ON-LINE INTERACTIVE GRAPHICS

THE DESIGNER'S DREAM OR THE PRODUCTION MANAGER'S NIGHTMARE

S. H. Zelinger
California Computer Products, Inc.

Abstract

This paper discusses computer automation, computer-aided design, and computer-aided production as applied to creating artwork from electronic design. The purpose is to establish distinctions among the three automated techniques and the equipment necessary to implement them. The conclusion is a recommended approach to justifying the cost and characteristics of the equipment.

A simple design is followed through its artwork stages as is done without computer aids, then as done with various computer aids. Finally, a technique for selecting and cost justifying the optimum computer-aided system is presented.

Throughout the paper, terms are defined. These definitions are not necessarily industry standards but are given for clarity while in context. It is the intent that one should be able to determine whether he has purchased or is in the process of purchasing an expensive toy or an extremely valuable tool that will make his operation less costly, more productive and hence more profitable. If this determination is made, the concept of computer-aided design will have been looked upon in its proper perspective and never again confused with the concept of computer-aided production!

Design Objective

Assume that a design engineer is given the task to produce a printed circuit module that outputs a signal indicating whether a light is on or off. The light may be actuated independently from three sources: A, B, and C.

STEP 1: (The Engineer's Design Sketch) The engineer will quickly sketch the logic circuit necessary to perform the desired function. The circuit diagram will take the appearance of Figure 1.

The notes on the diagram are instructions to the design draftsman as to what components to use, the type of board to be used, etc.

STEP 2: (The Assembly Drawing) The second step is the design draftsman's responsibility. His output is the assembly drawing shown in Figure 2. This output is returned to the design engineer for additions, deletions and alterations.

STEP 3: (Printed Circuit Artwork Masters) After approval of the assembly drawing shown in Figure 2, the skilled draftsman has the responsibility of laying out the circuit board and producing the artwork master (usually four times actual size) which will be used as the mask for the etching process. This artwork is shown in Figure 3.

Before the tape-ups are photographically reduced and the circuit board blank etched, the tape-ups are verified against the assembly drawing.

On-Going Steps

Other steps involved in producing the item designed are programming the N.C. drill machines, the wire wrap machines, the automatic insertion machines and producing the physical layout drawing used for the technical manuals. It is important to mention that the majority of the information necessary to produce the remaining documentation is contained within Figures 1, 2 and 3.

Artwork Summary and Definitions

To this point, various types of artwork have been shown pertaining to a basic logic design. Now, a definition of terms is in order.

a. Schematics Artwork (Figures 1 and 2). A nondimensioned diagram depicting electronic, electrical, hydraulic, logic (in the electronic sense), combination electronic and logic circuitry, etc.

b. Printed Circuit Board Artwork (Figure 3). A diagram (usually four times actual size) of the physical electrical paths and component connection pads of a circuit. This diagram (in the form of a tape-up) is used as the artwork master, which is reduced, imprinted on the printed circuit board blank, and used as the etching mask for the production of the printed circuit boards.

c. Production Artwork (Figure 3). Artwork used directly in the manufacturing process.

d. Communicative Artwork (Figures 1 and 2). Artwork used indirectly in the manufacturing process (as a visual aid).

e. The Schematics Producer. A skilled draftsman working with a designed schematic. The schematic is assumed to be created by the design engineer in the form shown in Figure 1.

f. P.C.B. Artwork Producer. A skilled draftsman working with a self-designed P.C. layout. The layout is for the most part complete and to scale.

Computer Automation

Totally automating the process described would require as input data the following logic equation:

$$F = A'B'C + A'BC' + AB'C' + ABC$$

The above logic equation constrained by component specifications, manufacturing specifications and standard procedures is sufficient to produce artwork of the type shown in Figures 2 and 3. Wire lists, N.C. drill data and component insertion and wire wrap data would also be generated. Software is available which is able to perform these duties; however, the software usually pertains only to logic design and cannot readily be included in a general discussion. If, however, software of this type were readily available, the equipment need only consist of a large computer and a high precision photoplotter.

Although there is no general automated technique today, several other techniques through software and specialized hardware have been developed to produce the artwork shown in Figures 2 and 3. It is this development to which the remainder of this paper is dedicated.

Computer-Aiding

The term "computer-aiding" must now be used rather than automation to be consistent with the previous topic. However, one does not see the term "computer-aiding" itself. The industry has attached other words, acronymed it and, to date, used it and abused it as the famous SNAFU acronym. One word attached is "design," the acronym is CAD. For the purpose of this paper, a clear distinction will be made between CAD and (to confuse the issue even more) CAP.

a. Computer-Aided Design (CAD): A combination of hardware and software used by a designer as a tool to aid in the creation of new designs. The input data for the most part is design intuition.

b. Computer-Aided Production (CAP): A combination of hardware and software used by a skilled craftsman as a tool to aid in the production of materials previously designed.

True computer-aided design acquires its information from the imagination of the designer; for example, body design of automobiles. With a true CAD device, the designer may see the shape he imagines, alter the shape because of design intuition and then view the change immediately while it is fresh in his mind. More generally, CAD, graphically speaking, is being able to view the contour, the shape, the design object itself. The reader can envision other examples using the general definition.

True computer-aided production acquires its information from designed data and aids the production personnel (draftsmen, machine tool operators, typists, etc.) in doing their job faster, better and cheaper.

CAP is extensively used in the numerical control industry. The industry uses machines for drilling, milling, cutting, and wire wrapping which are controlled by punched paper tape. The data required to punch the paper tape is provided by a programmer who uses a visual aid of the product and a program language. This visual aid is either a detailed dimensioned drawing of the mechanical part or a dimensioned drawing of the electrical layout in the case of wire wrapping.

One receives little resistance asserting the cost/effectiveness of CAP in numerical control; but what, if anything, can be said about CAP systems used for the creation of the diagrams discussed? The schematic (visual aid) is an independent, separate production item necessary for implementing the use of numerically controlled machines, etc.

An apology is in order for implying graphic CAP to aid in the preparation of the artwork in Figures 2 and 3 rather than CAD. The reason for the implication is that producing the artwork is a graphic problem, whereas designing the circuit is not and therefore does not require a graphic solution. It is also assumed that the designer will not be the individual producing the artwork. His job was finished upon presenting the schematic shown in Figure 1.

Does the skilled draftsman need CAD? If your answer is yes, then ask yourself if a skilled draftsman needs a device whereby he may see a shape he imagines, alter the shape because of design intuition, and then view the change immediately while it is fresh in his mind. Will a location of a resistor on the schematic alter the function? Make it salable? Of course not. Will a well-defined indentation in a fender of an automobile make it more salable? Will an exposed gas tank cover make an automobile more salable? Ask Chrysler Corporation about intuitive design changes.

