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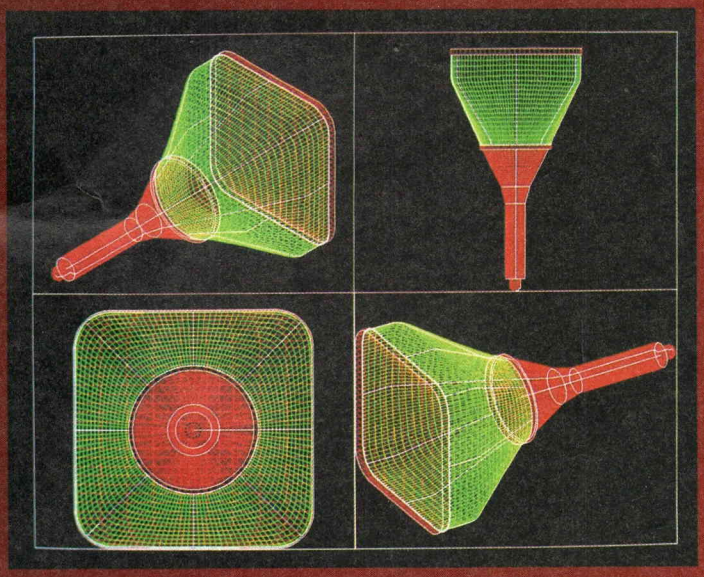
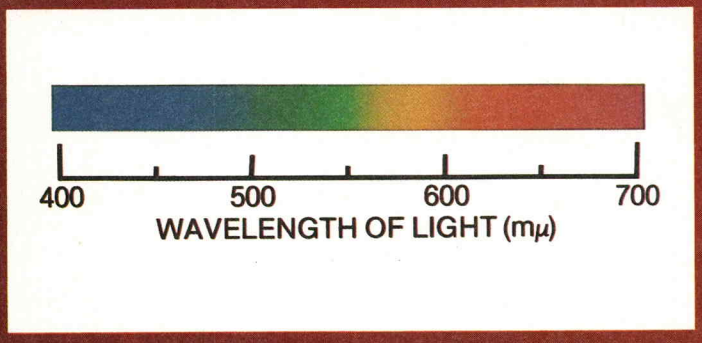
VOL. 8 NO. 2
SUMMER 1984

Tekniques

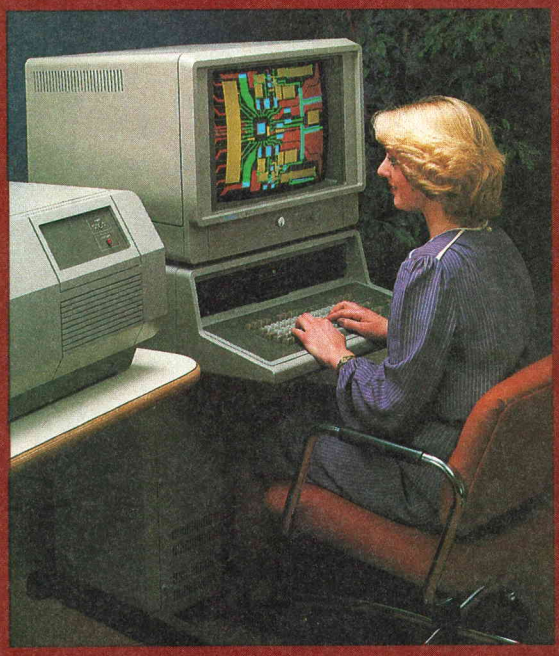


4115B Enhancements: 3-D, Pop-Up Menus, Window Management, Segment Subroutines

Local Programmability: A Comprehensive Review



Color: The Third of Three Articles on Combining Color for Effective Displays



Tektronix®
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Tekniques

In This Issue

Special Features

4100 Series

4110 Series

41XX Local Programmability

4050 Series

Peripherals

TEKniques, the IDG Applications Newsletter, is published in the Information Display Group of Tektronix, Inc., Mail Stop 63-635, P.O. Box 1000, Wilsonville, Oregon 97070. It is distributed to TEKTRONIX computer and terminal users.

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To submit articles to *TEKniques* or for information on reprinting articles, write to the above address. Changes of address should be sent to the IDG Program Exchange serving your area (see Program Exchange addresses).

*Editor's Note:

New Managing Editor for *TEKniques*

It might be called the seven year itch for after that length of time as managing editor of *TEKniques,* I feel it's time to move along. Thank you all for your support. Your applications, programming tips and suggestions have made *TEKniques* the success it is. (I'm not leaving Tek, just moving to the 411X Graphics Terminals Series as a manuals writer.)

Patricia Kelley

Indexes

Indexes for past issues of *TEKniques* may be found as follows:

Volumes 5, 6, 7 – *TEKniques* Vol. 8 No. 1
Volume 4 – *TEKniques* Vol. 4 No. 8
Volume 3 – *TEKniques* Vol. 4 No. 1
Volume 2 – *TEKniques* Vol. 3 No. 1
Volume 1 – *TEKniques* Vol. 2 No. 1

Keep User Library Catalog

The catalog of program abstracts for the user's library (now the IDG Program Exchange, formerly the Applications Library and 4050 Series Applications Library) should be retained. As descriptions of programs contributed to the library are printed in the *New Abstracts* section of *TEKniques,* clip these pages and add them to your catalog binder. You'll have an up-to-date reference of user programs available.

Although the abstracts are added to the catalog at each reprinting, there is no set reprint schedule, and the new catalog copies are only sent to new subscribers or current users who haven't received one. If you don't have a copy of the catalog, contact your local Tektronix office.

IDG Program Exchange

For each program accepted into the Program Exchange, you receive one of the packages in exchange. Remember that each package is comprised of from six to over 20 programs.

Readers who wish to contribute to the IDG Program Exchange for Tektronix Graphics Systems may acquire documentation instructions and forms by writing to:

Tektronix, Inc.
IDG Program Exchange
Mail Stop 63-575
P.O. Box 1000
Wilsonville, OR 97070

Back Issues

Back issues of *TEKniques* Vol. 4 through the current issue are available by writing to the address noted under IDG Program Exchange or contacting your local Tektronix office. Although issues from Vol. 1 through 4 are out of print, the Programming Tips for the 4050 Desktop Computer in those issues are compiled in a booklet which is included in the IDG Program Exchange package "Programming Aids T2," part number 062-5972-01.

Beginning with *TEKniques* Vol. 6 No. 3 (Fall, 1982) coverage was expanded to include all of Tektronix IDG graphics displays, not just the 4050 Series.

On the cover:

The Tektronix 4115F58 3-D Wireframe Kit gives the 4115B Color Graphics Terminal a 3-D wireframe capability in addition to its current 2-D feature set. Between 12,000 and 30,000 polygons in the mixture of triangles, meshes and strips, and up to 60,000 vectors can be stored locally for increased performance. Most 3-D transforms a user will likely ever need are available including rotation, scaling, clipping and skewing.

With Local Programmability, you enjoy the independence of a standalone computer. This issue reviews the functions of the software modules in the Local Programmability package, and their relationships to one another.

Identifying how we think to guide color use is the topic of the third and final article in the series on the effective use of color.

Tektronix Local Programmability: For Casual User or Experienced Programmer

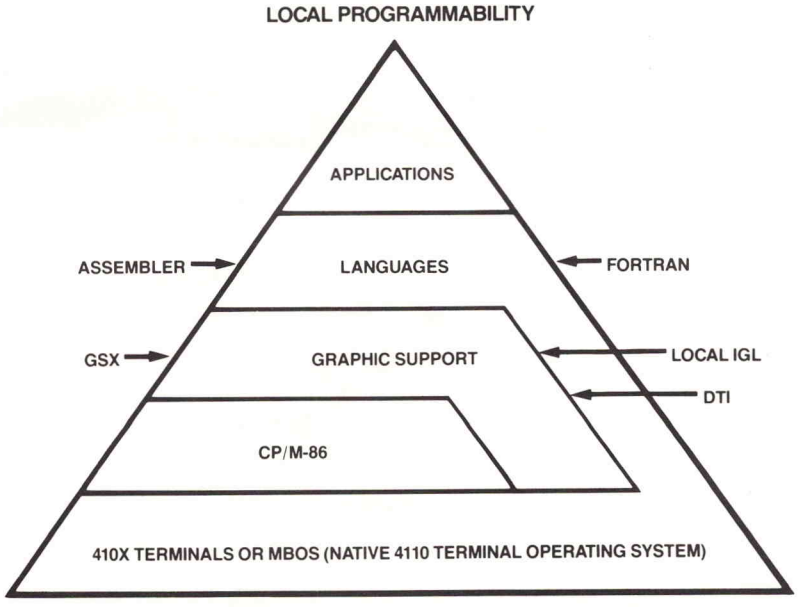
Previous issues of *TEKniques* discussed Local Programmability for Tektronix terminals.* Because of Local Programmability's expanding nature, however, a review of its elements and a closer look at some recent additions will bring you up to date.

Providing standalone processing for Tektronix 411X, 410X, and 4014 Terminals, Local Programmability comes in two flavors: as software for the B-Series of Tektronix

**TEKniques* Vol. 6 No. 4 – "4110 Local Programmability Brings Distributed Processing to Graphics Applications"

TEKniques Vol. 7 No. 1 – "4110A Local Programmability: A Closer Look"

TEKniques Vol. 7 No. 2 – "Local Programmability Extended to Tektronix Low-Cost Terminals"



INTERACTION OF LOCAL PROGRAMMABILITY SOFTWARE

A Quick Reference to Local Programmability Components

411X B-Series Terminals

Package #	Description	Manuf.
4100P01	CP/M-86 Operating System	DR
	and Utilities	DR/Tek
	ASM-86 Assembler	DR
	GSX Graphics Extension	DR
	DTI Library	Tek
	BDOS Library	Tek
	FORTRAN-86 Compiler & Utilities	Intel
	Program Exchange Utilities	Tek
4100P02	CP/M-86 Operating System	DR
	and Utilities	DR/Tek
	ASM-86 Assembler	DR
	GSX Graphics Extension	DR
	DTI Library	Tek
	BDOS Library	Tek
	ASM86 Assembler	Intel
	Program Exchange Utilities	Tek
4100P11 (add to 4100P02)	FORTRAN-86 Compiler & Utilities	Intel
4100P12 (add to 4100P01)	ASM86 Assembler	Intel
4100P73	Local PLOT 10 IGL	Tek
	Opt. 21	
	Opt. 24	
	Opt. 36	

410X and 4014 Terminals

Included with 4170 Graphics Processing Unit	Manuf.
CP/M-86 Operating System	DR
and Utilities	DR/Tek
ASM-86 Assembler	DR
GSX Graphics Extension	DR
DTI Library	Tek
BDOS Library	Tek
FORTRAN-86 Compiler & Utilities	Intel
Local PLOT 10 IGL	Tek
MODEM86	CP
Program Exchange Utilities	Tek
BIOS Source	Tek
Color Drawing Board	Tek
Optional:	
4100P12 ASM86 Assembler	Intel

Applications/Utility Software

Package #	Description	Manuf.
4100P22	SuperCalc^2 (raster terminals)	Sorcim
4100P24	InfoStar (raster terminals)	MP
4100P25	DR Graph (raster terminals)	DR
4100P27	WordStar (raster terminals)	MP
4100P30	TekniCAD (raster or DVST)	Tek
4100P72	Terminal Control System (TCS) (all terminals)	Tek

DR = Digital Research, Inc. CP = Compuview
Tek = Tektronix, Inc. MP = MicroPro International Corporation

411X Terminals or as a hardware/software combination for the Tektronix 410X and 4014 Terminals.

Why the difference? The 411XB Terminals, such as the 4114B and 4115B, already contain the disk devices, processors and interfacing necessary to support Local Programmability; consequently, they require software only. The 4105, 4106, 4107, 4109 and 4014 Terminals, however, must be equipped with the required hardware which is packaged in the Tektronix 4170 Graphics Processing Unit (GPU), shown in Figure 1, and which connects to these terminals through an RS-232 link. Included as part of the 4170 GPU package is a set of software tools.

Let's briefly review the tools implementing Local Programmability.

411X B-Series Terminals Local Programmability Components

Those individuals using Tektronix 411XB Terminals have a choice of two software packages which supply the elements necessary to develop and run programs locally. One package (4100P01) includes:

- CP/M-86® Operating System and Utilities
- ASM-86® Assembler
- GSX™ Graphics Extension
- DTI Library
- BDOS Library
- FORTRAN-86® Compiler and Utilities
- 4110 Program Exchange Utilities

The second package (4100P02) includes:

- CP/M-86 Operating System and Utilities
- ASM-86 Assembler
- GSX Graphics Extension
- DTI Library
- BDOS Library
- ASM86® Assembler
- 4110 Program Exchange Utilities

Users who choose the 4100P01 package may add the Intel ASM86 Macro Assembler by ordering package 4100P12; those who chose the 4100P02 package may add the FORTRAN-86 Compiler and Utilities through package 4100P11.

A local version of Tektronix's PLOT 10 Interactive Graphics Library (IGL) is also available under package 4100P73. Opt. 21 provides the Primary Command Set, Panel Support and Emulation, Fancy Text, Special Feature Escapes and Segments. Opt. 24 includes all functions in Opt. 21 plus Line Smoothing and 3D Graphics Support. Opt. 36 offers Line Smoothing and 3D Graphics Support to users who already have Opt. 21.

Local Programmability software for the 411X B-Series Terminals is supplied on 8" single-sided, double-density, soft-sector disks.

4170 GPU Local Programmability Components

When individuals using the Tektronix 4105, 4106, 4107, 4109 or 4014 Terminals desire Local Programmability, they order the 4170 Graphics Processing Unit which includes the following software:

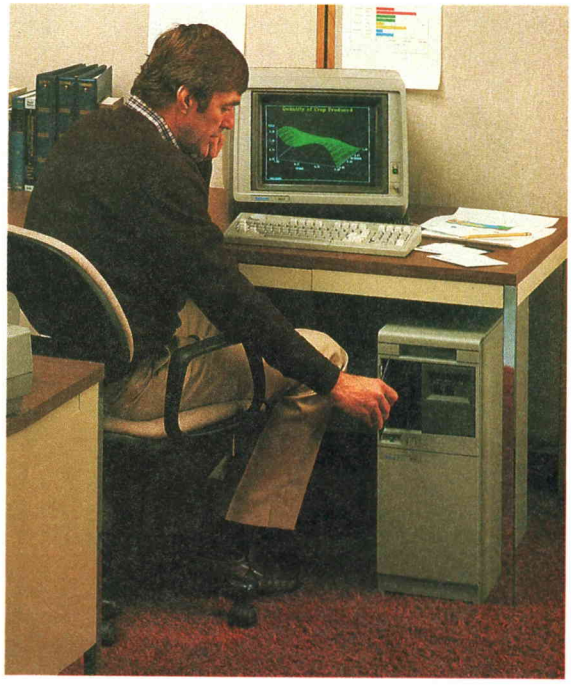
- CP/M-86 Operating System and Utilities
- ASM-86 Assembler
- GSX Graphics Extension
- DTI Library
- BDOS Library
- FORTRAN-86 Compiler and Utilities
- Local PLOT 10 IGL – Primary Command Set, Panel Support and Emulation
- MODEM86
- Program Exchange Utilities
- BIOS Source
- Color Drawing Board

Users may add the Intel ASM86 Macro Assembler by ordering package 4100P12.

Local Programmability software for the 4170 GPU is supplied on 5¼" double-sided, double-density, soft sector, 48 TPI disks.

Applications software available for Local programmability is subject to terminal/memory limitations, i.e., raster terminals only, or the minimum memory required for TekniCAD.

Tektronix Local Programmability is available for the 411XB Series Color Graphics Terminals, including the 4115B shown above, as a set of software.



Users who have 410X Terminals and desire Local Programmability, order the 4170 Graphics Processing Unit to provide them with the required hardware. The software is included.

Functions of Local Programmability Components

CP/M-86 and Utilities

An industry-standard 16-bit operating system, CP/M-86 manages the hardware resources to achieve good performance in a single-user, single-program environment. It loads programs and data into memory, making the best use of available RAM space; it manages the disk operations such as setting disk parameters, formatting a disk, reading and writing the disk, erasing disk files and so forth; and it directs other input/output operations including those associated with the terminal keyboard and screen, tablets, printers, etc.

CP/M-86 is written specifically for the Intel 8086 and 8088 microprocessors, but its structure allows it to run machine-independent programs, i.e., you can transport programs easily from one computer running CP/M-86 to another so long as the programs conform to the CP/M-86 operating system precepts. Because this concept is important to understand the versatility of Tektronix Local Programmability, we will take a moment to identify the structure of CP/M-86.

By separating CP/M-86 into an invariant portion and a variant portion, machine-independence is achieved. The invariant portion is the same regardless of the system on which CP/M-86 is installed. Software authors don't have to know anything about their specific hardware; instead they write their programs in terms of CP/M specifications and let CP/M-86 take care of the hardware-related details.

The variant portion of CP/M-86 is tailored specifically for the computer/terminal and peripherals on which it will be running.

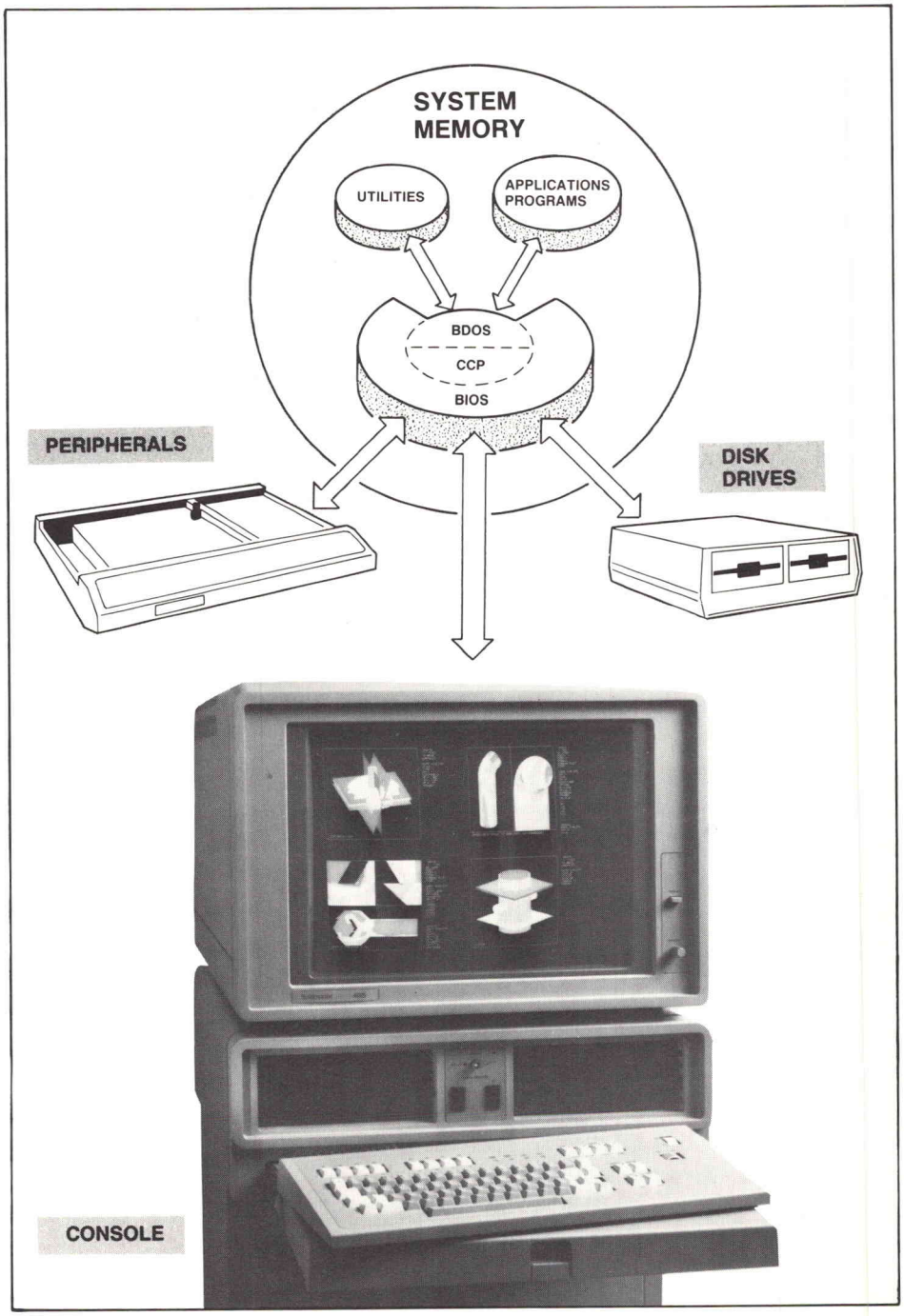
Let's look at how this is implemented. CP/M-86 consists of the Command Control Processor (CCP), Basic Disk Operating System (BDOS) and Basic Input/Output System (BIOS). The invariant parts of CP/M-86 are CCP and BDOS, and, thus, are machine-independent. The CCP interprets commands entered by the operator and issues responses. The CCP calls upon BDOS to perform file processing and direct input/output. BDOS figures out where the needed I/O subroutines are in BIOS, then calls upon them to perform the I/O handling.

Thus, it is the BIOS program segments that are used by the functions in BDOS to handle the actual transfer of data to disks, printers, keyboard, screen and any other physical device connected to the computer. Consequently, BIOS is the only part of CP/M that is modified for each specific computer. It is this split between machine-independent and machine-dependent routines that makes CP/M-86 one of the most portable operating systems in existence.

When you order the 4170 GPU, in addition to the CP/M-86 operating system you get several standard CP/M-86 utilities, and a number of supplemental utilities developed by Tektronix. These utilities facilitate program development, disk management, host communication, and many other tasks.

ASM-86 Assembler

The ASM-86 Assembler from Digital Research is small and fast, producing a machine-readable command file from your ASM-86 assembly language source file. This command file can be invoked by simply typing in its name on the keyboard. Programs developed in ASM-86 assembly language can be used to implement new commands for the CP/M-86 operating system. The ASM-86 Assembler can also be used to assemble CP/M-86 source programs written by other users or vendors.



The modular structure of the CP/M-86 Operating System permits programs to be easily transported from one computer/terminal to another.

FORTRAN-86 Compiler and Utilities

Designed specifically for the Intel 8086 microprocessor and 8087 co-processor, FORTRAN-86 conforms to FORTRAN-77 for minicomputers, with expansions which bring it close to FORTRAN-77 for host computers. FORTRAN-86 programs can directly output character data to a terminal and can call GSX, DTI or IGL routines (described later) to access the sophisticated 411XB and 410X Series graphics features.

The LINK86 utility combines separate object code modules into a single module. It accepts the modules as individual files or extracts them from libraries.

LIB86 will join a series of object modules into a library, will add and delete library modules and will generate a listing of the modules.

CREF86 provides a cross-reference among external and public symbols in multiple modules.

LOC86 changes a relocatable 8086 object module into an absolute object module which can be loaded and run, included in a library or converted to 8086 hexadecimal format by OH86.

ASM86 Assembler

Intel's ASM86 is a macro assembler that produces 8086 object code modules with 8087 instructions that are linkable to object modules produced by FORTRAN-86. Thus, you can write the more time-critical and space-critical routines in 8086/8087/8088 Macro Assembly Language and include them in your application program written mainly in FORTRAN.

BDOS.LIB

Some programmers will wish to access BDOS and BIOS functions directly from their application program. Of course assembly language programs can pass the selected function code and parameters in the appropriate registers, but a higher level of communication is possible through BDOS.LIB. The file BDOS.LIB contains many subroutines that may be used in FORTRAN programs to access operating system functions.

