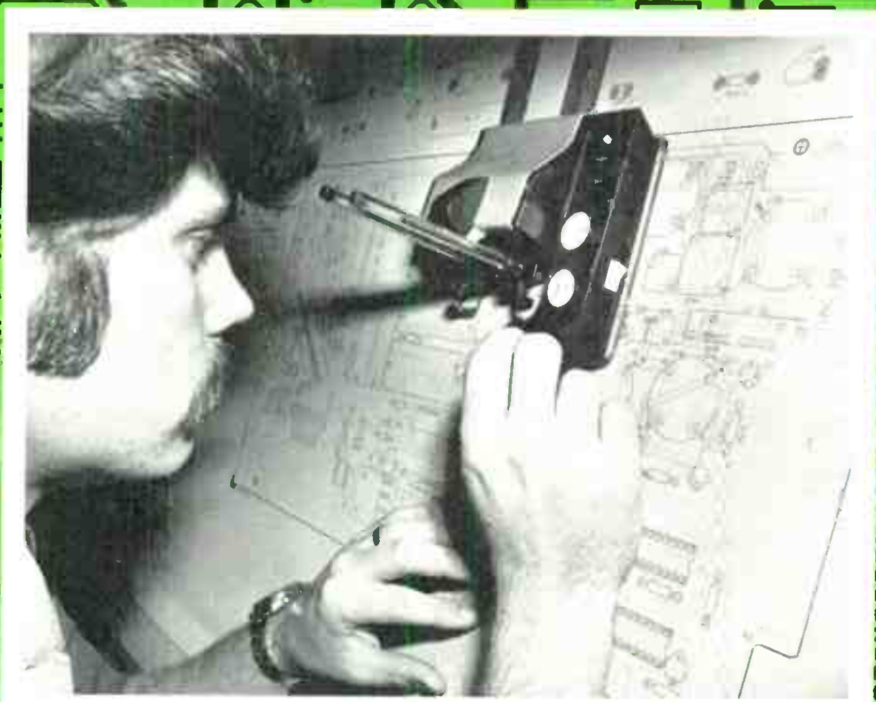
GTE LENKURT

# DEMODULATOR

JANUARY 1974

## Computer-Aided Drafting and Documentation Systems



**With shortened development schedules and refined manufacturing techniques, manual design drafting methods have become expensive bottlenecks in the development of sophisticated electronic equipment.**

Drafting slowdowns are apparent in the design and development of printed circuit (P.C.) boards – whether printed wiring boards or integrated circuits with both wiring and components chemically formed on an insulated substrate. These bottlenecks are the result of the advanced and complex circuit requirements coupled with the efficient chemical processes that are used to fabricate the boards after the design and drafting have been completed. The chemical processes used in the manufacturing of P.C. boards are quite sophisticated and have become automated over the years. It follows that automation in the development cycle of P.C. boards must be applied to support the accuracy and uniformity of the end product.

## Artwork Layout

After the engineer and circuit designer have developed the best printed circuit design for their desired purpose, the circuit is given to a drafting department to prepare the necessary artwork for fabrication of the P.C. board. In this process, all wiring paths must be carefully laid out and all the components located on the appropriate layers of the P.C. board. There is a layer for each material deposited on the board – copper, solder resist, silk-screened markings, etc.

After the best layout has been determined, the designer must draw the interconnection patterns for each layer of the board. In drawing these interconnection patterns, close attention must be paid to the design standards which specify line thickness, pad size, and proximities to each other.

This layout and interconnection pattern must be prepared in such a way that photographic masks (referred to as photo tooling) can be produced for the fabrication of each layer of the P.C. board. The artwork for these masks can be produced using a manual drafting technique that consists of making 2:1 "tape ups" for each layer of the board, or an automated (computer-aided) technique that generates 1:1 photo tooling. Before a P.C. board design is released to production, it is also necessary to provide punched paper tapes for numerically controlled (N.C.) production machines used for such operations as automatic drilling.

An automated system should offer consistent quality, maintain industry standards, require a minimum amount of storage space, and provide an efficient method for making design changes. Such a system has devices for input, processing, storage or memory, editing, and generating the artwork needed for the P.C. board masks and N.C. tapes for production. Figure 1 shows a typical automated drafting and documentation system.

## Drafting Techniques

The "tape-up" used in the manual production of the photo tooling for each layer of the P.C. board is made by manually copying the interconnection patterns on each layer. Strips of tape of the correct width and length



*Figure 1. The automated drafting and documentation system shown has a digitizing layout table, a minicomputer, paper tape punch, and editing station. The photo plotter (not shown) is in a separate darkroom.*

are applied to a sheet of stable film in this process. This "tape-up" also includes the pads, conductive areas for component leads. For some standard component pin configurations, pads have been grouped so that the draftsman needs only one pad configuration for the entire component. This composite shape must be applied to the artwork for all the layers of the board.