COMPUTER-AIDING THE ASSEMBLY DRAWING (STEP 2): Prior to computer aiding the assembly drawing, let's determine what the draftsman actually did to produce his work. Figure 4 shows a preliminary draftsman's sketch. This sketch, done quickly, was used to produce the assembly drawing (Figure 2). Figure 4 is the key. This figure may mean several hundred thousand dollars worth of automated equipment or just several thousand dollars worth of equipment.

Very few skilled draftsmen can visualize the layout of an entire diagram and then in one pass produce the final result. Most skilled draftsmen, however, do have the ability to quickly sketch a layout to almost the exact scale. They automatically sketch resistors, capacitors, transistors, gates, etc., at their proper size. This is not surprising because that's what they were trained to do. Most take pride and are meticulous about creating almost the entire final drawing the first time. The key point is that regardless of the equipment one uses to computer aid the assembly drawing, the sketch in Figure 4 will almost certainly be the document used as the input vehicle. For this reason alone, anyone desiring to "computer-aid" should take maximum advantage of the information on this diagram.

Aiding the Production of Assembly Drawings Via Computer Graphics

To this point the circuit has been designed; however, the artwork has not been produced (at least via computing techniques). Therefore, let's talk about computer-aided production rather than the abused phrase computer-aided design.

Using Interactive Computer Graphics

Visualize the design draftsman at the console of an interactive system. He has his sketch (Figure 4) and a user's manual (or perhaps he already knows how to use the system). He initializes the system, takes his magic wand (light pencil, joy stick, or whatever), and calls for the symbol of a particular logic gate. Behold, one appears on the screen (see Figure 5). It looks almost exactly like what he had sketched (that shouldn't be too surprising). At this point one should be able to observe a look of accomplishment about the design draftsman, not because he sees a fine-looking symbol depicting a logic gate, but because he remembered how to call the symbol out of the memory banks of the computer in the first place. Elapsed time - 15 minutes.

He then goes through some manipulations on the elaborate keyboard or the magic wand or a sophisticated combination of both. There is a flash on the screen and behold, four little logic gates all in a row. Elapsed time - 15 minutes 30 seconds (not bad!).

Within the next five minutes (elapsed time now 20 minutes 30 seconds) he has managed to produce all of the necessary components in positions relative to one another that appear almost identical to the components on the sketch he now conceals (lest his supervisor observe that he has managed to produce, using several hundred thousand dollars of equipment, that which was produced using a 15 cent pencil and a .5 cent piece of paper).

The next step is tough - the hook-up problem. Using the "zoom" capability of the system, he is able to connect, turn corners, reposition, etc. Fifteen minutes later he sits back and admires a diagram which all except for text data (letters and numbers), looks identical to his sketch. Elapsed time - 35 minutes 30 seconds.

The fatal mistake has been made. He sat back and admired his work. How many design draftsmen do you know who will view their work for any length of time without observing where something could stand improvement? It's natural; it's their profession. To change a drawing for an esthetic modification normally takes an effort (erasing, etc.). However, with the magic of interactive graphics, changes may be made easily. Sure enough, for the next five, ten or even fifteen minutes the draftsman will alter his work to become more esthetic. Elapsed time - 45 minutes.

Now for the text information. By using the keyboard, the draftsman keys in the desired pin numbers, wire labels, notes, etc. This will complete the task. Elapsed time - 60 minutes.

This is not intended to discount the concept of on-line interactive graphics. It is intended to reveal that to produce the desired result from the information contained in Figure 4, other, less costly, equipment may be used.

The desire to computer-aid may generally be placed into one of two categories:

> In the first, the intent is either to increase drafting output while keeping manpower constant or to decrease manpower while keeping output constant.
>
> The second exists in companies that are developing complete automation of documentation (inventory, bill of materials, parts lists, wire lists, etc.) on manufactured items. In this type of installation, the aim is not to cut drafting costs so much as to make the total documentation system more manageable and efficient.*

For the purposes of this paper, let's assume that it is intended to produce the artwork faster, less expensively and more reliably.

Using Off-Line Digitizing

Consider again the draftsman's sketch of Figure 4. By simply placing the artwork on a digitizer equipped with symbol menus, keyboard menus, and control menu functions and digitizing the layout, connections, and areas where text is to be placed, the artwork may be prepared for use in a computer system quickly (see Figure 6). By having the data prepared on punched cards and having a keypunch operator sequentially prepare the text data, the entire drawing input may be prepared within minutes. The draftsman cannot continually view his progress. This saves time, and the equipment is far less costly.

The drawing may come back in error; however, if the system is designed properly, error correction is efficient. The draftsman will quickly correct the error and spend less time, if any, making alterations for esthetic reasons.

The key point of this system is that although it may take slightly longer to deliver the drawing, the draftsman's time on the drawing is reduced. The end result is a higher productivity - the primary goal in the first place. In fact, a survey of some companies using on-line interactive graphics in the manner described revealed that use of the scope soon reduced to almost nothing once the users became acquainted with the systems. In fact, they agreed that their systems had become off-line devices. The conclusion was that the interactiveness served as a tool only during the learning process - a very expensive educational aid indeed.

Off-line digitizing was selected rather than the on-line interactive approach because of the form in which the input data existed (Figure 4). If the company employed the design engineer to do all the tasks, Figure 4 would not have been produced; and perhaps an equally strong argument could have been presented for the on-line interactive technique.

COMPUTER-AIDING PRINTED CIRCUIT ARTWORK MASTERS (STEP 3): Preparing artwork for printed circuit masters may be automated directly from the information contained on the assembly drawing by using the logical wire list. This applies usually to logic circuits. More generally, however, the automation process consists of inputting the information contained on a sketched layout. Once again, the process may be on-line interactive or off-line digitizing. Since the information to be input is most likely in a scaled form, the same arguments against going on-line interactive apply.

The printed circuit artwork shown in Figure 3 is used directly in the fabrication of the printed circuit board. The diagram must be accurate not only electrically but also dimensionally. The tape-up is photographed, reduced to actual size and used as the mask for the circuit board blank. Contrast this artwork to that of the assembly drawing (Figure 2) which is used only as a visual aid. The value of automating this artwork is twofold. Not only is the process sped up, but the output may go directly on a high-precision photoplotter at the actual size. The process eliminates the necessity to do the tape-up and, by means of a quick plot, reduces the time and cost of verifying the artwork before photoplotting.