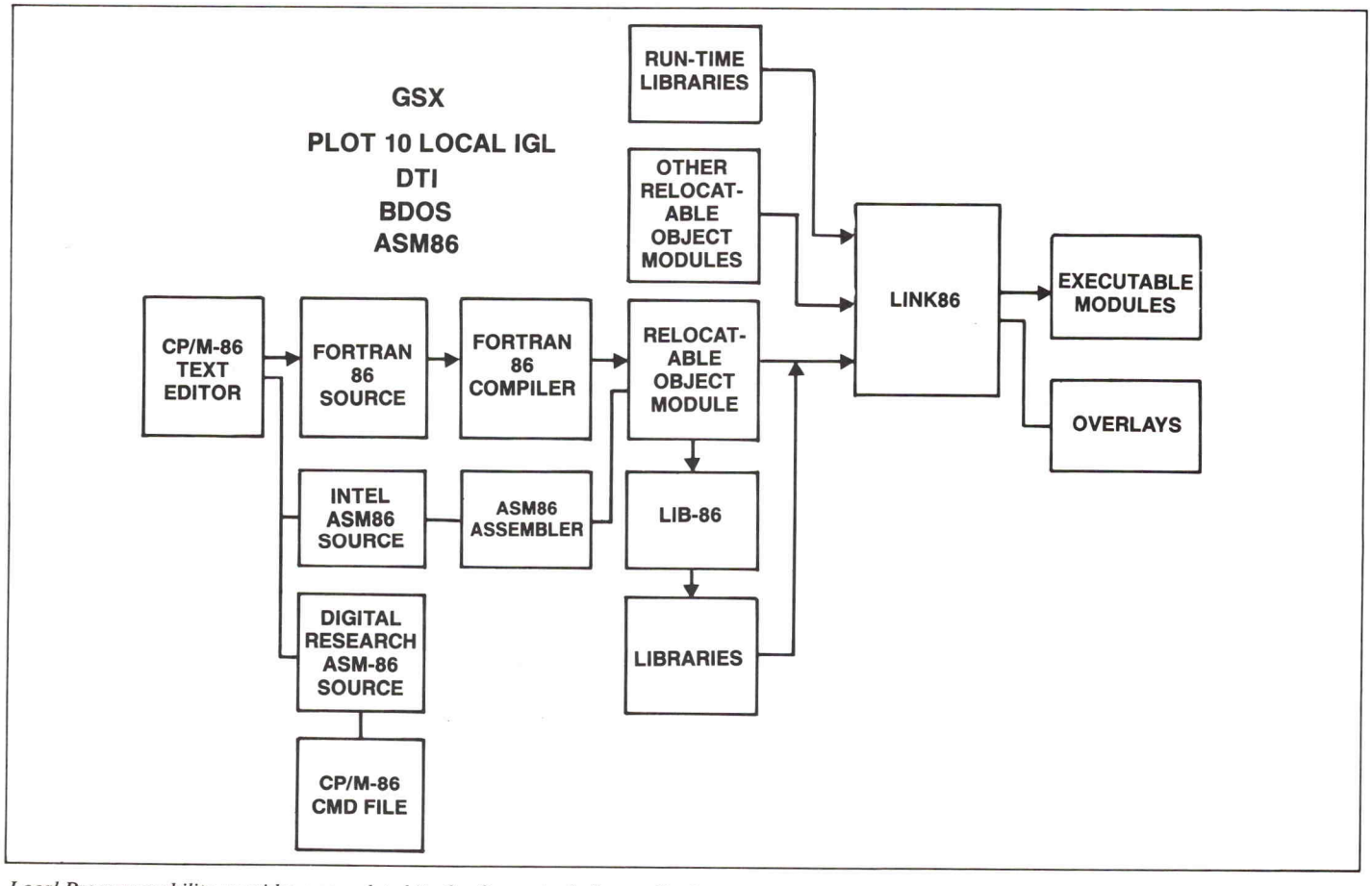
GSX Graphics Extension

All graphics devices are not alike. Terminals, printers and plotters produce text differently, draw lines differently and fill in areas differently. Graphics applications programs can work with GSX through a standard calling sequence. GSX translates these standard calls to fit the peculiarities of each graphics device and supplies the right program to run the device you are using.

GSX provides this device-independent software interface for your application program in a manner similar to the CP/M-86 operating system. It is split into two parts: the Graphics Device Operating System (GDOS) which is machine-independent, and the Graphics Input/Output System (GIOS) which is tailored for your particular hardware environment.

The default device driver is located in a special file called ASSIGN.SYS. When you enable GSX (by simply typing the command GRAPHICS, a file by that name containing the device driver routine is loaded and connected to the appropriate logical device of GSX. For example, suppose GSX opens ASSIGN.SYS and finds DD4115 as the first entry; it then locates the file called DD4115 and attaches the device driver contained in that file to the logical device of CONOUT. When graphics characters are sent through GSX to the terminal screen, GSX uses the 4115 device driver to display them.

Tektronix has added extensions to GIOS which improve performance of applications involving lots of text-editing and which sup-



Local Programmability provides a complete kit of software tools for applications programmers.

port the color features available in Tektronix terminals.

Local PLOT 10 IGL (Interactive Graphics Library)

Based on SIGGRAPH's proposed Core system of computer graphics standards, Local PLOT 10 IGL consists of a basic module – the Primary Command Set – which contains the fundamental routines needed to do graphics. Panel Support and Emulation serves as an interface for devices which have panel capability or it emulates panels. Selection of font, size, slant, color, and other text attributes are provided in Graphics Text Composer. Special Feature Escapes provide access to unique device-dependent features of Tektronix 4100 Series terminals including multiple views, zooming, inking, rubberbanding and so forth. Segments support routines permit easy interactive manipulation of local picture segments. Line smoothing facilitates drawing curved lines or creating text characters. Routines in 3D Graphics Support can be used to move, draw, and transform vectors in three-dimensional world space.

These FORTRAN-callable subroutines provide you with a rich set of graphics tools which interface directly with the terminal's features. Furthermore, the routines of Local PLOT 10 IGL are directly compatible with the host version of PLOT 10 IGL. You simply download your program source file, compile and link it to Local PLOT 10 IGL.

Or, you can also develop applications programs on the 4110B Series terminals or the 4170 GPU and upload them to the host-resident IGL and run the program from the host. Thus, using Local PLOT 10 IGL you can choose where an application can be run most efficiently – on the host, the terminal/4170 or a combination of the two – without modifying the applications program.

DTI

One of the key features of Local Programmability is that it provides convenient local access to the terminal-resident functions through the Direct Terminal Interface (DTI). A library of FORTRAN-callable subroutines that correspond directly to each of your terminal's functions, DTI enables you to exercise all terminal features from your applications program by calling the appropriate DTI subroutines.

Some of the significant graphics features which may be manipulated directly through DTI are picture segments, scrollable dialog area, panels, GIN, text and many others.

GSX/DTI/IGL

Which library of graphics routines should you use? GSX is recommended for applications that will be transported to non-Tektronix graphics devices for which a GSX device driver is available.

DTI supports the features of 41XX Terminals with a callable DTI routine for every 41XX Series Terminal command. For applications using Tektronix Terminals, DTI provides a direct path to the special features of the terminals, in a minimum amount of memory.

Local PLOT 10 IGL provides a device-independent set of subroutines that provide higher-level graphics functions than those of DTI and GSX, and thus requires more memory. IGL should be used when working with applications programs that require device and host independence. Applications which run IGL in the host environment can use IGL at the local level for compatibility. Tektronix device drivers are included in both host and local IGL.

MODEM86 (4170 GPU only)

(Functions similar to those described below for MODEM86 are implemented by the HOST utility for 411XB Local Programmability.)

The MODEM86 utility enables you to quickly and easily transfer data between the 4170 GPU and a host computer (including another 4170 GPU). Files may be transferred without error checking; no protocol is specified between the MODEM86 program and the host other than the host or 4170 should be ready to receive data.

For communications between a 4170 and another system running MODEM86 or between a 4170 and a system running a MODEM86-compatible program, such as XMODEM, a special protocol may be used to ensure error-free file transfer. This is a convenient way to access the public domain CP/M-86 programs available through users groups.

Other features in MODEM86 include dialing/redialing intelligent modems, autologon, and so forth.

Program Exchange Utilities

Included with Local Programmability is a collection of programs contributed by Tektronix engineers. Although these programs are not supported by Tektronix, they contain a number of useful utilities including text editors, a CP/M-86 assembler post-processor, programming aids, file copiers, quick batching, date and time, and a special memory pseudo disk drive (the latter is available through the IDG Program Exchange for the 4170).

BIOS Source (4170 GPU only)

As you will recall, the BIOS segment of CP/M-86 is hardware-dependent. This means Tektronix engineers have implemented code within the BIOS to drive Tektronix graphics terminals, disks, plotters, etc. To aid knowledgeable programmers who may wish to tailor the BIOS to a particular need, Tektronix provides its BIOS source code. Because the code is clean and reliable, it is a useful model for designing new device interfaces.

More Information

Most of the above topics were covered in the three issues of *TEKniques* referenced earlier. You will probably wish to review those issues for more information.

Applications Software

Tektronix supplies several applications software packages for locally programmable Tektronix terminals. Three of these packages were reviewed in *TEKniques* Vol. 7 No. 4:

PLOT 10 Computer-Aided Drafting provides standalone drafting for a very low cost on the 411XB and 410X terminals equipped with Local Programmability.

SuperCalc² is an advanced electronic spreadsheet package available on the 411XB raster terminals and the 4170 GPU.

WordStar brings dedicated word processing to Tektronix raster terminals equipped with Local Programmability.

With the addition of DR Graph and InfoStar, the data interchange facility (described in separate articles), the separate software packages provide a total performance greater than any integrated package available today for microcomputers.

Utility Software

Long the standard in graphics software, the PLOT 10 Terminal Control System (TCS) is the basis for many of the graphics applications available today. A composite of FORTRAN IV subroutines linked through a set of common variables, TCS provides the applications programmer with fundamental tools for developing a wide range of graphics displays. Simple business graphs and forecast diagrams or complex architectural renderings can be generated using TCS.

For host-based applications previously developed using PLOT 10 TCS, Local PLOT 10 TCS provides the opportunity for them to move into a high speed, large memory 41XX Series Graphics Terminal or 4170. Large host time-shared systems can benefit from the instant response time of locally implemented TCS applications.

Advantages of Tektronix-Supplied Applications Software

Why should you buy WordStar or other third

party software from Tektronix instead of your local computing store? For the same cost (i.e., manufacturer's recommended end-user price) special installation work has been done for you by Tek, saving you many hours to achieve the same thing. By purchasing from Tek, you also have Tek's software support.

Although a package will run on Tektronix Local Programmability if it is CP/M-86 and VT100* compatible, you lose the advantage of Tektronix color graphics terminals because VT100 mode is monochrome. Depending on the INSTALL program supplied by the manufacturer, you could possibly tailor the package to take advantage of your terminal's features through a question and answer session, but it would take some time.

Tek includes with each applications package a file which tailors the advanced features of the Tektronix terminal you are using to the functions of the application. It takes five to 10 seconds!

For example, in addition to using the TAB key to move from column to column or row to row in DR Graph, you can use the joy disk or function keys of the terminal to control the cursor. They have been automatically programmed for you.

You also receive a supplemental instruction manual prepared by Tektronix for each package which is system-specific. For the inexperienced user, it provides step-by-step directions to load the operating system, format new disks, back up the originals and configure the terminal before running the application package. Users who are familiar with CP/M-86 and who have a configured system can jump directly to the section which gives explicit instructions for running the package.

Tektronix has also included a tutorial on the disk which explains features and commands of the package/terminal configuration in an easy-to-understand manner.

Because the package/terminal tailoring has been done through the interface to the CP/M-86 BIOS section, the package hasn't been changed. You still have your original CP/M-86 compatible program, portable to other systems, but tailored for your Tektronix terminal at no extra cost or time invested by you.

Running Other CP/M-86 Compatible Software

A decided advantage to having the CP/M-86 operating system in your locally programmable Tektronix terminal is the wide variety of software available.

If authors of the programs maintain the device-independent structure within their packages, you should be able to run them on your system. Questons to ask the supplier of the software to ensure compatibility are:

- Can I get the program on compatible media in CP/M-86 format?

  All 8" disks are standardized, so if it is in standard IBM 3740 CP/M-86 format, it will load into Tektronix B-Series Local Programmability.

  The 5¼" disks, however, are not standardized. But if the program disk is formatted for the IBM PC running CP/M-86, it will load into the 4170 GPU. The program itself must use only CP/M-86 features and not IBM PC-specific features.

- Does the program support an industry-standard terminal such as the Digital Equipment Corporation VT100?

  If it does, the installation program configures the operating system to that terminal. Since Tektronix 411X and 410X terminals have a VT100 emulation mode, the software should run under Local Programmability.

- If the program performs graphics operations, check to see that it uses the GSX Graphics Extension.

Summary

As you can see, for the first-time computer user or the experienced programmer, Local Programmability provides a complete kit of software tools.

If you are a casual user, you can load the operating system, then run your application package such as DR Graph or InfoStar and simply follow the menus and prompts.

For applications programmers, the FORTRAN-86 compiler and utilities coupled with the two Assemblers available provide a wide flexibility. And the routines contained in BDOS, IGL, GSX and DTI permit a choice of paths to terminal functions.

System programmers can integrate their Tektronix terminals into their specific environment, tailoring the operating system and device drivers as their requirements dictate.

*VT100 is a registered trademark of Digital Equipment Corporation and identifies a popular alphanumeric terminal.

Compatibility Among Tektronix Locally Programmable Terminals

For the most part, programs written in FORTRAN-86 using GSX, IGL, or DTI are *upwardly* compatible with some obvious limitations, e.g., raster terminal functions which must be simulated or ignored on DVST terminals.

When IGL is used as the graphics interface, the routines call on device drivers to implement a function. The Tektronix drivers will call on the terminal's firmware if the function is resident, or will simulate it, e.g., panel fill on a DVST terminal, or ignore it.

Because the graphics device drivers which support the GSX interface must implement a defined set of graphics primitives, portability among graphics devices is guaranteed. However, the graphics functions possible are limited and, consequently, GSX doesn't take full advantage of Tektronix terminal capabilities.

The principal difference between 4170 DTI and 4110 DTI routines is in GIN reports and terminal status and settings reports. And, because of the differences in terminal features, certain routines may not be present or may cause undesirable results during execution. A table included in the 4170 instruction manual details the DTI compatibility among the terminals. By determining on which terminal Local Programmability is running by invoking the terminal report function, the applications programmer can avoid using graphics routines that the target terminal cannot support.

Data Interchange

An extremely powerful aspect of the four business packages supplied by Tektronix – WordStar, SuperCalc^2, InfoStar and DR Graph – is their ability to exchange data with one another. It is the "glue" that allows this set of packages to provide a total performance greater than any integrated package available today for microcomputers.

MicroPro has designed all of its programs so they can combine forces and accomplish a wide variety of practical tasks. Thus, data files produced by InfoStar may be accessed directly by WordStar. And, in the non-document mode, WordStar can produce and edit printable ASCII text files in nearly any format. Using this facility WordStar can access printable data files generated by SuperCalc^2.

Sorcim offers a utility program (SDI) that allows interchange of data files with the products of other vendors. By running data produced by SuperCalc^2 through SDI, InfoStar and DR Graph can use it.

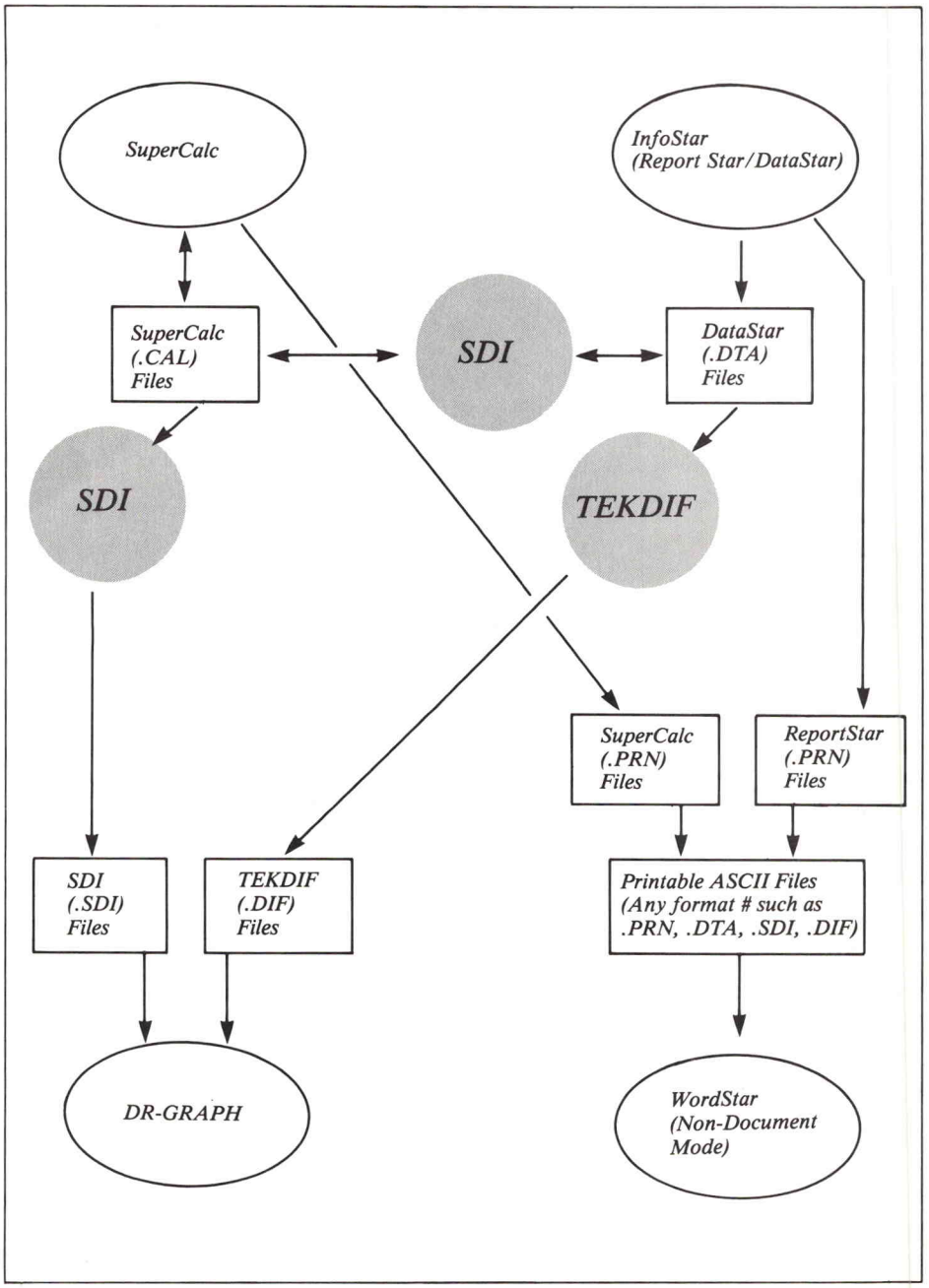
To enable smooth interchange of data from InfoStar to DR Graph, Tektronix has supplied the TEKDIF program.

The entire procedure takes very little time. Simply call in the SDI file or the TEKDIF file and follow the prompts. Once you have selected your formats, the source file and the target file, the process begins without further intervention on your part.

The simplicity of the conversion belies its power. Let's take a look at an example of these packages working together.

Create your financial model using SuperCalc^2 and save it. Invoke SDI and select the format compatible with DR Graph. Create one or more graphs using the data from the converted file.

Or use the SuperCalc^2 data, run it through SDI, selecting the format compatible with InfoStar. This data may now be entered into your database management file, used by ReportStar and sent to WordStar.



Applications programs are shown by ellipses, while the information files that they produce or use are shown as rectangles. The two programs shown in tinted circles, SDI and TEKDIF, are utility programs used to convert one file format into another. The arrows show how files are produced by or used as input by the programs. For a program to use a file that it did not generate, the file must either be in a format that the program can accept, or be converted to usable form by a utility program.

DR Graph

A powerful member of Tektronix-supplied business applications software for the locally programmable 411XB raster terminals and the 4170 GPU-410X raster terminals, is DR Graph. This new graphing package allows you to create all the commonly needed business graphs.

Because DR Graph is menu-driven, a first-time user can actually create a graph in just a few minutes without referring to the manual. DR Graph leads you through each step by providing either a list of options or a form to fill out. While it initially makes many of the graph's design decisions, such as line type and text size, it allows you to easily change these defaults.

You can create or edit a line, bar, pie, step, stick, or scatter graph and DR Graph will automatically plot the data points. DR Graph also supports text-only graphs allowing you to select text placement, font, color and size. You can combine as many as four graphs on a page specifying their order and layout.

By integrating advanced terminal features into DR Graph, Tektronix has enhanced the friendly user interface. For instance, if you have a 410X terminal and 4170 GPU, you may use the joydisk to move freely around forms or menus while entering data. Or if you are a touch typist you may prefer to use the tab key, line feed key, space bar or return key for data entry.

Tektronix's integration of DR Graph extends to full support of Tektronix hard copy devices. Copy can be created on either plotters or ink jet copiers which can produce copies on either paper or transparencies.

All the device specific routines have been installed in GSX G10S which is called by the GDOS section of GSX.* Thus, the integrity of the device independence of DR Graph is maintained.

*See separate Local Programmability article detailing how GSX interacts with application programs.

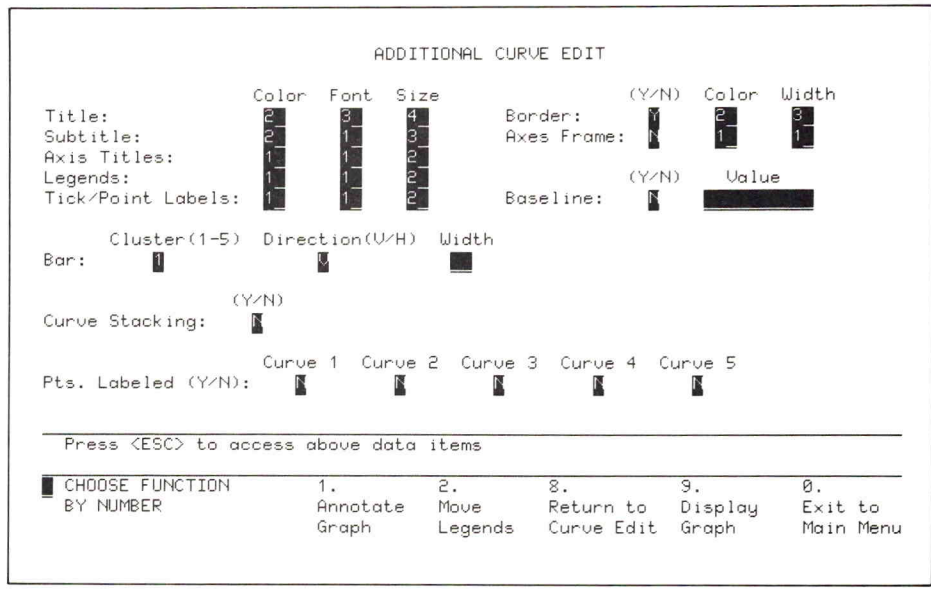


Figure 1. DR Graph's friendly user interface prompts you for your input through a form fillout mode or menu selection. Shown is the second "page" of a two-page curve edit menu in DR Graph. The shaded areas are the fields of the form which hold the current selections for the various curve attributes. To access and change the attributes, note that you would first press the ESC key. Then pressing the joy disk (or alternatively, keyboard keys), you can move to the various fields on the form, entering new data as you go. Pressing the ESC key again would return you to the lower menu.

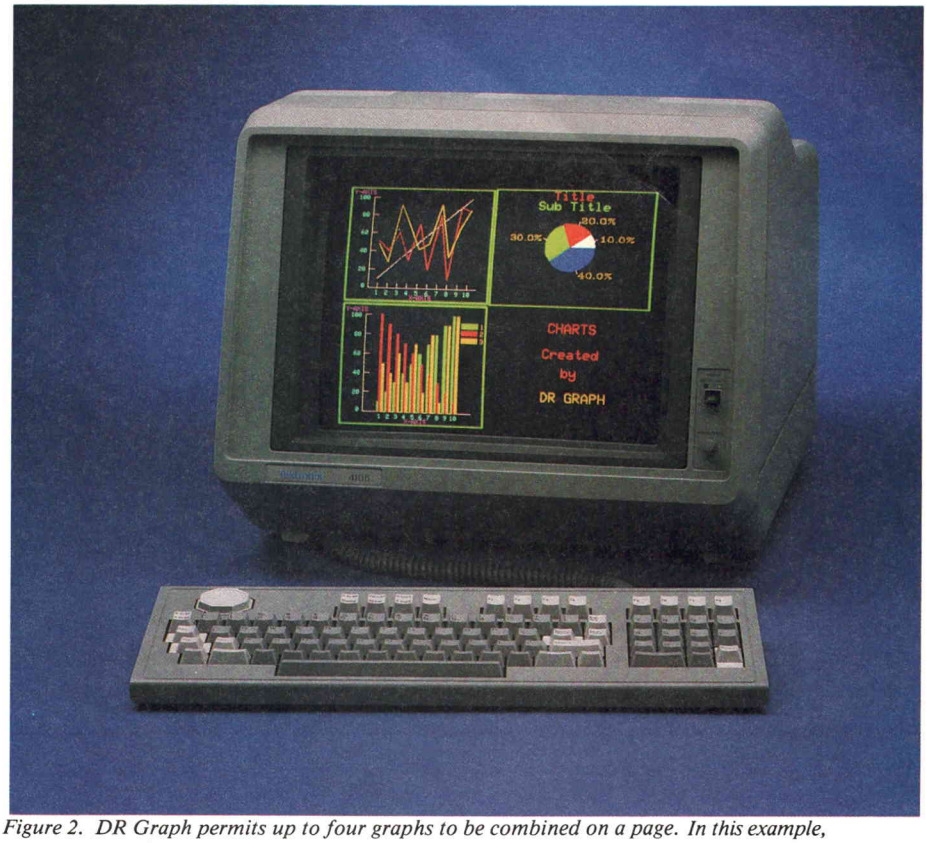


Figure 2. DR Graph permits up to four graphs to be combined on a page. In this example, text, pie chart, line, and bar with line graphs have been collected into one display.

