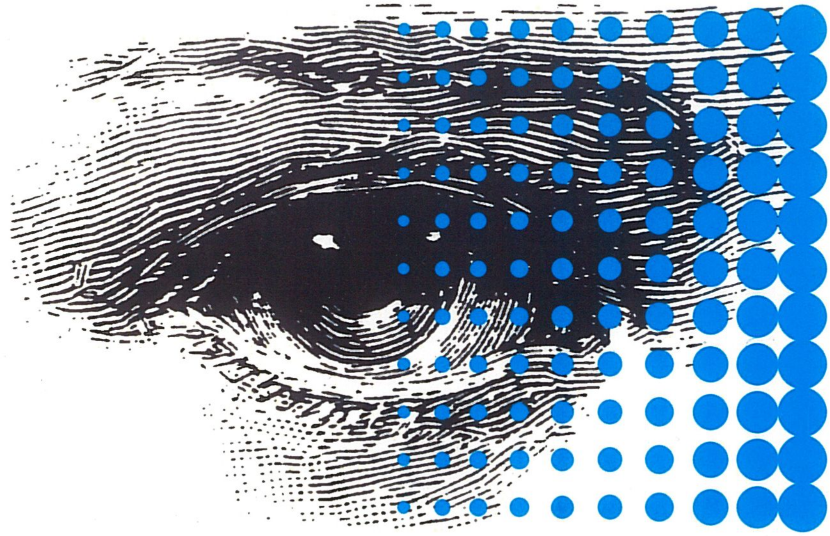
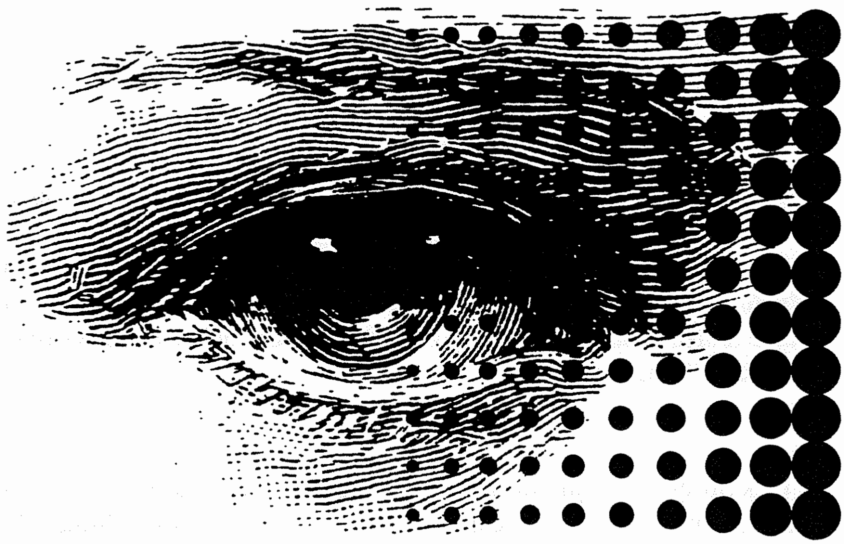


DISPLAYMate

VIDEO DISPLAY UTILITIES

SONERA
TECHNOLOGIES



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DISPLAYMate

VIDEO DISPLAY UTILITIES

REFERENCE MANUAL
VERSION 1

SONERA™
TECHNOLOGIES

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Contents at a Glance

Table of Contents

Part II Everything You Need To Know About Video Systems

About Sonera Technologies

Since 1984 Sonera Technologies and its sister company Beta Data have been providing quality computer education and consulting services, primarily in the Northeast, and throughout the United States as well.

We offer a wide range of instructor led training courses for Programmers, Analysts, Operators, Systems Programmers, User Personnel, and Managers of major corporations. Our curriculums focus primarily on IBM mainframes and personal computers, and include Assembly Language and C Programming, SYBASE, CICS, Data Communications and LANS, DB2, EASEL, IMS, JCL, MVS, Operator Training, PC Training, TSO, and VSAM. The PC training curriculum includes course offerings in DOS and OS/2, and in application areas such as database management, spreadsheets, word processing and desktop publishing.

We specialize in customized on-site education for corporate customers. Other services include course development, training the trainer, and consortium offerings. We also provide consulting services in all of the above areas as well. If your company is interested in our consistently high quality training and services, please call us at 908-747-6886 or write to:

Sonera Technologies
Computer Education
P.O. Box 565
Rumson, NJ 07760

About This Manual

Organization

This manual includes more information than any single user is likely to need. Read it as a reference instead of like a book. A comprehensive *Index* together with a brief *Contents at a Glance* and a detailed *Table of Contents* will help you locate information on items of interest. Within any chapter or section, information is logically grouped and presented in order of overall importance. Bold text is used to highlight each topic in order to allow easy scanning.

The manual is divided into three parts:

Part I deals with installing, running, and using the DisplayMate Video Display Utilities program. References to the Appendices are included for readers interested in further details.

Part II contains *Everything You Need to Know About Video Systems.* It first explains video adapter and display basics, then how to select and buy an adapter or display, and also how to maintain them in good condition. Two chapters discuss VDT safety and factors affecting user comfort and productivity. The first chapter reviews the health issues of electric and magnetic fields, and electromagnetic radiation from VDTs. The second chapter considers ergonomic factors in the design and use of VDTs and how they affect users.

Part III includes *General Information* such as the Appendices, *In Case of Difficulty, Sources of Additional Information, Glossary,* and *Index.* The Appendices include specialized or detailed reference information to supplement the general discussion in the manual. The reader is referred to the appropriate appendix in the body of the manual. The *In Case of Difficulty* chapter explains how to deal with problems encountered while running DisplayMate. A detailed section on *Video Display System Trouble Shooting* discusses general procedures for diagnosing a malfunctioning video display system. A chapter on *Sources of Additional Information* lists other manuals, books, organizations, and publications that may be of interest to users of DisplayMate.

Manual Terms and Conventions

- Display, video display, VDT, VDU, and monitor all refer to the computer's television style output screen. VDT is an abbreviation for Video Display Terminal. VDU is an abbreviation for Video Display Unit.

- PC or Personal Computer generally means any IBM PC, XT, AT, PS/2 computer or 100% compatible.

- Quotation marks "" indicate that you should literally type the information between the quotes, but *not* the quotes themselves.

- An indented line of text in bold indicates that you should type the information shown on the line and is identical in meaning to the quotes above.

- All DOS command lines require that you press the <Enter> key as the last item on the line in order to execute the request. The <Enter> key is generally not shown explicitly in the text. Input to DisplayMate does *not* require use of the <Enter> key to terminate input, except when entering data for measuring screen distortion or for skipping tests.

- All input to DisplayMate is case insensitive, meaning that either upper or lower case letters are equivalent. The manual examples are generally shown in lower case.

- Special purpose keys, Keypad keys, and Function keys are shown encased in angular brackets < >. These are single key identifiers found on the keyboard; do *not* type the text shown inside the brackets.

  Examples: <Enter>, <Space Bar>, <Esc>, <End>, <F10>.

  Some of these keys may be identified on the key caps either spelled out in full or abbreviated.

  Examples: <Ins> or <Insert>, <Del> or <Delete>,
  <PgDn> or <Page Down>.

- Function keys may be referenced as <F*n*>, where *n* is a number to be determined by the user.

- If the text or program refers to a Function key number that is greater than what is available on your keyboard, then press and hold the <Shift> key, which promotes the Function key numbers by 10, followed by the appropriate Function key <F1> to <F10>. For example: for <F12>, press an <F12> key if it is available, otherwise press and hold <Shift> followed by <F2>.

- <Shift> and <Ctrl> are two keyboard keys that modify the meaning of the keyboard key that they are used with. In either case, press and hold the <Shift> key or <Ctrl> key and then press the second key shown. Either key may be released first.

  Example: <Ctrl><Break> means press and hold <Ctrl> and then press the <Break> key.

Part I

How To Use DisplayMate

Chapter 1

About DisplayMate

The DisplayMate Video Display Utilities is a new type of software product designed to help you optimize and get the most from your computer's video display and adapter. People are visually oriented, so the video display is the primary way the computer system and the application software communicate with us. Its quality and capabilities determine how well you can work with your computer and what you can accomplish with it.

People have been reading books and other printed materials for more than 500 years, so we have learned how to use this medium comfortably, efficiently, and effectively. On the other hand, the computer video display has been around for about 25 years, and in common use for less than 10, so it is hardly surprising that we have not yet learned to use it as well. This includes hardware manufacturers and software developers in addition to the general computer user.

DisplayMate has been designed to help solve this problem: the software will demonstrate the good, the bad, and the ugly aspects of your computer video display system. The manual will explain video displays and how to use them best. What's more, we will show you how to optimize your display and set it up properly, how to operate and work with your display effectively, how to detect sources of eye strain and minimize them, help you determine what service adjustments may be needed to improve its performance, and eventually guide you in selecting and buying your next video display system. DisplayMate should be used to train your VDT users and to prepare for the upcoming VDT laws and regulations.

Many people spend between 200 and 2000 hours per year face to face with their video display. Since most users hold on to their display for an average of 3 years, they may eventually spend upwards of 600 to 6000 hours studying their screen. So the quality of the video display has a considerable impact not only on their productivity and comfort but to a certain degree on their quality of life as well. If a display is operated poorly, or performs poorly, you may suffer from eye strain, headaches, general stress, and you will certainly not enjoy your work. If you spend a lot of time with your display, this can lead to vision problems and affect your general health. That is why it is essential that you take the time to learn about your video display and how to use it in the best possible way.

DisplayMate offers two separate test tracks: one designed especially for non-technical users, and the other for technical users that want an in-depth look at the video display system. The *Non-Technical Program* operates in a fully automatic mode, concentrates on visual tests that do not require technical interpretation, and provides information to guide the non-technical user. The *Technical Program* has more tests, more options, and provides detailed technical information about the hardware and video modes and video system internals.

DisplayMate will first provide you with a visual evaluation of your display through a series of carefully chosen visual test patterns. No technical experience is necessary because it operates automatically and *your* eye is the final judge. Many of the tests will demonstrate visual effects that are generally below your conscious level of detection in the everyday use of your display. The tests will show you the strengths and weaknesses of your display and point out the hidden advantages and disadvantages as well. That will help you make better use of your current hardware and software, or demonstrate a need to change or upgrade your current video system.

If you decide to buy a new video display or video adapter, DisplayMate can help you choose which ones are best for you. It provides the most thorough set of compatibility tests and the most comprehensive video system performance tests available. The compatibility tests can also check memory resident programs that you install in your system to determine under what modes they can operate safely.

When assembling and buying a computer system, many people don't stop to consider the ultimate importance of their video display. Why? Because the display is one of the few components that must be judged in terms of qualitative performance rather than through the use of specifications that are more easily evaluated, like CPU speed or disk drive capacity. The feel of a keyboard and mouse also come under this category, but they are nowhere near as subtle or multi-dimensional as the visual display. Should you buy a more expensive display that is supposedly better, or just go for an extra 40 MBytes of disk space? You can certainly sink your teeth into the latter, and that is one reason why the video display system often suffers during budgeting. But the subtle limitations of a display will slowly extract a price of their own.

From a different perspective, many users assume that price and quality go together, a fact some manufacturers take advantage of when pricing the displays in their product line. DisplayMate allows you to readily determine the quality yourself by using our visual test patterns, and then comparing it to their price. It is possible to save your eyes and your wallet at the same time.

If you take DisplayMate shopping with you, then you can visually evaluate the displays and easily test the video adapters for compatibility and speed performance at the same time. The *Video Obstacle Course* will let you quickly see how the display stacks up to a tough set of hurdles; the complete test series will check every aspect of the display and adapter. Because the DisplayMate tests will uncover the hidden disadvantages and weaknesses in a display or adapter, you are unlikely to be surprised by problems when you install the new equipment in your system, and you are more likely to be pleased with the video system you buy.

After installing a display and setting it up there is a tendency to forget that it needs continuing attention to keep it in tip-top shape. Not only does a display noticeably age over time, but the conditions under which it operates may change repeatedly during the course of a single day because of changes in room lighting, in the application software, or in the users habits or needs, and because of drift within the display itself. This situation closely parallels how we read printed materials: we periodically adjust them to correspond to changes in the lighting, position, orientation, and the task at hand. It is extremely important that you similarly adjust your video display during the course of your work. The DisplayMate master Test Pattern can be used to align and checkout the display when you first turn your computer on in the morning in the same way that television stations transmit a test pattern every day. A simple command will produce the test pattern whenever an adjustment in the display's controls is needed during the course of the day.

DisplayMate collects and presents a large amount of information about each video system that can either be summarized or provided for detailed inspection. If you are responsible for a large number of computer systems, DisplayMate will help you keep track of all those varying video systems by reporting the hardware internals of each system, and then analyzing the configuration and demonstrating the capabilities of each machine. This will help you manage your inventory and help with upgrade, inspection, and maintenance programs.

Chapter 2

Uses For DisplayMate

Introduction

In this chapter we summarize a number of the most important uses for the DisplayMate Video Display Utilities in order to help you get the most from the software and the manual, and to give you an idea of the breath of applications that are possible.

The uses are organized into the following categories: Display Setup, Image Quality, Evaluation, Testing, Hardware and Software Compatibility, Speed Performance, Education, Video System Information, Management, Programmers and Developers, and Manufacturers and Service Centers.

Display Setup

In order to minimize eye strain and maximize user comfort and productivity, it is important that the user controls on a video display be regularly adjusted via a simple and fast setup procedure provided by DisplayMate.

- Use the DisplayMate *Setup Display* test series to initially adjust the user controls on your display properly, or whenever a major tune-up is necessary.
- Use the master *Screen Test Pattern* every time you turn on your computer, in order to keep the display optimally adjusted. Also use it during the course of the day when there are changes in room lighting, when there are significant changes in the user work area, or if the setup parameters drift.
- For video projection systems use the DisplayMate test patterns to minimize the projector setup time and maximize setup accuracy.

Image Quality

DisplayMate will allow you to evaluate visually the image quality of your display through a series of carefully chosen analytical test patterns. A large number of tests have been specifically developed for DisplayMate and can be found nowhere else, not even in expensive laboratory test equipment costing $20,000 or more. Here we mention a few important and interesting tests:

- Most displays cannot actually produce their manufacturer's stated resolution. This manual will tell you why, and the DisplayMate program will let you measure the display's actual resolution limit.

- The single most important problem for a color display is the error in the registration of the red, green, and blue images, often called the color convergence error. DisplayMate includes a number of tests for color registration for which Sonera Technologies has applied for a patent, because they are significantly more sensitive and accurate than prior methods. As a result, DisplayMate can uniquely show you the degree to which your display suffers from this problem.

- If you need to compare the geometric distortion on two displays, need to check your display against a manufacturer's specifications or guarantee, or simply want to know how accurate your display is, you can use the DisplayMate fully interactive *Screen Distortion Measurement* menu. It greatly simplifies the process of measuring screen distortion by automatically prompting you to measure the lengths of a small number of carefully chosen lines on the screen, and then producing a report on the percentage errors for each type of distortion. The manual explains what these errors mean and how to interpret the results.

Evaluation

- DisplayMate can help you evaluate your current video display system and point out its strengths and weaknesses. You can use this information to make better use of your current hardware and software, or to demonstrate the need to change or upgrade your current video system.

- DisplayMate can help you evaluate the quality, performance, and compatibility of any video system hardware you may be considering to buy. With our tests you can easily compare different displays and adapters. DisplayMate can help you find the display and adapter best suited to your needs, and can help you make the best display and adapter purchase.

- After you have purchased a video display, you should use DisplayMate to evaluate the unit you have received. There is generally a considerable sample-to-sample variation in video displays, and you must decide whether the one you received compares favorably with the one you originally evaluated, and whether it meets your expectations and requirements. You can then decide with the help of DisplayMate whether the display should be adjusted or returned.

Testing

- The DisplayMate tests can be used to determine if your video display system is operating as it should and ought to be used as part of a regular inspection and testing program. A display that is not performing up to par will be a source of user discomfort and eye strain as well as result in lower productivity. Such a display should be serviced or replaced.
- If you uncover a problem with your display, the information you gather from DisplayMate can be used to guide the service technician in eliminating the specific problem that bothers you. For example: stating that the red-green color registration is off at the top right of the screen will insure that this is what is fixed.
- From the DisplayMate tests you will learn your display's capabilities and shortcomings. By manipulating some of the test patterns you will learn which image display formats are most appealing to you and are also suitably matched to the abilities of your video display system. That will help minimize eye strain.
- DisplayMate also allows you to monitor your display's continuing performance and aging.
- Qualified service technicians can use DisplayMate for diagnostic tests and for display alignment.
- A portable computer with a standard video display output connector can be used with DisplayMate as a portable video display test facility.

- You can also use the DisplayMate test patterns to test your hardcopy printer or laser printer, provided you have installed software for graphics screen dumps.
- You can setup and test your home TV with the DisplayMate test patterns if you have an adapter with a composite video output, such as IBM's Color Graphics Adapter.

Hardware and Software Compatibility

The entire DisplayMate program is a comprehensive test of compatibility because it uses virtually every video adapter BIOS function and register to probe for hidden flaws and limitations in the hardware. We have, however, attempted to place the tests that are most likely to detect compatibility problems within a special *Compatibility Tests* menu.

- An extensive *Compatibility Tests* menu allows you to determine the degree of compatibility with the standard IBM hardware. Few adapters approach 100% compatibility. In many cases DisplayMate will point out non-standard hardware and software configurations; otherwise, you will need to evaluate the screens visually to determine the results.
- Any computer that has a fully compatible video display system may develop incompatibilities as a result of other hardware or software programs that are added to the system. By running DisplayMate in your normal environment and comparing it to a basic system configuration you can isolate the causes of most incompatibilities.
- A significant fraction of all memory resident programs that are called up via a hot-key will produce a compatibility problem in one or more of the standard IBM video modes. This can result in a minor glitch, a major glitch, or even crash your computer. DisplayMate is ideal for discovering such compatibility problems because it will operate in any of the standard video modes, and because it exercises the full breadth of the adapter's functions and capabilities.

Speed Performance

Video adapter manufacturers emphasize the speed performance of their cards much like automobile manufacturers do. Some of the claims are either unrealistic exaggerations or are dreamed up in their advertising departments.

- DisplayMate has a comprehensive and fully automated set of tests to measure the video system speed performance. Sixteen separate tests are performed in graphics modes and fifteen in text modes. In the *Non-Technical Program* the results are summarized as a *Display Speed Index* for text, and another for graphics. The index compares the performance of your system with 3 standard IBM systems. The *Technical Program* allows the tests to be run in any standard video mode, and also provides a detailed tabulation of the absolute speed in operations per second for each test, and compares each value to 3 standard IBM systems.
- Many memory resident programs will significantly degrade video system speed performance because they intercept and examine video commands. You can run the DisplayMate *Speed Performance Tests* with and without the memory resident programs, to see to what extent they slow down the video system performance.
- Screen accelerators are utility programs that are supposed to improve the speed performance of certain specific video BIOS functions. As a rule, they will decrease the performance of all other video BIOS functions. You can run the DisplayMate *Speed Performance Tests* with and without a screen accelerator in order to measure the various improvements and degradations involved.

Education

Part II of this manual includes an in-depth discussion on *Everything You Need to Know About Video Systems.* Chapters are included on:

- *Video Display System Basics* where you will learn the fundamentals of video system hardware. We discuss only the practical issues that are relevant to the visual and functional performance of displays and adapters. The advantages and disadvantages of each type of hardware are compared.
- *VDTs: Are They Safe?* examines the issue of electric and magnetic fields and electromagnetic radiation in video displays. We have attempted to provide an even handed discussion of this emotionally charged issue.
- *Maximizing Comfort and Productivity* discusses the issues of ergonomics relevant to VDT users. We examine sources of eye strain and discuss how to minimize or eliminate their effects. We consider a multitude of issues

beginning with color registration, geometric distortion, glare, flicker, Moires, aliasing, plus many others.

- *Selecting a Video Display System* discusses the practical and technical issues involved in selecting a video display or adapter for purchase. We examine everything from System Bus Conflicts that can arise with some 16-bit cards, to features such as automatic mode detection, to warranties and out of warranty repair. A section on *Buying Video Hardware* is provided to help those with little experience in purchasing computer equipment from either a dealer or mail order house.
- *Maintaining Your Display* explains how you can keep your video hardware operating in tip-top condition for as long as possible. We examine issues such as the effects of aging, maximizing life expectancy, field service adjustments, and trouble shooting video displays.

Video System Information

DisplayMate collects and presents a large amount of information about each video display system.

- In addition to informing you of the type of video adapter and display in each system, DisplayMate can in most cases provide the name of the video adapter manufacturer, the video BIOS copyright date, and the version number, if present. Inactive adapters and displays are also identified, as are standard functions that are not uniformly available and may vary with date of production or with manufacturer, such as a Light Pen Interface and the BIOS string function.
- DisplayMate will display a full screen of tabular information for each standard video mode available on the computer system, customized for the actual hardware configuration on the machine.
- DisplayMate also provides a fully documented tour through the video portion of the computer's *BIOS Data Area*. When individual bits have a special function, they are separately documented also.

Management

If your organization has a large number of personal computers, DisplayMate can help you manage them more effectively and efficiently. For any of the tests considered here, the menu programming capability of DisplayMate will allow you to automate a procedure by repeatedly running the same batch of tests, without the need to enter menu commands from the keyboard. If you plan to install DisplayMate on each machine, please contact us for information on site licenses. Large organizations can use DisplayMate:

- As an educational tool to inform your VDT operators on how to setup and use their video displays properly. It is also important to inform them about the problems that can arise from the improper use of video displays. Liability issues require that every employer do this.
- For inventory management to help you keep track of your video display system hardware. In addition to informing you of the type of video hardware in each system, DisplayMate can, in most cases, provide the name of the video adapter manufacturer, the video BIOS copyright date, and the version number, if present.
- As a tool to manage upgrade, inspection, and maintenance programs for your current video hardware. The quality of the video displays can be evaluated from the *Display Tests* or *The Video Obstacle Course.* Video adapters can be evaluated in terms of compatibility and speed performance. DisplayMate will alert you to non-standard video hardware.
- To help in selecting hardware for on going purchase programs.

Programmers and Developers

- Use DisplayMate to evaluate the capabilities and shortcomings of the different video adapters, so that your software is designed to utilize video system capabilities fully and not overtax them.
- Use the Video Mode and Video Data Area information to design, explore, and debug software.

Manufacturers and Service Centers

- Use DisplayMate to test video displays and adapters for complete functional operation.
- Minimize setup and alignment time and maximize accuracy with the DisplayMate test patterns.
- Use the DisplayMate *demo* option in order to demonstrate the quality of displays and adapters for sales demonstrations or trade shows.
- The menu programming capability of DisplayMate will allow you to run a set of tests without having to enter menu commands repeatedly from the keyboard.
- If you have an automated test facility, a special version of DisplayMate is available for running fully automated tests under external hardware control. Please contact us for further information.

Chapter 3

Installing DisplayMate

Introduction

Before beginning the installation of DisplayMate you should first review the *System Requirements* in Appendix A. We also recommend that you make a backup copy of the original DisplayMate distribution disk and store the original in a safe place. Should you lose, accidentally destroy, or damage one of the disks, then you can make another working copy from the original distribution disk. Detailed instructions for making a backup copy are provided in Appendix B. We have provided two installation guides: a *Quick Start* manual version for proficient computer users in Appendix C, and a *Standard* automatic installation version in Appendix D.

Quick Start Installation

The *Quick Start Installation Guide* is for users that are proficient with their computers and with DOS, and prefer to skip the automatic installation procedure and do the installation themselves. It includes information on reading the README documentation, copying the DisplayMate files to your hard disk, adding DisplayMate to your PATH, and automatically producing a master Test Pattern when you turn on or reboot your computer. The *Quick Start Installation Guide* also provides abbreviated information on starting DisplayMate, including a few of the most important command line options, and tips for running and controlling DisplayMate. The *Quick Start Installation Guide* is located in Appendix C.

Standard Installation

The *Standard Installation Guide* provides users of DisplayMate with an automatic procedure to install the software onto their hard disk. The installation routine will first check your disk drives, determine if you have enough disk space available, allow you to select the name of the directory for DisplayMate, create that directory if necessary, copy the necessary files to the directory, and, with your permission, add a command line to your AUTOEXEC.BAT file to modify your DOS PATH and another to automatically produce a master Test Pattern when you turn on or reboot your computer. Finally, it will allow you to read or print the contents of the README documentation file included in the distribution diskette. Extensive error checking and recovery procedures are included to make the installation as painless and safe as possible. The *Standard Installation Guide* is located in Appendix D.

Chapter 4

Running DisplayMate

Introduction

This chapter provides a complete description on how to run the DisplayMate Video Display Utilities program. Before beginning this chapter you should have already installed DisplayMate on your computer system as described in Chapter 3. The first three sections following this introduction provide general background information on running DisplayMate:

- Getting Started
- Keyboard and Mouse Control
- Program Options

Thereafter, the sections describe each *Main Menu* selection in turn. If you prefer something super-brief, then try the 1½ page *Quick Start for DisplayMate* in Appendix C.

DisplayMate offers two separate test tracks: one designed especially for non-technical users, and the other for technical users that want an in-depth look at the video display system. The *Non-Technical Program* operates in a fully automatic mode, concentrates on visual tests that do not require technical interpretation, and provides information to guide the non-technical user. The *Technical Program* has more tests, more options, and provides detailed technical information about the hardware and video modes and video system internals. The video test modes in the *Non-Technical Program* are selected automatically, whereas in the *Technical Program* they also can be selected manually. The

Technical Program will test a computer with dual displays automatically, whereas the *Non-Technical Program* will only test a single display at a time.

DisplayMate is organized into the following major subdivisions:

Setup Display: This set of test screens provides a guide for properly setting up and adjusting your video display. After completing this setup procedure you can easily keep the display optimally adjusted by using the master *Screen Test Pattern* every time you turn on your computer, or whenever an adjustment in the display's controls is needed during the course of the day.

Video Obstacle Course: This set of tests will let you quickly see how well your video display stacks up to a tough set of hurdles. Most displays will fail several or more of these visual tests.

Display Tests: This menu provides access to the largest collection of tests within DisplayMate. The tests are organized into 6 categories:

- Geometry Tests
- Display Resolution Tests
- Adapter Resolution Tests
- Color and Gray-Scale Tests
- Text and Font Tests
- Miscellaneous Tests

Descriptions for each category are provided in the *Display Tests* section, below.

Speed Performance Tests: This is a fully automatic comprehensive set of tests for measuring the speed of your video display system. A total of 16 tests are performed and the results are shown relative to 3 IBM computer systems.

Compatibility Tests: This menu includes tests that are most likely to detect compatibility problems in your video system. There is a *Video Modes Test Suite,* a series of *Configuration Tests,* and a set of specialized compatibility tests for each type of video adapter.

Screen Distortion Measurements: This is a fully interactive set of screens that prompt you to measure the lengths of a small number of lines on the screen, and then produces a report on the percentage errors for each type of geometric distortion. The manual explains how to interpret these errors. This selection is only available in the *Technical Program.*

Select Video Test Mode: Normally, DisplayMate runs in *Automatic Mode* selection where it selects the most appropriate video mode for each test. This menu allows users in the *Technical Program* to select any particular video mode supported by the hardware to run the tests.

Hardware and Mode Information: DisplayMate will provide information about the video hardware and the video BIOS. In the *Technical Program,* DisplayMate also produces a full screen of tabular data for each standard video mode available on the computer system, customized for the actual hardware configuration on your machine.

Video Data Area Information: In the *Technical Program,* DisplayMate provides a fully documented tour through the video portion of the computer's *BIOS Data Area.* When individual bits have a special function, they are separately documented also.

Getting Started

This section provides a brief overview on running DisplayMate to help you get started quickly. The remaining sections of this chapter provide detailed explanations for all of the program's features.

To run DisplayMate type:

dmu

from the DOS prompt, provided you added the program's home directory to your DOS PATH during the installation procedure. If you did not, then you will need to enter the path along with the program name by typing:

c:\dmu\dmu

You can run DisplayMate from any command shell or graphical environment you like, but initially we recommend that you start it directly from DOS because such programs may introduce compatibility problems into your video system. Memory resident programs, also called Terminate and Stay Resident (TSR) programs, can also cause problems, so it is better to remove them from memory or, at the very least, not activate any of them while DisplayMate is running.

After you have run DisplayMate in a "vanilla" configuration on your computer, hopefully without discovering any compatibility problems in your video system, you should run it in your normal environment to see if any new problems arise. You can also test your memory resident programs by running them during the DisplayMate tests in order to check for software compatibility problems. It is also a good idea to compare the results of the Speed Performance tests to see if your normal environment is slowing down the video system significantly.

DisplayMate has a number of options that can be specified on the command line that allow you to control and configure the program. None are required, but eventually you may find them helpful in running DisplayMate. The command line options also give you access to a number of advanced features, such as menu programming, which lets you automate the execution of DisplayMate. You can obtain a listing of all the command line options by typing:

dmu ?

For further information see the *Program Options* section below, or Appendix E.

You can have DisplayMate run a fully automatic demonstration program for you by typing:

dmu demo

at the DOS prompt. This will produce a *Non-Technical Program* demo; for the *Technical Program* demo type:

dmu tech demo

The demo can operate in a fully automated and unattended fashion, but you may interact with it at any time using the Function and Keypad keys to control the tests and the display manually.

DisplayMate will also produce a single master *Screen Test Pattern* on your display by typing:

dmu tp

The test pattern will be displayed for 20 seconds and then you will be automatically returned to DOS. Add this line to the end of your AUTOEXEC.BAT file so that you can adjust your display when you first turn on your computer. The *Screen Test Pattern* section, below, explains other test pattern options, including how to change the duration of the test.

Program Selection Menu

Figure 4.1 shows the *Program Selection Menu* for selecting the Technical Level of the Tests. It appears right after the opening screen for DisplayMate. To select the *Non-Technical Program* you merely have to press the <Space Bar> or <Enter> keys because the menu highlight bar is already on that selection, or you may press the <F1> key. To select the *Technical Program* press the <F2> key or use the Keypad Arrow keys, or move your mouse forward or backward; then press the <Space Bar> or <Enter> keys or click the left mouse button to make your selection. A simple command line option allows you to specify the technical level and skip this menu altogether: see the section on *Program Options,* below.

Main Menu

DisplayMate is a menu driven program that is controlled by using the Keypad keys or a mouse. Figure 4.2 shows the *Main Menu* for both the non-Technical and Technical Programs. All of the principal features of DisplayMate are available from this menu. To move the menu highlight bar up and down use the Keypad Arrow keys, or move your mouse forward or backward. To select an item press the <Space Bar> or <Enter> keys. An alternative and faster method is to press the numbered Function key shown at the left of the item. To exit DisplayMate from the *Main Menu* press the keypad <End> key, or press the <Esc> key, or move the menu highlight bar to the line marked *Return to DOS* and press <Space Bar> or <Enter>.

```
DisplayMate Video Utilities                              Version 1.1
--------------------------------------------------------------------
Program Selection Menu:


Choose the Technical Level for the Tests:

Function Key  <F1>  =  Select  Non-Technical Program

Function Key  <F2>  =  Select      Technical Program

--------------------------------------------------------------------
Press the Function Keys <F1> or <F2> to execute your choice.
- - - OR - - -
Use the Keypad Arrow Keys <↑> or <↓> to move the menu highlight
    bar to the line of your choice, then press the <Space Bar>
    or <Enter> Keys to execute your choice.
- - - OR - - -
If you have a Mouse use it to move the menu highlight bar to
    the line of your choice, then click the left mouse button.
    For help at any time click the right mouse button.
--------------------------------------------------------------------
Press <Fn> <↑> <↓> <Home> <End> <Page Up> <Page Down> <Space Bar> <Enter>  ?
```

Figure 4.1 *Program Menu for Selecting the Technical Level of the Tests.*

If a monochrome display is connected to a color adapter and masquerading as a color display, then the menu screens may be difficult to read because the colors are mapped to different intensities. This situation is common on portable computers. Two command line options are available to improve screen readability: the "B" option sets the background to black, and the "C" option sets all the foreground colors to white and the background to black.

dmu –B *or* **dmu –C**

The bottom line of each menu screen or information screen shows a list of the most important keys that are available; see Figure 4.2. For additional information at any time you can obtain *Help* by typing "?" or "h" or pressing the conveniently located <Ins> key on the keypad. If you have a mouse, click the right mouse button. *Help* will provide an explanation about the screen you were looking at plus a more complete summary of the Function keys and options available to you. The *Keyboard and Mouse Control* section below provides a detailed explanation for all DisplayMate Function keys. One of the *Main Menu* selections allows you to change the Technical Level of the tests; another is the

```
DisplayMate Video Utilities                                  Version 1.1

Main Menu for non-Technical Program:

Function Key <F1>    Introduction (Press the F1 key)
             <F2>    Setup Display

             <F3>    Video Obstacle Course
             <F4>    Display Tests
             <F5>    Screen Test Pattern

             <F6>    Speed Performance Tests
             <F7>    Compatibility Tests
             <F8>    Display Hardware Information

             <F9>    Set Program Options
             <F10>   Switch to Technical Program

 Key Pad Key <End>   End (Return to DOS)

Use the Function Keys <Fn> or Keys <↑> <↓> then Press <Space Bar> or <Enter>
For Help Type  ?  or  h  or  press the  <Ins>  key.   For Other Functions...
Press <Fn> <↑> <↓> <Home> <End> <Page Up> <Page Down> <Space Bar> <Enter>  ?
```

```
DisplayMate Video Utilities                                  Version 1.1

Main Menu for Technical Program:                          Auto Test Mode

Function Key <F1>    Setup Display
             <F2>    Video Obstacle Course
             <F3>    Display Tests
             <F4>    Screen Test Pattern

             <F5>    Speed Performance Tests
             <F6>    Compatibility Tests
             <F7>    Screen Distortion Measurements

             <F8>    Select Video Test Mode
             <F9>    Hardware and Mode Information
             <F10>   Video Data Area Information

 <Shift><F1> <F11>   Set Program Options
 <Shift><F2> <F12>   Switch to non-Technical Program

 Key Pad Key <End>   End (Return to DOS)

Press <Fn> <↑> <↓> <Home> <End> <Page Up> <Page Down> <Space Bar> <Enter>  ?
```

Figure 4.2 *Main Menu for the Non-Technical and Technical Programs.*

Program Options Menu, which allows you to change many of the program options interactively.

Some of the *Main Menu* selections will lead you into another menu in order to refine the available choices further. If you wish to follow the natural progression of tests, DisplayMate will automatically step you through the program by automatically advancing the menu highlight bar. The easiest way to move from one screen to the next is to press the conveniently located <Space Bar> key, or to click the left mouse button. To terminate a test series, or to move to the next higher level menu, press the <End> or <Esc> keys.

For all the test series an *Automatic Help* facility provides a *Test Prompt Screen* before every display test that describes the test, and explains what to watch out for on the screen. If you like, you can turn off this feature from the command line or from the *Program Options Menu.*

During any of the test series the Function keys perform the following:

<F1> and <F2> cycle through the available foreground colors.

<F3> and <F4> cycle through the available background colors.

<F5> sets the colors to their default values.

<F6> toggles between normal and reverse video.

<F7> toggles the Color Burst on and off for CGA Adapters.

<F8> toggles between color and monochrome for VGA and MCGA displays.

Other Function keys are described in the next section. To maneuver within a test series use the <Page Up> key to return to a previous test screen. Use the <Home> key to return to the first test in the series. The <Del> key will redisplay the title of a test. The *Keyboard and Mouse Control* section below provides a detailed explanation for all these keys.

Keyboard and Mouse Control

DisplayMate is controlled by using the Keypad keys, Function keys, the Space Bar, Enter, and Escape keys, and with a Microsoft compatible mouse. This section provides a detailed description of what each key or mouse action does. The usage of most of the keys and the mouse should be apparent to anyone who has used personal computer software before. If you press an invalid key while DisplayMate is running, an error tone will be produced.

Note that when the internal automatic timers of DisplayMate are enabled (with the E, S, T, DEMO, or TP options), DisplayMate will proceed on its own if it receives no keyboard or mouse input within a specified period of time.

Help: To request help at any time type "?" or "h" or "H" or press the <Ins> Keypad key, or click the right button on your mouse. If you are in the *Program Options Menu,* you will need to press "h" or "H" twice because the first press selects the *Help* option. The <Ins> key, sometimes labeled <Insert>, is handy because it is conveniently located on most keyboards. Think of it as Insert Help. To pop out of *Help* press <Ins> again, or any other key.

Options: To change any of the program options go to the *Main Menu* and select the *Set Program Options* item. The options may also be specified from the command line that invokes DisplayMate. See the *Program Options* section below, or Appendix E.

<Space Bar> or <Enter>: Pressing the conveniently located Space Bar key or the Enter key means proceed within DisplayMate. Clicking the left mouse button also means proceed. If you are in a menu, the currently highlighted item will be selected; if you are in a test screen, then the next test will be presented. You can proceed through the entire DisplayMate program by merely pressing <Space Bar>. During test screens <Enter> means proceed, and also restore standard colors and normal video.

Mouse: Click the right mouse button for *Help,* and click the left button to proceed, just like pressing the <Space Bar> key. In a menu, moving the mouse forward or backward will shift the highlight bar up and down. If your mouse has a middle button, it will behave like the right button and activate help.

<Esc>: The Escape key will stop whatever DisplayMate is doing and return you to a menu. If you are already in a menu, it will return you to the next highest menu, or to DOS if you are in the *Main Menu.* While using the Escape key in this way is now a common practice, it is also a misuse of the meaning of that key; therefore, we recommend using the keypad <End> key instead.

Reset: If something goes wrong with the video system due to a hardware or software incompatibility, first try pressing "r" or "R" (for reset). This will reset the Video system and redraw the screen. In most cases this will correct the problem. See the chapter on *In Case of Difficulty* for information on dealing with compatibility problems.

<Ctrl>C or <Ctrl><Break>: Pressing either combination of keys will abruptly terminate DisplayMate and return you to DOS, or wherever you invoked DisplayMate. This is a standard quick way out of DisplayMate. It can also be an emergency way out in case your video system has an incompatibility that has caused a malfunction or system lock-up, where the computer no longer responds to normal keyboard input. Under these circumstances <Ctrl><Break> is more likely to work than <Ctrl>C. Before you do this, try Reset or Escape above, and see the chapter on *In Case of Difficulty.*

Function Keys <F1> to <F20>: The standard IBM keyboard includes keys <F1> to <F10> on the left, and the enhanced keyboard includes keys labeled <F1> to <F12> along the top. Other keyboards may include additional Function keys. For Functions <F1> to <F10> press the indicated Function key. For <F11> to <F20> press the indicated key if it is available on your keyboard; otherwise press and hold the <Shift> key, which promotes the Function key numbers by 10, followed by the appropriate Function key <F1> to <F10>. For example: for <F12> press the <F12> key if it is available; otherwise press and hold <Shift> followed by <F2>.

In a menu, the Function keys are used to select a menu item by pressing the Function key indicated at the left of every item. Menu items that do not show a Function key are unavailable on your video system and are shown in the color cyan. The menu highlight bar will skip over them.

In a test screen, the Function keys are used to control the colors and other aspects of the image:

<F1> and <F2> change the foreground color to the previous or next values, respectively.

<F3> and <F4> change the background color to the previous or next values, respectively.

<F5> sets the colors back to their default values: normal video with a white foreground and a black background.

<F6> toggles between normal and reverse video.

<F7> enables or disables the Color Burst for the composite video output on IBM CGA adapters. See the heading *Color Burst,* below.

<F8> toggles between color and an equivalent gray-scale monochrome image for the MCGA and VGA adapters.

<F9> produces a screen that reports on the results of the configuration tests in the *Video Modes Test Suite.*

Note that not all keys are available on all tests or on all video systems. Invoke *Help* to find out which Function keys are active.

<PgDn>: Use the keypad Page Down key to proceed to the next test screen. In a menu, Page Down will move the highlight bar to the last menu item.

<PgUp>: Use the keypad Page Up key to return to the previous test screen. If you are already at the first screen of the series, there is no action. In a menu, Page Up will move the highlight bar to the first menu item.

<Home>: Use the keypad Home key to return to the first screen of a test series. If you are already at the first screen, there is no action. In a menu, Home will move the highlight bar to the first menu item. In the *Select Video Mode* menus in the *Technical Program,* the Home key is labeled like a Function key and will select and execute the first menu item.

<End>: The keypad End key will stop whatever DisplayMate is doing and return you to a menu. If you are already in a menu it will return you to the next highest menu, or to DOS if you are in the *Main Menu.*

<Up Arrow> and <Down Arrow>: Use the keypad Up and Down arrow keys in a menu to move the highlight bar up and down to the item of your choice. Use the <Space Bar> or <Enter> keys to select that choice. For Screen Distortion Measurements in the Technical Program, the arrow keys are used to move the cursor to or from the First and Second End-Point input values.

<Left Arrow> and <Right Arrow>: Use the keypad Left and Right Arrow keys in the *Program Options Menu* to increase, decrease, or toggle the state of the selected option. The arrow keys are used to backspace and forward space in a data entry item for Screen Distortion Measurements in the Technical Program and for skipping tests, below.

<Backspace>: Use the backspace key to correct data entry errors for Screen Distortion Measurements in the Technical Program and for skipping tests.

<Ins>: The keypad Insert key is used to request help at any time. Think of it as Insert Help. To pop out of *Help* press <Ins> again, or any other key.

<Del>: During test screens the keypad Delete key is used to redisplay the name and title for the test. The name and title are displayed at the start of a test but are then erased so as not to interfere visually with the test.

<Ctrl> <PgDn>: Use this key combination to skip over the next test screen and go directly to the test that follows it. It is equivalent to pressing <PgDn> twice.

<Ctrl> <PgUp>: Use this key combination to skip over the previous test screen and go directly to the test that precedes it. It is equivalent to pressing <PgUp> twice.

Skip Tests: If you need to skip over a number of tests to save time or to avoid a compatibility problem, press "s" or "S" (for skip). At the prompt, type in the number of tests to be skipped over followed by <Enter>. Use a minus sign "-" to skip backwards. If you attempt to skip backward beyond the first test in a series, you are positioned at the first test.

< + >: Use the plus key when an automatic timer is in effect and you wish to spend the maximum time, 60 seconds, on that test screen or menu. Otherwise, DisplayMate will proceed after there is no keyboard or mouse activity for a time that was previously specified. The timer is reset any time a key is pressed, so occasionally pressing "+" will maintain the display indefinitely. See the *Options* section below for information on how to set or change the timers.

<Ctrl> <Home>: If you have a Demo or Menu Program in progress, and wish to receive manual menu control after the current menu selection has finished, press <Ctrl> <Home> at any time. After executing your manual request, the Demo or Menu Program will continue where it left off.

<Ctrl> <End>: If you have a Demo or Menu Program in progress and wish to receive immediate manual menu control, press <Ctrl> <End> at any time. After executing your manual request, the Demo or Menu Program will continue where it left off. Note: Pressing <End> while a program is in progress will merely skip to the next menu item in the program.

Color Burst: If you have a composite video display connected to a CGA video adapter, then you can alternately turn the Color Burst on and off by pressing "b" or "B" (for burst) at any time. This will work everywhere except within the *Program Options Menu.* In most cases, turning the Color Burst off will substantially improve the screen image on a composite display by disabling the encoded color signals that are sent to the display. The Color Burst does not affect standard direct-drive video displays. See the *Glossary* and the *Video Displays* section in Chapter 5 for more information. Within a test series, the <F7> Function key can also be used to control the Color Burst. If you have a composite display, then you should run DisplayMate with the "C" option, which sets all the menu and result screens to black and white. See the *Program Options* section, below.

Press any Key to Continue: means DisplayMate will wait until you press a key that normally displays a character on the screen. This excludes the <Shift>, <Ctrl>, <Alt>, <Caps Lock>, <Num Lock>, <Scroll Lock>, <Print Screen>, and <Pause>. You may also click any of the buttons on your mouse. Aside from "waking up" the program, the meaning of the key is ignored and not interpreted as a command, unless you are requesting

Help or requesting a video system reset by typing "r". If the screen has been blanked (with the S option), or is in the process of being dimmed, it will respond to any key found on an IBM keyboard except <Print Screen> and <Pause>, including the <Shift>, <Ctrl>, <Alt> keys.

Menus

Move the menu highlight bar to the selection of your choice by using the <Up Arrow> and <Down Arrow> Keypad keys, or by moving your mouse forward or backward. The <Home> and <PgUp> Keypad keys will move the highlight bar to the first menu item, while <PgDn> will move it to the last menu item. The item is selected by pressing the <Space Bar> or <Enter> keys, or by clicking the left mouse button.

An alternative and faster method to select a menu item is to press the numbered Function key shown at the left of the item. For Functions <F1> to <F10> press the indicated Function key. For <F11> to <F20> press the indicated key if it is available on your keyboard; otherwise press and hold the <Shift> key, which promotes the Function key numbers by 10, followed by the appropriate Function key <F1> to <F10>.

Menu items that do not show a Function key are unavailable on your video system, and are shown in the color cyan. The menu highlight bar will skip over them. In the *Program Options Menu* the items are selected by typing one of the letters shown at the left of the screen rather than with the Function keys.

Typematic Action and Overrun

If you press one or more keys down very quickly, or hold a key down so that its typematic action begins repeating at 10 or more keystrokes per second, DisplayMate may not always be able to execute the commands as quickly as they are generated. The keystrokes then accumulate in the keyboard input buffer. DisplayMate eliminates this overrun condition in two different ways:

(1) For the "proceed" keys, <Space Bar> and <Enter>, all prior or pending keystrokes for these keys are flushed and ignored whenever DisplayMate begins a

wait state; *i.e.*, the proceed keys are not effective until after DisplayMate pauses to wait for your input;

(2) For all other Function and Keypad keys, DisplayMate analyzes all pending keystrokes and executes a single final action; intermediate states and screens are skipped and not shown.

As an example: if you very quickly press the <PgDn> key four times during a test series, the first key press will initiate the next test screen, with the remaining three saved in the keyboard input buffer. When this first screen is finished, DisplayMate will read all the pending input, skip the two intermediate tests and immediately proceed to draw the fourth screen. Alternatively, if you very quickly press the <Enter> key four times, DisplayMate will proceed to the next test screen and wait for your next command.

Num Lock State

DisplayMate automatically locks the Keypad out of the Num Lock state so that the keypad Function keys remain active at all times, regardless of the number of times you press the Num Lock key. When DisplayMate terminates, it restores the Num Lock state back to its initial condition. On IBM and true compatible computers, the Num Lock Status Light, when present, always accurately reflects the true Num Lock state, so you will see the light go out when DisplayMate starts up, and then go back on when DisplayMate terminates.

On other computers the Num Lock Status Light may become confused and be out of step with the true Num Lock state, which is under program control and not keyboard control. For these machines, ignore the status light while DisplayMate is running. If you do not touch the Num Lock key while DisplayMate is running, then the Num Lock Status Light will be correct after DisplayMate terminates. If you inadvertently touch the <Num Lock> key, you may have to resynchronize the light by toggling it twice after DisplayMate terminates. If the keyboard has "dumb" status lights that simply count keyboard strokes, then see your keyboard manual for instructions on resetting the status lights.

Keyboard Compatibility Problems

If your keyboard is not fully IBM compatible and you experience difficulty controlling DisplayMate from your keyboard, or you use ANSI.SYS to reassign keys on your keyboard and want those reassignments to remain in effect while DisplayMate is running, then use the "k" command line option to have DisplayMate read the keyboard using DOS instead of the system BIOS:

dmu -k

When using the "k" option you will not be able to use the <F11> and <F12> Function keys on an enhanced keyboard unless you have DOS 4.0 or later and have installed the ANSI.SYS driver with the "/X" parameter. A line similar to the following should appear in your CONFIG.SYS file in the root directory of your main disk:

DEVICE=ANSI.SYS /X

See your DOS manual for details appropriate to your system.

Mouse Compatibility Problems

When DisplayMate starts, it automatically searches for a mouse driver in the computer. If your mouse is not fully compatible with the Microsoft Mouse, it may cause DisplayMate to behave in an unpredictable manner. Note that almost all mice are compatible. If you experience difficulty controlling DisplayMate using either your mouse or keyboard, then use the "p" command line option to have DisplayMate completely ignore the mouse:

dmu -p

The *Program Options Menu* also allows you to activate or deactivate your mouse. Go to the "P:" option and toggle its state using the <Space Bar> key. If the mouse is active and working properly you can also click the left mouse button to deactivate the mouse. If you wish to reactivate it, then use the <Space Bar> key.

Program Options

DisplayMate has a number of options that control the program that can be specified from the command line or modified in the *Program Options Menu.* The options control the following functions:

- the menu display format, in order to improve readability,
- the level of automatic help provided,
- the type of keyboard and mouse input,
- whether to use fast or slow screen output, primarily for CGA video adapters,
- whether the screen will be blanked after a specified period of inactivity,
- the insertion of a time delay when changing video modes to reduce bounce,
- menu programing functions used for automating DisplayMate execution.

You can obtain a listing of the command line options by typing the following at the DOS prompt:

dmu ?

The output is shown in Figure 4.3 and provides a convenient summary of all of the options available. The *Program Options Menu* is reached from the *Main Menu* and allows the options to be modified interactively. Figure 4.4 shows the *Program Options Menu.* A few of the options that affect program initialization may only be set from the command line.

In this section we will discuss the most important options in an abbreviated fashion. A complete guide to the program options is available in Appendix E.

Demo: The simplest command line option will produce a demo of DisplayMate for you. For this option type:

dmu demo

at the DOS prompt. This will produce a *Non-Technical Program* demo. For the *Technical Program* demo type:

dmu tech demo

```
DisplayMate Video Utilities                                 Command Line Options

B:        menu screen Background color set to black.
C:        menu screen foreground Color set to white & background to black.
D=n.nn:   mode change Delay time set to n.nn seconds (0 to 2).
E=n:      Expiration time for menus set to n seconds (0 to 60 with 0=OFF).
F:        force Fast direct screen updates with screen snow for CGAs.
H=n:      auto Help set to level n:  n=0 off;  n=1 on;  n=2 maximum help.
I:        menu screen Intensity set to low.
K:        use DOS instead of the system BIOS to read the Keyboard.
L=n:      set program technical Level:  n=1 non-technical;  n=2 technical.
M=n:      test Mode set to mode n.
N:        force slower BIOS screen updates with No-Interference.
O:        generates a listing of the Options in effect.
P:        ignore any mouse Pointing device.
R:        continuously Repeat demo or menu program.
S=n:      idle time for Screen blanking set to n minutes (0 to 60 with 0=OFF).
T=n:      cycle Time for display screens set to n seconds (0 to 60 with 0=OFF).
X:        set eXtended mode change delay time for multi-frequency displays.

0 to 13:  select up to 16 menu items by number to be executed in order.
NONTECH:  selects the Non-Technical Program.  The same as L=1.
TECH:     selects the     Technical Program.  The same as L=2.
DEMO:     activates an automatic Demo Program.
TP:       produces a master screen Test Pattern.

Options may be upper or lower case letters and preceded by flags "/" or "-".
Options without parameters may be concatenated. Equal signs "=" are optional.
Examples:  "dmu -r demo"  "dmu tp"  "dmu nontech -obx t=10"  "dmu L=2 2 3 4"
```

Figure 4.3 *Command Line Options Output Screen.*

If you want the demo to Repeat continuously, type:

dmu R demo

Test Pattern: Another simple command line option will produce the DisplayMate master Test Pattern on your display for 20 seconds, and then automatically return you back to DOS:

dmu tp

The default time can be changed with the "T" option, which is described in the *Screen Test Pattern* section, below, and in Appendix E.

```
DisplayMate Video Utilities                                Version 1.1
----------------------------------------------------------------------
Program Options Menu:

H:   2      auto Help set to level n:  0=off  1=on  2=maximum
B:   ON     menu screen Background color set to black
C:   OFF    menu screen Colors set to white on black background
I:   ON     menu screen Intensity set to low
F:   OFF    force Fast screen updates with screen snow for CGAs
N:   OFF    force slower screen updates with No-snow for CGAs
P:   OFF    ignore any mouse Pointing device

S:   10     idle time for Screen blanking set to n minutes
D:   0.25   mode change Delay time set to n.nn seconds (0 to 2)
X:   OFF    eXtended mode change delay for multi-scan displays
T:   30     cycle Time for display screens set to n seconds
E:   OFF    Expiration time for menus set to n seconds

<End>       Return to Main Menu
----------------------------------------------------------------------
Use <↑> <↓> or type the option letter at left to select an option.
Use <←> <→> or the <Space Bar> key to change an option setting.
Press <End> to return to the Main Menu.  For Help press  ?  or  <Ins>.
```

Figure 4.4 *The Program Options Menu.*

Menu Readability: The most important options are those that affect menu readability since nothing can be accomplished if it is difficult or impossible to read the menus. DisplayMate automatically sets these options based on the video hardware configuration it detects. This should be satisfactory except for monochrome displays that are connected to color adapters and are masquerading as color displays. This is often the case in portable computers and may require setting one of the options. The options are also available to suit your personal preference. They are:

- **B:** sets the menu screen background color to black. On color displays the background is normally set to blue.
- **C:** sets the menu screen foreground color to white and the background color to black. This is probably the best option for monochrome displays.
- **I:** sets the screen intensity for menu text to a low intensity. Normally the menus are written with high intensity text on a blue background. This option is meant to be used with the *B* or *C* options in case the screen appears excessively bright, but it can also be used by itself.

Another option tells you about the options you have set:

- **O:** generates a screen listing of the *Command Line Options in Effect.*

Figure 4.5 shows a typical *Command Line Options in Effect* screen, which, if requested, is the first screen displayed by DisplayMate.

```
                    Command Line Options in Effect

    O:  Option generating this listing.
    B:  menu screen Background color set to black.
    I:  menu screen Intensity set to low.
    S:  idle time for Screen blanking set to 10 minutes.
    D:  mode change Delay time set to 0.25 seconds.
    T:  cycle Time for display screens set to 20 seconds.
    TECH:  Technical program.

    Errors were detected for the following options: E L

    The following invalid options were detected: G Y









    Press any key to continue...   or   Wait for time-out to proceed.
```

Figure 4.5 *The Command Line Options in Effect Screen.*

These and all other command line options are invoked by simply typing their option letter after the program name. For example:

dmu B

sets the menu screen background color to black. Note that the option letter is generally suggestive of the option name.

If there is more than one option, you simply type the option letters one after another, with one or more intervening spaces. If the options don't include an "=" parameter, as is the case for most of the options, then the intervening spaces can be left out. You can use upper or lower case letters and insert option flags "/" or "−" in front of the letters for readability. The following three examples are all equivalent:

```
dmu o b i
dmu −B /i o
dmu OBI
```

These same options may also be modified in the *Program Options Menu* by first moving the menu highlight bar to option you wish to modify. Do this with the keypad <Up Arrow> or <Down Arrow> keys, or by simply typing the option letter. Then use the <Space Bar> key to change the option setting from *OFF* to *ON,* or vice versa. The menu screen settings will take effect the next time a screen is drawn. You can easily make this to happen right away by toggling the help key <Ins> or by typing "r" for reset. When you are done with the *Program Options Menu* type <End> or <Esc> to return to the *Main Menu.*

Keyboard Input: The "K" option will have DisplayMate read your keyboard using DOS instead of the system BIOS. Type:

```
dmu −K
```

Use this option if your keyboard is not fully IBM compatible and you experience difficulty controlling DisplayMate from your keyboard, or you use ANSI.SYS to reassign keys on your keyboard and want those reassignments to remain in effect while DisplayMate is running. Note that when using this option you will *not* be able to use the <F11> and <F12> Function keys on an enhanced keyboard unless you have DOS 4.0 or later and have installed the ANSI.SYS driver with the "/X" parameter.

Mouse Input: This option will have DisplayMate completely ignore any mouse on your computer. A mouse that is not fully compatible with the Microsoft Mouse may cause DisplayMate to behave in an erratic manner. To have the mouse Pointing device ignored type:

```
dmu −P
```

Use this option if you experience difficulty controlling DisplayMate with either your mouse or keyboard.

Automatic Help: provides a *Test Prompt Screen* before every display test that describes the test and tells you what to look out for on the screen. You can control this facility from the command line or from the *Program Options Menu.* Setting the level of *Automatic Help* from the command line is slightly different from the previously discussed options, because it takes a parameter: 0, 1, or 2: 0 turns this feature *OFF,* which is what experienced users will most likely want; 1 turns it *ON;* and 2 sets it to *MAXIMUM,* which is the default and adds information on the Function keys to the *Test Prompt Screen.* The parameter is set with an equal sign as follows:

dmu H=0

sets *Automatic Help* to *OFF.* Options with parameters must be separated from adjoining options by one or more spaces. No spaces are permitted between the option, the equal sign, and the parameter value. The equal sign itself, however, is optional. So we can set the option by merely typing:

dmu H0

To change this option in the *Program Options Menu,* proceed as in the discussion of the previous options and move the menu highlight bar to the help option. Do this with the keypad <Up Arrow> or <Down Arrow> keys or by simply typing the option letter, "h". Note that typing "h" will normally produce a help screen, but here it will move the menu bar to the help option line, *unless* the bar is already on the help option, in which case help will be invoked as usual. This idiosyncrasy does not apply to the other methods for invoking help: "?" and <Ins>. To change the parameter value use the <Left Arrow> and <Right Arrow> keypad keys to increase or decrease the value. The <Space Bar> key increments the parameter until it reaches a maximum, then it wraps around to the minimum value and begins climbing again.

Technical Level: You can specify the Technical Level for the tests on the command line and avoid the *Program Menu* by typing:

dmu nontech *or* **dmu L=1**

specifies the *Non-Technical Program* and

dmu tech *or* **dmu L=2**

specifies the *Technical Program.*

Screen Blanking: Another option with a parameter is Screen blanking, which will cause DisplayMate to blank the screen automatically after a period of inactivity, specified in minutes. For example:

dmu S=20

The time value can be anywhere from 0 to 60 minutes, with 0, the default, turning off this feature. A message and beep mark the beginning of the screen shutdown in order to alert a user to the action about to take place. The screen can be restored by pressing any key on the keyboard, or by clicking any mouse button. This option may also be modified in the *Program Options Menu.* It applies only to DisplayMate, and does *not* install a general screen blanking routine in your computer.

Mode Change Delay: If the image on your video display breaks up or bounces when switching video modes, you can use either of two options to blank the screen for a short period of time after a mode change. That should make the switch less visually disturbing. Note that this is a shortcoming of your display and/or video adapter, and is generally most pronounced on multi-frequency displays. The "X" option will eXtend the blanking time to a fixed 0.5 seconds. The Delay "D" option allows you to specify the blanking time from 0 to 2 seconds in 0.01 second steps. For example:

dmu X

sets the delay time to ½ second.

dmu D=0.75

sets the delay time to ¾ second. Of course, DisplayMate will appear to run more slowly because of the added delay. A half-second can sometimes feel like a long time. This option may also be modified in the *Program Options Menu.*

Screen Access Method: In drawing text screens, DisplayMate will access the screen memory directly for all video adapters except the CGA. On the CGA, direct access produces harmless but annoying interference called snow. In this case DisplayMate uses the built in BIOS functions that synchronize with the adapter hardware and do not produce snow. Unfortunately, they are about 25 times slower than direct access. Some non-IBM CGAs do not produce snow and can benefit from the speedup without any side effects. Some users prefer to put up with the snow in order to obtain the speed up. To force Fast direct screen updates, use the "F' option:

dmu F

DisplayMate also allows the reverse option for adapters that are not fully IBM compatible and can benefit from using the BIOS routines for drawing text. To force slower screen updates with No-interference, use the "N" option:

dmu N

The screen updates will take noticeably longer, but should still take only a fraction of a second. These options may also be modified in the *Program Options Menu.*

Setting Up Your Display

Properly setting up and adjusting the user controls on your display is an essential, but often neglected, aspect of operating your computer. It must be done not only when you first install the video system, but on a regular basis if you are to minimize eye-strain and maximize user comfort and productivity. The user controls that need adjustment include: Brightness, Contrast, Centering, and Size. Properly setting the Brightness and Contrast controls is particularly important when photographs and other gray-scale images are being presented in order to obtain a linear light output. Other aspects of setting up a display, such as choosing the display's location, height, and orientation are discussed in Chapter 7 on *Maximizing Comfort and Productivity.*

DisplayMate has a *Setup Display* selection in the *Main Menu* that will guide you through setting up your display with a series of test screens. You will need to go through the complete *Setup Display* series only when you need a major tune-up of your video display system. Most of the time you should use the DisplayMate master Test Pattern, a single screen test image described in one of the following sections, in order to fine-tune your display during the course of your day's work. You need to make adjustments for the following conditions:

- Changes in room lighting, particularly if sunlight affects your work area.
- The optimum settings on the display drift with time. This is particularly the case while the display is warming up during the first hour after it is turned on. During this period the image centering and black-level or screen brightness may vary significantly.
- If you change your work organization or desk layout during the course of the day, you should also adjust your display as well.
- Different software programs may use different display modes, screen formats, layouts, and colors, that can benefit from setup adjustments.

If after going through the *Setup Display* test series you are unable to obtain a satisfactory display image with the user controls, then it is important that you have a field service technician adjust the display's internal controls. It is a serious mistake to use a display that is out of adjustment.

The *Setup Display* series is selected from the *Main Menu* and it is controlled in the same way as all of the other DisplayMate test series:

- You normally proceed from test to test by pressing the conveniently located <Space Bar> key or the <Enter> key. If you have a mouse, click the left button.
- Use the <Page Up> Keypad key to return to any previous tests in the series, and use the <Home> key to return to the first test screen.
- Use the <End> or <Esc> keys to terminate the test series and return to the *Main Menu.*
- Use the <Ins> Keypad key to request help at any time. If you have a mouse, click the right button.
- Use the <Del> Keypad key to redisplay the name and title of the test.

See the *Keyboard and Mouse Control* section above for a complete description of all the control keys.

The Function keys <F1> to <F10> are deactivated for all but one of the setup screens, unless you have a VGA or MCGA with a color display; then the <F8> Function key toggles between color and an equivalent gray-scale monochrome image. This allows users with a color display to see what an image will look like on a monochrome display.

If the *Automatic Help* facility is active, then each test will be automatically preceded by a *Test Prompt Screen* that provides a brief description of the test and also tells you what to look out for in the image. This, as well as additional information, is available for each test through the normal help facility, which also provides a brief description of what each Function key and Keypad key will do.

User Controls

In this section we describe the function of the user controls found on video displays. Not all controls are available on all displays. Generally, the more expensive displays include a greater number of user controls for adjusting the image.

If a control is not available as an external user control, then in most cases it is provided as an internal control for a service technician. So if your display cannot be properly adjusted using the external controls, then have a field service technician adjust them. *Warning:* internal controls are only for qualified technicians; unqualified service personnel are likely to not only misadjust the display further, but may seriously injure themselves from the lethal high voltages present in most displays.

Brightness: The brightness control uniformly increases or decreases the light output from the varying screen intensities. If you increase the brightness too high, the background will become visible and will cease to be black. As you decrease the brightness, more and more of the low intensity information will disappear because it falls below the black-level established by the brightness control. Some displays include a "Black Level" control that generally functions like a brightness control.

Contrast: The contrast control varies the difference in light output from the lowest and highest screen intensities. When the contrast is at a minimum, dark gray, white, and bright white may all be indistinguishable. As the contrast is increased, the difference between the intensities will become more and more pronounced.

You will find 3 different kinds of contrast controls: the first will work like your TV and not affect dark gray much, but will boost the intensity of white, and also of bright white, to an even greater degree; the second will not affect white but will decrease dark gray and boost bright white; the third will not affect bright white but will decrease white, and also dark gray, to an even greater degree. Further confusing matters, the contrast on some models will decrease as the knob is turned clockwise, opposite to what most people expect. For digital displays you'll need to vary the contrast control in order to figure out which style you have. All analog displays work like the TV contrast controls that most people are use to.

