2644A uses an ASCII RS232C communications interface and can transfer from semiconductor memory at rates up to 2400 baud (9600 baud on binary output).

Price is $4400.00 in quantities of six and will be available in October.

Hewlett-Packard Co.
1501 Page Mill Rd.
Palo Alto, CA. 94304

Circle Readers Service Card No. 103

LOW-COST 10-mW LASER SYSTEM

A 10-milliwatt helium-neon laser system, designed for OEM applications, has been introduced by Hughes Aircraft Company's electron dynamics division.

Designated Model 3035H, it consists of separately packaged laser head and power supply. The laser head, measuring 23-1/2 inches in length, is claimed to have the highest power per unit length of any commercially available He-Ne laser. It is available with random polarization standard, or in an optional linearly polarized version.

The head, with CW output at 632.8 nanometers, TEM_{00} mode, features a near-hemispheric cavity to enhance beam stability and speed warm-up. The pre-aligned internal mirror plasma tube design eliminates the need for cleaning or field adjustment of the optics, and non-hydroscopic sealants are used to protect the tube from contamination caused by high humidity environments.

The regulated power supply is available for AC operation at 100 volts, 115 volts, or 230 volts. Power supplies are packaged

in a low-silhouette enclosure.

Price is $995.00 for single quantity.

Hughes Electron Dynamics Division,
Laser Products
3100 West Lomita Blvd.
Torrance, CA. 90509

Circle Readers Service Card No. 104

0.625-INCH CHARACTER GREEN LED READOUT

This light source is made from high efficiency discrete gallium phosphide diodes arranged in a seven-segment format, with a right hand decimal point. Current passing through the diodes, generates a bright, highly legible green character with very low power consumption for a character of this size. The contrast ratio between the illuminated and non-illuminated segments is enhanced by a nonglare window.

Each character is available with or without a printed-circuit board which includes the decoder driver. The decoder-driver requires four lines or information bits in a 8421 BCD code for each character.

In addition, it also has terminals on the p-c board for automatic blanking of the leading and/or trailing edge zeros. A lamp test input to the unit over-rides all other

inputs and enables the operator to check for a possible display malfunction.

The unit costs $4.95 each in the U.S.A. in 1000 lot quantities.

Dialight
203 Harrison Place
Brooklyn, N.Y. 11237

Circle Readers Service Card No. 105

LOW-COST SYSTEM ENDS PICTURE SHAKE AND BOUNCE

DYNASCIENCES announces a new low-cost VIBRA STOP LENS for image stabilization. The VIBRA STOP needs no power and is completely self-contained in a compact light-weight unit, yet is capable of performance comparable to that of sophisticated gyro/servo lens systems or complicated isolation mounts in eliminating bouncing, shaky pictures.

This system is expected to prove useful for telephoto still photography, for laser and IR stabilization, and in electro-optically directed systems. Key features of this system are: Light – only 3 pounds,

Small – 4-3/4 in. diameter, 4½ in. length, Passive – no power required, Versatile – fits standard cine and still lenses up to 73 mm (2-7/8 in.) O.D.

Other features include: High light transmission – 95%, Fully coated achromatic optics, 60 mm clear aperture, Compensation lockout – for conventional use without removing the unit from the camera, and it adapts to a universal camera mount.

Cost of the unit is $750, including carrying case.

DYNASCIENCES
Township Line Rd.,
Blue Bell, PA. 19422

Circle Readers Service Card No. 106

OPTICAL FILTERS IMPROVE READOUT VISIBILITY

Two new optical filters specifically designed to improve the readability of high efficiency red light emitting diodes under conditions of high ambient light as bright as direct sunlight have been introduced by the Panelgraphic Corporation.

These filters are reddish-orange in color, matching the color output of the LEDs. The controlled density of the filters permits the designer to drive the high efficiency LED display with a lower than normal average forward current and obtain excellent contrast enhancement. Chromafilter® Scarlet Red 65 provides relative transmission of display light of approximately 55%; the higher density Red 66 color provides a transmission factor of approximately 33%. Both figures are measured at 635 nm, color peak of the high efficiency LED.

The Chromafilter Scarlet Red 65 color is available in acrylic sheets .060" and .125" thick, and in Panvin™ sheets .030" thick. Panvin filters recently passed UL's 94V-0 flammability test. The lower transmission Red 66 is initially available in acrylic sheets of .060" and .125" thicknesses. Both materials can be cut, punched, formed, and silk-screened. Finished sheet stock or complete filter panels to user specifications are available.

The filters are available from stock for immediate delivery.

Panelgraphic Corp.
10 Henderson Drive
West Caldwell, NJ. 07006

Circle Readers Service Card No. 107

HIGH SPEED 12-BIT A/D CONVERTER OFFERS THERMAL STABILITY AT LOW PRICE

Featuring only 12ppm/°C gain tempco, Analogic claims the MP2712 provides in-spec performance at up to 75% greater temperature change than its nearest price competitor.