InfoStar

Both casual users and applications developers will appreciate InfoStar. Using this package with your Tektronix locally programmable raster terminal, you can construct a database management system tailored to your needs. From job scheduling to hotel reservations to construction job costing, most any data processing chore can be handled by InfoStar.

Because InfoStar is menu driven, it allows you to manipulate data without learning a database language. Its different levels of help provide extensive help messages or only reminders.

The modular structure of InfoStar permits you to load and invoke only the programs necessary for a particular database management task. We'll take a look at these modules beginning with the first step in constructing a database through final report generation.

Forms Design

Within InfoStar, the forms design, data entry and retrieval, and file maintenance portions are located in a module called DataStar. DataStar is further segregated into FORMGEN and DATASTAR.

Using FORMGEN, you design the forms you will need for later data entry. Forms up to 254 characters wide by 255 lines long may be designed. Forms larger than the screen are scrolled from side to side or up and down through cursor control.

As you specify your datafields (the spaces to be filled out on the form) and label them, you can attach special attributes to the fields. These attributes control the sequence of data entry on the form, highlight certain fields, prevent the entry of incorrect or omission of required information on the form, format data entered and so forth. Up to 25 fields may be used as keys for record searching and manipulation.

When defining the datafields on your form, you may stipulate that the datafield information is to be constant, is to be calculated from data entered in other fields (e.g., totals of field 4 and field 5), or both. Datafields also may be derived by reading values from a separate reference datafile (also created in DataStar), for instance, tax information, salary rates, customer names, etc.

Once your form is complete and stored, it can be moved to DATASTAR for data entry. During the data entry task, the form may not be altered. Thus, one person can design the form and another can enter the data.

Data Entry/Retrieval

After entering the DATASTAR module, you can key in data on your displayed form and verify each record as it's entered, or you can enter data in "batch" mode, which stores each record without pausing for verification. Later you can retrieve the batched records and verify them.

Commands in either mode permit you to control your cursor, insert or delete characters, jump from field to field, copy from a previous record, or send the record on the screen to a printer.

DATASTAR also contains the programs to retrieve data and maintain your disk files. You can select a specific record by choosing the key field specified when you designed your form, or select records through scanning. The scanning method permits you to retrieve all the records in a datafile, or retrieve by certain fields, e.g., everyone who resides in Oregon or everyone who purchased cement in June of 1982. These methods can be toggled back and forth.

Records may be modified, deleted or printed when they are retrieved.

Report Generation

Contained within the ReportStar module are all the routines necessary to access the raw data stored by DataStar and display it in meaningful reports. Other features of ReportStar make it more than a report generator.

Quick Report

Within a minute or two a simple report can be composed and displayed. Using defaults, the Quick Report feature makes most of the decisions about the report's format, retrieves your data and displays it. Because you are permitted to edit it, Quick Report is useful as a building block for more customized reports.

Report Design

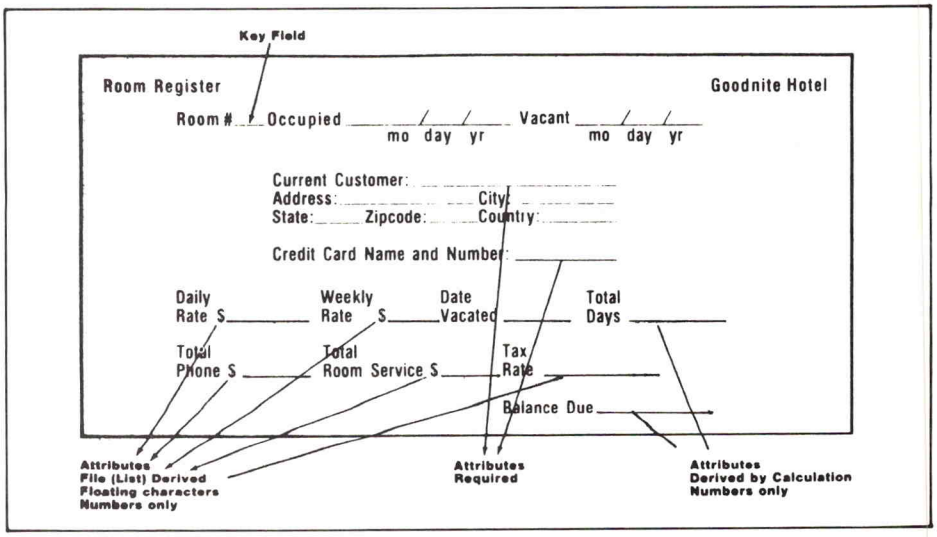
Just as you designed your own form for data entry, you can design your own form to display your data files. Decide what you want, then use ReportStar's prompts and menus to enter rows, columns, titles, labels, datafields, etc.

You can specify that data for the datafields come from one or more data files generated by DataStar, from calculations, or from entry at run time.

Subtotals and totals for any appropriate collection of datafields may be specified. The report's format can include boldface, special characters such as dollar signs, minus signs, and so forth.

Once you have designed your report form, the Report module loads data into all the report fields on your form, performs any calculations and prints the report. It permits you to use more than one data file stored on more than one disk; you can change disks while Report is running.

The flexibility InfoStar gives you for forms design, data entry, and reporting has only been touched upon, but you should have some idea of the power and versatility of this conversational database management package.



When designing a form, you can assign attributes to a form's fields which enable DataStar to do much of the data entry work for you. In this example, the data entry operator is required to enter the customer's name and credit card information. DataStar will access the daily and weekly rates, phone charges and room service charges from another file and fill them in, and calculate and complete the total days, tax rate and balance due.

4170 GPU Color Drawing Board

For 4170 GPU users who are impatient to get started, the Color Drawing Board (CDB) program provided in the 4170 Program Exchange disk can be loaded and run to generate a simple chart to create a picture or just to take a look at the 4105, 4106, 4107 or 4109 features. CDB adjusts itself to the features of the terminal on which it is running and, through menus, works interactively with you.

Using CDB you can create, edit, save and recall drawings using its friendly interface. The best way to learn CDB is to use it! Step-by-step procedures are provided to get you started. The following demonstrates some of the commands available.

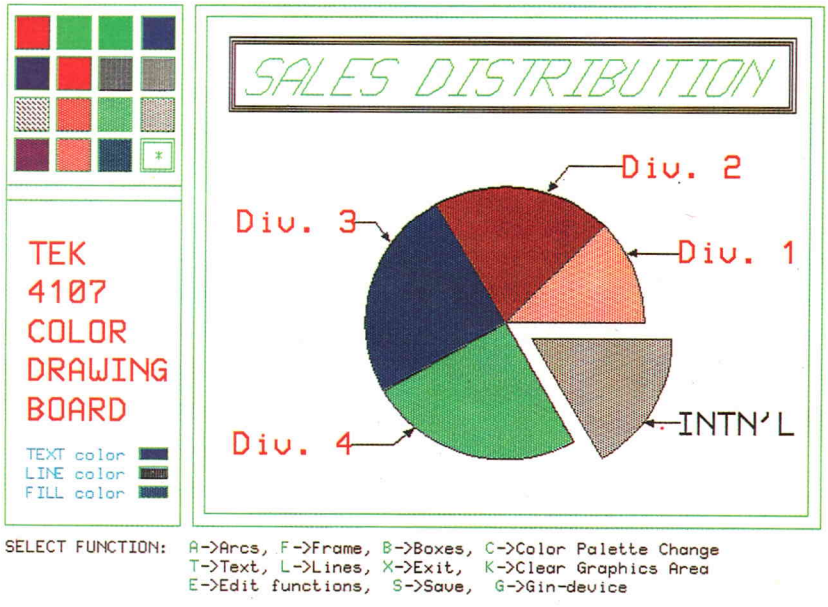


Figure 1. The drawing area, color menu, and function menu, along with a created pie chart, displayed on a 4107 Terminal by the Color Drawing Board program, have been captured on a 4695 Color Copier in the above figure. Arcs in the pie chart have been filled. Any arc, circle or box may be filled or unfilled. Notice the lines have been terminated with optional arrowheads. A collection of lines may also be identified as a panel. Rubberbanding on the 4106, 4107 or 4109 Terminals aid in positioning the lines.

A selection of size, angle and position customizes text. On the 4106, 4107 or 4109 Terminals, as demonstrated above, text precision and slant may also be specified. A framing command turns on or off the framing box around the drawing.

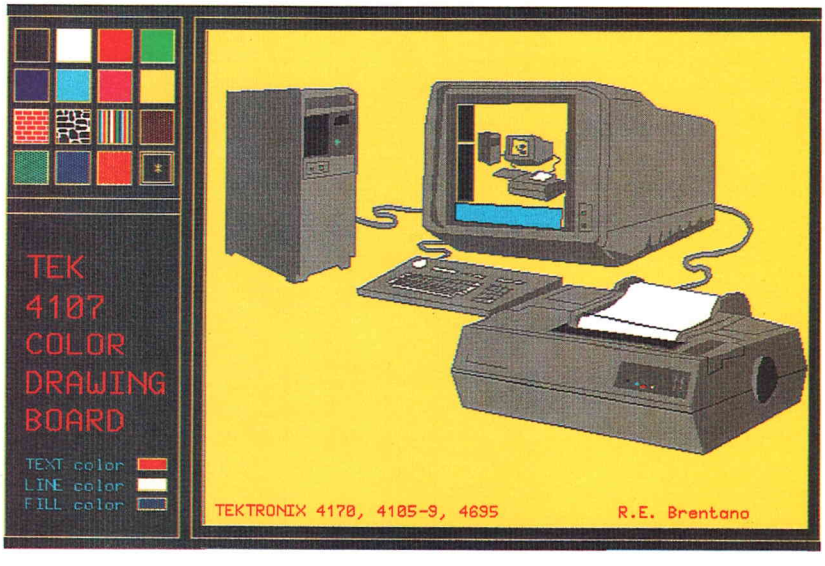


*Figure 2. Colors of the text, lines or fill patterns are easily changed. The * block changes the entire color menu. Notice the different colors in this menu compared to that of Figure 1. Or, you can select any color or pattern stored in the terminal.*

You can also press the dialog key on the terminal to remove the command prompts or menu.

Figure 3. Three pictures created using Color Drawing Board illustrate its versatility. The GIN device may be either the terminal's cursor or the 4957 Graphics Tablet.

Workstations: The Practical Evolution

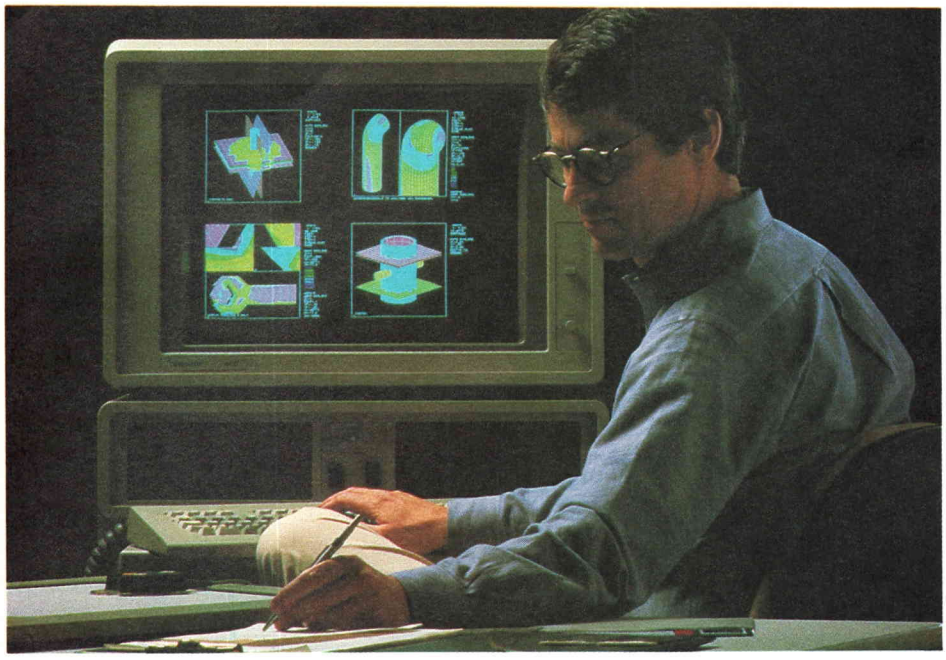


Figure 1. Multiple windows permit several jobs to be monitored simultaneously.

What is a workstation? How is a workstation different from a desktop computer or a personal computer? Should the word "workstation" be reserved for single-user, single-purpose systems?

The answers depend on who you talk to. A survey by Advanced Resources Development, Inc., defined workstation to include word processors, desktop computers, and terminals attached to a host. Most computer people agree that this definition is too vague to be really useful. They contend that the word "workstation" applies only to standalone systems used by one person. Thus a secretary's word processor can be called a workstation, as can a manager's personal computer and an electrical engineer's dedicated CAE system.

For some people, a workstation isn't a workstation unless it contains special-purpose hardware enhancements and "vertical applications." For them, a word processor or single-user CAD system can be called a workstation, but a personal computer or desktop computer, being general purpose, can't.

Not everyone agrees on the special-purpose orientation, though. Most computer-product manufacturers are completely willing to use the words "desktop computer" and "engineering workstation" interchangeably. But as an article in *Electronic Business* pointed out, any field that can handle three different meanings for the acronym PC (personal computer, printed circuit, and programmable controller) probably won't be bothered by having overlapping definitions of the word "workstation."

By any definition, however, the workstation market is one of the fastest growing computer-related fields of the eighties. In the remainder of this article, we'll focus on graphics workstations used primarily by scientists and engineers, and look at the key technologies that are coming together to produce the workstations of the mid-eighties.

The Evolving Workstation

The most successful products are evolutionary – they grow out of customer needs and technological improvements, and a company's ability to intergrate available technologies in a new way. For example, Tek's 4050 series began in 1975 with what was essentially a BASIC language machine connected to a DVST terminal. Over the years, higher performance microprocessors, larger memory, more varied graphic input and output devices, and data communication enhancements have been added.

Workstations represent the next step in the evolution of desktop computers. Here are some of the advances we're seeing in workstation technologies:

More processing power. The processing power of today's chips make it cost-effective to offer greater and greater programmability at the workstation level. The cost of computing is continuing to drop, and workstations are utilizing both 16- and 32-bit microprocessors, depending on the amount of intensive computing required by the particular application area.

More memory. Memory chips are becoming less expensive as well, again making it possible for companies to build cost-effective workstations with two megabytes of memory.

More sophisticated tools. Many workstations are offering compilers for C, Fortran, Pascal, in addition to Basic. Workstations are also providing support for a broader range of tasks, including project control and documentation.

More local mass storage. Disk drive technology has been steadily refined over the years, providing more capacity in a smaller package for less cost. With Winchester-technology disk drives, workstations can economically provide several hundred megabytes of local storage.

New Capabilities

Although workstations are evolving from today's desktop computers, they have important new capabilities as well.

Perhaps the most significant addition is networking technology. Typically, a workstation is connected via a Local Area Network to other workstations and to peripheral devices. Facilities are available to handle workstation-to-workstation "mail" and file transfers. There may also be a data base manager so that users at several workstations can share data on a project. The workstation can also communicate with a host computer to run very large jobs that are beyond the workstation's capabilities.

This distributed processing allows workstation users to have the power and the quick response time of a dedicated system, as well as the economy of sharing resources and data with other workstation users.

Advances in graphics play a large role in the new workstations. The abundance of memory and processing power makes possible new types of displays. For example, we're now seeing bitmapped displays, where each dot (or pixel) on the screen is controlled by an asso-

ciated word or byte in memory. With bitmap technology, it becomes easy to integrate text and graphics on screen, change from one font to another, or enter signatures into a file.

An alternative method of representing graphics is vector graphics, where a picture is defined by a combination of vectors (lines), polygons (enclosed areas), and panels (filled areas). The graphics primitives that describe a picture are stored in a display list and converted by a list processor into pixels in a bit map. Because vector graphics are device-independent, graphic images can be transferred between workstations and recreated at the available resolution without concern for display differences. Vector graphics also allow "zooming" to show new detail.

Many workstations also provide a graphics editor, which allows users to generate and modify pictures interactively on the screen.

Color plays a role too. See the accompanying article, *The Effective Use of Color: Cognitive Principles,* for a discussion of color's contribution to the workstation environment.

The combination of graphics with developments in cognitive engineering is leading to new human/computer interfaces. Basically, this means that workstations are becoming both more fun to use and more productive. Here are some things you'll be seeing more of in workstation user interfaces:

Menus show the user a list of functions that the system can perform. Having a menu reduces the user's need to remember command names and syntax. It also eliminates the need to remember what "mode" the system is in, because the menu displays only the functions that the system can perform in its current mode.

Icons and pointing devices such as a "mouse" further simplify the task of selecting an item from a menu. An icon is a pictorial representation of a menu action. For example, a trashcan has been used on some systems to represent the act of removing or deleting a file. To select a menu operation, the user moves the mouse to make the cursor point to the desired icon on the screen.

Windows allow a user to take full advantage of a workstation's multi-tasking capabilities. Windows divide the terminal screen into several regions, each of which can support a separate system process. For example, a programmer might want to edit a file and compile a program at the same time. By creating separate windows for each process, he or she can edit the file and, at the same time, monitor any messages that the compiler outputs.

Windows further increase the usability of menus and online help systems as well. This information is displayed in a separate window, and the user can view both the menu or help information and his or her own work at the same time. Without windows, the user who calls up an online help system more than likely has his work area overwritten by the help display, making it necessary to either take notes or remember the information.

These and other advances in user interface design mean that workstations can offer the power and flexibility of more sophisticated operating systems such as UNIX™, without the difficulties in learning and use that these operating systems traditionally have entailed.

Workstations are also taking advantage of increasing standardization, which means that programs will be more portable and that user's have less of a learning curve to overcome when they begin to use a new system.

The Fall 1983 issue of *TEKniques* discussed emerging international computer graphics standards. Basically, three related standards are being developed that will aid in making graphics applications portable among workstations and other systems:

- The Graphical Kernel System (GKS) is a set of standard subroutines that can be called by a high-level-language application program. GKS allows a programmer to work without concern for the specific device on which the program will run.
- The Virtual Device Interface (VDI) provides a device-level interface. VDI makes all devices appear identical by defining a standard input/output protocol and isolating the unique characteristics of a physical device in a software module called a device driver.
- The Virtual Device Metafile (VDM) specifies a standard format for recording graphics on mass storage devices. A metafile interpreter can read the file and generate VDI commands for a graphics output device. VDM thus makes it possible to store pictures and to transfer them between systems.

A new ANSI standard BASIC – the first revision since 1977 – is currently in the public comment period and is expected to be completed in 1985 or 1986. The new standard is built for today's more capable machines, and is significant for its integration of graphics and structured programming concepts into BASIC.

Solutions to Problems

The networked resources and sophisticated tools of workstations are the latest step in the evolution of the practical side of computer science – from batch processing on a large mainframe through interactive time-sharing on a mini-computer and local processing on a desktop computer. But whatever the technology, workstations can be seen as potential problem solvers. Workstations, like all good technology, will provide solutions to problems – from the stress analysis of a newly designed mechanical part to a graph that represents the expected profits from selling that part.

Stay in touch. *TEKniques* Vol. 8 No. 3 (Fall issue) will take a look at the workstation evolution at Tektronix.

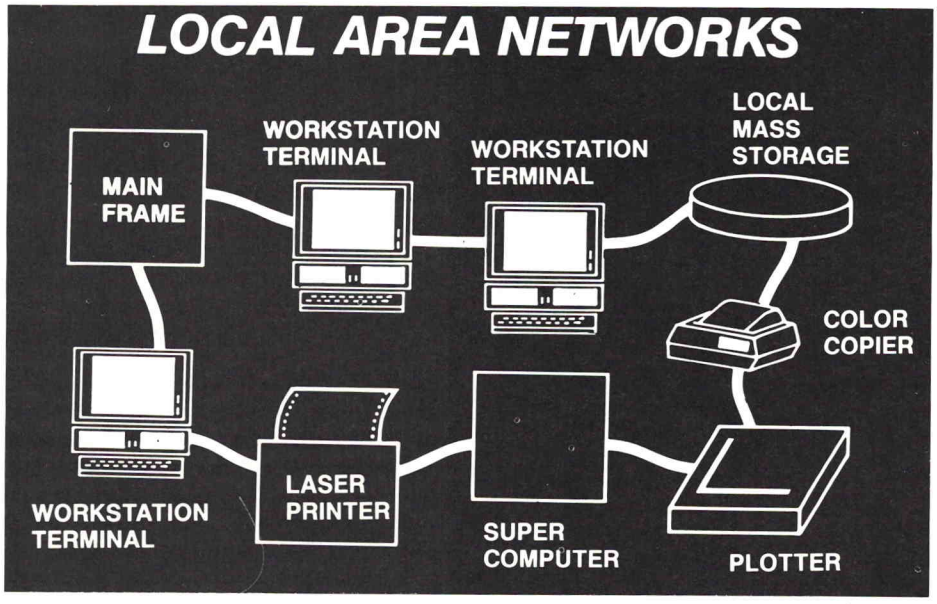
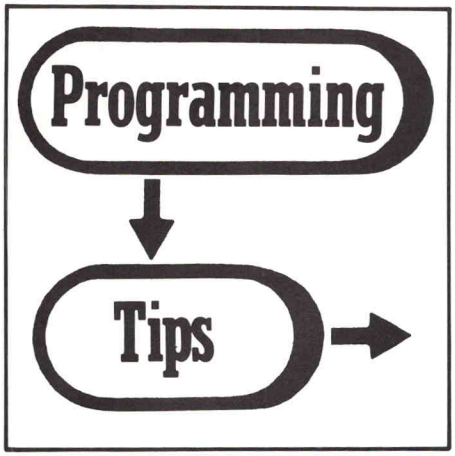


Figure 2. Local area networks play a large role in the evolution of the workstation environment. High speed communication channels allow expensive resources to be shared among many workstations without performance degradation.



Changing the 4110 Thumbwheel Rate

Operators of the Tektronix 4110 Series of Terminals who have Version 6 firmware or later can redefine the "speed" at which their thumbwheels operate.

When the thumbwheels are enabled for a graphic input (GIN) operation, the terminal samples their movement 22 times a second. The GIN position is moved a distance determined by the number of counts accumulated when sampling occurs and the entries in a thumbwheel rate table.

The number of counts accumulated depends on how far you turn the thumbwheels between samplings by the terminal. A complete revolution of a thumbwheel causes 44 counts to be accumulated.

The rate table is an integer-array with 14 elements. Elements 1 and 2 signify the thumbwheels and must be set to 0 and 0, respectively. Elements 3 through 14 are GIN-space units in the range of 0 to 4095. When the terminal is shipped, the rate-table elements are: 0 0 16 32 64 128 192 256 320 384 448 512 576 640.

Thus, if sampling by the terminal shows an accumulated count of four, the fourth *GIN-space unit* entry (array element 6) in the rate-table is used to determine the distance to move the GIN position. In the default rate table this would be 128 GIN-space units. If the count is one, the first GIN-space unit entry (array element 3) is used which moves the GIN position 16 GIN-space units, and so forth.

Up and right thumbwheel movements cause positive count changes. Down and left cause negative changes. If the count is negative, the negative of the respective rate-table entry is used.

An escape command alters the rate-table:

HOST SYNTAX

<EC>IU int-array: *rate-table*

SETUP SYNTAX

<EC>IU *rate-table*

where **<EC>** is the escape character or key.

For example, the SETUP command:

<EC>IU 0 0 20 40 60 80 100 120 140 160 180 200 220 240

would lessen the distance the GIN position moves (compared to the default table rates).

If only the first two elements are entered, e.g.,

<EC>IU 0 0

the command is ignored.

If only partial elements are entered, e.g.,

<EC>IU 0 0 20 40

only those elements are replaced in the rate table.

The first two elements must be present.

If you want to approximate the feel of a 4014 terminal, enter these values for a rate-table:

0 0 80 160 240 320 400 480 560 640 720 800 880 960

Pressing the SHIFT key while moving the thumbwheels causes rate-table values to be ignored and a scaling of 1 to be used for positive movements and −1 for negative movements.

Color of GIN Cursor, Framing Box, etc., on 4115B

by Susan Scoonover
Brad Powell
Tektronix, Inc.
Wilsonville, OR

The "border-index" parameter of the Set View Attributes Commands sets the color index on the 4115B for:

a) the viewport border
b) GIN crosshair cursor (which is segment 0)
c) Zoom/Pan framing box
d) Alpha cursor in the graphics area
(does not affect cursor in dialog area)

3D Wireframe Kit Enriches 4115B Computer Graphics Terminals

by Ken Knepper
Tektronix, Inc.
Wilsonville, OR

A 3D wireframe kit expands the intelligence of the Tektronix 4115B Computer Display Terminal, putting a wide range of three-dimensional display functions under local control. Installed in a 4115B, the kit enables the terminal to perform the complex calculations required to create and project 3D wireframe objects onto the terminal screen. Tasks such as structural analysis and design, finite element modeling, or thermal and vibration analysis can call on the 4115B Terminal's firmware to process the images at display time. User interaction is speeded and prior processing by the host computer is reduced or eliminated.