If the same machinery used to automate the assembly drawing (Step 2) is used to automate the P.C. artwork (Step 3), one begins to see a possible cost justification. The process of automating the P.C. artwork used designed data as input. Once again, the automated function was to produce the artwork.

One can certainly argue how important on-line interactive graphics would be for graphic computer-aided design. However, it is difficult to see how any company could possibly justify using on-line interactive graphics for other than CAD in its strictest sense. Nevertheless,

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* S. H. Zelinger, "Documentation by Automation," PROCEEDINGS OF THE TECHNICAL PROGRAM - NATIONAL ELECTRONIC PACKAGING AND PRODUCTION CONFERENCE, 1971, p. 221.

companies have spent large sums of money to install on-line interactive graphics.

Why? Because the company probably thought they needed CAD when they actually needed CAP. These companies claim they can produce artwork as described previously with their CAD system, and indeed they can. However, if you ask them to describe their increase in production output, they will probably agree that their CAD system works as a computer-hindered production (CHP) system. The truth must eventually manifest itself as one of three things: 1) increased overall cost, 2) decreased overall cost, or 3) no change in overall cost.

The Need for CAD

Does the electronics company need CAD? Absolutely! The more computers aiding the design of electronics, the better. Does the electronic engineer need CAD in the form of on-line interactive graphics? NO!

The engineer does not need a graphic solution. In this case he could care less how pretty the transistor looks. All the engineer is concerned about is that a transistor is needed. Put the engineer in front of a scope and he'll spend much more time placing transistors than designing (or determining) how many he needs.

The Need for CAP

Does an electronic company need CAP? Before answering that question, first answer a more basic question. Does a company need skilled production personnel?

Some people say draftsmen or design support personnel will soon be replaced by the computer. The statement couldn't be further from the truth. Anyone who thinks that way continually neglects the inputter, or he assumes the inputter to be the designer.

CAD in writing this paper would be to speak into a machine that would output the document formatted, punctuated, spelled correctly, gramatically structured and altered to say what was intended. Since this device is not here yet (except for a dictaphone and a highly skilled secretary), this document must go through a production phase. That means the rough handwritten draft must be processed by a skilled typewriter operator who 1) knows how to spell, 2) knows how to format, 3) knows how to structure, and 4) knows how to punctuate. This person uses as input what has either been quickly written or dictated. The design is finished. Eliminating the support personnel would require the designer to be the inputter for further processing. Why should the designer have to do it? His work is already done! If production support didn't exist, you would be required to read this paper in this author's own hand which would result in no one (myself included) reading it! The same statements apply to artwork.

The answer to the question of the necessity of production support personnel is clearly yes. Now, does a company require CAP?

First, what is CAP? True CAP is a device whereby the skilled draftsman (or design support person) may produce the desired product more efficiently than without the device. That is, he may spend less time doing the job with CAP than without.

From this definition, does a company need CAP? Again consider this situation before answering. A particular CAP device enables a draftsman to produce a drawing in one-fourth the time. You employ one draftsman who gets one input per day and produces one drawing per day. Buy the device and he still gets one input per day. The benefit? The draftsman need only work two hours per day. The answer is clearly no for this company.

Consider another situation - same company. However, you anticipate the input to increase from one to four per day. The CAP device will allow you to handle the load and still employ the one draftsman. Is the draftsman needed? The answer is clearly yes.

Do you need CAP? The answer is clearly undetermined! The four draftsmen will certainly handle the load as will the CAP device with only one draftsman.

The answer then becomes a function of economics. Assume the CAP device costs less than hiring three draftsmen. Suppose the CAP device is much more costly than hiring three draftsmen. The choice is then easy. However, let's assume that the CAP device is equal to hiring three draftsmen. What would you do? Suppose your input load drops back to one per day. Can you lay off three draftsmen? Can you lay off the CAP device?

These factors weigh heavily for CAP but not so heavily for CAD. Any time you aid the designer to produce more and better designs you benefit the company. The cost factor is merely if you can afford CAD or if you can afford not to have it. With CAP it's a straightforward analysis with several complicating factors that boil down to simple economics.

Justifying CAP

For the examples stated it is apparent that on-line interactive graphics is not the equipment for CAP. If nothing more, the reason is the form of the input.

Input into CAP is already designed data. The input into CAD is design intuition from which designed data results. It stands to reason that if the input material is different, the equipment necessary to operate on the data can be different. Perhaps one machine need not be as sophisticated as the other. This is true with CAD versus CAP. CAD equipment is and should be more sophisticated. The trap that some companies fall into is, "if CAD can do CAP, let's buy one big CAD." If this reasoning had any validity, not one company would ever buy another adding machine once they had purchased a computer.

If your company feels the necessity for CAP, its justification should not ever be a function of your CAD needs. You are making a mistake if you discount different equipment for CAP than for CAD. You are having the wool pulled over your eyes if you are sold CAD with the idea it will be compatible with CAP. They are as different as black and white and should be treated as such. Allowing your production people to utilize the CAD system will defeat both purposes.

CAP equipment takes many forms. The system for aiding the production of artwork described should be off-line,so that many can use the system, production work speeds along without unnecessary delays, and the job gets done faster at less cost. Now, how do you know whether you need CAP and what side benefits result?

As a first cut in justifying CAP, consider your drafting personnel only, not your engineering design personnel, and compute what is called the transparent case.

The Transparent Case

Here are the factors that should be known:

a. The number of drawings produced per year

b. The number of personnel producing drawings

c. The cost (burdened) of personnel producing drawings.

(You may have several types of drawings. Take each one separately and determine the average.)

From 1, 2, and 3 the cost per drawing may be computed.

The need of the transparent case is one of two:

a. Same number of drawings per year, same cost, less personnel.

b. Same number of personnel, same cost per drawing, greater number of drawings.

Both needs imply a device which increases productivity, or produces more drawings in less time.

The reason it is called the transparent case is that one cannot distinguish whether the company output is done using CAP or not.

EXAMPLE:

Suppose a company has six draftsmen who produce 2,000 final drawings per year. All costs taken into consideration, it is established that it costs $20,000 per year to staff each draftsman. The cost per drawing is approximately 20,000 x 6/2,000 = $60. Suppose now that a particular CAP system can sustain a load of 2,000 drawings per year with two draftsmen. The transparent case would be computed as follows: Two draftsmen at $20,000 per year is $40,000. To maintain the cost per drawing at $60 each, the CAP system cannot exceed a per year cost of $80,000. Now what is meant by a CAP system? The CAP system can be broken into several parts. One part is the direct expense for the equipment; another is company personnel chartered to support the equipment. The CAP system in question could possibly be supported by a qualified keypunch operator. The reason for a keypunch operator is twofold. She may be taught to operate an off-line system (not use it - operate it); and when not operating the system, she could supply the voluminous amount of text data required for drawings. Another part of the system is the indirect expense (overhead) required to house the system (space, power, supplies, etc.). Still another is the maintenance required to support the system.

