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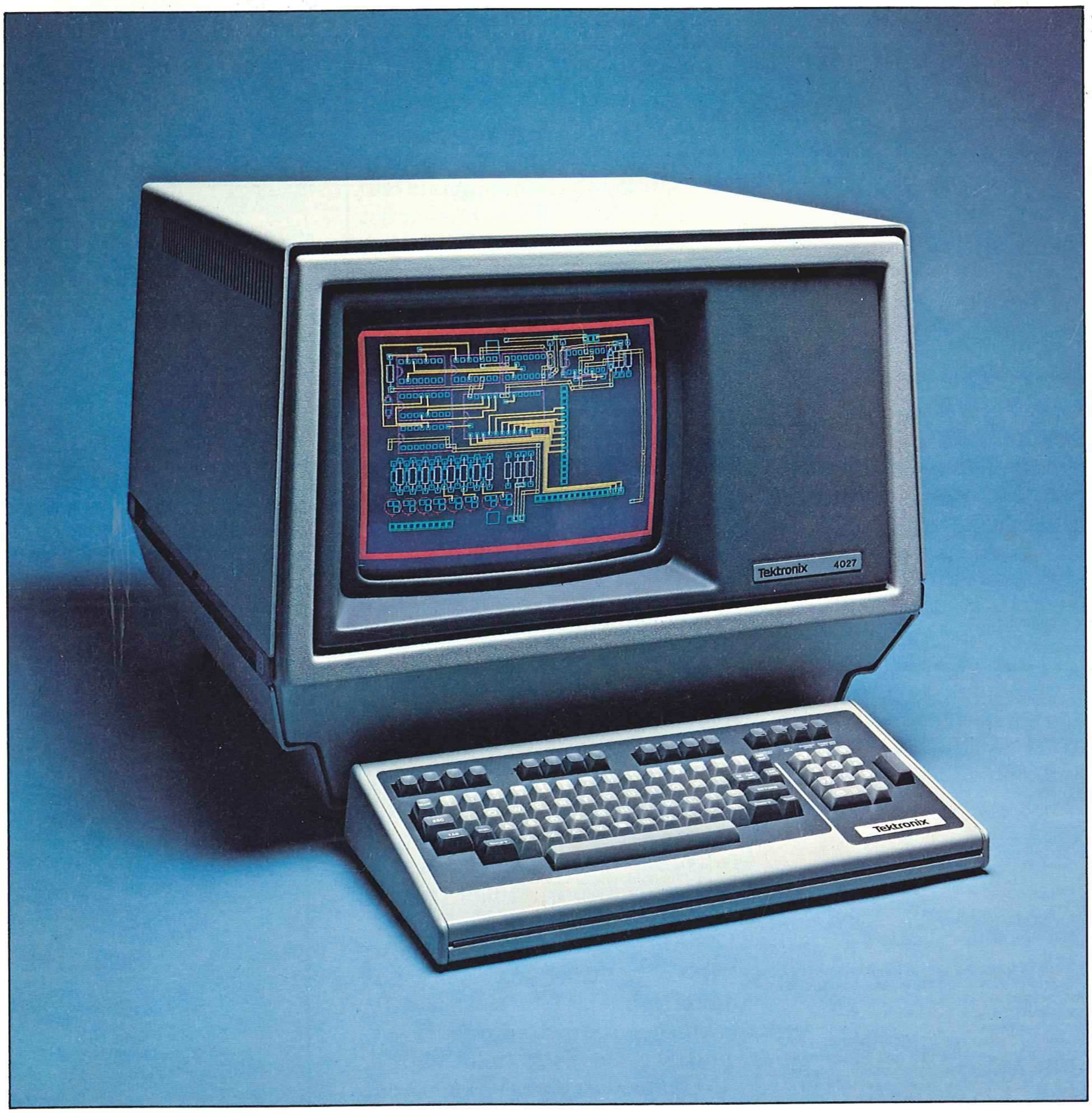
Tekscope



Tektronix®
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Tekscope

Customer information from
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Beaverton, Oregon 97077

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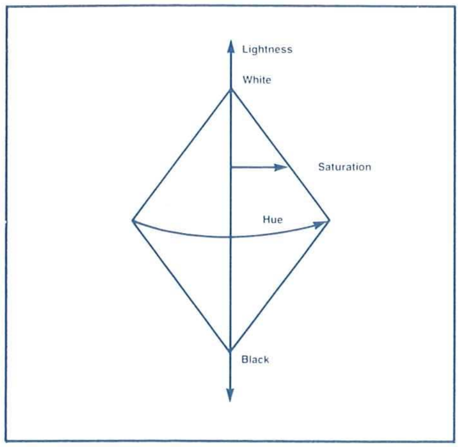
The 4027 Color Graphics Terminal is a compact, high performance computer terminal with a raster scan display. The memory required for both graphics and color is greatly reduced by using the virtual bit mapping technique developed for the TEKTRONIX 4025. Up to eight colors from a palette of 64 can be displayed simultaneously.

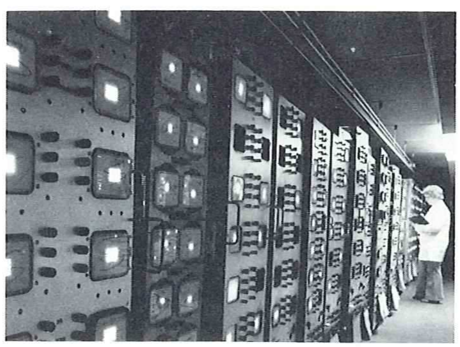
An Easy Language for Talking with Color Machines

A new color standard developed for the 4027 greatly facilitates selecting a color and getting it on-screen with the first attempt. It is easy to change color just a shade, or radically.



Reliability — the Continuing Challenge

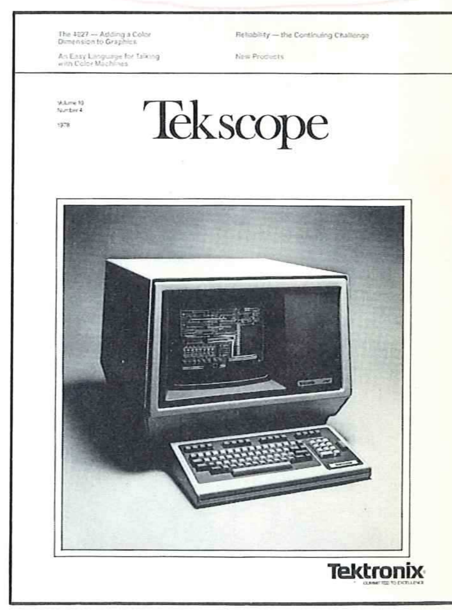
Reliability doesn't just happen. You have to make it happen through people, programs, and perseverance. Here is just a brief overview of some of the activities dedicated to helping us meet this continuing challenge.



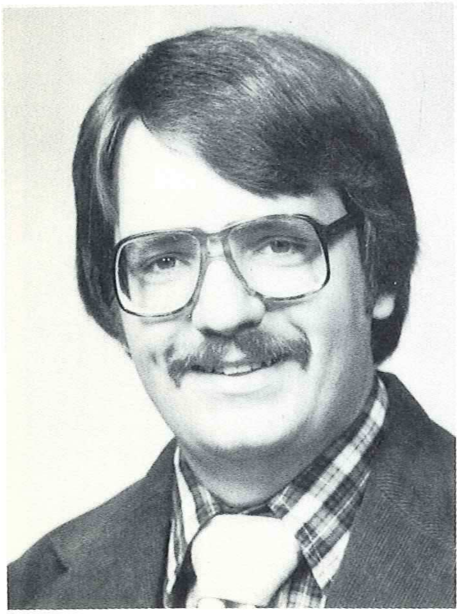
Tekscope is a bimonthly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique. A new products section gives a brief description of products recently introduced and provides an opportunity to request further information.

To better serve customers who maintain their TEKTRONIX instruments, the service information formerly appearing in Tekscope will be expanded and published in a publication dedicated to the service function.

Cover: The use of color in developing a circuit board layout provides a convenient means of identifying select elements, as shown in this photo of the 4027 Color Graphics Terminal.



The 4027—Adding a Color Dimension to Graphics



Ken Willett came to Tek in October 1975 after receiving his BS in Physics and Mathematics from Whitman College and completing a year in the computer sciences graduate school at Washington State University. Since coming with Tek, Ken has worked on the 4020 Series Computer Terminals and PLOT 10 Easy Graphing Software.

Our everyday lives are greatly influenced by the use of color. Color movies, color television, and color printing carry much greater impact than their black and white counterparts.

Color has recently entered the world of computer graphics. And it offers much more than just the natural appeal of color. For example, it provides a means of separating information in multi-element charts and graphs. It can be used to call attention to a particular feature in the display. And it enhances human pattern recognition.

Color bit map displays have traditionally suffered from the high cost of memory involved (up to 120 kilobytes). Now, using the virtual bit map technique developed for the 4025 alphanumerics/graphics terminal,[1] memory required for color graphics is greatly reduced. In virtual bit mapping, the operator uses a software program to establish a graphics region on the display screen. The rectangular graphics region can be displayed anywhere in the display area, with the remainder of the area considered alphanumerics.

The graphics region is then further divided into graphics cells. A graphics cell is the same size as an alphanumerics cell — 14 dots high by 8 dots wide. A unique approach to graphics programming uses a display list and pointers to allocate graphics memory to only those cells containing graphics information. The remaining graphics cells appear in the display list as spaces. This greatly diminishes the memory required, especially for simpler graphs.