IBM's Enhanced Color Display has a little trick to it: the contrast control has no effect when the control is pushed in, which is its normal operating position, and it selects an internal factory setting. You must pull the contrast control out in order for the control to work.

Picture Control: This is a single control that varies both the contrast and the brightness at the same time. If you don't like the way the manufacturer has coupled the variation of the two controls, then you're out of luck.

Size and Centering / Position: These may be either controls or switches that are used to frame the image on the screen properly. In some cases, the size and centering/position controls will interact with one another, so that the size will affect the centering/position, and vice versa.

Some displays include an overscan/underscan switch that controls the overall image size. In the overscan mode the image is slightly larger than the screen, so that the edges of the image are not seen; in the underscan mode the image will be an inch or so smaller than the screen. Video displays are generally operated in the underscan setting, so that information is not lost near the edges and corners of the screen.

Normal / Reverse Video Switch: is found on many monochrome and portable computer displays. The switch inverts the image either from the common white text on a black background to the paper style black text on a white background, or vice versa. It can be used to improve screen readability under many conditions. If you set the switch to reverse video, then some screen images in DisplayMate will not appear correctly.

Mode Switches: are found on many multi-frequency displays. They control the display's interpretation of the video signals coming from the video adapter as being either: MDA, CGA, EGA, or analog VGA/MCGA. The switches must be set to agree with the type of video adapter you have, otherwise the screen colors will not be correct.

Often there are two mode switches: one marked monochrome/color, which means you have an MDA or Hercules adapter attached to the display, or else you have a CGA, EGA, MCGA, or VGA color adapter. A second switch is often marked 8/16/64: the first selection ignores the intensity signal on a CGA, resulting in only 8 colors; the second is a standard 16 color CGA or an EGA in a 200 line low resolution mode; and the third is for a standard 64 color EGA in a 350 line high resolution mode. One of the switches may also include an analog setting for VGA and MCGA adapters.

The better multi-frequency displays can figure this out by themselves and will have a third switch marked auto/manual, which allows the display to automatically set the mode, or gives you the option specifying this manually with the previous two switches. The manual mode is required for non-standard video modes.

Color Switches: Some color displays include a color switch that translates all non-black colors to a single color, such as green, amber, or white. These monochrome modes may be more appealing to some users when working in text mode, such as in a word processor. Some displays also include switches marked color/monochrome or 8/16/64 colors, which are actually mode switches, and are discussed above.

Pincushion Distortion: A number of the better quality displays are now including an external user control to help correct pincushion distortion, a common form of screen geometric distortion. This will allow you to minimize the curvature of the image on the left and right sides of the display. Most displays include this control as an internal service adjustment. See the section on *Screen Distortion Measurements* later in this chapter for a thorough discussion of this topic.

Static Convergence: Some expensive displays include horizontal and vertical static convergence controls that allow you to touch up the overall color registration on the screen. Since color registration is never perfect, this allows a user to minimize whatever bothers him or her the most. The color registration tests in the *Video Obstacle Course* or *Display Tests* are the best places to adjust these controls.

Degaussing: Some color displays include a manual degaussing button that is useful if you expect to leave your display on all the time. Degaussing restores color purity that has been degraded by variations in stray magnetic fields. Most color displays have automatic degaussing circuits that work only when the display is turned on, provided it has been off for a reasonable length of time, like one-half hour.

Vertical Hold: This is the same control found on many home TVs and is used to prevent the image from rolling or bouncing vertically. This control should not be necessary on computer displays and may indicate inadequate automatic synchronization circuitry.

Setup Screens

In this section we provide a brief description of each setup screen and what to look out for in each image. You will see all of the setup screens if you have a VGA video system. For the other video systems you will see only those screens that are appropriate for your hardware; the others will be automatically skipped by DisplayMate.

In some cases, it may not be possible to setup your display "perfectly." You may have to make compromises based on your visual preferences. This may require that you go through the setup screens more than once in order to balance the adjustments.

If the images on your display look substantially different from the text descriptions, then your video system hardware may be incorrectly configured, or you may have a compatibility problem. See the *In Case of Difficulty* chapter near the end of this manual.

Brightness & Contrast Adjustment: In this screen you perform an initial setting of the display's brightness and contrast controls. In color systems the bottom rectangle should show 3 sets of two lines each. In most monochrome systems the first low intensity set will be missing.

The first step is to set the Brightness Control, often marked by a symbol of the sun. Increase the brightness until the screen background just becomes visible. Then decrease it until the background just becomes black again.

Next, adjust the Contrast Control, often marked by a half dark circle, so that each set of lines is visible, clearly distinct, and graduated in intensity. The brightest set of lines should not be too bright or appear blurred.

Since these two controls interact, it will generally be necessary to alternately adjust the controls until you get the right combination.

Color Verification: The six colors should appear as described. If all you see is a color name in white, then that color is missing. If the colors are incorrect, the most likely cause is an incorrect setting of the display mode switches that were described above. Use any of the Color or Mode or Text switches on the display in order to obtain a correct set of colors. Other possibilities include memory resident software that has manipulated the default color palette. If you have a monochrome display, then the lines will appear in an equivalent monochrome intensity. Each of the lines should be plainly visible and easy to read.

Primary Colors: You should see 8 colors for CGA / MCGA video systems, and 12 colors for EGA / VGA video systems. The colors should be as described. If some of the colors are incorrect or missing, there may be problems with the display mode switches that were described above. Other possibilities include incorrect configuration settings for the video adapter, and memory resident software that has manipulated the default color palette. If you have an EGA adapter and the low intensity "Dark Red" primary color is missing, then check the P1 monochrome/color strap on the adapter. See the installation instructions for the adapter.

CGA Compatible Colors: You should see 16 labeled colors that should appear as described. These are the standard colors that are used in all IBM color video systems. If you have an EGA or VGA you will notice that the "Bright" colors on this screen are different from those in the *Primary Colors* screen, above. This is because the standard IBM bright colors are "lightened" versions of the primary colors, and include significant additions of white light to give the colors a whiter, more pastel appearance. Many video adapters and displays have trouble with "Brown," and may produce a color that is hard to distinguish from red. In some cases, a minor adjustment in the brightness or contrast may improve the appearance of some of the colors.

Color Combinations: This screen displays all possible color combinations for the standard colors in text mode. The bright colors are identified in all capital letters. This screen has several purposes:

- You can search through the screen to find appealing color combinations for your work, and also discover combinations that may cause eye strain and fatigue.
- On monochrome displays, many of the color combinations will be invisible because certain high contrast colors have the same or similar monochrome intensities. Some computers have utilities that allow you to modify the correspondence between color and intensity. This screen may help in modifying the mapping to improve the visibility for color combinations used by your software. If you have a color VGA or MCGA video system, press the <F8> key to see how the screen appears in monochrome.
- Certain color combinations may demonstrate problems with the video system. The colors may not line up properly: there may be gaps, intensity ridges, and flickering and dancing color edges. You should use the *Video Obstacle Course* and the *Display Tests* to look into the problem further.

Reverse Video Check: If you are planning to work in reverse video with dark text or graphics on a white background, this screen allows you to check the appearance of this presentation format during the setup procedure. The characters should have sharp edges and appear uniformly black. If they don't appear as crisp as the normal video characters in the *Brightness and Contrast Adjustment* screen, then your display may not be up to the task. See the section on *Normal Video versus Reverse Video* in Chapter 5. In some cases, a minor adjustment in the contrast control may improve the readability of the screen.

Intensity Range Check: You should see two blocks, each with 3 uniformly graduated intensity steps. Many flat-panel displays on portable computers cannot reproduce small intensity variations; with them you may see only one or two steps per block.

The top block has three low intensity steps beginning with black. If it does not reproduce properly, then you have set the brightness control so low that low intensity information is being lost. Adjust the brightness control to bring out the low intensity steps.

The bottom block has three high intensity steps ending with bright white. If it does not reproduce properly, then you have set the contrast control so high that the whites are saturated. Reduce the contrast to bring out the high intensity steps.

Color Scales: You should see 10 colors, each with 25 color steps uniformly increasing from black to a maximum brightness. In some cases, a minor adjustment in the brightness or contrast may improve the appearance of the color scales. None of the color hues should change with intensity, and all should fade uniformly to black together. If your display does not behave in this manner, then it needs servicing.

Defocusing and Blooming Check: High intensity images may not appear as sharp as low intensity images because of effects called defocusing and blooming. You should compare the relative sharpness of the dark gray, white, and bright white images. Look, for example, at the thickness of the gap between the double lines, at the size of the hole in the "o," or the gap between the double angular brackets. Check whether the dot patterns at the center of the screen are all equally sharp. If the high intensity set appears blurred, then reduce its high intensity using the display's contrast control.

Screen Focus Check: Compare the sharpness of the 9 sets of dot patterns on the screen. On most displays, the pattern at the center of the screen will be the sharpest. If the other sets are not reasonably sharp, then the display requires servicing.

Screen Framing and Aspect Ratio: Use this series of screens to check and adjust the size and centering / position controls on your display. Up to 4 screens may be displayed depending on your video system: the primary, secondary, and tertiary graphics modes, and the primary text mode. Each of the screens will show an outer rectangle that defines the image area in that mode, an inner square, and a circle for graphics modes. For the first screen, adjust the size and centering controls so that:

- The outer rectangle is centered on the screen with a ½" border to the edge of the screen.
- The inner square appears as a square. Using the tick marks, measure the height and width of the square and adjust the size controls until they are equal.
- The circle should appear to be a uniform smooth circle. If not, then the display has some degree of geometric distortion. You should use the *Video Obstacle Course* and the *Display Tests* to look into the problem further. In the *Technical Program,* the *Screen Distortion Measurement Menu* can be used to measure the screen distortion interactively.

After adjusting the first screen, move on to the other screens in the set. If the images are out of adjustment, then your display will require further adjustments. Some displays will have separate size and centering/position user controls for each of the modes, in which case you can adjust them in the same way as the first. If separate size controls are not available, then you may be able to obtain a satisfactory compromise among the modes that you use most often. Otherwise, your display will most likely require servicing to balance all of the different modes using the internal controls.

A Test Page of Text: Use this screen to check the readability of your display with various color combinations.

- The keys <F1> and <F2> can be used to change the foreground color.
- The keys <F3> and <F4> can be used to change the background color.
- The key <F6> can be used to switch between normal and reverse video.
- The key <F8> can be used to switch between color and monochrome for VGA or MCGA displays.

Color Bar Test Pattern: This screen resembles the color bar test pattern used in television systems. Use it to evaluate the quality of the colors on the display. In some cases, a minor adjustment in the brightness or contrast may improve the appearance of some of the colors.

Screen Test Pattern: This is the master test pattern produced by DisplayMate. You should use it to regularly fine-tune your display during the course of your day's work. What you see will depend on the capabilities of your video system. It generally includes circle and crosshatch patterns that are used to check for geometric distortion, for adjusting the display's size controls so the image has the correct *Aspect Ratio* and the test circles are displayed as true circles, and for centering and framing the image on the screen. The subpanels within the main circle contain elements from the *Setup Display* test screens, and are useful for setting and checking the screen brightness, contrast, focus, color balance and color registration.

The Video Obstacle Course

The Video Obstacle Course™ is a set of 32 visual tests that allow you to quickly see how your video display stacks up to a tough set of hurdles. Most displays will fail several or more of these visual tests, and by this we mean the screen images will appear significantly degraded over what a high quality display should present. You will have little difficulty in picking out unsatisfactory images. The eye and brain are particularly good at understanding the underlying idea that is being conveyed in a screen image, even if you have never seen it before. From there it is a simple intuitive process to figure out the difference between what you think the image should look like and what it actually does look like. As an example, you do this every time you review photos that have just been developed. Your eye can easily detect subtle problems in the prints, even if you did not take the photographs.

The tests in *The Video Obstacle Course* are drawn from the complete set of tests provided by DisplayMate. If you are planning to go through the complete *Display Tests* menu, then there is no need to take *The Video Obstacle Course* because you will see each of these tests again. However, you can quickly flip through *The Video Obstacle Course* just to get an idea of how your display is doing. The following section on *Display Tests* explains how you can use the information that you gather from these tests to optimize your display and to improve the manner in which you use it.

The *Video Obstacle Course* is selected from the *Main Menu.* There are 32 tests in the series; however, not all of the tests are available with all adapters and video modes. What you will see depends on the capabilities of your hardware: in general, the MDA, which is restricted to monochrome text modes, will produce the fewest tests, and the VGA, which is the most versatile of the adapters, will produce the most tests. Tests that are incompatible with the video adapter hardware are automatically skipped. Appendix G provides a listing of all the tests.

If the *Automatic Help* facility is active, then each test will be automatically preceded by a *Test Prompt Screen* that provides a brief description of the test and also tells you what to look out for in the image. This, as well as additional information, is available for each test through the normal help facility, which also provides a brief description of what each Function key and Keypad key will do. In general, the Keypad keys control the sequence of the tests and information about the tests, while the Function keys control the colors and appearance of the test images.

In most tests you are encouraged to play with the foreground and background colors, switch from normal to reverse video, and switch from a color to a monochrome view of the image if you have a VGA or MCGA display system. This will help you to explore not only the capabilities of the hardware, but also your visual reactions to the different image formats.

For some tests one or more of the Function keys may be deactivated because their use would interfere with the goals of the test. Foreground color control is not available in tests that already use several foreground colors at once. Pressing the Function key in these circumstances will result in no action. You can check the help screen to see which keys are available. For some video adapters or video modes, one or more of the Function keys may be locked because that capability is not allowed by the hardware. For example: in the high resolution graphics mode of the CGA, the background color control key is locked because the hardware forces the color to black. Pressing the Function key in this circumstance will result in an error tone.

All your Function key selections are carried forth from test to test. If DisplayMate imposes its own selection for a particular test, it will reinstate your prior selections for the next test.

The *Video Obstacle Course* is controlled in the same way as all of the other DisplayMate test series:

- You normally proceed from test to test by pressing the <Space Bar> key. If you have a mouse, click the left button.
- Use the <Page Up> Keypad key to return to any previous tests in the series and use the <Home> key to return to the first test screen.
- Use the <End> or <Esc> keys to terminate the test series and return to the *Main Menu.*
- Use the <Ins> Keypad key to request help at any time. If you have a mouse, click the right button.
- Use the <Del> Keypad key to redisplay the name and title for the test.

See the *Keyboard and Mouse Control* section above for a complete description of all the control keys.

The Function keys <F1> to <F10> are used to control the colors and other aspects of the screen image. The help screen and automatic test prompts show what each of the keys do:

<F1> and <F2> change the foreground color to the previous or next values, respectively. For most adapters, 16 colors are generally available.

<F3> and <F4> change the background color to the previous or next values, respectively. For most adapters, 16 colors are generally available.

<F5> sets the colors back to their default values: normal video with a white foreground and a black background. This spares you from having to repeatedly use the <F1> to <F4> keys to get back to the standard white on black colors.

<F6> toggles between normal and reverse video. This key will reverse the current foreground and background colors.

<F7> enables or disables the Color Burst for the composite video output on IBM CGA adapters. See note 4, below.

<F8> toggles between color and an equivalent gray-scale monochrome image for the MCGA and VGA adapters. This allows someone with a color display to see what an image will look like on a monochrome display.

The following notes provide additional details for the Function keys that may be of interest to some users:

1. In general, 16 foreground and background colors are available for most video adapters and video modes. For monochrome modes there are 3 "colors:" black, white, and bright white. Monochrome displays operating in color modes will generally produce a different intensity for each color in an attempt to convey color information. The <F1> to <F4> Function keys will cycle through all the possibilities allowed by your hardware, except in the case of the VGA/MCGA 256 color mode, where only the standard 16 colors are presented because going through all 256 colors is tedious and not very interesting. DisplayMate will automatically skip over color combinations where the foreground and background colors are the same.

2. In most tests where DisplayMate imposes its own choice of colors, it will prevent the user from changing them with the <F1> to <F4> Function keys because that would interfere with the goals of the test. Under these circumstances, the color selections that were in effect during the previous test will be reinstated for the following test. For a few tests, however, DisplayMate will allow you to modify the colors it believes are best. If you change these suggested colors, they will not carry forward to the next test; instead, your color selections from the prior test will be reinstated as before.

3. Normally, DisplayMate automatically selects the best video mode for each test. In the *Technical Program,* the *Select Video Test Mode* menu may be used to choose any video mode supported by your hardware for running the *Video Obstacle Course.* This not only allows you to test your adapter in all the various compatibility modes, but also shows you how the lower resolution and color modes will appear.

4. On the IBM CGA, toggling <F7> to turn the Color Burst on or off will have no effect on direct-drive color displays, except in the 320×200 medium

resolution graphics mode, where 2 additional color palettes are available instead of the standard 4. See Chapter 5 for a discussion of effects of the Color Burst on a composite display image.

Display Tests

The *Display Tests Menu* is selected from the *Main Menu* and provides access to the largest collection of DisplayMate tests. All of the tests are in the form of visual test patterns that have been carefully formulated to highlight particular strengths and weaknesses of computer video displays. Every person has a unique set of sensitivities and preferences to the inherent shortcomings in video displays. What is particularly irritating to one person may not bother another very much. So your own eye is the final judge in all of the tests.

You can use the tests in a number of ways:

- To become aware of, and identify the problems and shortcomings of your display that bother you. You may not be consciously aware of some of the problems, yet they may still be able to affect you adversely via reduced productivity, headaches, and the like. Simply being aware of these problems may help you cope with some of their effects.
- To reduce whatever problems you discover by further adjusting your display to minimize their effects on you. For example: if you detect a serious problem in color registration for a particular color on your display, you can make your color selections to avoid that color entirely. Also, if you detect serious geometric distortion at one of the corners of your display you may be able to use the size and centering controls to keep that problem from seriously affecting your image.
- To reduce whatever problems you discover by changing how you work with your display, and by changing your work habits.
- To alert you for the need to have your unit adjusted or serviced by a qualified technician. You will also be able to guide the technician in adjusting and minimizing the problems that bother you the most.
- To alert you to the need to upgrade your display and adapter.

Figure 4.6 shows the *Display Tests Menu.*

```
DisplayMate Video Utilities                              Version 1.1

Display Tests Menu:                                      Auto Test Mode

Function Key <F1>   Introduction

             <F2>   Geometry Tests

             <F3>   Display Resolution Tests

             <F4>   Adapter Resolution Tests

             <F5>   Color and Gray-Scale Tests

             <F6>   Text and Font Tests

             <F7>   Miscellaneous Tests

Key Pad Key  <End>  Return to Main Menu

Use the Function Keys <Fn> or Keys <↑> <↓> then Press <Space Bar> or <Enter>
For Help Type  ?  or  h  or  press the  <Ins>  key.   For Other Functions...
Press <Fn> <↑> <↓> <Home> <End> <Page Up> <Page Down> <Space Bar> <Enter>  ?
```

Figure 4.6 *Display Tests Menu.*

The tests are broken down into 6 categories:

Geometry Tests: provides a series of test patterns that let you visually check for a variety of forms of geometric distortion on the display. Effects such as curvature, linearity, interference, and regulation are displayed.

Display Resolution Tests: provides a series of test patterns that let you visually determine the actual resolution limit of your display and see its effects on a number of image formats. Effects such as line brightness, Moires, defocusing, and blooming are displayed.

Adapter Resolution Tests: demonstrates the effects of the finite resolution of the video adapter on the quality and appearance of various images. Effects such as aliasing, jaggies, confusion, and fusion are displayed.

Color and Gray-Scale Tests: demonstrates the capabilities and shortcomings of a video adapter and display at producing their gamut of colors and intensities on the screen. Effects such as color registration, color timing, color purity, shading, and streaking are displayed.

Text and Font Tests: demonstrates the various text and font capabilities of your video system. Effects such as font readability, variable row spacing, and color attributes are displayed.

Miscellaneous Tests: examines a variety of special effects that can affect your video system. Effects such as uniformity, flicker, persistence, interference, mode switching, and color mask distortion are displayed.

Not all of the tests are available with all adapters and video modes. What you will see depends on the capabilities of your hardware. In general the MDA, which is restricted to monochrome text modes, will produce the fewest tests, and the VGA, which is the most versatile of the adapters, will produce the most tests. Tests that are incompatible with the video adapter hardware are automatically skipped. Appendix G provides a listing of all the tests.

If the *Automatic Help* facility is active, then each test will be automatically preceded by a *Test Prompt Screen* that provides a brief description of the test and also tells you what to look out for in the image. This, as well as additional information, is available for each test through the normal help facility, which also provides a brief description of what each Function key and Keypad key will do. In general, the Keypad keys control the sequence of the tests and information about the tests, while the Function keys control the colors and appearance of the test images.

In most tests you are encouraged to play with the foreground and background colors, switch from normal to reverse video, and switch from a color to a monochrome view of the image if you have a VGA or MCGA display system. This will help you to explore not only the capabilities of the hardware, but also your visual reactions to the different image formats.

For some tests one or more of the Function keys may be deactivated because their use would interfere with the goals of the test. Foreground color control is not available in tests that already use several foreground colors at once. Pressing the

Function key in these circumstances will result in no action. You can check the help screen to see which keys are available. For some video adapters or video modes, one or more of the Function keys may be locked because that capability is not allowed by the hardware. For example: in the high resolution graphics mode of the CGA, the background color control key is locked because the hardware forces the color to black. Pressing the Function key in this circumstance will result in an error tone.

All your Function key selections are carried forth from test to test. If DisplayMate imposes its own selection for a particular test, it will reinstate your prior selections for the next test.

The *Display Tests* are controlled in the same way as all of the other DisplayMate test series:

- You normally proceed from test to test by pressing the <Space Bar> key. If you have a mouse, click the left button.
- Use the <Page Up> Keypad key to return to any previous tests in the series and use the <Home> key to return to the first test screen.
- Use the <End> or <Esc> keys to terminate the test series and return to the *Main Menu.*
- Use the <Ins> Keypad key to request help at any time. If you have a mouse, click the right button.
- Use the <Del> Keypad key to redisplay the name and title for the test.

See the *Keyboard and Mouse Control* section above for a complete description of all the control keys.

The Function keys <F1> to <F10> are used to control the colors and other aspects of the screen image. The help screen and automatic test prompts show what each of the keys do:

<F1> and <F2> change the foreground color to the previous or next values, respectively. For most adapters, 16 colors are generally available.

<F3> and <F4> change the background color to the previous or next values, respectively. For most adapters, 16 colors are generally available.

<F5> sets the colors back to their default values: normal video with a white foreground and a black background. This spares you from having to repeatedly use the <F1> to <F4> keys to get back to the standard white on black colors.

<F6> toggles between normal and reverse video. This key will reverse the current foreground and background colors.

<F7> enables or disables the Color Burst for the composite video output on IBM CGA adapters. See note 4, below.

<F8> toggles between color and an equivalent gray-scale monochrome image for the MCGA and VGA adapters. This allows someone with a color display to see what an image will look like on a monochrome display.

The following notes provide additional details for the Function keys that may be of interest to some users:

1. In general, 16 foreground and background colors are available for most video adapters and video modes. For monochrome modes there are 3 "colors:" black, white, and bright white. Monochrome displays operating in color modes will generally produce a different intensity for each color in an attempt to convey color information. The <F1> to <F4> Function keys will cycle through all the possibilities allowed by your hardware, except in the case of the VGA/MCGA 256 color mode, where only the standard 16 colors are presented because going through all 256 colors is tedious and not very interesting. DisplayMate will automatically skip over color combinations where the foreground and background colors are the same.

2. In most tests where DisplayMate imposes its own choice of colors, it will prevent the user from changing them with the <F1> to <F4> Function keys because that would interfere with the goals of the test. Under these circumstances, the color selections that were in effect during the previous test will be reinstated for the following test. For a few tests, however, DisplayMate will allow you to modify the colors it believes are best. If you

change these suggested colors, they will not carry forward to the next test; instead, your color selections from the prior test will be reinstated as before.

3. Normally, DisplayMate automatically selects the best video mode for each test. In the *Technical Program,* the *Select Video Test Mode* menu may be used to choose any video mode supported by your hardware for running the *Display Tests.* This not only allows you to test your adapter in all the various compatibility modes, but also shows you how the lower resolution and color modes will appear.

4. On the IBM CGA, toggling <F7> to turn the Color Burst on or off will have no effect on direct-drive color displays, except in the 320×200 medium resolution graphics mode, where 2 additional color palettes are available instead of the standard 4. See Chapter 5 for a discussion of effects of the Color Burst on a composite display image.

Screen Test Pattern

DisplayMate provides a master screen test pattern that is useful for quickly setting up and evaluating a display. Use it every time you turn on your computer in order to keep the display optimally adjusted. Also use it during the course of the day when there are changes in room lighting, when there are significant changes in user work organization, or if the setup parameters drift. It is similar in nature to the test patterns that are used and occasionally transmitted by television stations to test their equipment, but has been specifically designed for computer displays.

The master *Screen Test Pattern* includes circle and crosshatch patterns that are used to check for geometric distortion, for adjusting the display's size controls so the image has the correct *Aspect Ratio* and the test circles are displayed as true circles, and for centering and framing the image on the screen. The subpanels within the main circle contain elements from the *Setup Display* test screens and are useful for setting and checking the screen brightness, contrast, focus, color balance, and color registration. See the section on *Setting Up Your Display* for information on how to use the various elements in the Test Pattern.

The test pattern can be called up as a selection from the *Main Menu* or directly from DOS via a command line option:

dmu tp

By adding the above line to the end of your AUTOEXEC.BAT file, you will obtain the test pattern every time you turn on your system. Without any additional parameters, the pattern will remain for 20 seconds and then you are automatically returned to DOS. The display time can be changed to any value between 1 and 60 seconds by adding the following:

dmu tp t=45

sets the time to 45 seconds. Setting t=0 will disable the timer altogether, so the test pattern will remain until you press any key to continue. If you want to keep the test pattern on until you get around to looking at it, but don't want it showing all the time, then activate the screen blanking option as follows:

dmu tp t=0 s=1

will blank the screen after 1 minute. Pressing any key thereafter will restore the test pattern, and pressing another key after that will return you to DOS.

Speed Performance Tests

The speed of your computer's video display system is one of the most important aspects of the computer's overall performance - second only to the raw system microprocessor speed.

A slow video system not only reduces your productivity, but can also try your patience. A fast and snappy video system is fun to work with. A difference of only a few tenths of a second may seem superfluous, but it can make all the difference in a user's perception of speed in a repetitive task like updating the display screen.

Surprising to some is the fact that the video adapter is generally more important than the microprocessor when it comes to video system speed, *i.e.*, switching display adapters on a given computer generally has a greater effect on video speed than changing computers with the same display adapter. The reasons are discussed in Chapter 5 on *Video Display System Basics*. The video display itself has no effect on the objective video system speed, although it can adversely affect human performance if, as on IBM's Monochrome Display, an unusually long persistence phosphor leaves trails of old information around so long that it interferes with the new information.

Video adapter manufacturers emphasize the speed performance of their cards, much like automobile manufacturers do. Some of these claims are either unrealistic exaggerations or are dreamed up in their advertising departments.

DisplayMate contains a fully automatic and comprehensive set of tests that measure the speed of your video display system. In the *Non-Technical Program,* a performance *Display Speed Index for Text* and a *Display Speed Index for Graphics* are separately computed and shown relative to an IBM PC with a CGA, an IBM AT (8 MHz) with an EGA, and an IBM PS/2 model 70 (25 MHz) with a VGA. A total of 31 separate tests are performed, which take 35 seconds and are invisible on the screen. This provides a comprehensive yet simple means to compare the performance for various hardware and software combinations.

Figure 4.7a shows the *Speed Performance Test Results* for the *Non-Technical Program.* The column headings for the PC and AT systems indicate the adapter used for the Text mode tests. The reference adapter for Graphics mode tests is always the same type as your own adapter. An index value of less than 1 means your video system works slower than the reference system; greater than 1 means faster and better. The *Display Speed Index* measures how quickly your computer can access and draw images on the video display. It is a weighted average of a broad range of video system operations. For any particular application program you use, the video system performance obtained will depend on which particular operations are used most often by the software, as well as how efficiently the software itself has been written. How the index relates to the overall speed at which a program runs depends on how screen intensive or graphics intensive your software is. Even if it is a small factor, the speed of a video system is something directly observed by the user, and is an important component of overall system performance.

The *Speed Performance Tests* is a selection of the *Main Menu.* In the *Non-Technical Program,* simply selecting this item will start the measurement process that produces the test results 35 seconds later. A message *Performance Test in Progress,* together with the amount of time remaining in the test will appear at the top of the screen, but it will briefly disappear from time to time.

```
DisplayMate Video Utilities                              Version 1.1

Speed Performance Test Results:


                                     Performance    Relative    to
                                     PC/CGA    AT-8/EGA    PS2/70-25

Display Speed Index for Text         27.3        5.8         1.9


Display Speed Index for Graphics      4.9        2.2         0.9

The Display Speed Index indicates the relative speed of your
video system with respect to the above three computer systems.
Less than 1 means slower. Greater than 1 means faster and better.

The Technical Program provides a detailed analysis of these results.

                    Press any key to continue...
```

Performance Test Tabulations for Mode 18: 640 x 480 16 Color Graphics

Test Description:	Operations Per Sec	Performance PC/VGA	Relative AT-8/VGA	to PS2/70-25
BIOS Scroll Screen	20	4.0	2.2	0.9
BIOS Clear Line	579	5.2	2.8	1.1
BIOS Clear Screen	21	5.3	2.7	1.2
BIOS Write Character	4945	4.0	2.6	1.2
Direct Write Character	20274	5.5	1.8	0.8
BIOS Write TTY Character	1161	3.5	1.9	0.9
BIOS Write String	4658	3.7	2.5	0.8
Direct Write String	26131	5.3	1.8	1.6
BIOS Write Dot	13526	6.9	4.5	1.1
Direct Write Dot	19764	4.9	1.4	0.5
Direct Short Line	4103	5.3	1.5	0.6
Direct Long Line	199	5.0	1.5	0.6
Direct Small Block	2008	5.0	1.4	0.5
Direct Large Block	48	4.8	1.6	0.6
Video Memory Speed, KBytes	2869	5.8	3.7	2.2
BitBlt Memory Speed, KBytes	751	4.0	2.0	1.1
Display Speed Index [mode 18]:		4.9	2.2	0.9

Press any key to continue...

Figure 4.7 *Performance Test Results.*

On CGA systems you will occasionally see harmless "snow" interference. During the tests, it is best not to touch the keyboard or mouse, or have any other computer activities going on in the background, as they will all steal time and affect the results. Of course, you may wish to run the tests with and without background activity in order to measure its impact on performance.

You can abort the tests at any time by pressing <End> or <Esc>, and you can also request *Help* at any time in the usual way by pressing "?", "h", or <Ins>.

Many memory resident programs will significantly degrade video system performance because they intercept and examine video commands. You can run the DisplayMate *Speed Performance Tests* with and without the memory resident programs installed, in order to see to what extent they slow down your video system. Screen accelerators are memory resident utility programs that are supposed to improve the speed performance of certain specific video BIOS functions. As a rule, they will decrease the performance of all the other video BIOS functions. You can run the DisplayMate *Speed Performance Tests* with and without a screen accelerator installed, in order to measure the various improvements and degradations provided.

One way to remove the memory resident programs is to deactivate them by following the instructions provided with each program. In most circumstances, the easiest way will be to insert a backup copy of the original Startup DOS distribution diskette provided with your system in the "a:" disk drive, and then rebooting the computer by simultaneously pressing the keys <Ctrl> <Alt> <Del>, or by powering down the computer, waiting 20 seconds and then turning it back on again. After you run the DisplayMate performance tests with the system in this basic configuration, or if for some reason the above procedure does not work, remove the diskette and restart your computer in the normal fashion.

In the *Technical Program* the same performance tests may be run in any video mode, and provide detailed tabulations for the absolute speed in *Operations per Second,* as well as the relative performance with respect to the above three systems, for each of 16 BIOS and graphics functions. A weighted mean *Display Speed Index* is computed for each video mode. Figure 4.7b shows the *Performance Test Tabulations* for the *Technical Program.* A different mix of tests are used for text and graphics modes. Each of the tests is identified by name. Tests that are labeled "Direct" are internal DisplayMate functions that operate directly on the hardware and are very efficient and fast. In some cases the differences between the "BIOS" and "Direct" speeds may be greater than 10 to 1. A detailed discussion of these tests is presented in Appendix H.

The comparative speeds among the three systems will vary substantially from video mode to mode. The comparative speeds also vary from test to test, and are an indication of the variation in video system performance that you are likely to see in your computer. For any particular application program you use, the video system performance obtained will depend on which particular operations are used most often by the software.

After selecting the *Speed Performance Tests* in the *Main Menu* you will see a *Select Performance Test Mode* menu where you choose the video mode for running the tests. The menu highlight bar is initially placed on the current *Video Test Mode* or on the previous performance mode selected. We recommend first running the tests in the *Primary Graphics Mode* and the *Primary Text Mode.* These modes are identified as the *Default Modes* at the top right of the menu. The tests begin immediately after mode selection. The graphics mode tests take 18 seconds, and the text mode tests take 17 seconds, and are invisible on the screen. The test guidelines that were discussed for the *Non-Technical Program* apply to the *Technical Program* as well.

Compatibility Tests

The compatibility issue examines the extent to which a given video system, complete with its video adapter and display, is functionally identical with one or more of the standard IBM video systems. This is a crucial question if you have a non-IBM video system, because the video adapter should be able to run *all* of the same software as the IBM adapters and generate the same screen images. The display should provide a comparable image with the same color balance as the IBM displays. Not only must the video adapter be able to run all of your current software, but you also should be assured that it will properly run all the software you will buy in the future. Compatibility is also a relevant issue for the IBM hardware because many of the IBM video systems are not fully hardware compatible with the IBM adapters they supersede, although these shortcomings have become standards in themselves and are well known and documented. For more information see the *Compatibility* section of Chapter 5 on *Video Display System Basics*.

The entire DisplayMate program is a comprehensive test of compatibility, because it uses virtually every video adapter BIOS function and register to probe for hidden flaws and limitations in the adapter. We have, however, attempted to place the tests that are most likely to detect compatibility problems within a special *Compatibility Tests* menu, which can be reached from the *Main Menu*.

Few adapters approach 100% compatibility. In many cases DisplayMate will point out non-standard hardware and software configurations; otherwise you will need to evaluate the screens visually in order to determine the test results.

Any computer that has a fully compatible video display system may develop incompatibilities as a result of software programs or hardware that are added to the system. By running DisplayMate in your normal environment and comparing it to a basic configuration for your computer, you can isolate the causes of most such incompatibilities.

The signs of compatibility failure can range from the delicately subtle to the disastrous: unintended flicker or the temporary disruption of the display; missing or incorrect screen colors; distorted geometry or a broken-up image; shifted or missing sections of an image; patterns of garbage appearing on the screen; a locked system or a system crash; a system that will not boot; one or more adapters that malfunction; or even the permanent failure of some components in rare instances.

If the *Automatic Help* facility is active, then each test will be automatically preceded by a *Test Prompt Screen* that provides a brief description of the test and also tells you what to look out for in the image. If for some reason you are unsure of what you should be seeing in the test screens, run DisplayMate on a different brand of computer, preferably a "vanilla" IBM system, and compare. If you do experience a functional compatibility problem, then proceed to the *Compatibility Problems* section of the *In Case of Difficulty* chapter in the back of this manual. That section will provide you with detailed information on how to resolve the problem or, at the very least, how to work around it.

In general, it is difficult to figure out the true source of a compatibility problem. You are more likely to come away with a phenomenological understanding of a class of things an adapter has trouble dealing with. For example, many adapters have trouble loading and switching text mode fonts. After running the tests you may find that an adapter will tend to lose the bottom few lines of the screen display after repeated font loads. The precise cause may be unknown, but you will have a good idea of the scope of the problem. See Chapter 5 for additional information on video system compatibility.

Compatibility Tests Menu

The *Compatibility Tests* menu is reached from the *Main Menu* and allows you to select a number of different tests including: a *Video Modes Test Suite, Configuration Tests,* and specialized adapter compatibility tests for each type of video adapter. Figure 4.8 shows the *Compatibility Tests Menu.*

```
    DisplayMate Video Utilities                              Version 1.1
-------------------------------------------------------------------------
    Compatibility Tests Menu:

    Function Key <F1>  Introduction

                 <F2>  Video Modes Test Suite

                 <F3>  Configuration Tests

                 <F4>  MDA/Hercules Compatibility Tests

                 <F5>  CGA/MCGA Compatibility Tests

                 <F6>  EGA Compatibility Tests

                 <F7>  VGA Compatibility Tests

     Key Pad Key <End> Return to Main Menu
-------------------------------------------------------------------------
Use the Function Keys <Fn> or Keys <↑> <↓> then Press <Space Bar> or <Enter>
For Help Type  ?  or  h  or  press the  <Ins>  key.   For Other Functions...
Press <Fn> <↑> <↓> <Home> <End> <Page Up> <Page Down> <Space Bar> <Enter>  ?
```

Figure 4.8 *Compatibility Tests Menu.*

The *Video Modes Test Suite* and the adapter compatibility tests are controlled in the same way as all of the other DisplayMate test series:

- You normally proceed from test to test by pressing the <Space Bar> key. If you have a mouse, click the left button.
- Use the <Page Up> Keypad key to return to any previous tests in the series, and use the <Home> key to return to the first test screen.
- Use the <End> or <Esc> keys to terminate the test series and return to the *Compatibility Tests Menu.*
- Use the <Ins> Keypad key to request help at any time. If you have a mouse, click the right button.

Function key control over color and other variables is *not* available in the *Video Modes Test Suite.* Some of the adapter compatibility tests allow you to toggle between normal and reverse video using the Function key <F6>; however, all other Function keys are inactive. See the *Keyboard and Mouse Control* section above for a complete description of all the control keys.

Video Modes Test Suite

The *Video Modes Test Suite* provides a comprehensive set of tests for each video mode available on your computer system. Figure 4.9 shows the output from one of the test screens in the Suite. The top section of each test screen displays the complete character set and color bars for all of the available colors, except for the 256 color VGA/MCGA color mode, which will display only the standard 16 CGA colors. For text modes, a second screen displays the ruling and block characters, the display attributes (such as blinking, intensified, and reverse video), and a block version of the cursor.

These tests are meant as a supplement to the extensive tests provided throughout DisplayMate. Pay careful attention to these screens because they have been designed to show off compatibility problems that may not be apparent elsewhere in DisplayMate. Look for glitches in the characters and in the color bars; the *Automatic Help* facility will advise you of specific items to watch out for.

The bottom section of each test screen shows the results of several compatibility tests performed in that mode and include:

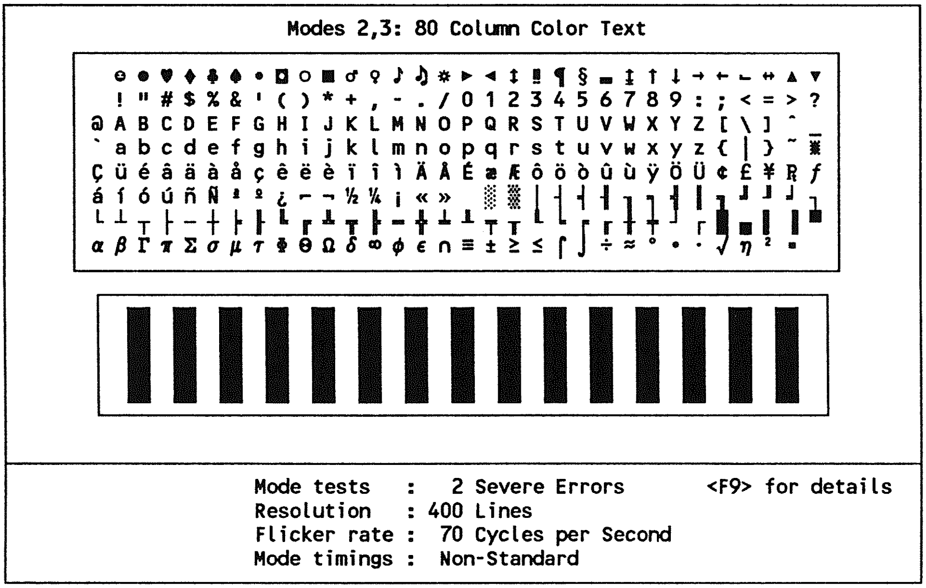

Figure 4.9 *A Video Modes Test Suite Screen.*

- A *Configuration Test* for the mode, explained in the next section.
- A measurement of the actual resolution of the mode determined directly from the hardware. DisplayMate will mark it as a *Non-Standard Resolution* if the value is different from the IBM standard. In some cases this will result from invalid information supplied by the hardware rather than a problem with the resolution. This condition is just as bad, and can produce problems with some software. Non-Standard Resolutions are more likely with portable computers that have flat panel displays, because the manufacturer may use the somewhat higher resolution needed by graphics modes in the text modes. This may cause problems with software that loads its own fonts. The mode may also be marked as *Double-Scanned,* indicating that the video adapter is reducing its natural resolution to produce the video mode's resolution. The IBM VGA and MCGA *Double-Scan* many of their modes; many portable computers do as well. When it is unexpected, double-scanning can throw off the timings assumed by certain software.

- A measurement of the actual flicker frequency of that mode, determined directly from the hardware. This measurement takes 1 second, but it may be interrupted and aborted by advancing to the next video mode, if you want to move on quickly. The flicker frequency is the rate at which the image is redrawn on the screen by the hardware. Flicker is known to be the cause of visual fatigue. The effects of flicker are discussed in Chapter 5 on *Video Display System Basics,* and in Chapter 7 on *Maximizing Comfort and Productivity.* In general, the higher the flicker frequency the better; however, a non-standard flicker frequency can throw off the timings assumed by certain software. It can also throw off the speed of animation software. Some video adapters offer an increased flicker frequency capability in order to minimize the effects of subliminal flicker. Many portable computers with flat panel displays have non-standard flicker frequencies in order to accommodate their special hardware requirements.
- A measurement of the horizontal and vertical retrace timings for the mode. This measurement takes 1 second and cannot be interrupted once it has started. Any deviations from the standard values are reported. Retrace times longer than the standard are unlikely to cause problems; however, shorter times may lead to serious compatibility problems with some software. The retrace intervals are used by software programs to update hardware registers without causing interference on the screen. Screen animation software will use this time to update the screen, so as not to cause any visible flicker. In the CGA this period is used to update the screen without causing interference called *snow.*

Configuration Tests

The *Configuration Tests* look for inconsistencies and incompatibilities in the computer's video BIOS Data Area, in comparison to those in IBM video systems. The *Configuration Tests* menu selection performs an analysis of Data Area values that were in effect and were stored when DisplayMate started up. In some cases application programs may improperly tamper with the Data Areas and leave them in a disordered state, which can lead to problems later on, possibly even a system crash. DisplayMate will alert you to this condition. In many cases, DisplayMate will correct inconsistent Data Area values. Other problems in the Data Area are the result of incompatibilities or bugs in the adapter's video BIOS. Configuration tests are also performed for each mode in the *Video Modes Test Suite,* discussed above.

In the *Non-Technical Program,* the *Configuration Tests* selection will inform you if there are any indications of configuration problems in your system and will attempt to indicate how serious the problems may be. Only a non-technical summary of the test results is provided. The severity of each condition is rated as *Minor, Severe,* or *Major.* The likelihood of a particular problem affecting a software application will depend on the type of information that it gathers from the Data Area. In many instances, configuration problems discovered in the Data Area are an indication of a broader compatibility problem in the adapter.

The *Technical Program* provides the complete results for each of the individual *Configuration Tests* and can help technical users in the analysis of some compatibility problems. Figure 4.10 shows the output from the *Technical Program* tests for an EGA adapter, with several conditions marked for illustration purposes only. Most entries will be labeled as "ok" or as "-", if the test does not apply to your adapter. Conditions to watch out for are *Non-Standard* and *Invalid.* Non-standard values are unusual, but still legal and valid. Either condition can result from unusual applications or bugs in the BIOS, or from programs that have corrupted the *Data Area.* Other labels provide information about the parameter such as: *Enabled, Defined,* and *Not Defined.* A more complete discussion on the meaning of the *Configuration Tests* and the *Video Data Area* is given in Appendix I.

Adapter Tests

Compatibility tests for each adapter standard that is compatible with your installed video system can be selected from the *Compatibility Tests Menu* by using the menu highlight bar. The other adapter selections will be automatically skipped over and will appear in cyan rather than yellow, and have no Function key identification to the left. For example: if you have a single VGA adapter, then compatibility tests for the MDA, CGA, EGA, and VGA adapters will be accessible and should *all* be run in turn. Tests for the Hercules Adapters will not be accessible.

If the *Automatic Help* facility is active, then each test will be automatically preceded by a *Test Prompt Screen* that will provide a brief description of the test

```
Non-Standard Configuration Tests:
------------------------------------------------------------------------
Status At Entry to DisplayMate:
    Video Parameter Tables                : Non-Standard
    Pointer Data Areas                    : ok
    Font Definition Tables                : ok
    Graphics Character Extensions         : Not Defined
    Auxiliary Character Sets              : ok
    Character Height                      : ok
    Screen Rows                           : ok
    Screen Columns                        : ok
    Cursor Emulation                      : ok
    Display Memory Size                   : ok
    Palette Save Area                     : Enabled
    Palette Loading                       : -
    Palette Profile                       : -
    Display Combination Code Table        : -
    PS2 Scan Lines                        : -
    Gray Summing                          : -
    Display Switching                     : -
------------------------------------------------------------------------
Press <Page Up> <Page Down> <Home> <End>  ?  or  <Space Bar> to continue...
```

```
Invalid Configuration Tests:
------------------------------------------------------------------------
Status At Entry to DisplayMate:
    Video Mode                            : ok
    Video Equipment Flag                  : ok
    Display Page                          : ok
    Mode  Register                        : Invalid
    Color Register                        : ok
    Reserved Bits                         : ok
    Reserved Bytes                        : Invalid
    EGA Configuration Switches            : ok
    EGA Monochrome Flag                   : ok
    EGA Active     Flag                   : ok
    PS2 Monochrome Flag                   : -
    PS2 Scan Lines                        : -
    PS2 All Modes                         : -
    Pointer Table Length                  : -
    Display Combination Index             : -
    Display Combination Code              : -
    Display Switching                     : -
------------------------------------------------------------------------
Press <Page Up> <Page Down> <Home> <End>  ?  or  <Space Bar> to continue...
```

Figure 4.10 *Technical Program Configuration Tests Results.*

and also tell you what to look out for in the image. This, as well as additional information, is available for each test through the normal help facility, which also provides a brief description of what each Function key and Keypad key will do.

The IBM video adapters are not fully downward hardware compatible with one another. This is the result of a design decision by IBM and is well known and documented. Some software written for the older adapters, particularly the MDA and CGA, will not run properly on the later EGA and VGA adapters. A number of the software tests examine this issue and indicate on the test screen which IBM adapters will fail the tests. Many of the non-IBM EGA and VGA cards do offer at least partial hardware compatibility for the MDA, CGA, and Hercules adapters, and they should pass many more of the compatibility tests. Most claim 100% compatibility, but few will pass all the tests. If you have a non-IBM video adapter set for automatic mode switching, then it may become confused at some point during the tests. See Chapter 8 for additional information on *Automatic Mode Switching*.

Since IBM sets the standard, IBM video adapters are by definition compatible - bugs, flaws and all. None of the tests take advantage of the known bugs that are found in all of the IBM video adapter BIOS. Some non-IBM adapters actually reproduce the bugs for compatibility reasons, others do not; it is not always clear which is the best approach. In general, the IBM adapters are well designed and pass all the tests they should, with one notable exception: the IBM EGA will fail the *BIOS* and/or *Direct Font Switching Tests* when installed on *some* IBM systems due to a timing flaw in the hardware. This is also true on the newer 1984 IBM EGA chip set.

Screen Distortion Measurements

A surprising number of CRT video displays produce rather noticeable amounts of geometric distortion. There may even be a wide variation from unit to unit of the same make and model. The distortion may also change with the age of the display. Non-CRT displays, such as LCD, Gas Plasma, and Electroluminescent displays, are susceptible to only one type of geometric distortion, aspect ratio error.

If you need to compare the geometric distortion of two displays, need to check your display against a manufacturer's specifications or guarantee, or simply want to know how accurate your display is, you can use the DisplayMate fully interactive *Screen Distortion Measurement Menu,* which is available only in the *Technical Program.* It greatly simplifies the process of measuring screen distortion by automatically prompting you to measure the lengths of a small number of carefully chosen lines on the screen, and then producing a report on the percentage errors for each type of distortion. This section will explain what the errors mean and how to interpret the results.

Measurement Sets

The *Screen Distortion Measurement Menu* is divided into 3 separate sets of 4 measurements each. You can measure just 1 set, 2 sets, or all 3, but they must be measured in order. Figure 4.11 shows the *Screen Distortion Measurement Menu.* Each set allows DisplayMate to compute different types of geometric distortion, and you can examine the *Screen Distortion Measurement Results,* which is another menu selection, after each set. The forms of geometric distortion that are computed after each set are:

Set 1. Screen size, aspect ratio, and squareness error.

Set 2. Keystone and pincushion or barrel distortion.

Set 3. Bow curvature and linearity error.

The meanings of these terms will be described below. Non-CRT displays do not suffer from any of the distortions computed from Sets 2 and 3, so you should only measure Set 1 for them. With the completion of all three sets, DisplayMate will compute a *Screen Distortion Index,* for an overall indication of geometric accuracy.

Quick Explanation

The sections below carefully explain how to measure and enter input data. It's rather easy to do, so if you don't want to read the entire explanation and would rather just give it a try, here are the important points:

```
DisplayMate Video Utilities                                  Version 1.1

Screen Distortion Measurement Menu:                    Video Test Mode 18

<F1>    Introduction to Screen Measurements

<F2>    Set #1   4 Measurements  [size, aspect ratio, squareness]

<F3>    Set #2   4 Measurements  [keystone,  pincushion / barrel]

<F4>    Set #3   4 Measurements  [bow curvature, linearity error]

<F5>    Display Screen Measurement Results

<F6>    Display Linearity Test Patterns

<End>   Return to Main Menu

Measure just 1 set, 2 sets, or all 3 sets.
Sets must be selected in order: 1, 2, 3.
Results <F5> can be displayed at any time.

Press <Fn> <↑> <↓> <Home> <End> <Page Up> <Page Down> <Space Bar> <Enter>  ?
```

Figure 4.11 *Screen Distortion Measurement Tests Menu.*

- Measure the scale markings for both ends of a test line. If the "0" of the tape measure or ruler is at one end, then the first value will be zero.
- Move your head so that the measuring eye is directly in front of the line's end-point. Do not sight along an angle.
- Each entry can consist of one or two numerical values, one of which can be a fraction. Valid examples of measurement values are:

  "10.78", "11.75 + 0.27", "6.25 / 8", "11 7/8", "12 – 3.5/8"

  Figure 4.12 shows one of the measurement screens.

- To accept a default or previously entered value, simply press <Enter>.
- Use <Backspace> or <Left Arrow> to erase a character. Use <Space Bar> or <Right Arrow> to insert a space.
- Use <Up Arrow>, <Down Arrow>, and <Enter> to maneuver between the prompt lines on the same screen.

- Use <Page Up>, <Page Down>, <Home>, and <Enter> to move from screen to screen.

You should now skip to the section describing the *Types of Geometric Distortion*, below.

Measuring Instrument

In order to measure the lengths of the lines that will be drawn on the screen, you will need a ruler or tape measure. We recommend a cloth tape measure, like the type often used in sewing, because it is soft and can conform to any screen curvature. You can generally buy them in supermarkets or sewing stores. Metal tape measures will not conform well to the screen curvature and may scratch the screen.

Using a ruler has several disadvantages: it won't work well with curved screens, the outer bezel that frames the screen will generally prevent the ruler from getting close to the screen, and you may scratch the screen if you are not careful.

The measurements can be made in whatever units you like: generally, millimeters, centimeters, or inches. You don't need to tell DisplayMate which one, because the results will be reported in the same units as the data. We recommend centimeters, because it is easy to interpolate between the scale markings. You'll need to interpolate when the point being measured doesn't fall exactly on one of the scale markings, but rather lies part way between two tick marks. For example, if the distance is 17.6 centimeters, and the end-point falls about one-third of the way between the *6th* and *7th* millimeter markings, the interpolated distance is 17.63 cm. If you use inches, DisplayMate will help by accepting input with fractions like 3 5/8; in fact, you can interpolate the fractions with a form like 5.3/8, which means you are about one-third of the way between 5/8 and 6/8.

How to Take Measurements

If you have a tape measure, put the end or "0" precisely on the start of the test line, stretch the tape so the edge closely follows the line across the screen, then carefully read the value at the other end of the line. You can use either end of the line as the starting point. Be as careful as possible in setting and reading the tape measure, in order to minimize measurement errors and inaccuracies.

If you are using a ruler, it will probably be necessary to rest the ruler on the outer screen bezel. Since it won't be possible to put the end or "0" of the ruler on the start of the test line, you will need to read the ruler markings for both ends of the test line, and then separately enter the two values. DisplayMate will get the length of the line by subtracting the values.

In order to get accurate readings it is important that you move your head for each measurement, so that your measuring eye is directly in front of the line's end-point. This is especially important if you are using a ruler. If you sight at an angle, the scale markings and the end of the line will shift and not line up properly. This will result in a measurement error known as parallax.

Entering the Measurements

DisplayMate will prompt you to enter a measurement value after it draws a test line. In text modes, diagonal lines cannot be drawn, so only the end-point arrows will appear. If you previously measured the line, it will provide the prior measurement as a default value, which you can accept by simply pressing <Enter>. This makes it easy to edit and remeasure the lines more than once. If you have not measured the line before, a default value will be generated for a 13" diagonal screen that has no distortion. Do not accept this value unless you are running a demo. Figure 4.12 shows one of the measurement screens.

Each screen requires a separate measurement for each of the two end-points of the line. DisplayMate will prompt for each one in turn. You can use either end of the line as the first measurement point. If the "0" end of the tape measure or ruler is precisely on one of the line's end-points, then press <Enter> to accept the default value, which should be zero for the first point. If it is not zero, then you will need to enter that value in the same way as the second point, which is described next.

Each measurement can consist of one or two numerical values, one of which can be a fraction. Enter the numerical value using the keys 0 to 9 and the keys "+", "−", ".", and "/". The input must be in one of the following forms:

```
Measure First End-Point:
Previous  Value = 0
Enter New Value = 0


Measure Second End-Point:
Previous  Value = 23.75
Enter New Value = 23.85_          ◄

|-------------------------------------------------------------|

Previous Length = 23.75
Current  Length = 23.85


Press 1234567890 . + - / <↑> <↓> <←> <→>
      <Home> <End> <Page Up> <Page Down>
      For Help Type  ?  or  Press  <Ins>
```

Figure 4.12 *A Distortion Measurement Screen.*

a
a (sign) b
b / c
a (sign) b / c

where **a, b,** and **c** are decimal numbers of the form: **(sign) nnn.nnn** and where **(sign)** is + or – or a blank " ", which is interpreted as "+". The **(sign)** of **c** is ignored, and multiple signs are not allowed, such as: "1 – –3".
Valid examples are:

"10.78", "11.75 + 0.27", "6.25 / 8", "11 7/8", "12 – 3.5/8"

- A maximum of 20 characters is allowed; an arrowhead marks the end of the input area. The current typing position is marked by a blinking cursor. Press <Enter> or <Down Arrow> at the end of the input line.
- Use the <Backspace> or <Left Arrow> keys to erase a character.

- Use the <Space Bar> or <Right Arrow> keys to insert a space.

If you press an invalid key, you will hear an error beep. If you enter a value incorrectly, the message *Invalid Input Data* will appear. The blinking cursor will return to the end of the input line and you can edit or re-enter the value.

After you enter both measurements, DisplayMate will show the previous and current lengths that have been measured for the test line.

- Use the <Up Arrow> key to return to either of the screen's two data entries lines.
- Use the <Down Arrow> or the <Enter> keys to proceed down to the next data entry, or to the length summary for the screen. If you are at the length summary, press <Enter> or <Page Down> to proceed to the next measurement screen.
- Press the <Page Up> key to return to the first data entry in the current screen. If you are already at the first data entry, then you will return to the previous measurement screen.
- Press <Page Down> to proceed to the next measurement screen.
- Press the <Home> key to return to the first entry of the first measurement screen in the current set.
- Press the <End> or <Esc> keys to terminate the current set and return to the *Screen Distortion Measurement Menu.*
- For *Help* at any time, press <Ins>, "?", "h", or "H".

Types of Geometric Distortion

CRTs are susceptible to certain forms of geometric distortion that arise from problems in the magnetic deflection system, or in the electronic circuits that control them. Most of these distortions are similar to those found in the optical systems of slide and transparency projectors. The distortions are classified according to how they affect the screen image and are shown in their pure forms in Figure 4.13. Most displays will suffer from combinations of these distortions to varying degrees. For convenience, the images are shown for a square display; however, all PC displays are 33% wider than they are tall. For clarity, the

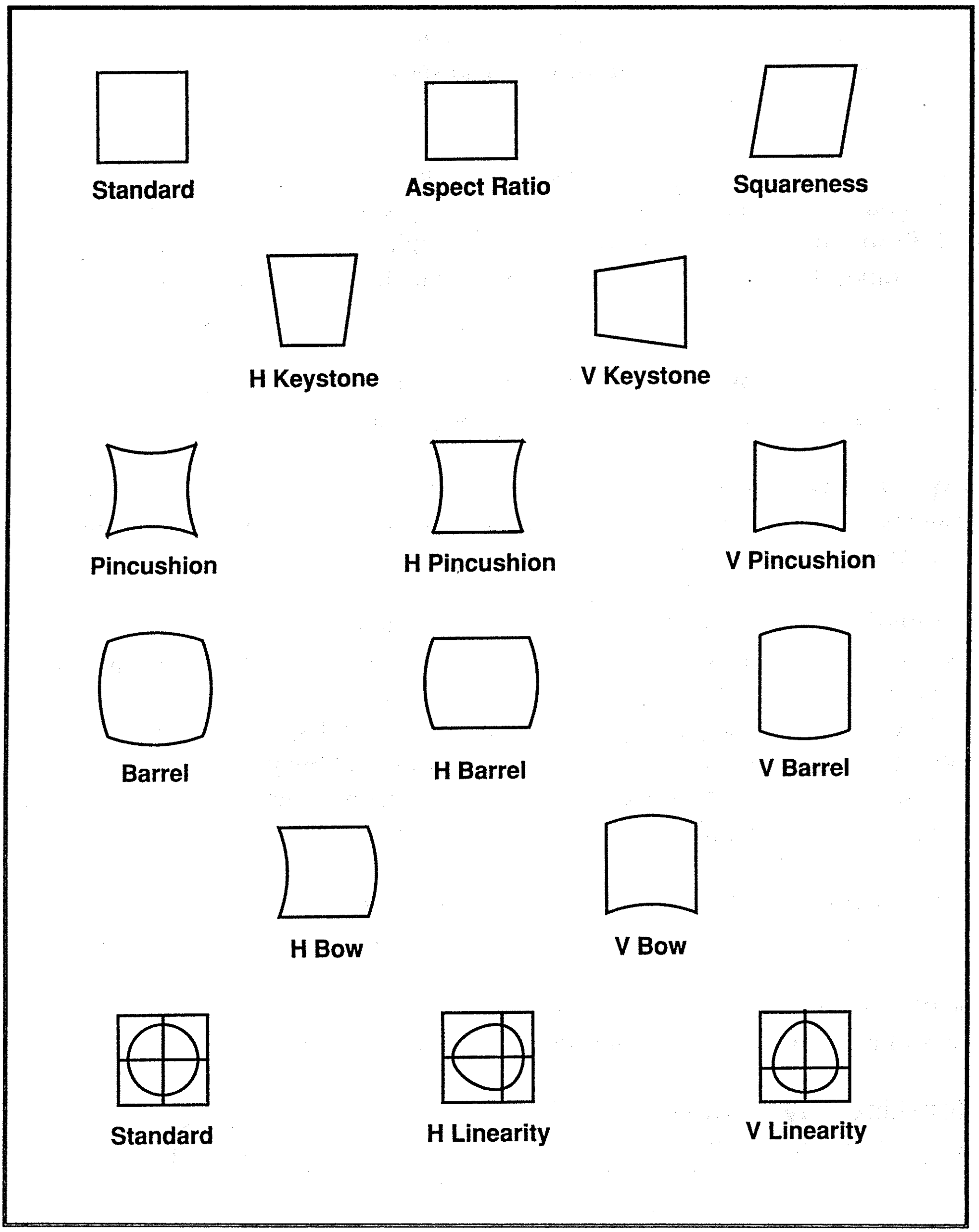

Figure 4.13 *Types of Geometric Distortion.*

distortions are shown in both their horizontal and vertical varieties separately; in some cases the combined distortions are also shown. Below, we describe each of the errors shown in the figure:

Aspect Ratio: The aspect ratio describes the overall shape of the display and corresponds to the numerical ratio of the display's width to height, which is 4:3 or 1.33 for all IBM video adapters. If your display does not have the correct aspect ratio, then squares will appear like rectangles, and circles will appear like ovals.

Squareness Error: In this form of distortion, the sides of the image are not at right angles to one another, and the image will look like a parallelogram.

Keystone Distortion: This is a form of trapezoidal distortion where the image is narrower at one end. It has an appearance similar to the wedge-shaped stone at the top of an arch, hence its name.

Pincushion Distortion: This form of distortion is present in all CRT displays, and must be corrected by special circuitry. The distorted image resembles a sewing pincushion, hence its name. It arises from manufacturing a CRT screen with a surface that is flatter than its natural spherical shape. The flatter the screen, the more pronounced the effect, and the greater the amount of pincushion correction that is required. In many cases, pincushion distortion can be eliminated, or significantly reduced, by adjusting the display.

Barrel Distortion: This is the inverse of pincushion distortion; it generally arises from overcorrecting for that effect.

Bow Distortion: This is similar to pincushion distortion, but the opposite sides of the image curve together instead of being opposed.

Non-Linearity Distortion: This is a distortion where the image is non-uniform and is compressed in one area. Circles will appear egg shaped.

Interpreting the Results

After you have measured the 3 sets, the *Screen Distortion Measurement Results* will look something like Figure 4.14. With fewer than 3 sets, one or more fields will be marked: *No Measurement Data.*

```
Screen Distortion Measurement Results:        Video Test Mode 18
-----------------------------------------------------------------
Display Image Height        18.23  measurement units
Display Image Width         23.78  measurement units
Display Image Diagonal      30.00  measurement units
Aspect Ratio                 1.30

Aspect Ratio Error          -2.2 %
Squareness   Error           3.4 %

V Keystone   Error           3.6 %
H Keystone   Error           4.6 %
V Pincushion Error           0.7 %
H Barrel     Error           3.3 %

V Bow        Error           4.5 %
H Bow        Error           3.0 %
V Linearity  Error           3.6 %
H Linearity  Error          -3.3 %

Screen Distortion Index      3.2 %
-----------------------------------------------------------------
                  Press any key to continue...
```

Figure 4.14 *Distortion Measurement Results.*

The results specify the large scale deformations in the screen image in terms of the standard forms of geometric distortion shown in Figure 4.13. The analysis is based on measuring key points in the periphery and center of the screen. If the errors are not excessively large or pathological, the analysis into the component errors will be accurate.

The results should quantify what you have already determined visually, through using the test patterns in the *Video Obstacle Course,* the *Geometry Tests* in the *Display Tests Menu,* or in the *Display Linearity Test Patterns* in the *Distortion Measurement Menu.* The errors are all reported as a percentage deviation from the distortion free result. Errors with a positive sign have deviations in the same sense as the distortions shown in Figure 4.13; errors with a negative sign have a symmetry opposite to the figure.

Any distortion error that is greater than 2% should be easy to spot visually. If you have made your measurements with reasonable care, the effect of measurement errors is small; this is discussed in the section *Measurement Errors,* below. If an error is greater than 100%, it is reported as "> 100%," and you have made an error in entering the data. The *Screen Distortion Index* reported at the bottom of the screen is the average of the absolute values of all the errors.

