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SIGDA NEWSLETTER

SPECIAL INTEREST GROUP ON DESIGN AUTOMATION

Contents:

SUMMER 1973 VOLUME 3 NUMBER 3

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MEMBERSHIP

SIGDA dues are $3.00 for ACM members and $5.00 for non-ACM members. Checks should be made payable to the ACM and may be mailed to the SIGDA Secretary/Treasurer listed above, or to SIGDA, ACM Headquarters, 1133 Avenue of Americas, New York, N.Y. 10036. Please enclose your preferred mailing address and ACM Number (if ACM member).

SIG/SIC FUNCTIONS

Information processing comprises many fields, and continually evolves new subsectors. Within ACM these receive appropriate attention through Special Interest Groups (SIGs) and Special Interest Committees (SICs) that function as centralizing bodies for those of like technical interests...arranging meetings, issuing bulletins, and acting as both repositories and clearing houses. The SIGs and SICs operate cohesively for the development and advancement of the group purposes, and optimal coordination with other activities. ACM members may, of course, join more than one special interest body. The existence of SIGs and SICs offers the individual member all the advantages of a homogeneous narrower-purpose group within a larger cross-field society.

ACTIVITIES

1) Informal technical meetings at SJSS and FJCC.
2) Formal meeting during National ACM meeting + DA Workshop.
3) Joint sponsorship of annual Design Automation Workshop.
4) Quarterly newsletter.
5) Panel and/or technical sessions at other National meetings.

FIELD OF INTEREST OF SIGDA MEMBERS

Theoretic, analytic, and heuristic methods for:
1) performing design tasks,
2) assisting in design tasks,
3) optimizing designs

through the use of computer techniques, algorithms and programs to:
1) facilitate communications between designers and design tasks.
2) provide design documentation,
3) evaluate design through simulation,
4) control manufacturing processes

EDITORIAL

My last editorial and a meeting at the 10th Design Automation Workshop seems to have done some good. For the first time I had a tough job as an editor--I had to choose between items for publication. Keep it up. That way we can put out a better newsletter.

Plans right now are for another newsletter in October. That means input by September 22. I'm looking forward to hearing from you.

The paper I've chosen was presented at the 10th D.A.W. but not published in the Proceedings. I thought that you might enjoy reading it as much as I enjoyed hearing about it.

Steve

CHAIRMAN'S MESSAGE

ELECTIONS

We have a new set of officers as of July 1, 1973. The election committee was headed by John Hanne with Don Humcke and John Rini as members. Eighty-five members out of the total membership of around 340 voted or 25% showed up at the polls. I consider this a good show of interest. Thanks again to the election committee for a job well done.

The new officers are:

Chuck Radke, Chairman
Dave Hightower, Vice Chairman
Lori Capodanno, Secretary/Treasurer

Their addresses appear on the back of the front cover. Please feel free to contact any of them or any member of the appointed committees or Board of Directors if you have any concerns relative to SIGDA.

APPOINTED POSITIONS

I have made several appointments to help me carry out SIGDA's activities during the next two years with renewed "vigor."

EDITOR: Steve Krosner

TECHNICAL COMMITTEE CHAIRMAN: Dave Hightower

MEMBERSHIP CHAIRMAN: Lori Capodanno

PUBLICITY CHAIRMAN: Lori Capodanno

SIGDA REPRESENTATIVE ON 1974 DA WORKSHOP COMMITTEE:
Steve Szygenda

SIGDA BOARD OF DIRECTORS: John Hanne
Steve Szygenda
Don Humcke
Larry Margol
Chuck Rose

I feel we have a team which will help SIGDA carry out its intended role. The responsibilities of these appointed positions appear later in the Newsletter.

POSSIBLE NEW BY-LAWS:

As indicated previously, the dues for SIGDA may have to be increased. There are certain ACM Headquarters overhead costs for SIG/SIC operations which ACM charges all the SIG's on a pro rated basis. For SIGDA, this is now 74¢ per member. I am thinking in terms of the following schedule:

ACM Members	4.00
Students	4.00
Non-ACM Members	6.00
Subscribers	6.00

I would appreciate your comments. Before I recommend any changes in the By-Laws, I (with the Editor) intend to publish Newsletters with improved content.