The addition of color to the graphics display requires a change from a single memory plane to three memory planes. Thus, a virtual bit map cell in the 4027 is a block of RAM which is 8 by 14 by 3 bits, rather than 8 by 14 by 1 as in the 4025. Each pixel (raster dot) within the cell may be displayed in any one of eight colors by properly setting the three RAM bits associated with that pixel. The basic 4027 contains 48 kilobytes of color graphics memory with options available to extend the total to 192 kilobytes.

While eight colors are enough for many applications, there was a problem in selecting which eight colors, in the spectrum of possible colors, were appropriate for a given application. It was clear that no one choice of eight colors was adequate for all applications, and that some method was needed for changing the selection under program control.

To provide this capability, a color map was included in the display hardware (See Fig. 2). The inputs to the mapping mechanism are the three bits in the virtual bit map for a particular point. The outputs of the map are two bits for each of the three guns in the color monitor. This allows the user, under program control or via keyboard commands, to set any one of the eight colors available, to one of 64 possible selections in the map. The Tektronix graphics terminal color standard (see page 7) was developed to allow easy control over selections from the 64-color palette.

Polygon concept saves memory

At this point in the design, the 4027 looked like a 4025 with color. However, there is a difference between adding color to a monochrome graphics terminal and building a good color terminal. This difference results from the fact that users demand different operations from a color display than the traditional selection of vectors and characters.

Most color pictures for which a color terminal is used contain solid-colored areas. This concept led to the development of the 4027 polygon feature. A polygon is a set of points describing the perimeter of an area. The interior of the polygon boundary is usually filled with a desired color or pattern. (See Fig. 3).

Here again the virtual bit mapping technique proved to be a major asset because most polygons contain entire cells of a fixed color. For these interior cells, it is not necessary to allocate graphics memory; a reference to a solid cell of the appropriate pattern or color is simply placed in the display list. In general, a solid area picture (such as a map), which is displayed on the 4027 as a set of polygons, will require significantly less graphics memory than the same picture drawn and cross-hatched on the 4025. Graphics memory in the 4027 is used only to draw the outline of the polygon. Firmware enables using another color to border the polygon if desired.

Fig. 1. The 4027 Color Graphics Terminal. A molecular modeling application is displayed.

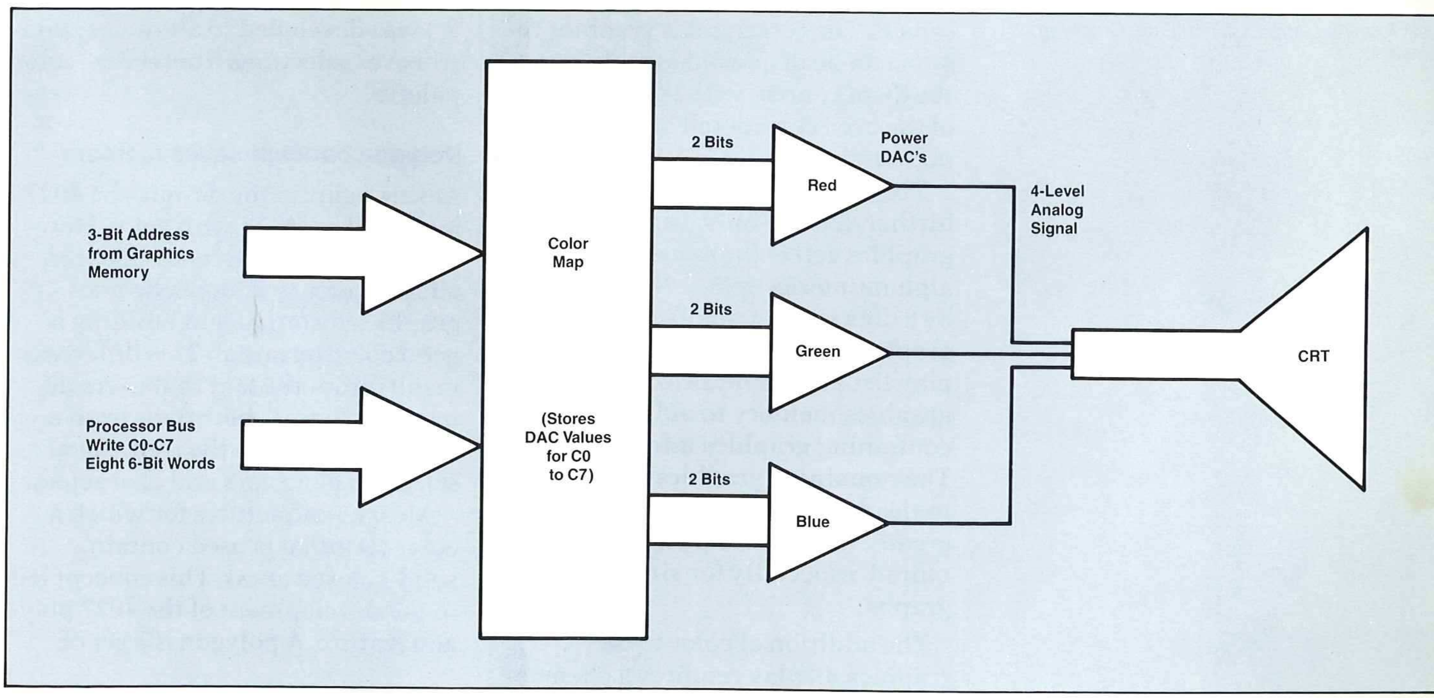


Fig. 2. Values of hue, light, and saturation for eight colors are stored in the color map in the form of eight 6-bit words. A 3-bit address from the graphics memory selects one of the 6-bit words as the output to the power DAC's driving the red, green, and blue guns of the color crt. Each gun is driven to one of four levels including off.

Patterns extend color choices

In some applications, eight distinguishable area types are not adequate. In order to increase the selection, the pattern concept evolved. Patterns are to polygons what dashed lines are to vectors. A pattern is a user-defined 8 by 14 grid, where each point in the grid may be one of the 8 colors. Once the pattern has been defined, it may be used to fill polygons. The pattern is simply repeated over the interior of the polygon.

There are two major uses for patterns. One is to generate additional colors by uniformly mixing dots of different colors.

Using this technique, pictures containing 125 distinct colors have been generated from patterned mixtures of the eight basic colors.

Let's consider an example of using a pattern to generate a desired color. Assume the color map for a 4027 has been set according to Figure 4. Note that the color map is coded such that Red = C4, Green = C2, and Blue = C1. If we add Red and Green (i.e., C4 + C2) we get Yellow (C6). We are now in a position to define color patterns.

A master pattern cell consisting of 8 by 14 raster dots, or pixels, is shown in Figure 5. The numbers in the master cell can be thought of as levels which correspond to the values of Red, Blue, and Green for the color we desire to generate. For example, assume we want to construct a color mixture of Red = 3, Green = 1, and Blue = 4. Each position in the master cell with numbers less than or equal to 4 (≤4) must get a Blue contribution, those with numbers less than or equal to 3 (≤3) must get a Red contribution, etc.

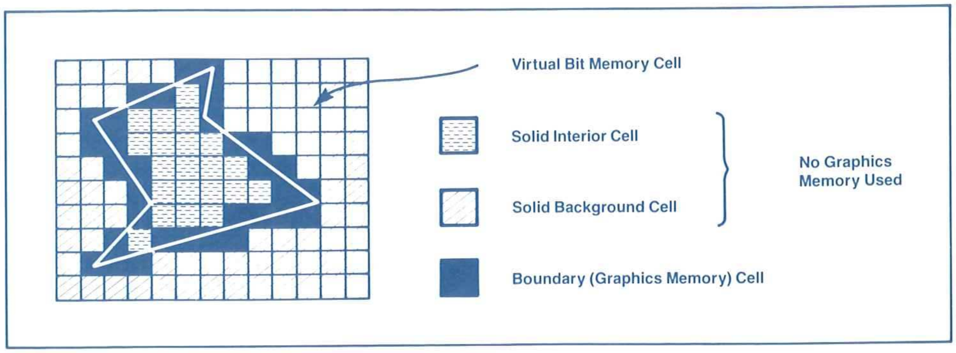


Fig. 3. The use of polygons makes efficient use of memory. Only the boundary cells require graphics memory. For the background and interior cells, a reference to a solid cell of the appropriate color is simply placed in the display list.

MAP #	HUE	LIGHTNESS	SATURATION	COLOR
C0	0	0	0	Black (K)
C1	0	50	100	Blue (B)
C2	240	50	100	Green (G)
C3	300	50	100	Cyan (C = B+G)
C4	120	50	100	Red (R)
C5	60	50	100	Magenta (M = R+B)
C6	180	50	100	Yellow (Y = R+G)
C7	0	100	0	White (W = R+G+B)

Fig. 4. Color map used for patterning. The colors selected provide the broadest range of discernible colors through patterning.

Note that the master cell is populated with a repeat of the pattern outlined in the upper left corner of the master cell. Let's focus our discussion on this sub-cell. (Fig. 6(a)). We start with a cell of all Black (K) as shown in Figure 6(b). Those elements with a value of ≤3 then receive a Red contribution as shown in Figure 6(c). Next, those elements with a value of 1 receive a Green contribution as shown in Figure 6(d). And, finally, those elements with a value of ≤4 receive a Blue contribution as shown in Figure 6(e). We then recode the RGB color codes to the appropriate color combinations from the color map in Figure 4; the result is shown in Figure 6(f).

