Computer-Aided Graphics and Design

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Preface

This text has evolved from a series of lecture notes that were used to present a seminar on automated drafting and computer graphics to Continuing Engineering Education students at Clemson University. Much of the material has also been student-tested in undergraduate engineering graphics classes at the same university. It is, therefore, hoped that all errors, ambiguities, and confusing explanations have been corrected.

Computer-Aided Graphics and Design is a three-semester-hour course. For shorter courses or seminars, the chapters dealing with descriptive and vector geometry may be omitted without destroying the continuity of the text.

The computerized approach of engineering graphics is an indispensable supplement to the manual/analytical methods taught in the regular graphics courses. Producing graphics by computer for many types of applications, especially those involving massive amounts of data or repetition, is much more efficient than by traditional manual methods. There remain, however, many types of graphical problems that can be more easily analyzed by a combination of methods. No attempt has been made to replace all engineering graphics with computer/automated methods. Only those graphical procedures are presented which are felt to make a definite contribution to the effective graphical communications area.

The selection of material in this text is based on the premise that the reader has had a course in engineering graphics. Therefore, many basic situations are included without lengthy explanations or solutions. This makes it possible to keep the emphasis on computer graphics.

Methods of using existing automated drafting programs are stressed, as is the procedure for writing new ones. The emphasis, however, is on the use rather than the creation. It is the author's belief that this delimitation is necessary in a first course in computer graphics, because computer-aided design requires more ingenuity, inventiveness, imagination, and patience. An ability to create new designs can best be developed by experience after the basic computer application techniques are well understood.

The unique features of this book include the following:

1. It is a complete study of engineering graphics, not a computer text.
2. Types of automated equipment and their use are explained in lay terms.
3. The book has a substantial amount of illustrative examples with computer solutions explained in step-by-step fashion.
4. All common methods of graphical construction are presented, although the computer/automated method is emphasized.
5. A unique combination of automated and manual skills is used in many of the problem solutions.

The author makes no claim to originality of the engineering graphics examples used. This book has drawn heavily on the earlier works of others. It is a pioneer effort in the computerization techniques of heretofore manual methods, however. The references consulted are listed in the bibliographies and in various footnotes. The unique character of this book lies in its industrial orientation: the sequencing of the computer graphics topics which are discussed and the documentary and user-oriented manner in which they are presented.

To present this industrial orientation, a number of leading industrial organizations have generously assisted the author by supplying appropriate illustrations and photographs needed in developing certain topics. Every photograph supplied by a computer graphics vendor has been identified by a courtesy line. The author deeply appreciates the kindness and generosity of these companies and the personnel who found the time to consult and allow the author to visit their various manufacturing plants.

The author is grateful to Professors Jon Duff and C. W. Malstrom of Ohio State University and Clemson University, respectively, for their many valuable suggestions in regard to Chapters 1 and 3. Special appreciation must be expressed to the other members of the engineering graphics staff who suffered through the various stages of the course Computer-Aided Graphics and for their patience in learning a new technological development.

Not to be forgotten are the many persons, some students and some teachers, who have made valuable contributions to this classroom text. The author's indebtedness to excellent, intelligent students is hereby reaffirmed.

Daniel L. Ryan

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Chapter 1

Introduction to Automated Drafting

A complete study of engineering graphics must include something about the age of computerization and how it affects work done by a designer or engineer. The human is smart, creative, and slow, while the computer is stupid, uncreative, and very fast. The problem then is to allow human and machine to work well together as a team. The automatic drafting machine is such a computer-related piece of hardware. Certainly their characteristics complement each other, but their languages are very different. We think in symbols and pictures, while the computer understands only simple electrical impulses. Computers and automated graphics are playing an increasingly large part in our lives. Over the past decade, automated drafting applications, particularly for computer-aided design, have been justified because they can save money and time and can improve the quality of the drawings. Dollar savings of from 3:1 to 6:1, and time savings of from 20:1 to 50:1, are typical of those quoted in applications explained later in this text.

Automated drafting or computer graphics is a way of converting the computer's impulses into engineering documents and, conversely, to translate the operator's instructions into electronic data. In many of the more sophisticated systems, we need know little about computer programming in order to control the human-machine effort. In general, automated drafting or computer graphics includes any device which converts computer language to people language, or any device that converts people language to computer language, with the intent of solving problems by creating graphical images.