It might have appeared at first that this company could afford to purchase equipment at a cost of $80,000 per year or lease at a rate of $6,666 per month. Look how the picture has changed. The keypunch operator costs approximately $15,000 per year. The remaining costs then shouldn't exceed $65,000 per year. Maintenance typically costs 10 percent per year of the lease price of the system. If you burden your personnel for space, power, and supplies at 40 percent per year, then the same burden rate should apply for equipment leased. The transparent justification can then be reduced to the following equation:

$$L + .4L + .1L = \$65,000$$

Where

L = Lease rate paid to the supplier per year

.4L = Burdened costs incurred by the company

.1L = Maintenance costs incurred by the company

Solving for L in the above equation -

L = $43,333 per year or $3,600 per month

The computer industry today leases $100,000 worth of equipment for approximately $3,000 to $4,000 per month (excluding service) on a three-year commitment. This gives somewhat of a picture of the cost justification, and one knows that computerized equipment is priced such that $100,000 doesn't go very far.

What is the meaning of leasing a system for $3,600? Suppose you had only two draftsmen and you were faced with a year's production of 2,000 drawings. You have a decision (if you do not want the cost per drawing to exceed $60). Hire four more draftsmen, lease CAP and pay $3,600 per month plus $360 per month maintenance or lease four new draftsmen. Since the company can afford $80,000 for the year, he may lease draftsmen according to the following:

L + .4L = $80,000

Where

L = Lease rate paid to the draftsman job shop

.4L = Supplies, space, power, etc. (no health, retirement and other fringe benefits included)

Then L = $60,000 or $5,000 per month.

Assuming that these qualified draftsmen are available, it is interesting that the company can afford to pay more for leased personnel than leased equipment. True, the value of computerization is lost. What then is the value of computerization?

Value of CAP

It is said that CAP has the value of: 1) increased productivity, 2) standardization (reliability) and 3) reduced costs (file management).

Aside from being good buzz words for the CAP salesman, what dollar value can be placed on values one through three?

1. Increased Productivity: Increased productivity is quite meaningful. The ability to make draftsmen more productive may be easily evaluated as was done for the transparent case. The buyer is in a position of saying to the CAP salesman, "I am willing to pay your company $3,600 per month plus $360 per month for equipment and service which will enable my two draftsmen to output the work of six." The dollar value of increased productivity is the buyer's willingness to pay for the CAP system versus having more personnel. As was demonstrated, this dollar value may not buy such computing equipment. The CAP salesman barks back and says, "Our CAP system is much more than that dollar value; however, what about the benefit of standardization?" True, CAP does offer standardization.

2. Standardization: Each company working on various projects does recognize the value of standardization but is reluctant to pay too much for it. How much is too much? As a first cut, consider 10 percent of the cost of the drawing. This buyer should be receptive to paying $66 per drawing in lieu of $60 per drawing if all drawings are standard. However, standardization does imply reliability; therefore, the buyer should be totally receptive to a 10 percent increase in cost.

3. Reduced Costs; It does sound as if talking reduced costs is paradoxical, since we've just increased the cost 10 percent for standardization. However, reduced costs can be realized if proper file management allows subsequent follow-on drawings to be produced faster and cheaper. For instance, after the company produces the 2,000 drawings, the next 3,000 drawings could be produced the following year because of the ability to create new from old efficiently. A well-designed CAP system should provide this ability if needed.

The Sustained Case 1: It is now possible to compute the Sustained Case 1 rather than the transparent case. Remember that the transparent case computes the willingness to pay for increased productivity. The Sustained Case 1 computes the willingness to pay for standardization along with increased productivity.

Assume that the value of standardization is 10 percent. New cost per drawing is $66. Total cost for the year is 66 x $2,000 or $132,000. Two draftsmen cost $40,000; one operator costs $15,000. The balance is $77,000. Using the same equation:

L + .4L + .1L = $77,000

L = $51,333 per year or $4,280 per month

The total payout to the vendor is $4,280 + $428 = $4,700 per month versus $3,600 + $360 = $3,960 per month. The increase is not 10 percent but 19 percent.

This should be carefully interpreted, as an approximate 20 percent increase in willingness to pay for productivity buys standardization effecting actually only a 10 percent increase in overall cost.

It would be incorrect to interpret that the salesman is asking for 20 percent to provide the additional benefit of standardization when in fact you are only paying 10 percent (three cheers for the salesman).

The Sustained Case 2: In the Sustained Case 1, a dollar value was placed on standardization. This case places dollar value on reduced costs. Suppose that once the 2,000 drawings are produced, the CAP system enables a production of 3,000 the next year. This is due to the efficient file management and editing capability of the CAP system. The subsequent work appears to be a 50 percent increase in production. Our buyer should be willing to pay 20 percent more to produce the original drawings to realize a 50 percent increase in production the following year. The new cost per drawing is now $72 (20 percent increase). The first 2,000 drawings cost $144,000. The draftsmen cost $40,000, and the keypunch operator costs $15,000. Therefore,

L + .4L + .1L = $89,000

L = $59,400 per year or $4,950 per month + $495 per month service

To evaluate the benefit, you must consider the two-year period. The cost for the two draftsmen is $80,000, the cost for the operator is $30,000, and the cost for the CAP system is $178,000. Total cost over the two years is $288,000. The total number of drawings is 5,000. This results in a cost of $57.60 per drawing, a 4 percent reduction in cost from the manual method. Paying a customer $4,950 per month for this benefit appears justified - $4,950 per month is approximately $150,000 to $175,000 worth of CAP equipment on a three-year commitment which now may buy a significant computer product.

Total Justification

To finalize the analysis of our hypothetical company, suppose the manager requests a budget for CAP equipment that:

a. Makes two draftsmen output the work of six draftsmen the first year (transparent case).

b. Makes two draftsmen output the work of nine draftsmen the second year (Sustaining Case 2) and sustains that load for subsequent years.

c. Needs the benefit of standardized drawings (Sustaining Case 1) and is willing to pay some price for the benefit.

The company presently realizes a cost of $60 per drawing using six draftsmen full-time, producing 2,000 drawings per year. The manager assumes he can afford to pay 10 percent for standardization and 20 percent additional for the first year to realize a 50 percent increase in production the second year.