FINANCIAL VIABILITY

I am happy to report that I turned in a budget which contains four separate newsletter issues in fiscal year 1974 (July 1, 1973 to June 30, 1974). Steve Krosner and I, in a new brochure to be printed in July, 1973, assure the SIGDA membership of at least three issues. Our finances are in good shape and Headquarters ACM has been of great service to us and other SIG's in stabilizing costs to the SIG's.

Elsewhere in this newsletter, Steve Krosner is publishing his plan for newsletter publication. Please mark the dates down and through your contributions help us meet our projections.

DA WORKSHOP SUCCESS

I want to openly thank Mike Galey as General Chairman and Bob Hitchcock as Program Chairman for a terrific job done in relation to the 1973 Workshop held in Portland, Oregon, June 25-27. There was a good crowd and an excellent technical program.

The Call for Papers for the 1974 Workshop appears elsewhere in this issue. Start thinking and acting now to work on that paper. Also plan to attend next June in Denver.

SIGDA also participates in other conferences, notably the ACM Conference and sponsors several technical sessions at conferences each year. We feel these sessions give us a balance and let non-members, non-DA oriented individuals hear about Design Automation; keep these other conferences in mind too for your papers. However, we look upon the DA Workshop where one can concentrate on DA, obtain the latest input, and discuss recent DA activity.

C. E. Radke

DUTIES OF APPOINTEES

BOARD OF DIRECTORS OF SIGDA

The Board will be chosen to provide a wide geographical representation. The Board will consist of five members appointed by the Chairman. These appointees should be chosen because of their established position within the Design Automation activity, their ability to provide assistance as required, and their wide understanding of the future needs within the DA area. Representation should be from both academia and industry and should not include double representation from any one organization.

Although it is desired to keep responsibilities of the members general, certain responsibilities can be stated as follows:

1. Provide assistance to the Executive Committee through their contacts when certain talent or contributions are required for specific SIGDA activities.

2. Provide, as appropriate, support to objectives of SIGDA.

3. Provide the Executive Committee with constructive criticism and input directed at improving SIGDA.

TECHNICAL COMMITTEE CHAIRMAN

A Chairman of the Technical Committee shall be chosen by the SIGDA Chairman. The Technical Committee Chairman may in turn appoint a committee to support him in his responsibilities. The responsibilities are:

1. To organize the technical part of the SIGDA meetings held at various conferences.

2. To coordinate the organization of SIGDA sessions at various conferences.

3. To assure appropriate publicity is obtained for the various SIGDA technical functions.

4. To assist the Newsletter editor in improving the technical content of the SIGDA Newsletter.

5. In general to be responsible for the technical contribution of SIGDA to its members.

MEMBERSHIP CHAIRMAN

A Chairman of the Membership Committee shall be chosen by the SIGDA Chairman. The Membership Committee Chairman may in turn appoint a committee to support him in his responsibilities. The responsibilities are:

1. To correspond with all individuals who inquire about SIGDA.

2. To respond on a timely basis to all applicants for membership in SIGDA.

3. To work with central ACM Headquarters on membership problems.

PUBLICITY CHAIRMAN

A Chairman of the Publicity Committee shall be chosen by the SIGDA Chairman. The Publicity Committee Chairman may in turn appoint a committee to support him in his responsibilities. The responsibilities are:

1. To collect from the Executive Committee and Committee Chairman all announcements which need to be made in the SIGDA Newsletter and CACM on a timely basis.

2. To transmit for publication announcement of SIGDA activities to other SIG Newsletters and other appropriate professional news periodicals.

3. To have printed and distributed an up-to-date brochure on SIGDA.

4. To assure SIGDA literature is available for distribution at all conferences at which ACM takes part and to initiate such distribution of SIGDA interests significantly overlap.

EDITOR OF SIGDA NEWSLETTER

An Editor for the SIGDA Newsletter shall be chosen by the SIGDA Chairman. The Editor in turn is required to appoint an Editorial Board headed by himself and consisting at a minimum of the following Assistant Editors:

Assistant Editor for News
Assistant Editor for Bibliography and Reviews
Assistant Editor for Feature Items

The Editor shall be responsible to set a schedule for Newsletter publication and copy deadline and to enforce this schedule. He shall assure a minimum of three separate issues of the SIGDA Newsletter for fiscal year (July 1 through June 30). He shall be responsible for establishing, obtaining approval and adhering to a budget and publication plan for the SIGDA Newsletter.

