COMPUTER AIDED DESIGN OF PRINTED CIRCUIT BOARDS USING REMOTE GRAPHICS AND TSO

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ABSTRACT

This paper describes how one company decided upon and obtained the state-of-the-art in designing printed circuit boards with remote graphics through TSO.

BACKGROUND

The development of a Computer Aided Design (CAD) system for the production of PC boards was initiated at Martin Marietta about 8 years ago and resulted in a program which has been used very productively over the past 6 years. This program, now called H115, has reduced costs and time, improved quality and accuracy, and has afforded higher manufacturing yields with less manpower, greater standardization, and better appearance. Only one set of input data is required to prepare the artwork masters, its associated punched tapes for numerically controlled machines in PC board production, and a complete set of engineering drawings. Manual drafting, artwork, and production functions are largely eliminated in this automatic system after a freehand circuit layout is prepared. The H115 program runs on the IBM 370/168 computer at Data Systems central facility. This centralization has allowed all divisions within the Company to have access to these automated techniques. Significant cost savings, averaging 25 percent or more have resulted through the use of this program. In addition, the Company and customer have benefited by having consistent, uniform documentation and hardware.

Certainly the biggest advantage of the program up to this time has been its ability to generate all required drawings and N-C tapes automatically from one set of input data, with no manual drafting of any kind required to complete a documentation package.

Over the past 6 years, numerous program improvements have been made with the ultimate automated design system in mind, where the H115 program would be the post processor for a CAD system. This approach of producing the post processor program before the front end CAD system was no accident. Starting at the end and producing something which is useful right away and then expanding from there is an acceptable method for pursuing a CAD system[1].

Figure 1 shows the work areas involved in producing PC boards under the current system for a benchmark board. Analysis of this shows that the most costly operations are those associated with producing an accurate layout (9.5 days/80 hours) and preparing the input (3 days/22 hours). It was felt that since the H115 post processor had been developed to a high degree of sophistication, the most potentially rewarding area to attack would be this layout area consisting of a total of 12.5 days and 102 hours.

INITIAL STUDY

Four types of systems were considered to solve the layout problem:

1. a stand alone digitizing system,
2. a stand alone routing system,
3. a batch routing system running on existing hardware, and
4. an interactive routing system running on existing hardware.

The first of these (i.e., digitizing system) was quickly discarded as not solving the layout problem nor reducing the costs associated with Figure 1.

The third method was finally discarded because no available system could be found to do an adequate job on dense boards, while an inhouse development would take too long.

All further studies were conducted comparing the two remaining configurations: a stand alone routing system (unnamed), and an interactive routing system on our IBM 370/168 computer (SCI-CARDS from Scientific Calculations, Incorporated of Rochester, New York).

Figure 1 compares these 2 systems based on the 40 dip benchmark board. Either system would significantly reduce the current costs associated with designing printed circuit boards.

A more detailed study was then conducted to determine which of the two systems should be acquired.

DETAILED STUDY RESULTS

There are three fundamental engineering requirements for any Printed Circuit Board Design Computer System which would be installed for use by the Orlando Division:

1. The system must be interactive and allow for computer aided design with a 19 inch or larger CRT.
2. The performance and cost of the system must be predictable.
3. The system should be responsive to the designer's commands.

Besides the three engineering requirements given above, the underlying requirement of any new system is that it be cost-justified with respect to any other available system, and is expandable to meet the expected growth in the workload. Figures 2 and 3 summarize the differences of the two systems being considered and Figure 4 contains the summary costs. Note: Labor and computer rates used in this and other figures are for illustrative purposes only. Hardware and software costs used are also representative. Data Systems recommended that a SCI-CARD Software System, which operated on an IBM 370/168 under VS and TSO, be acquired as superior to the other available system.

The SCI-CARD System provides all of the capabilities noted above and provides the additional benefits of requiring significantly lower initial investment, of

being accessible to more than one user at a time, and of being expandable with only minor additional expenditures. SCI-CARDS can be interfaced by means of minor program modifications with a post processor thus creating a completely integrated system at a relatively small cost. SCI-CARD terminals can be installed in any of the local design areas (as well as in the Denver facilities) if desirable.