Below, we discuss the interpretation of each type of error or measurement reported:

Display Image Height, Width, Diagonal: These specify the size of the active screen area, in whatever units you originally measured them in. The values are averages of several data values.

Aspect Ratio: This specifies the ratio of the display image width to height. It should be 1.33. The *Aspect Ratio Error* specifies the percentage deviation from the proper shape. For positive values, the image is too short for its width; for negative values, it is too tall for its width.

Squareness Error: This specifies the degree to which the image area is tilted like a parallelogram. If the error is positive, the tilt is to the right; if it is negative, the tilt is to the left. If this error is a problem, try reducing the size of the display area to minimize its visual impact.

Keystone Error: The vertical "V" error specifies the degree to which the image height differs on the right and left sides of the image. A positive value means the image is larger on the right, a negative value means the image is larger on the left. The horizontal "H" error specifies the degree to which the width of the display varies from top to bottom. A positive value means the image is larger at the top; a negative value means the image is larger at the bottom.

Pincushion / Barrel Error: If the word pincushion appears, the image bulges inward; if barrel appears, the image bulges outward. The percentage specifies the relative size of the bulge compared to the vertical "V" height or the horizontal "H" width. If the Bow error, discussed next, is more than ¼ of the pincushion or barrel value, then the distortion is not symmetric on either the left-right or top-bottom sides, a case we will discuss separately, below.

Bow Error: The vertical "V" error specifies the degree to which the image curves upward. The horizontal "H" error specifies the degree to which the image curves to the right. If the Bow error is more than ¼ of the pincushion or barrel error, then the distortion is not symmetric on either the left-right or top-bottom sides, a case we will discuss separately, below.

Linearity Error: The vertical "V" error specifies how uneven the image is top to bottom; the horizontal "H" error specifies how uneven the image is left to right. A positive value means the image is compressed on the bottom or on the right, a negative value means the image is compressed on the top or on the left.

Combined Bow and Pincushion / Barrel Distortion:

Bow and pincushion / barrel distortion are common forms of distortion that are found in a significant fraction of all CRT displays. Both describe the degree of curvature in the image, so in many situations both forms of distortion will be present at the same time. When both forms are present, the curvature on the left and right sides or the top and bottom sides of the screen will not be equal. Figure 4.15 shows 4 combinations of bow and pincushion / barrel distortion:

(a) Pure pincushion distortion with no bow distortion.

(b) Pure bow distortion with no pincushion or barrel distortion.

(c) A combination of bow and pincushion distortion that results in a straight right edge and a curved left edge.

(d) A combination of bow and pincushion distortion that results in a straight left edge and a curved right edge.

The percentage values reported in the figure are the percentage deviations from the distortion free result. In (a) the central width is 20% narrower than the outer width. In (b) the sides curve 10% of the width towards the right. In (c) the central width is 10% narrower than the outer width, which is the pincushion value. One of the sides curves 10% to the right and the other doesn't curve at all,

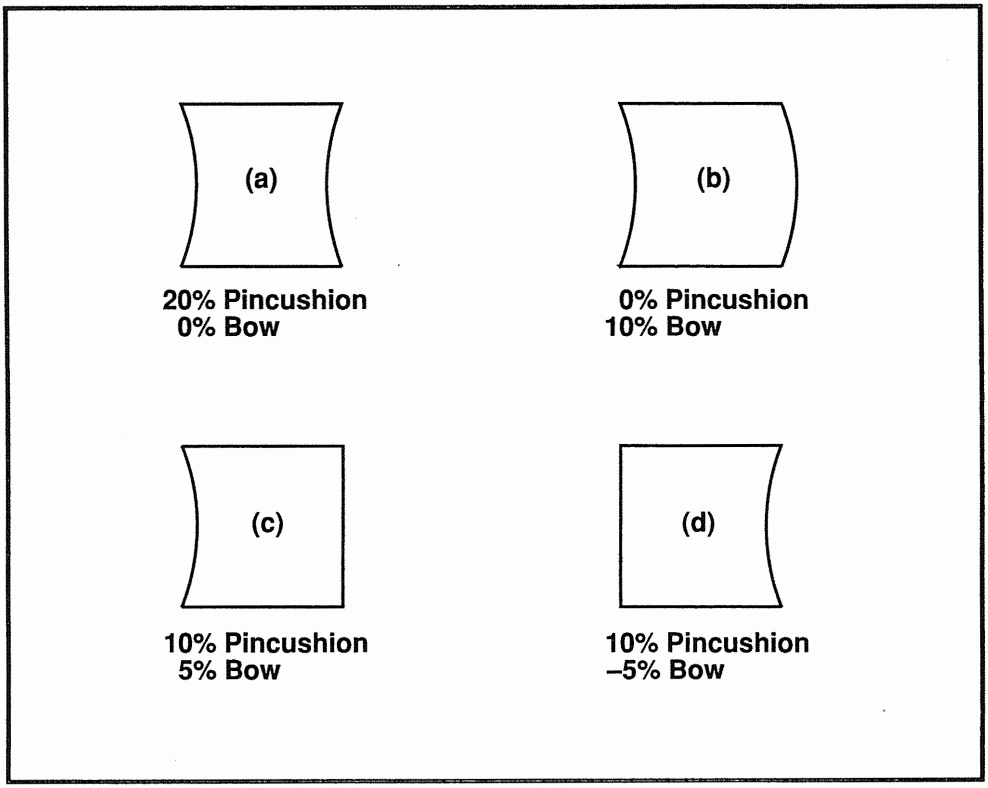

Figure 4.15 *Combinations of Bow and Pincushion / Barrel Distortion.*

so the mean bow distortion is 5%. In (d) the curvature is merely opposite to that in (c).

Measurement Errors

If you have made your measurements with reasonable care, the effect of measurement error is small. For example, with a tape measure you should be able to measure lengths to better than 1 mm. That will introduce errors of order 1/3% for a 13" display, which is substantially smaller than the 2% or greater nonlinearities that are typically being measured. For a ruler, the measurement error should be less than 1/8", which works out to errors of order 1% for a 13" display.

The error that results from the curvature of the screen is also quite small. For a typical 13" display, the geometric distortion resulting purely from the screen curvature alone is 0.4%. The curvature error will be less for larger size display screens. This same error applies to measurements with a tape measure, which follows the curvature.

Comparing with Manufacturer's Specifications

The *Screen Distortion Measurement Results* provided by DisplayMate has much more information than most manufacturer's specification sheets. The errors computed by DisplayMate represent errors in the shape of the screen, which we will refer to as *Shape Errors.* Most manufacturers provide a non-linearity error that represents the error in the position of single points on the screen, which we will call *Positional Errors.*

In order to compare *Shape* and *Positional* errors together you must either divide the *Shape Error* value by 2, or multiply the *Positional Error* value by 2. This is because *Shape Errors* result from combinations of pairs of *Positional Errors:* plus on one side and minus on the other, which doubles the error. The *Shape Error* is the better measure of distortion because it describes the visual impact of geometric distortion. For example: a *Positional Error* of 10% corresponds to a *Shape Error* of 20%. In essence, the *Positional Error* understates the screen distortion by a factor of 2.

In some instances, the *Shape Error* can be 4 times larger than a *Positional Error.* For example, you may see a figure of "under 10%" in a specification sheet for geometric distortion or non-linearity. According to industry standards, this means that no point on the display will be displaced from its true position by more than 10% of the height of the screen. On a typical 13" diagonal size display, this means that points may be up to ¾" away (plus or minus) from their intended location. A display with this amount of distortion would most likely be unreadable. In fact, for pincushion distortion, one of the most common distortions, the central width of an image could be a full 3" narrower than the outside width and still be in full technical compliance with a 10% non-linearity specification for a 13" diagonal display, because no single point on the screen would be more than ¾ " away from its intended location. This is graphically illustrated in Figure 4.16, but for only half the distortion we have been discussing. No point in the figure is displaced by more than 5% from its true location, which is shown as the embedded square, yet this amount of pincushion distortion is intolerable.

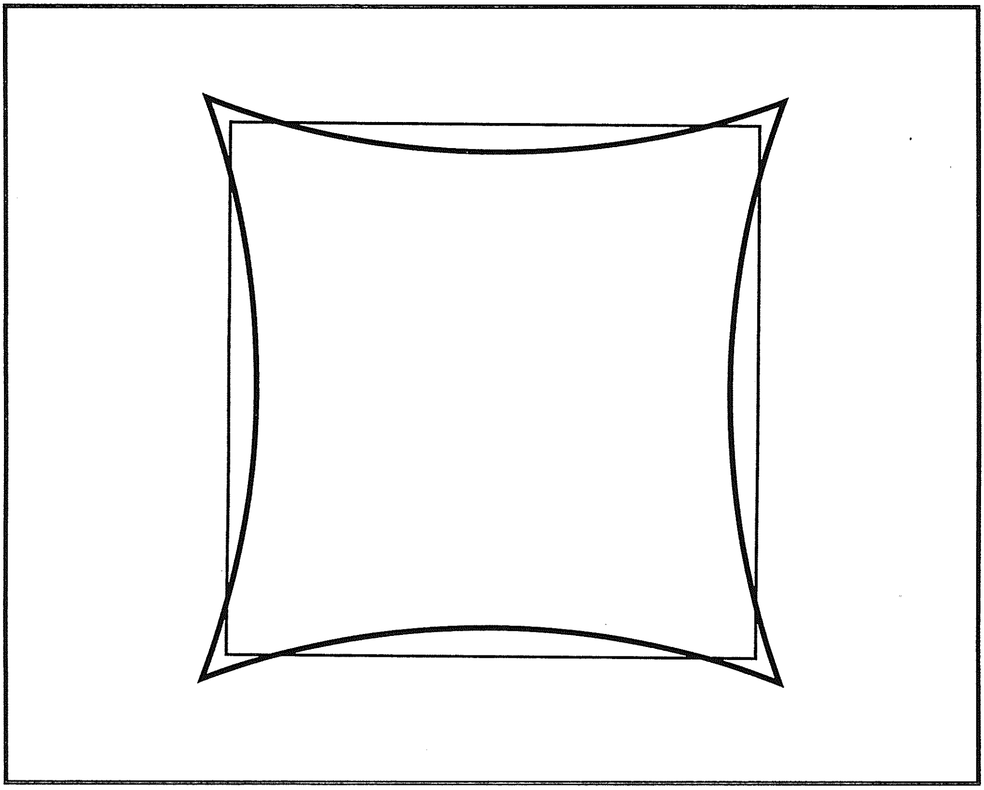

Figure 4.16 *Pincushion Distortion for a 5% Position Error Distortion.*

For a 13" diagonal display, we think that plus or minus 4 mm (about 1/6*th* inch) is a reasonable upper limit for the *Positional Error* distortion. That works out to 2%. The equivalent *Shape Error* is 4%.

One final note: the horizontal "H" errors computed by DisplayMate are expressed as a percentage of the screen width, and the vertical "V" errors are expressed as a percentage of the screen height. The industry standard for geometric error specifies that all errors should be specified with respect to the screen height. To express the "H" errors in terms of screen height, you must multiply them by 1.33, the aspect ratio.

Selecting the Video Test Mode

The *Video Test Mode* selection is available only in the *Technical Program.* Each of the video adapters has the ability to be programmed with a variety of parameters that configure its internal video hardware. The parameters control, for example, the organization of memory, the resolution, scanning frequencies, and color selection. In writing the BIOS software for the adapters, IBM has defined a series of standardized parameter sets that are called *Video Modes.* All software that runs on the computer is expected to use one of these video modes.

Each video adapter has a *Primary Graphics Mode* and a *Primary Text Mode* that provide the highest resolution and selection of colors that it is capable of producing. The CGA, MCGA and VGA also have secondary graphics modes that provide a greater selection of colors than the primary mode, but at a lower resolution. All of the other video modes in each adapter are provided for compatibility with older adapters, so that old software can still be used on the new hardware.

IBM has defined 20 standard video modes. They are summarized in Table 4.1. Of these modes, 3 are used only by the IBM PCjr and are no longer supported, 2 are used internally by the EGA and VGA to load fonts into memory, leaving 15 video modes now in common use. In many cases the video modes have submodes that allow for particular variations in hardware parameters. The MDA has only 1 mode, the CGA has 7, the EGA has 12 main modes and 6 submodes for a total of 18, the MCGA has 9 main modes and 8 submodes for a total of 17, and the VGA has 15 main modes and 9 submodes for a total of 24. In all, there are a grand total of 67 video modes and submodes on the 5 IBM adapters, each at least a little bit different from any other, and all supported by DisplayMate. The submodes are automatically handled by DisplayMate.

Mode	Emulation	Name
0, 1	CGA-VGA	40×25 Color Text
2, 3	CGA-VGA	80×25 Color Text
4, 5	CGA	320×200 4 Color Graphics
6	CGA	640×200 2 Color Graphics
7	MDA	80×25 Monochrome Text
8-10	PCjr	*PCjr Graphics Modes*
11-12	EGA	*Reserved for Loading Fonts*
13	EGA	320×200 16 Color Graphics
14	EGA	640×200 16 Color Graphics
15	EGA	640×350 Monochrome Graphics
16	EGA	640×350 4/16 Color Graphics
17	MCGA	640×480 2 Color Graphics
18	VGA	640×480 16 Color Graphics
19	MCGA, VGA	320×200 256 Color Graphics

Table 4.1 *Standard Video Modes.*

The CGA has three pairs of modes that are equivalent to submodes: 0 and 1, 2 and 3, 5 and 4 (note order). Each of these mode pairs is identical except that the *Color Burst* signal for television style composite displays is disabled for the first mode and enabled for the second. For the standard direct-drive color displays that are now used on almost all computers, there is no difference between the modes, except in the case of modes 4 and 5, where the color palettes change (see the *CGA* section of Chapter 5). In all of the other video adapters the modes in each pair are identical. To switch between the mode pairs on the CGA, alternately press the "B" key (for burst). During any test series toggle the <F7> Function key. See the *Glossary* and Chapter 5 on *Video Displays* for explanations of composite and direct-drive displays.

The submodes on the EGA depend upon whether a Color Display or an Enhanced Color Display is being used, and also upon how much memory is installed on the adapter. This is discussed in the *Video Adapters* section of Chapter 5. The submodes for the MCGA and VGA are discussed in Appendix I.

DisplayMate normally runs in *Automatic Mode* selection, where it will select the most appropriate video mode for each test. This will generally be one of the primary modes for the video adapter in your computer, and will provide the optimum test display for your hardware. In the *Technical Program* there is a *Select Video Test Mode* menu that allows you to specify any particular video mode supported by the hardware to run the tests. This not only allows you to test your adapter in various compatibility modes, but also shows you how the lower resolution and color modes will appear on other adapters. This menu is shown in Figure 4.17.

To select a particular video mode or the *Automatic Mode,* move the menu highlight bar to the desired line and press the <Space Bar> or <Enter> keys, or press the Function key indicated at the left of the entry. You may also use the keypad <Up Arrow> and <Down Arrow> keys to move the highlight bar. Video modes that are not available on your computer will be automatically skipped over by the highlight bar. They will also appear in cyan rather than yellow, and have no Function key identification to the left. If you have a mouse, move it forward or backward to vary the position of the menu highlight bar, then click the left mouse button to select a particular mode. To exit the menu without changing the currently selected mode, simply press <End> or <Esc>.

```
DisplayMate Video Utilities                                  Version 1.1

Select Video Test Mode:                             Current Mode is Auto

<Home>  Mode Auto   Test Mode will be Automatically Selected
<F1>    Mode 0,1    40  x 25  Lines         16    Color   Text
<F2>    Mode 2,3    80  x 25  Lines         16    Color   Text
<F3>    Mode 4,5    320 x 200 Resolution    4     Color   Graphics
<F4>    Mode 6      640 x 200 Resolution    2     Color   Graphics
<F5>    Mode 7      80  x 25  Lines         Monochrome    Text
<F6>    Mode 13     320 x 200 Resolution    16    Color   Graphics
<F7>    Mode 14     640 x 200 Resolution    16    Color   Graphics
<F8>    Mode 15     640 x 350 Resolution    Monochrome    Graphics
<F9>    Mode 16     640 x 350 Resolution    4/16 Color    Graphics
<F10>   Mode 17     640 x 480 Resolution    2     Color   Graphics
<F11>   Mode 18     640 x 480 Resolution    16    Color   Graphics
<F12>   Mode 19     320 x 200 Resolution    256   Color   Graphics
<F13>   Hercules    720 x 348 Resolution    Mono/Color    Graphics

<End>   Return to Main Menu and Cancel any new Mode Selection

                     For <F11-13>   use    <Shift><F1-3>
Press <Fn> <↑> <↓> <Home> <End> <Page Up> <Page Down> <Space Bar> <Enter>  ?
```

Figure 4.17 *Select Video Test Mode Menu.*

Hardware and Mode Information

Information about the video hardware installed in your computer system is available in the *Main Menu* by selecting *Hardware Information* in the *Non-Technical Program* or *Hardware and Mode Information* in the *Technical Program*. The information is gathered directly from the system hardware and system software. It includes the type of Active Video Adapter and its attached Display. If your computer system has a second, inactive video system installed, information identifying it is also shown. On EGAs, the amount of video memory installed on the adapter is reported. Figure 4.18a shows the *Video System Configuration* screen output.

The video adapter may be marked as "Double-Scanned," or as having a "Non-Standard Resolution." Double-scanning allows some newer "super CGA" adapters to double the resolution for text modes while providing the standard lower resolution graphics modes. The characters in the text modes should appear comparable in quality to those provided by VGA systems. Non-Standard Resolutions are more often found on portable computers that have flat panel

```
    Video System Configuration:
 ------------------------------------------------------------------------


                    The Active Video Controller is a:
                      Video Graphics Array  (VGA)


                    The Active Video Display Unit is a:
                          Analog Color Display



                   No Inactive Video System was Detected.


              System BIOS dated 10/19/81 should be Upgraded.
 ------------------------------------------------------------------------
 Press <Page Up> <Page Down> <Home> <End>  ?  or  <Space Bar> to continue...
```

```
    Video System Information:
 ------------------------------------------------------------------------

    Adapter BIOS at: C000:0000  to  C000:5FFF     Length = 24K Bytes
          Copyright: IBM Corp. 1984, 1986
               Date: 10/27/86

    System BIOS
          Copyright: IBM 1981
               Date: 10/27/82

    Video RAM Memory Access :  8 Bits Wide
    Video ROM BIOS   Access :  8 Bits Wide

    Light Pen Interface : No
    BIOS Write String Function : Yes

    Primary Text     Mode  3 : 80 Column Color Text
    Primary Graphics Mode 18 : 640 x 480 16 Color Graphics

 ------------------------------------------------------------------------
 Press <Page Up> <Page Down> <Home> <End>  ?  or  <Space Bar> to continue...
```

Figure 4.18 *Video System Configuration and Information output screens.*

displays because the manufacturer can utilize the higher resolution needed by the graphics modes in the text modes. On EGAs the most likely Non-Standard Resolution value is 400 lines, which should make text mode characters appear comparable in quality to those provided by VGA systems. Note that non-standard resolution text modes may occasionally introduce compatibility problems with a few software programs.

Under some circumstances, DisplayMate's designation of a display as either Color or Monochrome will be functionally correct but visually incorrect. This is because in some cases monochrome displays are connected to color adapters and masquerade as color displays, particularly in portable computers. Some color displays can masquerade as monochrome displays, particularly with multi-frequency displays. Monochrome displays emulate color by producing a different intensity for each color, often resulting in poor image contrast. The system hardware and software are unable to discern whether the screen is actually producing color or not. What matters for the DisplayMate tests is the functional designation, which specifies how the system and application software treat the display.

If you have an IBM PC manufactured before April 1983 with a system BIOS ROM dated before 10/27/82, then a new ROM chip must be installed before you can upgrade your system to either EGA or VGA. If DisplayMate finds this to be the case, the following message will appear at the bottom of the *Video System Configuration* screen:

System BIOS dated xx/xx/xx should be Upgraded.

While IBM no longer sells the "BIOS Update Kits" (Part Number 1501005), they are available from used computer parts dealers and also from some manufacturers of compatible ROM BIOS. Your computer dealer should be able to locate one for you. IBM used to charge $35 for the kits.

If you have an IBM EGA, and the memory installed onboard the adapter is reported to be only 64 KBytes, then we recommend that you upgrade the video memory to 128 KBytes. With only 64 KBytes you are restricted to 4 colors in the Primary Graphics Mode (mode 16) and to a single font in text mode. Many software packages do not support the restricted 4 color mode. With 128 KBytes you can have the full 16 colors and also two fonts loaded in text modes. Some software packages, particularly word processors, support dual fonts. A full 256

KBytes allows 4 fonts to be loaded in text modes. To add memory, you will need an IBM EGA Graphics Memory Expansion Card (IBM Part Number 1501201) that attaches to the main EGA card. The expansion card is still available directly from IBM or an IBM dealer, or it can be bought from a used computer parts dealer. The memory chips can be bought by mail order; look in the back of most PC magazines for an appropriate mail order house. You will need 8 chips, type TMS4416, with access times of 150 ns or less. The cost should be about $20. Alternatively, you can buy a non-IBM EGA card that comes with a full 256 KBytes for under $100.

In the *Technical Program,* additional hardware information is provided in a second *Video System Information* screen, shown in Figure 4.18b. Shown are the video adapter BIOS ROM size and memory areas, and also the copyright and version dates for the video BIOS and the system BIOS. In most cases this will indicate the name of the manufacturer of the adapter. In some circumstances, the routines that scan for this information may be fooled by context and will produce incomplete output.

The *Video System Information* screen also identifies the data path widths of the video RAM memory and video ROM BIOS. Most video adapters have only 8-bit paths. In order to operate with a 16-bit data path, the adapter must be 16-bits wide, it must be plugged into a 16-bit wide AT, ISA system bus, it must be set for 16-bit operation, and there can be no 8-bit adapters that occupy the same memory range. Note that DisplayMate measures the speed of video ROM BIOS, not RAM BIOS. If you have installed a video BIOS driver in RAM, DisplayMate is unable to determine where the BIOS executes because of interrupt vector chaining. Additional information on data path widths is provided in the *Speed Performance* section in Chapter 5, and in the *16-bit Adapters and System Bus Conflicts* section in Chapter 8.

The width reported is the actual operational data path. Widths greater than 16-bits are generally not available and are not detected by DisplayMate. Note that for some 16-bit adapters the operational width of the data path may change with video mode. You can determine this by comparing the *Memory Speed* measurement in the *Speed Performance Tests* for different video modes. If the variation between modes is in the range of 2:1 or more, then not all modes are operating with a path of 16-bits.

Also shown in this screen is information on functions that are not uniformly available on certain adapters, and may vary with the date of production or manufacturer, such as a Light Pen Interface and the BIOS string function. This screen also identifies the *Primary Text Mode* and the *Primary Graphics Mode* for the video system.

In the *Technical Program,* the screens thereafter provide parametric data for each Video Mode available on your computer system. Figure 4.19 shows a *Video Mode Information* screen.

```
     Video Mode Information:
  ----------------------------------------------------------------------------
     For Display Modes  2,3    :  80 Column Color Text
         Pixels                =  720H x 400V
         Text                  =  80 Columns x 25 Rows
         Character Box         =  9H x 16V Pixels
         Character Size        =  7H x 10V Pixels with 3 descenders

         Palettes              =  1
         Palette    Colors     =  262144
         Foreground Colors     =  16
         Background Colors     =  16
         Gray Levels           =  64

         Screen Aspect Ratio   =  1.33  H/V
         Pixel  Aspect Ratio   =  0.74  H/V
         Adapter Memory        =  256 KBytes
         Loadable Fonts        =  8
         Display Pages         =  8

     Available Display Modes   :  0 1 2 3 4 5 6 7 13 14 15 16 17 18 19
  ----------------------------------------------------------------------------
  Press <Page Up> <Page Down> <Home> <End>  ?  or  <Space Bar> to continue...
```

Figure 4.19 *Video Mode Information screen.*

For any given mode, the values depend upon the type of adapter, the type of display, and the amount of installed video memory. The information is valid only for video adapters that are 100% compatible with IBM video adapters. The parameters are explained in Chapter 5 on *Video Display System Basics,* and in the *Glossary.*

Video Data Area Information

The *Video Data Area Information* selection is available only in the *Technical Program.* The BIOS Data Area is a special area of system memory that is used by the BIOS routines to store the values of internal working variables that control the computer's operation and specify its hardware configuration. Video information is also stored in the Interrupt Vector Data Area and in other areas that are specified by pointers within the two system data areas.

DisplayMate makes it easy for technical users to decode the generally cryptic information in the data areas, determine the state of video system, and gain access to the video adapter's data tables. The *Technical Program* provides a fully documented tour through the video portion of the computer's BIOS Data Area, Interrupt Data Area, and video pointer areas. When individual bits have a special function, they are separately identified. Some of the information shown is not documented, or is incorrectly documented by IBM. Figures 4.20a and 4.20b show the *Video Data Area* screens. Individual bits are identified by name. When shown in normal video the function is ON, and when shown in reverse video the function is OFF. Note that for some bits the ON condition is indicated by a binary "0," instead of the more usual "1." Explanations for the entries in the *Video Data Area Information* screens are provided in Appendix I.

Not all of the values in the data areas are valid for every video adapter. DisplayMate marks the invalid data entries in red. On IBM systems, the data areas that are not used are generally 0; on other systems you may find gibberish. Some non-IBM video systems may fill in parameters that are only used by the more advanced IBM video adapters, so you may see apparently valid values in red. Since they are non-standard they cannot be relied on, even if the values look reasonable.

In a basic configuration or a *vanilla* system, all the address pointers in the data areas will point to the system and video adapter BIOS in high memory. Some system and application programs change the pointers so that they point into their own memory areas. This allows them to intercept all requests for system services and modify the video system in some manner. DisplayMate will mark all of these as a *Non-BIOS Address,* to the right of the address, and in red in order to call your attention to them. All such redirections represent potential compatibility problems. The most common redirection is the Video BIOS interrupt: a mouse

```
    Video Display Data Area 40:49

        Video Display Mode          3   80 Column Color Text
        Display Columns             80
        Page Buffer Size            4096 Bytes
        Page Starting Address       0H
        Page Cursor Positions       (0,0)     (0,0)     (0,0)     (0,0)
         0 to 7  (Column,Row)       (0,0)     (0,0)     (0,0)     (0,0)

        Cursor Type                 DH / EH     Start / End Lines
        Active Display Page         0
        Controller Address          3D4H
        Mode  Register Setting      00101001 = 29H
                                    Blink 640X200 Video B&W Graphics 80X25
        Color Register Setting      00110000 = 30H
                                    Palette Alt Intensity Red Green Blue

    Video Equipment Flag            2   Color Mode with 80 x 25 Text

    Video Display Mode at Entry     3   80 Column Color Text

Press <Page Up> <Page Down> <Home> <End>  ?  or  <Space Bar> to continue...
```

```
    Video Control Data Area 40:84

        Rows-1                         24
        Character Height               16
        EGA Mode Information           01100000 = 60H
                                       ClearScreen 256K Reserved
                                       Active Wait Monochrome Emulation

        Feature Connector              0000     = 0H
        Configuration Switches             1001 = 9H
            Primary   Adapter:         EGA Enhanced Color Display
            Secondary Adapter:         None or MDA

        PS/2 Mode Information          00010001 = 11H
                                       400Lines Switching Reserved 400Lines
                                       Palette Monochrome GraySum AllModes

        Display Combination Index      11
                  Active Display:      VGA with Color Display
                Inactive Display:      No Display

Press <Page Up> <Page Down> <Home> <End>  ?  or  <Space Bar> to continue...
```

Figure 4.20a *Video Data Area Screens 1 and 2.*

```
      Video Interrupt Data Area:

            Retrace Interrupt IRQ 2      0AH     F000:E6DD
            Video BIOS Interrupt         10H     1AE6:0A36    non-BIOS Address
            Video Parameter Table        1DH     F000:F0A4
            Graphics Char Extensions     1FH     C000:3B8D
            Relocated Video Interrupt    42H     F000:F065
            Enhanced Character Table     43H     C000:378D


      Font Character Definition Data Area:

            ROM 8 x  8 Font (00H - 7FH)          C000:378D
            ROM 8 x  8 Font (07H - FFH)          C000:3B8D
            ROM 8 x 14 Font                      C000:3F8D
            ROM 9 x 14 Font Alternates           C000:4D8D
            ROM 8 x 16 Font                      C000:4EBA
            ROM 9 x 16 Font Alternates           C000:5EBA

 ____________________________________________________________________________
 Press <Page Up> <Page Down> <Home> <End>  ?  or  <Space Bar> to continue...
```

```
      Video Pointer Data Area 40:A8              C000:05C6

            Video Parameter Table                C000:1342
            Palette Save Area                    0000:0000
            Text      Aux Character Set          0000:0000
            Graphics Aux Character Set           0000:0000
            Secondary Save Pointer               C000:05E2
            Reserved                             0000:0000
            Reserved                             0000:0000


      Secondary Save Pointer Table:              C000:05E2

            Table Length                         26  Bytes
            Display Combination Code Table       C000:0AD3
            Second Text Aux Character Set        0000:0000
            User Palette Profile Table           0000:0000
            Reserved                             0000:0000
            Reserved                             0000:0000
            Reserved                             0000:0000

 ____________________________________________________________________________
 Press <Page Up> <Page Down> <Home> <End>  ?  or  <Space Bar> to continue...
```

Figure 4.20b *Video Data Area Screens 3 and 4.*

driver, screen blanking utility, and many TSR programs generally intercept it. Other redirections of greater concern are those that modify the default video parameters, fonts, or palettes. Additional technical information on the Video Data areas is available in Appendix I.

You can examine the state of the Video Data Area for any of the standard video modes, and also examine the values that were in effect and were stored when DisplayMate started up. The *Video Data Area Information* is a selection of the *Main Menu* in the *Technical Program.* After making the selection you will see a *Select Video Data Mode* menu where you choose the video mode you wish to examine, or you can pick the *Initial Data Area at Entry to DisplayMate.* There is a brief pause while DisplayMate switches to the requested mode, and stores the Video Data Area parameters. There are 4 screens in the *Video Data Area Information* series, as shown in Figures 4.20a and 4.20b. You move from screen to screen using the usual <Space Bar> or <Enter> keys, or by using the keypad keys <Page Up>, <Page Down>, <Home>, and <End> to maneuver forward and backward between screens. If you have a mouse, you can also click the left button to flip through the screens.

Part II

Everything You Need to Know About Video Systems

Chapter 5

Video Display System Basics

Introduction

In this chapter we will examine the practical fundamentals of personal computer video display systems. Our goal is to present the practical issues that you must be aware of in order to select and use video display system hardware that will be properly matched to your software requirements and visual needs. You do not need to know or understand the material in this chapter in order to use DisplayMate.

In the sections below we first discuss *Video Display Adapter* basics and then *Video Display* basics. Because the functional capabilities of the two are so interdependent, it is not possible to completely separate the discussions for each. Later in the chapter there are sections on the different kinds of *Display Technologies*, on *Multi-Frequency Displays*, and on *Multiple Video Display Systems*. At the end of the chapter we examine video system *Compatibility* and *Speed Performance*. You do not need to read this chapter from end-to-end, because it is written as a reference. You can lookup the information you want.

A video system is made up of two essential components: a video display and a video adapter. The video display is nothing more than a specialized high resolution television. The computer itself is unable to generate the signals necessary to produce a video image on the display, so a specialized piece of hardware called a video adapter performs these functions. The video adapter must continuously translate the image stored in its memory into a steady stream of signals for its video display. The entire screen image must be completely redrawn about 60 times per second. This alone may require the generation of more than 75 million signals every second for a color display. At the same time this is happening, the video adapter must be able to execute a rapid and possibly continuous stream of instructions from the system microprocessor that modify the image as it is being displayed. Clearly, this is a demanding full time job.

Your software uses the system microprocessor to control the video adapter. The video adapter hardware determines the resolution, color, and other functional capabilities of your computer's video system. It is the video display's job to accurately transform the video adapter's signals into a high quality image.

The adapter and display must be specifically designed to work together, and that is why they are called a video system: they must be fully hardware compatible with one another and with the IBM standard. First, the video adapter must be compatible with the computer and its system bus. Next, each new generation of video system includes compatibility modes that allow it to emulate the prior systems so that you may continue to use software written for older adapters. Unfortunately, none of the IBM video adapters are fully 100% downward compatible with the adapters they supersede, so some software may not work with the newer IBM hardware. The *Compatibility* section below discusses this complex problem.

Since the introduction of the original IBM PC in 1981, IBM has introduced five general purpose video systems for its personal computer line. Three other video adapters produced by Hercules Computer Technology have also come into widespread use and have become video standards in their own right. The video systems are identified by the initials of the video adapter:

- MDA: Monochrome Display Adapter
- CGA: Color Graphics Adapter
- HGC: Hercules Graphics Card
- EGA: Enhanced Graphics Adapter
- HIC: Hercules InColor Card
- MCGA: Multi-Color Graphics Array
- VGA: Video Graphics Array

Table 5.1 provides a summary of the video adapters and some of their basic parameters that will be discussed below. None of these adapters can be considered state of the art video systems; rather they provide good quality graphics at a reasonable price. Many manufacturers of IBM compatible systems have given their products features and capabilities beyond the original IBM standard. This has given rise to a large number of super EGA and VGA video adapters, which will be discussed in the section *Enhanced EGA and VGA*. IBM has also introduced three additional lines of video systems for high-end professional users that we will briefly discuss later in the section *Beyond VGA*.

Adapter	Year	Flicker Frequency	Graphics Resolution	Color Palette	Character Box
MDA	1981	50 Hz	–	1	9×14
CGA	1981	60	640×200	16	8×8
HGC	1982	50	720×348	1	9×14
EGA	1984	50, 60	640×350	64	8×14
HIC	1986	60	720×348	64	9×14
MCGA	1987	60, 70	640×480	262,144	8×16
VGA	1987	60, 70	640×480	262,144	9×16

Table 5.1 *Video Display Adapter Summary.*

Video Display Adapters

In this section we first provide a brief introduction to video adapters and then discuss each of the adapters in historical order. It is not necessary to read about each of the adapters in order. Treat this section as a reference and only read about the adapters you wish to learn more about.

Each succeeding generation of video adapter offers enhanced capabilities and image quality. The older adapters continue to be relevant because they form the basis for the compatibility modes of the latest and greatest adapters. Actually, many of the later adapters are not fully compatible with the earlier adapters they replaced, so in some instances you may still need an original MDA, CGA, or EGA in order to run certain software. The older adapters are generally faster in terms of raw drawing speed, so they may still be a better match for slower computers and for some high speed graphics applications as well. About 50% of all IBM compatible computers still use original MDA and CGA video systems and it is important for the owners of these systems to be able to compare what they currently have with what is now available. In fact, many portable computers and inexpensive computers continue to offer CGA and MDA video systems.

Introduction

Most video adapters come on a separate card that is plugged into the computer's system bus; they are referred to as video adapter cards. Video adapters may also be referred to as video controllers, which technically is the name of the job they perform. A number of computers, including all of IBM's PS/2 line, come with a video adapter built right into the computer's main circuit board; they are referred to as planar video adapters. While that may be convenient and saves a valuable slot in the computer's system bus, you will need to figure out how to disable the planar video adapter if you want to use a different adapter later on.

All of the video adapters work via the principle of memory mapped video. The system microprocessor produces an image on the display by writing to particular locations in the adapter's memory banks. In text modes, changing the value of a particular byte of memory automatically changes the character that is displayed at a corresponding point on the display screen. Text modes can only produce a predefined set of characters at predefined locations on the screen, much like an ordinary typewriter. Some of the predefined characters include special symbols and combinations of horizontal and vertical ruling characters that allow horizontal and vertical lines and boxes to be drawn in text mode.

Bit Maps

Graphics is required in order to be able to draw arbitrary figures on the screen. In graphics modes, changing a particular bit within a byte causes a single dot on the screen to change its intensity or color. Graphic images are, therefore, often called *bit-mapped.* The dots are generally called *pixels,* which is short for picture elements. Sometimes the name is further contracted to *pels.* The pixels are arranged in rows and columns and each pixel has a row and column address that is used to identify it. Graphic images are therefore also referred to as *All Points Addressable,* or *APA* for short. The resolution of an image is specified by the number of pixel columns and rows in the form of "columns×rows," so 640×480 means there are 640 pixels horizontally by 480 vertically. In text modes just the number of columns and rows are indicated in a like manner, so that 80×25 means 80 columns by 25 rows. Note that in each case the horizontal figure appears first. Clearly, the higher the resolution, the finer the detail and the better the quality of the image.

An image is constructed by setting the memory bits to a desired state. For example, in order to draw a line or a character of text in a graphics image, the system microprocessor must figure out which pixels must be changed, then compute the memory addresses for those pixels, and finally go about setting each of the bits in turn. That takes a fair amount of time and work, and is the reason why graphics is much slower than text modes, which require only a single number to change an entire predefined character.

Font Resolution

A related and important specification that we must consider is the resolution of the text characters that are drawn on the screen. This applies whether they are displayed in text or graphics modes. The higher the font resolution the finer and more detailed the characters will be drawn. Each character is made up of an array of dots. The font resolution is specified as the number of horizontal and vertical pixels reserved for drawing each character and is called the *Character Box.* The box ranges from 8×8 pixels for the CGA to 9×16 pixels for the VGA.

The character box includes the space between characters, so the size of the actual characters is smaller. The character sizes range from 7×7 pixels for the CGA to 7×10 pixels for the VGA. Font resolution is considered in greater detail in Chapter 7.

Adapter BIOS

Each display adapter needs a set of specialized software routines provided by the manufacturer that can control its own complicated video hardware. The routines not only initialize the adapter but also provide a standardized set of services that allow other software programs to use the video adapter easily without having to become involved in the details of controlling the hardware. Routines of this sort are available for all of the computer's hardware and are given the name BIOS, for Basic Input/Output System. The information is generally contained in permanent Read Only Memory and hence is referred to as ROM BIOS. The original IBM PC had the BIOS for the MDA and the CGA built right into the system board's own ROM BIOS. The more advanced video cards such as the EGA and VGA contain their own on-board BIOS that are linked to the system BIOS. All of these routines were defined by IBM for each of their video adapters. Each manufacturer of IBM compatible hardware must provide a BIOS that is functionally identical with the IBM BIOS without actually copying it. This is much easier said than done.

Monochrome Display Adapter: MDA

The Monochrome Display Adapter, or MDA for short, was one of the two original adapters introduced in 1981 with the IBM PC. It produced text but no graphics and was directed toward professional business users. It remained the dominant video adapter until the EGA became a strong presence around 1986. The image quality of the MDA text characters is quite good even by today's standards: only the VGA exceeds the MDA character resolution, and then by only 15%. In fact, one reason why the original MDA produced such nice looking text is that IBM added circuitry to help connect adjoining pixels so that the characters have an unusually smooth appearance. Unlike the CGA, text can be written quickly without the appearance of snow on the screen and there is no flicker during scrolling.

The primary shortcoming of the MDA is that its image is refreshed only 50 times per second, or Hertz (Hz). In order to eliminate the perception of image flicker a special phosphor with an unusually long persistence time is needed. The phosphor is P39, a green phosphor that is also used in some radar screens. Many people do not like the green color. The long persistence gives rise to after images that can last a few seconds in dim lighting, and can make the screen unreadable if the screen content changes rapidly, such as during scrolling. Note that if you connect a multi-frequency display to an MDA adapter you will generally see flicker because the persistence of the phosphors on those displays is too short.

While the MDA is a monochrome standard, it actually uses an internal format that allows 16 foreground and background colors to be specified in the same way as the CGA and all other color cards. In fact, the schematics of the adapter provided by IBM indicate that early models of the MDA can produce full color images if connected to a multi-frequency color display; later models are missing a number of internal connections needed to bring out the color.

The MDA's internal 16 color format gives it a considerable degree of compatibility with color adapters. Initially, when most software was developed for the MDA, this compatibility benefited the CGA, but now most software is developed for color, so the MDA now runs a good deal of software intended for color text modes. All of the internally specified colors map to a uniform monochrome output with only one minor twist: if the internal color is blue, then the character will also be underlined. Other attributes that can be assigned include blinking, high intensity and reverse video.

A number of the 256 possible attribute assignments for the IBM MDA are unusual and have not been carried forward to the IBM EGA and VGA. Under some circumstances this will affect compatibility because the attributes will appear differently on the MDA. Both the MDA and the CGA share the same set of 256 text characters. The character set includes many special symbols, block characters, and characters for ruling horizontal and vertical lines on the display. The MDA has a single fixed font that is generated by the hardware and has enough memory to store only a single page of text on the adapter.

It is important to note that the monochrome MDA standard represents more than the mere absence of color. It is fundamentally different from the color adapters because the hardware uses different memory addresses, ports, and control registers. There are two families of video adapters and one has evolved from the MDA: the members include all of the Hercules graphics cards and the EGA and VGA when in monochrome mode. However, most present day video systems with monochrome displays actually function as color adapters that map the internal colors to varying monochrome intensities. For compatibility reasons the MDA standard continues with the successor EGA and VGA adapters, which provide modes functionally compatible with the MDA. They will run almost all MDA software without modification.

There is still a considerable amount of software around that was written primarily for the MDA standard, because it was the adapter chosen for most professional software up until the EGA became a strong presence around 1986. While the monochrome standard remains, most current software is written primarily with color in mind, and some software will refuse to work if it detects monochrome hardware.

Color Graphics Adapter: CGA

The Color Graphics Adapter, or CGA, was introduced with the original IBM PC in 1981 as an alternative to the MDA and was aimed primarily at the hobbyist and educational markets. While the MDA got most of the sales, the CGA got most of the attention because it is a much more interesting video adapter than the MDA. The CGA has 2 text modes in addition to 3 graphics modes, plus it has a light pen interface. There are two video outputs: one for a television style composite display, and a second for a high quality direct drive color display. Most CGA clones do not have the composite output and many do not have a light pen interface.

Today almost all computer systems use direct drive displays; however, IBM did not begin selling its own direct drive Color Display for the CGA until 1983. The composite output signal allows a home television to be used as the computer's video display, eliminating the need for a low budget buyer to purchase an expensive display for the computer. The resolution and image quality of a composite display is substantially inferior to that of a direct drive unit. However, all of the CGA video modes are designed for compatibility with American broadcast television standards, so they limit the CGA's performance to a certain extent. This fact also sets the flicker frequency for all CGA modes to 60 Hz, higher than the MDA's 50 Hz, but lower than the VGA and MCGA's 70 Hz. Note that you can use the composite output with DisplayMate to setup and test your home TV.

The CGA is still a relevant video adapter because a large fraction of the installed base remains CGA, and many inexpensive and portable computers are still produced with CGA video systems. The CGA is also the origin of the color family of IBM adapters. All subsequent color adapters have an architecture that has evolved from the CGA and they support all of the CGA video modes for compatibility reasons.

The CGA provides 16 colors: they are the primary colors red, green, and blue; plus the secondary colors brown/yellow, magenta, and cyan; plus white and black; plus bright, intensified versions of these 8 colors. Of the secondary colors: yellow is produced from equal combinations of red and green, magenta is produced from red and blue, cyan is produced from blue and green, and white is produced from red, green, and blue together. All 16 colors are specified from on/off combinations of the red, green, blue, and intensity signals that are generated by the adapter and transmitted to the display over 4 wires in the video cable. The four signals are commonly abbreviated as RGBI. Note that in computer graphics any unique combination of intensities is considered a color, and this includes black, gray, and white. The designation *bright black* is a special case and shows up as a *dark gray* on IBM displays. Some displays cannot produce dark gray and will instead yield black. Brown is actually a dark yellow, and IBM displays generate a reddish brown by using 2 parts red and 1 part green. Other displays will produce a dim banana yellow instead of brown. The intensified colors are not only brighter but also lighter in color. They have a significant white component and are not as saturated as the normal intensity colors. On EGA, VGA, and MCGA displays you will see a significant difference between the bright colors in the *Primary Colors* and the *CGA Compatible Colors* test screens. This set of 16 colors comprises the standard CGA color set that is produced by all IBM color video adapters.

In text modes each character is drawn with a foreground and background color from this set. When text blinking is enabled, only 8 dim background colors are available. Text modes can also produce a wide colored border that frames the active screen area. It is generally chosen to be the same color as the background, but it can be any of the 16 CGA colors. The border is also known as the overscan region. Of all the other adapters, only the EGA and VGA can produce borders: the EGA can successfully produce a border only in its 200 line compatibility modes; the VGA can produce a very narrow border in all of its modes.

The system BIOS supports two CGA graphics modes: a 320×200 medium resolution graphics mode and a 640×200 high resolution mode. The medium resolution mode provides four drawing colors chosen from one of six different palettes that are defined in hardware (see below). As with all graphics modes in all adapters, one of the colors included in the color count is the background color. That color is chosen separately and is the same for all pixels on the screen. Hence, there are only three foreground colors available. The high resolution mode provides a single foreground color on a black background.

The primary shortcoming of the CGA is the unusually low vertical resolution of 200 lines. Although compatibility with broadcast television standards would allow up to 240 lines, IBM reduced the resolution to 200 lines in order to limit the amount of graphics memory to 16 KBytes, a single set of 8 memory chips. The CGA's horizontal resolution is 640 pixels, the same as the VGA in graphics mode. As a result, graphics on the CGA is very coarse for lines that are close to the horizontal direction but is as fine as the VGA for lines that are close to the vertical direction.

Another consequence of the resolution imbalance is that the pixels are not square or round but rather oblong rectangles or ellipses with an axis ratio of 2.4:1. This means that horizontal lines will be 2.4 times wider than vertical lines, giving many images the appearance of having been drawn by a stylized calligraphic pen. Worst of all, displays generally cannot produce the proper 2.4:1 elongated scanning beam, making it likely that gaps will appear in between the raster lines. That will make vertical lines look like a collection of separated disconnected vertical dots instead of a single smooth line. The effect is generally the most troubling with text characters, which are much harder to read when they appear as a collection of dots.

The CGA includes 2 basic text modes: 40 columns wide and 80 columns wide. Both have the standard 25 rows. The 40 column mode is for use on composite displays that do not have sufficient resolution for the standard 80 column text screens. Since composite displays are no longer in common use, the 40 column modes are not generally used. In fact, a number of non-IBM EGA and VGA cards do not function properly in 40 column text mode, presumably because some manufacturers do not feel that this mode is worth the effort needed to get it right.

Both CGA text modes use a 7×7 font, with a one pixel descender for characters like "gjpqy." A major reason why CGA text is so difficult to read is that the character fills up just about all of the allowed 8×8 character box, leaving very little space in between characters. A descender can touch a tall character on the row below.

The IBM CGA actually has two built in fonts: the standard double-dot 7×7 font and a single-dot 5×7 version. In the double-dot format the strokes that make up all characters are never less than two pixels wide. The two pixel width matches the pixel aspect ratio of 2.4:1 discussed above, giving the characters a uniform thickness. On most displays the characters from the sharper single-dot version will have vertical strokes that appear too thin and too dim to be comfortably read. Selecting the single dot font requires soldering a jumper on the card.

The hardware in most CGAs is unable to properly arbitrate memory requests from the system microprocessor when in the 80 column text mode. This results in 2 very annoying effects: snow and scrolling flicker. Snow is the appearance of semi-random interference lines on the display as the result of the system microprocessor not synchronizing its memory accesses with the adapter. The system BIOS does this properly, but some software that accesses the screen directly may not bother with the restricted timing and thereby produce snow as a result. A major problem with the synchronization requirement is that it reduces the speed at which text can be written on the screen by roughly 25 to 1. Some users prefer high speed output and simply look through the snow.

A more disturbing phenomenon occurs when the screen scrolls while in the 80 column text mode: the screen is briefly blanked, which appears as flicker to the user. If the background color is other than black the flicker is quite pronounced. DisplayMate includes a test for CGA scrolling flicker.

The IBM CGA has a number of hardware modes that are commonly not found on other CGA adapters. One is the composite video output we have already mentioned. Another is a total of 6 color palettes in the 320×200 medium resolution mode. IBM documents only two: green/red/brown and cyan/magenta/white. However, all IBM color video adapters will produce at least 4: the above two plus another two that are intensified versions of them. The IBM CGA will also produce two additional palettes: cyan/red/white and an intensified version as well. Finally, the CGA has a graphics mode of 160×100 pixels with 16 colors that is unsupported by the IBM BIOS but documented in the Technical Reference manual.

Over the years many manufacturers have enhanced the CGA in a number of ways, giving rise to so-called *Super CGAs*. Some of these adapters will be considerably faster and not produce screen snow or scrolling flicker. Other variations include producing higher quality text modes with more than 200 lines of resolution. There are a number of Super CGAs with 400 line resolution. Often they are accompanied by additional non-standard 400 line graphics modes. You are unlikely to find much software to support these modes. The most popular of them is a 640×400 mode found on many AT&T and Olivetti computers. In general, it is better to move up to a standard adapter than to use a non-standard video mode.

Hercules Graphics Card: HGC

In 1982 a start-up company called Hercules Computer Technology introduced a video adapter card that produced 720×348 pixel resolution graphics on the IBM Monochrome Display in addition to providing high quality text identical with the IBM MDA. In text mode, the HGC is 100% hardware compatible with the IBM MDA. By upgrading to an HGC, users could enjoy both high quality text and graphics without having to change their software or their video display. Hercules is the only company, besides IBM, that has managed to introduce a video system that is universally accepted as a standard.

Hercules compatible modes are offered by many manufacturers of IBM compatible video systems. A stumbling block to its general acceptance was the lack of BIOS support for the graphics functions, which Hercules should have provided, but did not. The card was none-the-less quite successful because many major software packages included their own HGC support.

The HGC has 2 pages of graphics memory, but only one can be used if a color graphics card is present because of a memory conflict. An early version of the

HGC did not have the capability of disabling the upper page and therefore cannot coexist with a color graphics card.

In 1986 Hercules enhanced the product with the introduction of the Graphics Card Plus that allowed user defined fonts or character sets to be downloaded into the adapter's memory. Up to 3072 characters can be loaded at one time. Several new attributes are provided including underline, overstrike, and boldface. A number of word processors take advantage of the additional character sets and attributes to produce multiple font screen displays that approximate the eventual printed output.

Enhanced Graphics Adapter: EGA

The Enhanced Graphics Adapter, or EGA, was introduced in 1984 and remains one of the most innovative and sophisticated products developed by IBM for the personal computer line. The EGA was designed as an upgrade for both the MDA and CGA adapters: it provides a graphics mode for MDA users, and for CGA users there are 3 graphics modes with 16 colors, including one at a much higher resolution. The EGA's numerous features include:

- full support for all of the MDA and CGA video modes;
- it can drive the MDA's Monochrome Display and the CGA's Color Display in addition to its own Enhanced Color Display. The flicker frequency is 50 Hz for all monochrome modes and 60 Hz for all color modes;
- a new high resolution 640×350 graphics mode with 16 colors;
- a palette of 64 colors to choose from. The palette registers allow any 16 colors to be quickly and conveniently selected from the complete set of 64;
- a new 640×350 monochrome graphics mode that is different from the Hercules standard;
- instead of a fixed ROM based character set, it allows fonts or character sets to be downloaded into the adapter's RAM memory. Up to 4 sets can be loaded at a time;
- the character generator is highly programmable and allows screens with up to 43 rows of text using one of its standard character sets;

- the adapter can store images that are wider than the display can show at any one time. It allows any portion of the image to be conveniently and quickly displayed. This is especially useful for spreadsheets and word processing programs;
- it provides hardware for graphics blinking, smooth scrolling, panning, and split screens. These terms are explained in the *Glossary;*
- a feature connector allows external hardware devices to connect directly to the EGA;
- it provides its own onboard 16 KByte BIOS that is linked to the system BIOS and includes 64 to 256 KBytes of RAM memory.

The EGA is a highly programmable card with 72 control registers that are used to setup and control its multitude of functions. The complexity of the card actually slowed the acceptance of this adapter by many developers, and to this day only a small fraction of all software takes proper advantage of the advanced features provided by the EGA. Another problem is that both IBM and Microsoft have been very slow to incorporate any of the EGA's features into DOS. For example, 4 years elapsed before DOS would work with the 43 row EGA text mode.

The acceptance of the EGA was not helped by the technical documentation provided by IBM, which contains numerous errors and omissions. In fact, a number of EGA clones are incompatible with the IBM EGA because they implemented certain features according to the documentation. While IBM is probably not too sorry about that, the lack of proper documentation hinders the efforts of the software developers that ultimately determine the success of the product.

The 64 colors that the EGA and its Enhanced Color Display can produce are generated by providing 4 intensity levels for each of the red, green, and blue primary colors. All possible combinations of the 4 intensities result in $4 \times 4 \times 4 = 64$ different colors, which are transmitted to the display over 6 digital signal lines. The six signals are commonly abbreviated as RrGgBb because each primary color has a high intensity and a low intensity line. In comparison, the CGA has 4 digital signal lines and can produce 16 colors, while the MDA has only 2 signal lines and can, in principle, produce 4 intensities, but IBM used only 3 in its adapter. DisplayMate will display all 64 EGA colors.

The EGA memory is organized into 4 bit planes in order to provide a maximum of 16 simultaneous colors chosen from its 64 color palette. It has parallel processing capabilities that allow it to operate on a byte from each of the 4 planes simultaneously. While the EGA provides a number of hardware data processing enhancements that help reduce the amount of work the system microprocessor must perform in order to produce an image, its overall speed performance on an IBM AT computer is roughly half that of an IBM CGA adapter for the same video mode, because of its more complicated internal hardware architecture. There is also more programming overhead involved in drawing images in the high resolution graphics modes, which in most cases reduces performance by an additional factor of 2. These performance differences are not as great on an IBM PC as on an IBM AT, because of its slower processor and system bus. When upgrading to an EGA on a given computer, expect the overall graphics performance to decrease significantly. How much this will affect the overall performance of your software will depend on how graphics intensive it is. You can use DisplayMate to measure the performance yourself. See the *Speed Performance* section of Chapter 4 for further information.

The ability to download fonts into the adapter's memory provides an incredible degree of versatility for the adapter's text modes. In monochrome mode the EGA will produce 9×14 text identical with the MDA on a Monochrome Display. In color mode it will produce 8×8 text identical with the CGA on a Color Display. On its own Enhanced Color Display the EGA provides 8×14 text that has 1 pixel less space in between characters than in monochrome text mode.

While the EGA provides compatibility modes for both the MDA and CGA, it is not fully 100% downward compatible with either adapter, so some software written for these adapters will not run properly on an EGA. This should not be a problem for software written after 1984, when the minor compatibility restrictions imposed by the EGA became known. This has become a market opportunity niche for the clone manufacturers, many of whom sell EGA compatible cards that also offer full downward compatibility for the MDA, CGA, and Hercules adapters.

A good deal of the EGA circuitry is included in 5 custom computer chips that were initially thought to be too complicated to clone. Eventually the chip set was legally copied, which led the way to inexpensive clones that turned the EGA into a popular video adapter. Most of the early EGA clones suffered from serious compatibility problems with the IBM EGA, an issue that has pretty much resolved itself over time. The original cost for a fully configured IBM EGA video adapter with 256 KBytes of memory was $982. Today you can find a number of EGA cards for under $100.

The basic IBM adapter includes only 64 KBytes of memory, which unfortunately downgrades many of its features including a restricted palette of 4 colors instead of the full complement of 16 in its high resolution graphics mode. It also restricts the adapter to a single font in text mode. DisplayMate supports the 64 KByte mode; however, many software packages do not. A piggyback graphics expansion board allows the memory to be upgraded to 128 or 256 KBytes. All of the clone manufacturers provide their EGA cards with a full 256 KBytes of memory. Anyone who still has a 64 KByte IBM EGA should get a memory upgrade (see Chapter 4 for details) or consider buying a new adapter card.

IBM PCs manufactured before April 1983 do not have the ability of locating and linking to the EGA or VGA BIOS. Such machines require a new BIOS chip before they can be used with an EGA or VGA. See *Hardware and Mode Information* in Chapter 4 for details.

Hercules InColor Card: HIC

The Hercules InColor Card, or HIC, was introduced in 1987 and extends the Hercules monochrome graphics standard into the color regime. Like the earlier Hercules cards, it provides no built-in BIOS, so those functions must be supplied by external software. The HIC can display 16 colors from a palette of 64 colors, and is fully compatible with the earlier Hercules monochrome cards and the IBM MDA. Color is implemented using 4 planes of memory that function in a manner quite similar to the EGA. The HIC has downloadable fonts or character sets with full color information included. Up to 3072 colored characters may be loaded at one time. The resolution remains 720×348 pixels with two color pages available. The HIC uses the same Enhanced Color Display as the EGA. An amusing feature of the Hercules InColor Card is that it is classified as a monochrome card because it is compatible with the MDA.

Multi-Color Graphics Array: MCGA

The Multi-Color Graphics Array, or MCGA, is found only in the IBM PS/2 models 25 and 30. The real name for the MCGA is the *Memory Controller Gate Array,* but it is almost universally referred to instead as the Multi-Color Graphics Array, which we have adopted for DisplayMate. That is a better name for the adapter anyhow, because it is technically an extension of the original CGA. There do not appear to be any non-IBM clones that are compatible with the MCGA, and it is most likely headed for extinction because the newer IBM PS/2 models 25 and 30 now include a VGA instead of the MCGA. Furthermore, not all software supports the MCGA, so in some cases it may be treated as an ordinary CGA.

The MCGA is undoubtedly the most unusual video adapter that IBM has introduced. It was meant to be a low cost alternative to the VGA for the entry level PS/2 models. Technically it is a very interesting, but also a very strange beast; it is register compatible with the original IBM CGA, but includes the same analog outputs as the VGA and shares two video modes with it. Except for that, it bears no resemblance to the VGA or EGA. Actually, the MCGA bears the same relation to the CGA as the VGA does to the EGA. Users wishing to upgrade their MCGA computer to a VGA system merely need to plug a VGA adapter card into their computer (when the power is off, of course). A PS/2 feature called *Display Switching* automatically deactivates the MCGA and activates the VGA adapter.

The most important features of the MCGA are that it uses the same analog displays as the VGA and can produce images comparable in quality to the VGA. In text modes it has twice the resolution of the CGA with a character box of 8×16 pixels, a trifle less than the VGA. The characters are well formed and quite readable.

The MCGA implements all 7 CGA video modes plus two new graphics modes that it shares with the VGA: a two-color high resolution graphics mode with 640×480 pixels and a 256 color mode with a resolution of 320×200 pixels. The application of these two modes is discussed in the VGA section, below. The adapter's analog outputs allow the user to select colors from a palette of 262,144 colors instead of just 16 for the CGA or 64 for the EGA. The ability to fine tune the color selection is a significant advantage for user comfort. Flicker is less of a problem on the MCGA because the screen is refreshed 70 times a second for all but the high resolution graphics mode. The CGA and EGA have refresh rates of 60 Hz, and the MDA 50 Hz.

The MCGA faithfully implements all of the CGA hardware except that it provides no borders, no light pen interface, and it implements only 4 of the 6 CGA medium resolution color palettes. Since the intrinsic resolution of the MCGA is 400 lines, the original 200 line CGA graphics modes are generated by double-scanning. The MCGA uses dual-ported memory so it does not suffer from the CGA's snow and scroll flicker problems.

The MCGA supports downloadable and user programmable fonts, and also 512 character fonts, but they are implemented in an unusual manner that is quite different from the EGA and VGA. One especially interesting feature of the MCGA is that it will automatically compute the values for a number of its timing registers for the standard modes. The MCGA also includes many undocumented capabilities. For example, the MCGA includes full BIOS support for analog displays that operate at the CGA scan rate of 15.75 KHz, in addition to the standard PS/2 scan rate of 31.5 KHz.

Video Graphics Array: VGA

The Video Graphics Array, or VGA, was introduced in 1987 as the flagship video adapter for the IBM PS/2 line of personal computers. The VGA gets its name from the large gate array chip that performs just about all of the adapter's functions. Unlike the video adapter cards that preceded it, the VGA is built into the computer's main circuit board. That guaranteed that IBM would supply all of the video adapters for its PS/2 computer line.

The VGA is functionally very similar to the EGA, but includes a number of enhancements, the most important of which is the analog video output that controls the display with a set of three voltage levels. All prior adapters use a digital video output that has 2 to 6 control lines to specify the colors and intensities. The Digital-to-Analog Converter or DAC included with the VGA produces 64 intensities for each of the red, green, and blue primary colors, yielding a palette of 262,144 colors. The ability to fine tune the color selection is a significant advantage for color fidelity and user comfort. The DAC can store 256 palette colors but only one video mode can use more than 16 at a time.

The VGA needs a display that accepts analog video signals and that operates at a 31.5 KHz horizontal scan frequency. This will be discussed further in the section on displays, below. Flicker is less of a problem on the VGA because the screen is refreshed 70 times per second for all but the high resolution graphics mode, which is scanned at 60 Hz like all prior color adapters.

The VGA includes two interesting new video modes: a 640×480 high resolution graphics mode with 16 colors, and a 320×200 low resolution graphics mode with 256 colors. The 256 color mode is particularly useful for images that require fine color shading, such as photographic images. The 640×480 mode is the highest resolution mode provided by the VGA and is the only mode that has square pixels. Square pixels allow simpler and faster geometric calculations by the system microprocessor when producing an image. However, more important from a visual point of view is that square pixels produce better quality images because horizontal and vertical lines will have the same thickness and brightness.

The font resolution for the VGA is 9×16 in text modes and 8×16 in graphics modes, higher than any of the standard adapters. The characters are better formed with more space in between rows. While this means that the characters are smaller, there is no question that VGA text looks better and is more readable than in other adapters.

Another important achievement for the VGA is that it finally brings together the disparate worlds of monochrome and color that began with the MDA and CGA. The VGA will accept either a monochrome or color display and can run in any of its video modes with either display as well, *i.e.,* you can use a color display in monochrome modes and a monochrome display in color modes. The VGA automatically loads the appropriate palette and runs the software. The VGA also provides a number of unusual compatibility modes: it can run text modes at screen resolutions of 200 and 350 lines in addition to its native 400 lines. This corresponds to the screen resolutions for the MDA, CGA, and EGA and allows unusual software that explicitly depends on the screen resolution to operate properly.

The VGA automatically configures itself and does not require the user to set any switches. In particular, it automatically figures out whether it is connected to a color or monochrome display, not by examining the monitor identification signals provided by PS/2 video displays, as is generally presumed, but by examining how many of its three color video signal lines are being loaded down by the video display. This method is considerably more general and reliable than simply using the monitor identification signals.

There are a number of enhancements to the underlying EGA architecture. The most important is that the VGA control registers can be read by an application program in order to determine the video state of the VGA. In adapters other than the VGA and MCGA, the software can only guess the state of the hardware registers, with disastrous results for memory resident TSR programs, which must modify and later restore the video state when they are invoked on top of another program.

There are actually 3 IBM VGA adapters and they have slightly different hardware options and BIOS: the VGA on the Micro Channel PS/2s; the VGA on the PS/2 models 25 and 30 that use the AT style ISA system bus; and the PS/2 VGA adapter that can be plugged into an IBM PC or AT to provide it with VGA capabilities. The original cost for an IBM PS/2 VGA Adapter was $595. Currently you can find a number of VGA cards for about $100.

Enhanced EGA and VGA

The standard edition of DisplayMate considers only the standard IBM and compatible adapters used in one of the standard IBM video modes, and also the Hercules display adapters in their standard modes. However, all of the adapters are programmable and can be placed into an almost limitless number of possible display modes. This is particularly true of the IBM EGA and VGA video adapters. Furthermore, many of the manufacturers of IBM compatible video systems have given their products features and capabilities beyond the original IBM standard. All of these non-standard modes are referred to as Extended, Enhanced, or Super EGA or VGA, giving rise to the acronyms: EEGA, EVGA, and SVGA. In text modes they will offer more columns on the display screen (often 100 or 132) or more rows (up to 60 rows). In graphics modes they will offer more colors at one of the standard resolutions, typically 640×480 with 256 colors, or higher resolutions, typically 800×600 with 16 or 256 colors, or sometimes 1024×768 with up to 16 colors.