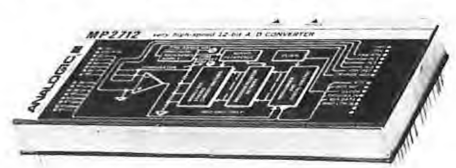
The MP2712 completes full 12-bit conversions in less than 4usec which provides through-put speeds up to 250,000 conversions per second while maintaining the full accuracy and linearity of the best available 12-bit converter.

With 4 full-scale pin-selectable ranges -0 to 5V, -5 to +5V, 0 to 10V and -10 to +10V – (a 4 to 1 sensitivity range) – the MP2712 provides the user with the flexibility to choose the range most suitable to the balance of his system.

The new module is packaged in a compact 2" x 4" x 0.440" Modupac shielded case that isolates the converter from both electromagnetic and electrostatic fields.

Accessible gain and offset adjustments are provided within the shielded case for the convenience of the user and to ensure that every unit shipped meets a guaranteed accuracy specification traceable to the National Bureau of Standards. These adjustments are driven from a built-in stabilized precision reference supply effectively isolating them from the possibility of introducing errors as a result of supply voltage changes which can otherwise contribute up to 3 least significant bits of error for fluctuations in the ±15V external supply voltages. The power supply sensitivity of the MP2712 is less than 12ppm/% change in supply voltage thereby freeing the engineer from concern that power supply stability will materially effect his converter accuracy.

For additional versatility the MP2712 can be short cycled, permitting tradeoff of resolution for speed if desired. The



unit also provides separate analog and digital power returns, permitting the user optimal configuration of his power grounds to eliminate ground loops and injection of digital ground noise into the A/D converter.

Very high quality resistor networks in the MP2712 assure maximum differential linearity tempco of only 3ppm/°C thus guaranteeing monotonicity over the full temperature range of 70°C.

Single unit price is $229.00.

Analogic
Audubon Road
Wakefield, MA 01880

Circle Readers Service Card No. 108

LOW-COST COLOR-GRAPHICS DISPLAY DRIVER

Ann Arbor's new S105 Color-Graphics Controller provides a low-cost means for displaying graphic and alphanumeric data on conventional TV monitors, in black-and-white or in color.

The Model S105 is intended for use in industrial and business systems requiring the display of graphics data, and where low-cost, high-speed response, silent-operation, visual-cueing, and remoteability are important considerations.

The controller provides video outputs for both black-and-white and RGB-color monitors. Graphics resolution is 80 points horizontal by 240 points vertical. Up to 1920 alphanumeric characters may be displayed, in an 80-character by 24-line format. In addition to color, the data may be displayed with a full-range of visual accents, including blink, dual-intensity, and reverse-video. Data input is 16-bit-parallel, asynchronous. The display can be selectively up-dated or completely rewritten in less than a second.

Single quantity price is $1490, with substantial OEM and quantity discounts available. Standard delivery is 75 days.

Ann Arbor Terminals Inc.
6107 Jackson Rd.
Ann Arbor, Mich. 48103

Circle Readers Service Card No. 109

MONSANTO CO.

The Electronics Division of Monsanto Company has announced immediate availability of a new series of T-1 size light emitting diodes. The lamps are available with two lead lengths and four colors: orange, yellow, green and an improved, high brightness red.

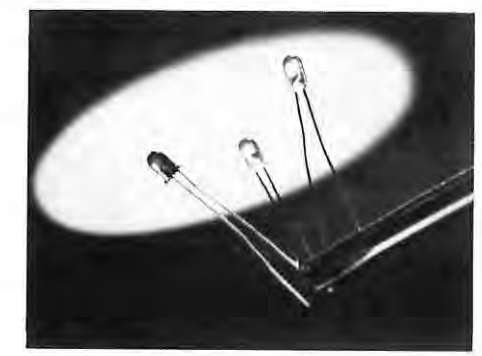
The following table summarizes the new lamp line. In the model number the "B" and "C" designators indicate the minimum lead lengths of 0.6-inch (15.2 mm) and 1.0 inch (25.4 mm).

Model No.	Color	Minimum Lead Length	Typical Luminous Intensity (20mA)
MV5174B	Orange	0.6"	5.0 mcd
MV5174C	Orange	1.0"	5.0 mcd
MV5274B	Green	0.6"	1.0 mcd
MV5274C	Green	1.0"	1.0 mcd
MV5374B	Yellow	0.6"	4.0 mcd
MV5374C	Yellow	1.0"	4.0 mcd
MV5774B	Red	0.6"	5.0 mcd
MV5774C	Red	1.0"	5.0 mcd

The new lamps use a material process, patented by Monsanto, by which emitters are made from nitrogen-doped gallium arsenide phosphide on a gallium phosphide substrate. This process greatly improves brightness and power conversion efficiency, allowing very bright indication at rated currents or operation at far lower currents than previously possible.