Present cost: $60 per drawing

Price of standardization: $6

Price of increased production: $12

Cost of CAP drawings for first year: $78

Number of drawings: 2,000

Total cost for first year: $156,000

Cost for draftsmen for first year: $40,000

Cost of operator for first year: $15,000

Cost of leased equipment: L + .4L + .1L = $101,000

L = $67,400 per year or $5,600 per month + $560 service

Table I represents the analysis of the CAP system versus the tried-and-true manual system over a five-year period.

The example shows that on a sustaining period, the buyer not only derives computerized benefits but realizes a cost reduction.

Before concluding, let's consider what would happen if the CAP system didn't function as described, couldn't hit the production of 3,000 for the additional years, and a third man was hired. The total cost would have jumped from $780,000 to $860,000. The cost per drawing would then increase to $61.50, a 2.5 percent increase for the benefit of standardization. Notice that the example excluded raises for the draftsmen.

Justification Summary

The hypothetical analysis showed three methods of determining how much one should be willing to pay for CAP. Although it is an oversimplified analysis, the reader should be able to qualitatively judge the CAP market and have an idea of what 100 to 200 thousand dollars in equipment is worth. Far too many people are blue-skying CAP. For some reason, they suffer from the concept that computers are magic and consider using CAP when, once presented with a first-cut analysis, they, in fact, have a hard time justifying their present staff. CAP (and CAD) systems are expensive; however, they do their work. If CAP carries the load of six or so personnel and your load requires six or more personnel, then you may feel the need. If you are carrying the load of four adequately, then CAP, although "neat," is too powerful and too expensive.

TABLE I

Manning Requirements (1st Year)	CAP Costs	Manual Costs
A. CAP: 2 draftsmen, 1 operator Man: 6 draftsmen	$55,000	$120,000
B. Direct CAP Expenses		
1. Equipment Lease ($5,600/month)	67,400	
2. Maintenance ($560/month)	6,740	
C. Indirect CAP Expenses ($2,240/month) (space, power, supplies) 40%	26,860	
TOTAL	$156,000	$120,000
Number of drawings	2,000	2,000
Cost per drawing	$78	$60
Manning Requirements (2nd year on)		
CAP: 2 draftsmen, 1 operator Man: 9 draftsmen	$55,000	$180,000
Five-Year Total Cost	$780,000	$840,000
Number of drawings	14,000	14,000
Cost per drawing	$55.71	$60

7 percent Cost Reduction with CAP

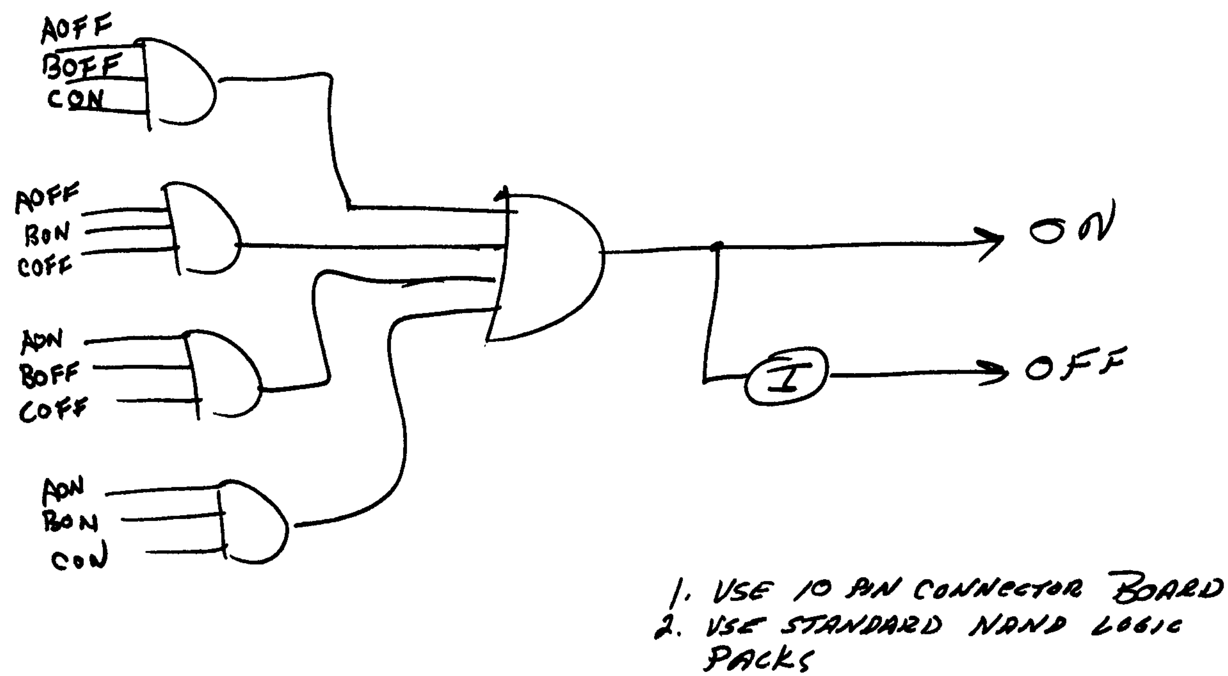
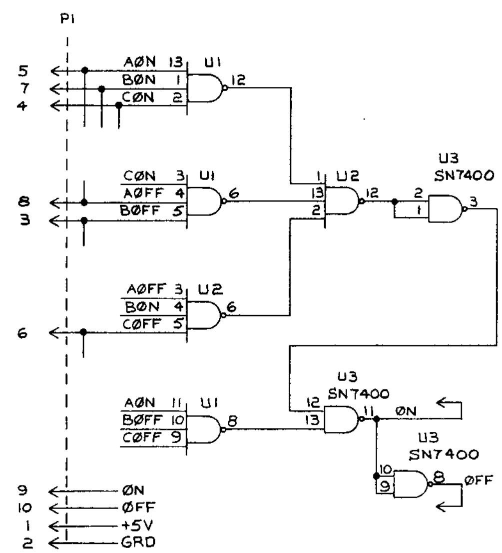


FIGURE 1 - TYPICAL ENGINEER'S SKETCH

REVISIONS			
SYM	ZONE	DESCRIPTION	DATE & APPROVAL
		[1] MAY BE REWORKED [2] CANNOT BE REWORKED [3] NONE	



REF DES	+5V	GRD
U1	14	7
U2	14	7
U3	14	7

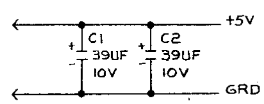


FIGURE 2 - DRAFTSMAN'S FINAL ASSEMBLY DRAWING

1 INTEGRATED CIRCUITS ARE SN7410 OR EQUIVALENT
NOTE: UNLESS OTHERWISE SPECIFIED

	ITEM NO	REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SIZE, DESCRIPTION & SPECIFICATION		ZONE
	4	1		PRINTED BOARD			
127740-9	3	2	10202-505-328	CAPACITOR	39UF±10% 10V	C1,2	
286230-8	2	2	10372-508-000	INTEGRATED CKT	NAND, 3 INPT, 14 PN	U1,2	
286160-7	1	1	10365-508-000	INTEGRATED CKT	NAND, 2 INPT, 14 PN	U3	