By repopulating the master cell with this sub-pattern, we have a master pattern which exhibits the proportionate color properties of the desired color mixture. It is then a straightforward task to encode this pattern into the form needed by the 4027.

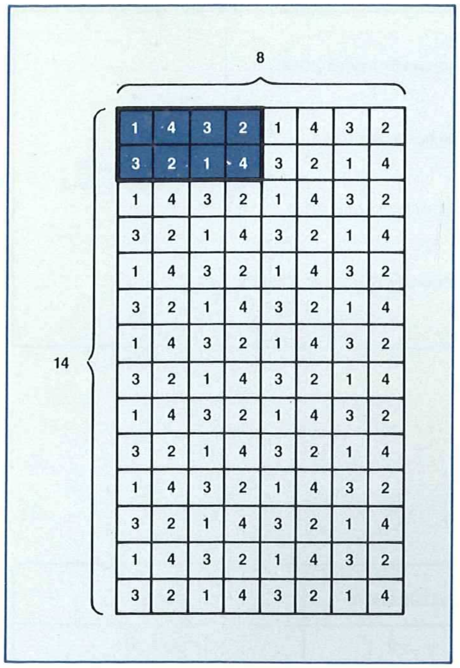


Fig. 5. A master pattern cell contains the same number of elements as alphanumeric cells. The numbers correspond to the values of red, blue, and green for a selected color. Note the two-row, four-column pattern is repeated throughout the cell.

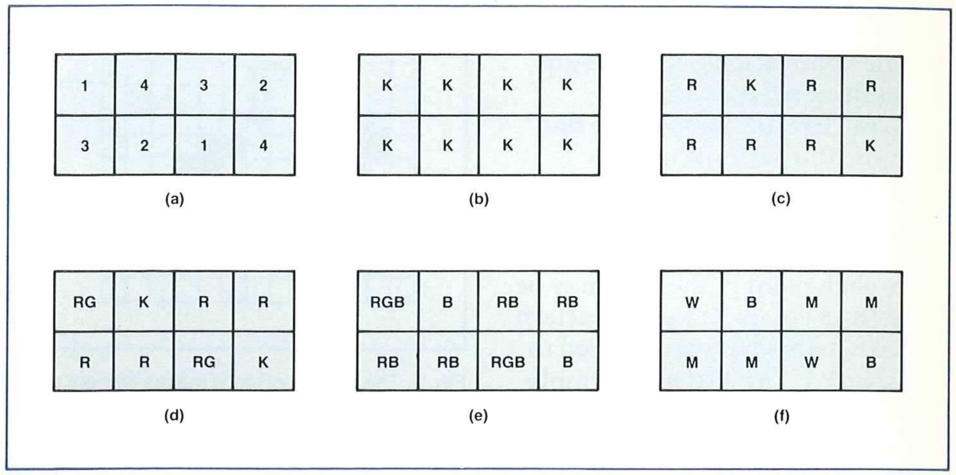


Fig. 6. (a) Basic pattern for the master pattern cell in Fig. 5. Numbers correspond to the values of red, blue, and green for a selected color. The desired color is Red = 3, Green = 1, Blue = 4. Starting with an all Black cell (b), Red is added (c), then Green (d), and finally Blue (e). The resultant colors are White, Blue, and Magenta (f).

By repeating the foregoing process for all combinations of Red, Blue, and Green in the range of 0 to 4 we can construct a set of patterns to simulate the colors for a 5-step per gun color system—a total of 125 colors.

Patterns are also used to fill polygons with more traditional area coverings, such as crosshatch and stripes. These capabilities are available in firmware in the 4027, making much more efficient memory use than if they were a part of the host software.

More than just a color terminal

The 4027 is more than just another color terminal—it is a very versatile alphanumerics/graphics terminal. One of the important operating features made possible by virtual bit mapping is the unique ability to scroll color graphics and alphanumerics together. This same technique enables definition of multiple graphic regions for easy recall from local memory.

The 4027 uses the same functional PLOT 10 Easy Graphing host software as the 4025. Easy Graphing offers support for up to six curves or colored bar charts, line graphs with special symbols and dashed lines, legends, titles, grids, hard copy, and plotter control.

For more demanding color graphic applications, the PLOT 10 Interactive Graphics Library offers all the support commonly required in graphics applications.

A wide range of options allows one to extend the display and color graphics memories and connect to a variety of peripheral devices including the 4632 Hard Copy Unit (Option 06), 4642 Printer, or the 4660 Series of interactive digital plotters. Both RS-232-C and GPIB Interfaces are available. A polling interface permits multiple-terminal configurations on the host computer line. And a Forms Ruling Option lets you duplicate essentially any form.

Summary

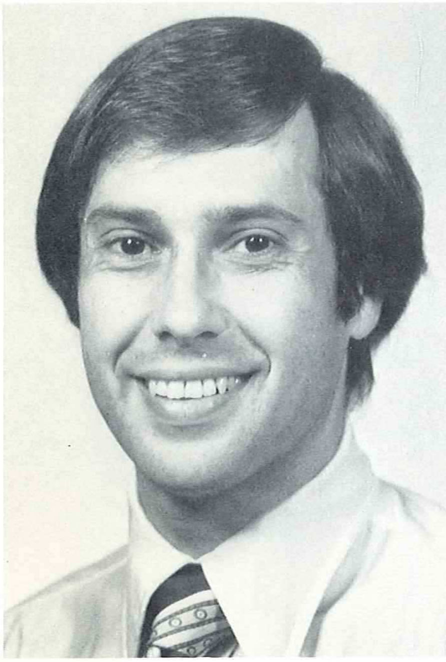
The 4027 Color Graphics Terminal is a compact, high-performance terminal with a 13″ raster-scan display.

The virtual bit map graphing technique allows one to perform many graphics functions with only a modest amount of memory. And a new color standard scheme provides a straight-forward, easy-to-learn method of specifying color. A wide range of options permits tailoring the 4027 to handle today's applications, and expand easily to meet tomorrow's.

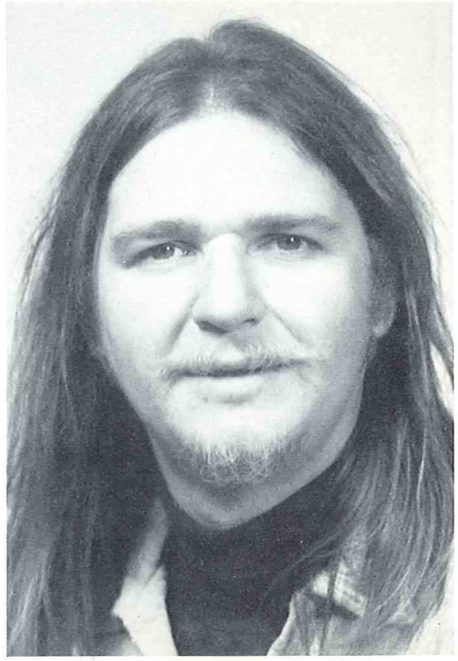
In the 4027, alphanumerics, graphics, and color merge to provide a new and more versatile tool for information display.

1. See "The Virtual Bit Map Brings High Resolution Graphics to the Alphanumerics Terminal User." Tekscope Volume 10, November 1, 1978.

An Easy Language for Talking with Color Machines



Stan Davis has been involved with computer terminal design since coming with Tektronix in 1968. He worked on the keyboard and other circuits for the T4002, was project engineer on the 4023, assisted on the 4081 program, and was project leader on the 4025 and 4027 programs. Stan received his BSEE and BA from Rutgers University in 1964 and an MBA from University of Portland in 1975.



Lee Metrick developed the color standard for the 4027 and did a great deal of innovative computer work on the use of half tones in color graphics. Lee received his BSEE from Syracuse University in 1965 and a Masters in Science and Industrial Engineering from the University of Michigan in 1970. He is completing his dissertation for a doctorate in Industrial and Operations Engineering, also at Michigan. Lee taught Computer Science for three years at the University of Kentucky. A newcomer to the Northwest, he has been at Tek since September 1977.

The world of color is filled with unclear and ambiguous terms such as intensity, value, chromaticity. Many methods exist for specifying color, but most are "machine" oriented. Early in the development of the 4027 Color Graphics Terminal, it was apparent that a people-oriented method for communicating with the terminal about color was needed. But how does one go about selecting a color and describing it in meaningful, precise terms? Before proposing a solution to this problem let's review some methods now in use.

Television is a light generator and is referred to as an additive color system. When red, blue, and green are combined in proportionate amounts, they add up to a color perceived as white. Colors for television-based computer terminals are often described as mixtures of RGB, for example, red 3, green 2, and blue 0.

Printing pigments are light filters and are subtractive. When magenta, yellow, and cyan pigments are mixed together in equal amounts and illuminated, they subtract reflected light so that black is perceived. the printing industry deals with separations of magenta, yellow, cyan, and luminance (black and white). It describes colors, for example, as 75% magenta plus 25% cyan.

How do people like you and I specify colors? We use names and adjectives. Most have a clear idea what the following names represent; red, green, blue, black, white, orange, purple, grey, dark grey, brown, dark red, pink. But how about dark magenta, walnut brown, Aztec blue, or passionate pink?