All products have a maximum lens height of .210 inch (5.33 mm). Barrel diameter is 0.130 inch (3.30 mm) and the viewing angle of the emitted light is 90°. Leads are square and will fit into a .020 inch (.508 mm) diameter hole. The lamps will mount on approximately 3/16 inch (4.72 mm) centers. Maximum power dissipation is 105 mW, with a maximum forward current capacity of 35 mA.

All models with a "B" suffix are $0.74 for 1 to 99. "C" model are $0.84 for the same quantities.



Monsanto Co.
Electronics Division
3400 Hillview Ave.
Palo Alto, CA. 94304

Circle Readers Service Card No. 110

AUTOMATIC PHOTOMETER

Photo Research has introduced an automatic version of its Spectra Pritchard Photometer, designated the 1980A. It features electronic auto-ranging over 4 full ranges (providing 6 decades of automatic digital readout) and automatic zeroing of dark current. Combined with Auto-Comp, a built-in patented system which electronically compensates for all system variables without the need for manual computations, the new feature makes direct readout virtually error free.

Full-scale sensitivity is obtained for brightness' from 10^{-5} to 10^{7} foot-Lam-

berts. Calibration of the 1980A, traceable to the National Bureau of Standards, is maintained by a built-in highly stable light source.

The Pritchard Photometer can be used to measure luminance, illuminance, radiance, color temperature, light polarization, and relative tristimulus values.

Photo Research
3000 N. Hollywood Way
Burbank, CA. 91505

Circle Readers Service Card No. 111

PACKAGED READOUT WITH .6" LED DISPLAY

Instrument Displays, Inc., now has available a line of decode displays with memory units featuring all logic functions on plug-in cards with readout on .6" LED display.

Normally, when the versatility of plug-in cards is employed, one must pay the penalty of costly individual connectors for each decade. However, with our packaging approach, only one connector is required, regardless of the number of decades being ordered.

In a single patended bezel and housing, anywhere from 2-8 decades can be provided. The method of mounting the readout and the way the bezel mounts to a front panel provide an excellent viewing angle. The individual logic cards mount directly behind the display, thereby permitting center-to-center spacing on only .6" per decade. Hence, a four digit display mounts in a panel cutout of 3.25"W x 2.1"H x 3.2"D, while the LED display provide a clear readable numeral up to 30 feet away.

An optional power supply is capable of being mounted within the housing, thereby providing a completely self-contained unit which can be easily sealed against oil, mist and dirt in order to be used in adverse industrial environments.

Decimal points are standard in every position and feature a front bezel that can be customized with the user's name and unit function.

Typical pricing for a four decade display completely packaged for a quantity of 25 would be $68 each. Delivery from stock in any number of decades.

Instrument Displays, Inc.
225 Crescent Street
Waltham, MA 02154
(617) 894-1577

Circle Readers Service Card No. 112

SUSTAINING MEMBERS

AYDIN CONTROLS
Fort Washington, PA 19034

BURROUGHS CORPORATION
Plainfield, New Jersey 07061

CARDION ELECTRONICS, a Division of General Signal Corp.
Woodbury, N.Y. 11797

CHERRY ELECTRICAL PRODUCTS CORP.
3600 Sunset Ave., Waukegan, Illinois 60085

CONRAC CORPORATION
New York, NY 11017

DATA DISC, INCORPORATED
686 West Maude Avenue, Sunnyvale, CA 94086

DIACON, INC.
San Diego, California 92111

DISPLAY COMPONENTS, INC.
Littleton, MA 01460

DuMONT ELECTRON TUBES AND DEVICES CORP.
Clifton, NJ 07015

FERRANTI ELECTRIC COMPANY
Plainview, New York

GENERAL DYNAMICS ELECTRONICS DIVISION
Box 61127
San Diego, CA 92138

GENISCO COMPUTER
17805 Skypark Circle Drive
Irvine, CA 92707

GML INFORMATION SERVICES
Lexington, Massachusetts 02173

HEWLETT-PACKARD COMPANY
Colorado Springs, Colorado 80907

HUGHES AIRCRAFT COMPANY
Culver City, CA 90230

IBM CORPORATION
Armonk, NY

NAC INCORPORATED
Minato-ku, Tokyo, Japan

OPTICAL ELECTRONICS, INC.
Box 11140, Tucson, AZ 85734

OWENS ILLINOIS, INC.
Box 1035, Toledo, OH 43666

PHILCO-FORD CORPORATION
Palo Alto, CA

PHOTO RESEARCH DIVISION KOLLMORGEN CORPORATION
Burbank, CA 91505

RANK ELECTRONIC TUBES RANK PRECISION INDUSTRIES LIMITED
Sidcup, Kent, England

REDACTRON CORPORATION, INC.
Hauppauge, NY 11787

SIEMENS AG
Munich, West Germany

SINGER-LIBRASCOPE
Aerospace & Marine Systems Group
Glendale, CA 91201

SYNTRONIC INSTRUMENTS, INC.
Addison, IL

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