The decision was made to acquire SCI-CARDS and operation of this system can now be described as follows: (Fig. 5)

SCI-CARDS is installed at the Great Lakes Data Center (Buffalo) running from Orlando or Denver on intelligent 21 inch CRTs under TSO at 1200 baud. The terminal's handling of most graphic editing functions requires the transmission of only graphic change data. An electrostatic plotter is used for CRT hard copy and printers provide a permanent audit trail. A high speed paper tape reader is the initial input device. Average response time in this configuration is 5-10 seconds.

SYSTEM OVERVIEW

Figure 6 shows an overview of the CAD system and its interfaces.

Overview Description

(1) An engineering schematic is prepared by an electrical engineer. This schematic should describe the logic which is to be included on the PC board.

(2) A SCI-CARDS designer must then mark up the schematic to prepare parts list and SCI-CARDS input.

(3) He will use the SCI-CARDS terminal using TSO on the 370/168 computer to interactively design the PC board described by the schematic. Final outputs from SCI-CARDS are a plot tape and a CAD file.

(4) Computer Graphics receives the plot tape and special instructions from the designer, and produces Schematic, Assembly and Drill Drawings as part of the final documentation.

(5) The post processor terminal is used by Computer Graphics, following any special instructions from the designer, and using TSO on the 370/168 computer, to produce the Artwork tape, the Drill tape, and Setup instructions.

(6) Artwork Generation is accomplished by producing a photoplot on the Gerber plotter.

(7) Manufacturing uses the artwork, NC drill tape, and setup instructions to produce the PC Board.

(8) Computer Graphics maintains the component libraries required by the system.

The study indicated that the use of this system would reduce the present schedule time, costs, and number of errors in producing digital printed circuit boards by up to 40 percent. Savings on the production of analog boards is also expected to be substantial. The study was based on a yearly volume of 150 new digital board designs and 100 revisions in the Communications and Electronics group. It is expected that a like volume is associated with Main Plant operations as well, but that half of these would be analog boards.

In summary, the studies performed show the SCI-CARDS system as the most desirable system currently available. This system is one of the least expensive of the systems examined, offers future expansion at a modest price, provides access to multiple users at multiple sites simultaneously, can be integrated with the existing post processor software at minimal cost, and offers the greatest reduction in the recurring cost of layouts. Finally, the SCI-CARD system can be installed without duplication of investment in computer hardware.

The SCI-CARDS production system is described in detail by Mr. Leonard Marks[2]. This system has now been used for nine months and has lived up to all expectations. Double sided boards containing up to one 16 pin IC per square inch have been completed (95% automatic), as well as multilayer designs.

References

1 Lerman, H.N., "The Roads to Design Automation", NEPCON, February 1969.

2 Marks, L., "Use of an On-Line, Time-Shared System to Design and Document Printed Circuit Boards", Design Automation Conference, June 1976.

	CURRENT SYSTEM	SCI-CARDS	STAND ALONE COMPETITOR
• Redraw Schematic	2 Days/16 Hrs	---	---
• Prepare Layout	9.5 Days/80 Hrs	---	---
• Prepare and Correct Input	3 Days/22 Hrs	.5 Days/4 Hrs	1.5 Days/12 Hrs
• Computer Operations, Plot and Check	3.5 Days/20 Hrs	2.5 Days/13 Hrs	2.5 Days/14 Hrs
• Produce Artwork and Drawings	3 Days/16 Hrs	3 Days/20 Hrs	3 Days/20 Hrs
• Final Check and Release	1 Day /10 Hrs	1 Day /12 Hrs	1 Day /12 Hrs
• • Total	22 Days/164 Hrs	7 Days/49 Hrs	8 Days/58 Hrs
• • Computer Costs	$175	$390	---

Figure 1 - 5" x 8" Double Sided 40 Dip Board

FUNDAMENTAL REQUIREMENTS	STAND ALONE COMPETITOR	PROPOSED SCI-CARDS
• Interactive CAD System with 19 inch or larger CRT	Yes	Yes
• Performance and cost of system are predictable	Yes	Somewhat
• System is responsive to designer's commands	Yes	Yes
• System is cost effective	Yes	Yes
• System is expandable	Somewhat	Yes
• Usable from other locations	No	Yes