The enhanced functionality is important and useful but there are a number of problems and risks involved in using non-standard modes. Most of these enhanced modes require a multi-frequency display because non-standard scanning frequencies are being generated by the video adapter. This is hardly a major obstacle, but many users do not have such displays. Some standard video displays without protection circuits may be damaged if the video adapter is programmed to generate non-standard scan frequencies.

This brings us to the first of three problems for enhanced EGA and VGA systems: non-standard modes are inherently non-portable because they generally require non-standard hardware. The modes that are available vary not only from manufacturer to manufacturer, but also from model to model. Software programs wishing to take advantage of one or more of the enhanced modes will generally have no direct or automatic way to detect the enhanced hardware so they need the user to specify the hardware configuration, and not all users will know this. Even enhanced modes that can run on the standard IBM adapters present a problem because the compatible adapters have only been tested on the standard modes and some may fail compatibility on non-standard modes.

There are so many "popular" enhanced modes that software programs cannot possibly support all of them. The solution has been for each video adapter manufacturer to include customized software drivers for the most widely used application programs. Each software driver allows the application program for which it was written the ability to use one of the enhanced video modes on a specific model adapter card. In general, it is not possible to use drivers from a different adapter card. Up to a dozen drivers are generally included with an adapter card. In many cases the drivers do not work perfectly and you will experience minor glitches using them.

This brings us to problem number 2: if your application programs are not on the included list of drivers you will be unable to take advantage of the enhanced modes. One important application that is supported is Windows, but outside of that environment there is not much software that supports the extended modes. If you write your own software you are also out of luck because BIOS extensions for the enhanced modes are generally not provided.

The real question is what will happen in the future? That is problem number 3. You might want to switch to or add specific application programs that are not on the supported list. Worse, the next release of your application program may be incompatible with the drivers originally included with your adapter card. The likelihood of receiving upgrades decreases with time. The flip side is: what if you want to upgrade your video hardware and your software is not supported by drivers on the new enhanced hardware? This possibility increases as the software ages and is no-longer "hot." What if your hardware breaks and you can no longer buy an exact replacement?

One solution to the above problems is to stay current with the latest state of the art hardware and software. Be prepared to upgrade regularly or switch. You'll get into trouble when you fall behind and get attached to any of your hardware or software.

Beyond VGA

Beyond VGA there are a number of key players, but no clear winners or definitive standards yet exist in this developing area. IBM currently has two entries, the 8514/A Adapter and the recently announced XGA, but they are not assured success by any means. A number of previous IBM video standards have failed over time including the PCjr, the MCGA, and the PGC, as will be discussed below. Because of the XGA, it seems likely that a similar fate awaits the 8514/A. All of the problems and risks described in the Enhanced EGA and VGA section above apply to these adapters as well. The greater cost of the higher resolution displays will continue to be the limiting factor in the general acceptance of the video standards considered here. Below, we discuss the current contenders for the market of video adapters that are more advanced than the VGA. Most will be included in the Advanced Edition of DisplayMate.

Super VGA

This is an enhanced VGA standard adopted in 1989 by VESA, the Video Electronics Standards Association, and is supported by many of the non-IBM enhanced VGA adapters. The resolution is 800×600 with 16 to 256 colors. A high resolution multi-frequency video display is required. This mode has 56% more pixels than VGA but represents only a 25% increase in linear resolution, which is much less than the 37% increase from EGA to VGA or 75% increase from CGA to EGA. This is a useful but only incremental increase in resolution. Note that not all video adapters that call themselves Super VGA, or that have resolutions of 800×600, are compatible with the VESA standard. Look for the VESA mark if you are interested in some degree of compatibility.

Super-duper VGA

This is also an enhanced VGA standard adopted in 1989 by VESA, the Video Electronics Standards Association, and is supported by some of the non-IBM enhanced VGA adapters. The resolution is 1024×768 with 16 to 256 colors. A high resolution multi-frequency video display is required. This is a major improvement over VGA with more than 2½ times as many pixels and 60% greater linear resolution. Unfortunately, the more than three-quarters of a million pixels may represent a significant burden to the system processor. Without a relatively fast processor, the graphics performance of this system will be unacceptably slow for many applications. The effect of resolution on speed is considered in the *Speed Performance* section, below. The need for an expensive processor makes this less attractive as an inexpensive high resolution graphics system. Next we consider graphics systems that contain a dedicated graphics processor.

The IBM Professional Graphics Controller: PGC

The Professional Graphics Controller was introduced by IBM in 1984 but never caught on, in part because of its high price, about $1800 plus the cost of a display. The resolution is 640×480 pixels with 256 colors drawn from a palette of 4096 and requires either the IBM PGC Analog Display or a multi-frequency display. The PGC has a dedicated on-board Intel 8088 microprocessor that is responsible for drawing the text and graphics on the display. This spares the system processor from performing this task, saving time, and speeding up the graphics and overall program execution. Besides its high resolution modes, the PGC can generate only CGA compatible graphics.

The IBM 8514/A Graphics Adapter

The 8514/A Graphics Adapter was introduced by IBM in 1987 to provide a high resolution display mode for the PS/2 line. The resolution is 1024×768 pixels with up to 256 colors from a palette of 16.8 million. The 8514/A includes an Advanced Function Controller that provides specialized onboard hardware to perform a limited number of low level graphics primitives such as line drawing, patterns, and area fill. This spares the system processor from performing this task, saving time and speeding up the graphics and overall program execution. The adapter and its display cost about $1500 each. It can only be connected to computers that have IBM's proprietary Micro Channel Architecture bus, and attaches to the VGA Auxiliary Video Extension Connector.

A major flaw of the 8514/A is that the display uses interlaced scanning. As is discussed in Chapter 7, this generally produces unacceptable flicker in many situations. Another problem is that IBM has not published information regarding the hardware internals of the adapter. This requires all programs to use the IBM software Adapter Interface, AI, a simple and non-extensible set of graphics commands. This makes it more difficult for clone manufacturers to copy the design, and frees IBM from maintaining hardware compatibility in future products. All of these factors have reduced the acceptance of the 8514/A standard. The 8514/A product line has been quietly extended by IBM to include two additional adapters that include the AI language, the Image Adapter/A and the Color Image Adapter/A, but all of this hardware may now be headed for eventual extinction because of the XGA, below.

The VESA 8514/A Standard

This is a clone of the IBM 8514/A adopted by the Video Electronics Standards Association, VESA, in 1990. It overcomes many of the problems with the IBM adapter by documenting the hardware internals of the standard. This was done by reverse engineering the IBM adapter. Many of the 8514/A clones are non-interlaced and available for computers that don't have IBM's Micro Channel Architecture, but rather use the industry standard ISA and EISA buses that work in virtually all PCs, XTs, ATs, and non-IBM 80286, 80386, and 80486 PCs.

The IBM Extended Graphics Adapter: XGA

The *Extended Graphics Adapter,* XGA, is IBM's most recent entry into high resolution graphics. The XGA comes on the main circuit board of IBM's newest 80486 microcomputers, in the same way that the VGA does on the older PS/2s. The XGA offers similar functionality to the 8514/A, including hardware to perform a limited number of low level graphics primitives. However, it is incompatible with the IBM 8514/A Graphics Adapter, so that all of the software that made use of the undocumented hardware features on the 8514/A will not work on the XGA. IBM is providing the same AI language as on the 8514/A, so that software that uses only that interface is "guaranteed" to be fully compatible.

The primary graphics mode of the XGA is 1024×768 with 256 colors drawn from a palette of 262,144. The XGA offers full VGA emulation, a new standard 132 column text mode, and a new 680×480 graphics mode with 65,536 colors. It has a nice feature that allows up to 8 XGAs per computer system. The XGA is also available as an adapter card for computers that have IBM's proprietary Micro Channel Architecture bus. Some of the XGA's features are intimately tied to the MCA bus, which will create some difficulties in implementing the XGA on the ISA and EISA bus computers that make up most of the non-IBM brand PC market.

Surprisingly, the XGA repeats the 8514/A's major flaw of using interlaced scanning, although there are claims that a non-interlaced version will be offered in the future. This time IBM is documenting the hardware internals of the adapter, with a "promise" to preserve the registers for future upward compatibility. IBM claims that the XGA is their next generation video standard and that it will eventually extend across its PS/2 line. We shall see...

Texas Instruments Graphics Architecture: TIGA

There are a number of PC graphics cards based on the TI 340X0 video coprocessor family with typical resolutions of 1024×768 or 1280×1024. The 340X0 is actually a high performance microprocessor that has been optimized for graphics. Because it is programmable, the functionality can be extended to meet the needs of application software. TI also provides a standardized software interface called TIGA that is used in many of the cards. It is similar in concept to IBM's AI but with substantially more functionality.

Video Displays

In this section we will examine a number of basic issues concerning video displays: *Normal Video versus Reverse Video, Color versus Monochrome,* and *Digital versus Analog*. The following two sections in this chapter consider *Display Technologies* and *Types of Displays*. A third section is devoted to an in-depth discussion of *Multi-Frequency Displays*. Many of the issues considered in Chapter 7 on *Maximizing Comfort and Productivity* relate to the quality of the images on displays. Chapter 8 on *Selecting a Video Display System* discusses matters involved in selecting and buying a video display.

Normal Video versus Reverse Video

The first item to consider when choosing a video display is whether you expect to use it in normal or reverse video mode. Reverse video is sometimes referred to as inverted video. In normal video, text and graphics are displayed on a dark background. The simplest case is white information on a black background but both the foreground and background may be colored, provided the foreground is brighter than the background. Historically, this is how most displays have been used. As you might expect, reverse video is the opposite: displaying dark text and graphics on a light background. The idea is to parallel the appearance of the normal printed page. Many people feel that reverse video is really the more natural video mode and it has become increasingly popular.

While the choice of normal video or reverse video is purely a subjective matter for the user, objectively it is more difficult for the hardware to properly display reverse video than normal video, so many displays that work fine in normal video will produce a less than satisfactory image in reverse video. The reasons are simple: contrast and resolution are much more critical in reverse video. Image flicker is also more apparent in reverse video. First we'll discuss contrast.

When a display is turned off, the dark screen establishes the "blackest black" the display is capable of producing. This will be nowhere near as dark as the jet black inks used in printing. Since comfort and readability are determined by contrast, which is the ratio of the brightest to darkest intensities in the image, it is necessary to turn up the screen intensity in order to achieve a satisfactory degree of contrast. In reverse video, most of the screen is on and producing light so the total amount of light given off can be substantial. Many people are bothered by this high brightness. Dark tinted screens can reduce the brightness and improve the contrast, but they often degrade the image because of internal reflections called halos, and because of defocusing and blooming in the image at the higher intensities. These terms are explained in the *Glossary* and in Chapter 7. The effects are greatest in reverse video because most of the screen is producing light.

In reverse video, dark text and graphics are created by rapidly and precisely turning off the scanning beam and then rapidly turning it back on again a brief instant later. This capability is a measure of the display's resolution. If this process doesn't occur quickly enough, the text and graphics will not only appear blurred but the beam will not have time to drop in intensity to reach the screen's black level, resulting in a decrease in the all important contrast. If vertical lines in the DisplayMate tests appear to be skinnier in reverse video than in normal video, then the display is not up to the task. You can switch from normal to reverse video in DisplayMate tests by using the <F6> Function key. This problem is not as serious for normal video because it is possible to turn up the screen brightness of the text and graphics to compensate for the effect without affecting the blackness of most of the screen, *i.e.*, in normal video, resolution does not affect contrast.

As we discuss below, color displays do not produce as sharp an image as monochrome displays, so if you really want reverse video then consider a good quality monochrome display that produces a crisp image. They will often be less than half the price of a color display. The color of the screen phosphor is especially important in reverse video, so be sure you find it pleasing. Many manufacturers offer a "paper white" phosphor; however, white is not a single color, and there is a considerable variation in the kinds of whites you may find. See *Color Temperature* in the *Glossary*. If you need color with reverse video, then consider only the highest quality color displays because reverse video on a poor quality color display is a disaster.

Color versus Monochrome

Up until just a few years ago most computer displays were monochrome, often green or amber, and most software did not possess color control. The IBM PC initially furthered this tradition with the introduction of MDA monochrome display hardware that was much higher in presentation quality than the CGA color hardware introduced at the same time. Most of the early IBM PC software was written with monochrome displays in mind, because the MDA was marketed for professional users.

There are a number of underlying differences between the MDA and CGA display systems and, as a result of compatibility issues, PCs to this day must exist in either a color mode or a monochrome mode. In the PC world, monochrome came to mean much more than the absence of color; it meant a completely different hardware display standard. Also, the color system had a graphics capability, but the monochrome did not. Color graphics was supposed to be for games and hobbyists, whereas serious users only needed high quality monochrome text presentations. Not everyone felt this way, so in 1982 a start-up company called Hercules Computer Technology became enormously successful by producing a monochrome graphics card. None-the-less, color to this day has generally remained synonymous with graphics.

The emergence of color graphics systems began in 1984 with IBM's EGA, which upgraded the resolution of color systems to that of monochrome. Although the EGA could be configured as a monochrome card, most of the hardware and functionality were devoted to color. Unfortunately, its relatively high cost, around $1800 at the time, and the difficulty in programming the adapter, led to a rather slow general acceptance until 1986. By then the cost of the hardware had fallen dramatically because clone manufacturers offered their own EGA cards and displays. This furthered the division between color and monochrome systems, but pushed the balance in the favor of color systems. From that point onward most software was written for color, and a good fraction of it will not run on monochrome systems for a variety of reasons.

In 1987 IBM solved the color/monochrome problem once and for all with the VGA, which supports all video modes in both color and monochrome. A monochrome system was now guaranteed of being able to run all color software. With this, monochrome once again reentered the main stream of PC displays.

The general perception is still that color is more and monochrome is less. Color sells. The highly colored displays you see in computer magazine ads make nice snappy attention getting copy, but you are likely to become over stimulated and fatigued if you regularly use that much color. Color is nice, but do you really need it? Color displays do provide the visually important dimension of color but produce grainier images because the screen is made up of phosphor dots or stripes, and they suffer from color registration and interference problems that can cause eye fatigue. Most printed matter seems to do just fine in black and white. Monochrome displays produce sharper images, cost about half as much as color displays, are smaller, and also weigh half as much as well.

When monochrome displays are connected to a color video adapter they often are designed to produce a different intensity or shade of gray for each displayable color. Unfortunately, strongly contrasting colors may map to similar intensities and result in poor contrast and low readability in a monochrome display. This not only can cause the user fatigue but also results in confusion relating to text and graphs identified by color. If non-black background colors are used, then the image will appear washed out or low in contrast. For some machines, particularly portable computers, utility software is available that allows the user to adjust manually the mapping from color to intensity. This process can often substantially improve the appearance of a particular piece of software.

Digital versus Analog

In digital displays the screen colors and/or intensities are controlled by transmitting numbers in the form of digital signals to the video display. Each number produces a unique color and/or intensity. The number of available colors or intensities is fixed by the number of signal wires:

2 for MDA displays, providing 4 intensities, but only 3 are used;

4 for CGA color displays, providing 16 colors and 2 intensities;

6 for EGA color displays, providing 64 colors and 4 intensities.

Digital displays are sometimes described as TTL, which stands for Transistor-Transistor-Logic, the technical name for the signal levels used in PCs.

The primary colors produced by the display are determined by the colors of the phosphors used in the screen. The secondary colors are determined by the drive circuitry in display and are preset at the factory to match the IBM standard to a certain degree. They generally cannot be modified by the user, although a service technician may be able to adjust the color balance. Television style brightness and contrast controls allow the user to modify the overall intensities produced by the display screen.

Now the 64 colors available on an EGA might seem to offer enough variety, but it is actually a rather limited selection. This becomes obvious when it is realized that each of the 64 colors is produced by setting the three primary colors to one of 4 possible intensities. Clearly, a range of only 4 intensities is quite restrictive, especially when it comes to mixing colors. More colors and intensities are necessary but it is impractical to achieve this by a further increase in the number of signal lines. The solution led IBM in 1987 to switch to the ultimate dirty word in digital computers: analog. Analog displays are available for the VGA and MCGA video systems.

In analog displays the screen intensities and colors are controlled by varying the voltage levels for each of the three primary colors. Since there are no built in limitations on how finely they can be adjusted, the number of possible intensities and colors that an analog display can produce is infinite. In fact, the number of colors that are available is limited by the number of distinct voltage levels that the video adapter can produce. For VGAs and MCGAs this is 64 intensities, for a grand total of 262,144 colors ($64 \times 64 \times 64$). Now this may seem like an absurdly large number of colors to choose from, but the eye can easily detect the jump from adjacent color to color. This can be a problem in color matching and in rendering photographic color images. Expensive, high quality professional displays generally offer 16,777,216 colors or 256 intensities, in order to produce high quality images. Even here the eye can detect the discontinuity of available colors.

From the above, it would seem as if analog were the clear choice. Unfortunately, because of their analog nature, analog video systems are susceptible to a number of problems that digital systems are relatively immune to: analog displays can suffer from color errors, color interaction, and electrical interference. Color errors arise from calibration problems in either the video adapter or the video display. In either case the colors you actually see will be different from the standard colors you should be seeing. If the red, green, and blue color channels are not properly balanced, then the colors will vary as the intensity changes, or as you change the user brightness and contrast controls; this effect is called a color tracking error. As a result, color balance and accuracy are much harder to achieve in an analog system, so there will be a greater variability in the actual colors produced than in digital systems. A related problem is color interaction, where colors in one part of the screen may affect the colors elsewhere, as a result of influencing the internal analog voltage levels.

Minute changes in the analog signal voltages can produce visible patterns on the screen. Any form of electrical interference will cause this to happen. The computer is itself filled with many signals that can contaminate the analog lines; even the video adapter can cause interference to its own analog video lines. Computer produced interference is especially annoying because a lot of the signals are synchronized and will give rise to structured patterns on the screen. So if your computer system or work environment produces screen interference, and it bothers you, it may be better to switch to an EGA or other digital adapter. DisplayMate offers a number of tests for interference.

Display Technologies

Video displays produce their images using several different types of display technology: Cathode Ray Tube or CRT, Liquid Crystal Display or LCD, Gas Plasma, and Electroluminescent display. CRTs are generally used with desktop computers while the others are found primarily in portable computers. Some people, concerned about reports of possible health risks from CRTs, are using non-CRT displays for their desktop computers. We consider this issue in Chapter 6 on VDT Safety.

Below we examine each type of display technology in turn and discuss their individual relative shortcomings. The manufacturer's literature and the sales person will point out the strengths of any display you are considering. Your eyes will immediately notice a display's good points. We have chosen to discuss the shortcomings of each display technology because it is easy to overlook them. There is no perfect display, and the best display will depend on individual preferences and circumstances.

Cathode Ray Tube: CRT

The CRT is the same device that is used as the picture tube in most home television receivers. It is a large vacuum tube with an internal electron beam that causes the phosphor coating on the inside of the screen to emit light. Cathode

Ray Tubes capable of drawing images have been around for almost 100 years and are among the most highly refined electronic devices made today. While the best CRTs are capable of producing the highest quality images available from video displays, compromises of varying degrees are required for the mass produced displays used in personal computers.

In a CRT, a narrow electron beam is deflected by external magnetic coils to produce a pattern of almost horizontal scan lines, called a raster, that is used to form the image. Errors and imperfections in the magnetic system make the CRT susceptible to producing images that are out of focus and that are geometrically distorted. If the beam spot size is too small then the raster of scan lines will be visible, which is annoying; if it is too large, then resolution is degraded.

The CRT is also more susceptible to aging and component drift, so the quality of the image may degrade with time. The phosphors in the CRT will slowly lose efficiency and also become discolored, burned, and damaged. This may be noticeable if the same software program is used repeatedly over a long period of time. Monochrome displays with long persistence phosphors are generally more susceptible to these problems. In quality CRT displays, all of the above effects are small. None-the-less, they can arise from bad design, bad factory adjustments, bad field service adjustments, and user abuse.

Most CRT screens are curved in one or two dimensions, like a cylinder or sphere, respectively. Curved screens generally produce more glare than flat screens. Although the screens do not have a lot of curvature, the eye is still aware of it because of depth perception. The curvature also makes straight lines appear curved, although this effect is small and can be eliminated entirely for the face on viewing direction. For these problems, the cylindrical screens are better than the spherical screens. A few CRT designs have flat screens, while all of the non-CRT displays are flat screened.

Monochrome CRTs can be expected to produce a crisp, smooth, and grain free image. The screen on color CRTs is made up of individual color dots or lines and will have a grainy appearance, like the non-CRT displays to be discussed below. Color CRTs are also susceptible to color registration errors that reduce resolution and produce color fringes that can be very annoying to look at.

However, in spite of all these problems, the CRT remains the leader in producing high quality display images for all criteria except size and weight. This includes: brightness, contrast, resolution, color rendition, large screen size, and low cost. CRTs account for about 85% of the video displays in use, but as alternative display technologies continue to improve they have begun taking ever larger shares of the market.

Liquid Crystal Display: LCD

An LCD is the same device that is used in most digital watches. The active element is a Twisted-Nematic liquid crystal, abbreviated TN, that can rotate the polarization of light passing through it by 90°. The display comes in many different varieties; the most popular include backlighting and contrast enhancing "Supertwist," STN, technologies.

The following discussion applies to all forms of LCDs, except the new "active matrix" displays, which are discussed separately, below: LCDs are lighter, cheaper, and consume less power than any other display technology. However, they have the lowest contrast of all display types, generally in the range of 3:1 to 20:1. They are also the slowest of the displays: an image will take a noticeable amount of time to appear and reach maximum contrast, and also will take a noticeable amount of time to disappear. This results in ghost images and blurring while a screen is scrolling.

LCDs have the poorest range of satisfactory viewing angles, typically about ±30°. It is often difficult for two people to view an LCD screen simultaneously, especially with large size high-resolution screens. The individual pixels on an LCD are generally noticeable as individual boxes that are separated by corridors running across the screen in both directions, like a double raster for CRTs. This effect may bother some people but should be less apparent on high resolution VGA LCD displays.

LCDs are susceptible to large scale shading and contrast irregularities across the screen. This can often be minimized by carefully adjusting the brightness and contrast controls. LCD screens, particularly the high resolution ones, may be electronically subdivided into as many as sixteen different geometric regions. Each of the regions will have slightly different characteristics, like brightness and contrast, which may make those subdivisions visually apparent.

Finally, LCD screens are especially susceptible to streaking: unusually bright objects will produce horizontal and vertical streaks across the entire length of the screen. After reading the above you may be surprised to learn that LCDs are the most popular and widely used display technology for portables. Why? Because each of these limitations has been painstakingly refined to produce a satisfactory display.

An LCD display without a backlight can only be used in well lit areas because it merely reflects ambient light. The display may also need to be tilted and positioned in order to properly reflect the light, so as to produce a viewable image. The contrast may be as low as 3:1. The only reason to buy a plain LCD for a portable computer is to minimize cost, battery weight, or package thickness.

Backlit LCDs are now the most common display on portable computers. The self-contained light not only makes it possible to use the display in poor lighting conditions, but it also produces improved contrast and visibility because LCDs are better at controlling light transmission than they are at reflecting it. The contrast is generally in the range from 10:1 to 20:1. The internal light generally represents the single largest drain on the battery for portable computers, between 5 and 10 watts. On many portables the intensity of the light can be controlled for both comfort and power conservation. The light itself is generally a fluorescent or electroluminescent light. The fluorescent tubes may emit a faint buzzing sound, the lighting may not be uniform and, in some cases, you may be able to make out the fluorescent tubes themselves. The fluorescent tubes come in two varieties: cold cathode and hot cathode. The cold cathode version consumes less power and lasts longer; the hot cathode version emits a much brighter light. The electroluminescent light is thinner and more uniform, but less electrically efficient.

The state of the art in LCDs is the so-called "active matrix" displays that use Thin-Film Transistors, TFT, to control each pixel individually. They seem almost too good to be true, offering a high contrast ratio, wide viewing angles of $\pm 60°$, and a response time that is more than five times faster than traditional multiplexed LCDs. The contrast is typically 40:1, with some manufacturers claiming ratios as high as 100:1. One shortcoming of the active matrix display is that the gaps between pixels are larger, making individual pixels more noticeable and resulting in a stronger raster effect as described above. The displays are not yet widely available because the costs are still very high for the screen sizes needed for portable computers.

Color LCDs are now available for expensive high performance computer workstations, and they are beginning to find their way into the PC marketplace. They are produced in both the active matrix and the traditional direct matrix addressing varieties. The active matrix displays are far better, producing colors that are reasonably vivid and saturated, but they can add several thousand dollars to the cost of the portable computer.

The current monochrome LCDs produce images with blue, green, or white tints. The color depends on the crystal, the degree of twist, the number of layers, and whether compensating filters or dyes are used. The most common now, in order of increasing attractiveness and cost, are: blue on green, blue on gray, and light gray on dark gray, commonly referred to as "paper white."

It takes some trickery to get different intensities or shades of gray from an LCD display. Many of the inexpensive units are strictly two-tone: on or off. This can produce difficulties with software that is designed for color systems, as discussed earlier in the *Color versus Monochrome* section of this chapter. The more advanced LCDs, particularly those intended for use with EGA or VGA adapters, will have up to 32 displayable gray levels. The gray levels are produced by a technique called *Pulse Width Modulation,* where a pixel is rapidly switched on and off, with the percentage of on time determining the perceived intensity. This technique may result in image flicker, or produce ripples that may be visually apparent for low intensities, for certain patterns drawn on the screen that interact with the switching frequency, or when the display is changing rapidly, as when characters are blinking on the screen.

Gas Plasma Display

Gas plasma displays are in effect a collection of addressable neon glow lamps. Their screens produce an orange-red light that many users do not find pleasing. Each of the individual pixels in a gas plasma display is noticeable as an isolated individual dot. When a dot is on, it is bright and large, but not large enough to blend completely with any adjacent dots that also might be on, so the dot structure remains noticeable. The characteristics of a pixel that is off depends on the type of plasma display. Gas plasma displays come in two grades: DC and the more expensive AC variety.

With DC gas plasma displays, when an element is off, it is not entirely off but is rather a small and dim dot that gives off some light and is still noticeable. The off elements collectively produce a uniform faint background glow that reduces contrast and readability. The orange-red background glow may bother some users. Furthermore, each of the dots is not uniformly bright but rather contains a small degree of noise flicker. The contrast, about 10:1, is reasonably good because the dots that are on will be much brighter than those that are off.

AC gas plasma displays are more expensive but have no background glow, no noticeable flicker because of a memory effect in the gas plasma, and no visible image noise. The contrast is generally 20:1 or more. The images are bright, crisp, and have good contrast.

Both AC and DC gas plasma displays have fast response times and offer broad viewing angles. Power consumption is relatively high, as much as 25 watts, making them unattractive for battery operated portables. Some newer gas plasma displays draw much less power. A few plasma displays contain a visible internal mesh that may produce disturbing Moire interference patterns (see the *Glossary).*

It also takes some coaxing to get different intensities or shades of gray from gas plasma displays. Many of the inexpensive units produce only two levels, on or off; others produce only 4 levels, off plus 3 on intensities. This can produce difficulties with software that is designed for color systems, as discussed earlier in the *Color versus Monochrome* section of this chapter. The better displays generally have 16 displayable gray levels. Gas plasma displays are currently the most popular displays on non-battery powered portable computers. Gas plasma displays that are not orange-red in color exist, but have not yet made their way into the general portable computer market. Full color gas plasma displays using phosphors have been demonstrated but are not yet in production.

Electroluminescent Display

Electroluminescent displays use an electric field to excite phosphors in a thin film glass. Electroluminescents are excellent: they are bright, crisp, have good contrast, respond quickly with no image lag or ghosting, and have a broad range of acceptable viewing angles. The contrast is in the range of 10:1 to 20:1. Unfortunately, they are expensive and are found on only a few portable computers. Power consumption is in between LCDs and Gas Plasma displays. As with LCDs, the pixels are generally noticeable as individual boxes separated by corridors running across the screen in both directions, like a double raster for CRTs. This effect may bother some people. Displays with 16 gray levels are available. Electroluminescent displays are yellow or orange-yellow. Other electroluminescent colors exist, but have not yet made their way into the general portable computer market. Full color electroluminescent displays have been demonstrated but are not yet in production.

Non-CRT Displays

The non-CRT displays have a number of properties in common that we have not previously discussed. Many of the non-CRT displays do not have the correct shape screen, referred to as the Aspect Ratio, the ratio of the screen's width to height. This ratio is designed into the display for size or cost considerations. The ratio should be 1.33, *i.e.*, the screen should be 33% wider than it is tall. Some of the non-CRT displays have aspect ratios as large as 3.0, for example, the IBM PC Convertible. When the screen has an aspect ratio greater than 1.33, images will appear expanded in the horizontal direction and contracted in the vertical direction. Text will appear squeezed vertically and will be harder to read. Graphics will appear distorted; in particular, circles will be stretched into eccentric ellipses. An aspect ratio of 1.5, not uncommon for portables, transforms a circle into an ellipse that is 13% wider than it is tall. This is quite noticeable, but tolerable for many users. An aspect ratio of 3.0 transforms a circle into an ellipse that it 2.25 times wider than it is tall. This will produce bizarre graphics.

For non-CRT displays the screen aspect ratio is fixed by design and cannot be adjusted because the pixel locations are set at the time of manufacture. However, the aspect ratio will change with the video mode in use because the modes have different resolutions. For example: the VGA uses resolutions of 480, 400, and 350 pixels. The only way to implement this on non-CRT displays is to reduce the size of the active region of the display, and this changes the shape of the image. The primary graphics mode on the VGA has 480 pixel rows, but the primary text mode has only 400 pixel rows, so 80 rows will go unused and the aspect ratio for text will be 20% greater than for graphics. The EGA compatible modes on a VGA have only 350 rows, so 130 rows will go unused and the aspect ratio will be 37% greater. Most CRT displays have an aspect ratio close to the correct 1.33 and can generally be adjusted to match this value exactly for all video modes. If you buy a non-CRT screen, make sure that the aspect ratio error, if any, will not bother you. DisplayMate contains several tests to check the aspect ratio.

Aside from the aspect ratio error, all of the non-CRT displays are completely free from geometric distortion errors that plague CRTs. This is because the location of every pixel is determined precisely at the time of manufacture. The non-CRT displays are also completely free from focusing errors that affect CRTs. Their images may still not be sharp for many other reasons, but focusing does not apply to them. The non-CRT displays also have perfectly flat screens, which helps minimize screen glare and other effects related to screen curvature; see Chapter 7.

Non-CRT displays have one more generic problem that involves video system compatibility: their internal video timings may be different from the standard video modes that were defined for CRTs. Any software that continually updates the screen, including animation software, may be affected. During such updates, sections of the screen may disappear or be filled by gibberish. DisplayMate contains several tests that display timing problems.

Types of Displays

In this section we consider the different types of video displays available, with the exception of multi-frequency displays, which are considered separately in the next section. Additional information relevant to selecting and buying displays is provided in Chapter 8 on *Selecting a Video Display System.*

Each succeeding generation of video display offers enhanced capabilities and image quality. For example: VGA displays are unquestionably better than CGA displays, but CGA displays continue to be relevant for a number of reasons: they are much less expensive, they often produce brighter screen images, have a much higher immunity to electrical interference, and they are smaller, lighter, and are frequently more rugged than VGA displays. Also, roughly 50% of all IBM compatible computers still use MDA and CGA video systems, and many portable computers and inexpensive computers continue to offer CGA and MDA video systems.

Each new generation of video system includes compatibility modes that allow it to emulate the prior systems, so that you may continue to use software written for older adapters. This is a source of confusion, particularly for displays, because many displays are advertised as being EGA, CGA, and MDA compatible, when all they are referring to are the software compatibility modes provided by the adapter connected to the display. Under these circumstances, the displays cannot actually be used with the adapters indicated. Note that unless a display is a multi-frequency display, it cannot be used with more than one video standard. Make sure the display you buy is hardware compatible with your adapter.

Digital Monochrome Display

When not used in a generic sense, this refers to a display for use with a Monochrome Display Adapter or any of the Hercules Monochrome Graphics cards. See also *Gray-Scale Display,* below. The IBM display uses a screen phosphor that emits green light; other manufacturers produce monochrome displays with amber and "paper white" screens. See the section in Chapter 7 on *Screen Color* for a discussion on the relative advantages and disadvantages of the different colors. The flicker frequency is 50 cycles per second (Hz), which is quite low and requires a long persistence phosphor to eliminate any sensation of flicker in the image. As a result, most phosphors used produce after images that can last a few seconds in dim lighting, and can make the screen unreadable if the screen content changes rapidly, such as during scrolling. In some cases the color of the phosphor may change as the image decays, an effect that may bother some people. The display uses a 9-pin D-shell connector. The IBM model number is 5151.

Digital Color Display

When not used in a generic sense, this refers to a display for use with a Color Graphics Adapter or an Enhanced Graphics Adapter in compatibility mode. The display is limited to 16 colors and a resolution of 640 horizontal by 200 vertical pixels. The flicker frequency is 60 Hz. The display uses a 9-pin D-shell connector. The IBM model number is 5153.

The primary shortcoming of the Color Display is the unusually low vertical resolution of 200 lines. On the other hand, its horizontal resolution is 640 pixels, the same as the VGA in graphics mode. As a result, graphics on the Color Display is very coarse for lines that are close to horizontal, but is as fine as the VGA for lines that are close to vertical.

Another consequence of the resolution imbalance is that the pixels are not square or round, but are rather oblong rectangles or ellipses with an axis ratio of 2.4:1. This means that horizontal lines will be 2.4 times wider than vertical lines, giving many images the appearance of having been drawn by a stylized calligraphic pen. Worst of all, displays generally cannot produce the proper 2.4:1 elongated scanning beam, making it likely that gaps will appear in between the raster lines. That will make vertical lines look like a collection of separated and disconnected vertical dots instead of a single smooth line. The effect is generally the most troubling with text characters, which are much harder to read when they appear as a collection of dots.

Gray-Scale Display

In general, a gray-scale display is a monochrome display that can produce a broad range of different intensities. The intensities are called gray levels, even though the screen may be green or amber in color. The Monochrome Display is not a gray-scale display because it can only produce 2 intensities in addition to black. In the PC world, gray-scale displays are generally connected to digital color adapters such as the CGA or EGA, and produce a different intensity or gray level for each color. They are often used in portable computers to save space, weight, and electric power consumption. For desktop computers, they have the advantage of producing sharper images and costing substantially less than color displays. The display uses a 9-pin D-shell connector. IBM has never marketed a separate gray-scale monitor.

Enhanced Color Display

This is a digital color display intended for use with the Enhanced Graphics Adapter, EGA; it can also be used with the Hercules InColor Card, and with the Color Graphics Adapter. The display is limited to 64 colors and a resolution of

640×350 pixels. The display uses a 9-pin D-shell connector. The IBM model number is 5154.

The display has two hardware modes that are selected automatically based on signals produced by the video adapter: a 200 line CGA compatibility mode and a 350 line native mode. It is important that the display have separate internal vertical size controls for each mode, so that the images are equal in size and properly fill the screen. Both modes have a flicker frequency of 60 Hz.

Analog Monochrome Display

This is a monochrome display intended to be used with a VGA or MCGA adapter. The screen will generally have a "paper white" color. The adapters convert color images to monochrome by using a *Gray-Scale Summing* method that is described in the *Glossary*. The display uses a sub-miniature 15-pin D-shell connector. The IBM model numbers are 8503 and 8507.

The display has three hardware modes that are selected automatically based on signals produced by the video adapter: 480 lines, 400 lines, and 350 lines. It is important that the display have separate internal vertical size controls for each mode, so that the images are equal in size and properly fill the screen. The flicker frequency is 70 Hz for all modes except the 640×480 high resolution graphics mode where it is 60 Hz.

Analog Color Display

This is a color display intended to be used with a VGA or MCGA adapter. The display uses a sub-miniature 15-pin D-shell connector. The IBM model numbers are: 8512, 8513, 8514, and 8515.

The display has three hardware modes that are selected automatically based on signals produced by the video adapter: 480 lines, 400 lines, and 350 lines. It is important that the display have separate internal vertical size controls for each mode, so that the images are equal in size and properly fill the screen. The flicker frequency is 70 Hz for all modes except the 640×480 high resolution graphics mode where it is 60 Hz.

Direct Drive versus Composite Displays

Almost all displays now sold for PCs are direct drive displays; this means the inputs to the display consist of separate signal lines for each of the video signals and for the horizontal and vertical synchronization signals. This provides the highest resolution and image stability possible. It requires a total of 5 signal channels or wires for color displays and 3 for monochrome. CGA displays require another signal line for an additional intensity channel; EGA displays require 3 additional signal lines for the secondary intensities for each primary color.

There are a number of situations where you may encounter video systems and video displays with alternative signal standards that combine and encode one or more of the direct drive signals into a composite signal. They include:

- encoders that combine the synchronization signals with one of the video signal channels in order to simplify the distribution of the video signals over large distances;
- video systems that allow computer graphics images to be recorded on a VCR, or that are meant for combining computer graphics with television video images. Since only the CGA is compatible with television signal standards, this generally also requires an interface device called a scan converter that translates the signals;
- the original IBM CGA produces a composite video signal that conforms closely to U.S. broadcast television standards.

The greater the number of signals that are combined into a composite signal, the more the image quality suffers. The advantage of combining the signals is that fewer signals need to be transmitted or stored.

The simplest composite signal is "composite sync," which combines and encodes the horizontal and vertical synchronization information into a single signal. Displays that include an "external sync" connector can accept composite sync. Composite sync is somewhat more susceptible to noise and jitter than direct drive sync. The use of composite sync reduces the number of signals to 4 for color and 2 for monochrome. The next level of composite signal combines the composite sync signal with the green video signal channel to produce "sync on green." This further increases the possibility of interference between the video and synchronization signals, and is more susceptible to noise and jitter than composite sync alone. The method reduces the number of signals to 3 for color and 1 for monochrome. Composite sync and sync on green are used by many monochrome displays and by some Super and Beyond VGA systems discussed earlier in this chapter.

The next degree of composite signal encodes all of the intensity and synchronization information into a single "Y" signal, and all of the color information into single color "C" signal. This results in only 2 signal lines. The most popular form of "Y/C" composite signal is known as "S-video," for Super-VHS, which provides this as a separate output signal on a 4-pin mini-DIN plug. The resolution of this method is limited, but it is significantly better than for composite video discussed below, plus it does not suffer from interference between color and intensity signals that also plagues composite video. This method represents the best compromise for combining computer graphics images from one of the standard adapters together with television video, including recording the result on a VCR. In order to maximize the image quality, be sure to have a television display that has special inputs for "Y/C" signals.

The highest degree of composite signal encodes all of the information into one signal called "composite video." This is the format used for broadcast television and is one of the standard output signals produced by the IBM CGA. While this method produces satisfactory images for television pictures, it is much less successful for reproducing precisely ruled high resolution computer graphics images. The resolution is relatively low, particularly for the color information, and there is a substantial amount of interference between the color and intensity information encoded in the signal. In most cases, disabling the color information encoded in the composite signal will substantially improve the displayed image. This is generally accomplished by turning off the Color Burst in the composite video signal.

Because of the digital methods used to generate the composite video on the CGA, the composite output with the color signal enabled is virtually useless due to cancellation effects that make the image disappear for certain combinations of colors and pixel positions. Good quality composite signal encoders can do a much better job than the CGA, although the output is none-the-less visually degraded because of the composite nature of the signal.

A composite video display will produce a higher quality image than a home television receiver because it is not constrained by the FCC channel restrictions and because the receiver circuitry degrades the video signal.

Multi-Frequency Displays

Multi-frequency displays, also referred to as multi-scanning or multi-synchronizing displays, have become one of the most widely used types of displays. In this section we will examine why this is so, consider the different kinds of multi-frequency displays, and discuss the relative advantages and disadvantages of multi-frequency displays compared with the standard fixed-scan displays.

Each of the PC video systems: MDA, CGA, EGA, and VGA has a different scanning frequency and signal standard. Most video displays will work with only one standard, so you may need a different display for each video adapter you support or plan to use. Several adapters, however, use the same standard: the monochrome Hercules cards use the same standard as the MDA, the Hercules InColor card uses the same standard as the EGA, and the MCGA uses the same standard as the VGA. The scanning standard refers to the horizontal and vertical scanning frequencies and their timings. The signal standard refers to how the color, intensity, and synchronization information are conveyed to the display. Implicitly included are the type of electrical connector, the number of wires, and to which pin each wire is connected. Table 5.2 summarizes the different signal standards for each video adapter. The first entry for the EGA is strictly for driving an MDA display; the other two are for the color modes. When you are choosing a multi-frequency display, make sure that it encompasses all of the signal standards that you need.

Note from the Table that the scanning frequencies for the Hercules HGC monochrome adapters are actually 1.6% smaller than for the IBM MDA. This difference is inconsequential for properly adjusted displays. Occasionally, you will find a fixed frequency display that will operate with an MDA but will be unable to lock onto an HGC.

Adapter	Horizontal Frequency	Vertical Frequency	Video Signals	Connector
MDA	18.4 KHz	50 Hz	2 Digital	9-pin
CGA	15.7	60	4 Digital	9-pin
HGC	18.1	49	2 Digital	9-pin
EGA	18.4	50	2 Digital	9-pin
	15.7	60	4 Digital	
	21.9	60	6 Digital	
HIC	22.0	60	6 Digital	9-pin
MCGA	31.5	70	3 Analog	15-pin
	31.5	60		
VGA	31.5	70	3 Analog	15-pin
	31.5	60		

Table 5.2 *Video Display Signal Summary.*

Advantages of Multi-Frequency Displays

Before the advent of multi-frequency displays one needed a separate display for each type of video system. Upgrading to a new video system required the purchase of a new display in addition to a new video adapter. The idea behind multi-frequency displays is to support more than one standard so that this need not happen often or possibly not even at all. One obvious flaw is that it is impossible to reliably predict the video standards of the future, so a multi-frequency display may be unsuitable for the next generation video systems. This happened with the introduction of VGA: many of the multi-frequency displays of the time could not deal with the VGA, so their owners had to buy a new display anyway. This may happen again in moving beyond VGA with some of the less versatile multi-frequency displays being unable to handle the next generation of video standards; see the sections in this chapter on *Enhanced EGA and VGA,* and *Beyond VGA.* The possibility of this occurring is reduced for the better multi-frequency displays because of the wide range of scanning and signal standards over which they operate. It is more likely that a new standard may use a different video connector, but cable adapters to convert them are inexpensive and should be easy to get when necessary.

Another important use of multi-frequency displays is that they support non-standard video modes for the standard video systems. The enhanced EGA and VGA modes that are provided by many board manufacturers fall into this category. Occasionally, some software programs will make minor adjustments in the standard video mode parameters; multi-frequency displays are more likely to tolerate such adjustments than fixed-frequency displays. Yet another important use of multi-frequency displays is that they can serve as a display for any computer that has a video system they support. This will give you the ability to swap displays among several computers without concern about compatibility issues.

Disadvantages of Multi-Frequency Displays

Multi-frequency displays have a number of obvious disadvantages:

1. For a given image quality they are more expensive than standard fixed-frequency displays because of the additional functionality and circuitry required;

2. The model you buy may not support all the video modes you need, now or in the future, requiring the purchase of an additional display later. The additional expense and inconvenience may postpone or prevent a video system upgrade;

3. A multi-frequency display may not properly handle some video modes. For example, the image may not be properly sized or centered on the screen. This is a common problem. Many displays have user controls that allow you to correct this situation manually; some will even store the control settings. Of those that do, some will restore the settings automatically, while others will require manually selecting the stored settings when the same video mode is again selected. Those with manual selection may only be able to store one or

two such settings, which may be insufficient to cover all the modes you work with. Those with automatic selection may store the settings from two or more similar video modes in the same memory location, with the consequence that you will have to manually reset the controls each time the software switches into one of these modes;

4. Multi-frequency displays cannot be fine tuned by the manufacturer to optimize the image display quality for each video mode the way fixed-scan displays can because of their much broader mission. Compromises are also required in order to support as broad a range of scan modes as possible. For example: the geometric distortion and accuracy of color registration in color displays may vary somewhat with scanning frequency. The fine tuning and optimization are generally performed at both the design stage as well as during production line adjustments of each individual unit. Good design and extra expense can generally overcome these shortcomings; however, the bottom line is how well the display passes visual tests presented by DisplayMate;
5. If you connect a multi-frequency display to an MDA or Hercules Monochrome graphics card, you will generally experience a fair amount of image flicker because the phosphor persistence has been chosen with the higher refresh rates of the other adapters in mind.

There are a number of disadvantages to multi-frequency displays that are not as obvious as those above, but that are just as important for image quality and user comfort:

6. The primary reason why multi-frequency displays do not look as good as fixed-scan displays is that they have a fixed size scanning beam that must accommodate all the resolution formats supported by the display. In most cases the spot size is set for the highest resolution mode, resulting in gaps between the raster lines that make up the image in all the lower resolution modes. This is not only ugly for graphics images but also causes readability problems for text characters, which appear as a collection of individual dots as opposed to fused pixels. This *Raster Visibility* problem causes user eye fatigue and is discussed further in Chapter 7;
7. Multi-frequency displays take considerably longer to lock-in and settle down after a video mode change than fixed-mode displays. It may take up to one full second to complete certain mode changes during which time the display image

may first appear broken up and then followed by bouncing and shrinking. During this time the display may produce screeching noises from the scanning and power supply circuits. This is not only a waste of time but can be quite irritating to both eyes and ears, especially if there are frequent mode changes.

Types of Multi-Frequency Displays

Another complication for multi-frequency displays is that there are major differences in the functional capabilities of displays that fall under this classification. Make sure that you understand what kind of multi-frequency display you are buying so that you are not disappointed later on. Running the DisplayMate test patterns in different video modes will help you understand which type you are dealing with.

Preset Frequencies: Some of the least expensive multi-frequency displays will only work at a number of preset scanning frequencies, possibly with manual selection required. Note that most of the standard IBM displays are already technically multiple fixed frequency displays: the Enhanced Color Display for the EGA must support 2 frequencies for the standard EGA video modes, so technically it is a dual frequency display. The PS/2 displays for the VGA and MCGA have 3 scanning modes, and the IBM 8514 display supports 4 scanning modes. These displays switch to one of the preset modes based on a code transmitted by the adapter. This technique allows standard preset frequency displays to lock onto a new mode much more quickly than the continuous frequency displays, below.

Continuous Frequencies: All of the better multi-frequency displays will operate over a specified range of horizontal and vertical scanning frequencies. Any video mode that falls within their range can be handled by the display. This will give you access to all of the non-standard video modes as well.

Automatic Sizing and Centering: After the display locks onto the scanning frequencies, additional adjustments are required in order to size and center the image on the screen. Although it can be quite a nuisance, you can generally do this manually using the size and centering controls, but make sure there is sufficient range in the controls to accommodate all the different video modes you plan to use. The better displays include circuits that will *try* to do this automatically for you. The automatic size and centering circuits may not work for all modes, so be sure to check for this feature carefully using DisplayMate. These circuits can only do an *approximate* job of centering and sizing the image because there is no way for them to determine the size of the border or overscan region of the image. This may require you to make some adjustments after the automatic circuits do their job, which can be quite a nuisance. Pay close attention to the vertical size, which is the most difficult of the automatic adjustments.

Preset Size and Centering: Many multi-frequency displays will have the appropriate size and centering adjustments for the standard video modes preset internally. If they were properly calibrated at the factory, then no manual adjustments will be necessary. The best multi-frequency displays will provide the best of both worlds: a continuous frequency capability together with preset size and centering for the standard video modes. Some will also make provisions for storing preset values for one or more of the non-standard video modes you may use.

Automatic Signal Determination: Each of the video adapters produces a different arrangement of signals on the video output connector. A multi-frequency display must be prepared to accept all the likely possibilities. This is often accomplished with a combination of automatic and manual switches. Many displays also require one or more connector or cable adapters to accomplish this. An adapter from 9 to 15 pins is required if both analog and digital signal video adapters are supported: MDA, CGA, EGA and all Hercules cards use the 9-pin D shell connector, whereas the VGA and MCGA use a sub-miniature 15-pin D shell connector.

The types of synchronization signals that the display accepts also vary. All of the standard IBM video systems use individual horizontal and vertical drive circuits; other adapters may produce a separate composite synchronization signal or include it as part of the green video channel. The latter is called *sync on green.* If you have a choice of synchronization, separate drive signals are the least susceptible to jitter, while composite sync on green will be the worst in this regard.

Multiple Video Display Systems

While the use of multiple display adapters for a PC is not common, there are a number of situations where they can be quite useful. For example, with computer graphics applications it is nice to have the keyboard and command activity on a separate screen, so as not to spoil the graphics image or reduce its size or resolution in a multiple window environment. Similarly, during program development it's nice to have debugging information come out on a separate display from the standard output.

By design, PCs can generally support two simultaneous displays: one from the monochrome family and one from the color family. This applies only to integral display systems that are part of the system hardware and software, not to slave auxiliary terminals connected via serial ports to the computer.

The monochrome display family descends from the original IBM MDA and the color display family descends from the original IBM CGA. Currently, both families include adapters that offer both color and monochrome text and graphics, so the family labels are purely historical. The MDA family includes the: MDA, HGC, EGA, HIC, and VGA adapters. The CGA family includes the: CGA, EGA, MCGA, VGA. Note that the EGA and VGA can exist in either color or monochrome modes. Of course, it is possible to add any number of non-standard video adapters to a PC; the only condition is that their video memory and control ports do not conflict with any of the standard IBM video adapters.

While the BIOS and DOS system software will only support one display at a time, it is relatively easy for programs to write to both displays simultaneously. When more than one display is connected, the operating system will generally initialize both adapters, (except for the original IBM PC) but will use only one of them. When the system is booted the active display is called the primary display. On the PC, AT, and EGA this is determined by user selected switch settings; otherwise it is predetermined on PS/2 hardware by the system software.

Thereafter the secondary display can be made the active display, and the primary inactive (and vice versa) via program control or by using the DOS mode command. To switch to monochrome family hardware, type:

mode mono

To switch to color family hardware, type:

mode co80

This allows sequential use of both video systems.

DisplayMate will identify dual display systems and identify which adapter is active and which adapter is inactive. In the *Technical Program* DisplayMate will automatically switch from one display to the other as needed. In the *non-Technical Program* the user must manually switch displays by using the DOS mode command, or by going into the *Technical Program* and choosing the *Select Video Test Mode* in the *Main Menu.*

Table 5.3 shows which adapter pairs can be used together. The basis for the table is rather easy to understand: you cannot install more than one adapter from each of the color and monochrome families in your computer at the same time. The EGA and VGA adapters belong to both the color and monochrome families, so if you install either of them together with another adapter they must operate in the mode opposite to the other adapter. In particular, it is not a good idea to install them together with a CGA adapter because they will then be limited to the monochrome video modes, which account for only 2 of the 9 EGA modes and 2 of the 12 VGA modes. Note that while EGA and VGA hardware will allow two EGA or VGA adapters to be installed in the same computer, there isn't any system software to support this capability. Also, PS/2 hardware and software allows two VGA or MCGA systems to be installed in the same computer and alternately activated via a procedure called *Display Switching*. This technique is used to upgrade a computer with an MCGA to VGA.

Compatibility

Introduction

The compatibility issue examines the extent to which a given video system, complete with its video adapter and display, is functionally identical with one or more of the standard IBM video systems. The video adapter should be able to run *all* of the same software as the IBM adapters and generate the same screen images. The display should provide a comparable image with the same color

	MDA	CGA	HGC	EGA	HIC	MCGA	VGA
MDA	×	•	×	•	×	•	•
CGA	•	×	•	•	•	×	•
HGC	×	•	×	•	×	•	•
EGA	•	•	•	×	•	×	×
HIC	×	•	×	•	×	•	•
MCGA	•	×	•	×	•	×	•
VGA	•	•	•	×	•	•	×

Table 5.3 *Allowed Combinations of Two Video Adapters.*

balance as the IBM displays. Not only must the video adapter be able to run all of your current software, but you also should be assured that it will properly run all the software you will buy in the future as well.

You will come to appreciate the importance of this issue the first time your computer or software program malfunctions as the result of a compatibility problem, which can range from the delicately subtle to the disastrous: unintended flicker or the temporary disruption of the display; missing or incorrect screen colors; distorted geometry or a broken-up image; shifted or missing sections of an image; patterns of garbage appearing on the screen; a locked system or a system crash; a system that will not boot; one or more adapters that malfunction; or even the permanent failure of some components in rare instances.

Compatibility is also a relevant issue for the IBM hardware because many of the IBM video systems are not fully hardware compatible with the earlier IBM adapters they supersede. This is the result of design decisions by IBM. In fact, these compatibility shortcomings have become standards in themselves and are well known and documented. As a result, some software written for the older adapters may not run properly on the newer ones. This can be an important consideration if you have older software that is essential and must continue to be used.

In order to obtain 100% downward compatibility you must purchase non-IBM video adapters that include additional compatibility hardware. However, if the video adapter is not manufactured by IBM, then it is unlikely to be fully 100% compatible with the IBM adapters it is supposed to emulate. This is hardly surprising considering that video adapters are complex pieces of hardware controlled by complex BIOS software. This means that *all* video systems, regardless of manufacturer, will have at least some minor compatibility problems lurking within. So the relevant issue is the type and degree of compatibility provided by a given video adapter. Most manufacturers claim 100% compatibility, but few will pass all the DisplayMate compatibility tests. Perfect, 100% compatibility is unnecessary for most users because most software uses a core of rather well tested features.

In any case, there is a trade-off between IBM hardware that sets the standard for compatibility, but also has built in compatibility limitations, versus clone hardware that may occasionally fall short on the IBM standard but offers compatibility features not found on IBM adapters. DisplayMate includes extensive compatibility tests, and the compatibility issue is discussed extensively throughout this manual.

Each IBM video system does include compatibility modes that emulate all prior IBM video systems, but there are well written software packages that will not run properly in these compatibility modes. Often it is older software that predates the video system in question and has unknowingly violated one of its compatibility restrictions. High performance software packages that utilize extensive direct hardware control and have been written with specific hardware in mind are also likely candidates.

Further adding to the confusion is that video displays and video adapter cards are often advertised as being EGA, CGA, and MDA compatible when all they are referring to are the software compatibility modes. The actual hardware itself will not work with real EGA, CGA, or MDA hardware, and software specifically written for those adapters may not work either. If you need true hardware and software compatibility, make sure you specify this explicitly.

Any computer that has a fully compatible video display system may develop incompatibilities as a result of software programs or hardware that are added to the system. This problem arises from conflicts between different pieces of hardware or software in the system. When this happens, the system will behave incorrectly in some manner, even though each of the component parts is individually IBM compatible. With hardware conflicts the system is unlikely to boot up at all, or one or more of its adapters may not function properly. It is then a matter of figuring out which is the offending unit by trying various combinations of hardware and software. If the problem is in hardware, it may be possible to eliminate the conflict by changing one or more adapter addresses.

The problem you are most likely to see, however, is a software conflict. These arise almost exclusively from memory resident software, often called "Terminate and Stay Resident" (TSR) programs, that remain as part of DOS after they are run and can continue to modify the computer's behavior until it is rebooted or powered down. You may not even be aware of them if they are installed from the AUTOEXEC.BAT file when the system is started. Memory resident programs include any software that can pop-up using "hot keys," and utilities like mouse drivers, screen accelerators, screen dimmers, and software that attempts to control or lock the colors or fonts on the screen. All of these, with the exception of the mouse driver, are likely to cause trouble in some situations. Running DisplayMate with and without the memory resident software will alert you to their effects on the video system. Additional information on dealing with hardware and software conflicts can be found in the *In Case of Difficulty* section of the manual.

Display Compatibility

Provided a display is at least nominally signal and scan compatible with a given video standard: MDA, CGA, EGA, VGA, *etc.*, the question of compatibility is a fairly simple issue: are images in all of the video modes appropriately sized and centered on the screen, and do the colors match those of an IBM display?

The first question can be evaluated using the *Framing and Aspect Ratio* tests in *Setup Display* selection of the *Main Menu.* Most displays will be able to handle the different modes in a satisfactory manner; however, some multi-frequency displays and flat-panel displays will not. This is discussed further in the *Multi-Frequency Displays* and *non-CRT Displays* sections earlier in this chapter.

For some applications, an accurate color match to an IBM display is important. For example, in rendering some photographic color images. Most users will generally be more concerned with getting a pleasing set of display colors. Individual tastes vary significantly in this regard: some users like vivid and saturated colors, while others prefer more subdued pastel colors. Which is just as well because there is a surprisingly wide variation in colors between different makes and models of displays.

For the analog VGA and MCGA displays, how the primary colors blend is an important aspect of color balance and color matching. Even when the primary colors match, the secondaries and other blends may not. Even if you aren't concerned about matching the IBM standard, the appearance of color blends is visually important. The color you get when you mix different intensities of the primary colors (red, green, and blue) depends on how the light output varies with the intensity signal; this is called the *Transfer Characteristic* and can vary significantly. The easiest way to see this is to examine the *Color Spectrum* test. A shallow Transfer Characteristic will result in an image that is dominated by the primary colors, with the secondaries appearing in narrow vertical strips. A steep Transfer Characteristic will result in an image that is dominated by the secondary colors, with the primaries now appearing in narrow vertical strips. Your visual preferences will determine which one you like the best. Other tests that are useful in examining color blending are the *Color Triangle* and *Color Scales* tests.

One minor but recurring issue is the question of the appearance of brown versus dim yellow in the standard set of colors. All IBM displays produce a reddish brown color where a dim banana yellow would be logically expected in the color set. The color is dark and difficult to distinguish from plain red. Some digital displays include a switch that will allow you to choose between the two colors. Most displays will produce IBM brown while a few will only produce dim yellow. On EGA, MCGA, and VGA adapters it is possible to reprogram the palette registers to produce dim yellow instead of brown. You can use the *Primary Colors* and *CGA Compatible Colors* tests in the *Setup Display* selection of the *Main Menu* to examine the quality of the colors. Note that there are a large number of tests in DisplayMate that are helpful in evaluating color.

Video Adapter Compatibility

Video adapter compatibility encompasses a broad range of issues, because adapters are not only complex pieces of hardware but they also contain a considerable amount of complicated software in their BIOS as well. For example, the BIOS for the IBM VGA is 3 times longer than the entire system BIOS for the original IBM PC.

There are several levels of compatibility for a video adapter:

System Bus Compatibility: The adapter must be compatible with the computer's system bus before it is usable. There are several buses that you are likely to encounter: the 8-bit bus for the original IBM PC and XT; the 16-bit bus for the AT, which is generally referred to as ISA, for Industry Standard Architecture; the 32-bit IBM Micro Channel Architecture bus, MCA; and the 32-bit Extended ISA, EISA. The wider the bus the faster the data transfer between the computer and the video adapter. See the *Speed Performance* section, below.

Virtually all of the video adapters that work with DisplayMate: MDA through VGA, will work in the PC, ISA, and EISA buses. Most, but not all, of the 16-bit ISA video adapters also will work in the 8-bit PC bus. Adapters that are designed for the MCA and EISA buses are almost exclusively in the high resolution, *Beyond VGA,* regime considered earlier in this chapter.

In some cases, adapters that work well in one computer system will not work properly in another. Generally this is the result of subtle signal or timing differences that can affect some combinations of hardware. IBM's own EGA adapter has timing problems that surface depending upon whether it is operating in an IBM PC or IBM AT. Other non-IBM EGA and VGA adapters are afflicted with similar problems.

Buffer Compatibility: The image buffer is another name for the video adapter memory that is used to hold the text and graphics images. All graphics software, and a good deal of text mode software, access the video buffer directly, so it is important that an adapter function properly at this level of compatibility; otherwise it will be virtually useless. You are unlikely to find a video adapter that doesn't meet this criterion.

BIOS Compatibility: The BIOS interface provides a set of software routines that are used to control the video adapter. The routines initialize the adapter and provide a standardized set of services that allow other software programs to use the video adapter easily, without becoming involved in the details of controlling the video hardware. They have been defined and standardized by IBM for its own adapters.

In order to be IBM compatible, an adapter must provide the same routines and the same functionality without actually copying the original IBM versions. This is a difficult job because there are over 60 services, and many include nuances and side effects that are not documented by IBM. Most of the current video adapters do a reasonably good job and provide a satisfactory degree of BIOS compatibility. Invariably, there are minor incompatibilities, and even bugs that creep into most BIOS. Perfect, 100% BIOS compatibility is unnecessary for most users because most software uses a core of rather well tested features. It is in the seldom used features where most of the compatibility problems lie, and you will have to decide how likely you are to enter into this regime with your software.

Register or Hardware Compatibility: This is the ultimate degree of compatibility, where the video adapter functions like a specified IBM adapter at the most fundamental hardware level. With hardware compatibility, a software program can manipulate any of the adapter's control registers and be assured that the adapter will behave properly.

Hardware compatibility was relatively easy to achieve for the MDA, CGA, and Hercules Monochrome graphics cards because they all use an off-the-shelf Motorola 6845 video controller chip. On the other hand, for an EGA or VGA clone manufacturer, hardware compatibility is a very difficult problem because the inner workings of the complicated custom computer chips that make up those adapters are undocumented and unknown to begin with. In fact, the EGA and VGA devices were initially thought to be too complicated to clone. It takes a good deal of persistent and clever reverse engineering to figure out how the chips work, and then to manufacture independent versions of them. Several companies specialize in this task, and most non-IBM video adapters use one of several available chip sets.

The EGA and VGA chip sets are now good enough that almost all video adapters have a higher degree of compatibility at the hardware and register level than at the supposedly easier BIOS level. As a result, well written software that bypasses the BIOS is likely to run properly on more computers and adapters than software that relies on the BIOS as much as possible. Programs bypass the BIOS in order to achieve substantial improvements in performance and also because the BIOS does not provide all the services needed to draw images on the display. Surprisingly, IBM documentation characterizes software that bypasses the BIOS as "ill-behaved," which is absurd, since virtually all software, including their own, falls under this category.

Since IBM sets the standard, IBM video adapters are by definition compatible, flaws and all. All of the IBM video systems contain bugs in the video BIOS software. Should compatible clones reproduce these errors? The answer is most likely yes, because in some cases the software you run may expect these bugs to be present and will execute work-arounds that may fail if the error is not there. In other cases it is best not to have the bugs around. Some non-IBM adapters reproduce the bugs for compatibility reasons, others do not; it is not always clear which is the best approach.

A related problem is that there are actually three IBM VGAs: the one on Micro Channel PS/2s, the one in the PS/2 models 25 and 30, and the PS/2 VGA Display Adapter - and they are noticeably different from one another at both the hardware and BIOS levels. They are sufficiently different, in fact, that some software will run properly on one but not the other. Some adapters are compatible with the Micro Channel version and some are compatible with the VGA Display Adapter.

DisplayMate contains a rather extensive set of compatibility tests that will test each type of compatibility. Bear in mind, however, that it is impossible to determine completely whether any video card is fully compatible. All of the video cards are complex and highly programmable pieces of hardware for which there are too many possible combinations of parameters to test exhaustively. This is especially true for the EGA and VGA adapters.

Additional problems arise with animation and other programs that rapidly update one or more hardware parameters, or that frequently manipulate many parameters at once. They may produce unusual timings, coincidences, or expose limitations that may not be apparent otherwise. If you are using software of this kind, it is essential that you carefully test it on the precise hardware configuration you will be using.

And finally, if your software is adjusting or even inventing its own video modes in order to get some additional resolution or colors, or other special features, you are especially susceptible to unknown compatibility problems because you are treading in uncharted waters. Many IBM video clone cards include a number of these special modes. Be aware that these modes are likely to be available only on that brand, possibly only that specific model of video card.

Speed Performance

The speed of your video display system is one of the most important aspects of a computer's overall performance - second only to raw microprocessor speed.