Numerical descriptors are more nebulous still. What color is created with red = 3, green = 3, and blue = 2? Or how do you get flesh tone by mixing magenta, yellow, and cyan?

Describing and generating colors at the paint store is an activity with which we're all familiar. We decide to paint the bedroom walls with a shade like the drapes, only lighter. At the store we select the Aztec blue chip from the collection. The clerk then finds the numerical machine instructions for mixing pigments and mixes the paint. The room is painted and the color evaluated. It should be a little greener and a little lighter, but changing it will be time consuming and expensive so we decide to live with it.

Interactivity a necessity

We need a better approach for working with color terminals.

The special thing about a color terminal is displaying images in the desired colors. This is best accomplished by interactivity. The user specifies a color. The terminal displays it. The user evaluates it and corrects it if necessary. It is important, therefore, that the method of describing colors facilitates this interactivity.

To be valuable to Tektronix and the industry, the method must not only work with the 4027, but also accommodate future products. These may have many more colors than the 8 out of 64 used by the 4027.

The method used to specify colors should:

- Be easily learned and remembered.
- Provide for interactivity.
- Work for displays.
- Work for copying devices.
- Work for devices with thousands of colors.
- Work for computers, data bases, transmission lines.

Selecting a method

While the commercial availability of color graphics terminals is new, color scientists have been around for some time. Theories and models abound. One text alone shows over 30 approaches for thinking about color. From these, two were selected for further consideration—the double-ended cone and the cube. The color cube (Fig. 1) relates directly to the hardware, but is difficult for people to use because it is difficult to portray the colors inside the cube in an organized, meaningful way.

In the double-ended cone (Fig. 2), colors are selected by specifying hue, lightness, and saturation. (This is often referred to as the HLS method). These attributes relate to how colors are perceived rather than generated. Hue is the characteristic associated with a color name such as red, yellow, or green. Lightness is the characteristic that allows the color to be ranked on a scale from dark to light. And saturation is the extent to which the color differs from a gray of the same lightness. For example, fire-engine red is highly saturated.

Colors are arranged in the geometry of a double-ended cone (Fig. 2). Variations in lightness are represented along the vertical axis with black at the bottom apex and white at the top apex. On a plane which intersects the cone perpendicular to the lightness axis, all colors are of equal lightness. Variations in saturation are represented by a radial distance from the lightness axis. And hue is represented as an angular displacement around a circle intersecting the cone.

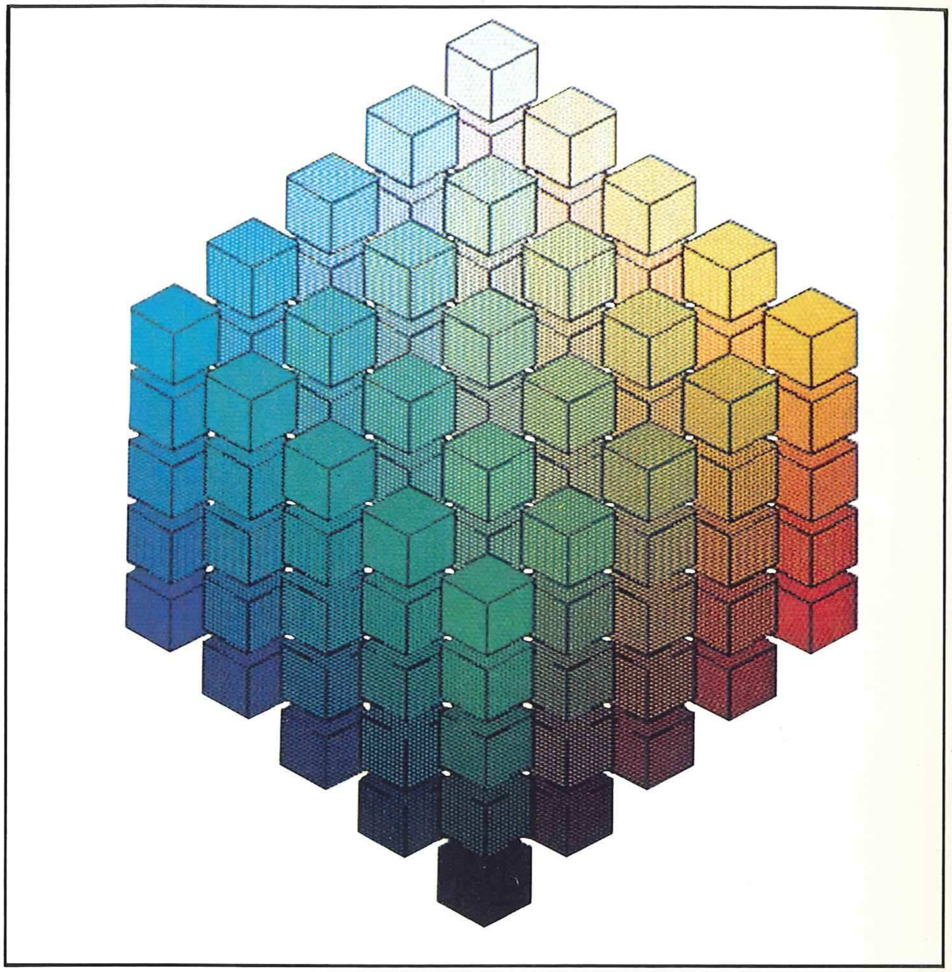


Fig. 1. The cube relates colors in a manner most comparable to the hardware, but it is difficult to visualize colors inside the cube. This photo was taken from the 4027.

Stated quantitively, hue is a variation of color advanced by degrees represented as an angle from 0 to 360 degrees from a reference where 0 degrees is blue.

Lightness ranges from 0%, which is black, to 100%, which is white.

And saturation is expressed as a percentage of the distance to the surface of the cone ranging from 0%, maximum white at that lightness level, to 100%, which is fully saturated.

The TEKTRONIX 4027 color standard (Fig. 3) illustrates one product implementation of the double-ended cone. The continuous and infinite theoretical cone has been approximated by the 64 regions of color that a 4027 can generate. The figure can be used to illus-

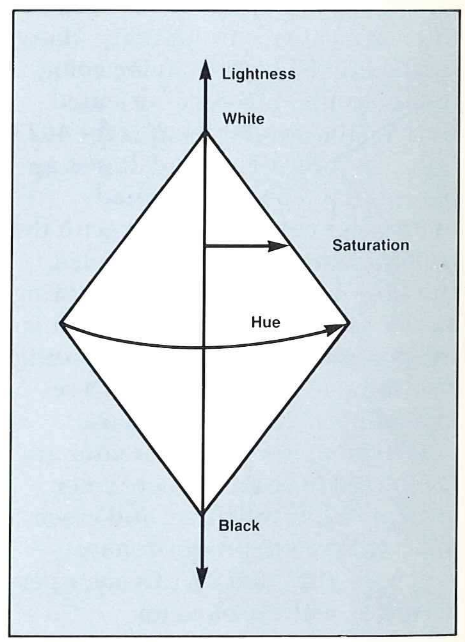


Fig. 2. The double-ended cone can be used to express colors in terms of hue, lightness, and saturation. Hue is expressed in degrees from 0 to 360, lightness from 0 to 100%, and saturation from 0 to 100%.