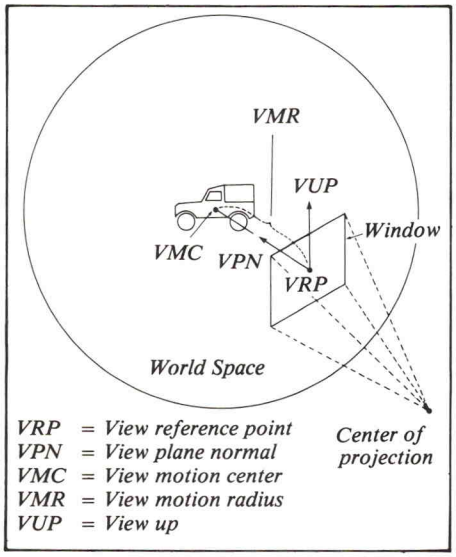


Figure 1. To locally implement zoom and pan on a 3D object in 3D world space, the 4115B terminal operator essentially manipulates certain interdependent parameters that determine how the object is displayed.

The window defines the rectangular area of world space selected for viewing. Its area may be increased or decreased; it may be moved around the object, closer to or farther from the object, tilted or rotated.

An arbitrary point defined on the displayed object, the View Motion Center (VMC), links in a direct line , the View Motion Radius (VMR), to a View Reference Point (VRP) on the Window.

Two direction vectors, view up (VUP) and View Plane Normal (VPN), indicate the top of the Window, and the perpendicular to the Window, respectively.

The Center of Projection defines the eye position (distance from the Window) of the viewer in the case of perspective projection.

Also included in the wireframe kit are the four major 4115B enhancements supporting window management, segment subroutines and editing, and circle/arc functions (see the separate article in this issue). These features are resident in the new hardware supplied, thus, are locally available upon terminal power up.

Known as the 4115F58, the 3D wireframe kit consists of a new processor set, firmware and microcode changes to the 4115B, and a new keyboard. The kit will be available in March, 1985.

Local 3D Pan and Zoom

Resident commands permit local pan and zoom in 3D space, including spherical pan. Using terminal keys and the thumbwheels, the designer can move the viewing window around the object in 3D global space, permitting the image to be viewed from the front, rear, side or at any orientation.

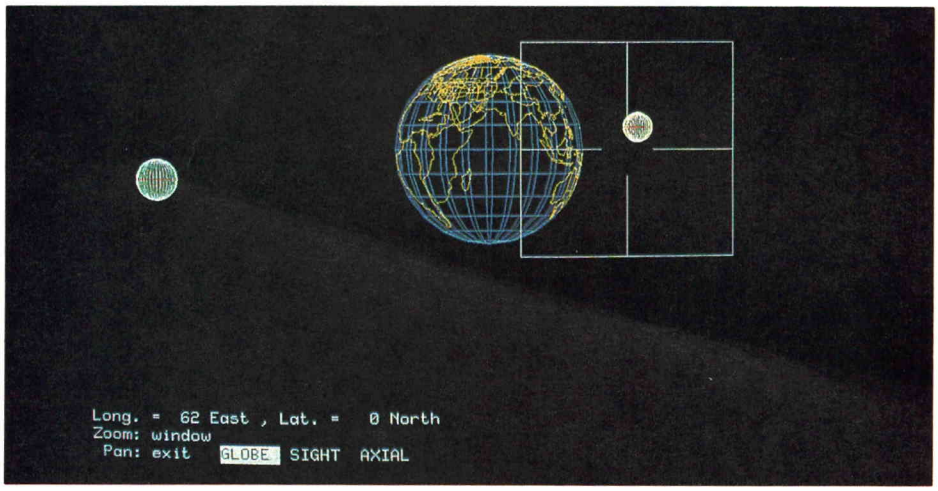


Figure 2. During 3D spherical pan (PAN mode/GLOBE submode), the operator rotates the thumbwheels on the 4115B Color Terminal to shift the Window to a different latitude or longitude or both in world space. During this process, the View Reference Point is held at a constant View Motion Radius relative to the View Motion Center. A framing box moves horizontally or vertically to indicate the changing position of the Window. When the operator presses the terminal's VIEW key, the object is redisplayed from the new viewpoint.

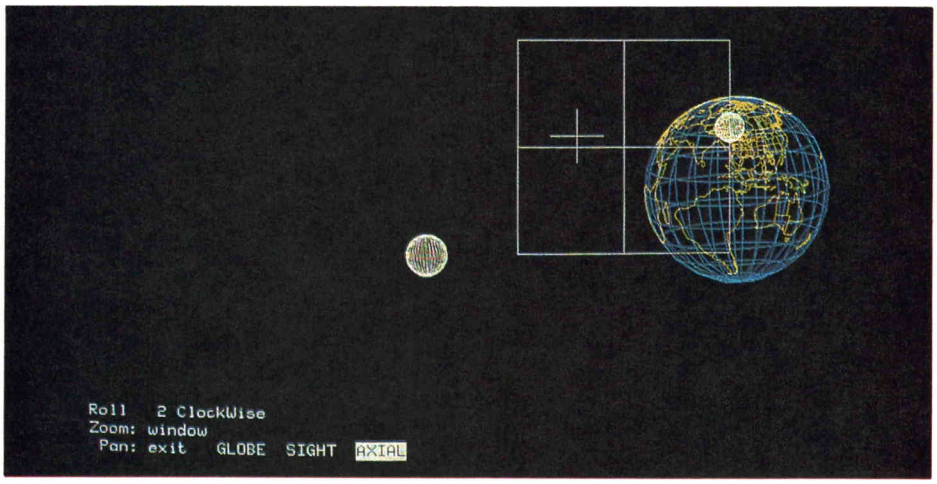


Figure 3. In this view, the Window has been shifted around the world to the left realigning the two moons in the viewer's line of sight and changing the view of the world. The submode has been changed to AXIAL and the operator has turned the thumbwheels to rotate the Window (the VUP vector) two units clockwise. At the next press of the VIEW key, the displayed picture will reflect the Window rotation. Notice the crosshair cursor in the framing box has moved up to indicate the impending clockwise shift of the Window.

Switching to zoom mode, the user can move the view window closer to the image or retract from it. The user can even move into objects, peeling back outer layers to take a look inside.

Throughout the pan and zoom operations, status lines (any or all of which may be turned off) inform the operator which mode prevails, of options available, and in the case of spherical pan, the latitude and longitude of the point on the sphere to which the UV plane is tangent.

Local 3D Transformations

New commands implement the most frequently used 3D transformations. The size of objects can be easily manipulated to conform to any scale, can be elongated, rotated or sheared. Local commands rotate objects on any axis and clip the images against a specified three-dimensional viewing box. Parallel or perspective projection may be chosen.

Text or markers, often supplied as handy reference points for complex images, or to annotate a display, will always face the viewer. This prevents the text or marker from rotating with an object and becoming illegible.

3D Cursors

For graphic input, the Z-axis may be assigned to one of the 4115B Terminal's thumbwheels. The viewer can then select an object and reposition it relative to its perceived distance from the viewing window. And when picking an object in 3D space, the Z-axis depth is also reported as well as the X and Y coordinate positions.

2D and 3D Share Space

Users can mix 2D and 3D information on the 4115B Terminal screen. 2D graphics can be created and positioned anywhere within the 3D world space, and both 2D and 3D objects can be displayed on the screen and viewed from any angle.

Up to 20K polygons, simple facets, or up to 60K vectors can be stored locally and manipulated without calling on the host computer.

New Processor Set, Keyboard

Replacing the 8086/8087 processor set, the new 80286/80287 from Intel provided in the 4115F58 runs approximately 2.3 times faster. The 24-bit terminal space permits the definition, manipulation and display of 3D vectors, wireframe panels and facets, plus 3D cursors for graphic input.

Because the new processor set shares the same "board" with the ROM/RAM memory, an extra slot is opened up for options to the 4115B such as disk interfacing, color hard copier, 3PPI, and so forth.

The new keyboard adds a numeric keypad and ports to support a joystick and mouse simultaneously.

Device Drivers

Support for the three-dimensional functions provided by the 4115B Terminals is planned for many software packages. Under consideration are mechanical engineering packages from GE CAE, MCS, PDA, Sperry Univac, and others.

In the graphics tool area, support is being planned from Precision Visuals Inc.

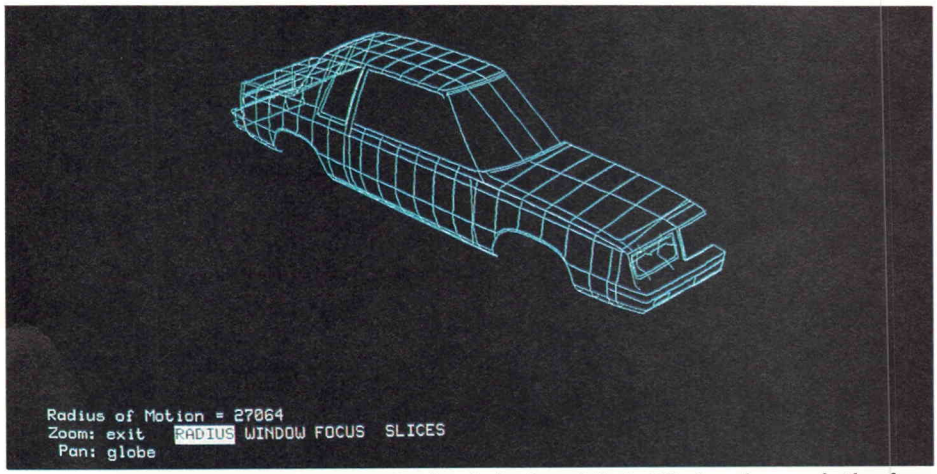


Figure 4. As the terminal operator moves the thumbwheels to shift the Window closer or farther from the displayed object, (ZOOM mode/RADIUS submode), a status line reports the change in the VMR. Notice that the framing box has been turned off.

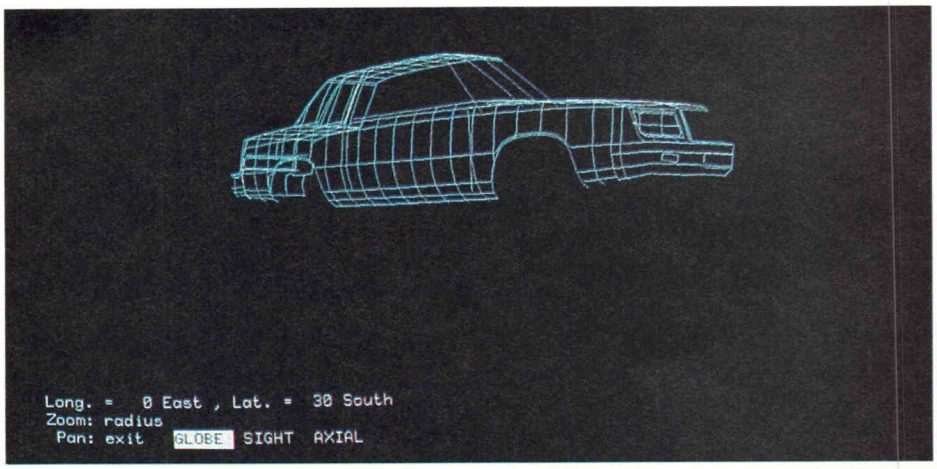


Figure 5. Returning to PAN mode, the operator has entered GLOBE submode to move around the car to a different view. The framing box remains off.

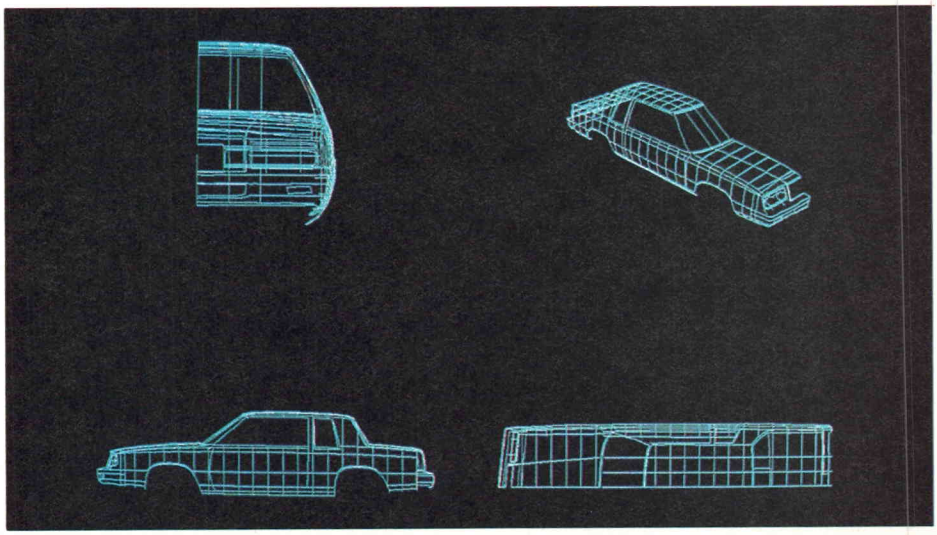
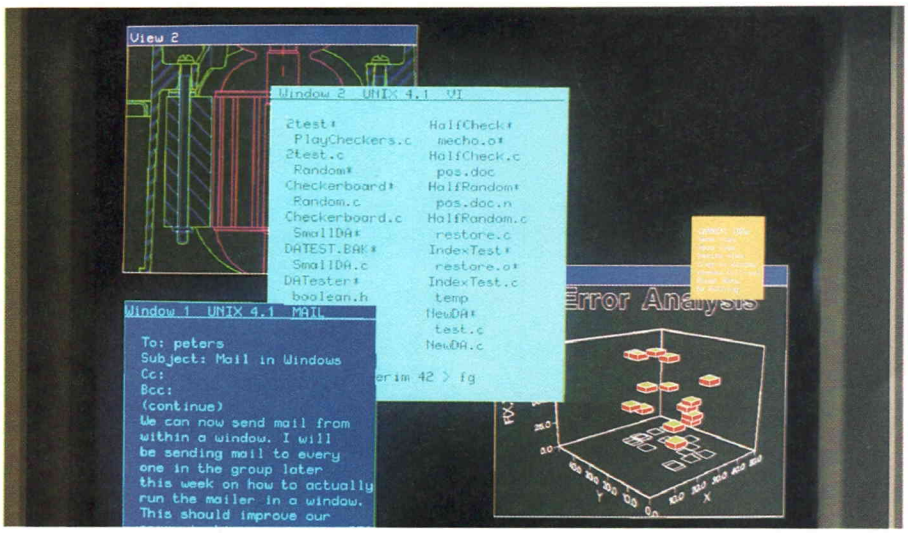


Figure 6. Multiple viewports contain four different views of the car in perspective projection. The operator may enter any of the views to locally PAN and ZOOM, rotate the object or perform other transformations.

4115B Enhancements Support Window Management, Segment Subroutines



Feature extensions in the Tektronix 4115P51 package for the 4115B Computer Display Terminal include 64 independent scrolling dialog areas to support host window management. Other features are pop-up menus, segment subroutines, segment editing and circular arcs.

Major enhancements to the 4115B Color Graphics Terminal provide powerful tools for the applicaitons programmer requiring the highest level of graphics performance and superior interactive operator interface. Packaged as software, 4115P51 is easily installed on a 4115B Terminal. It adds new commands to the existing feature set of the terminal, commands which are accessed in the same manner as existing terminal commands.

Segment Editing

4115P51 gives the 4115B the ability to perform general editing of segments without retransmitting the entire segment. Now defined segments can be changed instead of deleted and recreated. Users can erase part of a segment, insert additional graphics or replace information as desired. This feature provides a more effective, natural means of altering the contents of an existing segment, thus increasing productivity by reducing editing time.

Segment Subroutines

With the 4115B and 4115P51, it's possible to refer to a segment as part of another segment. Users can call segments from within other segments in the same manner as calling a subroutine in FORTRAN. A segment may contain graphic primitives, primitive attributes and calls to other segments. This subroutine capability is useful for local storage of pictures with many repeated elements, as in integrated circuit design and mechanical design.

Many graphic application programs build pictures, like mechanical parts or printed circuit boards, in a hierarchial fashion. Instead of describing every line or area explicitly, a picture is built of primitive shapes which are in turn constructed of such primitive elements as lines, text strings and areas. In these instances, the segment subroutine capability provides a local data structure that more closely matches the host data structure and reduces editing time and memory requirements.

Pick Operations

4115P51 permits the graphic input function to report complete information to the host regarding segments and segment subroutines within the pick aperture. The terminal can also report the viewport in which the cursor may be found. This extends the existing 4115B capability to report the full tree of subroutine references, if desired.

Host Window Management

The basic structure of providing multiple, visually separated work areas or viewports already exists in the 4115B. This portion of 4115P51 supports that structure with a set of new commands which provide valuable hooks for host window management.

Multiple Scrolling Dialog Areas

4115P51 permits up to 64 dialog areas on the screen simultaneously. This allows users to edit one text file while referring to another, and view both on the terminal at the same time. Since each dialog area has its own independent text buffer (off-screen scrollable memory), these dialog areas may be positioned to overlap each other. Even though partially obscured, they still may be scrolled. In addition, ANSI x3.64 standard editing commands are available in each dialog area.

This feature also provides the basis for other applications. For example, users can watch the output of a program and read their computer mail at the same time. The host must control the programs (such as mail and language compilers) and route the output to separate dialog areas.

Another application that multiple scrolling dialog areas makes available is the ability to talk to various hosts with a single terminal. By connecting the 4115B to other computers (via a LAN or other communications network), the multiple dialog areas allow easy separation of several contexts. Data switching and destination preambles must be handled by the host computer or communication system, but 4115P51 simplifies the task.

Pop-up Menus

4115P51 provides the ability to save small areas of the screen to terminal memory and then restore the image. This allows nondestructive display of transient information, either text or graphics. Users designing an interactive program can employ this capablity to pop up a menu, then bring it down without disturbing the underlying graphics.

Circular Arcs

This portion of 4115P51 allows 4115B users to draw circular arcs without sending every vector from the host computer. It adds commands to the 4115B terminal which specify three point arcs. These arcs are drawn as a series of vectors generated by the terminal, saving host computation and communications time. The number of vectors generated is under user control - the arcs may be as smooth or coarse as the situation warrants.

Performance

4115P51 keys so totally into the 4115B that it becomes an extension of the architecture and features. It is designed to work without hardware modification on Tek 4115B Computer Display Terminals. Although 4115P51 occupies only 30K of terminal memory, each enhancement may be individually loaded as needed.

Tektronix 4692: Second Generation Color Copier

by Harry Watkins
Tektronix, Inc.
Wilsonville, OR

A new member in the spectrum of Tektronix color copiers, the 4692 Color Graphics Copier, offers superior color output on A-size (8½ × 11") or A4-size (297 × 210 mm) paper or transparencies. Taking the ink-jet technology of the Tektronix 4691* a step further, the 4692 Copier delivers crisp graphics in up to 216 colors and halftones (256 when used with the 4510 Rasterizer).

Specially matched paper, transparency film and ink result in 4692 copies of the brightest, most highly saturated colors available outside of color photography. Business graphics, scientific data, maps or mechanical drawings may be copied from the terminal screen in rich true colors.

Under program control, the resolution can vary from 128 dots per inch to 154 dots per inch (dpi) to produce the maximum size image possible for the resolution of the terminal screen and the output media format. And the special media handling system eliminates options or setup changes when switching between paper or transparencies.

Users of Tektronix 4106, 4107, 4109, 4113B or 4115B Color Graphics Terminals will find the 4692 Copier an economical and reliable resource.

True Colors, Many Patterns

New water-based inks formulated by Tektronix produce true colors on the new clay coated paper and special acetate film. Three ink-jet cartridges create six vivid colors. Yellow, magenta and cyan inks mix, two at a time, to form red, green and blue. The separate black ink cartridge supplies a rich velvety black. Coupled with the white of the paper, eight distinct colors emerge.

Additional shades can be created by dithering (half-toning) in which tiny ink dots of the primary colors are placed in varied patterns, which the eye fuses into homogenous colors. Because the 4692 Copier offers an on-board 216 color pattern look-up table, the wide selection of colors and shades is achieved without requiring the host driver to develop and transmit the dithered patterns.

*The top-of-the-line Tektronix 4691 Color Graphics Copier was introduced in *TEKniques* Vol. 6 No. 4.

Ink-Jet Reliability

Like the Tektronix 4691 Copier, the 4692 Copier uses four air-assisted on-demand ink jets. During the copy process, four writing heads travel linearly across the paper held on a rotating drum. Each head has a tiny (40 micron) aperture which is automatically supplied with ink.

The head functions as a miniature pump to produce a discrete quantity of ink for each electrical pulse applied to it. Image information is sent to the head in the form of electrical pulses, which stimulate a piezoelectric crystal in the head. The crystal deflection causes a pressure pulse which forces a droplet of ink out of the head and toward the paper. Air flow accelerates and stabilizes the ink drops as they are ejected from each print head, resulting in higher speeds (over 20,000 droplets per second) and highly accurate drop placement.

A significant Tektronix innovation, the Ink Transient Suppressor, increases ink-jet reliability. Using a five-micron mesh filter, the Ink Transient Suppressor traps bubbles and particles that may have worked their way into the ink system. A one-way valve prevents ink from flowing away from the ink-jet heads, and a flexible diaphragm, exposed to air on one side and ink on the other, suppresses shocks when the copier is moved or jolted. Bubbles and head clogs are virtually eliminated.

When the copier is not in use, the head assembly is parked against a capping station that protects the jets and prevents them from drying out. Heads are automatically purged and washed each time the copier is turned on, and after every 50 copies. The operator may also manually initiate head purging from the front panel of the copier.

Maintaining the ink supply is a simple and clean process. Ink quantity is electronically monitored and a warning light for each color indicates when the ink is low. The self-sealing ink cartridges are snapped into place in seconds from the front of the copier. Between 3000 and 5000 copies can be made by each set of four cartridges depending on image density.

Variable Format

The 4692 Copier can fit the output format to the image, producing either horizontal or vertical output for the 4106, 4107, 4109 or 4113B. The image size is automatically scaled and pixel replicated to provide the largest reasonable image for the combination of terminal screen resolution and output format. Landscape (horizontal) format accommodates the high resolution of the 4115B Terminal.

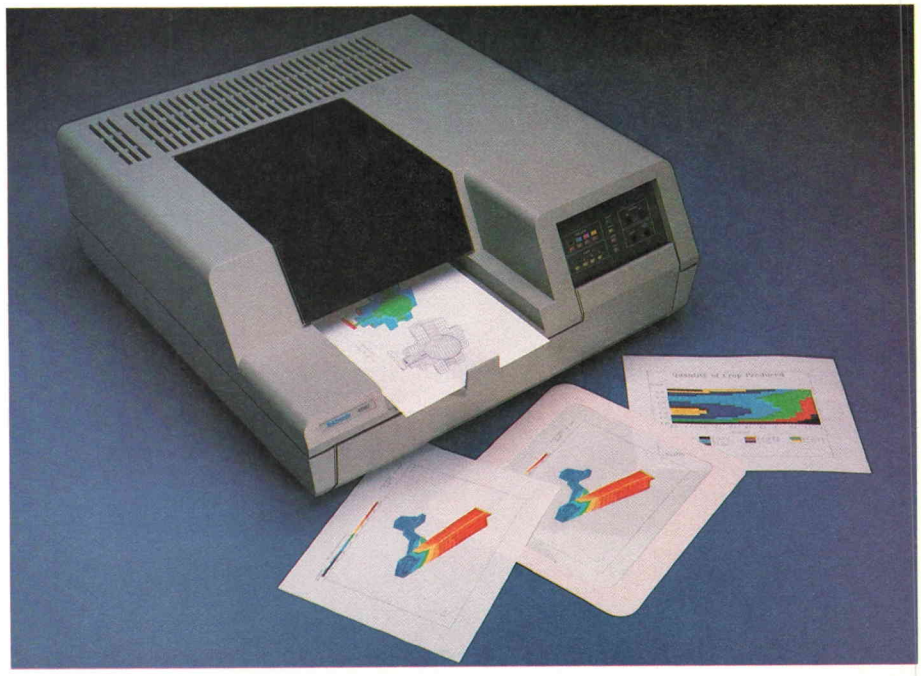


Figure 1. The 4692 Color Graphics Copier combines accurate dot placement and variable addressability as high as 156 dots per inch to achieve high-quality copy and color fidelity.

Variable Resolution

Although the default addressable resolution of the 4692 Copier is a fixed 154 dots per inch both horizontally and vertically, under software control this may be varied within a range of 128 to 154 dpi to fit the format, screen resolution and task. The less dense dpi produces an image in a shorter copy time, useful for quick preview copies.