A slow video system not only reduces your productivity but can also try your patience. A fast and snappy video system is fun to work with. A difference of only a few tenths of a second may seem superfluous, but it can make all the difference in a user's perception of speed for a repetitive task like updating the display screen.

Surprising to some is the fact that the video adapter is often more important than the microprocessor when it comes to video system speed, *i.e.*, switching display adapters on a given computer can have a greater effect on video speed than changing computers with the same display adapter. The video display itself has no effect on the objective video system speed, although it can adversely affect human performance if, as on IBM's Monochrome Display, an unusually long persistence phosphor leaves trails of old information around for so long that it interferes with the new information.

Video adapter manufacturers emphasize the speed performance of their cards, much like automobile manufacturers do. Some of these claims are either unrealistic exaggerations or are dreamed up in their advertising departments. The relevant factors influencing overall display speed performance are, in approximate order of importance: Adapter Architecture, Display Memory Access Speed, Display Memory Contention, BIOS Programming, and Screen Resolution.

Adapter Architecture: The internal architecture or organization of a video adapter determines how fast the hardware can operate. The IBM EGA and VGA adapters are considerably more complicated than the other adapters and, as a result, their overall speed performance on an IBM AT computer is roughly half that of an IBM CGA adapter for the same video mode. There is also more programming overhead involved in drawing images in the high resolution graphics modes, which in most cases reduces performance by an additional factor of 2. These performance differences are not as great on an IBM PC as on an IBM AT, because of its slower processor and system bus. When upgrading to an EGA or VGA on a given computer, expect the overall graphics performance to decrease significantly.

Display Memory Access Speed: The amount of time that it takes for the microprocessor to access the video adapter's memory is an important factor in how quickly an image can be drawn. That time depends on several factors:

1. The speed of your computer's data bus, which typically varies between 4.77 and 8.0 MHz, where MHz stands for Mega-Hertz, or millions of cycles per second. Some computers run their buses faster than 8 MHz, but this is unreliable because many adapter cards may not operate properly at those speeds. Most video adapters are connected to the microprocessor via the system data bus. When a video adapter is built into the computer's main circuit board it may communicate over a private data path with the microprocessor, and the above constraints do not apply.

2. The width of the computer's data bus can vary from 8 to 32-bits. Clearly, the wider the data path the greater the amount of information that can be transferred in a given amount of time. On PC class machines the bus width is 8-bits wide, on the AT and most other 80286 and 80386 computers the bus can be either 8 or 16-bits wide, and on some 80386 and 80486 machines the bus is 32-bits wide.

   Most display adapters come in 8 or 16-bit bus widths. Some can be strapped for either width, and some are even self-configuring and will automatically adjust to the width of your system. The performance improvement you are likely to see from a 16-bit adapter on a 16-bit data bus, compared to an 8-bit configuration, is generally small, not the factor of two or more that is often claimed by manufacturers. The principal reason is that the internal architecture of EGA and VGA cards is byte oriented, so that many operations can only be performed 8-bits at a time. Also, a lot of software does not take advantage of the available 16-bit operations.

3. On the EGA and VGA adapters, memory organization is more complicated and involves more layers of control in obtaining access than in other adapters. As a result, memory access speed can vary with video mode on these adapters.

Display Memory Contention: Both the microprocessor and the display adapter must access the special memory onboard the adapter that holds the display image. In general, they cannot do so at the same time. On the CGA, simultaneous access in text mode results in semi-random interference lines called "snow," while on the IBM EGA and VGA simultaneous access is prevented by arbitration hardware, so the microprocessor is forced to wait its turn. As the screen resolution increases, the adapter requires an increasing fraction of all the video memory cycles because more accesses are needed to generate each line of video on the screen. This, of course, reduces and slows down the microprocessor's access.

Another source of memory contention is the refresh cycle for the dynamic memory DRAMs used on most adapters. On the IBM VGA, 3 refresh cycles are required for each raster line as the image is being sent to the display. The overall impact of these effects is substantial: for example, on the IBM EGA the microprocessor may only be able to access display memory 20% of the time, in principle slowing down graphics by up to a factor of 5.

A few adapters have expensive dual-ported memory that actually allows simultaneous microprocessor and adapter access. Significant improvements in speed are possible with this access method, particularly at high resolutions, but there are other less expensive methods that are used by some manufacturers to reduce memory contention. The IBM MDA and MCGA have static dual-ported memory; some non-IBM EGA and VGA adapters also have dual-ported memory.

BIOS Programming: All EGA and VGA adapters contain specialized onboard software in ROM that is used to control the display hardware. The quality of this software affects performance significantly. The IBM BIOS is generally slow but very reliable, and is also the standard. A number of clone manufacturers have written BIOS software that is considerably faster than IBMs, but may not always be as reliable and bug free. You can compare the speeds for the "BIOS" functions to the DisplayMate "Direct" functions that are very efficient and fast by looking in the *Performance Test Tabulations* for the *Speed*

Performance Tests in the *Technical Program.* In some cases, the differences are greater than 10 to 1.

Screen Resolution: The higher the screen resolution, the greater the number of pixels, and therefore the more time and work that it takes the system microprocessor to draw an image. The relationship between resolution and speed is not as simple as it might first appear. If, for example, the horizontal and vertical resolutions were to both double, you might think that it would take twice as long to draw a line and 4 times as long to fill an area on the screen. Everything else being equal, you will generally see a substantially smaller increase with resolution because a good deal of the time that is spent for most screen drawing operations is taken up by setup operations that don't depend on resolution.

If, for example, only short lines are being drawn, then you will not see any decrease in speed with resolution. A similar situation applies for the text drawing as well. Area fills generally utilize a very efficient set of microprocessor instructions that significantly reduce the execution time that depends on resolution, so the effect here is also smaller than expected.

In general, a major factor relating speed to resolution is how well the setup components of the software drivers are written. It is not unusual to see variations as large as 5 to 1. Poorly written drivers will then show the *smallest* speed dependence with resolution. For them, the overriding performance factor will be the raw CPU speed needed to overcome their inefficiency.

Software to Enhance and Degrade Video Performance

Memory Resident Programs: Some users unknowingly degrade their video system performance with memory resident programs they install. These programs are sometimes called Terminate and Stay Resident, TSR, software and may be invoked with a special key combination, often called a hot key. Many memory resident routines intercept and examine video system commands in a process called interrupt chaining, to perform some aspect of their function. Examples of such routines include: mouse driver software, screen dimmers that shutdown an inactive display, and some security software. For example, on an IBM AT, a mouse driver adds 40 micro-seconds per video call. For writing text on an EGA, this reduces performance by 15 percent. By selectively deactivating memory resident software you can use DisplayMate to measure the performance degradation involved with each program.

Direct Screen Access: On most video adapters, software that writes directly to the video adapter memory may be more than 25 times faster in text mode than software that uses system BIOS software. Note that your entire program won't run 25 times faster, only the part that updates the screen. Software that has this capability may run significantly faster. On the IBM CGA and compatibles, an unfortunate side effect is the appearance of interference on the display, called "snow," that can be quite annoying.

If you have a CGA you can see this effect by running DisplayMate first with the "f" for fast option, *e.g.*, "dmu f" and again with the "n" flag, *e.g.*, "dmu n". DisplayMate automatically selects the fastest mode that doesn't produce interference.

Screen Accelerators: As discussed above, the BIOS software in ROM, used to control the video display hardware, is often not optimized for speed. For example, on the IBM PC and AT, the video commands that are used by DOS and many programs for writing text on the screen are quite slow. Alternative software is available that replaces these routines with ones that are optimized. Generally, they speed up several BIOS functions in text modes but do not affect graphics modes. An unfortunate side effect is that they slow down all the other functions that they don't optimize since they are memory resident software, as discussed above.

Not all software claiming to improve performance actually does so. Use DisplayMate to verify claimed performance improvements. More importantly, there is a danger of replacing specialized software written by the hardware designers with generic software by third party vendors. That could affect the compatibility of your computer with standard IBM software in one or more of the video modes or functions. Some packages may even crash your computer. Use DisplayMate to check memory resident software for compatibility.

RAM BIOS: On some computers, particularly 16-bit machines like 8086 PCs and 80286 ATs, copying the video BIOS from ROM memory into RAM memory may noticeably speed up programs that make extensive use of the BIOS. This is because RAM on these machines is generally faster than ROM, plus the data path is likely to be 16-bits wide instead of only 8-bits. This will require a special software driver supplied by the video adapter's manufacturer. Such drivers are available only for clone video adapters, as IBM does not provide one for its adapters. The driver will require somewhere between 16 and 32 KBytes of system memory. Use DisplayMate to decide if the speedup is worth the loss of memory. On 80386 and 80486 computers you should instead use the Shadow RAM facility provided by the system hardware and software, unless your adapter is set to allow automatic mode switching. See Chapter 8 for additional information.

Chapter 6

VDTs: Are They Safe?

Introduction

The answer to the question of whether VDTs are safe or not unfortunately still depends upon precisely which question you ask and to whom. The most publicized and emotional battle on VDT safety centers on the emission of electric and magnetic fields and electromagnetic radiation from the Cathode Ray Tube (CRT), which is the picture tube found in most VDTs. The other display technologies also produce the same emissions, but at lower or much lower intensities. This will be the topic considered in this chapter along with other issues that can have an adverse effect on VDT users, and that are *not* related to the quality of the display image nor depend on how the VDT is used in the work place. These latter equally important issues fall under the province of ergonomics, and will be the subject of the next chapter. From the ergonomic point of view, VDTs are safe, provided one pays careful attention to the quality of the display and to user work habits and comfort.

Ever since VDTs came into common use 25 years ago there has been a lingering concern that they may be hazardous to the user's health. There is still considerable uncertainty as to the validity and interpretation of the many studies and experiments involving fields and radiation. Part of the problem is that the VDT issue has evolved from what should be primarily an objective scientific debate into a very politicized fight with occasional bouts of name calling, mud flinging, and demagoguery. Some of the participants ignore or ridicule any evidence that seems to contradict their position, and present as an incontestable fact any evidence that supports it. Depending upon whom you listen to, you may come away with a feeling that VDTs have been proven either perfectly safe or deadly. The discussion is also tainted by the perceived self interest of certain parties: equipment manufacturers that may be worried about additional product development costs, product liability costs, and class action law suits. Employers may be worried about purchasing additional equipment and about potential employee law suits. On the other side are those who profit from the VDT scare, including writers and consultants who specialize in these problems and companies that manufacture protection devices or alternatives to CRTs.

Another problem is that it is extremely difficult to collect and analyze large uniform samples of data about human beings. Not only do people suffer from selective memory recall, which strongly biases many studies, but the studies can be affected by the prejudices and preconceived notions of the VDT users that are being studied. There is a *VDT effect* that is quite similar to the *UFO effect:* with VDTs on peoples minds, any unusual phenomenon in the work place is liable to be attributed to VDTs, which is reported and then further reinforces the effect.

Perhaps the most confusing aspect of the VDT safety question is the large number of conflicting and contradictory results that have been reported by the different studies. This is often the case in science when a new issue is being investigated. However, the studies are not all equally sound and equally valid, so even in the interim it is possible to weigh the confidence levels of various conclusions. Eventually, the scientific process converges on a single answer through corroboration and refinement. With widespread public interest, this debate has been reported in the national press. Unfortunately, the broad range of interim results can be exploited by parties that are trying to convince the public of their own point of view. Quotations from favorite studies are regularly used by both sides in order to document their respective positions.

With studies regularly coming out on opposite sides of the VDT safety question, an important conclusion is that, whatever the outcome, VDTs cannot not be terribly unsafe, otherwise a trend in the results would have appeared sooner, if not immediately. With over 40 million VDT users in the United States alone, any major safety problem should become readily apparent. On the other hand, many problems are not recognized as soon as they could have been detected, and there may be problems with long latency periods that may take years to develop. That issue, however, is true for just about everything, not just VDTs. The results could still turn out to be large enough to be classified as a public health concern.

Over the last ten years the following organizations have supported the position that VDTs are safe: the American Medical Association (AMA), the American College of Obstetricians and Gynecologists (ACOG), the American Academy of Ophthalmology (AAOP), the National Institute for Occupational Safety and Health (NIOSH), the National Academy of Sciences (NAS) and the National Academy of Engineering (NAE), the Institute of Electrical and Electronics Engineers (IEEE), the Centers for Disease Control (CDC), the Occupational Safety and Health Administration (OSHA), the Food and Drug Administration's Bureau of Radiological Health, and the World Health Organization (WHO). Of course, their conclusions were based on information available at the time, and none of these organizations are infallible or can predict the future. Some people will find these conclusions very reassuring, while others will find them to be yet another example of institutional rubber stamping.

The following sections will hopefully give you a better understanding of VDT safety. The next two sections discuss risk and explain the meaning of the field and radiation terms. The sections thereafter include discussions on:

- Radiation
- Vision Problems
- Electric Fields
- Magnetic Fields
- Pregnancy Hazards
- Dealing with Pregnancy Hazards
- Measuring the Field Strengths

If you wish to learn more about this area, see the chapter on *Sources of Additional Information* near the end of this manual.

You Can't be Too Safe?

There are many value judgments involved with the VDT safety issue, but the first and possibly most important one is the level of proof or degree of confidence necessary before raising a general public alarm. Almost everyone would agree that waiting for definitive proof or an understanding of the cause and mechanism involved in a safety issue is too strong a requirement to ensure public safety. Others argue that you can't be too safe, so it is important to spread the alarm when there is any suggestion of a problem, even if in the end it turns out to be wrong. The problem is that announcements of this sort produce adverse effects of their own.

In the case of VDTs, raising the public alarm causes worry and stress in VDT users. This by itself produces demonstrable effects. There is no question that some of the problems that VDT users suffer from arise from stress that results from worrying about using VDTs. Other VDT users may quit, switch, or lose their jobs as a result of the alarm over VDTs. This will, in many cases, result in a loss of income, and lost opportunities, such as education for oneself or one's children, which has its own attendant adverse long-term aftereffects. Indirect results such as depression, divorce, and suicide are also known to accompany these problems.

These alarms also cause some users to switch away from CRTs to other types of VDTs, but these also have their own shortcomings and adverse effects. In particular, CRTs generally produce the highest quality display images, so additional vision problems may arise as a result of a switch to non-CRT displays. These alarms also may cause users and companies to buy new computer hardware that they otherwise would not. Non-CRTs or "safe" CRTs are generally much more expensive than standard CRTs. In many companies these expenses will adversely affect VDT user salaries and hiring. If the CRT problems prove unfounded, then these resources could have been better spent on other things.

As a result, the degree of alarm needs to be weighed in terms of the effects it may produce and in terms of the general best interests of the average VDT user. But every user is different, and everyone, whether they realize it consciously or not, has their own level of tolerable risk. Nothing is perfectly safe. In fact, at some time just about everything has been reported to be dangerous at some level, so acting on every negative safety report may lead to complete paralysis. There is no intention here to try to diminish the possible dangers of VDTs, only to put them into a general context and to reduce the knee-jerk emotional reactions that some people may have. It is important to realize that you can harm VDT users from magnifying and dwelling on the dangers of VDTs, as well as in overlooking or diminishing their dangers. Finding the point at which these two matters balance is really the biggest problem.

Differentiating Radiation and Fields

Before beginning our discussion we need to explain the meanings of the field and radiation terms that appear in all of the discussions, especially since there is a lot of confusion about differentiating the various terms. There are three separate fields that we must consider:

- the electric field
- the magnetic field
- the electromagnetic field

The term *radiation* is only associated with the electromagnetic field, which is made up of a special combination of electric and magnetic fields that alternately sustain one another as they radiate and propagate through space at the speed of light. We will discuss this radiation in the next section.

The electric and magnetic fields given off by VDTs are *not* radiation fields but rather *induction* fields, because their primary effect is to induce electric charges, currents, and forces in all forms of matter, including human. These electric and magnetic induction fields are often *incorrectly* described as an electromagnetic field or as radiation.

The physical nature and behavior of all of these fields have been precisely understood for over 100 years. What is not well understood is how they affect human beings. The instruments that are used to measure the fields are incredibly sensitive and accurate. We will discuss each of these fields in turn; however, be forewarned that it is the magnetic field that is currently thought to have the greatest likelihood of producing a problem.

Radiation

The thought of radiation brings fear into the minds of most people. While some forms of radiation are dangerous, many others are not. Radiation is short for ElectroMagnetic Radiation, or EMR, and it encompasses an incredibly broad range of phenomena: radio waves, microwaves, infrared, visible light, ultraviolet light, and X-rays. VDTs emit measurable amounts of all of these forms of radiation. The human body itself gives off large amounts of infrared radiation. It is the most common form of heat radiation, and VDTs emit a good deal of it themselves. Of course, the heat can lead to burns and fire, but it is completely harmless at the low levels given off by VDTs. As we shall see, this same conclusion appears to be the case for all of the other forms of radiation as well. We will discuss each in turn in this section, and in the following section on *Vision Problems.*

X-rays are the strongest form of radiation that VDTs can give off, and for a while it was the greatest source of concern. Fortunately, there is now universal agreement that the level of X-rays given off by VDTs is substantially lower than what is naturally present in the environment and, therefore, does not pose any risk or cause for concern to VDT users. At one time there were recommendations that pregnant women wear lead aprons in order to protect their babies from this radiation. Not only is this completely unnecessary, but it is an example of a proposed safety measure that is more dangerous than the problem it was designed to overcome: the weight and confining nature of these aprons can be a pregnancy hazard by itself.

Radio waves that escape the VDT can cause interference to radio and television reception. As a result, all such equipment offered for sale in the United States must be shielded to meet electromagnetic radiation limits set by the Federal Communications Commission (FCC). Radio waves and all other forms of EMR can be effectively blocked by a layer of electrically conductive material. It is relatively easy for VDT manufacturers to accomplish this by applying a conductive layer on the inside of the cabinet. Some of the radio waves can leak out through the VDT screen, but they do not appear to pose a health problem to the VDT user, because the levels are low and comparable to the broadcast radio and television signals that permeate our planet.

If you don't find this statement convincing or reassuring, you can add a relatively inexpensive conductive shield in front of the VDT screen that will effectively block radio waves and other forms of radiation. The conductive layer is incorporated in some antiglare shields. See the section on *Radiation Shields* in Chapter 7 for additional information.

Vision Problems

A large fraction of all VDT users report a certain degree of temporary eye discomfort: generally fatigue, irritation, blurred vision, difficulty in focusing, plus related problems with headaches and dizziness. All of these effects appear to arise in ergonomic problems to be discussed in the next chapter.

There has also been major concern that VDTs might damage eyesight and cause permanent vision problems. This would result from the intense visual nature of VDT work, or from radiation damage. The general consensus to date is that there is no evidence that VDTs cause permanent eye damage.

It appears that the vision problems experienced by VDT users are no different from those that arise with any kind of visual near work. In many cases the problems attributed to near work are the result of the large number of users whose vision is not properly corrected to begin with. VDT users actually have a minor advantage because the typical distance for VDT work is in the range of 20 to 26 inches, about 8 inches further than the distances used in reading paper documents.

Fear spread through the computer user community in 1977 when two young *New York Times* employees developed cataracts a year after shifting to work on VDTs. Cataracts are a standard way of detecting radiation exposure for workers in nuclear reactors and similar occupations. They also occur naturally as the result of aging. The radiation produced by VDTs that could cause cataracts include: microwave, infrared, ultraviolet, and X-ray. However, the levels produced by VDTs are thousands to millions of times smaller than the levels required to produce cataracts. In particular, VDTs produce microwaves at a level that is almost undetectable, and produce substantially less ultraviolet than indoor fluorescent lights or outdoor sunlight. Infrared and X-rays were discussed in the previous section. Numerous studies have found no excess in the number of cataracts in VDT users. The conclusion is that VDTs do not produce cataracts in users, so the cause of the problem at the *New York Times* is not known. Of course, some VDT users will develop cataracts as the result of the natural aging process.

If you don't find these statements convincing or reassuring, we note that new cases of cataracts have not been reported at the rate that would be expected were VDTs a cause. With over 40 million VDT users in the United States, such an effect would be easy to spot. Epidemiological studies that look for statistical trends in populations also find no evidence that VDTs cause cataracts.

Electric Fields

Most of us have experience with electric fields as a result of walking across carpets, taking off sweaters, and even combing our hair in dry environments. In fact, electric fields are naturally present almost everywhere on the planet and our bodies normally carry a charge that produces an electric field. VDT screens produce static electric fields, and also alternating electric fields that reverse their polarity many times a second. In most cases you will be able to feel the static electric field if you place your hand very close to the screen. In some cases, you may get a mild shock similar to the kind you can get after walking across a carpet.

The worst effect that has been directly attributed to VDT electric fields is a facial rash, but the actual cause is unknown. The number of reported cases is relatively small and appear to arise only in low humidity environments. The problem seems to go away when the humidity level is brought up to a normal level. Other studies indicate that VDTs are not the source of the dermatitis because the condition arises whether a VDT is turned on or off. As a result, electric fields do not appear to be a health concern for VDT users.

If you don't find this statement convincing or reassuring, it is relatively easy to block the electric field using the same type of conductive layer that stops electromagnetic radiation. You can add a relatively inexpensive conductive shield in front of the VDT screen that will effectively block the VDT electric fields. The attenuation may be more than a factor of 100:1 for the static, ELF, and VLF frequencies (see the discussion under *Magnetic Fields,* below). The conductive layer is incorporated in some antiglare shields. See the section on *Radiation Shields* in Chapter 7 for additional information.

Magnetic Fields

Magnetic fields are produced by electric currents and, as a result, all electrical appliances, including VDTs, produce magnetic fields. Even though hair dryers and toasters may produce stronger magnetic fields than VDTs, they are used in close proximity for only a few minutes a day, whereas VDTs are often used for as many as 8 hours a day.

Over the last 10 years there has been an increasing concern that magnetic fields could pose a health hazard. This VDT issue has come together with related fears about electric power lines. Below, we briefly describe some of the evidence. Bear in mind that in most cases only a small fraction of the studies demonstrate the harmful effects being discussed.

- Some laboratory studies have shown that low-frequency electric and magnetic fields can affect living cells, particularly cell membranes. However, other phenomena such as light, heat, and mechanical force or pressure also affect cells without overall detrimental effects to the entire organism. Whole animal experiments have also been performed, primarily with mice and rats. Some of these experiments detected chemical and behavioral differences between exposed and unexposed animals. These results are interesting, surprising, and of some concern, but they do not tell us about the human health issue we are interested in.
- Some studies of electrical power workers have found higher incidences of leukemia and brain tumors. If the effect is real, it is not necessarily the result of the various fields, but could be due to other job related factors. Since none of the fields are known to cause any DNA or chromosomal damage, it is not believed that they can initiate cancer. So if this effect is real, then the fields may activate some other carcinogen. It is not clear whether these results are relevant to risks associated with VDT usage.
- Some of the most controversial studies have analyzed death certificates in relation to the power distribution lines and found that deaths from leukemia and cancer were higher for homes near high current power lines. Of the six

studies on childhood cancers: one found a doubling of the rate, another found a 50% increase, two found weak associations, and two found no effect at all. Note that doubling the cancer rate for children involves one additional cancer per 10,000 children per year, which can be considered as a large or small effect depending upon your point of view. For the adult cancers: two studies found no effect, and a third found an association. Both the data and analysis for all of these studies have been heavily contested.

These studies, along with those in the following section on *Pregnancy Hazards* indicate that there is some possibility that magnetic fields from a VDT could be a health problem. Again, bear in mind that in most cases only a small fraction of the studies demonstrate the harmful effects being discussed.

Unlike the other fields we have discussed, there is no easy way to shield or block the magnetic fields emanating from CRTs. CRTs produce two different types of fields that are described by the rate at which they switch polarity: Very Low Frequency (VLF) fields are produced by the horizontal deflection coils and flyback transformer in a CRT and are in the range of 15,000 to 32,000 cycles per second; Extremely Low Frequency (ELF) fields are produced by the vertical deflection coils and are in the range of 50 to 70 cycles per second.

The strength of the magnetic field decreases rapidly with distance from the VDT cabinet, in many cases by a factor of 10 in going from 12" to 36". The strongest emissions are generally from the sides and top of the VDT; the weakest, fortunately, is towards the front of the VDT. Most of the directional nature of the fields is a result of the location and symmetry of the deflection coils and is not a design parameter for the manufacturer.

It is possible to obtain a limited degree of shielding in two different ways:

- Using a conductive layer, similar to what will block the electromagnetic and electric fields, but substantially thicker. The lower the frequency, the thicker the conductor must be. A practical limit on the thickness restricts the shielding to the VLF fields, so the ELF fields, which are thought to have a greater potential for harm, leak through.
- Using a high permeability magnetic shielding alloy.

Neither type of shielding can be made transparent, so they cannot shield the direction of the screen, only the sides of the cabinet. This may help coworkers that are closer than 36" to your VDT. Don't forget someone in the next office, because walls and partitions are generally transparent as far as the magnetic fields are concerned. By the way, there are screen shields that are made of a fine mesh of conductive wires, which will provide a minor degree of VLF magnetic shielding for the user.

One way to reduce the magnetic fields coming through the screen is to move the internal shielding as close as possible to the deflection coils. This should only be done by the VDT manufacturer because it will cause field and circuit loading, and increase screen distortion. Another technique is to introduce additional coils that help cancel the fields in the direction of the user. A better approach adopted by some manufacturers, is to redesign the deflection coils to produce fields that have a weaker fringing component, so that leakage towards the user is significantly reduced. The technical difficulties involved with any of these methods is one of several reasons why manufacturers have been slow to introduce VDTs with reduced magnetic emissions.

Many CRT displays that are advertised as having low emissions generally provide little if any reduction in the ELF magnetic fields. Add-on external screen shields generally have no effect as well. See the section on *Electric, Magnetic, and Radiation Shields* in Chapter 7 for additional information.

Pregnancy Hazards

The biggest question mark on VDT safety has been whether VDTs can cause problems during pregnancy, either in the form of miscarriages or birth defects. There have been quite a large number of studies that have attempted to clarify this issue.

Laboratory studies have examined the effects of magnetic fields on chicken, mice, and rat embryos. Most of the studies have concluded that there are no visible defects or malformations as a result of exposure to the fields. An example of the difficulty of interpreting the results is the 1987 Henhouse Project, where 6 laboratories, located all over the world, conducted a series of embryo experiments using identical equipment and essentially identical methods. Two of the 6 laboratories had statistically significant increased incidences of abnormal embryos, while the other 4 did not. Again, it is difficult to say whether VDT users should be concerned with these results.

The issue of pregnancy hazards for VDT users first reached national attention in 1979 as the result of a cluster of problem pregnancies for VDT users working in the *Toronto Star* newspaper. Since then, a total of 12 clusters have been widely reported and investigated in workplaces in the United States, Canada, and Europe. In each case, more than 50% of the pregnancies in a particular office, during a specified time period, ended in a miscarriage, birth defect, still birth, premature delivery, or infant illness.

Normally, about 15% of all recognized pregnancies end in miscarriage, and 2% of all births include a birth defect. These are averages; ordinary statistical fluctuations will result in some groups with a higher than average value, and some with a lower value. Estimates of the number of clusters that should occur as the result of chance alone are at least 15 per year. Also, most studies of the clusters found no association between VDTs and miscarriage. The National Institute for Occupational Safety and Health (NIOSH) investigated 3 of the clusters and found a statistically significant association between miscarriages and VDT use in one of the locations. Since the clusters are all self-reported by the VDT users themselves, they have a built-in sampling bias, and are therefore not part of a uniform sample from which one can draw conclusions. The clusters pointed out the need for systematic studies to investigate pregnancy hazards.

The most interesting and relevant studies on pregnancy hazards are the epidemiological studies that statistically analyze populations of human pregnancies to determine whether VDT users actually experience a greater number of problems than non-VDT users. These studies measure the effects of all the hazards caused by VDTs, including all the ELF and VLF fields. The problem with this approach is that it is difficult to get a large sample of pregnancies that is free from bias.

Most of the epidemiological studies have found no difference in the rate of miscarriages and birth defects between VDT and non-VDT users. However, one important study has found a significant difference: the Kaiser-Permanente study found a large increase in the rate of miscarriages for clerical workers that used VDTs. In this group, there were 60% more miscarriages than expected for clerical workers that used VDTs less than 20 hours per week. When the usage was greater than 20 hours per week, there were 2.4 times as many miscarriages as expected. Surprisingly, no increase was found in the miscarriage rate for professional workers using VDTs, in either the less than 20 hours per week category, or in the greater than 20 hours per week category. In fact, there was actually a significant decrease in the under 20 hours category, which is not understood, and may be an indication of a flaw in the study or in the data analysis.

The Kaiser-Permanente study was a careful study of a large sample of pregnant women. However, there are many biases that could have affected the results. For example, the authors note that women who had adverse pregnancy outcomes may have overreported their exposure to VDTs and/or women with normal births may have underreported theirs. None-the-less, taken at face value, the study indicates that VDT fields or radiation are not the cause of the miscarriage problem because professional VDT users were not affected. Clerical workers generally work under tightly managed production schedules, whereas professional workers do not have as intense a VDT work regimen. These results imply that the miscarriage rate experienced by the clerical VDT workers is the result of ergonomic factors such as stress or working conditions.

The most recent and important study on pregnancy hazards is the U.S. government's National Institute for Occupational Safety and Health (NIOSH) epidemiological study. The NIOSH investigation found that pregnant women who work all day at video display terminals do *not* experience greater rates of miscarriages or stillbirths than women in similar jobs without VDTs. The study also examined the rate of miscarriages during the course of a pregnancy, particularly the early stages, and found no difference. Field measurements of the VDTs together with company time records were used in order to evaluate exposure levels. It is the most thorough and carefully designed study to date and provides the strongest evidence that VDTs are safe.

While most of the epidemiological studies have found no difference in the rate of miscarriages and birth defects between VDT and non-VDT users, there is still no general consensus among epidemiologists, so definitive conclusions are not yet possible.

Dealing with Pregnancy Hazards

Since the question of VDT safety during pregnancy has not been definitively answered, some women may wish to consider altering their work routines. There are several approaches to dealing with VDTs during pregnancy: one is for a woman to transfer or switch to a job that doesn't require the use of VDTs during her pregnancy. There are many pregnant women that cannot or do not want to do this, and such a change could result in stress, which is itself a hazard. Another alternative is prudent avoidance, which can take many forms:

1. Reduce the total amount of time spent working on a VDT.
2. While working on a VDT, regularly switch to other non-VDT tasks.
3. Take additional and frequent short breaks away from your VDT. For example: every 15 minutes get up and take a brief 3 minute walk.
4. Select a good chair and carefully adjust it for maximum comfort. Shift your sitting position often.
5. Follow the ergonomic recommendations in Chapter 7 on setting up your work area and your video display to maximize user comfort and productivity.
6. If you are worried about VDT radiation and fields, then move your VDT further back on your desk to minimize whatever fields may be present. If you are using a color CRT display, consider switching to a monochrome display, which generally produces a weaker field. Avoid sitting immediately next to, or behind, the VDTs of adjacent coworkers. Bear in mind that walls and partitions are generally transparent as far as magnetic fields are concerned. Consider installing additional shielding on your display as described in Chapter 7, or consider switching to a non-CRT flat panel display.

Measuring the Field Strengths

The results of "radiation" measurements are appearing with increasing regularity in newspapers and computer magazines. It is important for VDT buyers and VDT users that are concerned about the field emissions to be able to make comparisons between different models. However, the measurements, as well as their interpretation, are rather tricky, yet they are often treated with the simplicity of reading a voltmeter. It is almost never clear exactly what is being measured in these articles. There is a danger of being needlessly alarmed, as well as being handed a false sense of security from the measurements. The following items must be taken into account in making field measurements:

- There are three different kinds of fields that must be measured separately: electric, magnetic, and electromagnetic.
- There is a frequency spectrum of emissions. It is important to specify both the band and the bandwidth of the measurement. Depending on the sensor, a bandwidth correction may have to be made because of the harmonic content of the signals.
- It is important to know the kind of sensor used. Some sensors will respond to the field, while others will respond to the rate of change of the field.
- The frequency response of some sensors is flat, for others it is linear, and for still others it is nonlinear.
- Because the signals have complex waveforms, it is important to know whether the measurements correspond to peak, mean, or root-mean-square values. The values reported will vary by 3:1 between the methods. While non-ionizing radiation has historically been measured in terms of its energy or heat producing ability, which is determined by the root-mean-square value, there is no current basis for favoring this method.
- The sensor may respond to only one axis, component, or polarization of the field. Measurements along several directions are then required.
- In many cases, the measuring device will affect the field pattern. This must be evaluated independently.
- In all cases, background corrections must be made. Some sensors may respond to spurious signals, which must be eliminated.

Without a knowledge of the above factors, you can, at best, make a relative comparison between displays using your own meter. You cannot make comparisons with the values from other meters, and you cannot determine absolute field values. Also, do not compare field values between different types of displays: only compare VGA to VGA, EGA to EGA, *etc.* In addition to the above factors, the fields may be biologically active to varying degrees.

Before you make any decisions about any "radiation" measurements, make sure that the person who is taking them, and the person interpreting them, understand all of the above items.

Chapter 7

Maximizing Comfort and Productivity

Introduction

All of DisplayMate is directed towards maximizing user comfort and productivity, both the program and the manual. The present chapter is specifically concerned with issues that fall under the province of ergonomics: a broad, interdisciplinary applied science concerned with optimizing the functionality of things people use, and the tasks they perform, so that the workplace is properly adapted to the worker. This not only increases user comfort, but it also increases user productivity as well, a double payback for your investment.

Many researchers feel that the problems experienced by VDT users that are now receiving broad public attention under the dreaded suspicion of VDT "radiation" may in fact be caused by ergonomic problems. No one currently knows for sure, but there are a lot of strong opinions flying around. We have attempted to provide an even handed discussion of this matter in Chapter 6.

The primary approach to maximizing user comfort and productivity with video displays is to continually optimize and improve your work environment, your work habits and methods, and your equipment. Not just when you setup a work area or room, or when you buy and install the hardware and software, but every day and for every task. All too often users accept a computer system as is, and are afraid to adjust it or change it to suit their needs. Other users are either too busy or just plain forget that their display and work area need continuing attention.

To begin with, in order to properly select a video system you must first know something about video displays and adapters in order to understand the options available and the consequences associated with them; that is the subject of Chapter 5. The specifics involved in selecting and purchasing video displays and adapters is considered in Chapter 8. Finally, Chapter 9 discusses the often ignored topic of *Maintaining Your Display.* DisplayMate is designed to help you identify your display's strengths and weaknesses. Together with this manual it will help you optimize and get the most from your display.

This chapter includes two introductory sections on:

- Setting Up Your Work Station
- Minimizing Eye Strain

Most of the chapter is a discussion of:

- Common Display Problems

which includes such topics as *Color Registration, Glare and Reflections, Flicker, Font Resolution, etc.* Further information is available in the chapter on *Sources of Additional Information* near the end of this manual.

Setting Up Your Work Station

In this section we will summarize some of the most important issues involved in setting up your work station. A detailed discussion of the general work station and work environment is beyond the scope of this manual.

Screen Size: The screen size should be appropriate for the expected viewing distance and the type of work. For most users, a 13" to 15" diagonal screen should be satisfactory. Larger screens are needed for graphics with multiple display windows. Excessively small or large screens will increase eye fatigue.

Lighting: The lighting for a VDT work area should be modified to maximize contrast and minimize glare, while providing sufficient illumination for other activities. The display screens should be oriented perpendicular to windows and other sources of glare. Blinds should be used to control the amount of outside light entering the room through windows. The optimum lighting level for VDT work is generally about 200 to 500 *lux,* less than half of the standard office lighting levels of 750 to 1500 *lux*. Use indirect lighting where possible. Overhead lights should be recessed and baffled to reduce the possibility of their entering into a user's field of view, or causing glare. Uniformly balanced light levels are important in order to reduce eye fatigue that results from continual iris adaptation. If local task lighting is necessary, a dimmer should be available to adjust the light level.

Work Area: It is important to have an adequately sized work area, and a work table that is large enough for all necessary equipment and materials. A functional layout is very important, with frequently used items within easy reach.

Adjustable Everything: Just about everything needs to be adjustable in order to properly accommodate every user comfortably. Each user should frequently adjust his or her work station in order to find the optimum configuration.

- To begin with, you need a comfortable chair that is adjustable in height and has an adjustable and reclining backrest. Casters and an armrest are important. Adjust the chair first: the user's feet should be flat on the floor; if they're not, then use a footrest.
- The table height should be adjustable so that the keyboard is at a comfortable height. At the recommended height, your forearm should be nearly horizontal.
- The screen should be adjustable in height, position, and orientation. Place the display so that it is close to the straight ahead position where you will be sitting. The top of the screen should be near eye level, so that you are looking slightly downward, with an angle of roughly 20° toward the center of the screen. The tilt of the screen should be adjusted to help minimize glare. Placing the display on top of the computer system unit, which is itself on top of your desk, as is often pictured in many advertisements, is seldom an optimum position for a display.
- If you need a document holder for data entry, get one that is adjustable in height, position, and orientation. Set it up next to the display screen, at a comparable height and distance, so that you can easily switch your eyes between the document and the screen. This will minimize eye accommodation fatigue due to a change in focal distance.

Minimize Stress: Many people don't realize that VDT work can create a good deal of job stress:

- Physical stress and musculoskeletal strain arise from poor posture, poor quality chairs, poorly designed work areas, as well as the static and sedentary nature of VDT work. Change your seating position frequently and get up and stretch regularly.
- Psychological stress is the result of worker unhappiness. Many studies have found that VDT complaints correlate with general job dissatisfaction.
- General stress can arise from many factors including a high work load, machine pacing, and electronic monitoring of workers. This can be minimized by good job design, introducing flexibility into the work pace and schedule, and frequent rests in order to break the intensity of the VDT session.

Minimizing Eye Strain

In order to successfully minimize user eyestrain it is necessary to deal with a wide variety of problems, any of which may cause user eye discomfort. Below, we bring together and summarize a number of issues that are discussed throughout this manual:

- Maintain a good general work environment.
- Proper lighting conditions are essential. Pay particular attention to glare.
- Optimally position the display in your work area so that you can face it without any unnecessary twisting and turning. Regularly adjust its location and orientation to suit your own varying work needs.
- Have a good quality display and maintain it in a state of good adjustment. Clean the screen regularly (see Chapter 9).
- Regularly setup and adjust the display's controls to suit your own varying needs, in accordance with the room lighting and the software's screen appearance.

- Use computer software that has been ergonomically designed for user comfort and productivity. This includes things like good screen layout and a logical and clear presentation of information and requests for input.
- Regularly rest your eyes and take periodic work breaks away from your work area. To rest your eyes, close them for a while, look far away to change the focal distance, and exercise the eye muscles by looking all around.
- Have regular eye exams with an ophthalmologist or optometrist. A significant fraction of the population has improperly corrected vision, so before beginning regular VDT work have an initial eye exam, and tell the doctor that you will be working with a VDT. If you wear glasses, make sure that the prescription is up to date. Also consider getting a special pair of reading glasses with a prescription optimized for the distances involved in video display work, typically 20" to 26", which is about 8" further away than the distances used for reading books and other printed material. This becomes increasingly important after age 40.

Common Display Problems

In this section we discuss many of the problems affecting displays that directly impact user comfort and productivity. Improving some of these may require a few simple user adjustments to the display or to the software, while others may require a field service technician, or possibly even buying a new display.

It is very important to realize that the average user may not be consciously aware of some of the effects discussed below. In fact, some of these effects may even be subliminal and yet still be able to affect a user adversely. For example: screen refresh flicker may not be noticeable unless conditions are optimized for its detection, yet under normal conditions it may still cause user fatigue.

The wide range of topics covered in this section include: Color Registration, Geometric Distortion, Glare and Reflections, Electric, Magnetic, and Radiation Shields, Raster Visibility, Flicker, Image Lag, Screen and Font Resolution, Color Dot / Stripe Pitch and Moire Patterns, Aliasing, Screen Curvature, Contrast and Brightness, Video Projector Screen Brightness, Normal / Reverse Video, Screen Color, Screen Scrolling, Pixel Shape, Video System Speed, Screen Interference, and Display Noise.

Color Registration

Color displays are now the most common type of display in use, and the most serious problem for them is color registration. For color CRTs this problem is referred to as color convergence. An image is produced by superimposing independently generated red, green, and blue images. If the different colors do not line up properly all over the screen, you will see anything from colored fringes on text, lines, and other objects, to three separate images in extreme cases. This effect is the reason why color displays seldom appear as sharp and crisp as monochrome displays. Color fringing produces a loss of resolution. In this respect it is similar to an out of focus image, but causes even more eyestrain because of the systematic color mismatch. Anyone who has ever seen an improperly registered image printed in a magazine knows how painful this kind of problem can be.

Since it is impossible to eliminate color registration or convergence errors entirely, all color displays have it to some degree or another. The errors will vary with the location on the screen, and will be different for each of the three primary colors. Generally, convergence will be best near the center of the screen and worst in the corners. All color displays include internal adjustments set at the factory to minimize the overall error. How accurately this can be done depends on the quality of the display. How carefully it was actually done can vary substantially from one unit to the next. Color convergence and registration can be affected by rough handling in shipment, and also can vary with the age of the display. A qualified field service technician may be able to adjust and improve color registration on your display.

On most displays a misconvergence of only 0.1 mm is noticeable, about ¼ pixel on a 14" diagonal display. Not all manufacturers provide a specification for convergence in their literature. Often times the guaranteed limits are too large to be of much value. For example, it is not too unusual to see a guarantee of 1 mm. This is not only 2.5 times the width of a pixel, but is more than 1/3 the width of a text character, so an error this great would render the screen unreadable. Good quality displays generally provide a convergence of within 0.1 mm near the center of the screen, but the error along the periphery may rise to as much as 0.4 mm, a full pixel. The average error over the whole screen may be less than 0.2 mm.

DisplayMate includes a number of tests for color registration for which Sonera Technologies has applied for a patent because they are significantly more sensitive and accurate than all other prior convergence tests.

Geometric Distortion

A surprising number of video displays produce rather noticeable amounts of geometric distortion. There may even be a wide variation from unit to unit of the same make and model. The distortion may also change with the age of the display. Having to read contorted images will bother most users, so the best approach is to have the displays adjusted by a qualified field service technician as needed (see Chapter 9). The type and amount of distortion that can be tolerated will depend on the nature of the work and how the screen is utilized. For example: distortions are generally most pronounced on the screen's periphery, so staying away from that area for data entry operations will reduce the amount of distortion experienced by those users. DisplayMate contains a variety of tests for geometric distortion, including a *Main Menu* selection in the *Technical Program* for interactively measuring screen distortion. These are discussed in Chapter 4.

Glare and Reflections

The screen of any display acts like a mirror, and will reflect anything illuminated within a field of view into the user's eyes. The reflections are superimposed upon the display's own image, so they reduce contrast, wash out the intended image, and make it harder to read the display. This reduces the user's speed and accuracy, and give rise to discomforts that include headaches and tired eyes.

Glare is the name given to reflections that appear nebulous and featureless to the user. A brightly illuminated wall that is opposite the display will produce glare. Glare also results from diffuse reflections off the screen's surface; we will explain the meaning of this below. Pure (specular or mirror-like) reflections produce a detailed picture of whatever is opposite to the display. Like glare, this reduces contrast, but it also gives rise to a much more serious problem: the user will involuntarily alternate between focusing on the reflected image of the distant object or scene and focusing on the rather close by image of the screen itself. The constant shifting of the focal distance is very annoying and tiring.

Displays with polished glass screens are the worst offenders when it comes to glare and reflections: they are excellent mirrors. Fortunately, very few displays come this way any more. It is impossible to eliminate glare and reflections completely, but there are a number of ways to minimize its effects:

- By far the most important item is to orient the screen perpendicular to any bright sources of light, such as windows and lamps. Controlling the intensity and distribution of room lighting is very important. Blinds on windows can control outside light. Darkening the walls will reduce glare, but may make the room dreary. Darkening a room and using individual task lighting will reduce glare, but uneven lighting can also cause visual fatigue. Uniform indirect lighting is generally the best.
- Switching the display from normal video, light characters on a dark background, to reverse video, dark characters on a light background, will make glare less apparent because the screen itself has a uniform background illumination. Note that glare will still reduce the screen contrast; it just won't be as noticeable and distracting to the user. That, however, may actually be a disadvantage because the user may be unaware of the source of the discomfort. Not all users like reverse video because of the high screen brightness. It also requires a higher quality display to produce a satisfactory image (see Chapter 5).
- Curved screens catch light from a wider field of view than flat screens, so picking a screen with low curvature will reduce reflections somewhat. Screen curvature is discussed in detail below.
- A minor source of glare are the reflections off the bezel that surrounds all CRT screens. Dark colored bezels with a matte finish are best for minimizing this problem. A surprisingly large number of displays come with white bezels.

Virtually all displays sold include a screen treatment to reduce glare and reflections. The most common methods include:

Screen Coatings: Use of a screen coating or treatment can significantly reduce reflections. The most common methods are a direct etching of the screen surface and a silica coating of the screen. They give the screen a frosted appearance and produce diffuse reflections that scatter the light. This reduces the intensity of the reflected light reaching the eye of the user and, therefore, reduces glare. Another benefit is that the reflected images become somewhat nebulous and therefore less distracting, because the eye is unable to focus on them. A disadvantage is that the frosting also diffuses and speckles the screen's own image, reducing the resolution somewhat. The further away the frosting is to the light emitting layer of the screen, the worse this effect is. In particular, add on external anti-glare screens of this type may noticeably degrade the image. Any time the manufacturer's literature includes a nondescript claim about an anti-glare screen, it is most likely one of the above two methods.

Anti-Reflection Coatings: There are two common types of anti-reflection coatings that can be applied to the screen. A thin-film "¼ wave" coating reduces the intensity of any reflection by generating two reflections that tend to cancel one another. The cancellation is never perfect and depends on a number of variables, such as the angle of the incidence and the color of the light. By far the best and most expensive method is a refractive anti-reflection optical coating, the same method used on high quality optics and camera lenses. Multi-layer coatings are more effective than a single layer. Such coatings reduce reflections by moderating the increase in the index of refraction at the surface by a series of small steps. The coating remains effective over a wide range of angles and colors. Most of these coatings are very hard and will resist scratches and abrasion. A disadvantage of the optical coatings is that they absorb oils, particularly finger prints, which become iridescent. Cleaning them is more difficult (see Chapter 9). Anti-reflection coatings must be used in combination with tinted screens or circular polarizers, discussed below.

Tinted Layers: Using a tinted glass or plastic layer on the display will improve contrast because light reflected by the display screen must travel through the dark layer twice, whereas light generated by the display passes through it only once. For example: if the tinted layer has a transmission factor of 50%, then the light generated by the display will be reduced by a factor of 2, but light reflected by the screen will be reduced by a factor of 4, resulting in a factor of 2 improvement in contrast.

Tinted screens are generally used in combination with other methods of glare reduction because there will be a reflection at the front surface of the tinted layer. The most effective use of tinted glass is when it is incorporated directly into the glass used to make the display itself. Directly bonding the tinted layer to the display screen is almost as good. External, add on, tinted screens that are sold for contrast enhancement will introduce an additional reflection at the back surface of the tinted layer. Anti-reflection coatings on external filters should be applied to both the front and back sides of the layer.

Some manufacturers of tinted screens claim that their screens actually sharpen the display images. These statements are generally false or at best misleading. After a filter is installed the screen may appear sharper because it is uniformly darker; however, to make the comparison fair you must turn up the brightness and contrast so that the perceived image brightness returns to the prior levels. Under all normal circumstances the image will broaden, not sharpen.

Circular Polarizer: Another popular external glare reduction method is a " ¼ wave" circular polarizer, not to be confused with the " ¼ wave" thin-film coating, discussed above. The ¼ wave circular polarizer absorbs screen reflections because the reflected light goes through the polarizer twice and has its sense of rotation reversed. Internal display light is unaffected because it travels through the polarizer in reverse order and only once. Circular polarizers are significantly more effective than tinted glass at absorbing light reflected by the display screen. Just as with tinted glass, there can be a reflection at the front surface of the polarizer that should be reduced with an anti-reflection coating. Note that circular polarizers are generally made of plastic and may introduce distortion in the image.

Black Mesh Screen: A black mesh screen is one of the least expensive forms of glare reduction available. It works by absorbing any light that isn't traveling perpendicular to the screen; that includes virtually all of the glare producing light. Mesh screens, however, have difficulty absorbing light that comes in at a glancing angle from the side. Under those circumstances the mesh screen will itself produce glare. A disadvantage is that the mesh can interfere with the screen image unless it is extremely fine. Mesh screens may also produce Moire patterns; see below.

Screen Hood: In some instances a satisfactory solution to the glare problem can be obtained with a hood over the top and sides of the display. The hood simply prevents overhead and side lighting from reaching the screen by casting a shadow. Hoods may interfere with visibility and mobility in your work area.

High quality hoods are available for purchase, but it is also fairly easy to make a cardboard one yourself.

The methods discussed above will work with varying degrees of success, depending on the details of the manufacturer's process. The glare reduction factors claimed by manufacturers should not be taken too seriously. Some claim glare reduction factors of up to 250 to 1. Such numbers are either dreamed up in the advertising department or are the result of unrealistic test conditions. A good quality anti-glare filter with a multi-layer optical coating will reduce glare and reflections by about a factor of 20. Visually compare glare reductions before you buy anything.

Electric, Magnetic, and Radiation Shields

Video displays produce varying amounts of electric and magnetic fields and electromagnetic radiation fields. CRTs generally produce greater intensities of these fields than any of the other types of displays, particularly in the case of magnetic fields. As discussed in Chapter 6, it has not yet been determined whether any of these fields are harmful at the levels emitted by video displays. Some researchers feel that there is enough evidence to justify the installation of protective shields to help block these fields, while other researchers feel that there is insufficient evidence to justify the current level of public alarm. You will have to decide this issue for yourself with the help of Chapter 6.

An increasing number of manufacturers are now selling CRT displays that have reduced field emissions. Some of these displays were actually developed for the European market and are being sold here due to the mounting concern about VDTs in the US. Some have been redesigned to produce weaker fields, while others have merely been retrofitted with internal shielding. The Swedish guidelines for field emissions are the most stringent of all the "standards" and have become a benchmark of VDT safety. If you are worried about VDT fields then you should look for displays and shields that meet the Swedish guidelines. The 1987 guidelines relate to Very Low Frequency, VLF fields; the 1991 guidelines tighten the VLF limit and introduce a limit for Extremely Low Frequency, ELF fields.

A number of companies sell external shields for existing CRTs that significantly reduce the intensity of some of the fields that leak through the screen and toward the user. All of them work by introducing some kind of conducting medium through which the user looks at the screen. As a result, the shields will generally degrade the image somewhat, particularly those using conducting fibers. Unfortunately, these are generally the most effective at blocking the fields.

Many of the manufacturers become particularly ambiguous when describing the types of fields and the frequency ranges over which their products are effective. That often gives the buyer the impression that the shields block all of the potentially dangerous fields. Generally, the shields will block virtually all of the electric fields and electromagnetic radiation. Displays with built-in shielding will generally attenuate the VLF magnetic field significantly, whereas the external shields will seldom affect the VLF field much. Very few shields will block the ELF magnetic fields that are currently the greatest source of concern. Most will block magnetic fields at higher frequencies.

For those who want a shield to block emissions for all of the other directions besides the front, some kind of conducting box for displays may be available. However, since all of the fields decrease rapidly with distance, there is probably no need to do this unless someone is sitting closer than three feet to the back or sides of your display. If you are concerned about emissions from the bottom of the display toward your legs, a piece of aluminum foil under your display should be at least as effective as the shields for the screen. If you do this, use a field strength meter to make sure you have not inadvertently increased the emissions in other directions.

Raster Visibility

The image on a CRT video display is formed from a set of almost horizontal lines that are staggered vertically on the screen. The set of lines is called a raster and the total number of visible lines comprises the vertical resolution of the display. On many displays the image is not smooth, because there are gaps in between adjacent raster lines. In particular, vertical lines, including those making up letters in text, will appear as a set of disconnected dots. This is visually annoying and causes user fatigue.

Each resolution mode on a display has an optimum spot size for drawing the image. The cause of the raster visibility problem is that the spot is too small and leaves visible gaps. This is particularly a problem for multi-frequency displays, because they generally do not modify their spot size for each different resolution they support. In most cases, they will set their spot size for the highest resolution mode, resulting in a raster visibility problem for all the lower resolutions. The electron optics in CRTs is capable of altering spot size. DisplayMate includes a test for raster visibility.

The image on non-CRT video displays such as LCD, Gas Plasma, and Electroluminescent displays are made up of pixels with visually detectable spaces in between. The gaps may be noticeable as a set of dark horizontal and vertical rulings, and can be considered a two-dimensional raster visibility problem.

Flicker

Flicker arises because the video display images are not generated continuously, but are rather rapidly redrawn between 50 to 70 times per second (Hz), in a process called screen refresh. The screen brightness decays between the refresh cycles. This fluttering sensation in the image brightness gives rise to a well documented cause of visual fatigue. The threshold for detecting flicker varies from person to person, with the persistence of the screen phosphor, and with the observing conditions. Images that are displayed in reverse video generally produce a higher sensation of flicker. For most people, flicker is not apparent beyond 70 Hz; however, under some circumstances it can be visible upwards of 100 Hz. In addition, subliminal flicker, which is just below the threshold of conscious detection, may also produce visual fatigue.

The flicker frequency for most video systems is 60 Hz, but varies from a low of 50 Hz for the MDA to a high of 70 Hz for the VGA and MCGA. A number of European standards require a minimum flicker rate of 70 Hz, and many displays marketed there operate in the range of 72 to 75 Hz. The cost of both the video adapter and the display increase significantly with the refresh rate because of the faster signal rates involved.

The sensitivity to flicker varies from person to person, but it is generally higher for younger observers. For a given individual, the sensation of flicker generally increases with any of the following: a high intensity image, low intensity background lighting, a large size video screen, sitting close to the screen, and green colored light. Screens in reverse video also produce a higher sensation of flicker. Since the perception of flicker is often not obvious to most users, it is necessary to create conditions favorable for its detection in order to determine if it may be a problem. In order to maximize the sensitivity in the DisplayMate test for flicker you will need to increase the screen brightness, darken the room as much as possible, look at the screen from a distance much closer than usual, and vary the screen color. Conversely, when using your display you should take these sensitivity factors into account in order to minimize flicker.

A cheap trick to reduce flicker that works well for television images but not for computer displays is called interlaced scanning. Instead of drawing each raster line in turn top to bottom, the even lines are drawn the first time around, and then the odd lines are drawn in the second pass. The even field and the odd field comprise one entire image, which is called a frame. When the displayed images vary smoothly, such as in a television picture, the eye perceives the flicker frequency to be at the field rate, which is twice the frame rate. The entire image is still transmitted at the frame rate, so the flicker frequency has been doubled without doubling the data rate or increasing the cost of the system. Unfortunately, computer images are highly structured, so the information on the even lines is often different from the adjoining odd lines. As a result, interlace smoothing doesn't work well, and the perceived flicker rate falls back down to the frame rate. None of the standard IBM video systems, CGA through VGA, considered in DisplayMate utilize interlace. However, the high resolution IBM 8514/A and XGA video systems for PS/2 computers, discussed in Chapter 5, do utilize interlacing at a frame rate of only 43.5 Hz, significantly below that for any other display. Before upgrading to such a video system, you may wish to consider whether the flicker will be a problem for you. Note that this edition of DisplayMate will not run on an IBM 8514/A or XGA.

A problem related to interlace is jitter in the raster of lines that make up the image. This produces a tenuous flicker because the lines from successive rasters are not properly registered over one another. DisplayMate includes a test for both flicker and raster stability.

The amount of flicker produced by a visual display varies with the type of display. For CRTs it depends strongly on the persistence of the screen phosphors. Too long a persistence will produce another problem called image lag, which is discussed in the next section. Flicker on certain AC gas plasma displays is significantly less than other types of displays because they can make use of a memory effect in the plasma. LCD displays also generally have reduced flicker, simply because they are so slow that the image cannot change rapidly enough to cause this problem. However, both gas plasma and LCD displays can produce noticeable flicker when pulse width modulation techniques are used to produce intensity variations in the display (see Chapter 5).

Image Lag

Image lag arises when the screen light output responds slowly to a changing image. It is a problem for CRTs with long persistence phosphors, and for all LCDs, except those with an active matrix (see Chapter 5). Phosphors with varying degrees of persistence are used in CRTs to minimize the appearance of flicker in the image. When the flicker frequency is under 60 cycles per second, the persistence may be unusually long, giving rise to afterimages that can last a few seconds in dim lighting. The afterimages can make the screen unreadable if the screen content changes rapidly, such as during scrolling. In some cases the decaying color of a phosphor will be different from its normal emitting color; this can be particularly annoying with some white phosphors that have yellow or green light tails. DisplayMate has a persistence test for evaluating image lag.

For LCDs the problem is worse, because it takes a noticeable amount of time for the image to reach full contrast after it is drawn, besides taking a noticeable amount of time to disappear after the image is removed. If the image is changing rapidly as during scrolling, panning, fast screen updates, or animation, then the image may appear very dim or possibly may even be invisible. Afterimages like those of CRTs with long persistence phosphors may also be present. DisplayMate has scrolling, panning, and persistence tests that will allow you to evaluate the severity of these effects.

Font Resolution

Font resolution specifies how well the screen characters are formed, and therefore provides one measure of the quality and readability of text. Counter to wide spread belief, there is not a substantial difference between the font resolutions of the different video systems. CGA characters are formed by a matrix of 7×7 pixels with a 1 pixel descender for characters like "g" and "y." MDA and EGA characters are 7×9 pixels with 2 descenders, and VGA and MCGA characters are 7×10 pixels with 3 descenders. From these figures it is hard to understand why

CGA text characters are so often maligned by users as being difficult to read. The primary reason for this has to do with the amount of space in between characters. In some instances, the CGA characters will touch from one row to the next. Almost all of the extra resolution provided by the newer adapters goes into empty space in between characters. The MDA, EGA, VGA, and MCGA characters are in fact almost 30% smaller than CGA characters.

The *Character Box* size for the CGA is 8×8 pixels, for the MDA and EGA it is 8×14 pixels, and for the MCGA and VGA it is 8×16 pixels. In some cases the width is extended to 9 pixels, as discussed below. Figure 7.1 illustrates the character representations for the adapters. They are magnified, but drawn on the same scale. The characters will not look as harsh on CRT displays because the beam smoothes out all of the edges.

Another reason for poor CGA text readability has to do with raster visibility problems that affect most CGA displays: the pixels that make up the characters appear separated as a collection of individual dots, as opposed to fused pixels. In fact, one reason why the original MDA produced such nice looking text is that IBM added circuitry to help connect adjoining pixels so that the characters have an unusually smooth appearance.

None of the video systems that have been discussed here, from CGA to VGA, have sufficient resolution to be able to render different font type styles with an appearance that can be considered pleasing and easy to read in an 80 column format. The horizontal resolution of the characters and screen are related to the byte orientation of the hardware, which has 8 bits. As a result, all of the adapters produce characters that are 7 pixels wide, with 1 pixel left over for a space, and there are simply not enough dots available to produce readable variations on the boxy default fonts.

Several adapters generate characters that are 9 pixels wide in text mode only; they are the MDA, the EGA in monochrome mode, and the VGA. This 9*th* pixel is used exclusively to add more space in between characters in order to further improve readability, except for the ruling characters that are used for line drawing. The extra space allows a few characters to be widened in order to further improve their appearance; these include "mvwMTVWXYZ" plus a few other special characters.

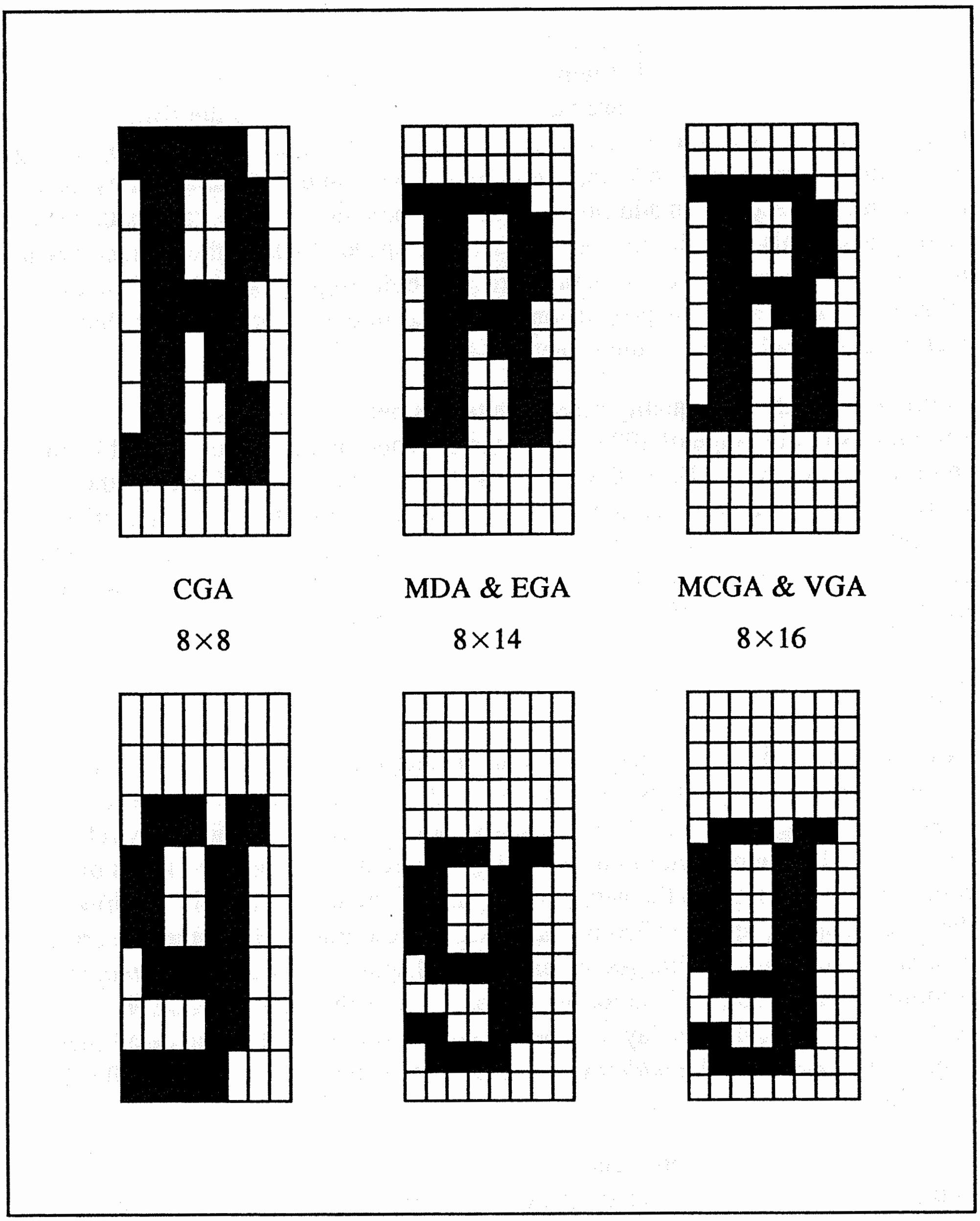

Figure 7.1 *Character Box for the "R" and "g" Characters.*

Slanted italic fonts generally have the worst appearance of all, and bold fonts have a bloated appearance that wipes out the important empty spaces inside most characters. Of course, there are numerous minor variations to the IBM style boxy font that many users may find more appealing to read. Graphical operating environments, such as Windows, can partially overcome this limitation by using larger size characters. In addition to reducing the number of characters that can be displayed, this also significantly reduces the speed at which the characters can be drawn on the screen, because the hardware byte alignment is gone. On the other hand, such fonts are proportionally spaced like most printed text; that increases the readability of the screen.

In order to obtain high quality screen fonts it is necessary to have screen resolutions in the range of 1024×768 pixels. These are currently available only in the Super VGA and Beyond VGA markets (see Chapter 5). Other methods to increase font readability include anti-aliasing techniques where the intensities of the individual pixels that make up each character are varied to produce smoother and significantly more legible text. Adapters with this capability are now making their appearance in the 256 color Super VGA market.