LIST OF MATERIAL OR PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS: .XX ± .03, .XXX ± .010
ANGLES: ± 0° 30'

DRILLED HOLES
.040 TO .1285: +.002, —.001
.136 TO .228: +.003, —.001
.234 TO .500: +.004, —.001
.515 TO .750: +.005, —.001
.765 TO 1.000: +.007, —.001
1.015 TO 2.000: +.010, —.001

DRAWN Tom Roy 3-30-72
CHECK
APPD
APPD
FINISH
HEAT TREAT
SURFACE ROUGHNESS PER MIL-STD-10 ✓

CALIFORNIA COMPUTER PRODUCTS INC.
2411 WEST LA PALMA, ANAHEIM, CALIFORNIA 92801

SCALE: NONE
SIZE: C
DO NOT SCALE THIS DRAWING
WEIGHT
SHEET 1 OF 1

FORM 101 DIETERICH-POST CLEARPRINT 1000H-8 7/71

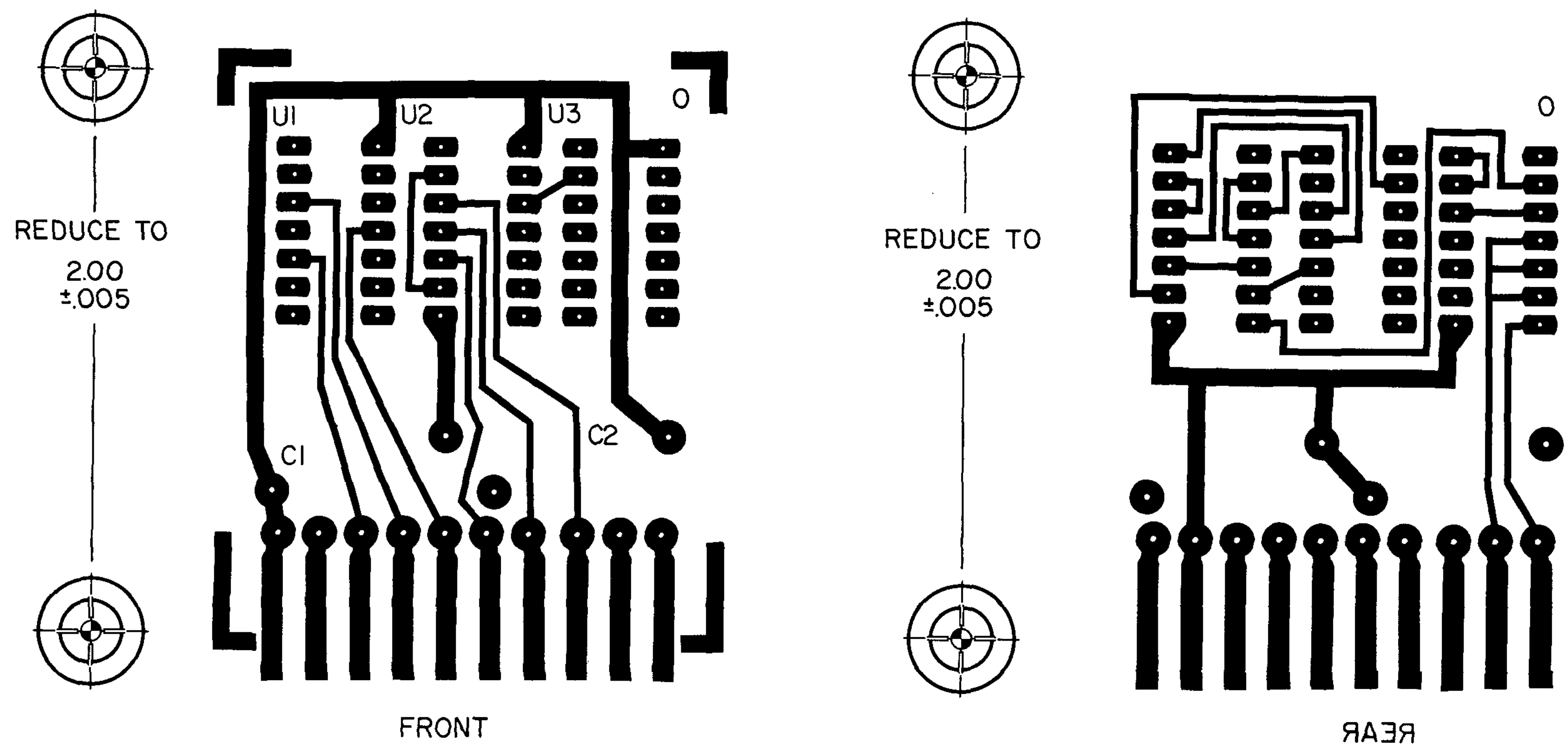
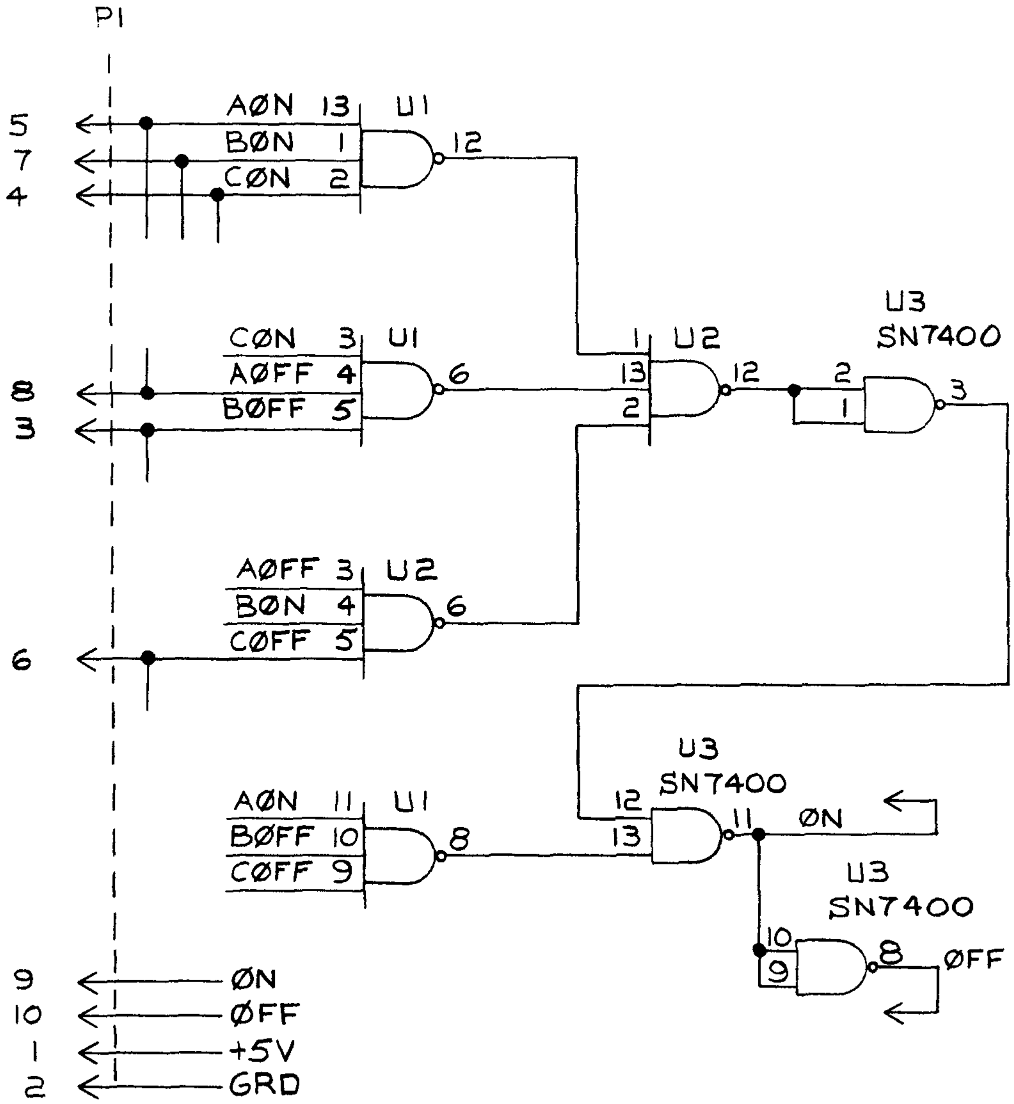