Easy to Use

The elegant design of the 4692 Copier makes media handling reliable and simple. Up to 100 sheets of paper or up to 50 sheets of transparency material can be processed automatically, and changing between the two types of media is quick. Just insert a stack of paper or acetate sheets in the media tray, flip a switch and it's ready to go. The copier even takes care of the interleaved paper between transparency media.

The 4692 Copier creates an image while the paper or acetate is on a spinning drum. A blower fluffs a sheet against the drum and simultaneously creates a vacuum at the leading set of holes on the drum. As the drum rotates, the leading edge of the paper is picked up and wrapped around it. A set of grooves around the drum "transport" the vacuum around the drum exterior, holding the paper firmly. The trailing edge of the paper is gripped by another set of holes under the vacuum.

Once the drum spins up to speed, the four ink-jet heads begin to create an image as they travel along the drum. Because each print location on the paper passes under all four ink-jet heads in sequence, the need for a multiple pass process is eliminated. After the image is completed, a set of "stripper bars" slip under the leading edge of the paper and break the vacuum. The forward momentum of the drum deposits the paper or acetate into the media receiving tray built into the top cabinet. The copies may be handled immediately without smearing.

Flexible Operation

Color copies can be initiated by pressing terminal keys or under host or local program control. Operation will be similar in most respects to the current 4695 and 4691 Copier processes. Dialog area copies, graphics area copies, or both may be taken from the terminal screens. A choice of inverted copy (black text on white paper) or uninverted copies of the screen are also selectable.

The 4692 understands the same escape sequence copy commands (copy format, multiple copies, check copier status, etc.) as those used with the 4691 Color Copier. Two additional commands are also supported:

- The Select Copy Density Command supports the 4692 Copier's variable resolution capability.
- A Set Repaint Byte command allows multiple images (up to four) to be printed on the same media before unloading. Thus, several images may be superimposed, or the same image may be repeated for increased optical density. This is especially effective to make particularly vivid transparencies.

Multiple Configurations

The 4692 Color Copier can connect directly to the Tektronix Color Graphics Terminals. Compatibility for the 4692 Copier and the 4106, 4107 and 4109 Terminals is through firmware upgrades. An Option 9 upgrade implements the 4692 device driver in the 4113B and 4115B Color Terminals. Call your local Tektronix Sales Engineer for details.

The 4692 can connect directly to host mainframes and non-Tektronix terminals which support the "Centronics" type parallel interface. A 4692 Device Driver Development Guide is available to aid in integrating the 4692 Copier into your system.

An optional four-channel multiplexer permits sharing of a 4692 Copier. Firmware sequentially interrogates each of the four input ports and flags other ports when one port is in use.

4692/4510 Combination

Coupling a 4692 Color Copier with the 4510 Color Rasterizer (see the separate article in this issue), permits the terminal operator to take full advantage of the high resolution of the copier and the color palette of the Rasterizer. Both landscape and portrait format output are available from this configuration.

When the 4692 is attached to the 4510, the Rasterizer's color palette takes precedence over the resident color look-up table in the 4692 and provides 256 solid and half-toned colors out of a palette of over 132,000.

A Selection of Copiers

With the addition of the 4692 Color Graphics Copier to the Tektronix color copier family, users may select the copier to fit their task. Where low cost and personal control of a terminal-dedicated copier are required, the 4692 is an excellent solution.

Where higher speeds, automatic media handling and standard A/A4 size output are required, the 4692 will be the preferred solution. With multiplexing, the 4692 spreads the cost per user.

Used with the 4510 Color Graphics Rasterizer, both the 4692 and 4691 Copiers are effective system resources for color hard copy, providing unmatched paper and transparency output regardless of the terminal.

For complex images such as geometric models or maps, the B-size copies of the 4691 provide the detail needed.

All three copiers offer superior image quality and outstanding price for performance.

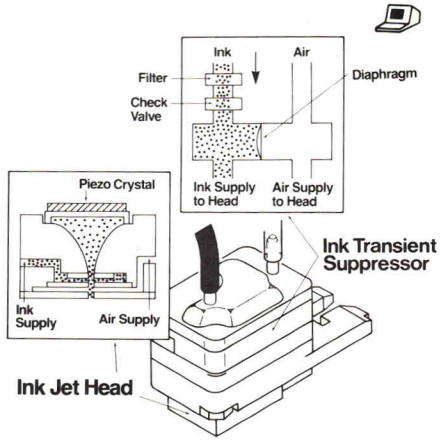


Figure 2. A new Tektronix design development, the Ink Transient Suppressor, increases ink-jet reliability. The Ink Transient Suppressor uses a five-micron mesh filter to trap bubbles and particles that may have worked their way into the ink system. A one-way valve prevents ink from flowing away from the ink jet heads, and a flexible diaphragm, exposed to air on one side and ink on the other, suppresses shock when the copier is jolted and moved. These features eliminate bubbles and head clogs.

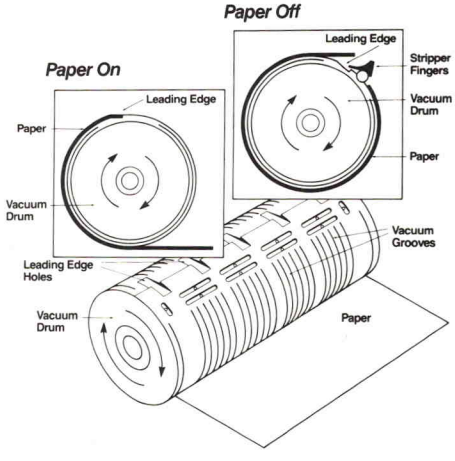


Figure 3. The 4692 Color Graphics Copier incorporates a new media-handling system designed for simplicity and reliability. A blower lifts a sheet of paper, or acetate, against the drum and simultaneously creates a vacuum at the leading set of holes on the drum. The leading edge of the paper is picked up and, as the drum rotates and wraps the paper around it, a set of grooves on the drum "transports" the vacuum around the drum exterior, holding the paper in place. The trailing edge of the paper is gripped by another set of holes under vacuum. The drum spins up to speed and the four ink-jet heads create an image as they travel along the drum. After the image is completed, a set of "stripper fingers" slip under the paper's leading edge and break the vacuum. The drum's forward momentum sends the paper into the receiving tray.

4510 Color Graphics Rasterizer: Full Resolution Color Output

Figure 1. A standalone hardware rasterizer designed for use with Tektronix 4692 and 4691 Color Graphics Copiers, the Tektronix 4510 Color Graphics Rasterizer converts high-level graphics commands into copier-compatible raster data without making additional demands on system software.

by Phil Kilcoin
Tektronix, Inc.
Wilsonville, OR

For copying finely detailed graphics images you will find the new hardware rasterizer from Tektronix an invaluable companion to a Tektronix 4691 or 4692 Color Graphics Copier. Connecting the 4510 Color Graphics Rasterizer between a host or terminal and a 4691 or 4692 Copier, you can copy a drawing, map, or graph at the full resolution of the copier in 256 colors from a palette of 132,651 colors.

The 4510 Rasterizer eliminates the need for a host-intensive software rasterizer and speeds the copy time. All of the rasterization and spooling tasks are performed by the 4510 Rasterizer. It accepts high level graphics commands across the RS-232 interface, converts them into raster format dots, and transmits them to the color copier. Host processor time is minimal; communications time is short; and you have your copy quickly – for meetings, for reports or for your own analysis.

Connecting the 4510 Rasterizer to the host permits work at the terminal and host to continue uninterrupted during the copy process once the file has been sent to the rasterizer. The 4 channel multiplexed RS-232 interface allows up to four users to access the 4510, making it a valuable system resource.

Full Resolution

Most color terminal displays don't have the resolution capabilities to match the Tektronix 4691 or 4692 Color Copiers. The 4510 Color Graphics Rasterizer overcomes this disparity. It knows which copier is attached, determines the media size being used, and rasterizes the image to the copier's full resolution, scaling the image for the media size and image orientation. This means a 1536 by 1152 "dot" resolution image on the A-size 4692 Copier, or a 2079 by 1560 dot resolution image on the B-size 4691 Copier will be accommodated.

Characters, which may be fuzzy on a terminal screen, become crisp and legible using the 4510 Rasterizer. "Stairstepped" raster lines become virtually smooth. Even E-size (34 × 44 inch) engineering drawings can be legibly printed on B-size paper using the 4510 Rasterizer and the 4691 Copier's ability to print 3.8 million points of color information.

Color Quality

The 4510 Color Graphics Rasterizer has a palette of over 132,000 colors, 256 printable per image. The colors have been carefully chosen to optimize the copy quality of the 4691 and 4692 Color Copiers and their ink and paper system. The 4510 has a default set of 256 colors which have been chosen to approximate the 256 default colors on the 4115B Terminal. You may define the 132,651 available colors using one of the three color systems: hue, lightness, saturation (HLS), red, green blue (RGB), or Cyan, Magenta, Yellow (CMY),

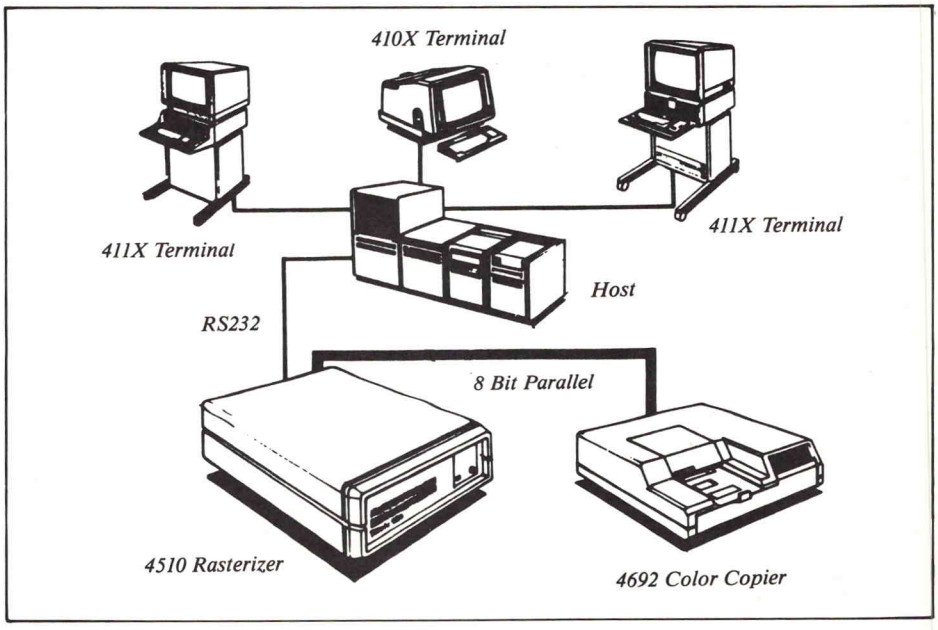


Figure 2. The 4510 Rasterizer may be connected directly to a host via a printer port.

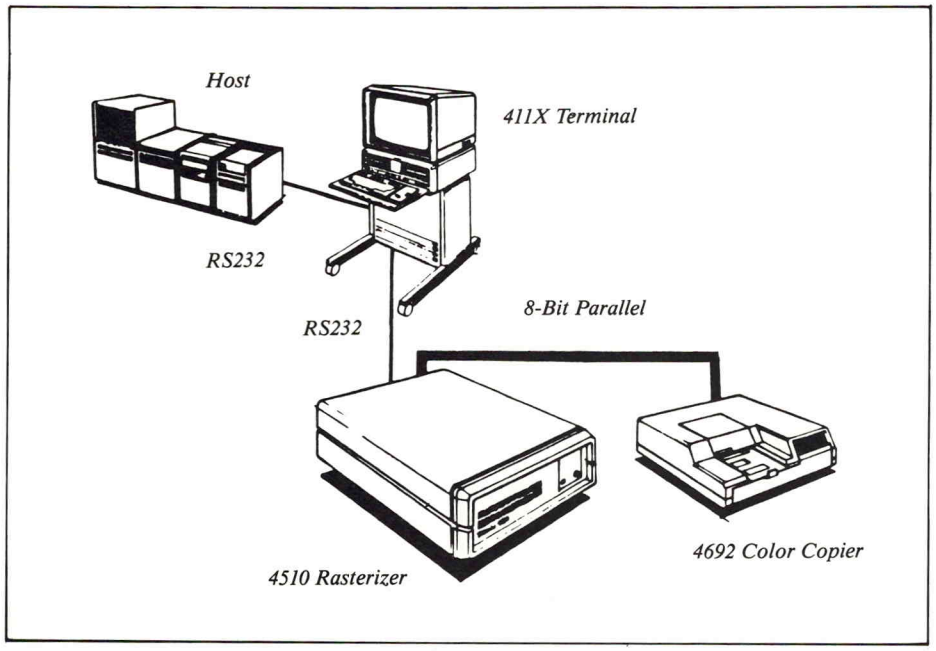


Figure 3. An alternate configuration connects the 4510 Rasterizer in loop-through mode to the host.

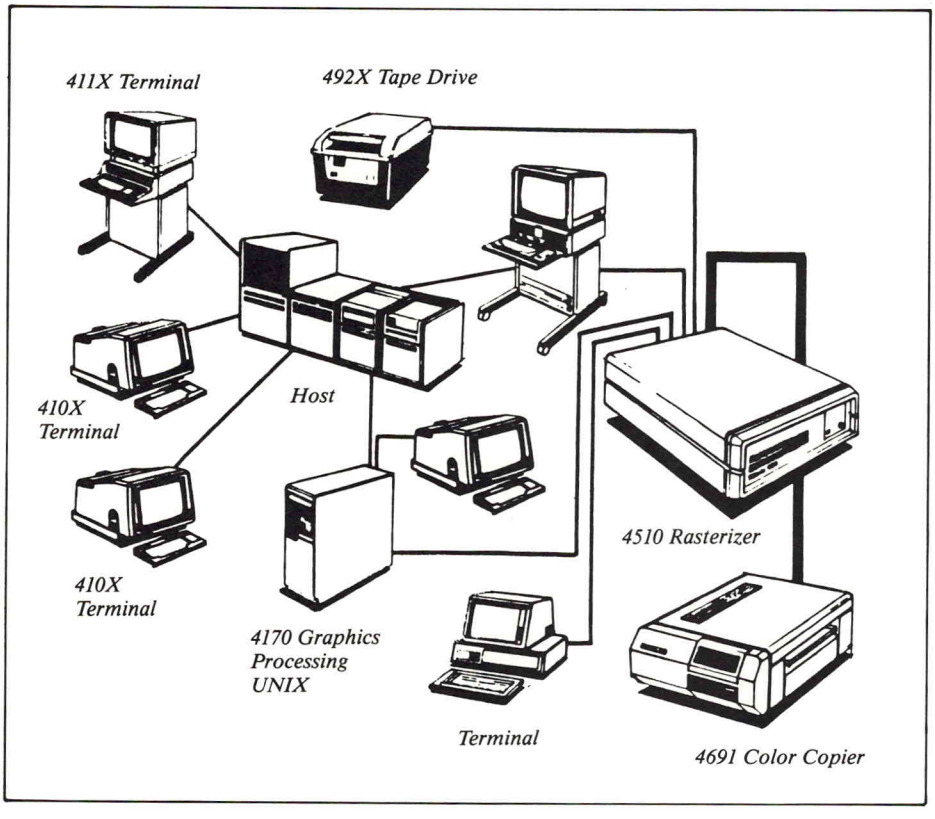


Figure 4. A variety of signal sources can be supported by the 4510 Rasterizer.

Intelligent Operation

The 4510 Rasterizer installs easily. Plug in the cable from the 4691 or 4692 Copier to the 4510, RS-232 cable from the host or terminal, power it up, and set the communication parameters. Thereafter it will require little or no attention.

The terminal or host initiates the rasterization process by sending specific header commands (environmentals, windows, etc.), followed by graphics primitives composed of vectors, panels, markers, rectangles, graphtext and so forth. When the entire display list has been received into its RAM, the 4510 begins to rasterize the display list in 32 pixel wide bands into one of two bit map memories. Also, as the rasterization process begins, the 4510 sends a copy command to the 4691 or 4692 Color Copier, causing it to pick a piece of paper. The 4510 then dynamically spools the portion of the image that has been rasterized to the copier while simultaneously reading the next band of raster data into the second memory bit map.

Multiple copies can be made from the same display list without requiring further interaction with the host.

After a copy is initiated from the host or local workstation, status LEDs indicate when the 4510 is rasterizing the data, and when it is spooling the data to the copier. Port LEDs on the back indicate which port is receiving data.

Flexible Command Set

The command set for the 4510 Color Graphics Rasterizer is compatible with the 410X/411X Color Display Terminals' graphics language with minor modifications for use with a non-interactive hardcopy output resource. This means that a 4105 driver, for example, can be used "as is" to send image files to the 4510 and it can be easily modified to accommodate the additional features of the 4510. Additional 4510 features include copier image orientation, alpha text rotation, scalable graphtext and wide lines.

Drivers for the 4510 Rasterizer are being developed for Tektronix PLOT 10 IGL, and PLOT 10 TekniCAD. Software vendors incorporating 4510 drivers into their packages are: ISSCO (TELL-A-GRAF and DISSPLA), PDA (PATRAN-G), Swanson Analysis (ANSYS), MCS (ANVIL 4000) and others. A programmers reference manual provides the details needed to facilitate the design of a device driver for the 4510 Rasterizer.

Shared Use

With its standard four-channel multiplexed interface, the 4510 makes it easy to share a 4691 or 4692 Color Copier, cutting the cost per user. Its four RS-232 ports can be attached to one or more hosts - directly, through modems, or looped through terminals. Other potential signal sources could also include Tektronix or other intelligent terminals or workstations, and off-line tape drives. Baud rates from 75 to 19,200 are separately adjustable for each RS-232 port.

Once a user has begun the rasterization process (sent a file to the 4510), the other three RS-232 lines can not interrupt the current "job." Users trying to access another RS-232 port will be flagged with a "busy" signal. Flagging prevents any data loss and keeps data transfer rates as high as possible.

Compatibility with 410X Color Terminals

The 4510 may be configured with the 4106, 4107 and 4109 terminals in either of two ways. The terminal may be used in "loop-through" mode where the file is sent from

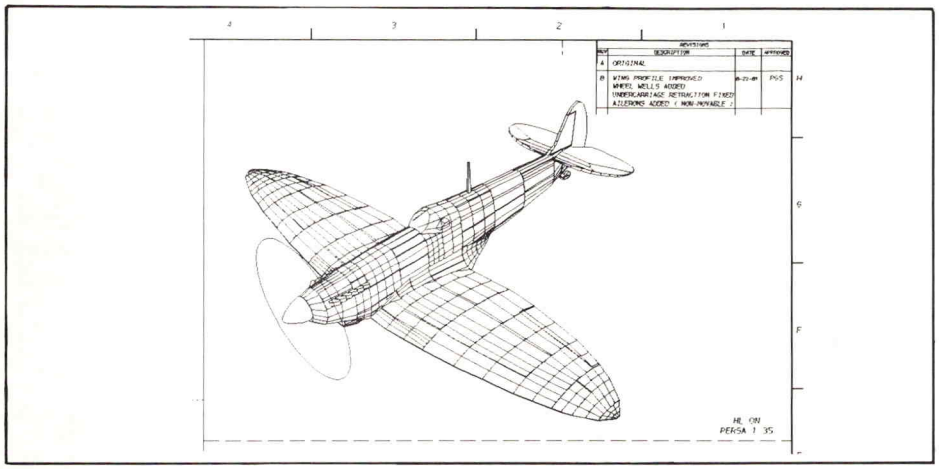


Figure 5a. Rasterized hard copy using 4510/4692. (Courtesy of Prime Computer.)

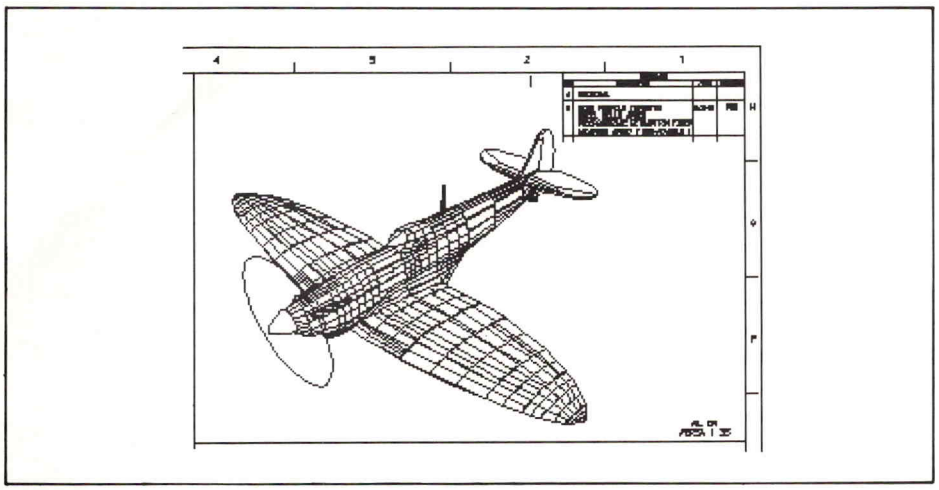


Figure 5b. Non-rasterized hard copy using 4113B/4692. (Courtesy of Prime Computer.)

the host to the "host" port on the terminal and out the "2PPI" interface to the 4510. The host communicates directly with the 4510. This operating mode can be initiated under software control or from the terminal with the *COPY HO: to PO:* command. Any terminal that supports "loopthrough (port copy)" communications through an RS-232 port can also be configured with a 4510 in this fashion. This mode of operation is not possible with a 4105 due to its lack of a peripheral port interface.

An alternative 4510/terminal operating mode is available, this will involve embedding 4510 device driver firmware in the 4106, 4107, and 4109 terminals. This will mean that installations with the appropriate drivers for 4106, 4107, or 4109 terminals can have access to the benefits of the 4510 without requiring an additional host device driver. A 4510 device driver will be part of the 4106/7/9 firmware upgrade planned for customer availability this fall.

Compatibility with 411X Color Terminals

The 411X Color Terminals can also operate in "loopthrough" mode as described for the 410X terminals.

The local memory capabilities of the 411X terminals allow the 4113B and 4115B terminals to act as a "host" and send files directly to the 4510 either out the host port (HO:) or the port peripheral interface. Therefore, the "SAVE SEG ALL TO H0:" and "SPOOL <filename> to H0:" functions allow appropriate image files to be sent directly to the 4510. This is followed by the appropriate copy command which generates a copy request to the copier.

NOTE: This method does not support pixel data, run length encoded data, or raster write encoded pixel data.

Memory Size

The capacity of the 4510's display list memory is determined by the option selected. Suitable for most business or scientific data analysis, 128K bytes handles approximately 12,000 vectors. With a capacity for 50,000 vectors, 512K bytes permits more complex scientific graphics, alpha-intensive activities, such as text design that use many vector generated characters, or mechanical and architectural applications. Complex CAD applications such as circuit board design and thematic and contour mapping could opt for the 2M byte memory which can manipulate approximately 200,000 vectors especially if using B-size output on the 4691.

Combining the Tektronix 4510 Rasterizer with a Tektronix 4691 or 4692 Color Graphics Copier provides superior quality color hardcopy independent of the terminals in use on the system. Because the 4510 Rasterizer can provide full resolution color copying capabilities to a number of users, the cost per individual user is reduced.

Rasterizing:

Converting graphic image files (vectors, panels, markers, graphtext, etc.) into raster format pixel information to be output at the full resolution capabilities of the attached copier.

IDG Graphics Systems Workshops

Local Programmability Workshops

Spending one week in a Tektronix workshop getting to know Local Programmability is the equivalent of three to six months of on-the-job education. The Tektronix Local Programmability Workshop is a hands-on course which teaches the FORTRAN programmer the basics of Local Programmability, its capabilities, and support libraries. The student will understand the operation of Tektronix graphics terminals. Tablet, plotter, copier and disk interaction with Local Programmability and the terminal is thoroughly reviewed. Basic and advanced data communications concepts are taught. The small class size of 12 students allows for individual attention. The schedule for the last half of the year is:

Gaithersburg, MD	Santa Clara,CA
Oct. 8–12	Sep. 10–14
Dec. 3–7	Nov. 5–9

IGL Workshops

An intensive workshop will give programmers or project managers a familiarity with IGL which will speed them on their way in program development. Instruction in the proper use of IGL routines eliminates the need for experimenting, permitting faster, more effective graphics applications design. Effective training results from keeping class size small and focusing on tasks typical of a user's work. The workshop features hands-on use of the entire Tektronix 4110 Series of graphics terminals, and peripherals such as tablets, plotter and copiers.

Several Summer and Fall workshops have been scheduled.

Gaithersburg, MD	Santa Clara, CA
Oct. 15–18	Nov. 12–15
Dec. 10–13	

Computer-Aided Drafting Workshops

A comprehensive workshop gives PLOT 10 Computer-Aided Drafting and PLOT 50 2-D Drafting users a jump on productivity. Taught by Tektronix professionals, the one week workshop equips the students with knowledge and skills usually gained only through months of experience. Instruction in optimum use of the Drafting system combined with "hands-on" training tailored to the user's environment accelerates the individual's effectiveness.