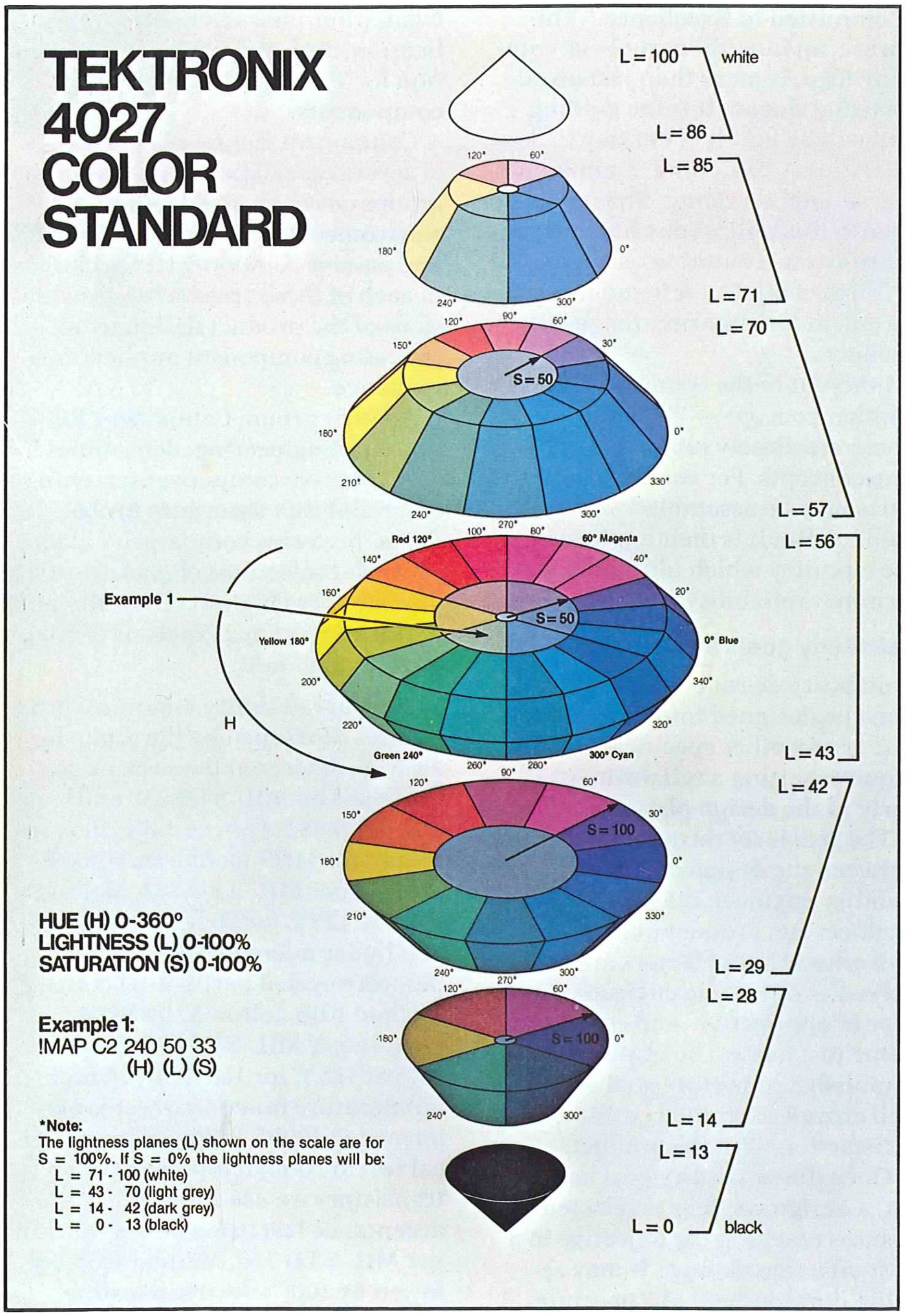


Fig. 3. The 4027 Color Standard is one implementation of the double-ended cone concept. It is relatively easy to specify a desired color in terms of hue, lightness, and saturation using such a standard.

trate the concept and assist a 4027 user in specifying color. It can be seen that fire-engine red can be obtained as follows: hue is red (120°), lightness is 50%, and saturation is full (100%). This would be specified as 120, 50, 100.

A look at the hardware

Having discussed the method for specifying color for the 4027, let's consider the hardware itself for a moment. The 4027 uses a delta gun, shadow mask, high resolution color tube. The user can select any 8 colors from a palette of 64, to display on-screen. A three-bit-deep, virtual bit map stores the information relating a color number, C0 through C7, to the color of a pixel (picture element or dot). The red, green, and blue guns of the cathode ray tube can each be driven in 4 levels, including off, creating up to 64 colors. A register arrangement in the display controller, called the color map, remembers which of the 64 colors to generate when, for example, C3 is called for.

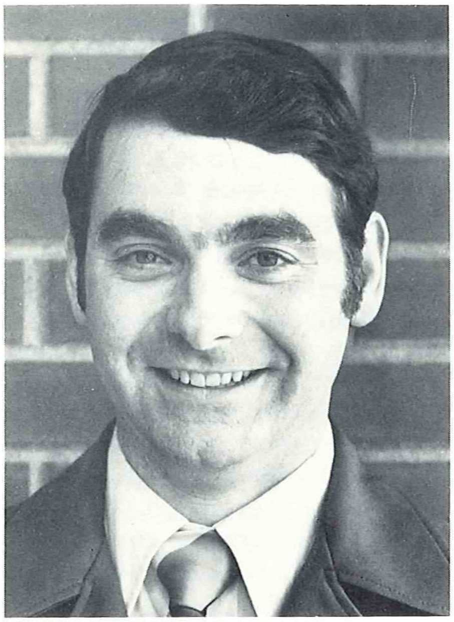
Use of the virtual bit map graphics technique and other features such as polygons and patterns, gives the 4027 unusual capability with only a modest amount of graphics memory. The 4027 is discussed in greater detail in a companion article in this issue.

Summary

The HLS method of specifying color provides a terminology and conceptual framework for working with color. It is easily learned and remembered. Users are able to select a color from the color cone and get it on-screen. They also find it easy to memorize the cone and input numbers to the 4027 that get close to the desired color, on the first try. After judging it, they can easily change hue, lightness, and saturation as needed.

The HLS method was adopted and developed for the 4027. It could be used by other Tektronix terminal and peripheral products. Indeed, it could well serve the industry internationally as a method for people and machines to effectively interact with color.

Reliability—The Continuing Challenge



William Peek is manager of Test and Measurement Operations and chairs the Corporate Reliability Committee. During his 16 years with Tektronix, Bill has been heavily involved in the development and design of Tek products–working as a project engineer in the 7000 Series, managing several product lines, and most recently, managing the Laboratory Instrument Division. He holds a BSEE and MSEE from Oregon State University.

"Committed to Excellence." This phrase, an integral part of our company logo, is more than just an advertising slogan. It is the guiding philosophy for all of our day to day activities — designing, manufacturing, selling, servicing. Strict adherence to this philosophy has earned Tektronix a reputation as a manufacturer of quality test and measurement and information display products.

Inherent in the term "quality" is another concept —"reliability." These are closely related but separate concepts. For example, quality parts may be assembled in a skilled manner. But it is their application in the circuitry which ultimately determines reliability.

Reliability goals a necessity

Reliability doesn't "just happen." It must be designed into the product just as any other specification. This requires setting a reliability goal early in the design phase.

The goal is set through discussions between the design engineer, the reliability engineer, manufacturing engineering, product marketing, and others. Many factors are involved — operating environment, type of application, and cost, to name just a few. The objective is to establish a reliability goal which will ensure continued customer satisfaction with the product.

Once the reliability goal has been set, a design strategy is selected that assures reaching the objective in a cost-effective manner. It may require development of a new integrated circuit, use of a premium part, or special temperature control techniques, perhaps all three. The design engineer has extensive support in making these decisions.

Component support

With the rapid change taking place in solid state and other devices, it is a real challenge for the design engineer to be knowledgeable about every component. At Tektronix, the Component Engineering group assists designers in this task. Their primary function is to provide evaluation, characterization, specification, and application information for Tektronix purchased components.

Component Engineering consists of several specialized evaluation groups covering analog, digital, electromechanical, optoelectronic, and passive components. Specialists in each of these areas serve as extensions of the product design team, providing component applications guidance.

Another group, Component Reliability Engineering, determines cost-effective component screening and reliability assurance procedures, performs comparative evaluations for selections of package style and vendor of highest reliability, and performs electrical analysis of components that fail.

Typical reliability assurance procedures developed by the group for discrete devices and microcircuits are based on MIL-STD 750 and MIL-STD 883. For example, the procedure for MOS memories is 100% burn-in per MIL-STD 883, Method 1015, at 125°C for 96 hours. Digital and linear microcircuits are temperature cycled per MIL-STD 883, Method 1010, followed by 100% burn-in per MIL-STD 883, Method 1015 at 125°C for 160 hours. A high-temperature functional test is performed at 100°C, followed by electrical test at room temperature. For transistors we use a reliability lot acceptance test using power burn-in per MIL-STD 750, Method 1036, followed by 100% electrical testing.

Note that these are "typical" procedures, and are modified accordingly to meet specific reliability requirements.

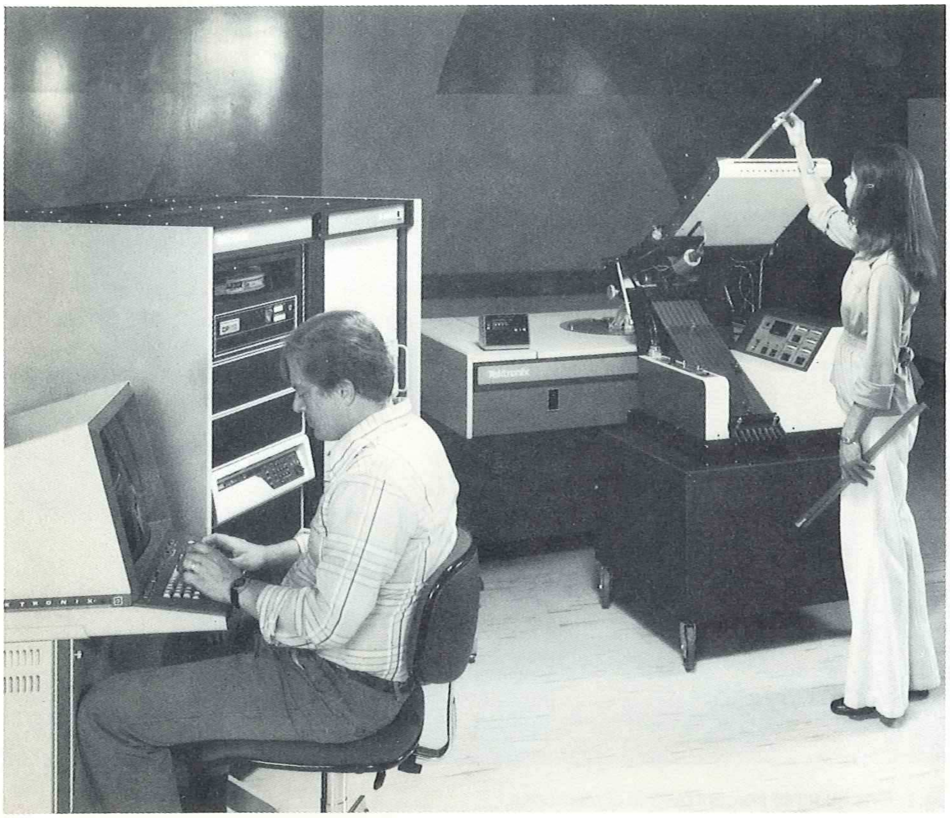


Fig. 1. Tek uses it's own S-3200 Series Test Systems to perform incoming inspection on millions of parts annually.