LETTERS

Editor,

I attended the 10th Design Automation Workshop and found it very worthwhile. I thought I would take this opportunity to highlight some of the things I saw for those who did not get to attend. The Software Session reiterated the need for testing and documentation of programs. Program optimization and verification was stressed. As Sergio Bernstein said, "Plan ahead, the head you save may be your own." The Special Interest Group meeting was very lively and somewhat emotional. Some people feel programming is an art form and not to be constrained by design automation discipline. Others feel programming is a tool we need to learn to use effectively and efficiently and adaptable to design automation.

The Testing and Simulation Session had good studies of functional simulation and fault analysis. "Functional Testing - A User Looks at Logic Simulation," pointed out the need for system testability and maintainability. Restrictes timing models generated inadequate test data and as a result good modules were being returned. The user also pointed out the government needs programs that can be run on different computers and this tied in nicely with the software paper "Programming for FORTRAN Compatibility and Machine Independence."

The textile industry was represented in the Manufacturing Session and the presentation showed how fabric patterns are designed and the real-time control of the loom. The luncheon speaker also showed slides of the results of several projects using design automation. These include marinas, urban centers and sawmill operations.

The 10th Annual Design Automation Workshop has brought together people from many industries and they found their problems are similar. Answers found in one discipline are often applicable to others.

W. Jean Sherman

CALL FOR PAPERS/MEETING NOTICES

The 2nd American Society of Mechanical Engineers (ASME) Conference on Design Automation will be conducted Sunday, September 9 through Thursday, September 13, 1973, in Cincinnati, Ohio.

The conference is sponsored by ASME.

Conference topics include the following areas of interest:

Problem formulation for automated design.

Optimization criteria and solution algorithms.

Computer technology applicable to design: information processing, graphic display, time sharing, data base, automated drafting, automated testing, automated design manufacturing systems.

SME's CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) Conference and Exposition will be held in Detroit on October 2-4, 1973. The program is incomplete, however, I am enclosing a copy of the first program brochure and an outline of the proposed second program to show areas covered.

MICRO 6, the Sixth Annual Workshop on Microprogramming sponsored by the ACM Special Interest Group on Microprogramming (SIGMICRO), will be held at the University of Maryland Conference Center, College Park, Maryland on Monday and Tuesday, September 24 and 25, 1973.

The Program Committee has received a number of good papers, and expects that Micro 6 will be one of the best workshops ever. There will be participants from France, Germany, and Italy as well as from various parts of the United States.

The general structure of the conference is as follows: Early Monday morning, Earl Reigel of Burroughs will give a tutorial session on what microprogramming is all about. This will be followed by a formal paper session chaired by Louise Jones of the University of Deleware. In the afternoon there will be two workshop sessions on the applications of microprogramming (chaired by Gary Kratz of IBM) and, concurrently with these, a session on architecture chaired by Bill Lidinsky of Argonne and one on graphics chaired by Andy van Dam of Brown University. The conference banquet (and social hour!) will be held Monday evening; Bill McKeeman of the University of California at Santa cruz will keynote the conference with a talk on "Mechanizing Bankers' Morality". On Tuesday, the first morning session will be on microprogramming languages (chaired by Ron Brody of Burroughs); this will be followed by a session organized by Y. S. Wu of NRL on microprogram controlled signal processors and, concurrently, a session on microprogramming in computer science education. Tuesday afternoon will be devoted to a panel discussion, on "The Future of Microprogramming"; Stu Tucker of IBM is in charge of this session.

Preprints of the papers presented at the workshop are currently being prepared and will be mailed to all advance registrants early in September. The preprints will include three types of papers: formal papers (30 minute formal presentations), regular session papers (15-20 minutes, including questions), and brief reports (5 minutes). There should be ample opportunity to ask questions in all of the workshop sessions. The program committee hopes that the preprints will provide the basis for much fruitful discussion.

SECOND TEXAS CONFERENCE ON COMPUTING SYSTEMS

AUSTIN, TEXAS, NOVEMBER 12-13, 1973

The Texas Conference on Computing Systems is an annual forum for the presentation of state of the art practice in computing systems and research results. This tentative list of sessions and invited papers indicates the scope and depth of the conference. Sessions will feature surveys of state of the art practice as well as reports on recent specific developments by means of invited and contributed papers.