Course Objectives/Content:

The workshop consists of lectures and laboratories emphasizing efficient working habits and a working knowledge of all system functions and capabilities. Specific topics which will be covered in the workshop are:

- Reviewing and using all functions
- Generation of quality ink drawings
- Digitizing drawings
- Geometric operations (lines, arcs, line smoothing)
- Note generation and editing
- Workset usage
- Blanking
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The Effective Use of Color: Cognitive Principles

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In the third article on the effective use of color we will consider the cognitive aspects of color. Of primary concern will be the problem of developing a mental model of the relationships between colors which can be used by the operator of a display system to locate specific colors and to relate sets of colors. We will also consider the use of some fundamentals of the way we think as guidelines for effective color use.

For devices with relatively small color palettes, such as the 4105 or 4107 Display Terminal with 64 colors or the 4695 Color Hard Copier with 8 colors, the location of colors is simplified. Although the operator may desire a particular red, he or she will have to accept the red which the device can produce. Yet a palette of 64 can prove formidable when a set of 8 or 10 equally salient colors is required. Literally the problem increases exponentially with a device such as the 4109 with 4,096 colors to the overwhelming palette of the 4115B with 16,777,216 colors. Here the specific red envisioned by the operator can, in all probability, be produced on the device – if the unique location can be found among the 16 million possible addresses.

Beyond the problem of the mental link of the operator to the color capabilities of a display device, some consideration needs to be given to capitalizing on our modes of thinking and associating with color. This area of study, summarily called cognitive ergonomics, is clearly the least mature subdiscipline within human factors. Despite the emerging nature of knowledge, some initial observations may be useful in the effective use of color. An example which was mentioned in the previous issue of *TEKniques*, involves the functional use of color stereotypes: red for warning, green for go and yellow for attention. As we all have experience with these meanings, maintaining the relationship maps nicely into the user's expectations.

As a means of understanding cognitive aspects of color, we must review initially the *physical* basis by which colors are produced on a hard copy or video display in order to understand the difficulties in forging an effective cognitive interface.

Color mixture

The process by which inks and dyes are combined to produce colors is called subtractive color mixture while the generation of colors through combinations of phosphor emissions follows the process of additive color mixture.

Subtractive color mixture. The perceived color of a surface, such as a sheet of paper, depends upon the capacity of the surface to reflect some wavelengths and absorb others. When a surface is dyed with a particular pigment, a new reflectance characteristic is created based on the capacity of the dye to absorb some wavelengths and reflect others. A surface dyed yellow, for example, might reflect wavelengths above 570 to 580 nm while absorbing most of the longer and shorter wavelengths. Part A of Figure 1 diagrams the energy distribution of a yellow pigment. Consider another surface dyed cyan (blue-green) such that wavelengths of 440 to 540 nm predominate. This energy distribution is shown in Part B of Figure 1. If we were to mix both pigments and deposit them on a surface, the resulting color would be green. The mixture of cyan and yellow produces green because the yellow pigment absorbs all of the short wavelengths (500 nm and below) and some of the middle band of wavelengths (500 to 550 nm). The cyan pigment absorbs all of the long wavelengths (560 and above) and some of the middle wavelengths (500 to 550 nm). The energy distribution of the mixture is shown in Part C of Figure 1. Thus, the yellow absorbs those wavelengths evoking the sensation of blue while the cyan absorbs those wavelengths evoking yellow. Between these two extremes, a band of wavelengths is "left over" which evokes the sensation of green. This type of color mixture is called *subtractive color mixture* as bands of wavelengths are subtracted or cancelled by the combination of light-absorbing materials.

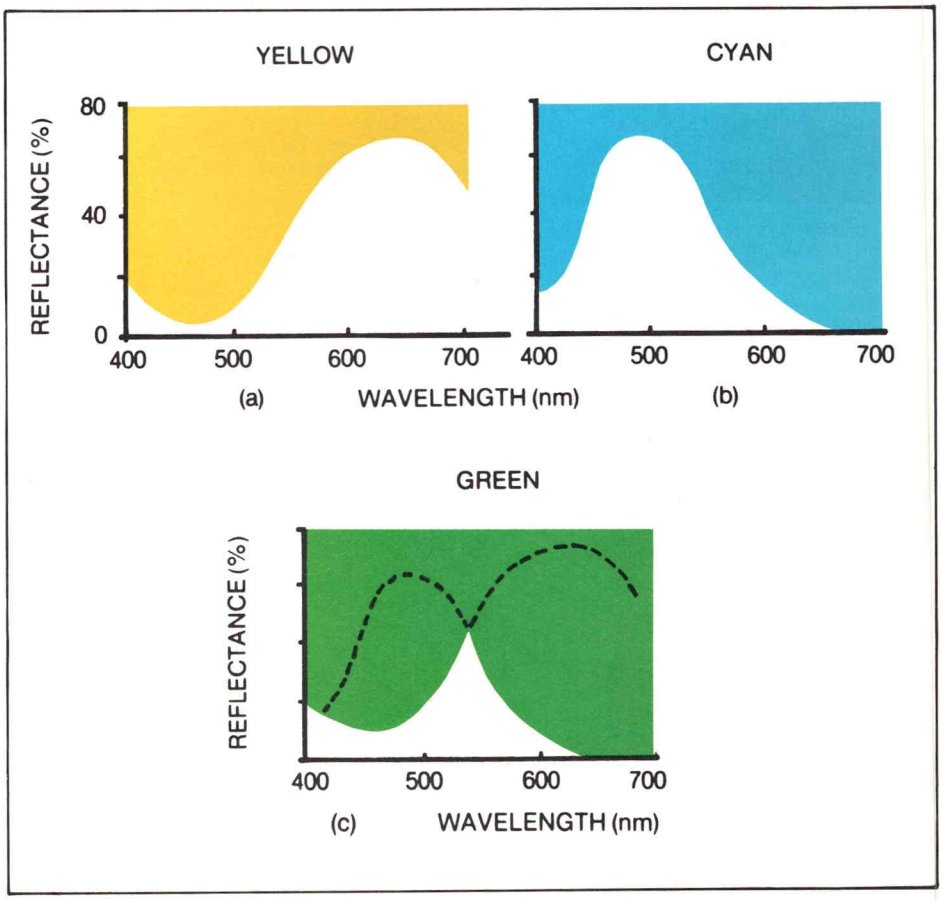


Figure 1. The subtractive color combination of inks and dyes.

If we add a third pigment to the mixture of yellow and cyan – one that absorbs the band of middle wavelengths such as magenta or violet – the surface would appear black because all of the light falling upon it would be absorbed. By this process of eliminating parts of the reflectance distribution through varying the amounts of each pigment, intermediate hues can be created. In the example, the resulting green would not be very light as much of the illumination falling on the surface is absorbed. The mixture of two pigments produces a reflectance surface which absorbs more light than either pigment alone.

With a palette of only two pigments, each with fairly broad reflectance distributions, consisting of a red and blue, we can create all the intermediate hues by varying the density of each pigment. The problem, however, is that the resulting hues will not be very light. Adding a third, fourth or fifth pigment to the palette helps markedly by increasing the overlap in the reflectance distributions of each so that when combined, lighter mixtures emerge. In fact, the minimal number of pigments required is three. These are often referred to as the *primary colors of subtractive color mixture.* An artist, of course, would use many more pigments in order to increase the purity and lightness of the colors produced by various mixtures.

Color hard copy, then, is produced by the subtractive combination of inks or dyes. In most applications the three primaries used are yellow, cyan (blue-green) and magenta. These three in all possible combinations provide a minimum palette of eight colors as shown in the table below.

Color	Subtractive Combination
Red	Yellow + Magenta
Green	Cyan + Yellow
Blue	Magenta + Cyan
Yellow	Yellow
Cyan	Cyan
Magenta	Magenta
White	–
Black	Yellow + Cyan + Magenta

Often pure black is included as a fourth color simply because the three primaries which produce the best chromatic color usually do not produce the best black.

To extend the hard copy palette beyond eight colors requires that different levels of the colors occur in each mixture. Two density levels of each primary increase the palette to 20 colors. An alternative means of extending the color gamut to much larger palettes is to employ a technique known as *half toning* in which colors are placed on the paper as tiny dots that can either vary in frequency or size. Pure red, for example, would require the highest dot frequency (i.e., 200 dots per inch) while a desaturated pink would result when the dot frequency was reduced to 120 dots per inch. In this technique, the resulting hue occurs as a result of the *additive mixture* of red and the white of the paper, whereby the dot frequency defines the density of the color component.

The size of the color palette depends, of course, on the number of perceptually discriminable densities that can be produced for each primary. Currently, it is difficult to obtain more than 15 to 20 discriminable densities which limits the hard copy palette to less than 8000 perceivable colors. Also the density of a given pigment does not increase linearly with increased absorption or dot frequency. That is, the hard copy color system has a "gamma" in which a large change in density occurs with a small initial absorption increase followed by a progressively lower amount of change as maximum density is reached. As noted in the previous article, an uncorrected gamma will produce a number of indiscriminable levels at the higher densities. Additionally, the combination of two discriminable levels, each of which are visible against a third color, may not be discriminable from the third color. The total available palette, then, will always be some number of colors less than the number of color addresses.

Additive color mixture. Colors can be mixed in another fashion in which bands of wavelengths are added to one another. In fact, this method of additive color mixture forms the underlying principle by which the visual system "mixes" colors. Additive color mixture is also the means by which color is produced on a color display.

The surface of a typical color display is made up of thousands of tiny dots of phosphor. The phosphors on the screen are grouped into threes – called *triads* – with one phosphor emitting long wavelength light (red), one emitting middle wavelength light (green) and the third emitting short wavelength light (blue). To display a red object on the screen, for example, all the red phosphors forming the outline and the interior of the object are made to emit light. A green or blue object would be produced in the same manner.

Intermediate hues to red, green and blue are produced by simultaneously making two or more of the three phosphors in a triad emit light. Because the phosphor dots are very small, when viewed from a distance the output of the three members of the triad fuse together or add to one another. The result is a homogenous appearing field of color. The principle is shown in Figure 2.

The top left graph shows the energy distribution of a typical blue phosphor while the middle left indicates the energy distribution of a typical green phosphor. When both are additively combined, the mixture shown on the right is produced. The mixture consists of a broader band of wavelengths which means that the mixture will be less saturated than the blue or green alone. The lower left chart shows the emission of a red phosphor which is combined with green in the lower right panel. The resulting hue of the mixture will be yellow. The exact color of the yellow would depend upon the relative intensities of the red and green phosphors. Increasing the amount of red while decreasing green would move the color towards orange. Conversely, increasing the intensity of the green would shift the mixture towards a yellow-green. Note that the mixture of two phosphors does not necessarily produce more energy in the wavelength region corresponding to the perceived hue. In fact, the mixture of two single wavelength, monochromatic lights can be adjusted to match a yellow – a yellow for which no energy is present in the emission spectra of either of the phosphors. Basically the perceived color on a visual display depends upon the ratio of intensities of the primary phosphors.

All three phosphors together produce a very broad distribution containing all of the visible wavelengths which, of course, evokes the sensation of white. Varying the intensity or gray level of the three phosphors produces differing levels of lightness. Because one is able to mix most hues, as well as the achromatic colors, by additively combining red, green and blue, these are called the *primary colors of additive color mixture.*

If we consider the visual spectrum of hues as a circle, we can locate the three primary colors as points on the circumference of the circle. Figure 3 shows this conceptualization. Mixture colors are produced by varying the proportions of the three primaries. White, denoted by the "w" in the center of the circle, is created when all three primaries are equally represented in the mixture. By increasing the amount of one primary while simultaneously decreasing the other two, various degrees of saturation of the predominant primary result. The broken line in Figure 3 indicates various levels of saturation for green ranging from a fully desaturated white (w) to the pure hue at "green." An intermediate mixture, such as greenish-yellow, can be produced by increasing the green and red (with a greater increase in green than red) while decreasing the blue. Varying levels of

saturation of the greenish-yellow are indicated by the dotted line.

Obviously the total number of colors that can be produced on a diplay depends upon the number of steps of gray level obtainable for each phosphor. If the electron gun can be stepped over four levels (2 bits), such as on the 4105 or 4107, the resulting palette has 64 colors. Systems such as the 4115B are capable of 256 steps from each gun (8 bits), which results in the huge palette of over 16 million unique combinations.

As with the color hard copy, the number of discriminable colors on a display depends upon the number of available gray levels for each gun. Obviously not all 16 million color addresses afforded by 8 bits per gun on the 4115B can be perceived. The reason for the large number of addresses lies in human perception. As the visual system is capable of detecting very small color differences with some hues, it is necessary to have sufficient levels to produce those fine distinctions even though the end result is a number of indiscriminable addresses. Green hues are subject to this problem as the eye does not discriminate small changes in the green particularly well. The gamma correction used on the 4115B does produce 100 perceivable levels for each gun, and a palette of almost one million colors. Obviously many of these can only be detected when the colors form a common border. The number of recognizable colors when they are not adjacent is considerably smaller. Even with a small color palette the gamma correction is imperative. For example, the 4105 would not produce a set of 64 recognizable colors without gamma correction.

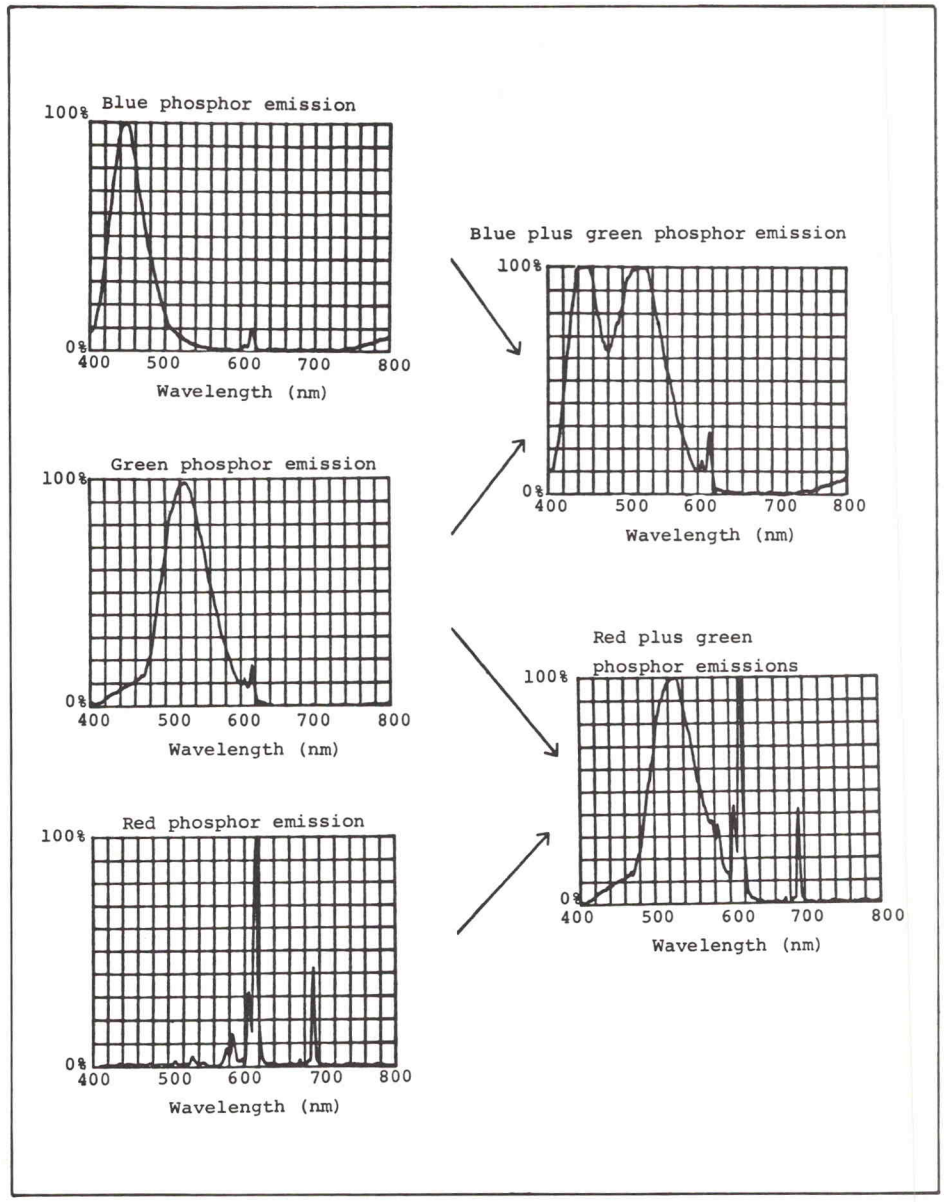


Figure 2. Additive color mixture with phosphor emissions.

Color description systems

The intricacies of color mixture require the development of descriptive systems which attempt to model these relations. The goal of such systems is to provide a means of characterizing color samples and allowing the user to mentally manipulate the available color palette. From a practical point of view, such systems aid in the specification of particular colors for use in art and industry by providing a numerical index for color. The systems described here do not represent an exhaustive list but, rather, characterize the most widely used for hard copy and displays. Ultimately we need to find a system which matches the expectations of the user. That is, not only should the location of colors be simple, the result of the specification should be exactly what the user expects.

Visual Display Descriptive Systems. An obvious approach to a descriptive system for visual displays is to indicate colors in terms

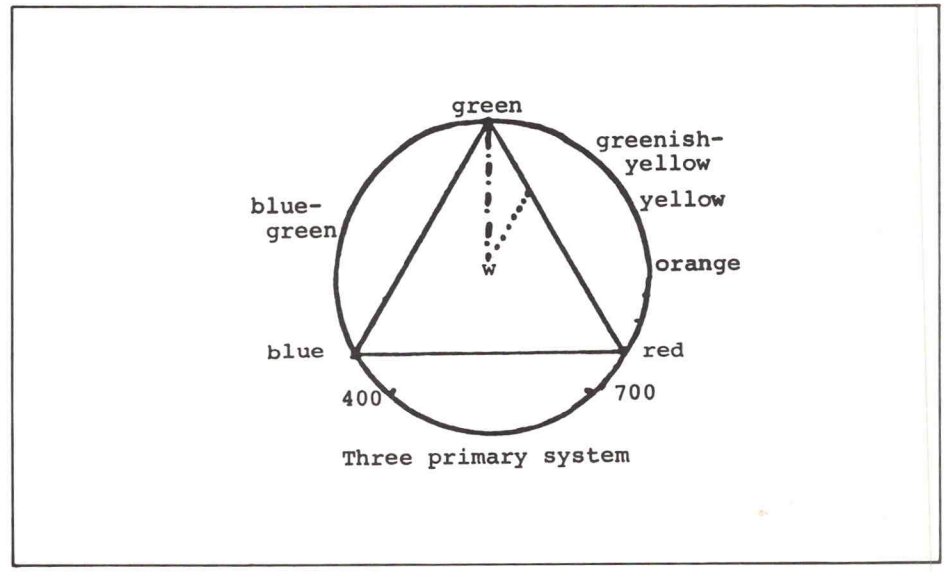


Figure 3. The mixture of colors by additively varying the proportion of each primary.

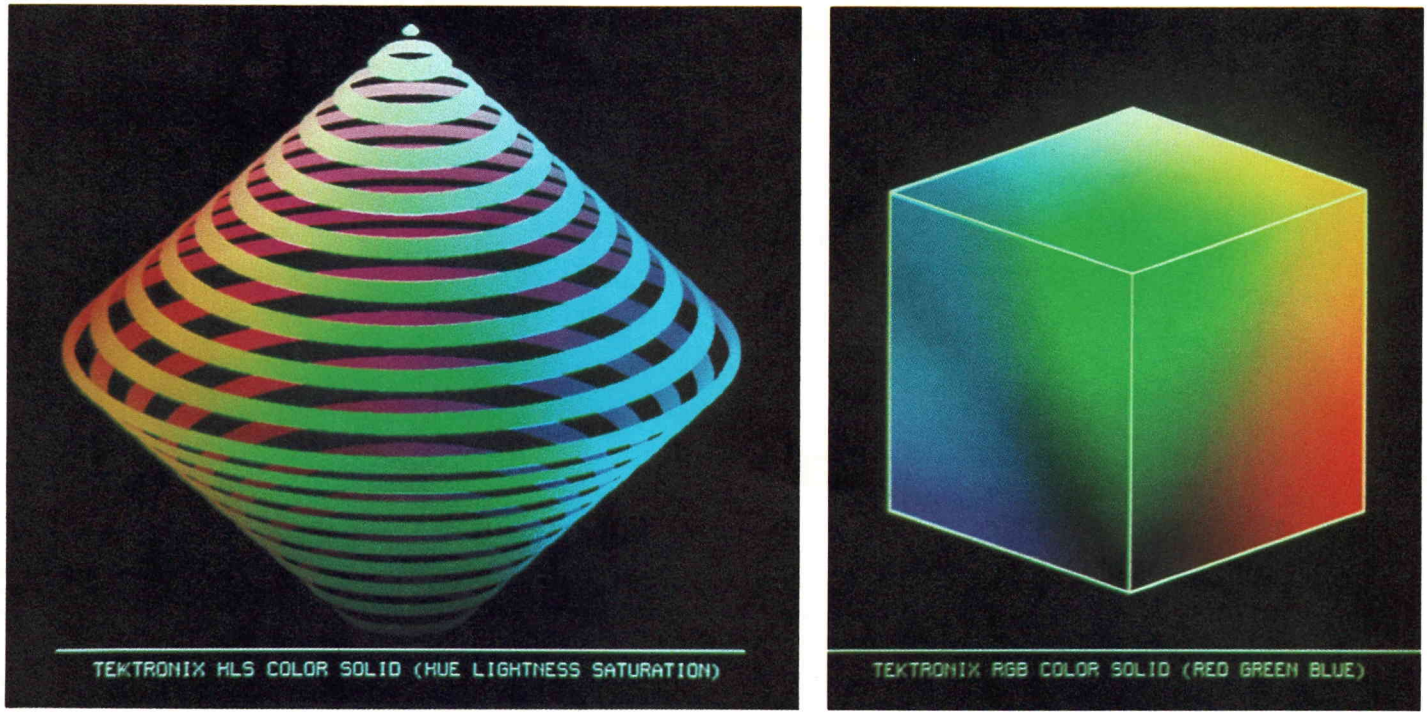


Figure 4. The RGB color discriptive system (right) and the HLS color discriptive system (left).

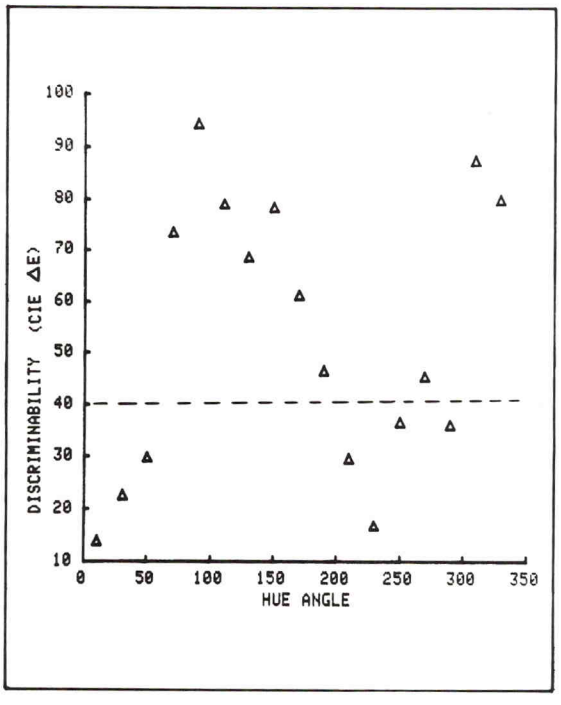


Figure 5. The discriminability of successive 20° hue segments on the 4115B.

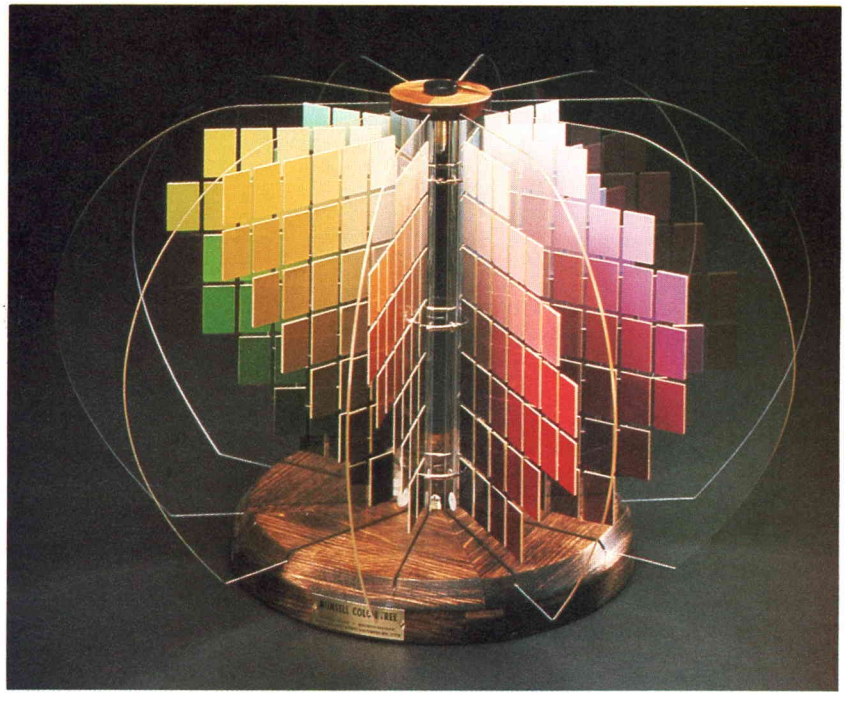


Figure 6. The Munsell color system.

of the additive relations of red, green and blue. The resultant *RGB System* specifies a trio of values ranging from 0 to 1 or 0 to 100% for each of the three primaries. The color relationships that result form a cube as shown in Figure 4. The RGB System is a simple and direct approach to the problem of color description that incorporates the principles of additive color mixture; that is, the user specifies color directly in terms of the electrical activity that the specification will induce.