Figure 2 - Fundamental Requirements

	SCI-CARDS	STAND ALONE COMPETITOR
• Automatic Gate and Pin Assignment	Yes	No
• Full Grid Re-entrant Router	Yes	No
• Automatic Trace Stripping	Yes	No
• Number of Present Users	None	Many
• Multiple Terminals	Yes	No
• Chance of System Troubles	Fair	Low
• Response Time	Good	Excellent
• Runs on Present Main Frame	Yes	No

Figure 3 - Important Differences

	CURRENT SYSTEM	SCI-CARDS	STAND ALONE COMPETITOR
• Non Recurring	----	$183,000	$370,000
• Annual Recurring	----	15,000	35,000
• Labor per Board (@ $16/Hr)	$2,624	784	928
• Computer per Board	175	390	----
• • Total per Board (3 Yrs @ 200/Yr)	2,799	1,554	1,720

Figure 4 - Summary Costs

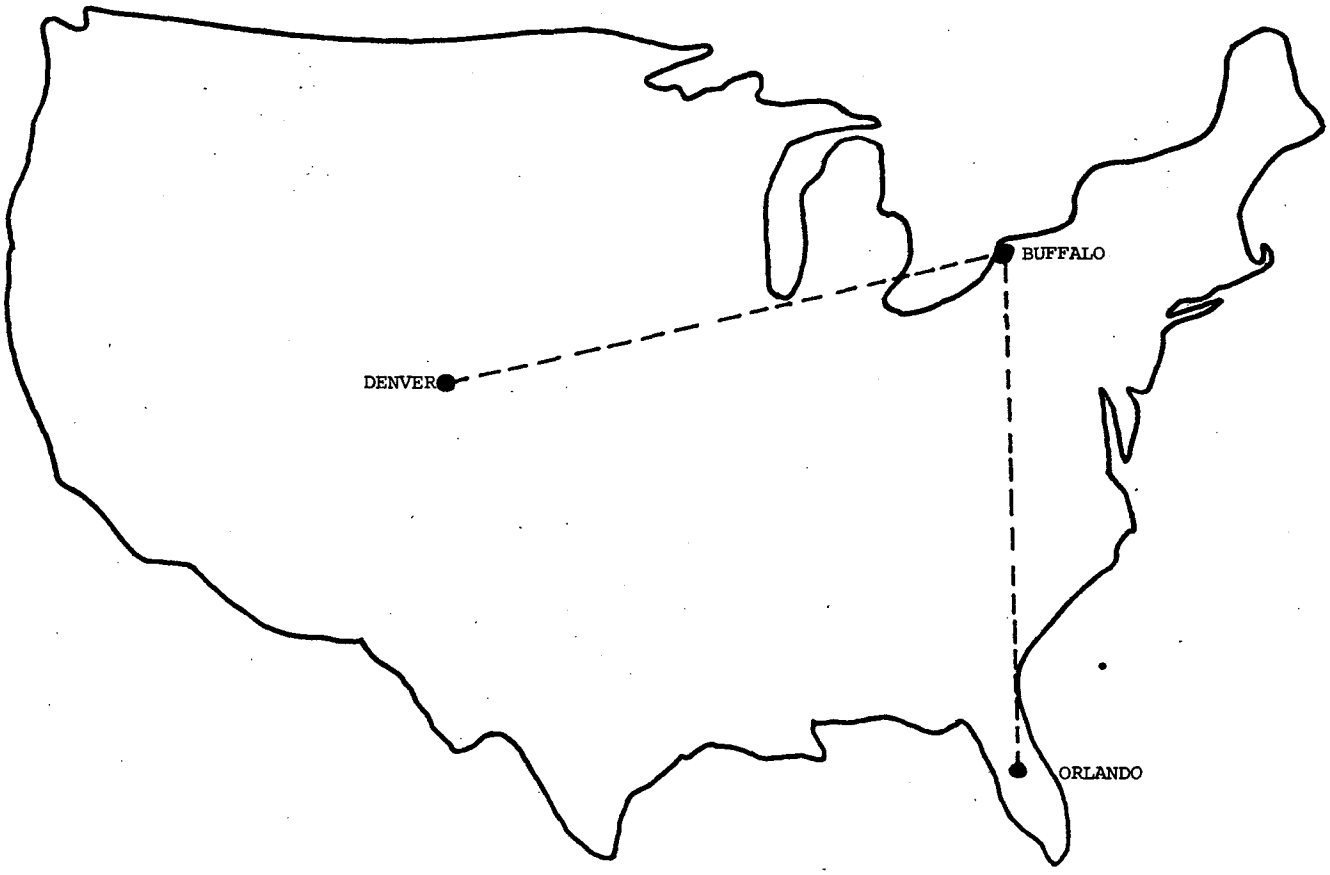

Figure 5 - SCI-CARDS Network

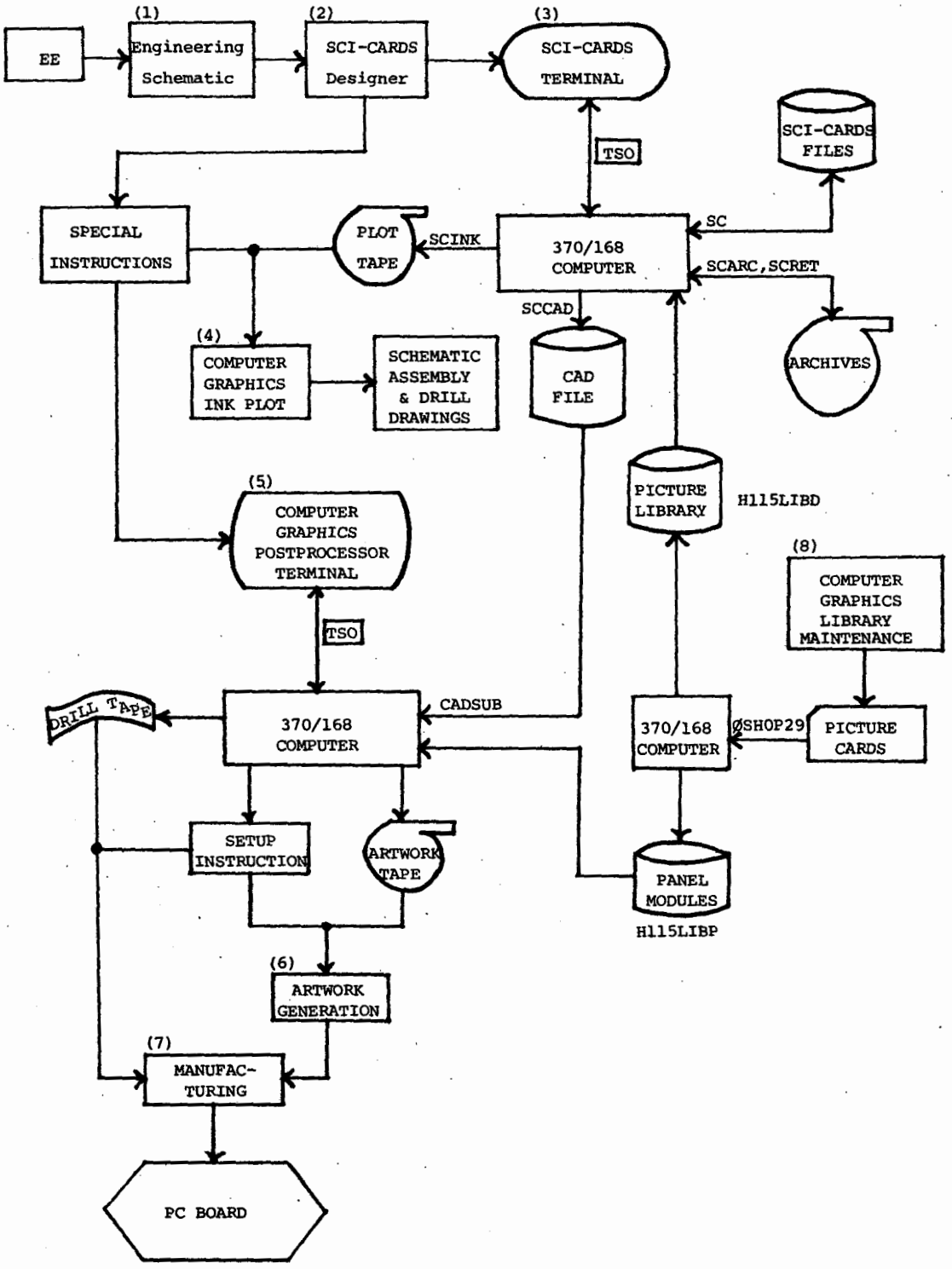

Figure 6 - CAD System Overview