FIGURE 3 - TWO-SIDED PRINTED CIRCUIT ARTWORK MASTERS



REF DES	+5V	GRD
U1	14	7
U2	14	7
U3	14	7

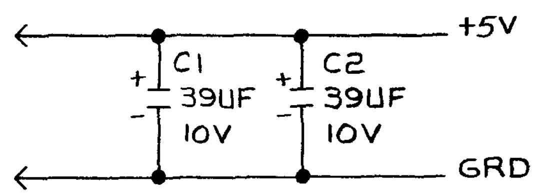


FIGURE 4 - PRELIMINARY DRAFTSMAN'S SKETCH

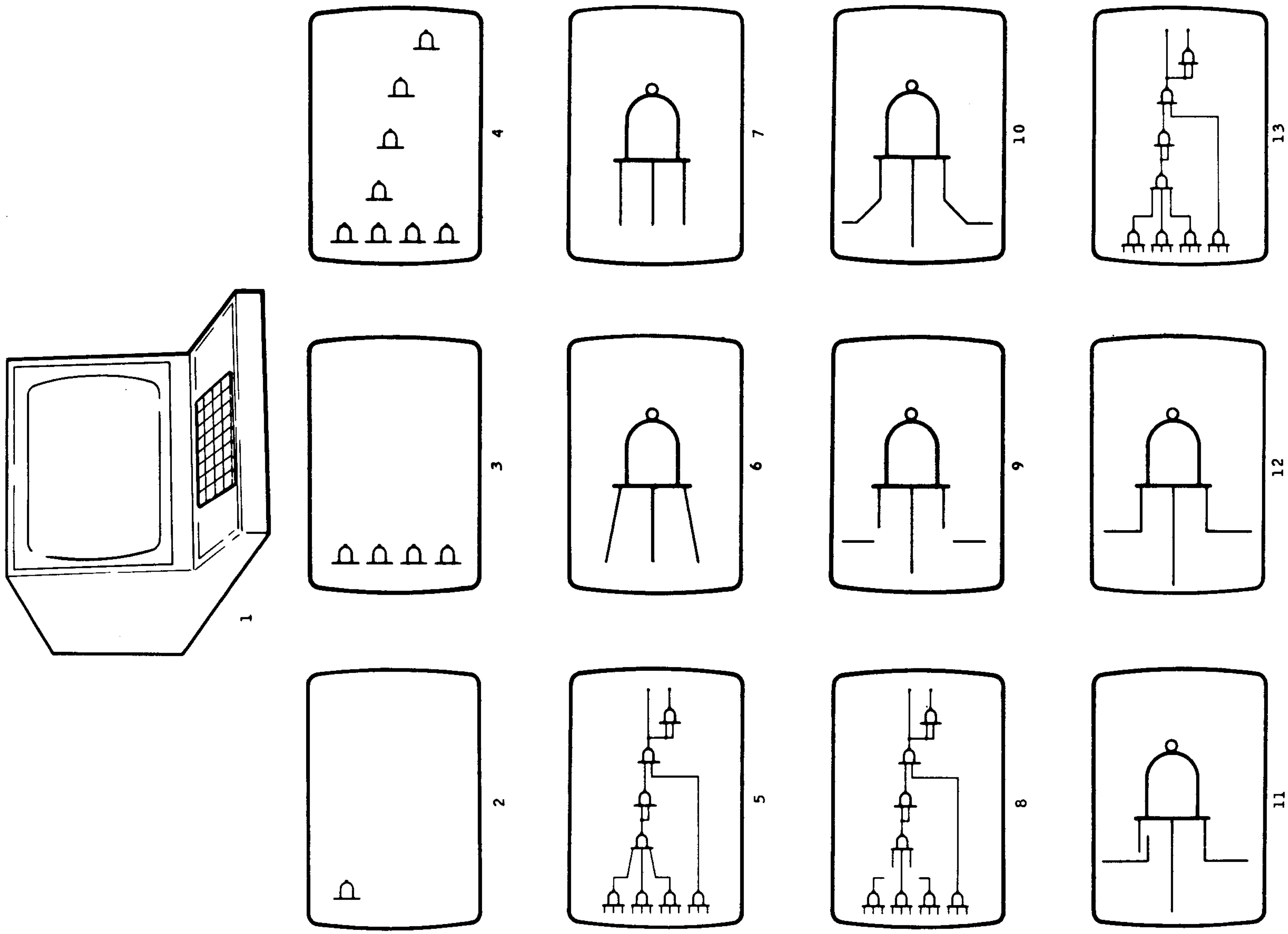
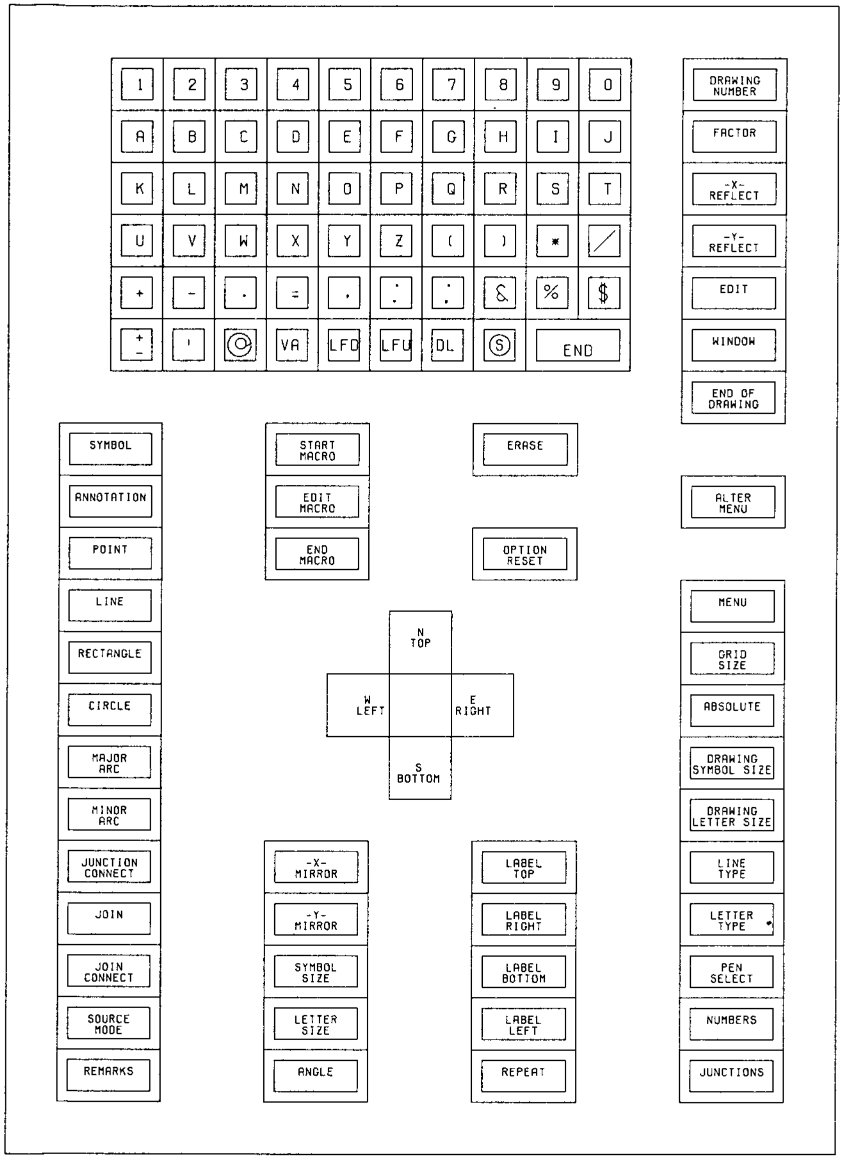