For individuals understanding the nuances of additive color mixture, the RGB System is comfortable. But, most people are more familiar with subtractive color mixture in which a combination of blue and yellow produces green. That red and green should yield yellow is not obvious. Even for those individuals with a clear understanding of additive color, the location and proper specification of colors within the interior of the cube, when some real value for all three primaries is required, proves difficult. Imagine selection of a medium brown, for example. The greatest difficulty is encountered when a color of proper hue and brightness has been located and a shift in saturation is desired. Such as shift would require a disproportionate change in all three values.

The second widely used system of color description for visual displays is a direct application of the perceptual relations of hue, lightness and saturation. A conceptual diagram of the version of an *HLS System* introduced by Tektronix in 1977 is shown in Figure 4. The hues are conceptualized as a circle surrounding the mid point of the lightness scale. The hues are arranged so that complimentary colors are located across from each other on a circle. Hue specification is in degrees starting with blue at 0° and following a spectral order around the circle (magenta = 60°, red = 120°, yellow = 180°, green 240° and cyan 300°). Lightness and saturation are expressed as percentages along a continuum ranging from 0 to 100%. Thus a cyan of medium lightness and intermediate saturation would be specified as 300°, 50%, 75%.

The strength of the HLS System lies in the reliance on perceptual attributes and the ensuing relationships between colors. Again, the inexperienced user will have difficulty locating colors in the interior of the color cone. Whereas a change in saturation given appropriate hue and lightness was problematic for the RGB System, it is brightness that creates difficulty for the HLS System. Any increase in brightness is inexorably linked to a change in saturation.

Another problem with the HLS System is the lack of correspondance between the size of the perceived change in hue and the number of degrees of hue angle separating the hues. Figure 5 plots the discriminability between adjacent colors (ordinate) for hue angle on the 4115B. That is, the discriminability index of the *CIE Uniform Color Space* has been calculated for pairs of colors separated by 20° of hue angle. For a very clear color difference, a value of 40 units is desired. Colors differing by 20 units or less are subject to confusion.[1] Any color differing from its immediate neighbors by a given amount will differ from all other colors by at least that amount. As the figure shows, the simple division of the hue circle into 18 colors (360° ÷ 20°) yields a palette of only 10 hues which differ from all other hues by at least 40 units. As a matter of interest the default colors of the 4105/4107 and the first 16 colors of the 4115B default color set were selected to meet the criterion of a minimum difference of 40 units.

Recently a third notational system, the *Color Naming System (CNS),* has been proposed.[2] The goal of the system is to capitalize on common English names for colors. A basic set of seven generic names (red, orange, brown, yellow, green, blue and purple) along with white, black and gray are used. A total of 31 hue names are derived by using adjacent hue names together to indicate a hue halfway between two generic hues (i.e., yellow-green) and the suffix *ish* to denote quarter-way hues (i.e., yellowish-green). Five lightness levels can be specified (very dark, dark, medium, light and very light) and four saturation levels (grayish, moderate, strong and vivid). A complete specification might read *light, grayish, yellowish green.* Although this proposal capitalizes on familiar names, the names may have very different connotations for different people. The relationship between brightness and saturation is not clearly distinguished as terms such as moderate or medium could be equally applied to saturation or brightness.

Including brown as a generic hue name in the CNS System solves the specification difficulty encountered in RGB and HLS. Yet, because brown is very dark orange, the distinction between dark brown and very dark orange is not intuitively obvious. The authors of the system suggest ways of limiting these ambiguities; however, these reduce the simplicity of the model. Finally, the total number of specifiable colors is 627 while many graphics displays offer palettes of many more. For small palettes, however, specific color names can be very useful. The 4105 and 4107, for example, use a version of the color naming concept for specification of a fixed set of default colors.

Hard Copy Descriptive Systems. For any hard copy systems capable of varying the density of the inks through half-toning or variations in transmisivity, the obvious system of specification is in terms of *CMY* -- cyan, magenta and yellow. The principle is the same as the RGB System in that numeric assignments to each primary specify the colors. Thus a green would be 50% cyan, 0% magenta and 50% yellow.

A perceptual based system, known as the *Munsell System* is widely used in the printing industry. It was introduced in 1905 by the artist Alfred Munsell. The system has undergone a number of modifications in the ensuing years. Munsell's goal was to provide interrelated scales of hue, lightness and saturation in which the size of the perceptual change in each dimension was spaced in equal steps.

In its current version, published by the Munsell Color Company, the system consists of an ordered array of color swatches which vary in hue, lightness (called Value) and saturation (called Chroma). The lightness scale consists of nine visually equally spaced shades of gray bounded by white and black. Hue is represented by a circular order in which a total of 40 steps divides the circle into equal units. The dimension of saturation relates the scales of hue and lightness with a maximum of 16 gradations. The Munsell system reflects a number of the relationships previously discussed, in that the maximum level of saturation and the lightness level assigned to the purest hues is not the same for all hues. Figure 6 diagrams a three-dimensional representation of the system – a so-called color solid.

The outer circumference of the distorted globe indicates the relative position of the hues with the point of furthest protrusion representing the maximally obtainable saturation for the particular hue. The central axis presents the range of achromatic colors with white at the top. The cutaway panel shows a collection of samples for a specific yellow (denoted 5Y). The single swatch on the far right of this panel, marked 9/14, indicates the lightest (9/) and most saturated (/14) sample of the hue (5Y). Thus, this sample may be characterized as 5Y/9/14. Moving horizontally toward the central axis variations in saturation (9/12, 9/10, 9/8, etc.) are indicated with hue and lightness held constant. Vertical columns specify levels of lightness (9/6, 8/6, 7/6, etc.) with hue and lightness constant while diagonal excursions demark changes in both lightness and saturation for the specific hue under construction.

As indicated, the Munsell system succeeds, to a degree, in incorporating a number of features of color appearance. The observation that some hues are always less saturated than others and that differences in lightness exist between hues is incorporated into the system. By the same token, it fails to take other aspects into account, most notably the effect of brightness and the associated changes in hue and saturation as brightness increases or decreases. Further, the influence of context is not represented in which the appearance of a color varies as a result of surrounding colors.

A somewhat different approach to color description is taken in the *Swedish Natural Color System* developed by Hård.[3] This system places emphasis on qualitative variations in color sensation rather than on equally spaced visual scales as in the Munsell system.

The underlying concept in the Swedish Natural Color System is that all colors can be described in terms of three pairs of mutually exclusive polar coordintes: Black-White, Red-Green and Yellow-Blue. By mutually exclusive we mean that a given color can display some aspect of one of each pole of a pair (i.e., whitish-reddish-yellowish) but never both poles of one pair simultaneously (i.e., whitish-reddish-greenish). In other words, certain unique colors can appear as mixtures of one another but others cannot. Thus, the sensation of reddish-yellow can occur but not the color reddish-green or the color yellowish-blue. Note that this is the way in which the human visual system encodes color.

Just as with the Munsell System, the Swedish Natural Color System includes a consideration of intrinsic lightness and saturation differences and fails to incorporate brightness and contrast effects. Additionally, the Swedish Natural Color System describes color relations in terms of mutually exclusive colors. Such a concept is unusual and requires some careful consideration of the logical consequence of relating colors.

Color Description and the Human Interface

Over the past few years Tektronix has been conducting studies aimed at evaluating the various color descriptive systems. The goal, of course, is to develop the best system in terms of the ease with which an operator is able to locate and produce desired colors. In one series of experiments we compared the RGB System, HLS System and a version of the Swedish Natural Color System as a means of specifying colors on a video display. A panel of a particular color was presented accompanied by an adjacent panel which could be changed by the observer via one of the three systems. We counted the number of steps the subject needed to perfect a match. As one might expect, the outcome depended upon the individual's experience with color systems. That is, those who had already used RGB or HLS tended to be much more efficient in the known system. For inexperienced subjects the HLS system proved the easiest followed by the Swedish System. RGB was clearly the most difficult.

The HLS System appears to be easier to use by naive users. Yet all our subjects were disturbed by the fact that the magnitude of experienced color change frequently did not correspond to the size of the numeric change in the specification system. In attempting to match a green, for example, subjects complained that a large number of hue or saturation steps were required in order to produce a noticeable color change while in other areas, such as yellow-orange, very few steps induced large color variations. The problem, of course, lies in the nonlinear nature of human perception and the fact that the implimentation of the HLS System does not take such nonlinearities into account.

Tektronix is currently developing a perceptually based color interface. Our goal is that the implementation algorithm linking the operator's input to the drive levels of the display electron guns or the frequency of dots of ink must include the nonlinearities of human color perception. This means that the algorithm must provide an invisible link. Each specification of the operator should result in a color or color change perfectly in line with his or her expectations. A first application of this work occured in the layout of colors in the default color table of the 4115B.

Starting with default color number 16 each successive set of 16 colors corresponds to a perceptually based sequence in which all colors are separated by an equal number of discriminable hue steps. Thus, if the operator chooses such a set of 16 colors, they will form a progression of hues circling the spectrum in equal units of perceived change. The specification of such a color set was possible as a result of color matching experiments in which a Munsell color sample was mounted in front of a display adjacent to a video sample.[4] Subjects adjusted the color of the video sample to obtain a match. By selecting samples throughout the visual spectrum, a visual display version of the Munsell color space could be developed. This perceptual color space, we feel, will form the basis of a color descriptive system which will allow the link between expectation and event.

Linking Hard Copy to Displays

Without a doubt the capabilities of color copiers will be expanded to increasingly larger color palettes. By nature of the fact that hard copy color is by and large subtractive while display is additive, no obvious algorithm exits to translate from one medium to the other. Now colors are related between display and hard copy by a look-up table that, due to the limited color copying capability, contain only a few entries. In some cases no attempt to relate the colors is made at all.

The communality of hard copy and display copy will require a common notation system. The most obvious candidate for such a descriptive system is the Munsell System. The results of our matching experiments with Munsell samples provide the opportunity to produce visually similar colors on a display and color hard copy. The first implementation of these results is in the 4115B and 4692 color ink jet copier. The printed colors and default colors have been perceptually matched so that a palette of 256 colors results. Naturally as the color capabilities of the hard copy increase we will extend the matching work to include compatible display and hard copy.

Using Color Effectively

The current knowledge of human mental processes is lagging far behind the data base of physiology and perception. Yet, the understanding of some cognitive processes allow the rudimentary beginnings of a cognitive science of color.

Don't overuse color. The section in the previous issue of *TEKniques* on perceptual principles concluded with the comment to use color sparingly. The importance of this concept bears repeating. Cognitive scientists have shown that the human mind experiences great difficulty in maintaining more than 5–7 elements simultaneously. If each color is to convey a specific meaning, then limit the number to about 6 clearly discriminable colors.

Be aware of the nonlinear color manipulation in video and hard copy. At this point it is not possible to provide the user with an algorithm which translates the physical colors of an imaging device into a perceptually structured set of colors. It is important to be aware that the video and hard copy systems are not designed with human perception in mind. As a result the simple problem of selecting a set of 18 mutually discriminable colors cannot be solved by dividing the hue circle into 18 equal parts as was shown in figure 6.

Group related elements by common background color. Cognitive science has advanced the notion of set and preattentive processing. In this context, one can prepare or *set* the user for related events by using a common color code. A successive set of images can be shown to be related by using the same background color. These colors can be very unobtrusive such as dark red, blue or brown and still serve the purpose of grouping.

Similar colors connote similar meaning. Elements that are related in some way can convey that message through the degree of similarity in hue. The range of color from blue to green is experienced as more similar than the gamut from red to green. Along these same lines, saturation level can be used to order displayed information. In an alphanumeric array, a heading might appear in green with information belonging to the headline in varying levels of desaturation as a function of the strength of the relationship.

Brightness and saturation draw attention. The brightness and most highly saturated area of a color display will immediately draw the viewer's attention. Thus, one should use these two attributes to lead the viewer to the portion of the display to be viewed initially.

Link the degree of color change to event magnitude. As an alternative to bar charts, the color graphics display can portray changes in magnitude with progressive steps of changing color. A desaturated cyan can be made to increase in saturation as the graphed elements increase in value. Progressively switching from one hue to another can portray a magnitude reaching dangerous proportions. A green segment progresses into yellow, orange and finally red at a given level as is portrayed in the profit/loss statement shown in Figure 7. The method of color coding event magnitude is particularly useful for *dynamic graphics* in which the impact of a specific change to the data base can be graphically depicted as a change in the graph's structure and, hence, color relations.

Order colors by their spectral position. In order to increase the number of colors on a display, a meaningful order to the colors can be imposed. The most obvious order is that provided by the spectrum with the mnemonic ROY G BIV (red, orange, yellow, green, blue, indigo, violet). In fact, a recent study by Fromme at Bell Labs showed that people see a spectral order as a natural one and select red, green and cyan as the intuitive choices for layers one, two and three of a multi-layer circuit board.[5]

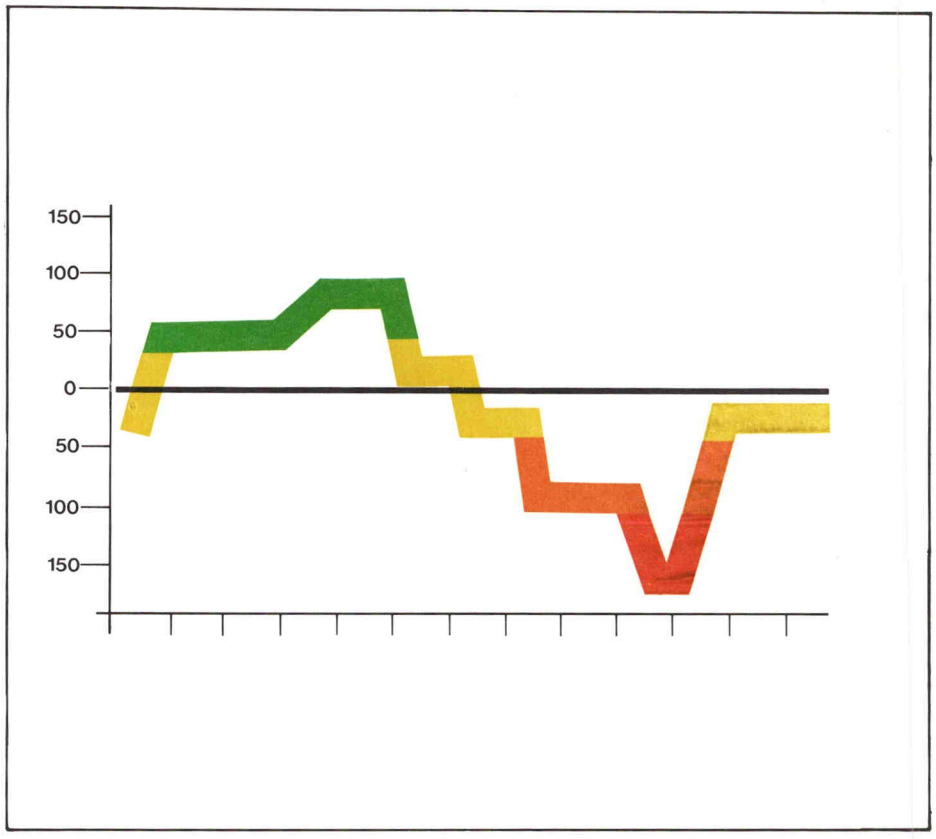


Figure 7. A color coded profit and loss chart.

Warm and cold colors should indicate action levels. Traditionally the warm (long wavelength) colors are used to signify action or the requirement of a response. Cool colors, on the other hand, indicate status or background information. Most people also experience warm colors advancing toward them – hence forcing attention – and cool colors receding or drawing away.

From the discussion in this note it should be clear that the cognitive aspects of display color are not yet well understood. Progress is being made in developing models of the complex color space which reflect our cognitive needs. As for the fully effective use of color as a means of tapping the way we think, much needs to be done.

References

1. R.C. Carter, "Visual Search with Color." *Journal of Experimental Psychology* 8 (1982): 127–136.

2. T. Berk, L. Browston and A. Kaufman, "A New Color Naming System for Graphics Languages," *IEEE Computer Graphics and Applications* (May 1982): 37–44.

3. A. Hård and L. Sivik, "NCS-Natural Color System: A Swedish Standard for Color Notation," *Color* 6 (1981): 128–129.

4. P. McManus and D. Mead, "Matching Video and Hard Copy Color," *SID Digest of Technical Papers* 15 (1984): 60–61.

5. F. Fromme, "Incorporating the Human Factor in Color CAD Systems," *IEEE Proceedings of the 20th Design Automation Conference* (1983): 189–195.

High Resolution and Command Set in New Tektronix 4106 Color Terminal

Tektronix has added a new member to the 4100 Family – the 4106 Computer Display Terminal.

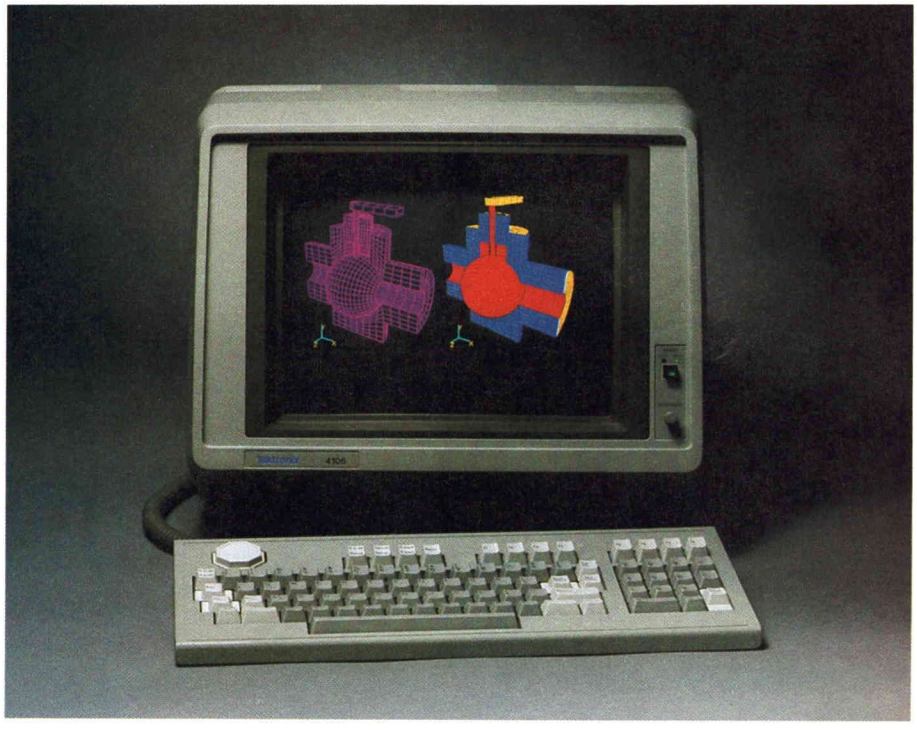
As the next step up from the 4105*, the 4106 gives lots of added value.

- Increased resolution (640 × 480)
- Sixteen simultaneous colors in the graphics area.
- Two additional RS-232 ports for peripherals.
- The full 4107 command set, including:
  - stroked graphtext
  - user-definable graphtext
  - multiple views
  - segments
  - surfaces
  - 4110-type GIN (inking, rubber-banding, gridding, user-definable cursor)
  - tablet support.

The 4106 differs from the next member of the 4100 Series, the 4107, primarily in the amount of local memory. When the settings are left at their factory defaults, the 4106 can hold:

65 simple segments**
or
one segment of 4000 short vectors***
or
up to 200 user-defined characters for graphtext.

Keep in mind that these numbers are not exact, but good approximations. Each figure is a rough maximum and is mutually exclusive. (You could have a segment with 4000 short vectors or 65 simple segments, but not both).



The Tektronix 4106 Color Graphics Terminal combines high resolution and versatile command set with a low price.

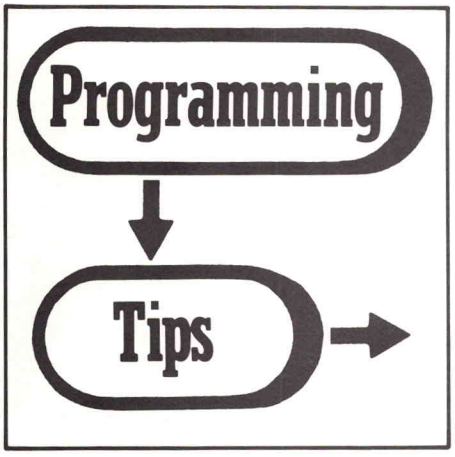
Several terminal features draw from a common memory pool. Unless an application is quite unusual, the 4106 should have plenty of memory for macros, views and other features.

Applications where segments are seldom or lightly used, but which require 4107 display quality in a lower-priced terminal, will find the 4106 offers an attractive alternative. And, a kit is available to provide it with additional memory if needed at a later date.

* The 4105, 4107 and 4109 terminals were introduced in *TEKniques* Vol. 7 No. 2.

** A simple segment is a line with less than eight vertices or a panel with less than six vertices.

*** A short vector has a combined change of x and y or less than 128 addressable points (not pixels).



410X and Epson Printers

by Peter Keep
Tektronix, Inc.
Wilsonville, OR

When using a 4105/07 with an Epson printer, you will always get an extra <LF> with every <CR>. This is because the Centronics standard, incorporated into the 410X terminals, specifies line 14 to be 0 volts. Epson uses this line, when 0 volts, to add an <LF> to each <CR>. The switches on the Epson do not help.

To overcome this, you can open line 14 on your printer cable at the printer end. This cable will then work with the 4691/92/95 and the Epson printers.

Enhancing 4014 Emulation on 4100 and 4110 Terminals

by Bill Bache
Tektronix, Inc.
Boston, MA

Several Computer Aided Design packages take advantage of a special characteristic of the 4014: namely, the brightness of the writing beam as vectors are drawn. This is often used, for example, to indicate which part of a drawing has been selected for editing. The software redraws that part of the drawing, and the user can tell from the brightness during redraw whether the correct part has been selected.

The function keys of the 410X or 41XX terminals can be programmed to allow the user to change the line color and/or line styles locally at any point during the program. Prior to selecting a part of the drawing, for example, the user would change the current line color by pressing a function key. Then, when the software redraws the part, it would appear in a different color. Furthermore, the user could continue to change the current line color when working with that part – such as clipping lines, for example. Each new redraw done by the software package can be made to appear in a different line color (and/or line style), within the limits of the terminal's colors and the number of function keys dedicated to this purpose.

For device drivers that don't take full advantage of the features in the hardware, this technique offers an alternative that requires absolutely no modifications to the host software and does not change the functional characteristics of the host software, as long as the user chooses an appropriately "quiet" moment at which to change the line color. The technique has been tested with EUCLID and with UNIGRAPHICS and worked well in both instances.

Example

The following commands could be entered in SETUP mode to program function keys F1 to F8 to set the current line color index to 0 to 7, respectively. Index 1 is the default index for 4014 emulation. Index 0 is the background color and could be used to erase part of a drawing.

```
DEFINE F1  /(Ctrl-P)(ESC)ML0(Ctrl-P)/
DEFINE F2  /(Ctrl-P)(ESC)ML1(Ctrl-P)/
DEFINE F3  /(Ctrl-P)(ESC)ML2(Ctrl-P)/
DEFINE F4  /(Ctrl-P)(ESC)ML3(Ctrl-P)/
DEFINE F5  /(Ctrl-P)(ESC)ML4(Ctrl-P)/
DEFINE F6  /(Ctrl-P)(ESC)ML5(Ctrl-P)/
DEFINE F7  /(Ctrl-P)(ESC)ML6(Ctrl-P)/
DEFINE F8  /(Ctrl-P)(ESC)ML7(Ctrl-P)/
```

Notes:

(1) There should be no spaces in the string between the slashes in each DEFINE command.

(2) There must be a space separating Fn from the first slash in each DEFINE command.

(3) (Ctrl-P) and (ESC) are the Control-P and Escape characters, respectively.