A Partial list of invited participants:

Programming Languages
Chm Harlan Mills (IBM)
S. R. Kosaraju (John-Hopkins)

Applications of Computation Theory
Chm K. S. Fu (Purdue)
Philip Lewis (General Electric Research Lab)
C. L. Liu (U of Illinois)

Operating Systems
Chm James C. Browne (U of Texas)
George H. Mealy (Harvard)

System Evaluation and Optimization
Chm C. V. Ramamoorthy (UC Berkeley)
William Lynch (Case-Western Reserve)
John Tarter (U of Alberta, Canada)

Data Management and Information Retrieval
Chm Paul deMaine (Penn State)
Robert Simmons (U of Texas)

Management of Computing Facilities
Chm Timothy Ruefli (U of Texas)
K. Knight (U of Texas)

Computer Communications and Networks I
Chm Mani Chandy (U of Texas)
Julius Aronofsky (SMU)
Donald Aufenkamp (National Science Foundation)
Eric Manning (U of Waterloo, Canada
Jerry Weeg (U of Iowa)
Paul Green (IBM)

Computer Communications and Networks II
Chm Robert Kuhn (Arpa)
L. Kleinrock (UCLA)
Eric Manning (U of Waterloo, Canada)

Reliability and Diagnosis
Chm Stephen Szygenda (U of Texas)
Herbert Chang (Bell Laboratories)
Francis Mathur (U of Missouri)

Computer Architecture
Chm Joseph Watson (Texas Instruments)
Michael Flynn (John-Hopkins)

Minicomputer System
Chm Frank Spiznogle (Texas Instruments)
John Allan (U of Texas)

Contributed papers of digest length (Approximately two thousand words) are to be submitted to the program chairman for review by August 1, 1973. Each paper is to be accompanied by an abstract. Authors will receive notification regarding acceptance of papers by September 15, 1973. The final version of the paper, for publication in the proceedings will be due October 20, 1973.

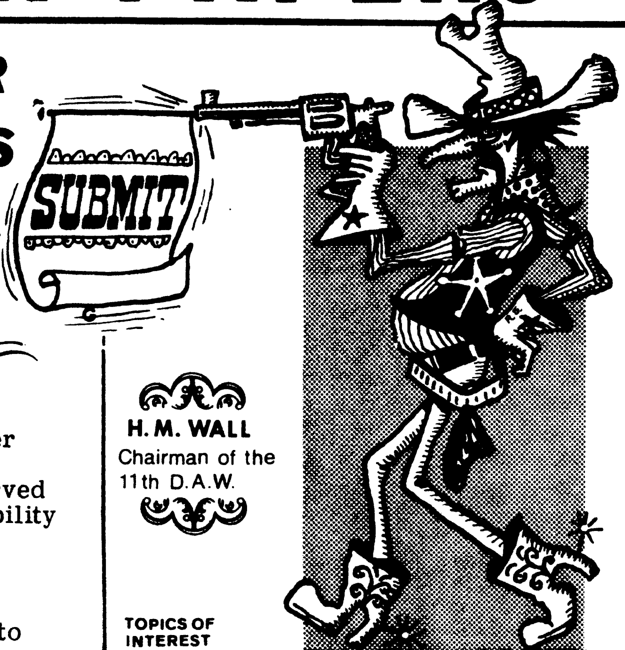
Program Chairman: Prof. Terry Welch, Department of Electrical Engineering, University of Texas, Austin, Texas 78712.

11th annual DESIGN AUTOMATION WORKSHOP

DENVER, COLORADO ★ ★ ★ ★ ★ ★ ★ ★ *EXTRA* ★ ★ ★ ★ ★ ★ ★ ★ VOLUME 1, NUMBER 1

CALL FOR PAPERS

REQUIREMENTS FOR SUBMITTING PAPERS



If you plan to submit a paper, you should send three copies of the paper, or a 1,000 word abstract to the program chairman no later than January 2, 1974. (Rough drafts are acceptable)

Accompanying the draft should be the full name, address and telephone number of the principal author, with whom all further direct communication will be conducted.

Notification of acceptance will be sent to you during the first week of February, 1974. After notification of acceptance, you will receive detailed instructions on the format to be observed in typing the final copy. To insure the availability of Proceedings at the Workshop, your final manuscript will be due April 19, 1974.

Final papers should be no longer than 5000 words, and the presentation should be limited to 20 minutes. Projection equipment for 35mm slides and vuegraph (overhead projector) foils will be available for every talk. Please indicate what, if any, additional audio-visual aids you require.