In an automated system, the major input device is a digitizer. The digitizer works in conjunction with a keyboard entry device such as a teletype. These two devices feed information to a minicomputer. Using the reticle of the digitizing arm as a pointer and the keyboard entry device to give the computer the necessary command and symbol selection, the operator enters, point-by-point, the ends of all lines and the location of all components and symbols. In performing this sequence of operations, the work is greatly speeded up by the computer's power to calculate, manipulate, and store the information being fed to it.

The operator of an automated system can also use some "shorthand" techniques to speed up his work even further. For example, for each component, one command locates the component, pads, and holes at the correct spacing. Figure 2 shows the five different instructions that are needed to make a complete pad. There are two copper pads, one for the solder side of the board and one for the component side; two negative images for the solder resist mask, one for the copper pad on the component side and one for the copper pad on the solder side; and information for drilling the hole through the center of the pad. If desired, it is also possible to add notes or component outlines to the board for use in production. By preprogramming the computer it is possible to have standard pad stacks that the operator can call up by using a "shorthand" code such as "PS75" at each desired digitized location on the board.

These pad stacks can be grouped together in standard pin configurations. Using the automated system, the operator would only need to digitize the location of pin #1 associated with the "shorthand" for the appropriate pin configuration. This can be carried even further if a matrix is formed of these same components (see Figure 3). Therefore, an automated system, prop-

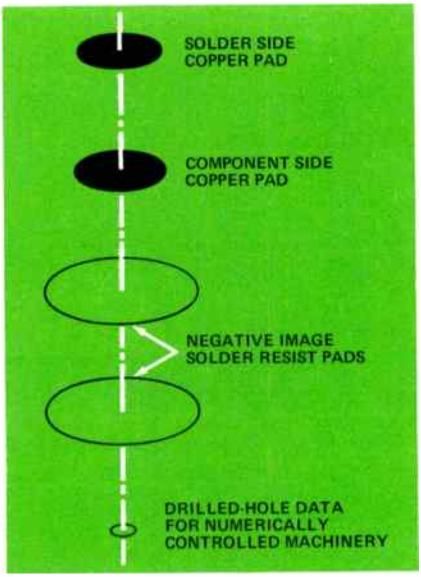



*Figure 2. By preprogramming, all elements of a pad stack can be easily and accurately positioned on all layers of a P.C. board.*

erly programmed, can eliminate much of the repetition involved with making the artwork masters for P.C. boards. With an automated system, the operator can enter and store recurring symbols, alphanumeratic callouts, clusters, or other patterns, and call them out at any desired location, or series of locations, and at any specified rotation and scale by digitizing the point and entering the "shorthand" name.

## Standards and Accuracy

The individual designers, to a large extent, have the responsibility for producing designs that are consistent with the technical industry standards. In a manual operation, an artwork inspector is often used to enforce these standards. However, when such standards are used and policed by humans, who are subject to such things as schedule pressures, these standards may not be uniformly enforced.

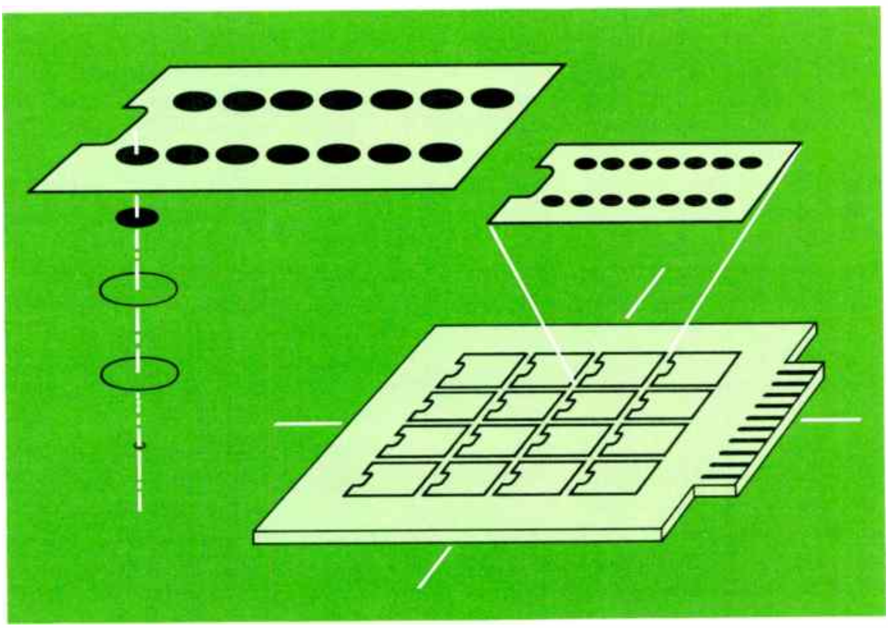


*Figure 3. "Shorthand" drafting techniques can be programmed so that standard component configurations and groups of components can be quickly positioned on the P.C. board.*