(4) These macros could be saved to a disk file on a 4110 terminal so equipped, and then reloaded from the disk with a single command prior to a CAD software session.

(5) On a 4100 terminal, a single nonvolatile numeric macro could be created which, when invoked, would define the function keys.

(6) The user need not switch to Setup mode in order to use the function keys as defined above.

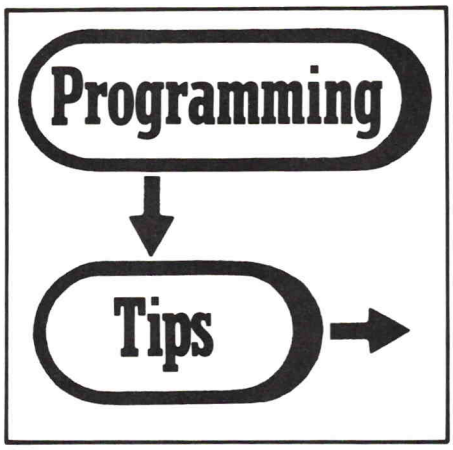
4100 Cursorkeymode and IBM Series 1 VM/CMS Interfaces

by Bill Bache
Tektronix, Inc.
Boston, MA

One method that IBM VM/CMS installations use to provide full-screen support for dial-up ASCII terminal users is through Yale interface software running on a Series 1 computer. If you are using a Tektronix 4100 Series Terminal, in VT100 emulation mode in such a system, you might have discovered, after logging off, that function keys F1 to F4 appear to have been redefined. Regardless of whether CODE is set to TEK or to EDIT, and even when KEYEXPAND is set to YES, keys F1 to F4 expand as (ESC)OA, (ESC)OB, (ESC)OD, and (ESC)OC, respectively. If these keys had been defined differently before the session, those definitions appear to have been lost.

The reason is that the Yale software issues a SET CURSOR KEY command to the "VT100" during the logon procedure and keys F1–F4 (which correspond to the VT100's cursor control keys) will not expand in SET mode. The macro definitions are still there, as a check with MACROSTAT in setup mode will confirm.

To recover the macros for these keys, simply specify CURSORKEYMODE NO in SETUP mode. This is equivalent to issuing a RESET CURSOR KEY command and, in conjunction with KEYEXPAND YES, will give you back your function key definitions.



CLOSE on 4052/4054 in Non-Header Mode

by Harold Vandeventer
Kansas State University
Manhattan, KS

If a program issues a WRITE or PRINT command (to tape) when in non-header mode (PRI @33,0:0,0,1), be sure to insert a CLOSE command immediately after it if the program will ever be run on a 4052/4054. This has been mentioned in earlier Programming Tips in *TEKniques,* but is so critical, it bears repeating.

Simultaneous GPIB and RS-232 Communication on 4050A Series

by Jim Gish
Tektronix, Inc.
Wilsonville, OR

The 4052A and 4054A can perform significantly faster than the 4052 or 4054 over the General Purpose Interface Bus (GPIB) due to special instructions that send information in blocks of characters as opposed to single characters. These new GPIB instructions, however, can interact with any incoming data from a host. Portions of the incoming data can be lost or one character can be replaced by a copy of the character that precedes it.

This interaction occurs because the 4052A or 4054A is blind to characters coming from the host while it is transmitting data over the GPIB. These side effects can be eliminated by reducing the number of characters sent over the GPIB at one time. The GPIB transfer should last no longer than it takes to receive one character from the host. Isolating the GPIB transmission and host communication so that they do not occur at the same time will also eliminate the problem. The former technique is very useful when dealing with ASCII data since it is easy to break a large data string into smaller chunks. If the host supports DC1/DC3 flagging, the latter technique is useful. If the host does not support any flagging, a form of software flagging should be implemented. The following example illustrates how a portion of a program using the DC1/DC3 flagging might work.

This interaction between the GPIB and RS-232 communication does not exist in 4054s or 4052s with Version 5.1 firmware because they send GPIB information a character at a time, and do not have the specialized instructions the 4052A and 4054A have.

Writing data to other non-GPIB peripherals, such as Extended Memory or the internal tape drive, is also not a problem because the GPIB is not involved.

```
1000 REM SET S$ TO A DC3 (STOP) AND T$ TO A DC1 (START)
1010 S$=CHR(19)
1020 T$=CHR(17)
1030 REM HOST TO DISK TRANSFER - HOST SUPPORTS DC1/DC3 FLAGGING
1040 REM READ FROM HOST, THEN SEND A DC3 TO STOP TRANSMISSION
1050 INPUT @40:A$
1060 PRINT @40:S$
1070 REM CHECK FOR END OF TRANSMISSION
1080 IF A$="END" THEN 1170
1090 REM A WAIT MAY BE NECESSARY IF THE HOST DOESN'T STOP
1100 REM IMMEDIATELY UPON RECEIPT OF A DC3
1110 CALL 'WAIT',0
1120 REM WRITE HOST DATA TO DISK AND RESTART HOST COMMUNICATIONS
1130 WRITE #1:A$
1140 PRINT @40:T$
1150 REM GO BACK TO READ MORE FROM THE HOST
1160 GO TO 1050
1170 END
```

Use MEM Statement Before Calling Editor ROM

by T.I. Barry
National Physical Laboratory
Teddington, Middlesex

The MEM function of the 4050 Series Desktop Computers forces the BASIC interpreter to combine the free memory into one contiguous block. This is necessary for the 4052R06 Editor ROM. The INIT and DELETE statements do not provide the compression function. Consequently, issue the MEM command before calling the Editor ROM.

IDG Program Exchange

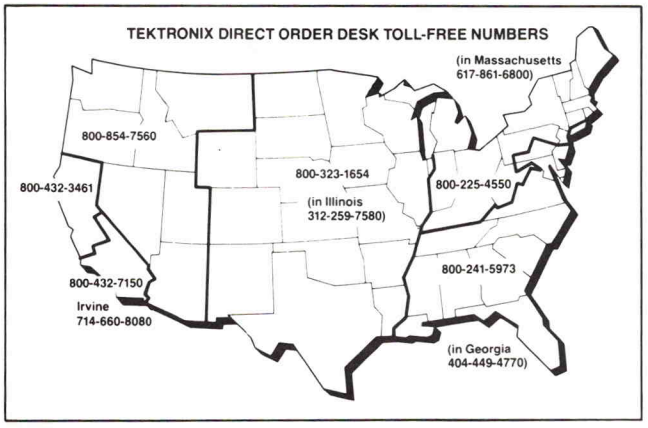
The IDG Program Exchange is a central location of user software for Tektronix Graphics Display Products. As programs are received, they are collected into packages according to the product they support. The packages are available to all uses through exchanges for program contributions or for a nominal charge.

Program Contributions

Contribute one program to the Program Exchange and receive the package of your choice in exchange. To receive documentation instructions and forms, contact the Program Exchange serving your area. In the U.S., you may TWX: 910-467-8708 or TLX: 15-1754.

U.S. Orders

Order IDG Program Exchange packages through the toll-free number of Tektronix Central Parts Ordering. The following map delineates the geographical regions and the toll-free number serving each region.



Call the number serving your area and give the customer service representative the nine-digit part number and name of the Program Exchange package you wish. If you have any questions, call your local Tektronix Field Office. Effective July 1, 1984, each Program Exchange package will cost $95 (U.S. dollars). Manuals, ordered separately, will cost $15 (U.S. dollars) each. (Note: The minimum acceptable Tektronix order is $25.00.)

Orders Outside U.S.

To order a copy of the catalog, or to order a package, contact the local Tektronix sales office or the Program Exchange serving your area. See Program Exchange Addresses section of *TEKniques*.

4000 Series Graphics Terminals

The 4010, 4020 and 4100 Series programs are packaged and nomenclated with the appropriate prefix and disk number.

Each package includes media with the source code together with the supporting documentation; listings are not included. Documentation may be purchased separately.

A 4000 Series catalog will be published when a sufficient number of packages are collected.

Package Title	Documentation Part #	Package Part #
4110 Local Programmability		
4110 LP Program Exchange Disk 1		062-6955-01
4110B LP Basic Slidemaker	062-7740-00	062-7740-01
4110B LP TekniCAD Demo	062-7679-00	062-7679-01

Software Support Category C

The program material contained herein is supplied without warranty of any kind, and without any representation regarding quality, performance or suitability. TEKTRONIX specifically disclaims any implied warranties of merchantability of fitness for a particular purpose. Software support is TEKTRONIX Category C: Software is provided on an "as is" basis.

Package Title	Documentation Part #	Package Part #
4115		
VAX/VMS Driver for 4115 DMA (Option 3A)	062-7305-00	062-7305-01
VAX/UNIX (Berkeley) Driver for 4115 DMA (Option 3A)	062-7327-00	062-7327-01
4170 Local Programmability		
4170 MEMDRIVE	062-7741-00	062-7741-01
4170 Basic Slidemaker	062-7739-00	062-7739-01
4170 CGRAPH	062-7742-00	062-7742-01
4170 Color Drawing Board	062-7766-00	062-7766-01

4050 Series Desktop Computers

The 4050 Series programs included in the IDG Program Exchange prior to September 1981 are packaged and nomenclated by function. Those programs accepted after September 1981 are packaged and nomenclated with the Volume and Number of the corresponding issue of *TEKniques* in which the package was announced.

Each package includes the source code on tape or disk (T = tape; D = disk) together with the supporting documentation; listings are not included. Documentation may be purchased separately.

The IDG Program Exchange catalog contains the abstracts describing the programs in each package along with representative output in most cases. The catalog part number is *062-6343-00.*

Package Title	Documentation Part #	Package Part #
Business Aids T1	062-5987-00	062-5987-01
Business Aids T2	062-5988-00	062-5988-01
CAD T1	062-5976-00	062-5976-01
CAD D1	062-5977-00	062-5977-01
Character Generator T1	062-5951-00	062-5951-01
Education/Research T1	062-5982-00	062-5982-01
Education/Research T2	062-5983-00	062-5983-01
Electrical Engineering T1	062-5978-00	062-5978-01
Graphing T1	062-5964-00	062-5964-01
Graphing T2	062-5965-00	062-5965-01
Graphing T3	062-5966-00	062-5966-01
Graphing D1	062-5967-00	062-5967-01
Graphing D2	062-5968-00	062-5968-01
Interfacing T1	062-5984-00	062-5984-01
Mapping T1	062-5980-00	062-5980-01
Mechanical Engineering T1	062-5979-00	062-5979-01
Programming Aids T1	062-5971-00	062-5971-01
Programming Aids T2	062-5972-00	062-5972-01
Project Aids T1	062-5985-00	062-5985-01
Project Aids D1	062-5986-00	062-5986-01
Recreational Plots T1	062-5989-00	062-5989-01
Slidemaker T1	062-5962-00	062-5962-01
Slidemaker D1	062-5963-00	062-5963-01
Text Processing T1	062-5969-00	062-5969-01
Text Processing D1	062-5970-00	062-5970-01
Utilities T1	062-5974-00	062-5974-01
Utilities D1	062-5975-00	062-5975-01
Tekniques Vol. 5 No. 4 T1	062-5981-00	062-5981-01
Tekniques Vol. 6 No. 1 T1	062-6443-00	062-6443-01
Tekniques Vol. 6 No. 1 D1	062-6442-00	062-6442-01
Tekniques Vol. 6 No. 2 D1	062-6515-00	062-6515-01
Tekniques Vol. 6 No. 3 D1	062-6516-00	062-6516-01
Tekniques Vol. 6 No. 3 T1	062-6514-00	062-6514-01
Tekniques Vol. 6 No. 4 T1	062-6704-00	062-6704-01
Tekniques Vol. 7 No. 1 D1	062-6715-00	062-6715-01
Tekniques Vol. 7 No. 3 DI	062-7276-00	062-7276-01
Tekniques Vol. 7 No. 3 TI	062-7275-00	062-7275-01
Tekniques Vol. 7 No. 4 T1	062-7455-00	062-7455-01
Tekniques Vol. 7 No. 4 T2	062-7456-00	062-7456-01
Tekniques Vol. 8 No. 1 T1	062-7611-00	062-7611-01
Tekniques Vol. 8 No. 1 D1	062-7612-00	062-7612-01

411X TekniCAD Demo
Part #062-7679-01

Author: Tektronix, Inc.
Wilsonville, OR
Equipment: 411X Terminal
1 or 2 Flexible Disk Drives
Memory Requirement: 512Kb

This package includes a substantial portion of the new Tektronix Computer Aided Drafting (TekniCAD) software that is a precision, general-purpose drawing tool. The package provides a unique opportunity to "test drive" the new software package before buying it. More complete information on TekniCAD's capabilities can be found in *TEKniques* Vol. 7 No. 4, and in the TekniCAD User's Manual, part number 070-5013-01.

A tutorial session introduces TekniCAD's features. It contains 56 pages of instruction and takes about 60 to 90 minutes to complete the self-paced learning exercise. A sample drawing can be displayed or a custom drawing can be created.

411X LP Basic Slide Maker
Part #062-7740-01

Author: Systems Analysts
Tektronix, Inc.
Equipment: 4113B or 4115B Terminal
Local Programmability
Optional-4662/3 Plotter
469X Color Copier
3PPI
Memory Requirement: 256K
Files: 1 FORTRAN Source
2 Documentation
11 Font
1 FORTRAN LTL

This program helps you prepare slides or flowcharts. Once completed, the slide can be plotted to a 4662/3 plotter or copied to a 4691 or 4692 Color Copier. Copies can be made on paper or transparency media.

4170 MEMDRIVE
Part #062-7741-01

Program 1

Title: MEMDRIVE
Author: John McGue
Tektronix, Inc.
Wilsonville, OR
Equipment: 4170 GPU and 410X Terminal
Files: 13 ASCII files (used for installation)
1 Binary Program

This utility creates a pseudo disk drive in memory. Since access to memory is much faster than access to a physical disk, system performance can be improved by placing frequently used files on the MemDrive.

Program 2

Title: RAM
Author: John McGue
Tektronix, Inc.
Wilsonville, OR
Equipment: 4170 GPU and 410X Terminal
Files: 1 Binary Program

This utility tells the user how much memory is available for use by transient programs and the paragraph address where it starts.

Program 3

Title: UMODEM
Author: Lauren Weinstein
Files: 1 ASCII Program

This file is a MODEM86 compatible C program which runs on UNIX. It can be placed on a host machine and used to upload/download files to and from a 4170.

Program 4

Title: CPMUTL
Author: Aaron Wohl
Files: 1 ASCII Program

This file is a MODEM86 compatible C program which runs on version 7 UNIX. It can be placed on a host machine and used to upload/download files to and from a 4170.

4170 Basic Slide Maker
Part #062-7739-01

Author: Systems Analysts
Tektronix, Inc.
Equipment: 4170 Graphics Processing Unit
4106, 4107 or 4109 Terminal
Optional-4662 Plotter
469X Color Copier
Memory Requirement: 256K
Files: 1 FORTRAN Source
2 Documentation
12 Font
1 FORTRAN LTL

This program helps you prepare slides or flowcharts. Once completed, the slide can be plotted to a 4662, 8 pen plotter, or copied to a 4692 or 4695 Color Copier. Copies can be made on paper or transparency media.

4170 CGRAPH Library
Part #062-7742-01

Author: G.W. Hicks
Tektronix, Inc.
Wilsonville, OR
Equipment: 4170 Graphics Processing Unit
4105/4106/4107 or 4109 Terminal
C-86™ Version 1.33 "C" Compiler
Memory Requirement: 256K

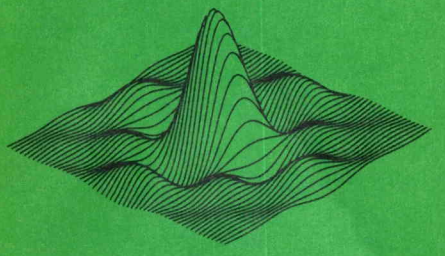
The CGRAPH Library is intended to give the "C" applications programmer a set of callable functions similar to the Tektronix DTI (FORTRAN) routines. This library of 148 routines provides a direct interface to the terminal's firmware.

4170 Color Drawing Board
Part #062-7766-01

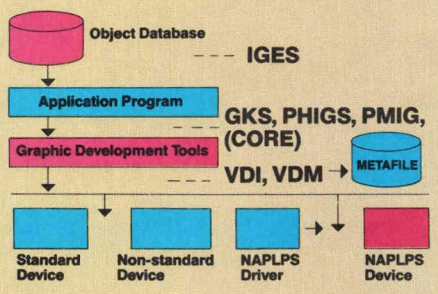
Author: Barry Lewine
Tektronix, Inc.
Wilsonville, OR
Equipment: 410X Terminal
4170 Graphics Processing Unit
Optional-4957 Tablet
-4695 Color Copier
Memory Requirement: 256K
Files: 8 Program
4 Data

You can create color pictures using this program without having to write a complex graphics program. Color Drawing Board permits quick pictures to depict artists' concepts, architectural renderings, unique graphs, or even schematics. Its text facilities produce smart presentation aids. A separate article in this issue of *TEKniques* illustrates some of the commands and their functions.

Tekniques

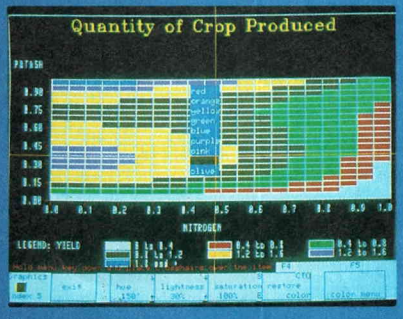


4050 Series

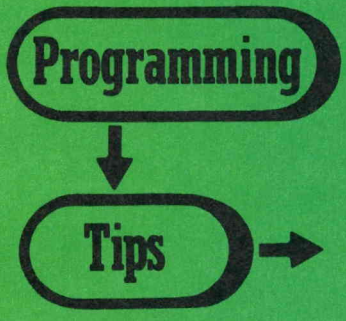


Special

4110 Series



4100 Series



Programming Tips

Program Exchange

Tekniques keeps you up to date... and it won't cost you a penny.

Name_____ Date_____

Title _____

Company _____

Department _____

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City/State/Zip _____

What Tektronix products do you have (check all that apply)

☐ 4050 Series ☐ 4010 Series ☐ 4110 Series ☐ 4100 Series

For which graphics applications are/will you be using Tektronix products?

☐ CAD/CAM (electrical engineering)
☐ CAD/CAM (mechanical engineering)
☐ CAD/CAM (architectural engineering)
☐ Mapping/cartography
☐ Scientific/technical data analysis
☐ Business/management
☐ Other_____

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Wilsonville, Oregon 97070

IDG Graphics Displays and Computing System Publications

The following is a summary of all current manuals related to IDG products.

The manuals may be ordered through the Tektronix Central Parts Ordering office serving your area. See page 0 for the map and numbers.

Key to Titles

Operator's = operation instructions for hardware product

Service = maintenance information

Instruction = operation and maintenance combined

User's = operation instructions for software product

Reference = programmable features

4010 Series Computer Display Terminals

Interface

021-0371-00 DC1/DC3 Protocol Generator Instruction	061-2868-00

4100 Series Computer Display Terminals

Standard

4105 Operator's	070-4527-01

Miscellaneous

410X Series Mod RJ (Joystick) Instruction	061-2771-02

4110 Series Computer Graphics Terminals

Service

M4115B	070-5007-01

Options

4110F09 4690 I/F Instruction Sheet	070-4558-01
4100F10 3PPI Instruction Sheet	070-4203-01
4100 Opt. 19 4695 I/F Instruction	070-5199-00
4100 Opt. 19 4695 I/F Service	070-5200-01
4110 119-0977-01 Flex Disk Drive Instruction	070-2504-02
4100F42 Opt. 03 4115B Single Flex Disk Drive Instruction	070-4898-01
4110F46 Opt. 1 M4115B Hard Disk w/Controller Instruction	070-5168-00
4110F46 Opt. 2 M4115B Hard Disk w/o Controller Instruction	070-5118-00
4110F46 Opt. 3 M4115B Hard Disk w/Add-on Kit Instruction	070-5169-00
4110F52 Second Flex Disk Drive Instruction	070-5101-00
4100F53 Second Hard Disk Installation Instruction Sheet	070-5119-00

Miscellaneous

M4115B Mod APL Keyboard Installation	061-2951-00

PLOT 10 Software

4010B06 Easy Graphing II

I/O Routines Installation Guides

Opt. 10 IBM 360/370 w/TSO	070-4572-01
Opt. 12 DEC System 10120 w/TOPS	070-4574-01
Opt. 13 Univac 1100	070-4575-01
Opt. 14 Honeywell 6000	070-4576-01
Opt. 15 CDC w/NOS 1.4	070-5096-00
Opt. 17 DEC VAX w/VMS	070-4579-01
Opt. 18 IBM VM/CMS	070-4580-01
Opt. 19 Prime 350-380	070-5097-00

4010C01 Interactive Graphics Library

Installation	070-4509-02
Special Feature Escapes User's	070-4484-01

4000P70 Graphical Kernel System

User's	070-4994-00
Reference	070-4993-00
I/O Routines Installation Guides VAX/VMS	070-5018-00

4100P50 Vector Raster Utility

User's	070-4834-00

Local Programmability

4100P10 CP/M-86 Basic Notes User's	070-5110-00
4100P22 SuperCalc^2 Instruction	070-4747-01
4100P24 InfoStar Instruction	070-4744-00
4100P25 DR Graph Instruction	070-4745-00
4100P27 WordStar Instruction	070-5001-01
4100P30 PLOT 10 TekniCAD User's	070-5013-01
4100P72 PLOT 10 TCS for 411X Instruction	070-4814-00
4100P72 PLOT 10 TCS for 4170 Instruction	070-5175-00
4100P73 PLOT 10 IGL Instruction	070-4896-00

4600 Series Hard Copy Units

Standard

4635 Imaging Recorder Instruction	061-2912-00
4691 Operator's Guide	062-1508-01

Options

4691 Opt. 2 4-Channel Multiplexer Instruction	070-5004-00
4695/4695P Opt. 1 User's	070-5124-00

Note: Users who belong to the Software Subscription Service automatically receive updates to their manuals along with the new code.

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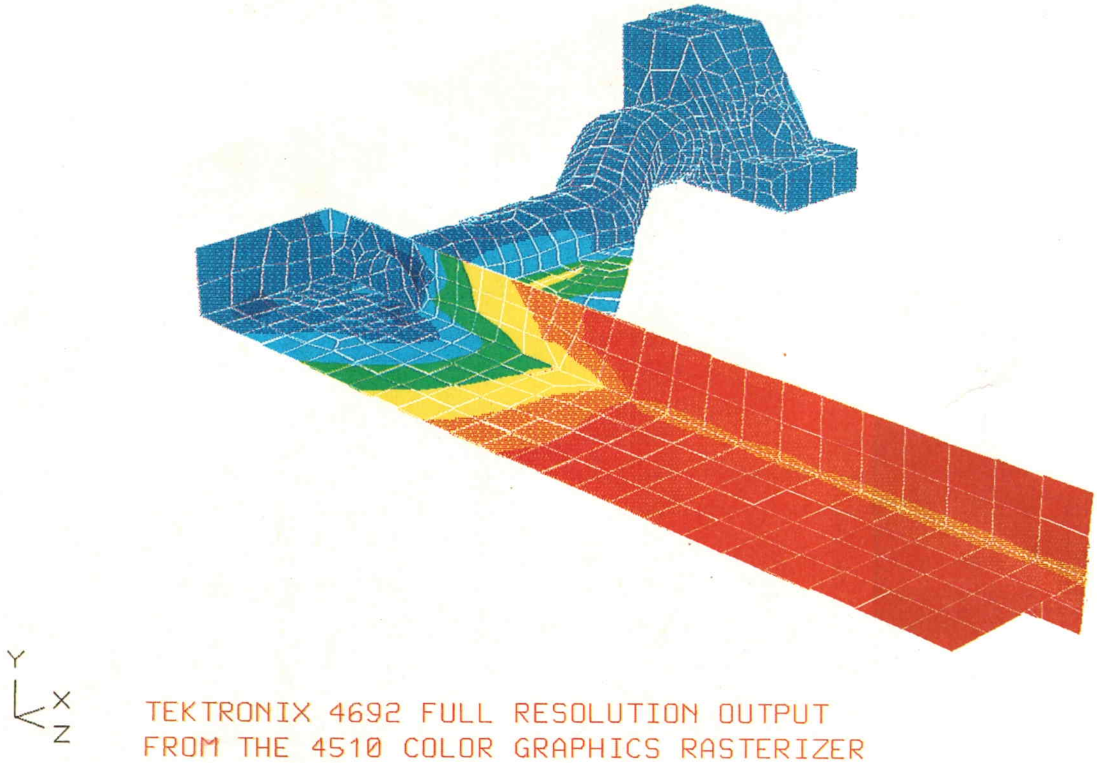

Coupling a Tektronix 4692 Color Copier with the Tektronix 4510 Color Rasterizer permits the host or terminal user to take full advantage of the high resolution of the copier and the color palette of the Rasterizer.

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