SPONSORS
ACM (Association for Computing Machinery) Special Interest Group on Design Automation
IEEE (Institute of Electrical and Electronics Engineers) Computer Society

BROWN PALACE
chosen for site of 11th D.A.W.
JUNE 17, 18, 19, 1974

DESIGN AUTOMATION

Design Automation is taken to mean the use of computers as tools which aid the design process and is often extended to include areas such as testing, simulation and certain portions of manufacturing. Typical examples of Design Automation involve the application of one or more functions to a given design area.

H. M. WALL
Chairman of the
11th D.A.W.

TOPICS OF INTEREST

DESIGN AREAS → / FUNCTIONS ↓	Manufacturing Process	Architecture	Mechanical	LSI	Electronic	Firmware	Software	Total Systems
Partitioning (Packaging)								
Placement (Packaging)								
Wiring (Packaging)								
Analysis								
Simulation								
Design Verification								
Testing/Quality Control								
Interactive System								
Design Language								
Change Control								
Theory								

Rough Drafts are to be sent to the Program Chairman:

S. P. Krosner
IBM Corporation
P.O. Box 1328
Boca Raton, Florida 33432
305-391-0050

AN INTERACTIVE SYSTEM FOR SEMI-AUTOMATIC ARTWORK GENERATION OF PRINTED CIRCUIT BOARDS

A. Mura - M. Tomljanovich
SELENIA S.p.A. Roma / Italy

ABSTRACT

An integrated interactive system for the P.C. boards production is described. The system comprises a minicomputer, a teletype, a paper tape puncher and reader and a package of analysis, control and post-processing programs.

The input data to the system consist of circuit schematics, coded in terms of electrical components and connections, and manual layouts of the P.C.B.'s. Both inputs are internally and mutually checked.

This operation is performed on-line with the digitizing phase, producing an intermediate punched paper tape and diagnostic printouts.

Information recorded on the paper tape are then split in order to obtain control paper for N.C. artwork, drill and insertion machines.

A core-resident components library supplies all the required supplementary data, i.e. pads size, holes diameter, drawing symbols, etc.

Important features of the system are :

- exhausive controls of the layout against the schematic and v.v.;
- very easily made and completely system controlled updating and/or correcting of both schematics and layout;
- no significant limitations.

Results obtained during first months of system's operation are reported; a cost reduction of about 50% and a turnaround time reduction of about 60% with respect to the manual system have been achieved.

INTRODUCTION

Often the term "non-creative design" is used to indicate the complex of activities which flow from the basic design and include the preparation of all detailed drawings and information required by the workshop for manufacture of the equipment. A good example of this is represented by the printed circuit board (p.c.b.s.) artwork production process.

It is general experience that it is this so-called "non-creative" design stage that involves the bulk of development costs and requires the greatest amount of project time. Automation of these activities has therefore been one of the main objectives of the CAD system suppliers.

Completely non-creative design, however, does not exist. In fact, in each human work process one can distinguish four coexistent steps or phases :

- creative phase
- detailing and copying phase
- inspection phase
- delivery and travelling phase.

In development of the printed circuit documentation, these four steps can be identified as :

- layout design (placement and routing)
- taping-up
- inspection
- miscellaneous activities (photographic reductions, blue-prints, filing mailing, transport, etc.).

The four activity steps may appear self-contained as they are carried out successively in time and even by different groups or departments, but they are closely connected and mutually dependent. Automation of the manufacturing process cannot deviate from this reality.

Various attempts have been made, some with success, to introduce CAD, or better CAP (where P stands for Production) in the manufacturing process pertaining to development of the p.c.b. artwork. Two main approaches can be envisaged.

The first (digitizing systems) has been oriented towards automation of the taping-up phase undoubtedly the least creative and one of the most expensive). Although this automation results economical for the taping-up phase itself, its effectiveness in the production and, above all, in the reduction of the turnaround time is often subject to discussion (increase in checking time, increase in delivery phases, etc.).

In the second, more complete approach, (automatic placement and routing systems) an attempt has been made to automate the creative step. Obviously, full success in this attempt means computerization of all the other phases.

Apart from considerations on the availability of means, man-power and time required to solve this task, it seems that this method does not give comparable results from the point of view of quality to those obtained by man. This method in any case causes moreover considerable changes in the subsequent manufacturing process which are often not taken into account.

This paper illustrates an approach, different from those indicated, which is half way between the two mentioned above, and which has led to a system in operation now for several months.