FIGURE 5 - SEQUENTIAL INTERACTIVE GRAPHICS DISPLAYS



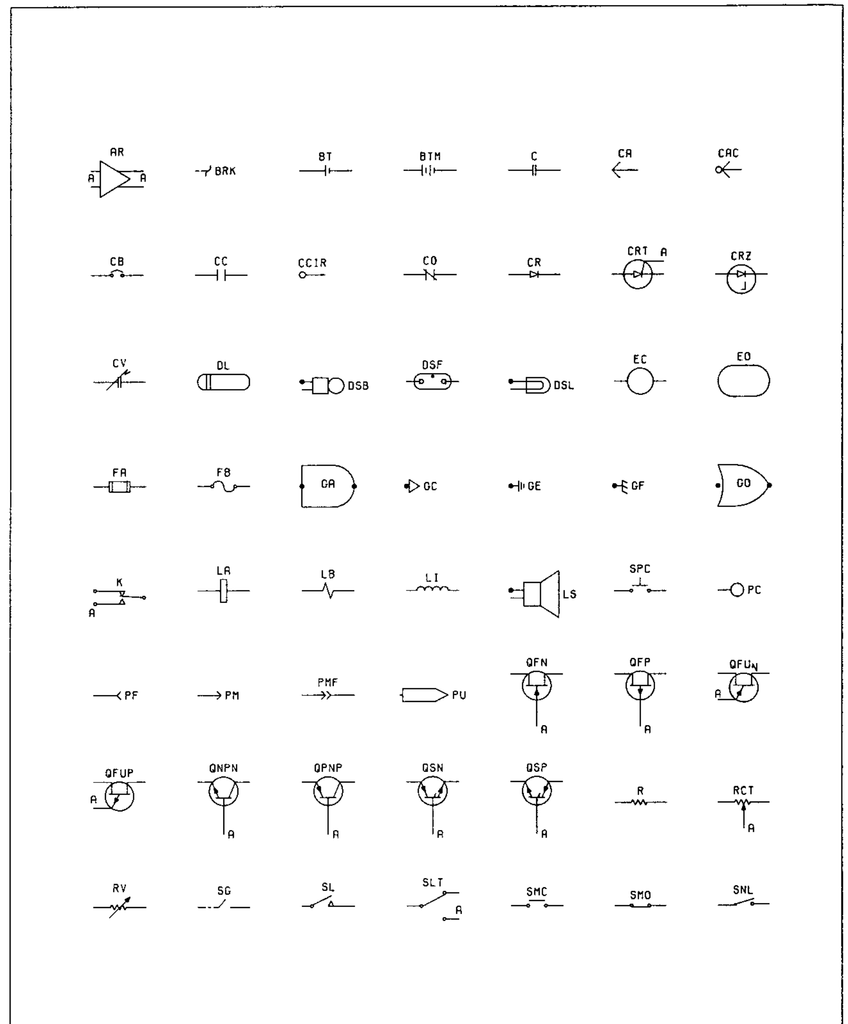


FIGURE 6 - DIGITIZER SYMBOL AND CONTROL MENU LAYOUTS