Screen Resolution

Resolution specifies how finely drawn the images on a video display appear, and is one of the primary factors affecting the quality and appearance of the screen image. Many of the other effects discussed in this section are indirectly related to resolution. It is important to understand that there are actually two kinds of resolution: one relates to the geometric format of the image, as it is specified by the video adapter, and is called the *addressable* resolution. The other describes how sharp and crisp the images appear on the display and is called the *image* resolution. The *image* resolution is generally lower than the *addressable* resolution because the display may not be able to produce all of the detail that is supposed to appear. The *addressable* resolution is the resolution you will see in manufacturer's specifications.

The *addressable* resolution describes the number of lines in the image and the number of pixels per line that are generated by the video adapter. This is uniquely determined by the parameters of the standard video modes defined by IBM. Each pixel has a unique address, hence the name *addressable* resolution, and all of the pixels are arranged in a fixed two-dimensional array of rows and columns. Since every image is produced by controlling the intensity of each addressable pixel on the screen, the amount of detail and the accuracy of the image are geometrically specified by the *addressable* resolution. The limited resolution of each mode gives rise to a visible coarseness that can be described in terms of the effects of aliasing, jaggies, Moires, confusion, and image fusion, which are discussed below. The *Adapter Resolution Tests* in the *Display Tests Menu* demonstrates all of these effects.

How closely the *image* resolution approaches the *addressable* resolution is a true measure of display quality for a CRT. It depends on whether the scanning beam has the proper size and shape for the video mode, and on how accurately and quickly the beam can be turned on and off. The latter is called the video bandwidth and is discussed in detail in Chapter 8. The *image* resolution is generally best at the center of the screen, and poorest at the corners. Bad focus and image blooming will reduce the *image* resolution, and on color CRTs it also depends on the dot or stripe pitch of the screen as described in the next section, and on the color registration as described in an earlier section. Image resolution is particularly important for screens operated in reverse video because it also affects screen contrast. This is discussed in the *Screen Contrast* section, below. For non-CRT displays the *addressable* and *image* resolutions generally coincide. DisplayMate has several sets of tests for image resolution.

Color Dot / Stripe Pitch and Moire Patterns

In most color displays the screen is made up of tiny red, green, and blue phosphor patches arranged in a regular pattern. This imparts a graininess to the image that is not found on monochrome CRT displays. The spacing is referred to as either dot pitch, mask pitch, or stripe pitch, depending upon the type of display involved, and specifies the distance between adjacent sets of red, green, and blue colors on the screen. Clearly, the smaller the better. Values currently range from about 0.20 mm to 0.75 mm, with the smaller values found on the best 14" displays, and the larger numbers found on cheaper displays, or on large screen displays that are not expected to be looked at up close. The larger spacings are quite noticeable and disturbing to the eye.

A common problem with most CRT color displays is the occurrence of wispy and wavy visual patterns on the screen that appear superimposed upon the image. They are called Moire patterns and are quite visually disturbing. They arise when there are an insufficient number of colored phosphor dots or stripes on the screen for the video display mode being used. DisplayMate includes several tests for color Moire patterns. Chapter 8 includes a detailed discussion on determining the dot/stripe pitch needed to minimize the appearance of Moires.

Aliasing

Aliasing results from the finite resolution of any image produced by a raster display. The pixels in the raster are arranged in a fixed two-dimensional array of rows and columns. Images that are made up of lines that are purely horizontal or vertical can be drawn accurately; however, all other lines will have a jagged appearance because they must be represented by illuminating the pixels that are closest to, but not actually on, the desired line. Aliasing is what gives screen images a coarse appearance. Individual dots drawn on the screen also suffer from the same alignment problem. When too many dots or lines are drawn in the same area, they may fuse completely into a solid or produce a Moire pattern that results from aliasing.

The effects of aliasing diminish with increasing resolution, so if these effects are interfering with the production of the image or are just plain visually annoying, then you need to switch to a higher resolution display. DisplayMate contains a set of *Adapter Resolution Tests* that demonstrate the problems associated with aliasing. If possible, compare the tests on two different resolution displays.

Screen Curvature

The screens of most CRTs are curved, while all non-CRTs have flat screens. In general, the less curved the screen the better. Curved screens will pickup reflections and glare from a wider area because of their curvature. While the curvature of most CRT screens is quite noticeable, the actual visual distortion resulting from that curvature is negligible for all but the very smallest displays, which have the highest intrinsic curvature. For example, for a 13" display, the geometric distortion resulting purely from the screen curvature alone is only 0.4%.

Although the screens do not have a lot of curvature, the eye is still aware of it because of depth perception. The curvature also makes straight lines appear curved, although this effect is small and can be eliminated entirely for the face-on viewing direction. The curvature also makes it difficult to make screen measurements with a ruler. An amusing optical illusion occurs when looking at a flat screen CRT for the first time: it appears to be curved inward because the brain is used to correcting for the outward curvature of CRTs. The illusion of inward curvature disappears quickly.

The natural shape for any CRT screen is along the surface of a sphere centered at the middle of the CRT tube. Virtually all CRTs are manufactured with a screen surface that is much flatter than the natural shape in order to minimize the effects mentioned above. That introduces pincushion geometric distortion that must be canceled by the use of special magnets and circuitry. The flatter the CRT the more critical those corrections are, and the more carefully you need to examine the periphery of the screen image for those distortions. See the *Screen Distortion Measurements* section of Chapter 4.

Screen Contrast

Contrast refers to the range of intensities that can be produced by a display, and it plays a major role in determining readability and image quality. The maximum brightness that can be produced without defocusing and blooming the image is one obvious limit on contrast. The more important and technically difficult problem is achieving the darkest possible minimum brightness. That is determined by how black the screen can be made to appear, which cannot be any darker than when the display is turned off. This will be nowhere near as black as the ink on this page, meaning that video displays do not have as high a contrast as printed matter.

Because of light reflection, the blackness of the screen is affected by the general level of room lighting, and that reduces contrast. The brighter the ambient lighting, the lower the screen contrast. The contrast specified by a manufacturer may be for a low or totally dark ambient light level, in which case the contrast you will get under normal conditions will be smaller. On CRTs, the phosphor coating material on the screen is generally white in color (regardless of the actual color it emits when excited) and tends to reflect room light efficiently and make the screen appear undesirably bright. On color CRTs, this problem is reduced significantly by introducing a black matrix coating in between phosphor dots or stripes on the screen, which absorbs much of the light and makes the screen appear darker.

For all video displays, the standard method employed to make the screen as black as possible, is to use a layer of tinted glass or plastic. In addition to darkening the screen, this also improves contrast because outside light must travel through the dark material twice, whereas light generated by the display passes through it only once. For example: if tinted glass has a transmission factor of 50%, then the light generated by the display will be reduced by a factor of 2, but light reflected by the screen will be reduced by a factor of 4, resulting in a factor of 2 improvement in contrast. It is also much better to incorporate dark glass directly into the display rather than bonding it on afterwards, because each additional layer of material introduces additional reflections. Many displays are in fact manufactured using glass that has transmission as low as 30%. This is the meaning of "dark bulb" in CRT specifications. Obviously, the lower the transmission the darker the screen and the higher the contrast that can be achieved. A limit is reached because the display's own light output is also attenuated.

Horizontal resolution also plays an important factor in screen contrast, because it can reduce the brightness excursions in thin lines drawn on the screen, including those found in text characters. This is particularly a problem in reverse video, because most of the screen is on. Text and graphics are created by rapidly and precisely turning off the scanning beam and then rapidly turning it back on again a brief instant later. If this doesn't happen quickly enough, the text and graphics will not only be blurred, but will also not have time to reach the screen's black level, reducing the all important contrast. If vertical lines (they are the hardest) look skinnier in reverse video than normal video, then the display is not up to the task. The resolution problem is not as serious for normal video because it is possible to turn up the screen brightness without affecting the blackness of most of the screen, *i.e.*, in normal video, resolution does not affect contrast. The *Line Brightness Test* in the *Video Obstacle Course* will demonstrate this effect. Screen contrast is also reduced by streaking, shadowing, and ghosting; tests for all of these are provided in DisplayMate.

Screen Brightness

The importance of high screen brightness is a lesson that has been carried over from the television industry. You will need an adequate reserve of peak brightness over and above what you set for normal viewing conditions in order to compensate for: unusually bright lighting conditions, the possible use of a tinted glare reduction screen, and the gradual reduction in the efficiency of the screen phosphors over time. When you check for high brightness reserve by increasing both the screen brightness and contrast controls, also check for defocusing and blooming at high brightness levels. DisplayMate includes a test for both focus and blooming.

When setting the display brightness be sure not to set it too high, particularly on a mostly dark screen that contains only a limited amount of text or graphics, because the eye may not properly adapt its sensitivity to sparsely distributed objects of high surface brightness. Some users have a tendency to do this in order to produce a high contrast image. Headache and eye fatigue may result from such a condition.

Screen brightness is generally specified in units of surface brightness called foot-Lamberts, abbreviated fL: 30 fL is considered relatively bright, 20 fL is average, and 10 fL is on the dim side. In some cases you will see the metric value specified: candela per square meter, abbreviated cd/m^2. To convert to fL divide by 3.43.

Video Projector Screen Brightness

Video projectors generate a large total light output that is spread out over a large screen area. The brightness perceived by the eye depends on the screen's surface brightness. The surface brightness for projectors is often quite low compared to standard video displays, particularly for the large screen sizes. However, they are normally viewed under controlled dim lighting situations so the image may have a satisfactory brightness for the audience. Still, the higher the surface brightness the brighter you can set the ambient room lighting. For a given projector, the surface brightness will decrease as either the square of the screen size or the square of the screen to projector distance, a perfect example of the famous inverse square-law.

For video display projectors the total light output is generally specified in the manufacturer's literature in the metric units of lumens. We need to compute the surface brightness, which depends on the size of the image over which the light is distributed. To compute the surface brightness, multiply the screen image width in inches by the screen image height in inches to get the image area. Divide the screen lumens by the image area, and then multiply the result by 144. The units are foot-Lamberts, as discussed in the previous section on *Screen Brightness*. This will be the perceived surface brightness for a perfectly diffusing matte white screen that provides the widest viewing angles.

Many projection screens concentrate the reflected light into a more limited area, in order to increase the brightness perceived by persons that are situated near the center of the screen. In order to take this into account, multiply the surface brightness obtained above by the "gain factor" specified by the screen manufacturer. Gain factors of 2 to 5 are typical, but some curved screens have gains as high as 20. The perfectly diffusing matte white screen has a gain of 1 by definition. Bear in mind that the higher the gain factor the narrower the field of view for the screen. For audiences in a narrow movie theater style arrangement, this should not be much of a problem. High gain screens may also produce a visibly speckled image and introduce visible striping on the image from the reflectors, so check the appearance before you buy a high gain screen.

One note of caution: the brightness specification for most projectors involves a certain amount of exaggeration by the manufacturer. The value shown is often for a small rectangle at the center of the screen at maximum brightness. The image will generally not be in good focus due to blooming, and the peak brightness will generally fall significantly if the entire screen is illuminated to this level, instead of just a small section. For this reason the usable brightness may be no more than half of the manufacturer's specification.

Normal / Reverse Video

In normal video, text and other information is drawn by illuminating pixels on a dark background, while in reverse video there is a light background, and text and other information are drawn in black, which corresponds in appearance to the printed page. Reverse video has become increasingly popular in part because the paper analogy is rather compelling in word processing and desktop publishing applications. Another reason is that glare, while still present, is less noticeable and distracting to the user. That, however, may actually be a disadvantage because the user may be unaware of the source of the discomfort.

Not all users like reverse video because the high overall screen brightness can cause discomfort. It is not possible to simply decrease the screen brightness because that reduces the all important screen contrast. However, a high quality tinted screen with anti-reflection coatings can be used to lower the brightness, while at the same time increasing the contrast. A major disadvantage of reverse video is that it requires a higher quality video display to produce a satisfactory image than does a normal video image (see Chapter 5). Screen flicker is also more noticeable in reverse video. Internal light reflections within the display, called halos, are also a greater problem for reverse video.

There are many different ways to switch to reverse video: some software programs provide this as an explicit option; in all others that give you a choice of screen colors pick, for example, black as the foreground color and white as the background color. Some monochrome displays let you set reverse video by flicking a switch; many portable computers provide it as a software option. You can switch DOS to reverse video if you have installed an optional console driver called ANSI.SYS. Otherwise you can buy a software utility that will let you accomplish this with an interactive menu driven program.

Screen Color

The so-called optimum screen colors have changed repeatedly over time. For monochrome displays: green, amber, and white have enjoyed official favor at one time or another. For color displays, studies claim to have identified optimum color combinations. Unfortunately, when users are given the ability to control the screen colors themselves, almost all color combinations wind up being someone's favorite, including those on the "forbidden" list.

The actual colors produced by a color display can vary noticeably from model to model, and depend upon the phosphors being used as well as the settings for the internal electronics of the display. Some will produce vivid and saturated colors, while others will produce mellower and more pastel tones, which is fine because some users like powerful saturated colors while others have a lower threshold for color overload. However, if precise color balance is important for image reproduction, you may need to match the colors found on the standard IBM displays.

Monochrome white displays are particularly popular now because in word processing and desktop publishing applications the correspondence with the printed white page is compelling. Many manufacturers sell so-called "paper white" displays. White, however, is not a single color and there is a considerable variation in the kind of whites you may find, for both screens and paper. Most will lie in the range of a white with the color of average daylight (specified as a color temperature of 6500° Kelvin) to a white with a bluish tinge (specified as 9300° Kelvin). The white on many displays and home televisions is 9300° Kelvin, which is considered too harsh by many users. Paper white displays that more closely match daylight white are often preferred.

Green displays are often chosen for low ambient light areas, whereas amber displays seem to be preferred for brightly lit areas. Looking at a display that has a vivid or saturated screen color for a period of time will often cause a form of eye fatigue where the user will see images tinted by the complement of the screen's color. This is known as the McCollough Effect. When noticeable, it typically lasts a few minutes, but it can last for a few hours, and in rare cases for days. For example, staring at a green screen may later cause white images to appear with a pinkish tint. The effect occurs with any form of color stimulation, and is not limited to video displays. It is thought to be a normal form of sensor fatigue and not harmful.

A real advantage of color displays is that they allow users to pick colors for themselves. The colors most pleasing to a particular user will be affected by the color scheme of the work area. They may also vary with the software being used as well as the type of image being displayed. Many software packages allow users to customize their colors, and DOS includes an ANSI.SYS driver that will provide user color control for many applications that do not provide this feature. CGA provides only 16 colors to choose from, EGA provides 64 colors, while VGA and MCGA provide a choice of 262,144 colors. Accessing the broader range of colors requires Attribute and Palette Register control, which is generally not provided by most software. There are specialized software programs that will provide this service, generally without interfering with the application software. Armed with this feature, users can create pastel and other colors that they may find more pleasing to their eye.

Screen Scrolling

The screen scrolls when the display is operating in teletype mode and the cursor reaches the bottom of the screen. All the information is shifted up by one line and the new text is inserted at the bottom. DOS itself operates in teletype mode as do most of its commands including TYPE, which is used to print files on the screen. There are many other software applications that will produce output in teletype mode, particularly those that continuously produce output like a news wire service. Staring at a scrolling screen for too long will give most people a headache, because the scrolling implemented on most computer displays appears as an instantaneous jump of information on the screen. One solution is to switch from scrolling to a page presentation, where the screen is repeatedly filled and cleared like the DOS command *MORE*. For users with EGA and VGA displays, a better solution may be the installation of a program that performs smooth scrolling. Text will then smoothly roll up the screen in the same way as credits appear at the end of many movies and television programs. DisplayMate provides a compatibility test that demonstrates smooth scrolling.

On most CGAs, a more disturbing phenomenon occurs when the screen scrolls while in the 80 column text mode: the screen is briefly blanked, which appears to the user as flicker. If the background color is other than black the flicker is quite pronounced. DisplayMate includes a test for CGA scroll flicker. The easiest solution is to install a screen accelerator program that eliminates this problem by being a bit more clever than the routines in the system BIOS. A word of caution: some screen accelerators are not well written, and will not only slow down your video system but they may introduce incompatibilities that may crash your computer under certain circumstances. Use DisplayMate to evaluate the speed and compatibility of any screen accelerator you are considering.

Pixel Shape

Only 2 of the 15 standard IBM video modes have pixels that can be considered either round or square; all of the other modes are oval or rectangular. The problem here is that virtually all CRT displays produce round pixels, which means they must set their spot size to either degrade resolution or produce raster visibility gaps. Most manufacturers choose the latter. CGAs have the most eccentric pixel shapes and this is a major reason for the poor quality of most CGA displays. The electron optics in CRTs is capable of altering spot shape. Similarly, non-CRT manufacturers are faced with a fixed pixel shape, but their only recourse is to vary the shape of the image away from its intended 4 to 3 aspect ratio. Generally, they shrink the vertical extent of the image so that, for example, circles will appear on the screen as ovals and text will appear squashed.

Another aspect to pixel shape is related to the visual appearance of lines and dots on the screen. CRTs produce the nicest looking lines and dots on the screen because of what is known as the aperture effect: the beam is rounded and has a smooth intensity profile, so that whenever it is turned on to draw something on the screen it will have a smooth appearance without any visually harsh rough edges. Non-CRTs will generally produce boxy images with sharp corners and edges. However, CRTs will produce rough looking boxy images when they are programmed to generate CGA compatible images by double-scanning each line. This method is used by EGAs, MCGAs, VGAs, and some so-called "Super-CGA" video adapters (see Chapter 5) in order to display CGA images.

Video System Speed

Video system speed is a matter that definitely affects user comfort and productivity because of the repetitive nature of updating the screen. And by this we are *not* referring to the generally negligible amount of time saved by a fast video system in actually drawing an image, but rather in the perceived difference in how users react to a snappy video system versus a slow as molasses one, even when only a few tenths of a second are involved. A slow video system may actually try your patience and cause stress.

Screen Interference

Screen interference is anything visible on the screen that ought not to be there. That can include electrical interference from the computer itself, from other nearby displays, and noise from the power line. It also can arise from problems within the display's own power supply and electronics, and from improper or unshielded video cables. This kind of interference modulates the image, often producing spikes or waves on the screen, and is often very disturbing. Less pathological, but just as disturbing, are the wispy Moire patterns that arise in color displays due to an insufficient number of color dots on the screen (see above and Chapter 4), and screen snow and scrolling flicker that arise in CGA video systems (see Chapter 5). Any such interference will generally be more apparent if the screen is in a reverse video mode or has a non-black background color.

Display Noise

Video displays can produce a number of annoying sounds including hum, high pitched squeals, and fan noise. Fan noise arises from the use of low quality fans. The other sounds should only be present in malfunctioning or improperly designed displays. They can arise in either the power supply or the deflection coils in a CRT, and are generally the result of mechanical looseness or magnetostriction. Of greatest concern are the high pitched squeals that are barely audible or even marginally subliminal: they may produce an unconscious irritation or annoyance. A CGA display has a horizontal frequency of 15.75 KHz, and an MDA display has a horizontal frequency of 18.5 KHz, both of which are at the upper end of the human hearing range. EGA and VGA displays have horizontal frequencies of 22 and 31.5 KHz, respectively. Switching power supplies may have frequencies as low as 25 KHz. Frequencies above 20 KHz are generally inaudible; however, in some cases, sub-harmonics may be produced that are in the audible range. A child is more sensitive than an adult to these high frequency sounds, and may be able to alert you to their presence; otherwise a calibrated sound meter is best.

Chapter 8

Selecting a Video Display System

Introduction

When selecting and buying a video display system it is necessary to consider another set of issues beyond those that have already been discussed. There are a lot of options, and also a lot of things that can go wrong. This chapter is specifically designed to help you make the right choices. Before getting involved in the specifics of buying video hardware you should be familiar with *Video Display System Basics,* discussed in Chapter 5, and with *Maximizing Comfort and Productivity,* discussed in Chapter 7.

Most of the chapter is devoted to sections on *Selecting a Video Adapter* and *Selecting a Display.* A section on *Buying Video Hardware* is included to help those with little experience in purchasing computer equipment. It discusses some of the issues involved in buying adapters and displays from storefront dealers and mail order houses.

Selecting a Video Adapter

Before you begin this section you should already know which type of video adapter you intend to purchase: MDA, CGA, HGC, HIC, EGA, MCGA, VGA. If not, then first refer to Chapter 5 on *Video Display System Basics.*

The topics covered in this section on adapters include: Hardware Compatibility, Compatibility Guarantees, Image Quality, Address Conflicts with Other Adapters, 16-Bit Adapters and System Bus Conflicts, Automatic Mode Switching, Automatic Display Detection, Non-Standard Display Outputs, Auxiliary Outputs, Adapter Software, Setup Switches, Mechanical Incompatibility, IBM versus Non-IBM, Documentation, Electromagnetic Interference, Technical Support, and Warranty and Repair.

Hardware Compatibility

Hardware compatibility is the single most important issue for a video adapter. There are several types of hardware compatibility to be considered:

1. Operationally, the most important compatibility issue is whether all software will run as it would on a true IBM adapter, and whether the adapter will produce the same display image as the corresponding IBM adapter for all software. This encompasses register, buffer, and BIOS compatibility, and has already been discussed extensively in Chapters 4 and 5. DisplayMate tests for all of them.

2. Many adapters are advertised as being EGA, CGA, and MDA compatible when all they are referring to are the software compatibility modes provided by the adapter. Make sure the adapter you buy is hardware compatible with your display.

3. Not all adapters will work properly with all computers that are considered to be 100% IBM compatible. Generally, this is the result of subtle signal or timing differences that can affect some combinations of hardware. IBM's own EGA adapter has timing problems that surface depending upon whether it is operating in an IBM PC or IBM AT. Other non-IBM EGA and VGA adapters are afflicted with similar problems. Sometimes compatibility problems arise from a design flaw. For example, early model AT&T PCs need a hardware modification to the system bus before they will properly run with any EGA or VGA adapters. This kind of problem seldom occurs any more, but if you have a very old system or an obscure brand of computer, you may need to inquire about compatibility problems.

4. Most of the non-IBM video adapters provide hardware emulation of more than one IBM adapter, and many can emulate most of the adapters considered here: MDA, CGA, EGA, VGA, and Hercules Monochrome Graphics cards. When some of the cards switch emulation modes, portions of the BIOS from the advanced VGA or EGA cards remain active. This dual identity may confuse

sophisticated software that carefully probes the functionality of the BIOS. DisplayMate will produce a message alerting you to this condition.

5. If your computer has a built-in video adapter, you will need to disable it unless you are planning a dual display system; see below. Most computers will allow you to do this by shifting a jumper on the system board. If you have an IBM MCGA video system, it is automatically disabled when a VGA adapter is connected to the system.

6. If you are planning to have two video adapters in your system, make sure they will not interfere with each other. Address and bus conflicts that can arise are discussed separately in two sections, below. You may still encounter compatibility problems even if you follow the guidelines set down by IBM for dual display systems, as discussed in Chapter 5. This can arise because many compatibles emulate more than one IBM video adapter, or it may be due to limitations or side effects from hardware or software enhancements provided by the adapter. Information for this sort of compatibility constraint should be readily available from the manufacturer. Also see the *Compatibility Problems* section in the *In Case of Difficulty* chapter.

Compatibility Guarantees

Many clones include a compatibility guarantee claiming to be 100% compatible with the appropriate IBM adapter or adapters. Some even offer to refund your money if they can't remedy your compatibility problem. Many of these guarantees are more marketing gimmicks than a statement of technical accuracy or a desire to correct any incompatibilities that you may discover. Under these circumstances, if you are very persistent you may collect on that guarantee. Perfect, 100% compatibility is unnecessary for most users because most software uses a core of rather well tested features. Most users will find the more recently introduced EGA and VGA clones to provide a satisfactory degree of compatibility.

Image Quality

There is a significant visible difference in the quality of the images produced by different video adapters, particularly when connected to a good display. If you are shopping for an adapter don't forget to consider this point. On VGA and

MCGA systems, the sharpness of the image can vary significantly with different adapters, and the adapter may also be the source of ringing and other interference problems that can show up on analog displays. The color balance on these systems can also vary as the result of differences in the adapter's analog outputs. On all color adapters, differences in signal timing between the different colors can produce color registration errors on the display. On systems with digital video, the adapters will vary as to how long a video extension cable they can drive (see the *Cables* section, below). DisplayMate has tests for all of these effects. To determine if a video adapter is the source of a problem, connect the same display and video cable to a second adapter and compare the images. This approach is better than connecting two different displays to the same adapter.

Address Conflicts with Other Adapters

Should any two adapters share common RAM, ROM, or Input/Output port addresses, the hardware will not operate properly and the system may crash. The likelihood of this happening increases with each peripheral you add to your system, since there are few rules for allocating addresses and a lot of different devices and manufacturers vying for them. If you do experience a conflict when installing a new adapter, you may be able to eliminate it by using option switches on one of the adapters to shift its addresses. Some adapters will automatically switch some of their default addresses if they find them already in use. Whenever addresses change, the software drivers for the adapter must be informed of the change; in some instances, that will happen automatically. As a rule, video adapters that use standard system or application software cannot have their addresses changed even though their hardware provides this capability.

Conflicts will occur if you install two video display adapters in your system and both attempt to function as either monochrome or color systems. Note that color adapters with monochrome displays are still functionally color systems, and that a Hercules InColor card is functionally a monochrome adapter in spite of the fact that it generates color. Hercules adapters normally operate with two graphics pages in RAM. If you have another video adapter you may only use the lower page by operating the adapter in "half mode" instead of the default "full mode."

Additional ROM address conflicts may occur with non-IBM video adapters because their BIOS is often larger than the corresponding IBM adapter as a result of the functional enhancements provided. For example, while the IBM EGA uses addresses C000:0000 to 3FFF (16 KBytes) and the IBM VGA uses C000:0000 to 5FFF (24 KBytes), some video adapters use up to 7FFF (32 KBytes), which is the amount of space that was originally allocated by IBM for video systems. However, non-video adapters may expect the space beyond 3FFF or 5FFF to be available and use it. Also, some non-IBM video adapters use scratch pad RAM in areas reserved for BIOS ROM, which may give rise to additional conflicts.

16-Bit Adapters and System Bus Conflicts

Sixteen-bit cards can transfer information twice as fast as 8-bit cards when connected to system buses that are 16-bits wide, such as in ATs and 80386 computers. Most 16-bit cards can also configure themselves as 8-bit cards if they are connected to 8-bit buses, such as in the original PC. So far so good. A subtle problem arises because the AT/ISA/EISA bus requires that all memory accesses be either entirely 8-bit or entirely 16-bit within 128 KByte designated regions of memory. If all the adapters that share these 128 KByte regions don't cooperate and act in unison, the system will not be able to communicate properly with the affected 8-bit cards. Those cards will malfunction as a result of the loss of data and may crash the system. Each adapter that has an automatic configuration capability must figure out what the other adapters are doing and configure itself accordingly; this is done by monitoring and testing the bus when the system is booting. Unfortunately, not all adapters properly indicate their configuration when the computer is booting, so a system bus conflict may arise anyway. It is then necessary to determine which memory region is at fault and manually configure each adapter in that region to either 8 or 16-bits by using the configuration switches on the card.

A single 8-bit card can act as a spoiler and force all 16-bit cards in the same 128 KByte region to degrade to 8-bits. This is a waste of invested hardware dollars and performance, but is sometimes unavoidable. Other times a little planning can eliminate the problem. For example: in dual video adapter systems, if one of the adapters is an IBM MDA or a Hercules card, then any 16-bit EGA or VGA card in the system will be forced into 8-bit video RAM memory accesses. If you don't really need these cards, then by removing them you will increase your video system performance. This has a relatively simple solution because there can be at most two legitimate contenders in the A000-B000 segments that are reserved exclusively for video RAM.

Sixteen-bit video adapters may also independently configure their ROM BIOS for 16-bit accesses. Since virtually all adapters in the system use the C000-D000 ROM BIOS segments, including disk, tape, and network adapters, the likelihood of succeeding with 16-bit ROM BIOS accesses is not as good as with video RAM. One solution is to use a BIOS driver that installs the video BIOS into system RAM, as discussed below under *Adapter Software*.

The performance improvement you are likely to see from 16-bit adapters is generally small, not the factor of two or more that is often claimed by manufacturers. The principal reasons for this are that the internal architecture of EGA and VGA cards is byte oriented so that many operations can only be performed 8-bits at a time; also a lot of software does not take advantage of the available 16-bit operations. In any case, 16-bit cards are probably a better buy in the long run even if you don't immediately benefit from their enhanced performance. They generally don't cost much more than 8-bit cards, but unfortunately they do sometimes provide more problems during installation.

Automatic Mode Switching

Most video adapters that emulate more than one IBM adapter can be configured to switch between emulated cards automatically, based on how the software accesses the adapter. In many instances this is convenient because it spares the user the need to type in a command to switch the emulation mode. Unfortunately, automatic mode switching can give rise to a number of problems:

1. The system may fail to boot or to reboot.
2. Sophisticated video software that carefully probes the video BIOS and video hardware may cause inappropriate mode switches and become confused if the hardware changes its identity.
3. You may not be able to use Shadowing RAM on 80386s and 80486s when automatic mode switching is enabled because the video BIOS changes dynamically.

In many cases there are work-arounds to these problems; otherwise you will need to deactivate automatic mode switching using one of the configuration switches on the card. Since automatic mode switching seems to create more problems than it solves, you may wish to deactivate it right from the start.

Automatic Display Detection

The IBM MDA and CGA and the Hercules cards can accept only one type of display, so automatic display detection does not apply. If no display is actually connected to these adapters, there is no way for the adapter to detect this or, more importantly, to communicate this information to software. The IBM EGA adapter can accept three different displays: digital monochrome, color, or enhanced color, and requires the user to set switches on the adapter indicating the type of display connected to the EGA. Beginning with EGA, many non-IBM adapters began offering automatic display detection to spare the user the need to set the display switches. This is reliable, and is accomplished by examining the loading on each of the connector signal lines. In some cases multi-frequency displays may confuse automatic display detection because the display is at the same time trying to do automatic adapter detection. Many adapters have manual display switches that include a special setting for multi-frequency displays.

On PS/2 computers and adapters, IBM also offers automatic display detection. The IBM PS/2 displays include three identification lines that can be read by an adapter to determine automatically which display is connected to it; however, they are ignored by the IBM VGA and are used only by the IBM MCGA and the advanced 8514/A and XGA adapters. The IBM VGA determines the loading on its different color signal lines, and concludes the display is color if the red and blue lines are terminated; otherwise it assumes the display is monochrome. In particular, if no display is connected, the adapter will be setup as a monochrome system.

Non-Standard Display Outputs

Many non-IBM adapters will support a wide variety of displays over-and-above those accepted by comparable IBM adapters. The idea is to allow you to upgrade your adapter without requiring you to purchase the proper display at the same time, or, if your display breaks, you can temporarily operate with a less desirable display. With adapters that support the Super VGA or the IBM 8514/A standards you may be able to run software for these high resolution systems without the proper display.

The goal of non-standard display outputs is to be able to run any video standard - VGA, EGA, CGA, MDA - on any display, be it digital monochrome, digital color, digital enhanced color, or analog display. A few adapters tackle this general problem but most will simply let you use any display in any video or adapter emulation mode that does not exceed the display's highest resolution. In order to use a display in a mode that has a resolution higher than its normal capability, the adapter must establish a scanning pattern that is interlaced. In general the appearance will be poor in quality with the image blurred, flickering and unsteady.

Many non-IBM VGA adapters provide a second 9-pin connector for output to any digital display in addition to the standard analog output. This is particularly useful if you have an older digital multi-frequency display that can support VGA resolutions. The digital outputs are limited to either 16 or 64 standard colors and will ignore software requests to reload the VGA palette registers. In many cases this will produce visually strange or unreadable images. When operating with digital outputs, some adapters may configure themselves as a corresponding EGA, CGA, or MDA while maintaining their VGA BIOS. This dual identity may confuse sophisticated software that carefully probes the functionality of the BIOS. DisplayMate will produce a message alerting you to this condition.

Auxiliary Outputs

While all compatible adapters provide a standard video output signal on the standard video output connector, many fail to provide the auxiliary outputs found on the IBM CGA, EGA, and VGA video adapters. If you make use of these outputs, double check that they are provided. The IBM CGA provides a composite video output on an RCA phono jack and connectors for a Light Pen and for an RF Modulator that allows direct connection to the antenna terminals of your home television.

The IBM EGA has a 32-pin Feature Connector, two auxiliary RCA phono jacks connected to the Feature Connector, and a connector for a Light Pen. The Feature Connector provides direct access to the board's internal signals. It is provided for interfacing with external special purpose hardware, such as advanced video adapters.

The IBM VGA adapter has a 26-pin Video Feature Connector that is similar in functionality but different from the 20-pin Auxiliary Video Extension Connector for IBM Micro Channel VGAs. A third form of VGA Pass-Through Connector has been defined by the Video Electronics Standards Association (VESA) that is pin-for-pin electrically compatible with the 26-pin IBM Video Feature Connector but is mechanically different. An adapter between these last two forms is a simple matter. All of these VGA connectors are used by advanced video boards such as those based on the IBM 8514/A or TI 340X0 to connect directly to the VGA hardware and to exchange digital and analog information with the VGA system. It can also be used to allow the VGA to use the advanced adapter's display. Note that there are two incompatible forms of VGA connectors: one for Micro Channel based computers and the other for AT/ISA/EISA based computers.

Adapter Software

Most non-IBM video adapters come with a variety of software programs to enhance and control features on the adapter. The quality, functionality, and speed of this software varies considerably. Many of these features are proprietary and found only on that model adapter, or on adapters by the same manufacturer. The software generally includes:

1. A diagnostic program that will hopefully test the video adapter hardware thoroughly, and make it easy to pin-point and correct problems.

2. A video mode utility that allows you to set both the standard IBM video modes as well as special modes available with that particular adapter.

3. A version of ANSI.SYS that supports the special modes on the adapter and is meant as a replacement for ANSI.SYS supplied by DOS. You can check for an ANSI.SYS driver by looking in the file CONFIG.SYS in the root directory of your primary disk drive.

4. A BIOS driver that installs the video BIOS, normally in ROM, into system RAM. On some computers, particularly 16-bit machines like 8086 PCs and 80286 ATs, this may noticeably speed up programs that make extensive use of

the BIOS. The driver will require somewhere between 16 and 32 KBytes of system memory. Use the DisplayMate *Speed Performance Tests* to decide if the speedup is worth the loss of memory. On 80386 and 80486 computers you should use the Shadow RAM facility provided by the system hardware and software, unless your adapter is set to allow automatic mode switching, which dynamically changes the video BIOS and must not be used with Shadowing RAM. Under these circumstances, you should follow the video board manufacturers instructions and use their driver.

5. Screen drivers to allow the use of enhanced resolution modes for certain popular programs like Windows, AutoCAD, WordPerfect, and Lotus 1-2-3. Each new release of an application program generally requires a new screen driver. Application programs without a driver will need to run in one of the unenhanced modes. You will find a significant variation in the speed performance of the drivers, depending on how well they are written. Often these drivers will not work perfectly and you will experience minor glitches using them.

6. Miscellaneous programs like screen blankers, font loaders, and editors.

Setup Switches

Most adapters include a block of miniature setup switches that must be set by the user to configure the adapter. These switches are generally located on the rear bracket and can be accessed without much difficulty. On a few adapters the switch block is internal to the card and you will have to open the computer and possibly remove the card in order to change any of those switches.

Mechanical Incompatibility

This was a more serious problem when video adapters were generally full size 13.2" long by 4.2" high cards. Sometimes the cards wouldn't fit inside the computer's slot cage for reasons as subtle as the chips being soldered too close to the edge of the card. This was the case for IBM's own MDA, which will not fit inside an IBM AT unless the AT's card support bracket is replaced with a PC style bracket. IBM's EGA has a piggyback card that increases the thickness of the adapter to the point where it may interfere with some adjacent cards.

Most current graphics adapters are generally undersized in height, length and thickness, so the above problems generally don't arise. However, there is a continuing problem from the use of 16-bit AT adapters in an 8-bit PC bus configuration, and the reverse, using 8-bit PC adapters in ATs. The connector or skirt on the bottom of the card may mechanically interfere with underlying system board components and connectors. ATs have two 8-bit slots to accommodate such cards and PCs generally have at least one slot that provides extra clearance. Finally, there are some undersized computers with small footprints that cannot accommodate standard size cards. Make sure the adapter card you select is small enough for your slot cage.

IBM versus Non-IBM

The IBM adapters are the original and defining hardware for the MDA, CGA, EGA, MCGA, and VGA video standards. Since it takes about a year for clone compatibles to appear after a new IBM product introduction, you will have no other brand to choose from initially. If you buy an IBM adapter, you are assured that any software you buy will run as it should, without any compatibility problems. The IBM adapters are well designed, reliable, and relatively bug free. On the other hand, IBM adapters are relatively slow, generally come with no options or enhancements, and are relatively expensive. In fact, late in the product cycle you can often buy non-IBM adapters for ¼ of the price IBM charges.

Although IBM adapters are by definition IBM compatible, they are often not fully hardware compatible with the earlier IBM video adapters they supercede. If you need 100% downward hardware compatibility then you will need a non-IBM adapter that includes additional compatibility circuitry. See the *Compatibility* section of Chapter 5 for additional information. Finally, many of the manufacturers of IBM compatible adapters have given their products features and capabilities beyond the original IBM standard, generally offering enhanced text and graphics modes, including Super VGA. Virtually all of them include a variety of software utilities to enhance and control the adapter.

Documentation

Something occasionally overlooked by both prospective purchasers and manufacturers alike is the quality of the documentation. Good documentation will save you installation time and help you get the functionality you need as painlessly and quickly as possible. The information needs to be clear, complete, and presented in an organized manner. Many manuals do a poor job of explaining the enhanced features available on the hardware, on how to use the software supplied with the hardware, and on detailed procedures for Trouble Shooting. Almost always missing is a comprehensive index, which is particularly important for locating obscure information.

Electromagnetic Interference

Most video adapters meet the more stringent FCC Class B emission standards for electromagnetic interference. We discuss the interference standards under a like named heading in the section *Selecting a Display,* below.

Technical Support

Most video adapter manufacturers provide unlimited telephone support. Many provide toll-free numbers, which means that if you are kept waiting on hold, it is at their expense, not yours. Good technical support is invaluable if you run into compatibility or other installation problems. Note that the technical support lines for some manufacturers are understaffed and perpetually busy. It may be a good idea to try calling before you buy. General customer service is useful for all other problems or requests for information.

Warranty and Repair

The details of manufacturers warranties vary considerably. A typical warranty for an adapter will be anywhere from one to five years, including both parts and labor. Out of warranty service is generally provided for a fixed fee of $50 to $100. Claimed turn around times vary from one day to two weeks. Of course, that can be a total disaster if you are dependent on your computer. Some manufacturers and retailers will provide a loaner adapter while yours is being repaired. With an overnight delivery service this will leave you out of commission for no more than 36 hours. If that is too long, then keep your old adapter around as a backup.

Selecting a Display

Before you begin this section you should already know which type of video adapter you will be using: MDA, CGA, HGC, HIC, EGA, MCGA, VGA. If not, then first refer to Chapter 5 on *Video Display System Basics*. Then, if you are considering a multi-frequency display, be sure to read the section by that name in Chapter 5.

The topics covered in this section on displays include: Hardware Compatibility, Controls, Internal Controls, Color Dot / Stripe Pitch, Video Bandwidth, Cables, Protection Circuitry, Size and Geometry, Mechanical Considerations, IBM versus Non-IBM, Documentation, Electromagnetic Interference, Safety, Technical Support, and Warranty and Repair.

Hardware Compatibility

Many displays are advertised as being EGA, CGA, and MDA compatible when all they are referring to are the software compatibility modes provided by the video adapter connected to the display. Make sure the display you buy is hardware compatible with your video adapter.

Controls

What are they and where are they located? The principal controls should be on the front and be conveniently adjustable. At the very least, they should include a Power On/Off switch and Brightness and Contrast controls. Occasionally, you will find them on the side, top, or back of the display and waste a lot of time groping and fumbling for them. We think the classic circular knob, dial, or thumb-wheel work best for finger adjustments, but you will find exotic controls such as balls, where it is not clear which axis or which direction to turn. Slide controls cannot be set as precisely as circular controls. Some of the more expensive displays may instead have buttons for digital control of the display characteristics. One particular advantage of digital controls for multiple mode displays found in EGA, MCGA, and VGA systems is that they generally have a memory feature, so that when the modes switch, you don't have to perpetually readjust the size and centering controls. This is especially advantageous for multi-frequency displays (see *Multi-Frequency Displays* in Chapter 5).

Most displays will have brightness and contrast controls that are quite similar in operation to the controls found on televisions. In some cases there is only a single "Picture" control that adjusts the brightness and contrast simultaneously. This will *not* allow the screen to be properly adjusted for all conditions and should be avoided. Some displays include a "Black Level" control that generally functions like a brightness control.

We also highly recommend separate vertical and horizontal size and position controls for CRT displays. Their use is intuitive and the only way you are sure to get a properly framed image. Some displays have neither; others have a multi-position horizontal size switch instead of a continuously variable size control. Some displays include a TV style vertical hold control. This should not be necessary and may indicate inadequate automatic synchronization circuitry.

A manual degaussing button is useful if you expect to leave your display on all the time. Degaussing restores color purity that has been degraded by variations in stray magnetic fields. Automatic degaussers work only when the display is turned on, provided it has been off for a reasonable length of time, like one-half hour.

Some color displays include a color switch that translates all non-black colors to a single color such as green, amber, or white. These monochrome modes may be more appealing to some users when working in text mode, such as in a word processor. Most color switches are found only on digital displays but a few analog displays will also perform this function. Many monochrome displays include a Reverse Video switch that inverts the image from the common white text on a black background to the paper style black text on a white background (or vice versa).

A number of the better quality displays are now including an external user control to help correct pincushion distortion, a common form of screen geometric distortion. Some expensive displays also include horizontal and vertical static convergence controls that allow you to touch up the overall color registration on the screen. Since color registration is never perfect, this allows the user to minimize whatever bothers him or her the most.

Internal Controls

Many displays contain internal controls that allow qualified service technicians to adjust the display. These are very desirable because they allow convenient and inexpensive field adjustments for problems commonly found in new displays after shipment or after the display ages over time. The controls may adjust pincushion distortion, geometric linearity, and focus. Displays that do not include external size and centering controls may include them internally. Multiple mode displays for the EGA, MCGA, and VGA generally include special size controls to balance the modes. Some color displays will also include convergence controls to adjust color registration. *Warning:* internal controls are only for qualified technicians; unqualified personnel are not only likely to misadjust the display further, but may seriously injure themselves from the lethal high voltages present in most displays.

Color Dot / Stripe Pitch

In almost all color displays the screen is made up of tiny red, green, and blue phosphor elements arranged in a regular pattern. The spacing between adjacent sets of red, green, and blue colors is referred to as the pitch of the display screen. The phosphors are arranged as stripes or triads of dots depending on how the display is manufactured.

On non-CRT displays there is one set of colors for each pixel, so the pitch is fixed by the size of the display and the resolution. For a display that is 8.5 inches wide, the pitch for most IBM compatible displays will be about 0.34 mm, which may be noticeable. On CRT displays the pitch varies and depends on cost: values currently range from about 0.20 mm to 0.75 mm, with the smaller values found on the best 14" displays, and the larger ones on cheaper displays or on large screen displays that are not expected to be looked at closely.

For CRTs there is a common misconception that a satisfactory image is produced when the number of color phosphor sets equals the display's resolution. This is not the case, because the image pixels are never perfectly aligned with the phosphor elements on the screen. Under these circumstances the alignment periodically worsens and improves and, as a result, gives rise to wispy and wavy visual patterns that appear superimposed upon the image. These disturbing Moire patterns have been discussed previously in Chapters 4, 5, and 7, and DisplayMate includes 5 tests for them.

In order to reduce the Moire patterns and the graininess of the image, it is necessary that the screen pitch be substantially smaller than the spacing between image pixels, so that as many color sets as possible are illuminated by each pixel. To eliminate these visual effects, the pitch may have to be as much as 2.6 times smaller than the pixel spacing. The actual value depends on the details of the screen and shadow mask geometry.

Few displays will have a pitch small enough to eliminate these effects entirely, so most will have some degree of Moire interference. In some cases the manufacturer may increase the beam spot size and thereby decrease the image resolution of the display. This trades off one bad effect for another, so if you don't see a Moire pattern, then check the screen resolution with DisplayMate.

The real test for these effects is visual, with DisplayMate. However, you can estimate them beforehand by comparing the ratio of the pixel spacing to the pitch. To calculate the pixel spacing in units of millimeters, first measure the width of the image area on the screen. This will generally be about 1 inch smaller than the total width of the screen. If your measurement is in inches, multiply by 25.4 in order to convert to mm. If you are attempting to calculate this from a specification sheet, look for an item like "viewing area" or "active display size." If only the diagonal size of the screen is available, multiply that number by 0.8 and subtract 1 inch for the screen border. If your measurement is in inches, multiply by 25.4 in order to convert to mm. Now divide this width in mm by 640, which is the highest resolution for the standard IBM color modes. This number will be the pixel spacing in mm. Finally, divide this number by the pitch for the display specified by the manufacturer, universally specified in mm. Almost all values will lie in the range of 1 to 2; the larger the better.

Video Bandwidth

The video bandwidth specifies the display's ability to accurately reproduce the transitions in the video signal coming from the video adapter, and is a major determining factor in the display's image resolution (see *Screen Resolution* in Chapter 7). The higher the video bandwidth the sharper the image, provided, of course, other factors such as focus, convergence, *etc.*, are in good condition. If you are planning to work in reverse video, pay particular attention to the video bandwidth specification, because it also affects the contrast ratio.

The most common manner of specifying video bandwidth is in terms of the maximum rate at which the display can accept pixels, which is technically referred to as the dot clock rate or the pixel frequency. If this rate is exceeded, the image will appear increasingly fuzzy and smooth. This form of video bandwidth specification is somewhat arbitrary because the degree of image degradation at the stated value is left to the judgment of the manufacturer. This specification may actually be listed under the title of "video bandwidth" instead of under "dot clock rate" or "pixel frequency," which is a misnomer because it is a rate and not a bandwidth. The dot clock rates for the standard adapters are shown in Table 8.1.

Adapter	Dot Clock Rate	Video Bandwidth
MDA	16.257 MHz	24 MHz, −3 db
CGA	14.318	21
HGC	16.000	24
EGA	16.257	24
HIC	19.000	29
MCGA	25.175	38
VGA	28.322	42

Table 8.1 *Video Dot Clock Rates and Bandwidths.*

Specifying the bandwidth of the display's video amplifiers is the true objective measure of video bandwidth, and many high quality displays will include it on their specification sheets. The video amplifier bandwidth is specified in the same way as for an audio amplifier in a stereo system: the frequency at which the response falls by 3 decibels, abbreviated as −3 db.

The minimum satisfactory video bandwidth for each of the video systems is shown in Table 8.1. If the manufacturer's specification does not include "−3 db," then it either refers to the dot clock rate or is a meaningless bandwidth specification. If the bandwidth is lower than the value in the table, the image will appear increasingly fuzzy and smooth; if the bandwidth is higher, the image will appear somewhat sharper.

For non-standard video modes you can estimate the needed video bandwidth in the following manner: the video frequency is half the dot clock rate because there are two pixels per cycle. In order to generate a visually sharp edge on a pixel, the third-harmonic frequency should be reproduced; there are no even harmonics. Therefore, the reference video bandwidth for a video display is:

$$\text{Video Bandwidth} = 1.5 \times \text{Dot Clock Rate}, \quad (\text{at } -3 \text{ db}).$$

The dot clock rate is often the same as the frequency of the crystal oscillator on the video adapter board. Crystals are generally bright metal cans with a frequency in "MHz" printed on top. If there is more than one crystal, use the highest value.

Cables

Each of the video systems requires a different video cable and connector. Exceptions are: (1) the VGA and MCGA cables are identical; (2) the EGA and Hercules InColor card use the same cable; (3) the MDA and Hercules Monochrome cards can use a CGA cable but not vice versa. The VGA and MCGA require a sub-miniature 15-pin D-shell connector; all the others need 9-pin D-shell connectors. If you are buying a multi-frequency display, make sure it comes with the appropriate 15-pin to 9-pin adapter(s). If you have an Apple Macintosh make sure you get the appropriate 15-pin adapter for it.

Both power and signal cables should be detachable from the back of the display and should be at least 6 feet in length. By the way, some displays do not come with a video cable included, others may have only a 3 foot long cable. Make sure the video cable will reach your system unit; it's better and cheaper not to have to buy extension cables. Image quality may degrade with extension cables.

On most digital video systems (MDA, CGA, EGA, Hercules) you can generally get away with at least one 6 foot extension, but for some adapter/display combinations you may not be able to use any extension cable without experiencing dropouts, lags, or crosstalk on the color or synchronization signals.

On analog video systems (MCGA, VGA) you may be able to go as far as 100 feet with good quality low loss cable. Analog cables should always include a 75 ohm coaxial cable for each of the three video channels bundled together within the body of the main cable. On the longer runs you will experience a loss of signal, and therefore contrast, which can often be corrected with the display's own brightness and contrast controls. For these, it is better to switch from the single bundled cable attached to the 15-pin D-shell connectors to a set of individual large diameter RG59/U low loss coaxial cables with BNC connectors at each end. Then obtain a set of adapters from the BNC connectors to the 15-pin D-shell connector. The maximum satisfactory distance will most likely depend upon the quality of the synchronization signals, which are TTL digital and not 75 ohms, so they may degrade more rapidly with distance.

The best and most expensive way to arrange for extensions up to 200 feet is to use distribution amplifiers that are specifically designed for this purpose. Two units are necessary: one by the computer and the other by the display. A special cable connects both units.

Some of the more expensive analog VGA/MCGA displays include inputs from both BNC and 15-pin D-shell connectors. Some also allow you to switch the 75 ohm termination on or off. This is required if you want to connect more than one display to your video adapter, as there can only be one termination on the line. To do this, connect the displays in a daisy chain; the last display in the chain must have its termination on, all others must be off. Again, the more expensive displays will provide special loop-through bridging connectors to accomplish this easily: one for the input side and one for continuing the chain. With good quality loop-throughs you should be able to bridge many displays together without a noticeable degradation in image quality. If your display doesn't provide a loop-through connection, then a "T" BNC connector should prove satisfactory.

Make sure your cables are shielded, otherwise you may violate FCC regulations for the generation of interference with radio and television reception (see below).

Protection Circuitry

One important feature to lookout for is the existence of protection circuits in the display to prevent damage to the screen phosphor and to the scanning circuits in the event of a hardware, software, or operational problem. Some poorly designed displays, including IBM's own MDA, lack these circuits. Displays without this feature may simply include a warning in their documentation about damage to the display under specified conditions. Sometimes displays with this feature make no mention of it at all. Display scanning can fail due to a hardware malfunction, connecting the display to the wrong adapter, attempting to operate a display in a non-standard video mode that is outside its scanning frequency limits, incorrect adapter programming, or improper cabling, including a disconnected cable. Under these circumstances the protection circuitry will prevent permanent damage to the display due to excessive currents or voltages. Scanning failure may also cause permanent damage to the screen phosphors by overheating or burning them. Under these circumstances the protection circuits instantly turn off the CRT beam.

Size and Geometry

The display should be appropriately sized for your work area. Make sure there is enough space and clearance to accommodate the display, particularly if there is a wall or isle behind your desk. With insufficient depth, the front of the display may be too close to your face or not allow sufficient space for your keyboard and palm rests. If depth is critical, look for CRTs with the highest deflection angle, typically 110°; they will have depths that are 3" to 5" smaller than the lowest 75° units. Note that most CRTs are 90° and that image quality tends to be better for the low angle deflections. Of course, the ultimate solution is a flat panel display that has virtually no depth.

If the display has a pedestal it should tilt and swivel over a range large enough to accommodate user preferences. The pedestal for the display should be as low as possible because you can easily raise a display if needed but you generally can't lower it without switching tables.

Screen sizes are measured diagonally. Don't be fooled by exaggerated screen sizes listed by many manufacturers. You will often see the screen size listed as "14 inches (13V)." The "V" code means Viewable screen diagonal in inches, as established by Electronic Industries Association, and is the real size, 13 inches, not the more prominent 14 inch value. The screen height will be 60% of the diagonal length, and the width 80%. The outer periphery of the screen is generally not usable; expect the active display area to be ½" to 1" smaller on 13" to 25" displays. For example: a 13" diagonal screen will have an active display area of about 7" by 9". Geometric and other distortions sometimes increase rapidly near the screen corners. Size controls will allow you to reduce the image size and thereby improve its appearance.

Mechanical Considerations

Most CRTs are quite heavy in addition to being bulky, with 13" to 19" CRT color displays weighing in the 30 to 70 pound range. A 25" color display will weigh about 100 pounds. For a given screen size, monochrome displays typically weigh half of what a color display does. The bulk and weight tend to discourage users from adjusting or moving their displays. Power dissipation is generally between 50 and 100 watts, although small 12" monochrome displays may dissipate as little as 25 watts, and large 25" color displays as much as 200 watts. The displays can get quite warm and may include noticeably noisy fans.

IBM versus Non-IBM

The displays IBM sells are good but they are certainly not the best in video display image quality. The prices of IBM displays are also relatively high. For non-IBM displays, the compatibility question is relatively straight forward and unlikely to be a problem. The primary reason for selecting an IBM display is the general advantage of dealing with a reliable single source to integrate your system, if your computer is an IBM. Also important is the reliability of their field service and (for some) the styling and appearance of the display cabinet. Right after a new product introduction, there are unlikely to be any compatible displays available, as was the case right after the VGA was announced. These considerations aside, it is relatively simple to select a display - let your eyes be the judge and shop around using DisplayMate.

Documentation

The documentation required for displays is much simpler than for adapters. Most manuals will discuss installation and explain the controls and switches on the display. We are not aware of any that will tell you how to adjust the brightness, contrast, or size controls properly. Often missing is a useful trouble shooting section.

Electromagnetic Interference

All computer equipment, including peripherals, generates a broad spectrum of radio frequency energy that may cause interference with radio and television reception and communications. As a result, all such equipment offered for sale in the United States is regulated by the Federal Communications Commission and must meet emission limits set by the FCC. Under FCC regulations, computer users are required to take whatever steps are necessary to correct interference problems at their own expense, and must discontinue using the offending equipment until the interference is eliminated. As a separate but related issue, different devices in a computer may interfere with one another or with other nearby equipment. We discuss methods for resolving these problems in *Screen Interference Problems,* in Chapter 9.

All computer equipment and peripherals are classified as either Class A or Class B, and must carry a permanent sticker identifying its classification, and include a warning statement in the instruction manual. The maximum emission by Class A devices is about 30 times greater than class B devices, so they are much more likely to cause interference. According to FCC regulations, a Class A device may be sold only to users in a commercial, industrial, or business environment. It may not be sold to anyone who indicates that the product will be used in a residential environment, including a home business.

Most video displays sold meet the more stringent Class B classification; however, many of the specialized large screen displays will carry a Class A rating. If you do not see a Class A warning on product information, you can conclude that the equipment is Class B because of the marketing restrictions for Class A devices; however, you may wish to check this explicitly to be sure.

Bear in mind that if you have an interference problem the equipment manufacturer is obligated to help you solve the problem only to the extent of assuring that the equipment complies with the maximum allowed emissions. Most manufacturers will provide help over and above this requirement.

Safety

Products from reputable manufacturers generally pass all required safety regulations. In the United States, electrical safety and implosion safety are specified by Underwriters Laboratories, UL. In Canada, safety requirements are specified by the CSA, and in Europe by the VDE and IEC. In the United States, X-ray safety for CRT displays is regulated by the U.S. Department of Health and Human Services, Bureau of Radiological Health.

Technical Support

From an operational point of view, displays are comparatively simple and require much less technical support than adapters. Your dealer is probably the best source of support for the occasional defective units and installation problems. The more difficult problem with displays concerns the quality of their image. We discuss this below, in the section on *Buying a Video Display*. Most display manufacturers provide telephone support, but primarily for dealing with repairs, and for general customer service, which is useful for all other problems or requests for information.

Warranty and Repair

The details of manufacturers warranties vary considerably. A typical warranty for a display will include a two year warranty for the CRT display tube, a one or two year warranty for all other parts, and one year covering labor. Generally, you must pay shipping charges both to and from the manufacturers service facility. Some manufacturers include a network of authorized service centers that may prove more convenient and expeditious. Typical turn around times will vary from three days to four weeks, but even this can vary considerably.

Out of warranty factory service, or factory authorized service, is provided at time and materials, with a cost generally ranging up to $100 per hour (IBM charges about $200 per hour), or for a flat fee such as $250 that often represents one-quarter to one-half of the new purchase price. One reason why the cost is so high is that the units are seldom actually repaired: generally one or more "field replaceable units" are substituted until the display works again. The only original part of your display that you get back may be the cabinet.

With such a high repair cost you may decide to simply buy a new unit or have it repaired at an independent service center. Some television repair shops may be able to repair some computer displays. Note that if you have your unit repaired at a service center there is a possibility that it may not work as well as it did originally, because service centers cannot duplicate the specialized and expensive test and alignment equipment and procedures used by the factory.

Buying Video Hardware

The information presented here on buying video hardware is provided to help those with little experience in purchasing computer equipment. It is meant only as a supplement to your own buying skills, and by no means covers all aspects of purchasing equipment.

There are four principal sales channels for PC computer hardware. Each provides a different degree of service and cost:

Systems House or Value Added Reseller: If you have more money than either time or computer expertise, then a systems house or value added reseller is where you need to buy your computer system. Systems houses generally design, develop, integrate, and install a complete computer system or facility to meet a client's unique operational specifications. Their services may include the customized design and development of specialized hardware and software, and possibly the construction or renovation of the actual facility. A value added reseller will generally provide a complete computer system or subsystem that performs a specific specialized task. Their product generally includes both hardware and software that has either been specifically configured, modified, or is proprietary.

Manufacturer's Direct Sales: Many computers and some video displays and adapters are sold only by the manufacturer directly to the end user. They advertise extensively in computer magazines and through direct mail campaigns, and in many cases will be the cheapest avenue for buying hardware. You generally deal with them only by mail and telephone, so our discussion of mail order houses below applies to them also. Often a major selling point is the availability of prompt, expert, and high quality toll-free telephone support. You may want to try out their telephone support services before purchase to see if this is actually the case. In some cases they also offer on-site service through one of the companies that specializes in that task. For large corporate accounts a manufacturer's direct sales program will be totally different in nature, generally offering large quantity discounts together with a full line of services including on-site sales and support.

Store Front Dealer: A good dealer will have a large selection of computer hardware and software on display for your inspection. You will be able to demo, test, and compare different combinations of hardware and software. Whether you are a novice or an expert, knowledgeable and helpful sales people will be able to offer appropriate advice, answer compatibility and functionality questions, and guide your selection. If you're buying a system, they will be able to fully integrate it for you, accept responsibility for compatibility issues and other problems that may arise, install and test all the software, possibly set it up at your location, show you the basics of using the system, and provide follow up support to get you through start-up problems. Unfortunately, dealers like these are becoming harder and harder to find. Good quality service and advice are valuable, and you should expect to pay more for anything you buy this way.

It is not uncommon for dealers to provide discounts of 20% to 33% off the manufacturers suggested list price, which is often set to allow for this kind of discounting. If the dealer is providing special services, then expect smaller discounts; if you are paying list price insist on the royal carpet treatment. Because of low margins and high carrying costs, many dealers will have only a limited selection of hardware and software on display. If your dealer is providing the equivalent of a high-priced mail order service for you, then you may be better off dealing with an actual mail order house.

Mail Order House: An increasingly large fraction of computer hardware and software is sold by mail order. A major advantage is that prices are often low, the selection often quite large, and delivery in many instances can be the very next morning. A major disadvantage is that you cannot see or try before you buy; however, many computer magazines provide extensive product reviews that may provide sufficient information to let you make a purchase decision. Some mail order houses provide excellent technical sales support that may answer hardware and software functionality and compatibility questions that you may have. Many manufacturers will also provide this kind of telephone technical support. While you must pay for shipping, you generally don't pay sales tax if it is an out of state purchase. If anything does go wrong you will most likely wind up paying for more rounds of shipping than you had anticipated. If the company is not cooperative, then waging a battle over great distances will place you at a disadvantage.

Purchasing Information

The following discussion applies to both dealer and mail order purchases:

Some large mail-order houses and chain-stores also sell their own private brand of video adapters and displays, often at substantial discounts. In many cases they will simply be a repackaged version of a standard brand, or a reduced feature version of a standard brand model. The biggest discounts and uncertainties will come from products manufactured by unknown factories somewhere in the Far East. Sometimes you will be able to find out the pedigree of the hardware; this is particularly important for video adapters because of the compatibility issue. In any case, try to arrange for a return privilege.

In general, the more heavily discounted the merchandise, the fewer the services and amenities you are likely to receive. Unfortunately, the reverse does not necessarily hold true.

You should ask whether the equipment carries the full U.S. warranty, either the manufacturer's or its authorized importer. If not, find out the terms and conditions of the warranty you will be offered. For some brands, such as IBM, you must purchase from an authorized dealer in order to receive the manufacturer's warranty. Foreign made equipment that is not obtained through the manufacturer's authorized importer, generally referred to as gray market goods, will not carry their warranty and may not have manuals printed in English. Some companies, particularly the heavy discounters, will mark all sales final, meaning if the unit arrives dead or defective you cannot return it, but must send it to the manufacturer yourself for repair. Other companies will replace defective merchandise within a specified period after the purchase, but not necessarily with a factory fresh unit. After this initial return period, some companies will handle warranty repairs for another specified period of time. This may be less trouble than locating your own authorized factory repair. It may even be quicker if they swap the unit for you.

Find out if the item is in stock. If not, then find out when it will become available and whether you will be charged immediately or on the actual delivery or shipping date. If the item is to be shipped, find out when. The shipping and handling costs may be as little as the actual shipping charges by the carrier or as much as 10% of the price of the goods. In general, it is better to pay by credit card because you have greater leverage and legal protection if something goes wrong. Some companies do not charge extra for credit cards, while others will charge between 2% and 5% for charging your purchase.

Find out if all sales are factory fresh merchandise. If not, and the company has a liberal return policy, you may get someone else's return. Return policies for non-defective equipment vary substantially. Find out if you can return merchandise if there is a compatibility problem, or if you don't like what you bought. There will be a specific time limit, if it is allowed. Many companies will charge a 5% to 20% restocking fee if you return non-defective merchandise for any reason. Most will not refund the shipping and handling charges.

Buying a Video Display Adapter

Once you have decided on which adapter you want, actually buying one is relatively easy and uncomplicated. There is generally little sample-to-sample qualitative variation for a particular make and model of adapter. They generally arrive in good working order and run trouble free for a long time; that is why it is easy for manufacturers to offer such long warranties on video adapters. What you do need to watch out for is that you get the latest versions of the video BIOS and software that generally come with non-IBM video adapters.

The BIOS chip will be among the larger chips on the adapter board. It is generally socketed, and has a sticker with a version number and date covering a window that is used to erase the software on the chip and allow it to be reprogrammed. The software diskette should have a version number displayed on its label; otherwise you will need to list the dates for the files in the diskette by typing "dir". DisplayMate can, in most cases, provide the BIOS copyright date and version number, if present. This information is available in the *Video Systems Information* screen in the *Hardware and Mode Information* selection in the *Technical Program.*

Check with the manufacturer to find out what the latest version numbers are, if you haven't already done so. Generally, dealers won't know this, and also won't know the version number for the stock sealed in a box. In all likelihood, you will have to try to get the updates from the manufacturer yourself. The final step is checking for compatibility by running DisplayMate and your applications software. If there is a problem, you should already know what your options are with respect to the dealer and manufacturer.