Component Reliability Engineering plays a vital role in our long-term reliability program by performing failure analyses of parts removed by our field service centers. Returned parts undergo electrical tests, and those found to be defective are analyzed to determine the failure mode. Parts are filed to be available for further analysis at a later date if desired.

Component Reliability Engineering also performs special analyses on request. For example, an extensive study was performed to determine the reliability of plastic encapsulated semiconductor devices under various humidity conditions. In an evaluation of devices removed by our field service centers, it was found that humidity was not a significant contributor to field failures.

Tek made components

While most of the activities just discussed are devoted to ensuring the reliability of purchased parts, there is comparable activity taking place relative to Tek-manufactured components. In many instances, the desired performance cannot be achieved with purchased parts. Accordingly, Tektronix has developed a substantial in-house component capability. This includes resistors, capacitors, transformers, coils, switches, relays, cathode ray tubes, solid state devices, printed circuit boards, etc. Each of the major component groups has its own reliability personnel and programs.

The Integrated Circuit Manufacturing (ICM) group has developed programs and testing capabilities that are among the most comprehensive in the industry. Reliability programs for new devices are established at the beginning of the design phase. Drawing upon years of experience, a checklist of some 34 factors has been prepared, against which new designs must be evaluated before design acceptance. One of these factors is the setting of a reliability goal for the device and defining life-test conditions.

Reliability inspection parameters for each device are established using MIL-STD 883 as a basis. Both mechanical and electrical tests are included. A look at just a few of the tests performed will serve to illustrate the thoroughness of the program.

Thermal shock consists of 15 cycles of −55°C to +125°C, air-to-air, with a 4-5 second transfer time. Fine and gross leak checks (on cavity packages) follow the thermal shock tests. On some devices leak checks are performed both before and after thermal shock. Next comes 10 days of temperature and humidity cycling. Temperature is cycled once every 24 hours over a range of −10°C to +65°C at humidities of 90 to 98%. Power may be applied during all or part of this test. The high temperature operating life test then follows. Ambient conditions and electrical conditions are adjusted to yield junction temperatures from 125 to 200°C, depending on the design of the device. Typical test times are 1000 hours, or as the reliability goal dictates. These tests are performed in series to qualify a new product for certification.

Production run devices receive 100% burn-in and 100% testing in accordance with the reliability goals set for them. In addition, life tests are performed on a continuing basis.

The ICM group performs its own failure analysis. Their sophisticated test equipment includes a scanning electron microscope (SEM), optical microscopes, curve tracers, cameras, and an electron microprobe (EMP). The photo in Figure 3 shows a typical application of the SEM in determining the source of an intermittent open in an integrated circuit lead.

The cathode ray tube is another key component manufactured at Tektronix. Reliability programs for this device center on maintaining tight control of production processes, analysis of field returns, and continuous life testing. New materials and processes are thoroughly tested before release for use in production units.

Tek has one of the finest electrochem facilities on the West Coast. Reliability of etched circuit boards is primarily a function of attention to the materials and processes used. A well-equipped metallurgical laboratory exists to ensure continuing quality and reliability in the metals we use. Because complex multilayer circuit boards require precise process control, much of the lab's activity is devoted to microscopic analysis of these boards to assure electrical and metallurgical continuity of the contacts. Boards are examined for the quality of through-hole plating following the critical processes, and again after the holes have been soldered, as in the assembly process. Close attention is also given to handling and cleaning techniques to avoid the development of leakage paths.

The foregoing examples are typical of the attention given to reliability by all of the component groups at Tektronix.

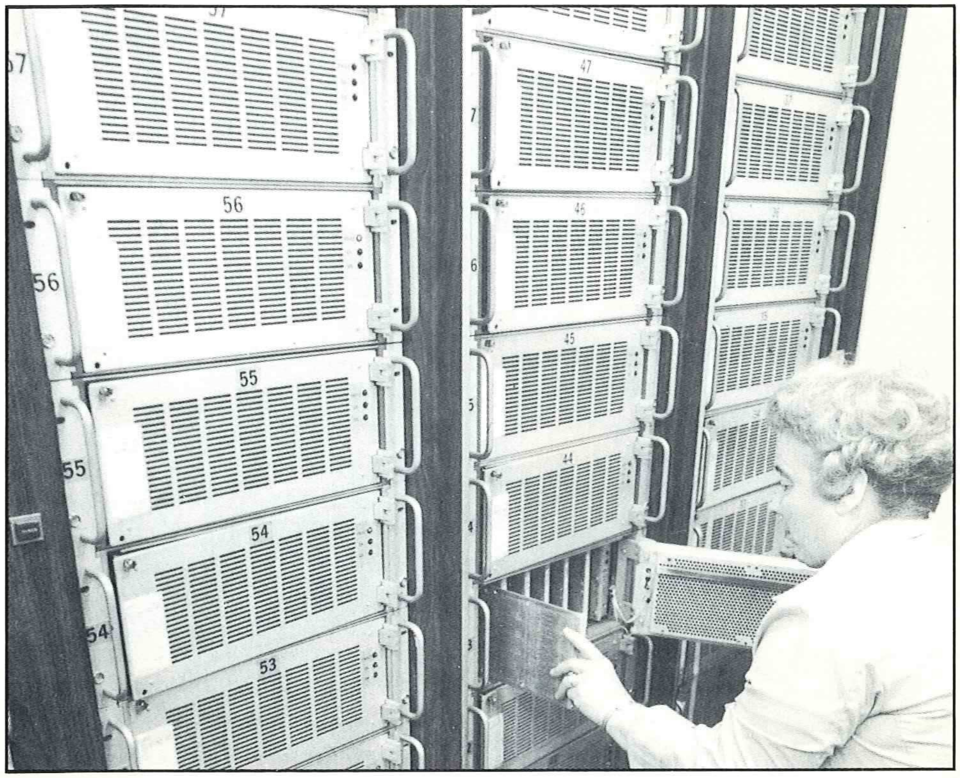


Fig. 2. One hundred percent burn-in of memories and other solid state components weeds out infant mortalities and marginal devices. Operator is loading components into the cycling rack.

Component reliability information

To realize maximum benefit from all of this component reliability activity, component information must be readily available to the design engineer and other interested parties. This is provided through personal consultation and by various internal publications.

A five-volume in-house parts catalog lists preferred parts, which have been determined to be acceptable for new design. Frequent updating keeps the catalog current. A companion publication, *Device Derating Guidelines,* provides further guidance in component selection. It includes stress and excursion limits, failure rate information, and derating notes. The information is derived from our own experience, manufacturers' notes and recommendations, and various reliability handbooks. MIL-HDBK-217B is referenced in much of the material.

A biweekly publication, *Component News,* keeps the engineering community up-to-date on new components, their application, and information on quality and reliability. *ManuFACTuring,* a monthly publication, facilitates communication among Tek manufacturing areas. It also serves as an informal liaison between engineering and manufacturing groups, with much of the content devoted to reliability. Other publications including application notes, designer's guides, and users' handbooks are published periodically. A selection of data books from outside vendors is also readily available.

Another source of information is a computer program called "RELY" available on our scientific computer.

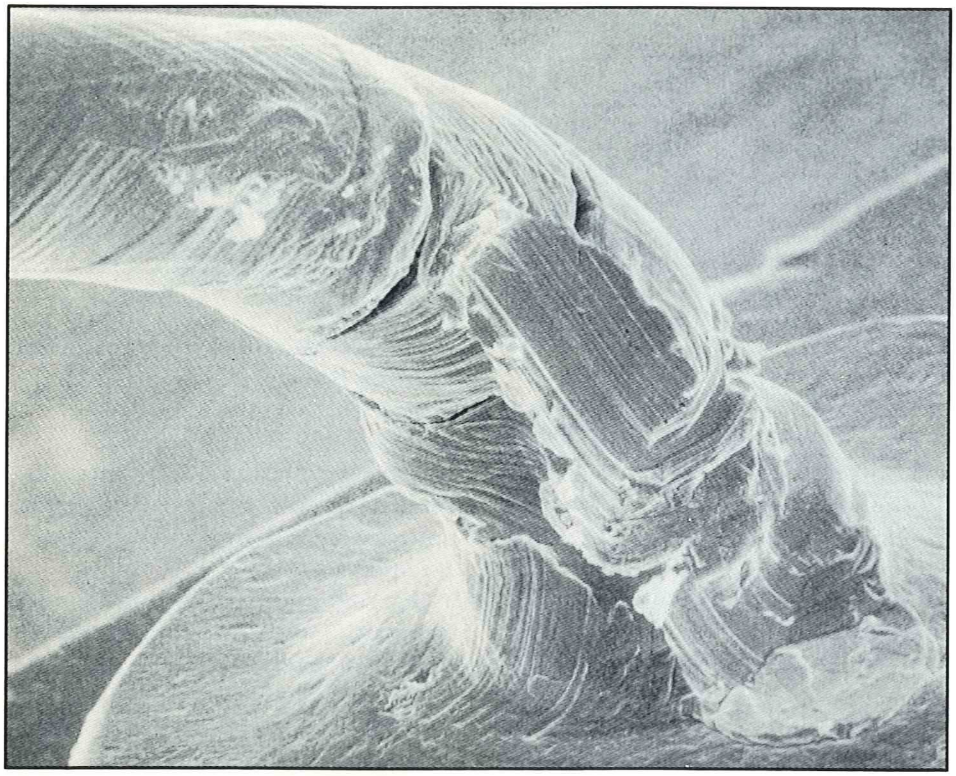


Fig. 3. The scanning electron microscope is a valuable tool for performing detailed analysis of semiconductor manufacturing processes. Source of a thermal intermittent is shown in this SEM photo revealing a cracked bond wire.