QUALITY OF COMPUTER-GENERATED DRAWINGS

Most automated drafting machines are easy-to-operate, self-contained, automated systems for the direct translation of rough sketches into high-quality finished ink on vellum drawings. The system is designed for simple, real-time operation by draftspersons or designers and is particularly useful for producing drawings containing repetitive symbology and text. It can be installed in a drafting room since it does not depend on an outside processing source. Applications include logic diagrams, technical illustrations, electrical and electronics schematics, piping and hydraulic layouts, CPM and PERT charts, and many other drawings where speed and accuracy are a must.

An example of an automated system and how it works can be studied by examining a typical block diagram as shown in Figure 1.1. The quality of a computer-generated drawing can also be noted since the diagram was produced by a digital computer (IBM 370) and plotter (on-line CALCOMP). Every illustration, diagram, and drawing used in this textbook was produced by a computer with the help and instructions of a human operator. An automated drafting method, then, would be the combination of these two elements to produce synergy, or united action. The logical basis for this concept lies in the fact that the human mind tends to solve problems heuristically (trial and error), while a mechanical system solves by the use of algorithms (error-free sequence of logic). By letting each (mind/machine) work to its best capacity, a new and better method can be automated. How this human-machine process is automated is rather simple. Strictly speaking, the automation of any process means the improvement or elimination of certain or all parts of the manual labor involved in doing a job. This does not

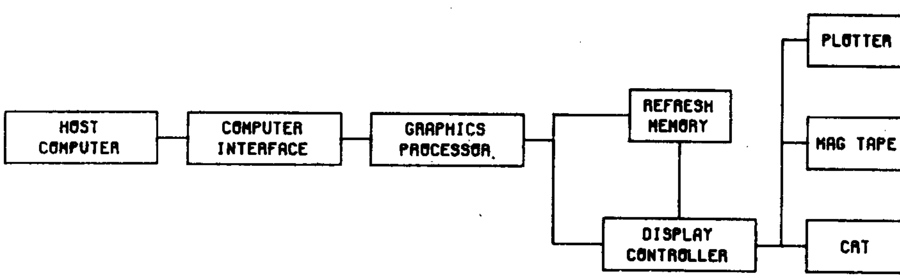

Figure 1.1 Typical automated graphics system.

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C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C * IT SHOULD BE NOTED IN THE TYPICAL AUTOMATED GRAPHICS SYS-        *
C * TEM BLOCK DIAGRAM THAT DATA CAN ALSO BE ROUTED FROM THE          *
C * DISPLAY CONTROLLER TO THE HOST COMPUTER. IN MANY CASES           *
C * THE HOST COMPUTER EMPLOYS A LINE PRINTER THAT WILL PRO-          *
C * VIDE A HARD COPY OF THE DISPLAY UPON COMMAND FROM THE            *
C * DESIGNER. IN ADDITION, A JOY STICK (CURSOR) IS USED TO ALLOW     *
C * THE DRAFTSMAN TO ENTER DATA AT SPECIFIC LOCATIONS. THE           *
C * HOST COMPUTER MUST BE ABLE TO OBTAIN THE DISPLAY AT ANY          *
C * GIVEN TIME FROM THE DISPLAY CONTROLLER AND MUST ALSO BE          *
C * ABLE TO OBTAIN JOY STICK LOCATION INFORMATION FOR DATA           *
C * ENTRY. THE DISPLAY CONTROLLER, UPON REQUEST FROM THE             *
C * HOST COMPUTER, ROUTES THE DESIRED DATA TO THE COMPUTER           *
C * FROM THE REFRESH MEMORY VIA THE INTERFACE.                       *
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
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mean the elimination of humans from the scene, for we have to start and stop the process, either directly by pushing a button or indirectly by programming another machine device such as a computer. Modern automated drafting terminals, for instance, can be preprogrammed so that all the data in a computer file can be displayed by pushing a single key on a typewriter keyboard. The signal of the depressed key releases a set of data points that can describe an entire engineering drawing or something as simple as a circle.