An automated system could have these industry standards programmed into it. The operator of an automated system would not be able to change these standards; therefore, the number of inspection steps required could be decreased. When industry standards for manufacturing are maintained during the design process, it becomes possible to use automated production and assembly machinery which could result in a faster production schedule.

The accuracy of most manual systems depends on the eyesight of the person doing the taping, but ±0.015 inches is an average figure for taping accuracy. In order to achieve greater accuracy on the finished board, masters are done at 2:1. This means that the photo tooling mask has an accuracy of ±0.0075 inches.

Automated systems can hold tolerances as close as ±0.002 inches; therefore, there is no need to work at 2:1. Automated systems work at 1:1 and eliminate the photo reduction step needed with manual techniques. (This also eliminates all the handling of the tape master which often results in artwork deterioration.)

With a manual system the registration between layers is quite variable – from ±0.005 inches to ±0.015 inches. The registration possible between the layers of a P.C. board where the artwork is generated with an automated system can be held as close as ±0.0015 inches. Automated systems can also supply drill tapes for holes positioned on a grid as fine as 0.002 inches, so that the holes should always be at the desired coordinate.

Because manual drafting systems have limited precision, large pads and wide conductor spacings are used to achieve a manufacturable product. The result is a medium component density, and one considerably below the density capability of the P.C. board manufacturing process itself. The accuracy and repeatability of an automated system imply greater efficiency in the layout design, utilizing space and materials to the best advantage.

## Checks and Changes

At any point in the input process, the operator of an automated system can stop and check his work. This is done by putting a pen into the digitizer's arm and having the computer plot out the information that has already been recorded. This plot can be done directly over the rough layout so that errors can be quickly detected. The operator can immediately change back to the digitizer mode and make any needed corrections or additions to the plotback just produced. He is able to go back and forth between these two modes until satisfied with the artwork output.

After the data is recorded in the computer memory, the operator calls on the computer to print out a command tape for operation of the photographic output plotter. This plotter produces the necessary 1:1 artwork needed for making the masks for each layer of the P.C. board. At this time, the operator can also punch out a paper tape for any N.C. machinery associated with the fabrication of the finished P.C. board. All of the data used for generating the photo tooling artwork and the N.C. tapes can be stored on magnetic tape cassettes. The data for as many as ten complete P.C. boards can be stored on one cassette.

With a manual system, a double-sized tape master for each layer of the P.C. board must be stored. Care must be taken in the storage of these tape masters so that the tape lines and pads do not fall off or get brushed off. Consequently, a much larger area must be provided for the storage of manually generated artwork masters than for the magnetic tape masters from an automatic drafting system.

INITIAL BOARD LAYOUT

| MANUAL SYSTEM TASK | MAN HOURS | AUTOMATED SYSTEM TASK | MAN HOURS |
|---|---|---|---|
| LAYOUT | 32.0 | LAYOUT | 28.0 |
| TAPING | 30.0 | DIGITIZING CHECK | 4.0 |
| DOCUMENTATION | 6.0 | DOCUMENTATION | 1.0 |
| DESIGN CHECK | 3.0 | ARTWORK | .5 |
| DRAFTING CHECK | 3.0 | DESIGN CHECK | .5 |
| PHOTO REDUCTION | .5 | DRILL TAPE | — |
| DRILL TAPE | 3.5 | | |
| TOTAL | 78.0 | TOTAL | 34.0 |

MODIFICATION TO EXISTING BOARD

| MANUAL SYSTEM TASK | MAN HOURS | AUTOMATED SYSTEM TASK | MAN HOURS |
|---|---|---|---|
| LAYOUT | 8.0 | LAYOUT | 6.0 |
| TAPING | 6.0 | CRT DISPLAY AND CHECK | 2.0 |
| DOCUMENTATION | 3.0 | DOCUMENTATION | 1.0 |
| DESIGN CHECK | 1.5 | ARTWORK | .5 |
| DRAFTING CHECK | 1.5 | DESIGN CHECK | .5 |
| PHOTO REDUCTION | .5 | DRILL TAPE | — |
| DRILL TAPE | 1.5 | | |
| TOTAL | 22.0 | TOTAL | 10.0 |