The system is based on a minicomputer which is fed with a description of the circuit diagram, and which checks, step by step, the operations of the draftsman who digitizes the routing layout of the printed circuit board, designed using traditional techniques. Only correct data are accepted and reproduced in output.

SYSTEM DESIGN

The system described forms part of a much larger scheme of CAD/CAP intended to reduce the time and possibly the costs related to design, manufacturing and testing of printed circuit cards.

The production process covered by the system starts from the circuit diagram released by the designer, and continues until the necessary documentation for the p.c.b. manufacturing (assembling included) is produced.

During the design stage of the system, the following preferred conditions, which also represent the main features, have been stated :

1 <u>maintain the whole process within the original groups (practically the drawing dept.)</u> :

- this tends to avoid the creation of other steps in the manufacturing chain, and the degradation of the specialists in the drawing office to an input device for some far-away computing centre; this fact can sometimes cause a sense of uselessness, job dissatisfaction (since the operator does not see the results of this work) and frustration (since the erroneous results, and only those, will come back to him).

2 <u>make the least possible changes to the manufacturing process before and after, keeping unchanged the interfaces</u>

- the main purpose is to avoid increase of the manufacturing process and to facilitate introduction and use of the new techniques.
  Often CAD/CAP systems reduce the costs of one manufacturing phase but cause an increase of other phase costs, since they require the use of new machines or an increase in man power. For instance, automatic routing programs will show a sensible increase in the feed throught hole count with respect to manual design (300%, or approximately 60% of the total holes count including the component pads).
  This is often not taken into account, and tends to limit the use of these automatic techniques to a large organization.

3 <u>check the whole process to avoid the introduction of errors</u>

In manual systems, this guarantee requires repeated costly and extensive checks during all design phases. These checks constitute one of the major causes of the long global turn-around time.
The remaining errors, which unfortunately always exist, must be debugged during breadboard testing by the designer who, being a logical animal, is not trained to trace faults that are of a "not-logic" nature. This again means an increase in cost and turnaround time, frequent feed-backs of modifications and, last but not least, it will create the impression of incompetency and inefficiency with regard to the drawing department.
To use an instrument which assures the exact corrispondence between end products and input design data has been one of the most appreciated characteristics of the system.

4 <u>not impose "a priori" limitations on the type of boards handled by the system nor on the type of components used</u>

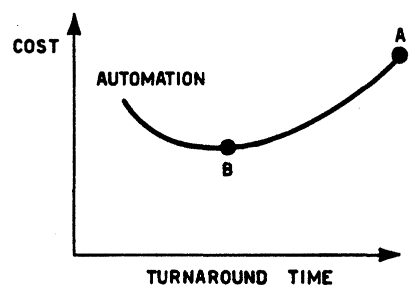
Standardization is not always possible, and without standardization it is difficult to obtain a good level of automation at reasonable costs. Flexibility is therefore an important and necessary requirement also because without particular restrictions or procedure modifications the system can immediately be used.

5 maintain the cost at such a level as to permit duplication of the system

Apart from considerations regarding reliability, one of the dangers which has to be avoided when changing to automation is creation of a bottleneck by pushing the use of the equipment to a maximum (two-three shifts).
It would be auspicable to work in one shift with three machines rather than in two or three shifts with one machine only. This, however, is only possible when the machine requires a moderate capital investment.

6 try to reserve the creative part of the work for man and the other phases for the machine

Automation should mean a reduction of costs and turn-around time. This, however, is not always true.
If one plots on a diagram the turn-around time, of a process versus, the cost, including amortization of the automatic system, the curve obtained as a function of the level of automation provided is that of figure 1, where A is the situation before automation. The minimum B is the point from which an attempt is made to automate the creative phase, and is the most convenient economical point with a minimum of capital investment.



SYSTEM HARDWARE

A typical hardware configuration for the system (figure 2) comprises :

1) a minicomputer with 16K memory;
2) teletype
3) paper tape reader
4) paper tape punch
5) digitizer.

Access to a photo-plotter is also required to obtain the output documentation.