The first drafting machine to come onto the market eliminated the need for the draftsperson to push and pull a triangle and T-square around the drafting table. The first step in automating the drafting procedure, then, would be the elimination of the pencil or pen from the draftsperson's hand. The draftsperson is still there to operate the machine much as was done before. A good example of these types of machine are the coordinatographs presently on the market. These are commonly called precision plotters for they are very accurate, usually within ±0.0008 inch. The pen or plotter point is held along the horizontal axis and is free to move from side to side over the range of the machine. At the same time the entire X or horizontal assembly can be moved vertically along the Y axis. The drawing surface is very flat to plus or minus five-thousandths of an inch and is exactly parallel to the axis of the machine. Optically ground glass is used for the drawing surface and is backlighted for easy visibility.

The draftsperson moves the required amounts in X and Y to create straight lines. Graphic shapes can be made with attachments that locate the center of each object. Irregular curves such as cam profiles, power curves, cross-section shapes, and others are plotted as a locus of points in space having X and Y values. A curve template is aligned to connect the points, while the pen follows the template to create the special curve. As the draftsperson creates the line, a device called an encoder senses the motion and translates this movement to an electronic display made up of devices such as nixie tubes. This feature can save nearly 50 percent of the recording time as compared with a manual method. Another time-saving advantage of the coordinatograph is the data recorder, which transfers electronic readings corresponding to X-Y positions to a storage device for later use by a computer. This process is called digitizing. Digitizing is so basic for building computer databases that people are employed by business and industry, 8 hours a day, as digitizer operators. Figure 1.2 illustrates a coordinatograph.

The person operating a coordinatograph draws only once, and then a permanent electronic record is kept in computer storage. In addition an off-line record is kept as a backup database. These techniques include punched cards, paper tape, magnetic tape, and floppy disk. Changes in the design are made by editing the storage medium and adding new information via electronic data entry. The computer can display the new drawing information on a cathode-ray tube (CRT), digital plotter, or microfilm. The engineer may choose to send the information by telephone to another office before it is displayed and while it is still a form of computer data. The electronic information is received at the new location and then displayed. Automated drafting quickly produces good, quality documents and in the final desired location. See Figures 1.3, 1.4, 1.5, and 1.6.

DEFINITION OF TERMS

Computers and automated graphics are playing an increasingly large part in engineering efforts. After some initial problems, we have learned to work with them.

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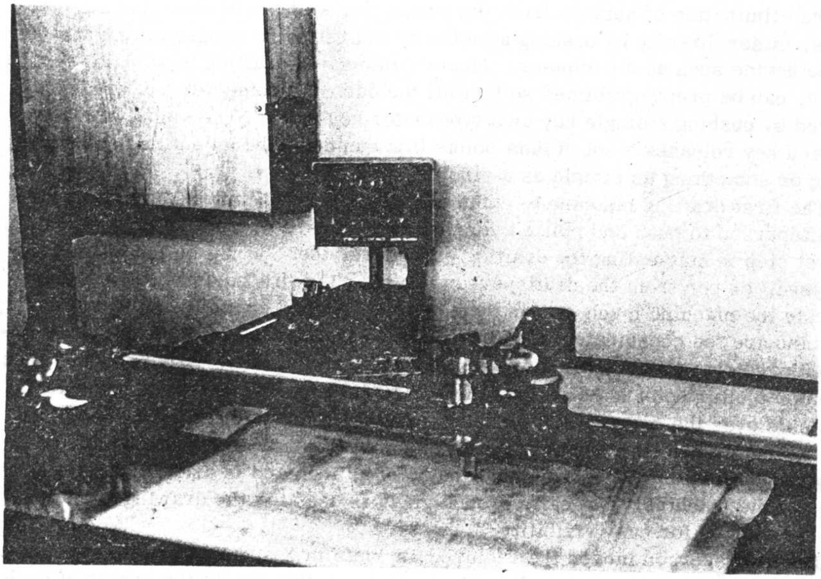

Figure 1.2 Coordinatograph used at University of Nebraska's graphics laboratory.