*Figure 4. An automated drafting and documentation system cuts printed wiring board artwork time by more than 50%.*

The reason for storing the master artwork for P.C. boards is so that they are available for design changes. With a manual system, it is necessary to work with the masters for all of the layers of the board in question to make sure that the intended change is consistent with the complete board design, and to insure that all the necessary modifications have been made on all the layers. It is also necessary to check any additional manufacturing materials pertaining to the board in question – such as N.C. drill tapes. When a component has been moved, eliminated, or added, the drill tape has to be modified so that the holes for the component leads correspond to these new locations. After all the changes have been made, new photo reductions must be made and the modified drill tape substituted in production.

With an automated system, the area, or areas, to be modified can be displayed on a CRT (cathode ray tube). With an editing pen it is possible to trace out on the CRT the areas to be changed, and by appropriately typing in the modification, the master magnetic tape can be changed. After all the modifications have been made, new 1:1 masks can be generated and a new drill tape punched. The convenient part of the automated system is that by using the same "shorthand" used in the input process, all layers that are affected by a modification can be changed at one time.

Figure 4 summarizes the differences in operations and time required to produce and then modify a printed wiring board using both a manual system and an automated drafting and documentation system.

The precision and versatility of most automated drafting systems make them useful for more than the production of printed wiring boards. Another process to take advantage of an automated system is the develop-

| INITIAL THICK FILM SUBSTRATE DESIGN | | | |
|---|---|---|---|
| MANUAL SYSTEM | | AUTOMATED SYSTEM | |
| TASK | MAN HOURS | TASK | MAN HOURS |
| LAYOUT | 6.0 | LAYOUT | 4.0 |
| RESISTOR GEOMETRY | 1.0 | RESISTOR GEOMETRY | .5 |
| ARTWORK PREPARATION | 2.5 | DIGITIZE & CHECK | 1.5 |
| DOCUMENTATION | 6.0 | DOCUMENTATION | .5 |
| DESIGN CHECK | 1.0 | PHOTO PLOT | .5 |
| PHOTO REDUCTIONS | .5 | LASER TAPE | — |
| LASER TAPE | 2.0 | | |
| TOTAL | 19.0 | TOTAL | 7.0 |

| MODIFICATION OF EXISTING THICK FILM DESIGN | | | |
|---|---|---|---|
| MANUAL SYSTEM | | AUTOMATED SYSTEM | |
| TASK | MAN HOURS | TASK | MAN HOURS |
| LAYOUT | 2.0 | LAYOUT | 1.0 |
| RESISTOR GEOMETRY | .5 | RESISTOR GEOMETRY | .2 |
| ARTWORK PREPARATION | 1.0 | CRT DISPLAY & CHECK | .8 |
| DOCUMENTATION | 3.0 | DOCUMENTATION | .5 |
| DESIGN CHECK | .5 | PHOTO PLOT | .5 |
| PHOTO REDUCTIONS | .5 | LASER TAPE | — |
| LASER TAPE | 1.0 | | |
| TOTAL | 8.5 | TOTAL | 3.0 |

*Figure 5. An automated system saves more than 50% in original design and modification of thick film circuits.*

ment of thick film products, since the drafting technique is similar to that used for printed wiring board masks. Figure 5 summarizes the differences in operations and time required to produce and modify the artwork for a thick film circuit mask using both a manual and an automated drafting system. The time required to manually modify a circuit is greater than the time required to produce original artwork using an automated system.

## Overall Benefit

In addition to the benefits already implied with an automated drafting and documentation system — improved accuracy, less storage space, easier design changes, more efficient use of materials — faster throughput eliminates the bottleneck that manual drafting and documentation systems can cause. Since faster throughput means that it takes a shorter time interval to go from initial concept to a finished P.C. board, it is possible for products to go through several prototype stages before the scheduled release date. This means that the released product can be of improved quality and reliability without any extensions of the development cycle.

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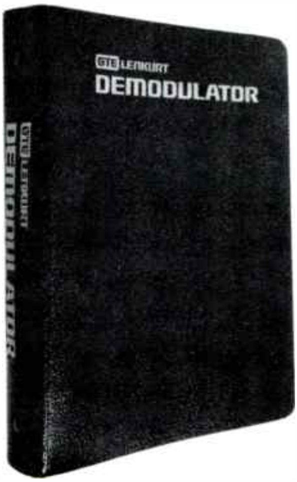


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