Buying a Video Display

Deciding which make and model video display you want may be the easiest part of buying a video display. There is often a considerable sample-to-sample variation in displays, so the hard part is unpacking your unit and deciding whether it is properly aligned and meets your expectations. If you bought the display from a storefront dealer and the floor sample is better than your unit, you might try cajoling them into swapping units with you. Your initial best bet is relying on the goodwill of the dealer or manufacturer to help remedy the situation. Know and arrange your options before you buy. If all else fails, you have two final options:

1. Return the unit, pay any restocking fee, and consider playing pot luck again.

2. Have the unit adjusted and aligned at your own expense. The cost should be $50 to $100.

It is a serious mistake to live with a video display that you are not happy with, and that may cause you eye strain and a loss in productivity. You may wish to include the cost of alignment as part of the budget for purchasing the display.

In the end you will likely have a better than average unit for the purchase price you are paying. This will partly offset the cost of alignment and reduce the risks of buying an unsatisfactory display.

Chapter 9

Maintaining Your Display

Introduction

Keeping your display in tip-top condition is necessary in order to continue to realize maximum user comfort and productivity, in addition to prolonging the display's useful life and getting the most from your investment. These issues are often overlooked by most video display users, yet they can be as important as choosing the right display.

There is no comparable chapter on maintaining your video adapter because generally nothing can be done for an adapter card except return it to the manufacturer for repair. If you are experiencing trouble, see the section on *Video Display System Trouble Shooting* in the *In Case of Difficulty* chapter near the end of this manual. Before sending an adapter in for repair, see the *Technical Support* and *Warranty and Repair* sections for video adapters in Chapter 8.

The topics covered in this chapter include: Screen Cleaning, Display Setup, Life Expectancy, Drift, Phosphor Burn, Aging, Field Service Adjustments, and Repair Service. Also included is a section on dealing with *Screen Interference Problems*.

Screen Cleaning

Screen cleaning is the easiest and possibly the most important aspect of regular maintenance. If you like to point with your fingers on the screen, you may need to do this daily, otherwise whenever there is a noticeable accumulation of dust or stains. The faceplate of most CRTs attracts superfine particles suspended in the air that may coat the screens so uniformly that you are not likely to notice the buildup. In general, it is best to clean your display first thing every Monday morning. In the absence of specific manufacturer's instructions, ordinary glass cleaner and paper towels should do fine. Spray the liquid onto the paper towel, not the screen, so that the drippings don't seep inside the display or stain bezel or other plastic parts.

The anti-glare coatings on some screens are delicate and may easily scratch or even rub off under excessive pressure. The hardest screens to clean are those with anti-reflection coatings that absorb oils, particularly finger prints, which give them a multi-color iridescent appearance. With those you may need to clean the screen several times before all the streaks disappear. There are also special cleaning kits with anti-static cleaner and soft lint-free cloths. The anti-static liquid may slow down the build up of dirt. Most of the time the kits come with an insufficient number of cloths.

Display Setup

Adjusting the controls on the display is something you also will need to do regularly. If the room lighting changes, you will need to adjust the screen brightness and contrast. The display itself is subject to drift, possibly over a period of hours, often requiring minor adjustments for centering and brightness. The fastest way to readjust the display is to call up the DisplayMate master Test Pattern by typing "dmu tp". By adding this command to the end of your AUTOEXEC.BAT file, you will obtain the test pattern every time the system is turned on. Further information on the test pattern command is provided in Chapter 4. Note that drift on the display is generally the greatest right after it is turned on, so you may wish to consider leaving your display on as much as possible, as discussed in the next section.

Life Expectancy

There are a number of simple things you can do to increase the life of your display: first is maintaining good ventilation in order to minimize the display's internal temperature. Keep all of the ventilation holes and slots free and clear, and never place papers or anything else on top of the display. If you notice dirt accumulating on the openings, then vacuum them clean.

Power line spike and surge protectors should not be necessary for well designed computer equipment, but they certainly don't hurt. Every once in a long while they may contribute to saving the life of your display or computer; for example, if lightning strikes nearby. If you experience periodic picture shrinkage on your display, then plug your computer into a power outlet that is controlled by a different circuit breaker or fuse. If you have recurring problems or experience other forms of power line interference, then do *not* rely on a spike or surge protector, but rather have the problem investigated by an electrician or an electronics technician.

Unless you have specific instructions to the contrary, it is generally a better bet to leave your display on as much as possible in order to prolong its life. Keep in mind that this is a general recommendation for most electronic equipment, so it applies only in the statistical average. High quality professional equipment is often left on permanently. You need not go to this extreme; however, it is better not to turn your display on and off more than once or twice a day. In many cases you may wish to consider leaving your display on all the time, except when you are away for extended periods of time.

The basis for this recommendation is that each time you turn your display on or off, voltage instabilities and current surges that stress some components may occur as the power ramps up or down. Temperature cycles inside individual components, as well as within the entire piece of equipment, may stress and prematurely age some components. In some cases poor quality electrical connections may fail or become intermittent. On the other hand, a long term exposure to heat causes the gradual deterioration of such things as the insulation used in components and circuits. This can change the values of some components in addition to increasing current leakage, and the likelihood of an outright failure. However, in a well designed display this should not be a problem. The cost of electricity for operating a display is small, about 16 cents per day for a typical 65 watt display if left on continuously (assuming 10 cents per kilowatt hour).

Drift

An additional and important reason for leaving your display on as much as possible is that most CRT displays will experience their greatest drift when first turned on. Many will require at least 30 minutes to an hour in order to stabilize completely. During this period the image centering and black level or screen brightness will often vary the most, and affect readability and user comfort. Other parameters, such as focus, may not be optimal during warm up. If you leave your color display on continuously, then press the manual degaussing button once a week if you have one. This should restore any gradual loss in color purity. Otherwise, turn your display off for at least half an hour from time-to-time in order to activate automatic degaussing the next time the display is turned on. If the color purity on the screen deteriorates, then perform degaussing as needed.

Phosphor Burn

All phosphors used in displays are subject to burn and to a loss of efficiency with time. Phosphor burn is seen as a patterned discoloration on the screen when the display is turned off, often in the form of stripes from recurring text output. A reduction in phosphor efficiency will occur slowly over a period of time, and may be noticeable as a pattern of reduced light output on the screen during the *Screen Uniformity Test*. If you make extensive use of a program that produces a structured output, then that pattern also will become embedded in the screen over time. While color displays are highly resistant to these problems, some long persistence phosphors used in monochrome displays are more susceptible to burn. The glass in some monochrome displays is also subject to discoloration.

If you leave your computer and display on most of the time, you may wish to use a screen blanking program to minimize the possibility of screen phosphor burn or a reduction in the efficiency of phosphor light output. A simple program that you invoke from the command line when you leave for lunch or for the day may be all you need. Use a memory resident (TSR) screen blanking program when convenience or security reasons are important factors. They will automatically blank the screen if they don't detect any screen or keyboard activity for a specific period of time. They also will let you manually blank the screen at any time, including from within an application program, by pressing a specific combination of keys. Note that a TSR program takes up memory, reduces video performance, may cause software conflicts, or become a nuisance by turning off the display when you don't want it to.

Aging

All electronic equipment ages, but the aging process is most easily seen in video displays where qualitative differences matter. It arises from the variation of certain electronic components with time, and from a gradual deterioration of the precise mechanical configuration and alignment of certain assemblies in the display. This deterioration process will be accelerated by frequent rough handling in shipment, or by frequently turning the display on and off. Some of these effects can be corrected by using the external user controls such as brightness, contrast, size, and centering. The changes may occur so slowly that you are unlikely to notice them if you frequently adjust these controls to optimize the setup of your display. In other cases, such as changes in focus or color registration, field service adjustments to the display will be required, as described in the section below.

Time is often particularly cruel to power supplies, which are the source of many problems and outright failures in video displays. Power supply problems may give rise to picture shrinkage and a decrease in screen brightness. A malfunctioning power supply may produce rippled output that will show up on the screen as flicker, or as an ever changing regular pattern superimposed on the normal screen image. Another common problem associated with power supplies is the appearance of hum bars, which appear as horizontal bars that slowly roll up the screen. They may brighten or darken the affected area of the screen as they roll by. In VGA and MCGA displays, hum bars will be most apparent in the high resolution graphics modes (modes 17 and 18); otherwise they will appear as a 10 cycle per second flicker for the other modes. Adjusting or replacing the power supply will generally solve these problems; however, the problem may originate in either the computer's power supply or the display's power supply.

Screen brightness is also likely to decrease with time, so purchase a screen with a brightness higher than what you really need. In CRT displays, the screen brightness will decrease slowly with time due to a reduction in the efficiency of the cathode (the "C" in CRT), and also the efficiency of the screen phosphors. In portable computers with LCD displays, another source of aging is the fluorescent tubes that backlight most displays, which may deteriorate slowly with time.

As displays age or malfunction they may begin producing hums, squeals, and fan noise. In addition to being annoying and disruptive to the user, the appearance of these sounds is often an indication that something more serious is the matter. Hums and squeals generally arise from the CRT deflection coils or from the power supply. The noise may merely indicate that something has come loose or, more likely, that the coils have deteriorated and are vibrating due to magnetostriction. Fan noise may indicate a problem with the fan motor or bearings, and may cause the fan itself to overheat. A reduced air flow will cause the display to overheat. Either case is dangerous and should be attended to immediately. Finally, if the insulation breaks down in the high voltage circuits of a CRT, a buzzing or crackling sound from corona discharge may be heard.

Field Service Adjustments

If your display is not performing satisfactorily you should try to have it adjusted. Many users wind up tolerating displays that are not performing up to par, without recognizing that they are hurting themselves as well as reducing their productivity. Most displays contain internal controls that allow qualified service technicians to correct problems commonly found in new displays after shipment, or after the display ages with time. The controls may allow adjustments for geometric distortion, focus, color registration, range limits for brightness and contrast, power supply voltage, and other special purpose adjustments. Displays that do not include external size and centering controls may include them internally.

Of course, nothing may be able to improve an inexpensive and low quality display, but if your display is not performing as well as when it was new, or if it does not perform as well as others of the same make and model, like the dealer sample that convinced you to buy it in the first place, then arrange for a field service adjustment. Finding someone qualified, and also willing, to adjust your display may not always be easy, since many service technicians will only swap component assemblies. A good television service center may be able to perform these adjustments provided they are familiar with computer displays. In most cases, using a service facility not authorized by the manufacturer will void your warranty. The cost of field service is likely to run between $50 and $100 per hour, but the work should not take more than one hour. *Warning:* internal controls are only for qualified technicians; unqualified personnel are not only likely to misadjust the display further but may seriously injure themselves from the lethal high voltages inside a display.

Repair Service

A display that is malfunctioning, or for which *Field Service Adjustments* are unsatisfactory or unavailable, will require servicing. A display also needs servicing if it is behaving in a strange manner, changes any of its characteristics rapidly, produces humming or crackling sounds, gives off a burning odor, becomes unusually hot, or produces smoke. Out of warranty factory service, or factory authorized service, is provided on a time and materials basis, with a cost generally ranging up to $100 per hour (IBM charges about $200 per hour), or for a flat fee such as $250 that often represents one-quarter to one-half of the new purchase price. One reason why the cost is so high is that the units are seldom actually repaired; generally one or more "field replacement units" are substituted until the display works again. The only original part of your display that you get back may be the cabinet.

With such a high repair cost you may decide to simply buy a new unit or have it repaired at an "independent" service center. Some television repair shops may be able to repair some computer displays. Note that if you have your unit repaired at a service center there is a possibility that after it is repaired it may not work as well as it did originally, because service centers cannot duplicate the specialized and expensive test and alignment equipment and procedures used by the factory.

Screen Interference Problems

Interference is anything visible on the screen that ought not to be there. That can include electrical interference from the computer itself, from other nearby displays, and various forms of noise from the power line. It can also arise from problems within the display's own power supply and electronics, and from improper or unshielded video cables. This kind of interference modulates the image, often producing spikes or waves on the screen, and is often very disturbing.

Other interference problems may simply be unwelcome shortcomings or side effects of your video system: on CGA systems, screen snow and scrolling flicker are the result of limitations in the video adapter hardware; on MDA systems the afterimage is the result of long persistence phosphors used to reduce flicker. Less pathological, but just as disturbing, are the wispy Moire patterns that arise in color displays due to an insufficient number of color dots on the screen; see Chapters 5 and 8.

You can use DisplayMate to help track down the source of interference in a number of ways:

1. First determine if the interference affects all colors equally, or if it is restricted to just a few colors. Select an appropriate test screen such as *Screen Uniformity and Flicker,* the first test in the *Video Obstacle Course.* Examine the primary colors in turn: red, green, and blue. A secondary color should be affected if either of its constituent primary colors is affected. In most instances the interference will not be color dependent; if it is, then concentrate on those colors in the tests.

2. Most interference problems are more apparent if the screen is in a reverse video mode or has a non-black background color. Low intensity colors will generally increase the sensitivity to interference. Use the Function keys <F1> to <F6> to adjust the screen colors and the normal/reverse video mode, to bring out the interference problem you are experiencing. Also try the test screen *Freedom from Background Interference,* the second test in the *Video Obstacle Course.* In this test the colors are fixed, so the Function keys will be inoperative.

3. The first step is to determine if something is the matter with your video cable. First check the connectors at both ends of the cable, unplug and then reseat each in turn. Tighten any anchoring screws on the connectors, and then wiggle the cable to check for a loose wire or connection. The grounding or shielding on the cable may be the problem; if you have another brand of cable, then try it instead. If you are using an extension cable, remove it and connect the display directly to the computer. If that solves the problem, then see the section on *Cables* in Chapter 8.

4. The next easiest step is to swap displays with another computer. If your original display still shows interference, or the swapped display shows no interference, then your display is at fault and requires servicing.

5. The next step is to determine whether the source of interference is external to your computer system. Make sure you keep loudspeakers away from your video display, particularly if it is color, because the fringing magnetic field from the strong internal magnets may affect the color purity of the display. First, turn off as many external pieces of computer equipment as possible in your immediate area. This should include printers, scanners, tape units, external disk drives, cd-roms, modems, and especially other computers and displays. Also turn off televisions, stereos, fluorescent lighting, and other equipment and machinery that can produce interference. If this solves the problem, then cycle through each one to find the culprit and have it serviced to eliminate the problem.

6. The interference may enter your system via the power line. To determine whether this is the case, plug your computer into a power outlet that is controlled by a different circuit breaker or fuse. You may need to use a long extension cord for this test. If the problem affects your entire building, then you may need to move the entire system elsewhere in order to establish this as the cause. If the interference is periodic, suspect things like a furnace or refrigerator. If it is aperiodic, then jot down the times in order to help track down the source. Something as innocuous as a faulty switch could be the source of your problem. Equipment that causes large amounts of interference may require adjustment or repair. Some power line problems can be solved by using a power line filter located at the source of the problem. Otherwise, you will need an electrician or electronics technician to help solve a power line interference problem.

7. If the source of interference appears to be internal to your system, then the next step is to determine which component is the problem: the computer, the video adapter, or other adapters. If you have another comparable video adapter that can be used with your display, plug it into your system after following the manufacturer's installation instructions. If that solves the problem, have your original adapter serviced. The next step is to remove as many plug-in adapters as possible from your computer. Ideally, this will leave only your video adapter and a floppy disk adapter in the system. If this solves

the problem, then cycle through each adapter to find the culprit, and have it serviced to eliminate the problem. Otherwise, have the computer serviced.

Part III

General Information

Appendix A

System Requirements

This Appendix outlines the computer system requirements needed for running the DisplayMate Video Display Utilities.

Supported Hardware

Computers: IBM PC, XT, AT, PS/2 (all models), or true compatibles.

Video Display Adapters: IBM MDA, CGA, EGA, MCGA, VGA, or true compatibles; or Hercules Graphics, Graphics Plus, InColor Card, or true compatibles. EGAs with only 64 KBytes are also supported, as are MCGAs using analog displays with a reduced horizontal scan frequency of 15.75 KHz.

Video Displays: Any color or monochrome display compatible with the above adapters, including multi-frequency displays. Laptop computer displays, such as LCD, Gas Plasma, and Electroluminescent are also supported.

Operating System: PC-DOS or MS-DOS versions 2.0 or later.

Memory: A minimum of 330 KBytes of free memory.

Optional Hardware Supported

Mouse: Microsoft Mouse, IBM PS/2 Mouse, or true compatibles.

Dual Display Systems: Any valid combination of two adapters that are listed in the Video Display Adapters section above.

Composite Displays: On CGAs the Color Burst can be controlled.

Partially Supported Hardware

Light Pens: Light Pens never really caught on because of the popularity of the Mouse as a pointing device. A Light Pen is connected directly to the video adapter, and is controlled via a Light Pen Interface. The hardware necessary to fully support a Light Pen Interface and the connection of a Light Pen is available on the CGA and EGA only. Register support for a Light Pen Interface is available on the Hercules cards and on early production models of the IBM MDA, although no provision is made for connecting a Light Pen to the adapter. The MCGA and VGA provide no Light Pen support at all. DisplayMate will test for and indicate the presence of a functioning Light Pen Interface in the *Video System Information* screen. The Light Pen Interface by itself is a useful diagnostic and graphics programming tool, and DisplayMate will use it, if available, in some tests. However, no support or tests are provided for the Light Pens themselves.

Hardware Not Supported

Vertical Interrupts: Vertical Interrupts are useful for certain specialized applications such as animation. Software support for vertical interrupts requires a precise knowledge of the exact hardware configuration for a computer, and hence it is not possible to write reliable, general purpose software supporting vertical interrupts. Vertical interrupts are supported by the EGA, MCGA, and planar VGAs that are included on IBM PS/2 main circuit boards. They are not supported by the IBM MDA, IBM CGA, the IBM PS/2 VGA adapter card for

PCs and ATs, or by the Hercules cards. Also, many non-IBM EGA compatible cards incorrectly implement this feature.

Non-Standard Video Modes: Only the standard IBM video modes numbered 0 to 7 and 13 to 19, and their appropriate sub-modes, are supported. Modes 8 to 10 are used only by the IBM PCjr, and are not supported. Modes 11 and 12 are used by the EGA and VGA to load fonts and are therefore indirectly supported. Only the standard Hercules graphics mode is supported; the RamFont modes of the Hercules cards are not supported.

Appendix B

Making a Backup Copy

We recommend that you make a backup copy of the original DisplayMate distribution disks, and then store the originals in a safe place. Should you lose, accidentally destroy or damage one of the disks, then you can make another working copy from the original distribution disk.

You will be using the DOS commands FORMAT and DISKCOPY to make the backup copy. If you do not have a hard disk, then in all the discussions and examples that follow, keep your DOS system disk in the drive until after you enter the indicated DOS command and you are prompted to insert the disks that are to be formatted and copied.

Some non-IBM versions of DOS require that the blank target disk be formatted first. If you know this to be the case, or receive an error message from DISKCOPY, then place the blank disk in the **a:** drive and type the following DOS command:

format a:

We remind you here that all DOS commands require that you press the <Enter> key to begin command execution.

If you have a single floppy drive, or two floppy drives of the same capacity, then type the following DOS command using the appropriate drive letters for your system:

diskcopy a: b:

otherwise type:

diskcopy a: a:

Place the original DisplayMate disk in the source drive corresponding to the first drive letter, and, if you have two drives, a blank disk in the target drive corresponding to the second drive letter. Follow the prompts issued by the DISKCOPY command to complete the copy. Remember that the source diskette is the DisplayMate disk and the target diskette is the blank one.

Put the original disk away in a safe place and label the backup copy.

Appendix C

Quick Start Installation Guide

This is a quick installation guide for users that are proficient with their computers and with DOS, and prefer to skip the automatic installation procedure in Appendix D and do the installation themselves. It includes information on reading the README documentation, copying the DisplayMate files to your hard disk, adding DisplayMate to your PATH, and automatically producing a master Test Pattern when you turn on or reboot your computer. This quick start installation guide also provides abbreviated information on starting DisplayMate, including a few of the most important command line options and tips for running and controlling DisplayMate.

Before beginning the installation, review the *System Requirements* in Appendix A. We also recommend that you make a backup copy of the original DisplayMate distribution disk, and store the original in a safe place. Detailed instructions for making a backup copy are provided in Appendix B.

Place the backup copy of the DisplayMate program disk in the **a:** drive. If you are not using the **a:** drive, then substitute that drive letter for **a:** in all the discussions and examples that follow. If you encounter problems during the installation, see the chapter *In Case of Difficulty* near the end of this manual.

For Experts Only

If you are an expert, you can skip the instructions in the remainder of this Appendix. Here is all you need to do:

1. Print or type the file README.DOC.
2. Make a directory called \dmu on your hard disk.
3. Copy all the files from the backup DisplayMate disk to the hard disk.
4. Add c:\dmu to your DOS PATH.
5. Add the command "c:\dmu\dmu tp" to the end of your AUTOEXEC.BAT file in order to automatically produce a master Test Pattern whenever you boot your computer.
6. Make the change effective by rebooting your system.

Skip to the section *Quick Start for DisplayMate,* below.

Reading the README.DOC Documentation File

A file called README.DOC contains information about changes, corrections, and additions that were made to the software and documentation after the manual was printed. If you have a printer, verify that it is online and ready, then type the following DOS command:

print a:readme.doc

or

copy a:readme.doc prn:

We remind you here that all DOS commands require that you press the <Enter> key to begin command execution. If you do not have a printer, or wish to view the files on your screen, then type the following DOS command:

more < a:readme.doc

When you have read the page on the screen, press any key to advance to the next screen page. If you do not have a hard disk, skip to the section *Quick Start for DisplayMate,* below.

Hard Disk Installation

DisplayMate requires approximately 330 KBytes of disk space. If you are unsure of the amount of disk space available on your system, type the following DOS command using the appropriate drive letter for your system:

chkdsk c:

On most systems this will be the **c:** drive as shown.

To install DisplayMate on your hard disk, first create a sub-directory for it. We recommend "c:\dmu". If you do not use "c:\dmu", then in all the discussions and examples that follow substitute the directory you have used instead of "c:\dmu". Type the following DOS command:

mkdir c:\dmu

Next, place the backup copy of DisplayMate in the **a:** drive and type the following DOS command:

copy a:*.* c:\dmu

Put the labeled backup copy of DisplayMate in a safe place.

Adding DisplayMate to Your PATH

In order to be able to execute DisplayMate conveniently from any sub-directory in your computer, you must add the directory for DisplayMate to your DOS PATH. If you do not do this, you will need to type the path for DisplayMate explicitly whenever you wish to invoke it from outside its home directory. To do this, type:

c:\dmu\dmu

In order to update the DOS PATH you will need a text editor or word processor to edit the "AUTOEXEC.BAT" file located in the root directory of your computer's start-up drive. This will normally be the **c:** drive. Switch to this drive by first typing the start-up drive letter followed by a colon:

c:

Next, switch to the root directory by typing:

**cd **

Before proceeding, it is *VERY IMPORTANT* to make a backup copy of your AUTOEXEC.BAT file in case something goes wrong. Type the DOS command:

copy autoexec.bat autoexec.dmu

Again, we remind you here that all DOS commands require that you press the <Enter> key to begin command execution.

The PATH statement in the AUTOEXEC.BAT file will look something like the following:

PATH c:\dos;c:\dbase;c:\wp

Append the full path name of the DisplayMate directory preceded by a semicolon ";" to the end of the text on the line, without adding any intervening spaces. The edited line should look like this:

PATH c:\dos;c:\dbase;c:\wp;c:\dmu

As an alternative, add the following line after all other PATH statements in the AUTOEXEC.BAT file:

PATH=%PATH%;c:\dmu

If you do not have access to an editor, then *CAREFULLY* type the following DOS commands:

copy autoexec.bat + con:

PATH=%PATH%;c:\dmu

<Ctrl>Z

We remind you here to press the <Enter> key after each input line. If you experience any difficulty, restore the original AUTOEXEC.BAT file by typing the following DOS command:

copy autoexec.dmu autoexec.bat

To make these changes effective, reboot your system by pressing the following three keys simultaneously <Ctrl> <Alt> <Del>.

Adding a Boot Test Pattern

If you would like to have the DisplayMate master Test Pattern automatically appear on your display for a brief period of time whenever you turn on or reboot your computer, you will need to add one line to the end of the AUTOEXEC.BAT file.

The procedure is exactly the same as for changing your DOS PATH, as discussed in the previous section. You will need a text editor or word processor to edit the "AUTOEXEC.BAT" file located in the root directory of your computer's start-up drive. This will normally be the **c:** drive. Switch to this drive by first typing the start-up drive letter followed by a colon:

c:

Next, switch to the root directory by typing:

**cd **

Before proceeding, it is *VERY IMPORTANT* to make a backup copy of your AUTOEXEC.BAT file in case something goes wrong. Type the DOS command:

copy autoexec.bat autoexec.tp

Again, we remind you here that all DOS commands require that you press the <Enter> key to begin command execution. Note that the name of this backup copy is different from that in the previous section.

You need to add the following line to the end of the AUTOEXEC.BAT file:

c:\dmu\dmu tp

If you do not have access to an editor, then *CAREFULLY* type the following DOS commands:

copy autoexec.bat + con:

c:\dmu\dmu tp

<Ctrl>Z

We remind you here to press the <Enter> key after each input line. If you experience any difficulty, restore the original AUTOEXEC.BAT file by typing the following DOS command:

copy autoexec.tp autoexec.bat

To check this change, reboot your system by pressing the following three keys simultaneously <Ctrl> <Alt> <Del>.

Quick Start for DisplayMate

This section contains abbreviated information on running the DisplayMate program. Chapter 4 contains a detailed description of all the capabilities and options of DisplayMate. To start DisplayMate type:

dmu

DisplayMate may be invoked with a number of command line options. To obtain a listing of these, type:

dmu ?

Options may also be changed from within the *Program Options Menu.* To improve menu readability on some displays, use the background "B" option to set the background to black, or the color "C" option to set the menu screens to a black on white format:

dmu –B *or* **dmu –C**

To run an automatic demonstration program type:

dmu demo

To see the complete demo for the *Technical Program* type:

dmu tech demo

Help: To request help at any time type "?" or "h", or press the conveniently located <Ins> key. If you have a mouse, click the right mouse button. Before every test, the *Automatic Help* facility provides a *Test Prompt Screen* that describes the test, and explains what to watch out for on the screen. Use the command line options or the *Program Options Menu* to turn off this feature.

Next: Press the <Space Bar> key to select the current menu item or to proceed from test to test. If you have a mouse, click the left mouse button.

Menus: Use the Arrow keys or a mouse to move the menu highlight bar up and down. Use the numbered Function keys to execute a menu selection. The <End> or <Esc> keys will terminate the menu and return you to the next highest menu. If you are in the *Main Menu,* either key will return you to DOS.

Tests: Use the <Page Up> key to return to the previous test screen. Use the <Home> key to return to the first test in the series. The <Del> key will redisplay the title of a test. The Function keys perform the following:

<F1> and <F2> cycle through the available foreground colors.

<F3> and <F4> cycle through the available background colors.

<F5> sets the colors to their default values.

<F6> toggles between normal and reverse video.

<F7> toggles the Color Burst on and off for CGA adapters.

<F8> toggles between color and monochrome for VGA and MCGA displays.

Reset: If you experience a minor compatibility problem and the screen doesn't look right, press "r" to reset the video system and redraw the current screen. This may solve the problem.

Abort: Use the <Esc> or <End> keys to terminate a test series or a menu. Use <Ctrl>C or <Ctrl> <Break> to terminate DisplayMate.

Appendix D

Standard Installation Guide

This standard installation guide provides users of DisplayMate with an automatic procedure to install the software onto their hard disk. The installation routine will first check your disk drives, determine if you have enough disk space available, allow you to select the name of the directory for DisplayMate, create that directory if necessary, copy the necessary files to the directory and, with your permission, add a command line to your AUTOEXEC.BAT file to modify your DOS PATH, and another to automatically produce a master Test Pattern when you turn on or reboot your computer. Finally, it will allow you to read or print the contents of the README documentation file included in the distribution diskette. Extensive error checking and recovery procedures are included to make the installation as painless and safe as possible.

Users that are proficient with their computers and with DOS may prefer to use the *Quick Start Installation Guide* in Appendix C, which also provides abbreviated information on starting DisplayMate, including a few of the most important command line options and tips for running and controlling DisplayMate.

Before beginning the installation, review the *System Requirements* in Appendix A. We also recommend that you make a backup copy of the original DisplayMate distribution disk, and store the original in a safe place. Detailed instructions for making a backup copy are provided in Appendix B.

Place the backup copy of the DisplayMate program disk in the **a:** drive. If you are not using drive **a:** then substitute that drive letter for **a:** in all the discussions and examples that follow. If you encounter problems during the installation, see the chapter *In Case of Difficulty* near the end of this manual.

To run INSTALL, first type the letter for the drive that contains the DisplayMate program disk:

a:

We remind you here that all DOS commands require that you press the <Enter> key to begin command execution. Next, type the following DOS command:

install

Follow the on-screen instructions. When the installation procedure has been completed, you will exit back to DOS and be in the DisplayMate home directory you have selected. Remove the backup copy of DisplayMate and proceed to Chapter 4, *Running DisplayMate*.

Appendix E

Command Line Options Reference

DisplayMate has a number of options that control and configure the program that can be specified on the command line. Many of these options can also be modified in the *Program Options Menu.* The section on *Program Options* in Chapter 4 provides an abbreviated discussion of the most important options. This Appendix is a complete guide to all of the options.

The DisplayMate command line syntax is very flexible. The following three examples are all equivalent:

```
dmu  B I O X T=20
dmu  -o /x bi /t=20
dmu  oxbi t20
```

Command line syntax is defined in detail as follows:

1. Options must appear on the command line from which DisplayMate is invoked, and be separated by one or more spaces or tabs as described below.
2. Options are identified by a single letter. Some options require that a parameter be specified, such as "T=2", while others have no parameter and merely indicate their presence, such as "B". Note that the option letter is generally suggestive of the option name.
3. Options may be specified as either upper or lower case letters.
4. Options may be preceded by the flags "/" or "−" for readability.
   Example: "dmu b t=2" and "dmu −b /t=2" are equivalent.

5. The equal sign "=" is optional for options that require a parameter. Spaces are not permitted between the option letter, any equal sign, and the parameter value.

   Example: "dmu L=2" and "dmu L2" are equivalent.

6. Options without parameters may be concatenated into one or more groups.

   Example: "dmu o x b i", "dmu ox bi", "dmu oxbi" are all equivalent.

7. Options may appear in any order. If an option appears more than once, the latest value takes precedence. If mutually exclusive options are specified, the latest one takes precedence without generating any error conditions.

To obtain a list of options online, type "dmu ?" or "dmu help". To have DisplayMate present a list of the *Command Line Options in Effect* based on your command line entry, include the "O" option. If errors are detected on the command line, DisplayMate will display the list of the options in effect and the errors.

The option letters are suggestive of their function. They are described alphabetically, below, with the function name highlighted in italics. Here we group them according to category:

Screen Control:	B, C, I, S.
Help and Information:	H, O, ?, HELP.
Program Control:	L, M, TECH, NONTECH.
Special Tests:	DEMO, TP.
Screen Writing Speed:	F, N.
Mode Switch Timing:	D, X.
Keyboard and Mouse Control:	K, P.
Program Timing:	E, T, S.
Menu Programming:	R, menu numbers.

B: This option will set the *Background* color to black for all menu and result screens. Use it to improve readability on certain displays, particularly with the flat panel displays found on most laptops. DisplayMate automatically sets the background to black if it detects a monochrome display. This option may also be changed within the

Program Options Menu. If you select this option, also consider the "I" option for low intensity colors.

C: This option will set the foreground *Color* to white and the background color to black for all the menu and result screens. Use it to improve readability on certain displays, particularly with the flat panel displays found on most laptops. DisplayMate will automatically set this option if it detects a monochrome display. This option may also be changed within the *Program Options Menu.* If you select this option, also consider the "I" option for low intensity colors.

D=n.nn: The mode *Delay* time option will blank the screen for the specified time whenever the video mode changes. This is intended for multi-frequency displays, which often produce unstable images for a brief period of time after a video mode change. The delay time may be anywhere between 0.00 to 2.00 seconds, in 0.01 second steps. A value of 0.5 seconds is suitable for many multi-frequency displays, and this can be specified more conveniently with the "X" option. This option may also be changed within the *Program Options Menu.* The only option that conflicts with D is X.

Example: "dmu D=0.75"

DEMO: This activates an automatic *Demonstration* program for DisplayMate. Other options may be used with demo; particularly useful are: "T" to change the test cycle time, "R" to have the demo repeat continuously, and "L", "TECH", and "NONTECH" to set the technical level of the tests. If "L" or "TECH" is not specified, then the *Non-Technical* demo program is presented. To run the *Technical Program* demo, use the "TECH" or "L=2" options. The only options that conflict with DEMO are TP and Menu Programming.

Examples: "dmu DEMO" or "dmu TECH DEMO T=30 R"

E=n: The menu *Expiration* option will withdraw a menu after a specified time interval has elapsed, and then proceed with program execution of the current menu selection, as indicated by the menu highlight bar. This prevents the program from permanently halting if no response is forthcoming. The menu highlight bar is automatically advanced to the next item after each selection executes. The value of n is 0 to 60 seconds, with 0, the default, turning off this feature. The elapsed time counter is reset to zero after any keyboard or mouse activity. The expiration time may be extended to 60 seconds for the current menu only by typing "+". This option may also be changed within the *Program Options Menu.*

Example: "dmu E=30"

F: This option will force *Fast,* direct screen updates that bypass the video BIOS for all the menu and result screens on CGA video systems. The writing speed will increase dramatically; however, on the IBM CGA and compatibles an unfortunate side effect is the appearance of interference on the display called "snow," which can be quite annoying. Some modern super-CGAs will not produce any snow, and this option is particularly useful for them. If you have software that eliminates the snow, you should try running with and without it, in order to look for compatibility and performance side effects. Direct screen updates is the default for all video systems except CGA. This option may also be changed within the *Program Options Menu.*

H=n: This option allows you to specify the level of *Automatic Help* on the command line. *Automatic Help* provides a *Test Prompt Screen* before every display test that describes the test and explains what to watch out for on the screen. *Automatic Help* is turned off with n=0, turned on with n=1, and set to maximum help with n=2, which is the default and adds information on Function keys to the *Test Prompt Screen.* This option may also be changed within the *Program Options Menu.*

Example: "dmu H=2" sets DisplayMate to maximum automatic help.

I: This option will set low *Intensity* colors for all menu and result screens. Use it to improve readability and user comfort, particularly with the "B" and "C" options. Note that when using this option, high intensity highlighting, which is particularly useful for monochrome displays, will not be available. This option may also be changed within the *Program Options Menu.*

K: This option will have DisplayMate read your *Keyboard* using DOS instead of the system BIOS. Use it if your keyboard is not fully IBM compatible and you experience difficulty controlling DisplayMate from your keyboard, or if you use ANSI.SYS to reassign keys on your keyboard and want those reassignments to remain in effect while DisplayMate is running. Note that when using this option you will not be able to use the <F11> and <F12> Function keys on an enhanced keyboard unless you have DOS 4.0 or later, and have installed the ANSI.SYS driver with the "/X" parameter.

L=n: This option allows you to specify the program *Technical Level* on the command line and skip the menu normally used to do this. The *non-Technical Program* is selected with n=1, and the *Technical Program* is selected with n=2. The NONTECH and TECH options are equivalent to the L=1 and L=2 options. The program technical level may also be changed from the *Main Menu.*

Example: "dmu L=1" selects the *non-Technical Program.*

M=n: The *Mode* option will set the video test mode to the specified value, otherwise a default mode is automatically selected based on the video system hardware. The mode number n must be supported by the current video hardware and be in the range of 0 to 19. The test mode may also be changed within the *Select Video Test Mode Menu* in the *Technical Program.*

Example: "dmu M=15" sets the test mode to Monochrome Graphics.

N: This option will force slow, *No-interference* screen updates using the BIOS for all the menu and result screens. Use it if your display is not fully IBM compatible and you experience interference in any text mode while the screen is being updated. The updates will take noticeably longer, but should still take only a fraction of a second. BIOS screen updates are the default for the 80 column CGA text mode. This option may also be changed within the *Program Options Menu.*

NONTECH: This option allows you to specify the *Non-Technical Program* on the command line and skip the menu normally used to do this. This option is equivalent to the "L=1" option. The program technical level may also be changed from the *Main Menu.*

O: This option will have DisplayMate produce a listing of the *Command Line Options in Effect* based on your command line entry.

P: This option will have DisplayMate completely ignore any mouse *Pointing* device on your computer. A mouse that is not fully compatible with the Microsoft Mouse may cause DisplayMate to behave in an erratic manner. Use this option if you experience difficulty controlling DisplayMate with either your mouse or keyboard.

R: The *Repeat* option causes the menu or demo program to repeat continuously until terminated with <Ctrl> <Home>, <Ctrl> <End>, <Ctrl>C, or <Ctrl> <Break>.

Example: "dmu DEMO R"

S=n: The *Screen* blanking option will cause DisplayMate to blank the screen automatically after a specified period of inactivity. A message and beep will mark the beginning of the screen shutdown in order to alert a user to the action taking place. The screen can be restored by pressing any key on the keyboard or clicking any mouse button. Aside from "waking up" the program, the meaning of the key is ignored and is not interpreted as a command. The value of n is 0 to 60 minutes, with 0, the default, turning off this feature. The elapsed time counter is reset to zero after any keyboard or mouse activity. This option may also be changed within the *Program Options Menu.* It applies only to DisplayMate and does *not* install a general screen blanking routine in your computer.

Example: "dmu S=20"

T=n: The cycle *Time* option will cause DisplayMate to proceed automatically to the next test in a test series after a specified time interval has elapsed. The value of n is 0 to 60 seconds, with 0, the default, turning off this feature. Keyboard or mouse input can be used to proceed before the cycle time is up. The elapsed time counter is reset to zero after any keyboard or mouse activity. The cycle time may be extended to 60 seconds for the current test only by typing "+". This option may also be changed within the *Program Options Menu.*

Example: "dmu T=20"

TECH: This option allows you to specify the *Technical Program* on the command line and skip the menu normally used to do this. This option is equivalent to the "L=2" option. The program technical level may also be changed from the *Main Menu.*

TP: This activates a version of the program that displays the DisplayMate master *Test Pattern* and then returns you automatically to DOS after a default cycle time of 20 seconds. This option is meant for users who wish to display a test pattern automatically when they turn on their system or when the display needs periodic adjustment during the day. The command "dmu tp" would then be included as the last line of the AUTOEXEC.BAT file. Other options may be used with TP; particularly useful are: "T" to change the display time, and "S" to activate screen blanking if you set "T=0". The only options that conflict with TP are DEMO and Menu Programming. See the section *Screen Test Pattern* in Chapter 4 for additional information and examples for using TP. Keyboard or mouse input can be used to terminate the test before the cycle time is up. The cycle time may be extended for an additional 60 seconds by typing "+".

X: The *eXtend* option will blank the screen for 0.5 seconds every time the video mode changes. This is intended for multi-frequency displays, which often produce unstable images for a brief period of time after a video mode change. The value of 0.5 seconds is suitable for many multi-frequency displays. If you wish to experiment and determine the optimum blanking time, use the "D" option, which allows any value between 0 and 2 seconds. This option may also be changed within the *Program Options Menu.* The only option that conflicts with X is D.

Main Menu number items:

This option sets up a menu program that allows *Main Menu* selections to be automatically executed in a predefined sequence. The menu items are specified on the command line by the number corresponding to their *Main Menu* Function key selection. If the selection corresponds to a sub-menu of the *Main Menu,* then every item of that sub-menu will be executed, unless sub-menu selections are also specified (see below). Up to 16 menu items may be specified in this way. See Appendix F on *Menu Programming* for further details.

Example: "dmu 7 6 5" executes *Main Menu* items F7, F6, and F5.

Sub-Menu number items:

This option allows selections that belong to sub-menus of the *Main Menu* to be individually specified for automatic execution from the command line. DisplayMate has three menus that are sub-menus of the *Main Menu:* the *Display Tests Menu, Compatibility Tests Menu,* and *Screen Distortion Measurement Menu.* The desired sub-menu items are specified following the *Main Menu* selection number discussed above, after an intervening decimal point "." separator, by using the numbers corresponding to their sub-menu Function key selections. No intervening spaces are permitted between any of the items. The sub-menu items are always executed in numerical order, regardless of the order specified on the command line. If sub-menu items are not specified, then every selection of that sub-menu will be executed. See Appendix F on *Menu Programming* for further details.

Example: "dmu 3.234" will execute the sub-menu items F2, F3, and F4 of the *Main Menu* selection F3.

Appendix F

Menu Programming Reference

This version of DisplayMate provides a limited form of menu programming that allows menu selections to be automatically executed in a predefined sequence and at a predefined rate. Menu programs are particularly useful for repeating the same batch of tests without the need to enter menu commands from the keyboard. The *demo* option presented by DisplayMate is an example of an internally generated Menu Program. This Appendix discusses menu programming and includes a number of programming examples.

While a Menu Program is running, all of the keyboard functions remain active at all times, allowing you to modify the course of the program manually whenever you wish. You may, for example, repeat some tests by pressing <PgUp> and skip others by pressing <PgDn>, or change the colors with <F1> to <F4>.

A special version of DisplayMate is available for running fully automated tests under external hardware control via the IEEE-488, parallel, and serial interfaces. Please contact us at 908-747-6886 for further information.

The menu items are specified on the command line by a number corresponding to their *Main Menu* Function key selection. See Appendix E for a complete discussion of all Command Line Options. Up to 16 menu items may be specified in this way. They are executed in the order in which they appear on the command line. At the start of each menu item DisplayMate will identify the current selection with a header.

Example: "dmu 7 6 5" is the equivalent of executing *Main Menu* items F7, F6, and F5, in that order. At the end of item 5, DisplayMate will present the *Main Menu* and wait for a manual command. The command line in the example does not include a specification for the Technical Level of the tests, so DisplayMate will prompt you for this information. As discussed in Appendix E on *Command*

Line Options, the technical level can be specified with the "L", "TECH", and "NONTECH" options.

Example: "dmu tech 7 6 5" will automatically place DisplayMate in the *Technical Program* and execute the Screen Distortion, Compatibility, and Speed Performance tests.

If you press <End> during a program, the current menu item will be terminated and the program will move on to the next item, if any. If you have a Menu Program in progress and wish to receive manual menu control after the current menu selection has finished, press <Ctrl> <Home> at any time. If you wish to cancel the current item and receive immediate manual menu control, press <Ctrl> <End> at any time; DisplayMate will present a menu. After executing your manual request, the Menu Program will continue where it left off. You can also terminate DisplayMate during a Menu Program by pressing <Ctrl>C or <Ctrl> <Break> at any time. You will be returned to DOS.

To have DisplayMate automatically terminate as the last item of a Menu Program, specify a number that corresponds to the <End> selection. That is one higher than the highest Function key number shown for that menu, and is 11 for the *Non-Technical Program* and 13 for the *Technical Program.*

Example: "dmu tech 7 6 5 13" will terminate DisplayMate at the end of the *Technical Program* and return you to DOS.

To have the Menu Program automatically pause during the program, place a "0" at the desired location. DisplayMate will present a menu and allow a single manual command before returning to the program sequence. Include as many manual "0" commands as you like.

Example: "dmu tech 7 6 0 5 13" will switch to manual mode before running the speed tests. If the manual menu selection you choose is to switch between the *Technical* and *Non-Technical Programs,* then DisplayMate will wait for a second manual command to execute. At the end of that request DisplayMate will return to its original *Technical* or *Non-Technical Program* and continue executing the Menu Program.

If the Menu Program specifies a switch between the *Technical* and *Non-Technical* programs, that switch remains effective until an item specifying another switch is executed. The menu numbers must always refer to whatever Technical Level is in effect at the time.

Example: "dmu nontech 6 10 5 13" runs the speed performance tests, first in the *Non-Technical Program* and then in the *Technical Program.*

DisplayMate has three menus that are sub-menus of the *Main Menu:* the *Display Tests Menu, Compatibility Tests Menu,* and *Screen Distortion Measurement Menu.* If the sub-menus are specified by their *Main Menu* selection number alone, then every selection of that sub-menu will be executed in order. DisplayMate allows sub-menu selections to be specified individually, following the *Main Menu* selection number discussed above, by first placing an intervening decimal point "." separator, and then listing all the desired sub-menu Function key selection numbers, without any intervening spaces. Each *Main Menu* selection can have an independent sub-menu specification.

Example: "dmu 3.234" will execute the sub-menu items F2, F3, and F4 of *Main Menu* selection F3.

The sub-menu items are always executed in numerical order, regardless of the order specified on the command line. Sub-menu selections specified for items that are not sub-menus are ignored. If the same sub-menu selection is specified more than once, it will be executed only once.

Example: "dmu 3.43323" will execute the sub-menu items F2, F3, and F4 once, and in that order.

To switch the sub-menu into manual mode, enter a "0" sub-menu selection:

Example: "dmu 3.0" will place the sub-menu in manual mode. DisplayMate will present the sub-menu and allow manual menu control. Perform as many manual sub-menu selections as you like, then press the <End> Keypad key in order to continue the *Main Menu* program. The "0" selection can also be used together with other sub-menu items.

Example: "dmu 3.0234" will allow a single manual sub-menu command, and then automatically execute sub-menu items F2, F3, and F4.

If you are in a sub-menu test series, pressing either <Ctrl> <Home> or <Ctrl> <End> will return you to the current menu as described previously. If you then wish to return to the *Main Menu,* press <Ctrl> <End> again.

There are a number of other *Command Line Options* meant to be used with menu programming. See Appendix E for details.

T: The cycle *Time* for test screens is set to the specified value. Manual keyboard input can be used to proceed before the cycle time is up, or to extend the cycle time for the current test only.

E: The menu *Expiration* option will withdraw a menu after a specified time interval has elapsed, and then proceed with program execution of the current menu selection, as indicated by the menu highlight bar. This will prevent the program from permanently halting if no response is forthcoming. The menu highlight bar is automatically advanced to the next item after each selection executes.

R: The *Repeat* option causes the Menu Program to repeat continuously until terminated with <Ctrl> <End> or <Ctrl>C or <Ctrl> <Break>.

M: The *Mode* option will set the default test mode to the specified value.

Note 1: You can generate a continuous demo program by typing the following command "dmu E=15 T=15". Because of the ordering of the *Main Menus,* this will result in alternating presentations of the *Technical* and *non-Technical Programs.*

Note 2: If you enter a Menu Program that merely switches from the *Technical* to the *non-Technical Programs,* as in "dmu nontech 10 12 R" or "dmu tech 12 10 R", then the only way to terminate the endless loop is with <Ctrl>C or <Ctrl> <Break>.

Note 3: If you enter sub-menu items that are invalid or inaccessible for the current hardware, such as specifying VGA compatibility tests for a CGA, those selections are ignored without producing an error message. This allows Menu Programs to run without incident on different hardware configurations. If you specify an out of sequence Measurement Set for the *Screen Distortion Measurement Menu,* such as selecting Set 2 without specifying Set 1, then DisplayMate will automatically schedule Set 1 before proceeding to requested Set2.

Appendix G

Tests Reference

This Appendix provides a summary table of all the tests in the DisplayMate Video Display Utilities. The tests are listed in order and grouped according to menu selection. Not all of the tests are available with all adapters and video modes. Tests that are incompatible with your video adapter hardware are automatically skipped. Some tests are skipped in the *Non-Technical Program.*

Setup Display

- Brightness & Contrast Adjustment
- Color Verification
- CGA / MCGA Primary Colors
- EGA / VGA Primary Colors
- CGA Compatible Colors
- Color Combinations
- Reverse Video Check
- Intensity Range Check
- Color Scales
- Defocusing and Blooming Check
- Screen Focus Check
- Screen Framing and Aspect Ratio: Primary Graphics Mode
- Screen Framing and Aspect Ratio: Secondary Graphics Mode
- Screen Framing and Aspect Ratio: Tertiary Graphics Mode
- Screen Framing and Aspect Ratio: Text Mode
- A Test Page of Text
- Color Bar Test Pattern
- Screen Test Pattern

Video Obstacle Course

- Screen Uniformity and Flicker
- Freedom from Background Interference
- Dark Screen
- Geometric Linearity
- Circular Test Pattern
- Horizontal versus Vertical Line Thickness
- Line Brightness versus Thickness
- Defocusing and Blooming Test
- Raster Visibility
- Resolution
- Corner Resolution
- Normal and Reverse Video Resolution
- Line Moire Pattern
- Fine Line Moire Pattern
- Dot Moire Pattern
- Fine Dot Moire Pattern
- Horizontal Color Registration
- Vertical Color Registration
- Horizontal Color Registration Blink Test
- Vertical Color Registration Blink Test
- 64 Intensities for Primary Colors
- Color Timing
- Digital Color Timing
- White-Level Shift
- Black-Level Shift
- Two-Dimensional Streaking
- Streaking and Ghosting
- Persistence Test
- Screen Regulation
- Local Regulation Distortion
- Screen Snow Test
- Scroll Flicker Test
- Text-Graphics Mode Switching

Display Tests

Geometry Tests

- Screen Framing and Aspect Ratio
- Tilt
- Horizontal Curvature
- Vertical Curvature
- Cross Linearity
- Pincushion / Barrel Distortion
- Coarse Geometric Linearity
- Medium Geometric Linearity
- Geometric Linearity
- Fine Geometric Linearity
- Circular Test Pattern
- Raster Spacing
- Synchronization Interference
- Horizontal Flutter
- Screen Regulation
- Local Regulation Distortion

Display Resolution Tests

- Horizontal Line Resolution
- Horizontal Bar Resolution
- Horizontal Resolution Wedge
- Horizontal versus Vertical Line Thickness
- Line Brightness versus Thickness
- Defocusing and Blooming Test
- Point Shape and Visibility
- Vertical Line Resolution
- Vertical Bar Resolution
- Vertical Resolution Wedge
- Corner Resolution
- Normal and Reverse Video Resolution
- Line Moire Pattern

- Fine Line Moire Pattern
- Dot Moire Pattern
- Fine Dot Moire Pattern

Adapter Resolution Tests

- Aliasing: Radial Rays
- Aliasing: Quartile Rays
- Stargons
- Scaled Diamonds
- Inscribed Circles & Squares
- Inscribed Circles & Polygons
- Logarithmic Resolution
- Resolution Tunnel
- Spiraling Square
- Recursive Triangles
- Resolution Spiral
- Lissajous Pattern
- Horizontal Nested Ellipses
- Vertical Nested Ellipses
- Nets
- Wave Sweep
- Nested Horizontal Wedges
- Nested Vertical Wedges
- Horizontal Nested Circles
- Vertical Nested Circles
- Circular Chords
- Rectangular Truss

Color and Gray-Scale Tests

- Horizontal Color Registration
- Vertical Color Registration
- Horizontal Color Registration Blink Test
- Vertical Color Registration Blink Test
- Cross Hatch Convergence Test
- Color Timing
- Digital Color Timing
- White-Level Shift
- Black-Level Shift
- Two Dimensional Streaking
- Streaking and Ghosting
- Streaking Test
- LCD Display Streaking
- Red Color Purity
- Green Color Purity
- Blue Color Purity
- Mode Colors
- 16 Gray Levels
- 64 Intensities for Primary Colors
- 64 Intensities for Secondary Colors
- Color Scales
- Color Spectrum
- Color Triangle
- VGA / MCGA 256 Default Colors
- VGA / MCGA Default Pastel Colors
- EGA Default Colors
- EGA Compatible Colors 0-15
- EGA Compatible Colors 16-31
- EGA Compatible Colors 32-47
- EGA Compatible Colors 48-63
- Color Bar Test Pattern

Text and Font Tests

- Color Combinations
- Color Text Attributes
- Default 9×16 Font Display
- A Page of Text in the Default 9×16 Font
- 9×16 Font Variable Line Spacing
- 9×14 Font Display
- A Page of Text in the 9×14 Font
- 9×14 Font Variable Line Spacing
- 9×8 Font Display
- A Page of Text in the 9×8 Font
- 9×8 Font Variable Line Spacing

Miscellaneous Tests

- Screen Uniformity and Flicker
- Intensity/Color Uniformity
- Freedom from Background Interference
- Ringing Interference Test
- Edge Brightness
- Border Test
- Dark Screen
- Raster Visibility
- Interlace Flicker & Raster Stability
- Persistence Test
- Screen Snow Test
- Drawing Flicker and Noise Test
- Scroll Flicker Test
- Text-Graphics Mode Switching
- CRT Shadow Mask Distortion

Compatibility Tests

Video Modes Test Suite

- Modes 0,1: 40 Column Color Text
- Modes 2,3: 80 Column Color Text
- Modes 4,5: 320×200 4 Color Graphics
- Mode 6: 640×200 2 Color Graphics
- Mode 7: 80 Column Monochrome Text
- Mode 13: 320×200 16 Color Graphics
- Mode 14: 640×200 16 Color Graphics
- Mode 15: 640×350 Monochrome Graphics
- Mode 16: 640×350 4/16 Color Graphics
- Mode 17: 640×480 2 Color Graphics
- Mode 18: 640×480 16 Color Graphics
- Mode 19: 320×200 256 Color Graphics
- Hercules Mode: 720×348 Monochrome/Color Graphics

MDA/Hercules Compatibility Tests

- MDA Mode Register Enable Test
- MDA Mode Register Blink Test
- MDA Attributes
- Text Attributes without Blinking
- Text Attributes with Blinking
- Hercules Configuration Register Test

CGA/MCGA Compatibility Tests

- CGA Mode Register Enable Test
- CGA Mode Register Blink Test
- CGA Color Register Test
- CGA Color Register Update Test
- CGA Color Palette Test
- CGA Mode 5 Palette Test

- Text Attributes without Blinking
- Text Attributes with Blinking
- BIOS Font Switching Test
- BIOS Dual Fonts Test
- MCGA Direct Font Switching Test
- BIOS Palette Fading Test
- Direct Palette Fading Test
- Palette Blend Test

EGA Compatibility Tests

- BIOS Font Switching Test
- EGA Direct Font Switching Test
- BIOS Font Loading Test
- BIOS Dual Fonts Test
- Smooth Scrolling
- Smooth Panning
- Smooth Panning & Scrolling
- Split Screen
- EGA Split Screen & Smooth Scroll
- EGA/VGA Write Modes Test
- Graphics Blinking Test
- Underline Register Test
- Register Updates

VGA Compatibility Tests

- VGA Video Enable / Disable Test
- VGA BIOS Font Switching Test
- VGA Direct Font Switching Test
- VGA Split Screen, Smooth Pan & Scroll
- BIOS Palette Fading Test
- Direct Palette Fading Test
- Palette Blend Test

Appendix H

Speed Performance Reference

This Appendix provides information to help you interpret the DisplayMate *Speed Performance Tests* that are described in Chapter 4 on *Running DisplayMate.*

The timing overhead needed to clock the performance is independently measured and removed from the tabulated values, which are presented in absolute operations per second, as called from the programming Language *C,* which is the language used to develop most software products. DisplayMate uses dedicated *Assembly Language* interface routines instead of the generic *int86* functions provided by most compilers.

Figure 4.7b shows the *Performance Test Tabulations* for the *Technical Program.* A different mix of tests are used for text and graphics modes. Tests that are labeled "Direct" are internal DisplayMate functions that operate directly on the hardware and are very efficient and fast.

Scroll Line, Column, Screen: These tests use video BIOS function 06H to scroll an area of the screen. The Line and Column tests measure how quickly the BIOS can scroll smaller odd shaped regions.

Clear Line, Column, Screen: These tests use video BIOS function 06H to clear an area on the screen. The Line and Column tests measure how quickly the BIOS can clear smaller odd shaped regions.

Write Character: The BIOS test uses video function 0AH to write text to the screen. The Direct test measures how quickly the C Language code "*q = c" executes, where q is of type "unsigned char far".

Write Character & Attrib: The BIOS test uses video function 09H to write text to the screen. The Direct test measures how quickly the C Language code "*q = c" executes, where q is of type "unsigned short far".

Write TTY Character: This test uses video BIOS function 0EH to write text to the screen. The cursor is positioned on the bottom line of the screen for immediate and continuous scrolling.

Write String: The BIOS test uses video function 13H to write a string of text to the screen. If the BIOS write string function is not available, then it is emulated using the BIOS Write Character together with cursor advance. The Direct test measures how quickly an optimized DisplayMate Assembly Language routine can write the same text on the screen.

Write Dot: The BIOS test uses video function 0CH to write a pixel on the screen. The Direct test measures how quickly an optimized DisplayMate Assembly Language routine can write the same pixel.

Write Line: These Direct tests measure how quickly an optimized DisplayMate Assembly Language routine can write lines on the screen. The *Long Line* is a full length screen diagonal; the *Short Line* is 1% of the full screen diagonal.

Write Block: These Direct tests measure how quickly an optimized DisplayMate Assembly Language routine can write filled blocks on the screen. The *Large Block* is ¼ of the area of the full screen; the *Small Block* is 1% of the height and width of the screen.

Video Memory Speed: This Direct test measures the speed of the video adapter's memory using the Assembly Language instruction "rep stosw". This places the microprocessor, system bus, and video adapter in the fastest possible data transfer mode. Full word 16-bit operations will occur if allowed by the computer and the video adapter; otherwise the hardware automatically switches to 8-bit transfers.

BitBlt Memory Speed: Bit block transfers are used to copy images from one screen location to another. This Direct test measures the speed of the video adapter's Bit Block video memory to video memory transfers using the Assembly Language instruction "rep movsb". Bit Block moves can only proceed 8-bits at a time because that is the width of the internal EGA/VGA latches that are used for these operations. The other adapters either don't have latches or are generally restricted to 8-bit bus operations anyhow.

Appendix I

Video Data Reference

The BIOS Data Area is a special area of system memory that is used by the BIOS routines to store the values of internal working variables that control the computer's operation and specify its hardware configuration. This Appendix provides information to help you interpret the DisplayMate *Configuration Tests* and *Video Data Area Information* screens, which are available only in the *Technical Program,* and are described in Chapter 4 on *Running DisplayMate.*

The *Configuration Tests* examine the *Video Data Area* to see if the parameters have valid values, and whether they are all internally consistent with one another. Each entry has a name that corresponds to one of the *Video Data Area Information* parameters.

Most entries will be labeled as "ok" or as "-," if the test does not apply to your adapter. Conditions to watch out for are *Non-Standard* and *Invalid.* Non-standard values are unusual, but still legal and valid. Either condition can result from unusual applications or bugs in the BIOS, or from programs that have corrupted the *Data Area.* Other labels provide information about the parameter such as: *Enabled, Defined,* and *Not Defined.* The severity of each condition is rated as *Minor, Severe,* or *Major.* Because of the large number of combinations of hardware, we cannot separately document the meaning of each test and condition. If there is a Configuration problem, then locate the parameter name in one of the *Video Data Area Information* screens. If the problem is not immediately obvious, then consult one of the *Technical References* in the Chapter on *Sources of Additional Information* near the end of the manual.

The *Video Data Area* is sub-divided into 7 separate areas that are reported in four *Video Data Area Information* screens. Each parameter is identified by its functional name, which is not necessarily the same as the cryptic name that is occasionally used by IBM. When individual bits have a special function, they are also separately identified by name. When shown in normal video the bit function is ON, and when shown in reverse video the bit function is OFF. Note that for some bits the ON condition is indicated by a binary "0," instead of the more usual "1."

Video Display Data Area 40:49 : This is the data area defined for the original IBM PC and is used by all of the video adapters. The parameter names clearly identify the function of each parameter. There are two parameter values that contain the settings for two Registers that are found on the MDA and/or CGA. They are emulated by the BIOS in all the other adapters for compatibility.

The bit fields for the *Mode Register Setting* are:

Blink: Trades the foreground text blinking capability for an additional 8 background colors.
640×200: This bit is ON for graphics mode 6.
Video: Enables or disables video to the display.
B&W: Controls the *Color Burst* for *Composite Displays.*
Graphics: This bit is ON for graphics modes 4, 5, and 6.
80×25: This bit is ON for the 80 column text mode.

The bit fields for the *Color Register Setting* are:

Palette: Selects one of the two palettes for graphics modes 4 and 5.
Alt: Specifies whether the intensity of the palette for graphics modes 4 and 5 is bright or dim.
Intensity, Red, Green, Blue: These bits specify the background color in graphics modes 4 and 5, and the foreground color in graphics mode 6. They also specify the border color in text modes.

Video Equipment Flag: This single byte data area at address 40:10 was originally defined for the IBM PC and identifies whether the video BIOS is controling a color or monochrome family adapter.

Video Control Data Area 40:84 : This is the data area originally defined for the IBM AT and EGA, and has been subsequently extended for the PS/2s.

The bit fields for the *EGA Mode Information* are:

ClearScreen:	Indicates whether the screen was cleared during the last video mode set.
???K:	Indicates the amount of memory installed in the adapter. This field is two bits wide.
Active:	Indicates whether the EGA or VGA is the active adapter.
Wait:	Specifies whether it is necessary to wait for retrace.
Monochrome:	Indicates whether the EGA or VGA is in a monochrome or color mode.
Emulation:	Specifies whether cursor emulation is enabled.

The EGA *Configuration Switches,* which are set by the user on EGA adapters, and emulated by the BIOS on PS/2s, are identified for both the *Primary Adapter* and the *Secondary Adapter.*

The bit fields for the *PS/2 Mode Information* are:

???Lines:	Specifies the line resolution in text modes, and can be 200, 350, or 400 lines. On the VGA, two bits are used, so this entry appears twice.
Switching:	Specifies whether PS/2 display switching is enabled.
Palette:	Specifies whether default palette loading is enabled.
Monochrome:	Specifies whether a monochrome monitor is connected.
GraySum:	Specifies whether gray-scale summing is enabled.
AllModes:	Specifies whether all video modes are available on the adapter. This bit is OFF for an MCGA, or if there is an MDA or CGA adapter along with a VGA.

The *Display Combination Codes* corresponding to the *Display Combination Index* are identified for both the *Active Display* and the *Inactive Display.* The Codes may be wrong due to BIOS bugs, particularly after Display Switching.

On the MCGA the submodes that are identified by the *Lines* bit depend upon whether a standard PS/2 display is connected or a non-standard analog display with a scan rate of 15.75 KHz is being used. The latter modes are not documented or officially supported by IBM. They are hardware generated 200 line versions of video modes 0 to 6 and 19 and are supported by the BIOS system software. They were undoubtedly intended as analog extensions to the original

CGA scan modes and require an analog multi-frequency display. The modes can be selected by either booting the computer with all monitor sense lines on the video connector at ground or by toggling the *Lines* bit.

On the VGA the submodes that are identified by the *Lines* bit are provided for compatibility with earlier adapters: all text modes will operate in 200, 350, and 400 scan line modes, except mode 7, which does not support the 200 line resolution in BIOS. The 200 line modes are generated by double-scanning the 400 hardware modes.

Video Interrupt Data Area: These are pointers to video functions in the microprocessor's interrupt table in low memory. The interrupt numbers are identified in hexadecimal. Addresses below segment C000 are marked as a *Non-BIOS Address.*

Font Character Definition Data Area: These pointers identify the location of all the standard BIOS fonts in ROM. They are not available on MDA and CGA adapters. The *Alternates* identify characters that are different when the *Character Box* is 9 pixels wide instead of 8 pixels.

Video Pointer Data Area 40:A8 : This table of pointers is defined and used by the EGA, MCGA, and VGA. The *Video Parameter Table* specifies the location of the actual table used by these adapters. The *Video Parameter Table* at interrupt 1DH specifies the video parameters for the MDA/CGA adapters. The *Palette Save Area* stores the current palette register settings. It is particularly useful for the EGA because the values of its palette registers cannot be read directly. Bugs in the IBM EGA implementation require caution in using this Save Area. The *Aux* character set pointers allow you to specify your own default character sets for certain video modes.

Secondary Save Pointer Table: This table of pointers is defined and used only by the VGA. Its location is specified in the *Video Pointer Data Area 40:A8,* above. The *Table Length* entry allows for future expansion. The *Display Combination Code Table* can be expanded or modified by changing its pointer. The *User Palette Profile* allows you to specify your own default palette for each video mode.