This program enables designers and evaluators to analyze the effect of parts population on reliability early in the design phase. The program, originally based on MIL-R-26474, has been updated to use MIL-HDBK-217B generic failure rates. It includes all applicable categories in 217B. Base failure rates for plastic encapsulated devices, which are not included in 217B, are derived from Tek field experience data. RELY is widely used to help us keep on target with respect to our reliability goals.

Product reliability engineering

Moving up from the component level, let's consider some of the programs and facilities devoted to product reliability. Tektronix uses a planned phase system of new product development and introduction.

By the time a design is completed, the reliability program for the new product must be established and a schedule for execution defined.

During prototype development, a number of units will be tested to ensure the reliability goal has been met. Once into production, routine reliability audit tests (usually 500 hours) are performed to verify the product meets expected quality and reliability levels.

Product reliability testing is the responsibility of the Product Reliability Engineering group. This group provides consultation in the setting of reliability goals and predictive analysis of reliability early in the design phase. It also establishes test procedures for verifying reliability. The procedures are designed around MIL-781 and are custom tailored to the product.

For example, a vibration test (usually 500 hours) is included for portables, to detect problems peculiar to their application. To accelerate life tests, instruments are cycled at elevated temperatures of 40° or 50°C. The group operates their own temperature-controlled test rooms and shake tables.

A well-equipped environmental laboratory and trained staff provide support to the engineering reliability group and others. Their capabilities and services are divided into three categories — the Dynamics Lab, Atmospherics Lab, and Electromagnetic Compatibility Lab.

As the name implies, the Dynamics Lab tests how well a product withstands physical abuse — shock, vibration, shipping, etc. Vibration tests are conducted over a range of 10 Hz to 55 Hz, or higher, with careful observation of components and mechanical structure. A "qualification shake" is included which consists of 75 minutes of swept and constant frequency vibration. This simulates operating and non-operating conditions experienced whenever the unit is wheeled on a cart or transported in a car trunk. A series of rotational drops simulate bench handling of the product. The product is then packaged for shipment and undergoes a vibration test simulating transit on a truck or cart. The packaging drop test calls for the product to be dropped on each corner, edge, and surface from a height of three feet for a total of 26 drops. Forces up to 60 "g's" are experienced in this test.

In the Atmospherics Lab the product is exposed to extremes of temperature, humidity, and other elements. Non-operating tests include exposure to a high of 125°C and a low of −65°C. Operating temperature tests are also conducted over a wide temperature range as called for

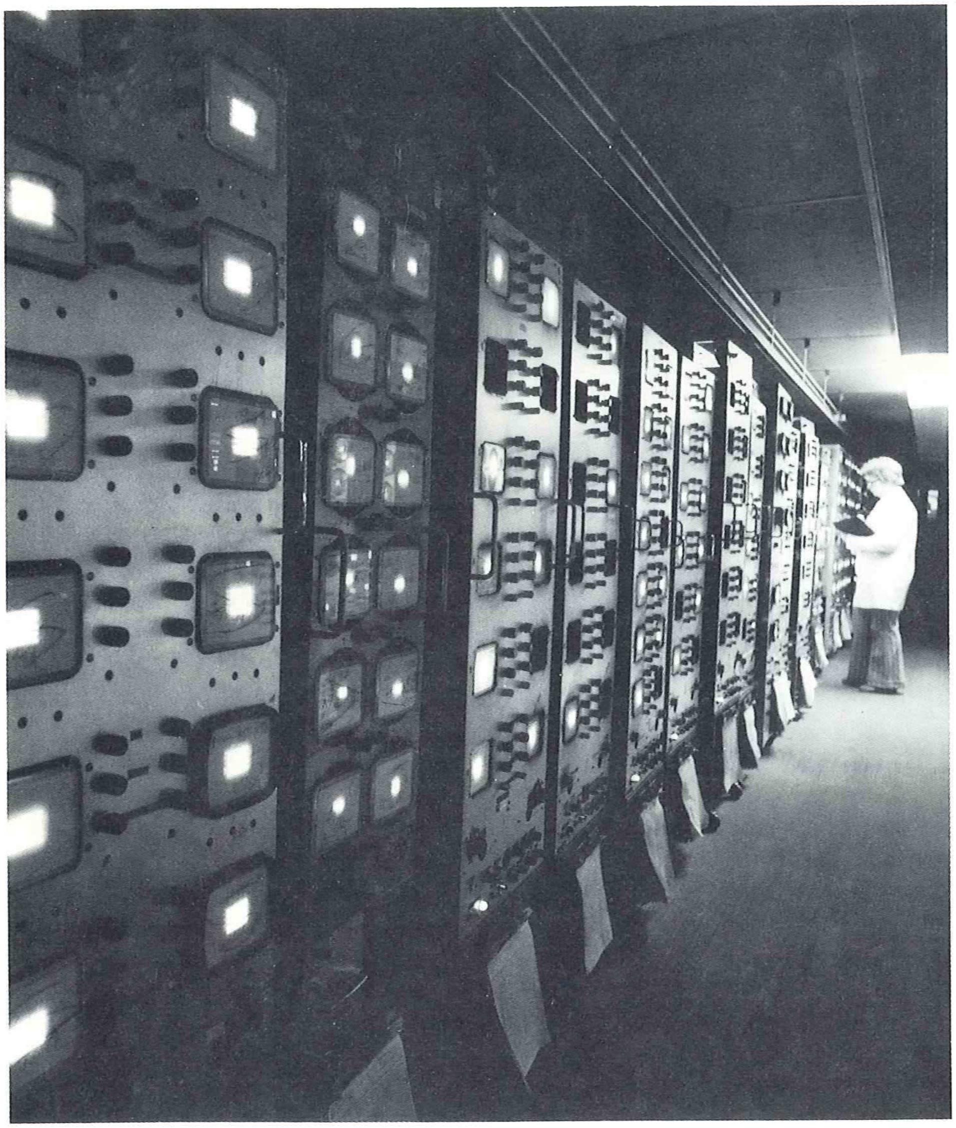


Fig. 4. Continuous life-cycle testing of cathode ray tubes ensures production units meet expected life times.

in the specification. Storage testing is performed at a 50,000 foot elevation to simulate transit in unpressurized aircraft freight compartments. The lab also performs salt spray, sulfide atmosphere, ultraviolet, flammability, and other tests.

In the Electromagnetics Lab the product is checked for electromagnetic emanations, either radiated or conducted, and for its susceptibility to such signals. Electrostatic discharge testing is also performed to measure both the charge build-up on the instrument and the effects of external discharges on its operation. The group also performs X-radiation tests.

Reliability feedback

With all of the foregoing materials, components, and finished goods tests, the ultimate test of reliability is the product's performance for the customer. How do we measure that performance?

A nationwide network of Tektronix service centers return all defective warranty parts with a report which gives the instrument type, serial number, circuit symbol, part number, and description of the part. The returned part is tested and then analyzed by the Component Reliability Engineering group discussed previously.

Failure data is recorded by the Reliability Information Services group. Failure information is gathered from many sources worldwide — Reliability Lab tests, manufacturing plants, Incoming Inspection, and manufacturing quality audits.

Warranty failure data, along with production data, is computerized and made available to top management and others on a routine basis. Data is supplied in several formats making it readily apparent when a problem exists with a particular production run, a part, or an application of a part.

A side benefit of this activity is the ability to determine parts inventories for field service centers. This improves the service centers' ability to stock the right parts for warranty repairs.

The reliability structure

Thus far we have discussed programs and facilities, but little about the people involved in reliability.

There is a high level of interest in reliability at the corporate level. A Corporate Reliability Committee provides visibility and coordination of quality and reliability activities across the entire product line.

Reports from the Reliability Information group showing the performance of each product line and a comparison of product lines are reviewed and discussed by the corporate group.