To many of us the computer is a genie that can produce monumental results, either technically wonderful or technically fouled up. Our uneasiness is due largely to a basic lack of understanding of what a computer can and cannot do. Used improperly, almost any mistake can be blamed on the computer. To gain acceptance some products are labeled computer-designed when in fact the design of the product had nothing to do with a computer. And when we know too little about a computer, we do not protest when some badly thought-out feature of a computer-designed system subjects us to inconvenience.

Unfortunately, a person who tries to learn more about computers quickly encounters a problem. A language full of colorful terms has evolved with computers. Slang, technical terms, and phrases used by computer manufacturers all contribute to the problem. To the professional engineer, it is a natural medium for expressing ideas, but to the uninitiated it is a puzzle to be solved. To help solve the puzzle the author offers this section of Chapter 1. Fortunately, understanding what automated drafting and computer graphics are all about does not require more than ordinary language. But being able to understand technical names for different processes is a big help. The description of digitizing in the earlier part of this chapter is an example.

With this as a general definition, automated drafting devices can be categorized as shown in Figure 1.7. That is, the devices are either graphic or nongraphic, and they are either interactive or batch. The implication of "batch" is that there is a significant time lag between the moment when the information is sent to the automated graphic system and the point at which an answer is received. For example, if the draftsperson wishes to make a change in response to the displayed drawing, he or she must not only remember the initial instructions for hours or days but must be willing to tolerate a similar delay in getting a response to the next change order. Likewise, the implication of "interactive" is that the draftsperson or designer is able to get immediate response to initial and subsequent changes. Graphic devices use points, lines, curves, circles, characters, etc., to build up a drawing, while nongraphic devices use a combination of characters, spaces, and line feeds to generate a nontextual shadow image. The Snoopy posters in every office are a good example of these shadow plots. See Figure 1.8.

A nongraphic batch device is a matrix printer, shown in Figure 1.9. The output is alphanumeric (A/N) and, except by building up a picture by a series of "X" or "." characters, the presentation is A/N-oriented. The output is generally processed in a batch mode because the printer is used to list the result of some computation or the output of some program.

The most widely used graphic batch device is the incremental digital plotter, such as CALCOMP, manufactured by California Computer Products, Inc. Along with the 10,000 or so plotters currently in use, 1000 CRT microfilm plotters such as the Stromberg Datagraphix are used for computer output or microfilm (COM).

The best example of the nongraphic interactive device is the teletypewriter (TTY). One market authority estimates that in computer environments alone there are 75,000 to 100,000 TTYs installed.* The TTY in most of the computer environments is interactive because it is possible for the operator to carry on a dialog with the computer. The operator types computer language statements, and the computer responsed with appropriate programmed answers. These answers are in letters, digits, or words. Just as the matrix printer can be used to plot data, the TTY can be used to show plots. Figure 1.10 illustrates this shadow effect. Another device in this general area is the CRT terminal. The A/N nature of this device, along with its higher send and receive speeds (anywhere from 3 to 30 times faster than a TTY), is making it a popular nongraphic interactive device.

When automated drafting and computer graphics are used together, most people think of the interactive graphic CRT terminal, such as the Tektronix 4010 shown in Figure 1.11 or the newer 4025 model. These units accept computer signals, process them into commands for function generators, and display the output on a TV-like screen. The more conventional computer-related devices perform a similar task, but a line printer or a TTY can only convert the computer impulses into words and phrases, while a plotter converts the impulses into pictures. Neither are capable of closing the loop, whereby we can easily transmit graphic instructions back to the computer. This capability is available in the interactive graphics console (see Figure 1.12). By means of a light pen, joy stick, or

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*Carl Machover, Automated Design Seminar, Department of Continuing Engineering Education, University of Wisconsin, October 11/12, 1975.