In Case of Difficulty

Introduction

This chapter is designed to help you solve most of the difficulties you may encounter while installing and running the DisplayMate Video Display Utilities. Sections are included for the following:

- Installation Problems
- Run Time Error Messages
- Compatibility Problems
- Contacting Technical Support

In addition, a trouble shooting section is provided to help you track down and solve general video display system problems that are not related to DisplayMate:

- Video Display System Trouble Shooting

If you are experiencing interference on your display, then see the section on *Screen Interference Problems* in Chapter 9.

Installation Problems

The installation of DisplayMate is a straight forward process that involves copying the files from the distribution disk onto your hard disk, and a simple modification of the AUTOEXEC.BAT file if requested by the user. There are not too many things that can go wrong if your computer is fully IBM compatible, you are running version 2.0 or later of PC-DOS or MS-DOS, you have sufficient disk space, and your disk drives are in good operating condition.

The discussion here is for the automatic installation procedure in Appendix D. Proficient computer users that opted for the manual installation procedure in

Appendix C can also follow the discussion for the automatic installation procedure because it also parallels the steps they need to follow as well.

In all of the installation instructions the Source disk drive refers to the floppy drive that holds the DisplayMate program diskette, and the Target disk drive refers to the hard disk drive where you are installing DisplayMate.

- The first thing to do if you have an installation problem is to double check that the Source diskette is properly inserted into the floppy drive, and that the gate for the drive is fully closed. This is most likely the problem if you receive the message: *Not ready error reading drive A, Abort, Retry, Ignore, Fail?* After checking the above, type "R" to request a retry.

- If you obtain the message: *General failure reading drive A,* or any message that includes: *Abort, Retry, Ignore, Fail?,* first check the drive and diskette as above, and then type "R" to request a retry. If the problem persists, then try using the floppy diskette on another computer. If the disk doesn't work there either, then you will need to make another backup copy of DisplayMate from the original distribution disk that you stored in a safe place. If you are having problems with the original distribution disk, then contact *Technical Support,* as described at the end of this chapter.

- Next, run the DOS command "chkdsk" that checks the disk to determine if it is functioning properly. Do this for both the Source diskette drive, assumed to be **a:**, and your hard disk Target drive, assumed to be **c:**. Type the following:

  chkdsk a:

  and

  chkdsk c:

  and remember to press <Enter> at the end of each line of input for DOS. If chkdsk reports problems with your floppy disk, then refer to the two previous items above. If chkdsk reports problems with your hard disk, then refer to your DOS manual for the appropriate procedures needed to correct and restore your disk, or alternatively, use one of the standard disk utility packages to fix the problem. Then rerun the DisplayMate installation procedure when your disks are functioning properly.

- Chkdsk will report the amount of free disk space available on your **c:** drive. You will need approximately 330 KBytes of free disk space to copy the DisplayMate programs. If you do not have that much, then free up some space by deleting unnecessary files. If you still don't have enough space, then you will need to run DisplayMate from a floppy disk copy. Do not use the original distribution disk as a working copy to run DisplayMate, as it may eventually become damaged or lost.

Installation Messages

The automatic installation program performs extensive error checking and attempts to provide clear and explicit error messages whenever possible. Messages that originate with DOS may not always indicate precisely what the problem is, but there are seldom more than a couple of possibilities. In all the messages, the Source disk is the DisplayMate program diskette and the Target Disk, Directory, or Drive refers to the hard disk where you are installing DisplayMate.

- *DOS version 2.0 or later is required.*

  The version of DOS currently running on your system precedes 2.0 and cannot be used for the installation. Restart your system using version DOS 2.0 or later, and then rerun the installation program. Note that DisplayMate also requires DOS 2.0 or later.

- *You have not invoked "install" from its own directory.*

  You *cannot* invoke install by including an explicit path in front of its name, such as "a:install". You must first type the drive letter for the disk drive that contains the DisplayMate distribution disk files, which is generally **a:**, followed by <Enter>, and then type **install** followed by <Enter>.

- *The Target Drive must be different from the Source Drive.*

  The destination directory where you will be installing DisplayMate cannot be on the same drive as the distribution disk.

- *The Target Directory path name is too long. The maximum is 63 characters.*

  DOS imposes a maximum length of 63 characters for any path.

- *The Target Drive letter you specified is invalid.*

  The drive letter must be in the range of A-Z (upper or lower case) and may not exceed the number of logical disk drives in your system.

- *The Target Directory name you specified already exists as an ordinary file.*

  The path and directory name you have entered is already being used as an ordinary file and cannot be used for a directory. Pick a new name or delete the file.

- *The Target Directory name you specified is invalid.*

  The path and directory name you have entered is for an invalid drive, or it does not conform to DOS rules. The name may include invalid characters or syntax. See your DOS manual for information on file and directory naming conventions.

- *The Source or Target Disk drive is not ready.*

  Double check that the diskette is properly inserted into the floppy drive, and that the gate for the drive is fully closed. Review the *Installation Problems* section, above. Press the <Enter> key to retry the operation. Press the <End> or <Esc> keys to abort the installation.

- *The Target Disk is write protected.*

  First double check that you have inserted the proper diskette in the Target drive. Move or remove the write protect tab, or use a different diskette. Press the <Enter> key to retry the operation. Press the <End> or <Esc> keys to abort the installation.

- *DOS is denying you access to create this directory or file.*

  DOS is refusing access to create the directory you have specified. The most likely reason is that you do not have *write access* on the disk or directory.

- *Unable to create this directory or file on the Target Disk.*

  DOS refuses to make the specified directory or file. The most likely reason is that you do not have *write access* on the disk or directory.

- *There is insufficient disk space to install the DisplayMate programs.*

  The installation program has determined that you do not have enough disk space left on the specified disk drive to copy all of the DisplayMate files. You need approximately 330 KBytes; the exact size specified depends on the cluster size of your drive. You should clear up some space or select a different disk drive.

- *File xxxx is missing on the Source Disk.*

  The indicated file was not found on the Source disk. The most likely cause is an invalid or improper copy of the original DisplayMate distribution disk. Locate the original DisplayMate distribution disk and make another backup copy. If the original distribution disk is damaged, then see the section on *Contacting Technical Support* at the end of this chapter.

- *Error reading file on the Source Disk.*

  DOS reports that an error occurred while reading the DisplayMate distribution disk. Run "chkdsk" on the Source drive as described above, and try again.

- *Error writing file on the Target Disk.*

  DOS reports that an error occurred while writing on the Target disk. Run "chkdsk" on the Target drive as described above, and try again.

- *The Target Disk is full.*

  This message should not occur because the installation program previously checked the Target disk for the necessary disk space. The most likely cause is another program writing to the disk at the same time. Smaller files than the current one may still fit on the Target disk, and may be successfully copied after this message appears. You should clear up some more space or select a different disk drive.

- *The Printer is not ready.*

  The printer is not responding to the request to print the README documentation file. Make sure that it is turned on, that the Online indicator is on, and that the paper is properly loaded. Press the <Enter> key to retry the operation. Press the <End> or <Esc> keys to abort the print request.

- *Unknown DOS error.*

  DOS reports a *General failure* or an error unknown to the install program. Press the <Enter> key to retry the operation. Press the <End> or <Esc> keys to abort the installation.

- *Out of Environment Space*

  The DOS environment area is used to store PATH and other information strings for the operating system. If you receive this message for the first time after adding DisplayMate to your PATH, you will need to either enlarge the environment, delete unneeded environment strings, or remove the PATH reference added for DisplayMate. See the SET command of your DOS manual for information on controlling and resizing the environment.

A related problem is that the PATH string will be truncated by DOS if it is longer than 128 characters, regardless of the size of the environment. DOS generally does not provide a message to alert you to this situation, so the tail end of your PATH could be missing without you being immediately aware of it. To verify your PATH, simply type "PATH" followed by <Enter>, and then check the output.

If you want to remove the modifications that were made to your AUTOEXEC.BAT file for DisplayMate, then either edit the file to delete the entries, or restore the backup file made by the installation program. To restore the original AUTOEXEC.BAT file you must go to the start-up disk, assumed to be the **c:** drive, by typing:

c:

Don't forget the <Enter> key. Then type:

**cd **

Next, type:

copy autoexec.dmu autoexec.bat

Reboot your system by pressing the following keys simultaneously <Ctrl> <Alt> <Del>. Your computer is now configured exactly as it was before you installed DisplayMate. To run DisplayMate you will need to include the path name yourself by typing:

c:\dmu\dmu

where we have used the default installation directory "c:\dmu".

Run Time Error Messages

The following messages may be produced by DOS when you try to run DisplayMate:

- *Bad command or file name*

  DOS is unable to locate DisplayMate. Either you incorrectly typed the program name, or DOS could not find it in the standard list of places specified in your DOS PATH. See Appendix C or Appendix D for a discussion of how to add the DisplayMate directory to your PATH, and see the discussion on *Out of Environment Space,* above. Alternatively, you can specify the path name explicitly by typing:

  c:\dmu\dmu

  where we have used the default installation directory "c:\dmu".

- *Program too big to fit in memory*

  You need about 330 KBytes of available memory to run DisplayMate. To find out how much you have available, run the DOS "chkdsk" command. The last line of output reports the number of *bytes free.* If you have memory resident (TSR) programs, you can free up some space by removing them from memory. If you still don't have enough space, try rebooting your system with a backup copy of the original DOS distribution disk. This will put your computer into a minimum configuration. Depending on your version of DOS, you will need about 400 KBytes of total memory.

- *Abort, Retry, Ignore, Fail?*

  This may occur if you are running DisplayMate from a floppy disk drive. DOS provides a reason for this error on the first line of the message. Double check that the Source diskette is properly inserted in the floppy drive, and that the gate for the drive is fully closed. Then type "R" to request a retry. If it still doesn't work, try using the diskette on another computer. If the disk doesn't work there either, then you will need to make another backup copy of DisplayMate from the original distribution disk that you stored in a safe place.

The following messages are produced by DisplayMate:

- *DOS version 2.0 or later is required.*

  The version of DOS currently running on your system precedes 2.0 and cannot be used for running DisplayMate. Restart your system using version DOS 2.0 or later, and then rerun DisplayMate.

- *Error beep or tone*

  This signal means that an invalid keyboard key was pressed, or an invalid option was specified on the command line. In a test series, a beep or tone will be produced if you press a Function key that is not valid for your video system hardware. For example: in the high resolution graphics mode of the CGA, the hardware forces the background color to black. Attempting to change the background color with the <F3> or <F4> keys will result in an error tone.

- *Errors were detected for the following options:*

  If you enter a command line option with an invalid parameter, this message will appear in the *Command Line Options in Effect* screen together with a list of the affected options. The parameter is either missing or is outside of the allowed range. If the word "Menu" appears, then an invalid menu programming selection was entered: the values are out of range or more than 16 selections were made. Because of the error, the option is either restricted to the allowed range or ignored. To terminate DisplayMate, press <End> or <Esc>; otherwise press any other key to continue. See Chapter 4 or Appendix E for additional information on command line options.

- *The following invalid options were detected:*

  If you enter a non-existent command line option, this message will appear in the *Command Line Options in Effect* screen together with a list of the invalid options. The option is ignored. To terminate DisplayMate, press <End> or <Esc>; otherwise press any other key to continue. See Chapter 4 or Appendix E for additional information on command line options.

- *BIOS System Timer Inoperative: Unable to Complete Performance Tests.*

  If your internal BIOS system timer is not fully 100% IBM compatible, then DisplayMate cannot perform the *Speed Performance Tests.* DisplayMate tests the timer at the beginning of the performance tests and produces this message if the results are not satisfactory. Ordinarily, DisplayMate automatically switches to the DOS timer if the BIOS timer is not working; however, the DOS timer is much too slow to use in the performance tests.

- *Invalid Input Data:*

  This message appears if you enter invalid numerical data for the interactive *Screen Distortion Measurements.* The input must be in one of the following forms:

  a
  a (sign) b
  b / c
  a (sign) b / c

  where **a, b,** and **c** are decimal numbers of the form: **(sign) nnn.nnn** and where **(sign)** is + or − or a blank " ", which is interpreted as "+". The **(sign)** of **c** is ignored and multiple signs such as: "1 − −3" are not allowed. Press <Enter> at the end of the input line. Valid examples are:

  "10.78", "11.75 + 0.27", "6.25 / 8", "11 7/8", "12 − 3.5/8"

  If you press an invalid key, you will hear an error beep. If you enter a value incorrectly, the message *Invalid Input Data* will appear. The blinking cursor will return to the end of the input line and you can edit or re-enter the value. See the section on *Screen Distortion Measurements* in Chapter 4 for additional information.

- *System BIOS dated xx/xx/xx should be Upgraded.*

  This message appears at the bottom of the *Video System Configuration* screen if DisplayMate finds that you have an IBM PC with a system ROM dated before 10/27/82. A new ROM chip must be installed before you can upgrade your system to an EGA or VGA. See *Hardware and Mode Information* in Chapter 4 for additional information.

Compatibility Problems

Few adapters approach 100% compatibility. In many cases DisplayMate will point out non-standard hardware and software configurations; in other cases you will discover compatibility problems by visually evaluating the test screens.

Any computer that has a fully compatible video display system may develop incompatibilities as a result of other hardware or software programs that are added to the system. By running DisplayMate in your normal environment, and comparing it to a basic system configuration, you can isolate the causes of most such incompatibilities.

The signs of compatibility failure can range from the delicately subtle to the disastrous: unintended flicker or temporary disruption of the display; distorted geometry or colors; a broken up image; shifted or missing sections of an image; superfluous patterns appearing on the screen; a locked system or a system crash. If you are unsure of what you should be seeing, run DisplayMate on a different brand of computer, preferably a vanilla IBM system, and compare.

In general, it is difficult to figure out the true source of a compatibility problem. You are more likely to come away with a phenomenological understanding of a class of things an adapter has trouble with. For example, many adapters have trouble loading and switching text mode fonts. After running the tests, you may find that an adapter will tend to lose the bottom few lines of the display after repeated font loads. The precise cause may be unknown, but you will have a good idea of the scope of the problem. See Chapters 4 and 5 for additional information on video system compatibility.

This section deals only with compatibility problems that arise while running DisplayMate. See the following section on *Video Display System Trouble Shooting* to track down and solve general video system problems that are not related to DisplayMate.

Minor Compatibility Problem

If you experience a problem, it will most likely be in the form of a minor glitch. Work through the following steps until your problem is solved or you discover the need to move to the *Major Compatibility Problem* section, below.

- Pressing "r" to reset the video system will cure many of the simple compatibility problems. If that solves the problem, then the video system was in a peculiar transitional state, which is the weakest form of incompatibility.

- If the problem remains, then backup to the previous test by pressing the <Page Up> Keypad key, press "r" and return to the test with the problem by pressing <Page Down>. Alternatively, proceed to the test that follows the problem test, press "r" and return to the test with the problem. If neither case solves the problem, then the video system has a state dependent compatibility problem.

- Try setting different colors by pressing the Function keys <F1> to <F4>. Press <F5> to return to default color selection. If you are in the *Technical Program,* then try the test in a different video mode by using the *Select Video Test Mode* menu.

- If the problem remains and your screen is at least marginally readable, and the keyboard and mouse continue to function properly, then you have a somewhat more serious compatibility problem. If your system does not respond properly to keyboard and mouse input, or your screen is unreadable, then move to the *Major Compatibility Problem* section, below.

- The next step is to operate your system in a basic minimum configuration and try the tests again. Turn the power off, insert a backup copy of the DOS distribution disk that you received from the manufacturer of your computer system, then turn the power back on. If your system cannot be operated in this manner, then perform whatever steps are necessary to deactivate all non-essential hardware and software. If this solves the problem, then one or more of the software and hardware items that were eliminated is the cause of the problem. To figure out which one, you will need to undertake the sometimes tedious and time consuming task of repeating the tests while including combinations of one or more of the previously eliminated items.

Major Compatibility Problem

Before beginning with the procedures discussed here, you should first try the recovery steps outlined under *Minor Compatibility Problem.*

1. Press the <End> or <Esc> keys followed by "r" to reset the video system. If that works you will be back in a DisplayMate menu, otherwise proceed to step 2. Next, repeat the same menu selection and all the tests up to the one preceding the previous failure. Then press "r". This may rid the video system of some peculiar condition. Now try proceeding to the test that failed previously. If things now work, then the video system has a transitional state compatibility problem. Otherwise, proceed to step 4.

2. Press <Ctrl>C or <Ctrl><Break> to try terminating DisplayMate. If that works, then you will be back at the DOS prompt; otherwise try to reboot the system by simultaneously pressing the keys <Ctrl><Alt><Del>. If that works, the system will reboot, otherwise you will have to power down the computer and then turn it back on after waiting 15 seconds. Restart DisplayMate, return to the menu, and proceed to step 3.

3. Try proceeding to the failed test again by repeatedly pressing <Space Bar> followed by "r", for reset. If that solves the problem, then the video system is again in a peculiar transitional state, but is more confused than in step 1 above.

4. Repeat the same menu selection and all tests up to the one preceding the failed test. Press <Ctrl><PgDn> or "s" followed by 1 to try to skip the failed test. If that doesn't work, then repeat the entire process but try "s" followed by 2 to try to skip two tests. If that doesn't work, then continue with 3, 4, *etc.*, until you get a satisfactory test or you return to the Menu. From the list of Tests in Appendix G, note which tests failed.

5. If you wish to pursue the problem, the next step is to try the video adapter in another computer. If that solves the problem, then there is most likely a timing problem between your original computer and the video adapter card that affects the function being exercised by DisplayMate. Determining which one is actually at fault may require an experienced hardware technician, and is probably not worth the effort. Another possibility is that there is a bug in the BIOS on the original system. On the other hand, if the compatibility problem remains on the other computer, then the video adapter has a problem in the hardware or in its BIOS routines. In either case, you should probably contact both the manufacturer of the computer and the video adapter to see if they can resolve the problem.

6. If all else fails, then turn the power off and remove as many plug-in adapters as possible from your computer. Ideally, this will leave only your video adapter and a floppy disk adapter in the system. Insert a backup copy of the DOS distribution disk that you received from the manufacturer of your computer system, then turn the power back on. If this solves the problem, then one of the adapters that you removed is causing the compatibility problem. Cycle through each adapter to find the source of the problem, and then call both the manufacturer of that adapter and the video adapter to see if they can resolve the problem.

Video Display System Trouble Shooting

This section discusses general trouble shooting procedures to be used if your video system does not appear to work properly. There are three separate analysis: one for a *New or Reconfigured System,* another if there is *No Display Image,* and a third if there is a *Bad Display Image.*

New or Reconfigured System

If this is a new video system, or a reconfiguration of an existing system, then perform the following tests:

1. Check that the display's power indicator is lit, and that the computer's disks and fan are whirring. If not, then skip to step 1 of *No Display Image,* below. Check that the video cable is plugged in at both ends. If there are retaining screws or clips on the connectors, fasten them. Increase the Brightness and Contrast controls all the way up if you are getting only a blank screen. If the screen doesn't produce any visible light, suspect a malfunctioning display. If it does, then suspect the video adapter or video cable.

2. With the power off, check that the adapter card is properly seated in its slot. Make sure it is inserted all the way down into its connector, and that the rear bracket for the card is properly screwed into the system unit. If you have a full length adapter card, make sure that it fits into the plastic support bracket at the front of the cage.

3. Turn the power back on and listen for any unusual beeps while the system is booting up. If the system detects a problem with the video adapter, the speaker will produce 1 long beep and 2 or 3 short beeps on IBM systems and adapters. This indicates an error in the video configuration switches, or a hardware failure within the adapter. Other beep codes indicate problems with other system components. Non-IBM systems may have different beep codes.

4. Early in the booting process you should see a blinking cursor on the top left of your display screen. At this point many non-IBM adapters produce a short identification on the screen. The system should produce only one short beep towards the end of the boot procedure after the memory has been checked, and then turn on the floppy disk drive and the hard disk to complete the boot-up procedure. If you do not see and hear these latter two operations, and there were no error beeps in step 3 above, then you most likely have a malfunctioning system unit.

5. At this point you should see one of several messages from DOS and a prompt or a request for input. On PC class machines, an incorrect setting of the system board video configuration switches may result in no screen display at all, including no visible blinking cursor. On AT class machines the system will attempt to find a functioning video system if there is an incorrect configuration setting and, if successful, will produce a message asking you to correct the configuration error by running the system setup program. If you have an EGA adapter, then the configuration switches on the card must also be properly set to match the type of display connected. If they are set incorrectly, then it is likely that you will see no screen display at all, including no visible blinking cursor. See your computer and video adapter manuals for the correct switch settings for your system. IBM VGAs and PS/2 machines do not have any configuration switches that can be set incorrectly.

6. If you are sure that everything is properly configured, then you should suspect a malfunctioning component. First, try a different video cable. If possible, try the display on a different computer system that is configured in the same way as your system. If it doesn't work, then the display is bad; if it does, then your computer and/or video adapter are bad. Next, try the video adapter in another computer to see if it is at fault. Alternatively, if you do not have access to another computer, try returning to your old system configuration to

see if that still functions properly. If it does, and you have a multi-frequency display, then the new video adapter is bad.

7. If the problem persists, contact your dealer or call each manufacturer's technical assistance line for further installation information.

8. Carefully go over the installation instructions for the display, video adapter, and computer, in order to make sure that they are all compatible and properly configured for one another. Pay particular attention to setup switches and option jumpers or straps. Consider whether your system may be suffering from address conflicts or system bus conflicts. These are discussed in detail in Chapter 8. Address conflicts can arise if you have more than one monochrome adapter or more than one color adapter in your system. If you have a Hercules adapter, make sure that it is in the "half" configuration to eliminate the possibility of conflicts with a color adapter. To eliminate the possibility of system bus conflicts, set all your 16-bit adapters to 8-bit operation. If all else fails, then turn the computer off and remove as many plug-in adapters as possible from your computer. Ideally, this will leave only your video adapter and a floppy disk adapter in the system. If this solves the problem, then cycle through each adapter to find the culprit, and have it serviced to eliminate the problem.

No Display Image

The following discussion presumes that the display and its attached video adapter are properly configured for one another. The most common problem is the lack of any display image. If you have a bad display image, then see the next section, below. Perform the following tests in order, until you get an indication of the source of the problem and/or remedy it:

1. Check that the display's power indicator is lit, and that the computer's disks and fan are whirring. If they are, then skip to step 2. Next, check that the power switches are on. Before proceeding any further, make sure you are fully aware of all safety precautions in dealing with AC power, otherwise find someone who is. Verify that the wall outlet and/or power strip has AC power. If it does, then look for a blown circuit breaker button or fuse on the display or computer. Most will not have either, but if either one is bad, check your owner's manual before resetting. Next, turn the display's power

switch off, disconnect the power cable from the power outlet, and then from the back of the display, if this is possible. Examine the cord and plugs for damage and reconnect them in the opposite order. Carefully seat the connectors at both ends and check for looseness. Turn the display's power back on. Do the same for the computer system unit. If that doesn't work, change power outlets and then swap power cords, if possible. If the display's indicator is still off, then have the display serviced. If the computer's disks and fan are still off, then have the system unit serviced.

2. Check for a screen blanking program by pressing the following keys in the order shown, and look to see if the screen is restored after each key: the <Shift> key, <Space Bar> key, <Enter> key, <Control>C, <Control><Break>.

3. Check that the external configuration switches have not been inadvertently changed. On multi-frequency displays check the mode switches, particularly the color/monochrome switch.

4. Increase the Brightness and Contrast Controls all the way up if you are getting a blank screen. If the screen doesn't produce any visible light, suspect a malfunctioning display. If it does, then suspect the video adapter or video cable.

5. Turn the display off and disconnect the video cable from the computer, and then from the back of the display, if this is possible. Examine the cable, its connectors, and the connectors on the computer and on the display for damage, and then reconnect them. Carefully seat the connectors at both ends and check for looseness. If there are retaining screws or clips on the connector, then screw or fasten them. Turn the display's power back on. If that doesn't work, remove any video extension cables. Next, try a different video cable if possible.

6. If you do not have a readily available second display identical in functionality to the original display, and known to be in good working condition, then skip to step 7. Power down both displays, connect the second display to your computer and power it up. If it works, then have the original display serviced. If not, then connect the original display to a second functioning

computer and power it up. If it works, then continue to check the original computer beginning with step 7.

7. Reboot the computer by simultaneously pressing the keys <Ctrl> <Alt> <Del> and listen for any unusual beeps while the system is booting up. If the system detects a problem with the video adapter, the speaker will produce 1 long beep and 2 or 3 short beeps on IBM systems and adapters. This indicates an error in the video configuration switches or a hardware failure within the adapter. Other beep codes indicate problems with other system components. Non-IBM systems may have different beep codes.

8. Turn the computer off, wait 15 seconds, and then turn it back on. Listen for any unusual beeps as in step 7.

9. Proceed as in step 7, but use a backup copy of the DOS Startup Disk.

10. Proceed as in step 7, but use the computer and/or video adapter diagnostic disk.

11. If you have access to another computer, then switch the video adapter. If it works, then have your computer serviced. If you have another video adapter identical in functionality to the first, and known to be in good working condition, then try it in your system. If it works, then have the original video adapter serviced.

12. If you still have no idea as to the problem, have both the computer and display serviced.

Bad Display Image

If the display produces an image, but it appears incorrect or distorted, then:

1. If the display is producing a single bright horizontal or vertical line, or a single bright spot, then turn off the display immediately to prevent damage to the screen phosphor, and possibly to other display circuits. Connect a different display to the computer. If it demonstrates the same problem, have the video adapter serviced, otherwise have your original display serviced.

2. If the display image looks clear, steady, and full size, but appears to contain garbage information, then the problem most likely lies with the video adapter hardware or malfunctioning software. To check for the latter, reboot the computer using a backup copy of the original DOS distribution diskette for your system and run DisplayMate to test the different video modes. If this clears things up, the problem most likely lies with a software program on your system, although it could be an intermittent hardware problem. If the problem remains, have your video adapter serviced.

3. If the display image is jumpy or rolls, is skewed, is off center or improperly sized, first try adjusting all the available user controls. Double check that the video cable is securely connected at both ends. See Chapter 9 on *Screen Interference Problems* to check whether that could be the problem.

4. Check that the external configuration switches have not been inadvertently changed. On multi-frequency displays, check the mode switches, particularly the color/monochrome switch.

5. Check the settings of all other external user controls.

6. Reboot the computer by simultaneously pressing the keys <Ctrl> <Alt> <Del>.

7. If you do not have a readily available second display identical in functionality to the original display and known to be in good working condition, then skip to step (8). Power down both displays, connect the second display to your computer and power it up. If it works properly, then have the original display serviced. If not, then have your video adapter serviced.

8. Run the diagnostics program for the computer and/or video adapter.

9. If there are missing or incorrect colors, or the image is unsteady or broken up, then check the video cable. Turn the display off and disconnect the video cable from the computer, and then from the back of the display, if this is possible. Examine the cable, its connectors, and the connectors on the computer and on the display for damage, and then reconnect them. Carefully seat the connectors at both ends and check for looseness. If there are retaining screws or clips on the connector, then screw or fasten them. Turn

the display's power back on. If that doesn't work, try a different video cable if possible.

10. Remove any video extension cables.

11. If the low intensity red primary color is missing on an IBM EGA, then check the P1 monochrome/color strap on the adapter. See the installation instructions for the adapter.

12. If the colors are wrong or unstable on a CGA with a composite video display, have a service technician adjust the trimming capacitor for the system clock.

13. If the image cannot be properly centered, appears compressed, or stretched, check the switch settings on the video adapter for the type of display.

14. If you have access to another computer, then switch the video adapter. If it works, have your computer serviced. If you have another video adapter identical in functionality to the first, and known to be in good working condition, then try it in your system. If it works, then have the original video adapter serviced.

15. If you still have no idea as to the problem, have both the computer and display serviced.

Contacting Technical Support

This manual, the help facility, and this chapter have been designed to help you solve most of the difficulties you may encounter while installing and running DisplayMate. If you have not already done so, please review the following appropriate sections of the manual before contacting Technical Support:

- System Requirements: Appendix A.
- Installation: Appendices B, C, D.
- Running DisplayMate: Chapter 4.
- Trouble Shooting This chapter.

If you need additional assistance, you may contact us through the channels listed below. In order to qualify for support services, you MUST be a registered owner of DisplayMate. If you purchased DisplayMate from Sonera Technologies, you are already a registered owner. If you purchased DisplayMate from a dealer or mail order company, you must return the enclosed *Registration Card* before you qualify for Technical Support. If the Software License is transferred to another party as stipulated in the Software License Agreement, then the original registered owner should contact us in writing in order to update our records. Registered owners also receive information on product updates, and can purchase updates and enhancements at a reduced price.

If your program disk or manual is defective or unusable, you must contact us in order to obtain a *Return Authorization* number before returning the item for replacement. This service is free under the terms of the 90-day Limited Warranty period.

When contacting Sonera Technologies for Technical Support, you will need to supply us with the following information:

- The version number and serial number of DisplayMate. These appear on the opening screen of the program.
- The production date of the DisplayMate disk. You can determine this by typing "dir a:" for the distribution disk.
- The type of video system you have: MDA, CGA, HGC, HIC, EGA, MCGA, VGA. The brand and model of your video adapter and video display.
- The brand and model of your computer. For example: IBM AT model 339.
- The BIOS version of your video adapter and computer. You can determine this from the *Hardware and Mode Information* selection in the *Main Menu* of the *Technical Program*. Copy down the information on the *Video System Information* screen.
- The version of DOS you are using. You can determine this by typing "ver" at the DOS prompt.
- The names of any memory resident programs you are using.

You may contact us via any of the following channels:

Mail: You may write to: DisplayMate Technologies Corp.
Technical Support
P.O. Box 550
Amherst, NH 03031

FAX: Our FAX number is: 603-672-8640.
Be sure to include your voice and FAX telephone numbers.

Telephone: Our telephone number is: 603-672-8500.
Hours are 9 am to 5 pm Eastern Time, Monday through Friday.

Email: Our address is: info@displaymate.com
Be sure to check the DisplayMate Website for additional information.

Website: Our address is: www.displaymate.com
The website includes extensive information on all our products.
There is also a *Top 10 Video Tips* section and demo versions of our DOS and Windows products.

Sources of Additional Information

Publications

The following are reference works on VDT ergonomics and safety:

American National Standard for Human Factors Engineering of VDTs
Published by The Human Factors Society, 1988.
Available from the American National Standards Institute. HFS 100-1988.
Addresses for both organizations are listed below.

NIOSH Publications on Video Display Terminals
National Institute for Occupational Safety and Health.
U.S. Department of Health and Human Services.
Address: 4676 Columbia Parkway; Cincinnati, OH 45226-1998.
Telephone: 513-533-8287.

Human Factors Reference Guide for Electronics and Computer Professionals
Compiled by: Wesley E. Woodson.
Publisher: McGraw-Hill Book Company, 1987. ISBN 0-07-071766-4.
Telephone: 800-722-4276.

Video Displays, Work, and Vision
National Research Council.
Publisher: National Academy Press, 1983. ISBN 0-309-03388-8.
Address: 2101 Constitution Avenue, NW; Washington, DC 20418.
Telephone: 202-334-3313.

VDT News
A bimonthly publication on VDT safety.
Publisher: Louis Slesin.
Address: P.O. Box 1799; Grand Central Station; New York, NY 10163.
Telephone: 212-517-2802.

Biological Effects of Power Frequency Electric and Magnetic Fields
Office of Technology Assessment; Congress of the United States.
Publisher: U.S. Government Printing Office, 1989.
Stock Number 052-003-01152-2.
Address: Washington, DC 20402-9325.
Telephone: 202-783-3238.

Currents of Death
by Paul Brodeur.
Note: We *cannot* recommend this book because of its sensational nature and extremely manipulative one-sided point of view.
For an in-depth review see: *Scientific American,* April 1990.
Publisher: Simon and Schuster, 1989. ISBN 0-671-67845-0.
Telephone: 201-767-5937.

Organizations

The following organizations are involved in studying, promoting, and informing computer users about VDTs:

9to5, National Association of Working Women:
Campaign for VDT Safety.
Address: 614 Superior Avenue, NW; Cleveland, OH 44113.
Telephone: 216-566-9308.

American National Standards Institute:
Distributes standards in all areas, including VDTs.
Address: 1430 Broadway; New York, NY 10018.
Telephone: 212-354-3300.

Center for Office Technology:
An industry association that provides information and education on VDTs.
Address: 575 Eighth Avenue; 14th Floor; New York, NY 10018-3011.
Telephone: 212-560-1298.

Communications Workers of America:
Occupational Safety and Health Program.
Address: 1925 K Street, NW; Washington, DC 20006.
Telephone: 202-728-2483.

Computer and Business Equipment Manufacturers Association:
An industry association.
Address: 311 First Street, NW; Washington, DC 20001.
Telephone: 202-737-8888.

Human Factors Society:
A professional society involved in all aspects of ergonomics.
Address: P.O. Box 1369; Santa Monica, CA 90406.
Telephone: 213-394-1811.

Labor Occupational Health Program; VDT Coalition; University of California:
Information on VDT safety.
Address: 2521 Channing Way; Berkeley, CA 94720.
Telephone: 415-642-5507.

Service Employees International Union:
Campaign for VDT Safety.
Address: 1313 L Street, NW; Washington, DC 20005.
Telephone: 202-898-3362.

Society for Information Display:
A professional society involved in all aspects of display technology.
Address: 8055 West Manchester Avenue; Suite 615; Playa Del Rey, CA 90293.
Telephone: 213-305-1502.

Technical References

IBM Publications:

The IBM manuals should be the final word on the hardware and software standards for its video displays. Overall, they are quite good (and quite expensive) but they are also fraught with a maddening number of errors and omissions. The BIOS Interface and Technical Reference documents the BIOS programming across the entire PC to PS/2 product line. The technical reference manuals for the PC, AT, and EGA contain the assembly language source code for the BIOS, and are the best source of information. Unfortunately, source code is not available for the VGA and PS/2 products. These publications can be ordered over the phone directly from IBM by calling 1-800-426-7282 and using a credit card. Check for the latest Part Numbers.

PS/2 and PC BIOS Interface Technical Reference. Part Number 68X2341.

PS/2 [VGA] Display Adapter [Technical Reference]. Part Number 68X2251.

PS/2 Model 30 [MCGA] Technical Reference. Part Number 68X2201.

Enhanced Graphics Adapter [Technical Reference]. Part Number 6280131.

PC AT Technical Reference. Part Number 6280070.

PC Technical Reference. Part Number 6322507.

Phoenix Publications:

Phoenix Technologies makes compatible BIOS for IBM clones, and should be an excellent source of independent information on how the BIOS actually works. Unfortunately, their publications are also fraught with a maddening number of errors and omissions. Fortunately, they contain a lot of useful information. At less than one-fifth the price of the IBM BIOS manuals, they seem like quite a bargain. They are generally available in bookstores. The ISBN number can be used to order them.

System BIOS for IBM PC/XT/AT Computers and Compatibles. Addison-Wesley Publishing Company, Inc., 1989. ISBN 0-201-51806-6.

CBIOS for IBM PS/2 Computers and Compatibles. Addison-Wesley Publishing Company, Inc., 1989. ISBN 0-201-51804-X.

Books:

The following books are an excellent collected source of information on video adapters and displays. They are generally available in bookstores. The ISBN number can be used to order them.

Abrash, Michael. Power Graphics Programming. Que Corporation, 1989. ISBN 0-88022-500-9.

Doty, David B. Programmer's Guide to the Hercules Graphics Cards. Addison-Wesley Publishing Company, Inc., 1988. ISBN 0-201-11885-8.

Ferraro, Richard. F. Programmer's Guide to the EGA and VGA Cards. Addison-Wesley Publishing Company, Inc., 1988. ISBN 0-201-12692-3.

Kliewer, Bradley Dyck. EGA/VGA A Programmer's Reference Guide. Intertext Publications, Inc. McGraw-Hill Book Company, 1988. ISBN 0-07-035089-2.

Somerson, Paul. PC Magazine DOS Power Tools. Bantam Books, Inc., 1988. ISBN 0553-34526-5.

Stevens, Roger T. Graphics Programming in C. M&T Publishing, Inc., 1988. ISBN 1-558-51018-4.

Sutty, George and Blair, Steve. Programmer's Guide to the EGA/VGA. Brady Books. Simon & Schuster, Inc., 1988. ISBN 0-13-729039-X.

Wilton, Richard. Programmer's Guide to PC & PS/2 Video Systems. Microsoft Press, 1987. ISBN 1-55615-103-9.

Glossary

This glossary contains definitions for terms relevant to computer displays. Many of the entries are inherently technical, but we have tried to make them understandable and useful to a wide audience.

Active Display: On computers with more than one display, the one that DOS and the system BIOS use for all output sent to or originated by them. The active and inactive displays may be interchanged under program control, or by using the DOS mode command.

Active Matrix: A technique for manufacturing LCD displays where each individual pixel is controlled by its own transistor. This greatly improves the contrast, response time, and range of acceptable viewing angles in comparison to the standard multiplexed LCD displays. The cost also increases substantially. Active matrix displays are also referred to as *TFT* displays; see *Thin-Film Transistors*.

Active Page: When more than one screen image can be stored in video memory, the one that the video adapter is presenting on the display.

Adapter: A circuit board that can be installed in a computer to interface specialized hardware to the computer system. The most common are video adapters (MDA, CGA, HGC, EGA, HIC, VGA) and serial and parallel adapters. Some computers already have a video adapter on the main computer circuit board, and do not need a separate video adapter card; however, you can generally add a different video adapter if you need to upgrade.

Aliasing: A result of the arrangement of pixels in a regularly spaced pattern on the screen, so that when drawing an image it is necessary to settle for the nearest available pixel instead of a pixel located just where you need it. When drawing an inclined line, this gives it a jagged appearance. When too many dots or lines are drawn in the same area, they may fuse completely into a solid or produce a Moire pattern that results from aliasing.

All Points Addressable: APA: Just another name for graphics. It means that each dot or pixel on the screen has a unique address and can be individually selected and controlled.

Alphanumeric Mode: A/N Mode: A non-graphics display mode in which only characters from a standard character set containing alphabetic, numeric, and selected special symbols can be displayed on the screen. Such modes are easier to program and are faster than graphic modes. A significant fraction of all software is restricted to alphanumeric modes.

Analog Display: The intensities and colors on an analog display are controlled by varying the voltage levels on the display's signal inputs. The voltage levels range from 0 to 0.7 volts, dc. This allows an infinite number of color and intensity variations. Video adapters with analog outputs can generally produce only 64 to 256 different voltage levels, so the number of colors and intensities that are actually produced on an analog display is determined by the adapter. The number of available colors for the VGA is 262,144, considerably greater than the 64 colors available for the EGA with a digital display.

Aspect Ratio: The numerical ratio of the video display image width to height, which is 4:3 or 1.33 for all of the IBM video adapters. This ratio descends from broadcast television and old motion picture standards. If your display does not accurately reproduce this ratio, then the output will appear distorted; for example, circles will look like ovals.

Attributes: In text modes an attribute is associated with each character position on the screen. It specifies the foreground and background colors, and the character's blinking status. For some adapters the attribute also specifies character underlining and font selection.

Auto-Sense: Auto-sense can mean that a video adapter automatically determines what type of display is connected to it, eliminating the need for the user to specify this via configuration switches. Auto-sense can also mean that the adapter automatically determines whether it is connected to an 8-bit or 16-bit wide system bus.

Auto-Switch: Many non-IBM video cards emulate more than one IBM video adapter. They can often be configured to switch automatically between the emulated IBM adapters based on how the software accesses the cards.

Auxiliary Video Extension Connector: Used by advanced video boards such as those based on the IBM 8514/A or TI 340X0 to connect directly to the VGA hardware and to exchange digital and analog information with the VGA system. It can also be used to allow the VGA to use the advanced adapter's display. The Auxiliary Video Extension Connector also goes by the names VGA Pass-Through Connector and Video Feature Connector. This form exists only on IBM systems with a Micro Channel system bus.

Background Color: The color of the screen where no text or graphics is displayed. The default background color is generally black. In reverse video the background color is white. In text modes each character can have its own background color. Graphics modes have one hardware defined background color, but many adapters can be programmed to have more than one background color.

Bandwidth: This is the frequency response of the video amplifiers in the video display, generally specified in MHz, up to the "-3 db" point, where the response has fallen by 50%. Sometimes the *Dot Clock* frequency is listed as the bandwidth; suspect this if "-3 db" is not included with the specification.

Basic Input/Output System: BIOS: The specialized software that performs direct hardware control of the computer and its peripherals, such as a video display system. Advanced video cards such as the EGA and VGA contain their own on-board BIOS.

Bit Planes: A method of organizing memory on the EGA, VGA, and HIC video adapters where the primary colors each have parallel memory maps with the same memory addresses. The planes can be manipulated separately or together when drawing an image.

Blooming: A loss of resolution in the display image due to defocusing that results from high image intensities.

Cathode Ray Tube: CRT: The technical name for the picture tube used in most computer displays and television sets.

Character Box: The number of horizontal and vertical pixels reserved for drawing each character on the screen. The sizes range from 8×8 pixels for the CGA to 9×16 pixels for the VGA.

Character Set: A collection of 256 symbols that is used as a template for drawing characters on the display in both text and graphics modes. In the MDA, CGA, and HGC the character sets are fixed in hardware; in the other adapters, they can be downloaded from ROM or disk memory.

Coaxial Cable: Coax: A special signal line for electrical signals that consists of two concentric conductors separated by insulating material. The signal is shielded, and the cable has precise electrical characteristics for the accurate transmission of video signals. The primary characteristic is called impedance, which is 75 ohms for the analog video systems discussed in this manual. A single 75 ohm termination at each end of the line maintains accurate signal levels and prevents reflections, which appear as ghosts in the image.

Color Burst: For composite video systems, the signal that synchronizes the color signal and marks the presence of color information.

Color Display: When not used in a generic sense, this refers to a digital color display that only connects to a CGA, or an EGA in compatibility mode. The display is limited to 16 colors and a resolution of 640 horizontal by 200 vertical pixels.

Color Graphics Adapter: CGA: One of the two original video adapter cards introduced in 1981 for the IBM Personal Computer. Now a video standard for the modes that were used by this card. Although superseded by EGA, VGA and other newer standards, the CGA remains the most widely supported video standard in use. Virtually all personal computer software can run on CGA hardware, with few exceptions. Many low-priced and portable computers still use this standard. Newer standards such as EGA, MCGA, and VGA support CGA text modes at much higher resolutions, and produce better formed characters that are nicer to read.

Color Map: A table or set of registers that translate the color numbers stored in the adapter's memory into the actual red, green, and blue colors sent to the display.

Color Temperature: A method of specifying color based on the resemblance to a body raised to a given temperature, generally measured in degrees Kelvin above absolute zero. Color temperature is often used to characterize the color of white phosphors. A temperature of 6500° Kelvin corresponds to a white that matches average daylight; a temperature of 9300° Kelvin corresponds to a white with a noticeably bluish tinge and is found on many displays and televisions. A temperature of 3500° Kelvin corresponds to a white with a noticeably red tinge, and is similar to the color of incandescent lighting.

Composite Video Displays: Low to medium quality television style displays where all the intensity, color, and synchronization signals are encoded into a single signal. They generally conform to broadcast television standards, but can have a higher resolution if no color signals are present. See *Color Burst.* When color information is present, it causes interference with the video intensity signal. As a result, color displays are useful only at low resolutions. Not commonly offered for PCs after 1984.

Configuration Switches: On EGA adapters, four switches set by the user that define the type and number of displays connected to the computer. On some adapters the switches may be emulated in memory, and controlled by software supplied by the manufacturer.

Cursor: A marker that indicates the current typing or drawing position on a display. In text modes, special hardware causes the cursor to blink automatically. In graphics modes, blinking cursor hardware is generally not provided, and a non-blinking square block is often produced in software.

Cursor Emulation: A BIOS compatibility mode for specifying the size and position of the cursor in terms of 8 pixel high CGA characters, instead of the actual character size being used by the adapter.

Default Video Mode: The particular video text mode the computer selects at power-on, or after a reboot. It depends on the type of video adapter and display connected to the computer. On PCs, ATs, and EGAs, it is determined by switches set by the user when the computer is installed. On PS/2s it is determined automatically by the BIOS.

Digital-to-Analog Converter: DAC: Used to convert numbers that define an image in video memory into voltages needed to control the intensities on an analog display.

Digital Display: A digital display can only produce a fixed number of intensities and colors on the screen. They are specified by transmitting numbers in the form of digital signals to the display that have a range of 0 to 5 volts dc. An MDA has 2 signal lines and can have 4 intensities (but only 3 are used), a CGA has 4 signal lines and can specify a total of 16 colors, and an EGA has 6 signal lines and can have a total of 64 colors.

Direct Drive Displays: High quality displays that contain separate lines for each of the video signals, and the horizontal and vertical synchronization signals. To be differentiated from composite displays, which use only one signal line and are no longer in common use for computer displays.

Display: The generic name for a computer's visual output device.

Display Switching: A protocol for switching between a system board video adapter and a video adapter card that belongs to the same video adapter family, and which, therefore, have hardware conflicts in memory or port addresses. It is used to switch between an MCGA and a VGA adapter on IBM PS/2 models 25 and 30, and is implemented via two undocumented hardware control ports on the IBM PS/2 VGA adapter.

Dithering: A method for producing colors and intensities not directly available on a video display by using patterns of pixels. Blending by the eye produces the desired appearance, although in most cases the pattern may still be visually evident.

Dot Clock: The rate at which pixels are transmitted to the display. This rate is generally expressed in millions of cycles per second, MHz. The higher the rate the more expensive the electronics needed in the video adapter and the video display.

Dot Pitch: In color displays, the distance between adjoining phosphor triads on the inside of the screen. Each triad is made up of red, green, and blue phosphor dots arranged in a triangle. The distance is generally expressed in millimeters. The smaller the distance, the less grainy and color fringed the image appears. Most displays used in PCs have a dot pitch in the range of 0.20 to 0.45 mm.

Double-Scanned: When the resolution of a video adapter is exactly twice what is needed for certain video modes, each line is duplicated twice. This gives all pixels a strong box-like appearance. Double-scanning is used primarily by the VGA and MCGA to emulate the 200 line resolution CGA and EGA modes.

Driver: Supplementary software that must be added to a computer's operating system in order to control new hardware or to control standard hardware in a new way.

Dual-Ported Memory: Memory on video adapters that can be accessed simultaneously by the system microprocessor and by the video adapter. This speeds up the drawing of images, and eliminates the need for contention circuitry to arbitrate simultaneous requests. It is generally referred to as *VRAM,* and is more expensive than the *DRAM* that is commonly used on most video adapters.

Dynamic Random Access Memory: DRAM: The most common form of memory found in computers and video adapters. It requires a special hardware refresh cycle every few milliseconds in order to prevent the loss of information. During the refresh cycle, the memory is busy and unavailable to the processor or the video adapter. Static RAM does not require a refresh cycle, but is considerably more expensive.

EIA-170 and EIA-343A: These are Recommended Standards by the Electronic Industries Association, EIA, for video signals. EIA-170 refers to composite video standards for broadcast television studios. EIA-343A refers to composite video standards for high resolution video systems with 675 to 1023 lines. For computer video display systems, they are sometimes used as video signal standards for connecting video equipment that may not share all of the timing parameters of the standard. Formerly referred to as RS-170 and RS-343A.

Electroluminescent Displays: Work by using an electric field to excite phosphors in a thin film glass. These displays produce bright images with high contrast and offer a wide viewing angle, but are expensive and consume a fair amount of power.

Enhanced Color Display: A digital color display intended for use with the Enhanced Graphics Adapter, EGA. It can also be used with the Color Graphics Adapter, CGA, and the Monochrome Display Adapter, MDA. The display is limited to 64 colors and a resolution of 640×350 pixels.

Enhanced Graphics Adapter: EGA: Introduced by IBM in 1984 as an upgrade for both the MDA and CGA adapters. It provides high resolution 640×350 graphics with 16 simultaneous colors, chosen from a palette of 64 available colors. It has a programmable character generator that allows up to 4 character sets or fonts to be downloaded at a time. Screens with up to 43 rows of text can be displayed using one of the standard character sets. Its other features include graphics blinking, smooth scrolling, panning, and split screens.

Enhanced Industry Standard Architecture: EISA: The name given to the 32-bit wide adapter bus on many 80386 and 80486 computers that is upward compatible with the ISA bus on AT computers.

Extremely Low Frequency: ELF: Corresponds to cyclic variations in the range of 5 Hz to 2 KHz, *i.e.,* 5 to 2000 cycles per second. Fields in this frequency range are produced by the vertical deflection coils in a CRT display.

Feature Connector: On EGA and VGA hardware, a special connector that provides direct access to the board's internal signals. It is provided for interfacing with external special purpose hardware, such as advanced video adapters.

Flicker: A fluttering brightness sensation that arises in video displays because the video display images are not generated continuously, but are rather redrawn between 50 and 70 Hz, or cycles per second, in a process called *Refresh*. The flicker rate is determined by the video adapter hardware and the video mode. Flicker is minimized by using a screen phosphor with an appropriate persistence. For most people, flicker is not apparent beyond 70 Hz; however, under some circumstances it can be visible upwards of 100 Hz.

Foreground Colors: The colors available from a palette that can be used to draw graphics or text on the screen. The number may vary from one to 256 or more, depending on the video adapter, video mode, and the amount of video memory available. Wherever foreground information does not appear, the background color is displayed.

Gas Plasma Display: A gas plasma display is, in effect, a collection of addressable neon lamps. Each pixel gives off an orange-red glow under adapter control. These displays produce bright images with high contrast, and offer a wide viewing angle, but consume so much power that they are almost never used in battery operated computers. They are very popular, however, for portable computers that use AC power.

Glare: Consists of reflections from the surface of a display screen that appear nebulous and featureless to the user, and cannot be focused into an image. A brightly illuminated wall that is opposite a display will produce glare. Compare to *Specular Reflections.*

Gray Levels: The number of different intensities a video display system can produce.

Gray-Scale Display: Any monochrome display that can produce a range of intensities. The color of the screen is not necessarily white, and may be green or amber, for example. In many cases, gray-scale displays emulate color displays by mapping the different colors to different intensities.

Gray-Scale Summing: A method of converting color images to monochrome images on the VGA and MCGA by adding the intensities from the individual red, green, and blue primary colors together for each color in the palette. The weighting factors are determined from the relative sensitivity of the eye to the different primary colors. While this accurately converts the intensities, visual contrast may be significantly reduced due to the loss of color information.

Halo: A doughnut shaped area around every illuminated pixel on the screen that results from internal reflections within the display screen. It reduces contrast and resolution.

Hercules Graphics Card: HGC: A video adapter introduced in 1982 by Hercules Computer Technology that is 100% hardware compatible with the IBM MDA, and also provides a 720×348 pixel resolution graphics mode.

Hercules InColor Card: HIC: Introduced in 1987, and extends the Hercules monochrome graphics standard into the color regime. It provides high resolution 720×348 graphics with 16 simultaneous colors, chosen from a palette of 64 available colors. It uses the same Enhanced Color Display as the EGA.

Hertz: Hz: Cycles or clock ticks per second. Named after the physicist Heinrich Hertz.

Inactive Display: In a two display system, the display that is not being used by BIOS and DOS for video output.

Industry Standard Architecture: ISA: The name given to the 16-bit wide adapter bus on AT and many 80386 computers.

Interlaced Scanning: A method in which all the odd scan lines of an image are drawn first, followed by all the even scan lines, *etc.* This technique effectively reduces the image flicker in broadcast television pictures, but is much less successful in the precisely ruled images in computer displays.

Inverted Video: Another name for *Reverse Video.*

Jaggies: The name given to the jagged appearance of inclined lines drawn on a video display due to the effects of *Aliasing.*

Kilo-Hertz: KHz: Thousands of cycles or clock ticks per second. Named after the physicist Heinrich Hertz.

Liquid Crystal Display: LCD: The same device that is used in most digital watches. It has very low power consumption so it is used mostly in portable computers. The display is restricted to a narrow range of viewing angles, and has a slow response time. Visibility is greatly improved when the LCD is back lit with a fluorescent or electroluminescent light.

Mega-Hertz: MHz: Millions of cycles or clock ticks per second. Named after the physicist Heinrich Hertz.

Memory Controller Gate Array: MCGA: The name given by IBM to the video adapter on PS/2 model 25 and model 30 computers. It is commonly called the *Multi-Color Graphics Array*.

Moire Patterns: A visual pattern, often with ripples and waves, that results from the natural interference of two phenomena. On video displays, this can arise from the effects of aliasing, and in color displays from an insufficient number of color phosphor dots or stripes on the screen.

Monitor: Another name for a video display.

Monochrome Display: Generally, any display that can produce only a single screen color. It may also specifically refer to the IBM display that is connected to the Monochrome Display Adapter.

Monochrome Display Adapter: MDA: One of two original display adapter cards introduced in 1981 for the IBM Personal Computer. This adapter produces high quality text displays, but no graphics.

Multi-Color Graphics Array: MCGA: An enhanced CGA video adapter, introduced by IBM in 1987, that includes some VGA features and modes. The real name for the MCGA is *Memory Controller Gate Array*. Available only on IBM PS/2 model 25 and model 30 computers.

Multi-Frequency Display: A display that can support more than one graphic standard from among MDA, CGA, EGA, VGA, SVGA. Such displays accept a range of analog and digital video signals and scanning frequencies.

National Television System Committee Video: NTSC Video: The standard for broadcast color television in the United States established in 1953.

This composite video standard was used in early PC color displays. See also *Color Burst* and *Composite Video Displays*. The first NTSC established broadcast standards for black and white television in 1941.

Normal Video: Displaying text or graphics on a dark background. The simplest case is white information on a black background, but both the foreground and background may be colored, provided the foreground is brighter than the background.

Page: A region of video adapter memory that holds one screen image. In some cases there is enough memory to store more than one image; in that case it is possible to switch rapidly between the pages.

Palette: The set of colors that a video system can display at any one time. Not all of the colors may be visible at once, and there may be more than one palette available to choose from.

Panning: When the image stored in the video adapter is wider than the display's resolution, only a portion of it can be displayed at one time. Panning is a hardware operation that allows different portions of the image to be displayed. The EGA and VGA contain hardware that allows the image to be smoothly panned, a single pixel at a time, so that no jitter is evident during the panning operation.

Pel: An even shorter version of Pixel.

Persistence: The characteristic of a phosphor that continues to emit light after it is no longer being excited. The persistence time is generally the length of time that it takes for the intensity to decay to 10% of the initial intensity.

Phosphor: A substance that gives off visible light when it is excited by an electron beam or electric field.

Pitch: In color displays, the distance between adjoining sets of color phosphors on the inside of the screen. Each set is made up of red, green, and blue phosphor dots or stripes. The distance is generally expressed in millimeters. The smaller the distance, the less grainy and color fringed the image appears. Most displays used in PCs have a dot pitch in the range of 0.25 to 0.45 mm.

Pixel: A contraction of picture element. An image is made up of individual pixels arranged in rows and columns. The resolution of the image is the total number of rows and columns in the image, expressed in the form "columns×rows," so 640×480 means there are 640 pixels horizontally by 480 vertically.

Pixel Aspect Ratio: The dots or points that make up a video image are not necessarily square, or even perfectly round. When they are not, a horizontal line will not have the same thickness as a vertical line, and the horizontal and vertical resolutions are not evenly balanced. The pixel aspect ratio is the ratio of the pixel's width to height. It ranges from a low of 0.4 for the CGA to 1.0 for the high resolution graphics modes in the VGA and MCGA. CRT video displays generally produce only round pixels, which means that there will be gaps between adjacent raster lines in the image when an aspect ratio other than 1 is required.

Pixel Density: The number of pixels per inch or centimeter in the horizontal or vertical direction.

Port: A special address used to send control information to the hardware in a computer system. Video displays are controlled by many ports. Address conflicts often make certain combinations of hardware incompatible.

Primary Colors: A set of colors that are added together in combinations to produce a broad range of derived colors. The standard primary colors are: red, green, and blue. The primary colors used in printing and painting work by absorbing light, so they are subtractive primaries and are the complements of the true primary colors: cyan, magenta, and yellow. They are sometimes mistakenly referred to as blue, red, and yellow.

Primary Display: The active display when the computer is turned on or rebooted.

Professional Graphics Adapter: PGA: Another name for IBM's PGC.

Professional Graphics Controller: PGC: The PGC was introduced by IBM in 1984 as a high performance graphics system. The resolution is 640×480 pixels with 256 colors drawn from a palette of 4096. It has a dedicated on-board Intel 8088 microprocessor that is responsible for doing all the work necessary for actually drawing the text and graphics on the display. This speeds up the graphics and the overall program execution.

Random Access Memory: RAM: The computer's memory that can be read and written by programs running on the machine.

Raster: The set of horizontal scan lines that is used to form an image. The total number of such lines from top to bottom is called the vertical resolution and ranges between 200 and 480 lines for standard PC video modes.

Read Only Memory: ROM: Permanent memory in a computer that contains specialized instructions that can be read but not altered by programs running on the machine.

Red-Green-Blue: RGB: Identifies the three separate hardware or signal components of a color system.

Red-Green-Blue-Intensity: RGBI: The particular hardware and signal components for a CGA and its Color Display. The four signals produce 16 different combinations of colors and intensities.

Red-red-Green-green-Blue-blue: RrGgBb: The particular hardware and signal components for an EGA and an Enhanced Color Display. The upper case letters refer to the primary, high intensity signal, and the lower case to the secondary, low intensity signal. The six signals produce 64 different combinations of colors and intensities.

Refresh: Video display images are not generated continuously, but are rather redrawn between 50 and 70 Hz, or cycles per second, in a process called screen refresh. The screen brightness decays between refresh cycles, giving rise to the sensation of *Flicker*.

Register: A location for storing and retrieving specific control information in a video adapter. Individual registers specify, for example, the horizontal and vertical resolution and the cursor location. The EGA has a total of 72 control registers.

Retrace: In CRTs, the time period during which the beam quickly returns to the left side of the screen to begin a new scan line (horizontal retrace) or to the top of the screen to begin redrawing the screen again (vertical retrace). During this period the beam is turned off and operations that can disturb the image can be safely performed during this interval. Non-CRTs do not require a retrace interval, but it must still be included because some software programs require it.

Reverse Video: Displaying dark text or graphics on a light background. The simplest case is black information on a white background as in the normal printed page, but both the foreground and background may be colored, provided the foreground is darker than the background. It is much harder to properly display reverse video than normal video.

RF Modulator: A device to convert the composite video signal from a CGA into a Radio Frequency signal suitable for input to the antenna terminals of a television receiver. You can buy an RF modulator at Radio Shack and other electronic hobby and parts supply houses, and at some stores that sell video games.

RS-170 and RS-343A: These are Recommended Standards for video signals by the Electronic Industries Association, EIA. They are now referred to as EIA-170 and EIA-343A. See *EIA-170* and *EIA-343A*.

Scan Line: A single horizontal line that is used to form an image. The set of scan lines is called the raster.

Scrolling: An operation where all the information on the screen is shifted up by one line of text, in order to make room for a new line of information at the bottom of the screen.

Secondary Display: In a two display system, the inactive display when the computer is turned on or rebooted.

Smooth Scrolling: Shifts all the information on the screen by only one pixel instead of one entire line of text. By doing this repeatedly, text smoothly rolls up the screen instead of jumping abruptly by one line. Only the EGA and VGA have hardware to perform smooth scrolling.

Snow: Semi-random interference lines that appear on a display when the CPU and video adapter simultaneously access display memory. This is annoying, but not harmful, and is a side effect of attempting high speed screen updates. This problem generally occurs only in the 80 column text mode on a CGA.

Specular Reflections: Pure mirror-like reflections from the surface of a display screen that produce a detailed image and allow the user to focus on them.

Stripe Pitch: In color displays, the distance between adjoining sets of color phosphors on the inside of the screen. Each set is made up of red, green, and blue phosphor stripes. The distance is generally expressed in millimeters. The smaller the distance, the less grainy and color fringed the image appears. Most displays used in PCs have a dot pitch in the range of 0.25 to 0.45 mm.

Super VGA: SVGA: Any of a number of non-standard video modes based on VGA hardware. Some enhance the number of color combinations, while others enhance the resolution. The most popular is 800×600 pixels. Each SVGA mode generally requires that a separate software driver be installed for each application program.

Teletype: TTY: Originally a typewriter that could send and receive information over a telephone line. Text would be typed onto a continuous roll of paper and slowly scroll away into a paper bin. Now the name for computer video display format that provides the same functionality through a protocol that includes scrolling.

Terminate and Stay Resident: TSR: A special class of program that remains as part of DOS after it is run, and can continue to modify the computer's behavior until the machine is rebooted. TSR programs include any pop-up software using hot keys, mouse drivers, screen accelerators, and screen dimmers.

Text Mode: Another name for alphanumeric mode.

Thin-Film Transistors: TFT: The name of the technology used for controlling LCD displays where each individual pixel has its own thin-film transistor. This greatly improves the contrast, response time, and range of acceptable viewing angles, in comparison to the standard multiplexed LCD displays. The cost also increases substantially. TFT displays are also referred to as *Active Matrix* displays.

Transistor-Transistor Logic: TTL: The technical name for the digital signals used in personal computers.

Very Low Frequency: VLF: Corresponds to cyclic variations in the range of 2 KHz to 400 KHz, *i.e.*, 2000 to 400,000 cycles per second. Fields in this frequency range are produced by the horizontal deflection coils and the flyback transformer in a CRT display.

VGA Pass-Through Connector: A variation on the IBM *Video Feature Connector* on boards following the Video Electronic Standards Association, VESA, standard. See *Video Feature Connector.*

Video Adapter: A circuit board that can be installed in a computer to control a video display. See *Adapter.*

Video Buffer: Special memory for a video adapter that is used to hold the image to be presented on the display. The CPU creates an image under program control by writing to this memory.

Video Controller: The hardware that controls the video display. A functional name for a video adapter.

Video Data Area: The BIOS video data area is a special area of system memory that is used by the BIOS routines to store the values of internal working variables that control the video system's operation and specify its configuration.

Video Display Terminal: VDT: One of many common names for a computer video display; others include CRT, VDU, monitor, and display.

Video Display Unit: VDU: One of many common names for a computer video display; others include CRT, VDT, monitor, and display.

Video Electronic Standards Association: VESA: A group of about 50 companies that cooperate in establishing common standards for video display systems.

Video Feature Connector: Used by advanced video boards such as those based on the IBM 8514/A or TI 340X0 to connect directly to the VGA hardware and to exchange digital and analog information with the VGA system. It can also be used to allow the VGA to use the advanced adapter's display. The Video Feature Connector also goes by the names: Auxiliary Video Extension Connector and VGA Pass-Through Connector. This form exists only on the IBM PS/2 VGA adapter.

Video Graphics Array: VGA: Introduced by IBM in 1987 as the flagship video adapter for the IBM PS/2 line of personal computers. It is functionally very similar to the EGA but includes a number of enhancements, the most important of which is analog video output, which provides a palette of 262,144 colors. Its highest resolution mode is 640×480 pixels with 16 simultaneous colors. Another important mode can produce 256 simultaneous colors with a resolution of 320×200 pixels. In text mode the VGA produces the highest quality text of all the standard adapters.

Video Mode: A specific configuration of the video adapter hardware programmed by the BIOS software. IBM has defined 20 standard video modes for its adapters. The MDA has only one video mode, while the VGA has 15 video modes. Virtually all software uses one of the standard modes to produce images on the display.

Video Random Access Memory: VRAM: Generally refers to specialized dual-ported memory on a video adapter. See *Dual-Ported Memory*.

Workstation: A high-powered personal computer with high resolution graphics, generally with a resolution of 1024×768 pixels or more.

Index

A

B B

C C

D

E *E*

F *F*

I

J J

K K

L L

M M

N

O

P

Q

R

S

T

U U

V V

W W

X X

Y Y