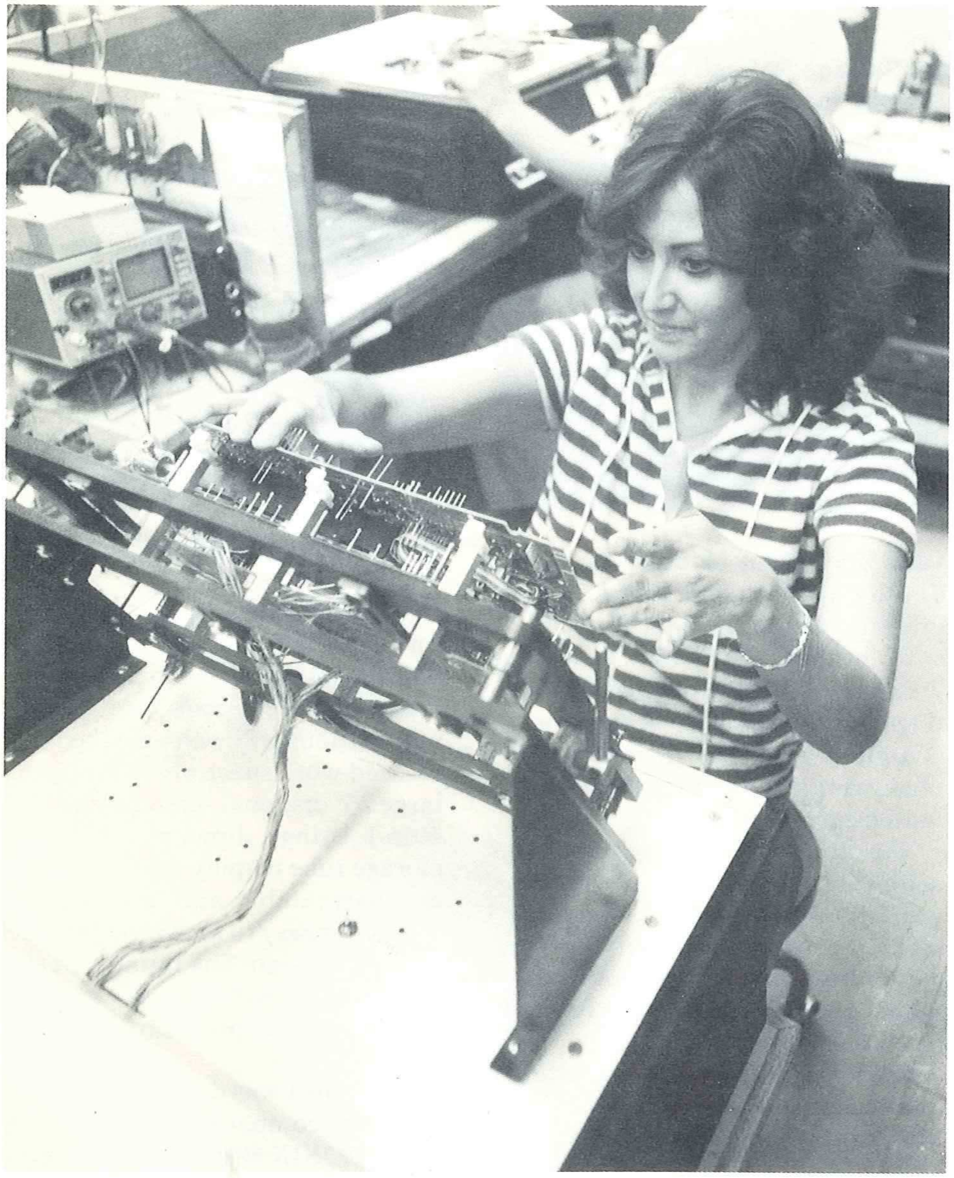


Fig. 5. Thorough testing of printed circuit boards before installation in final assembly is an important step in the reliability process.

A subcommittee, Reliability Engineering Sub-Committee Unit (RESCU), consisting of reliability specialists from the business units, make up a smaller, working group which identifies and resolves interdivisional problems.

A corporate quality audit group also randomly selects products from finished goods inventory and performs critical examinations. Included is a 500-hour accelerated life test.

In general, the reliability engineer has the responsibility for the reliability program for a particular product line. These specialists help designers develop new products to meet desired reliability goals. They also can, and have, put a hold on production of a new product until the reliability goal set for that product has been met.

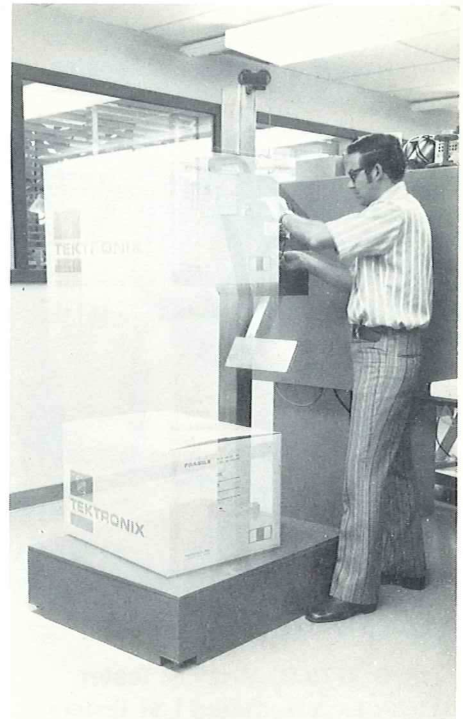


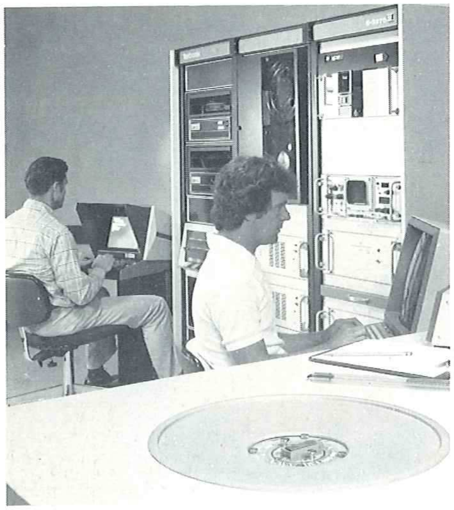
Fig. 6. A unit undergoes drop test to ensure packaging will prevent damage to instrument during transit.

Summary

With all of the activity devoted to reliability, one would expect every instrument shipped by Tektronix to perform perfectly for the entire warranty period and well beyond. Most do. But there are exceptions. A host of people at Tektronix are dedicated to making those exceptions a rarity.

New Products

Two New Automated LSI Testers

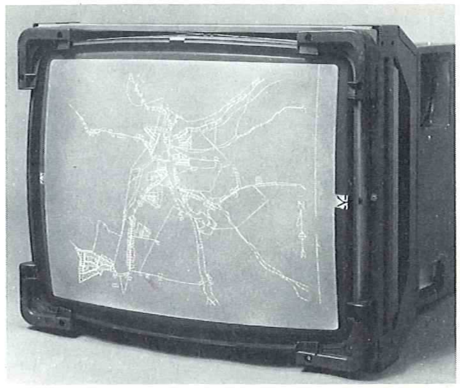


The S-3270 20 MHz LSI Tester

Two new automated LSI Testers have been added to the TEKTRONIX S-3200 Series. The S-3270 represents the state-of-the-art in device characterization while the S-3250 makes the proven capabilities of the S-3200 Series available in a medium cost, high performance production and incoming inspection test system.

Both machines offer a number of high performance features. Twenty megahertz operation permits testing the newer LSI devices at their full operating speed. A local memory of 4K of RAM per pin (shift register) is standard, and an additional 4K of RAM is available as an option. A seven-phase clock is standard, with 14 phases optional. Return to inhibit (RI) driver format for high speed I/O bus testing is included. Other driver formats included are non-return to zero (NRZ), return to zero (RZ), return to one, and return to complement. Operating software language is the device-oriented TEKTEST III, field proven on the S-3260. An extensive library of routines for reducing test data is also available.

25″ Storage/Refresh Graphics Display for OEM Market



GMA 125 Display Module

The GMA 125 is a high speed, 25-inch graphics display designed specifically for the OEM market. Featuring 70% more display area than 19 inch displays, the GMA 125 is ideal for computer-aided design and manufacturing, publishing, and automated cartography.

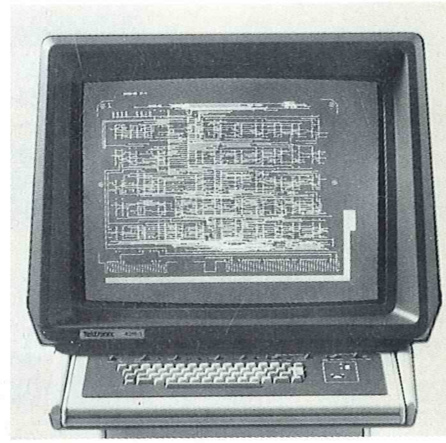
The direct-view-storage tube achieves high-quality, high-density graphics at low cost. And the substantial refresh (write-through) capability provides interactivity which greatly enhances the versatility of the system.

A full range of options, including analog and digital interfaces, minimizes the time needed for the OEM to electronically integrate the display into his product.

The high-efficiency, switching-type power supply reduces power consumption and weight. It also provides inherent compatibility with 220 volt, 50 hertz power source for international applications.

The GMA 125 chassis is a symmetrical structure so the entire unit can be rotated if a designer needs a long axis vertical format. It also can be mounted with any degree of tilt.

The 4010 Series Adds 25″ Graphics Capability.



4016-1 Computer Display Terminal

The designers of electronic circuit boards, utility networks, schematic diagrams, street maps, and similar applications will welcome the increased work space provided by the large 25″ diagonal screen of the 4016-1. Using a direct view bistable storage tube display, graphic lines are sharp, stable, and non-flickering making it easy to study the finer details of a design. The thumbwheel-controlled crosshair cursor makes it easy to interact precisely with this detail.

The 4016-1 was designed for complete compatibility with TEKTRONIX 4010-1 application software, communication support, and other Tektronix peripheral devices commonly used with the 4010 Series of terminals.

The 4016-1 includes a convenient detachable keyboard and detachable display.

A variety of hardware enhancements are also standard on the 4016-1. They include hardware generated solid, dashed, and dotted lines, point plotting with software-controllable point size, incremental "relative graphics" plotting, and four hardware character formats.

11/78 AX-4095

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