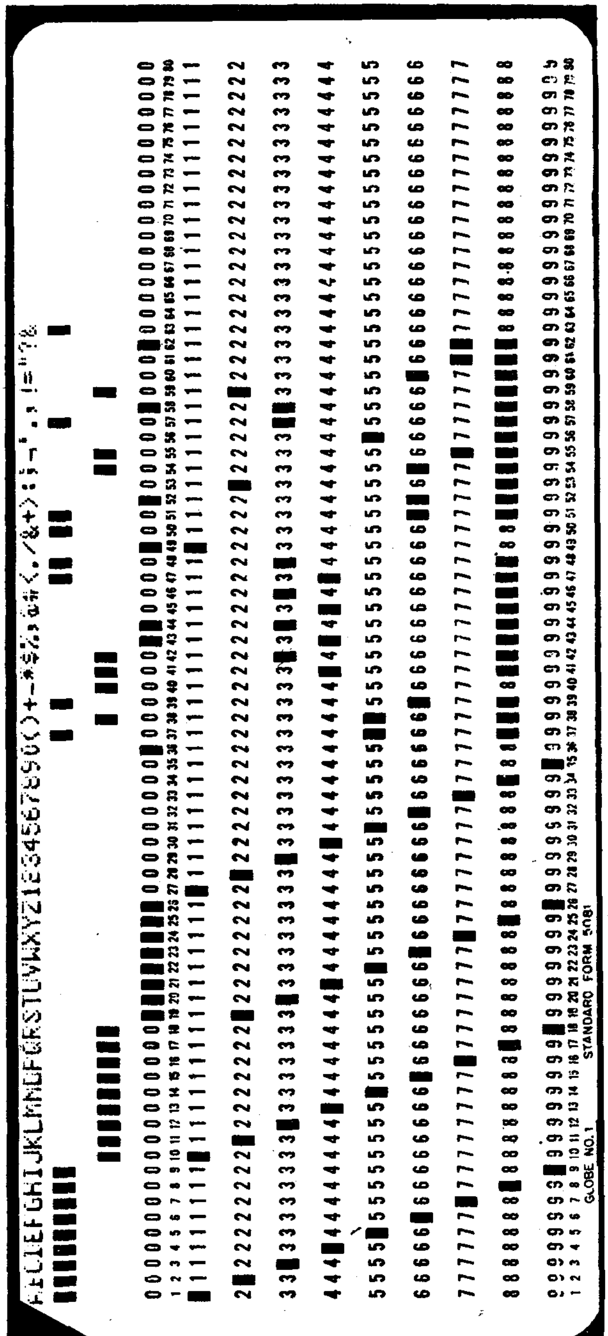

Figure 1.3 Record of digitized data on punched cards or punched tape.

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RUB OUT
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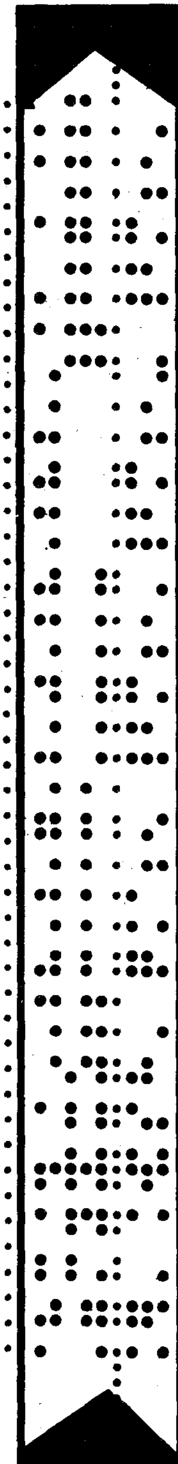
(
SPACE
)
BACK SPACE
↑
RETURN



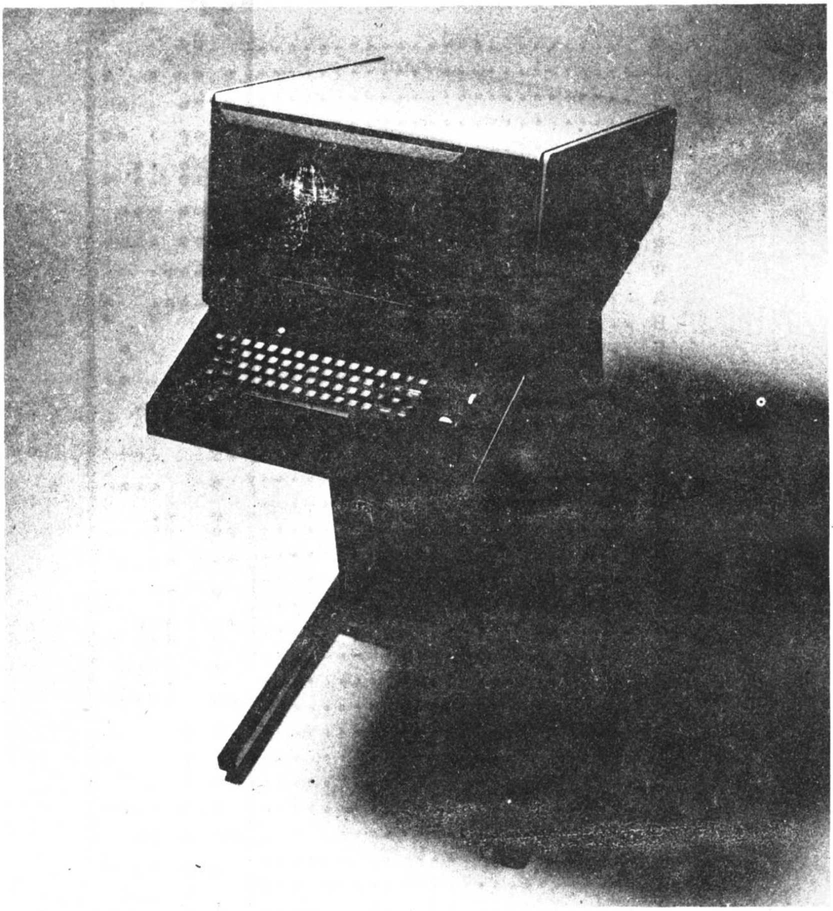


Figure 1.4 CRT display screen for digitized data. (Courtesy of Tektronix, Inc., Information Display Division.)

graphic tablet we can indeed send graphic pictures to the computer (see Figure 1.13).

For a complete list of computer graphics terms, refer to the Appendix A at the end of this chapter.

TYPES OF EQUIPMENT

The drafting process can be automated by establishing a cycle where we, the designers, begin and end a specific task such as drawing a line. The cycle should

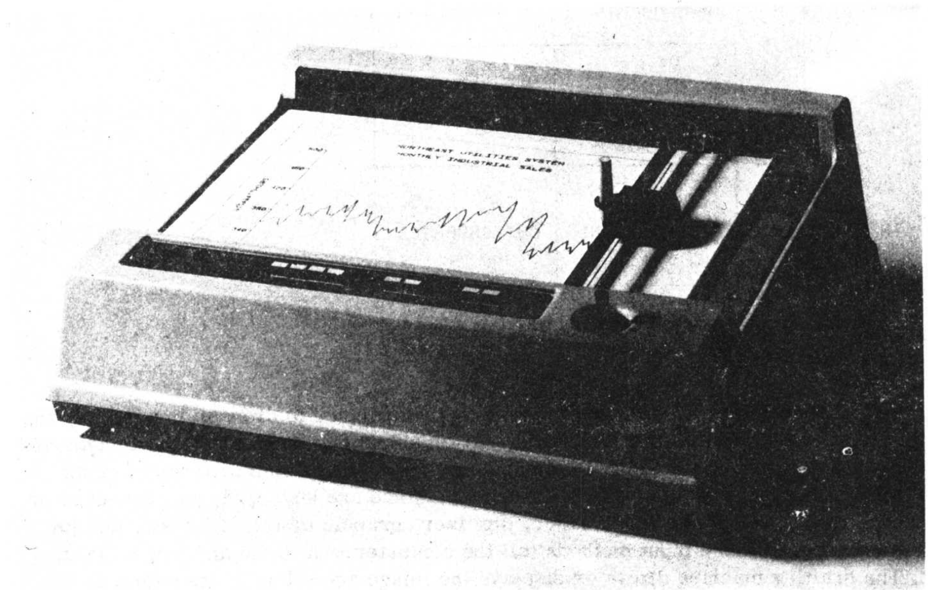


Figure 1.5 Interactive digital plotter. (Courtesy of Tektronix, Inc., Information Display Division.)

Figure 1.6 Modem for telephone line transmission. (Courtesy of Tektronix, Inc., Information Display Division.)

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