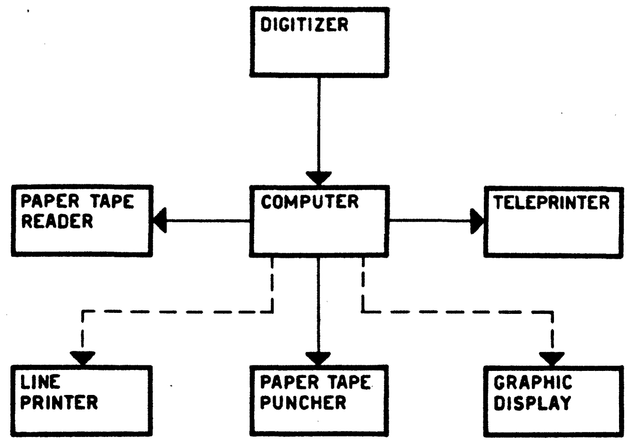


FIG. 2 SYSTEM CONFIGURATION

Options are :

- increased memory (up to 32K)
- high speed serial printer
- graphic display unit (storage tube).

The digitizer is a drafting board on which a drawing can be placed. A coordinate sensing device generates pulses to describe the movement of a probe as it is moved across the surface of the graphic input information board. The pulses are accumulated in the control logic in X and Y registers to keep track of the probe position, relative to the datum. A push-button, fastened to the probe, allows the operator to transfer the X and Y coordinates to the computer memory.
A keyboard can be added to the unit (figure 3) in order to transfer to the computer some control information together with the coordinates. A small area of the board, on which a set of virtual keys are drawn (menu), can be reserved in order to increase system flexibility and programmability (figure 4).

FUNCTIONAL OPERATION

A functional block diagram of the system is displayed in figure 5.

Operations are performed in six steps, as follows :

- schematic coding
- board data structure creation
- component placing (digitizing)
- connection description (digitizing)

BLUE	=	WIRING SIDE
RED	=	COMPONENT SIDE
CORNER	=	ROUTE BEND
E	=	ECHO
D	=	DELETE
R	=	RESET
F	=	END OF PATH
V	=	MENU
C	=	COMPONENT PIN
P	=	FEED-THROUGH HOLE
T	=	ROUTE BRANCH

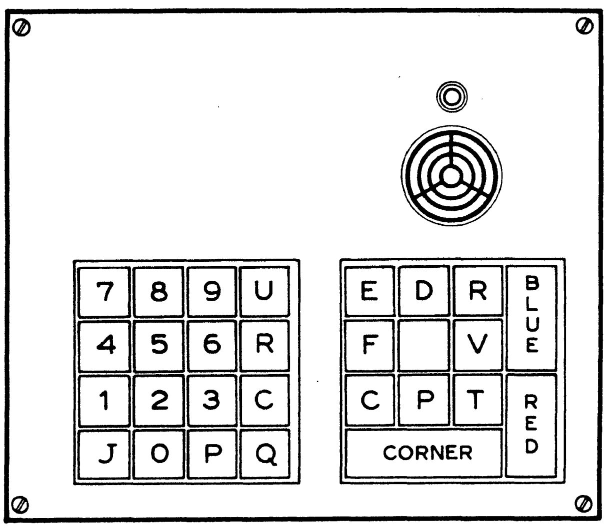


FIG. 3 _ KEYBOARD

DIGITIZER	READER	TOTALS	OVERRIDE	END OF PROCEDURE
A	B	C	D	E
F	G	H	I	J
K	L	M	N	O
P	Q	R	S	T
U	V	W	X	Y
Z	SPACE	+	—	•
0	1	2	3	4
5	6	7	8	9
SELENIA	CODE #	REVISION SIDE #1	REVISION SIDE #2	C. S.
NAKED HOLES #1	NAKED HOLES #2	HORIZONTAL #1	HORIZONTAL #2	HORIZONTAL #3
NAKED HOLES #3	NAKED HOLES #4	VERTICAL #1	VERTICAL #2	VERTICAL #3
DRESSED HOLES #1	DRESSED HOLES #2	DRESSED HOLES #3	DRESSED HOLES #4	TEST POINT
PATH WIDTH #1	PATH WIDTH #2	PATH WIDTH #3	PATH WIDTH #4	PATH WIDTH #5
PATH WIDTH #6	PATH WIDTH #7	PATH WIDTH #8	PATH WIDTH #9	PATH WIDTH #10
PATH WIDTH #11	PATH WIDTH #12	PATH WIDTH #13	PATH WIDTH #14	PATH WIDTH #15
TEXT	COMPON.	PATHS	AREAS	END OF JOB

FIG. 4 _ MENU LAYOUT

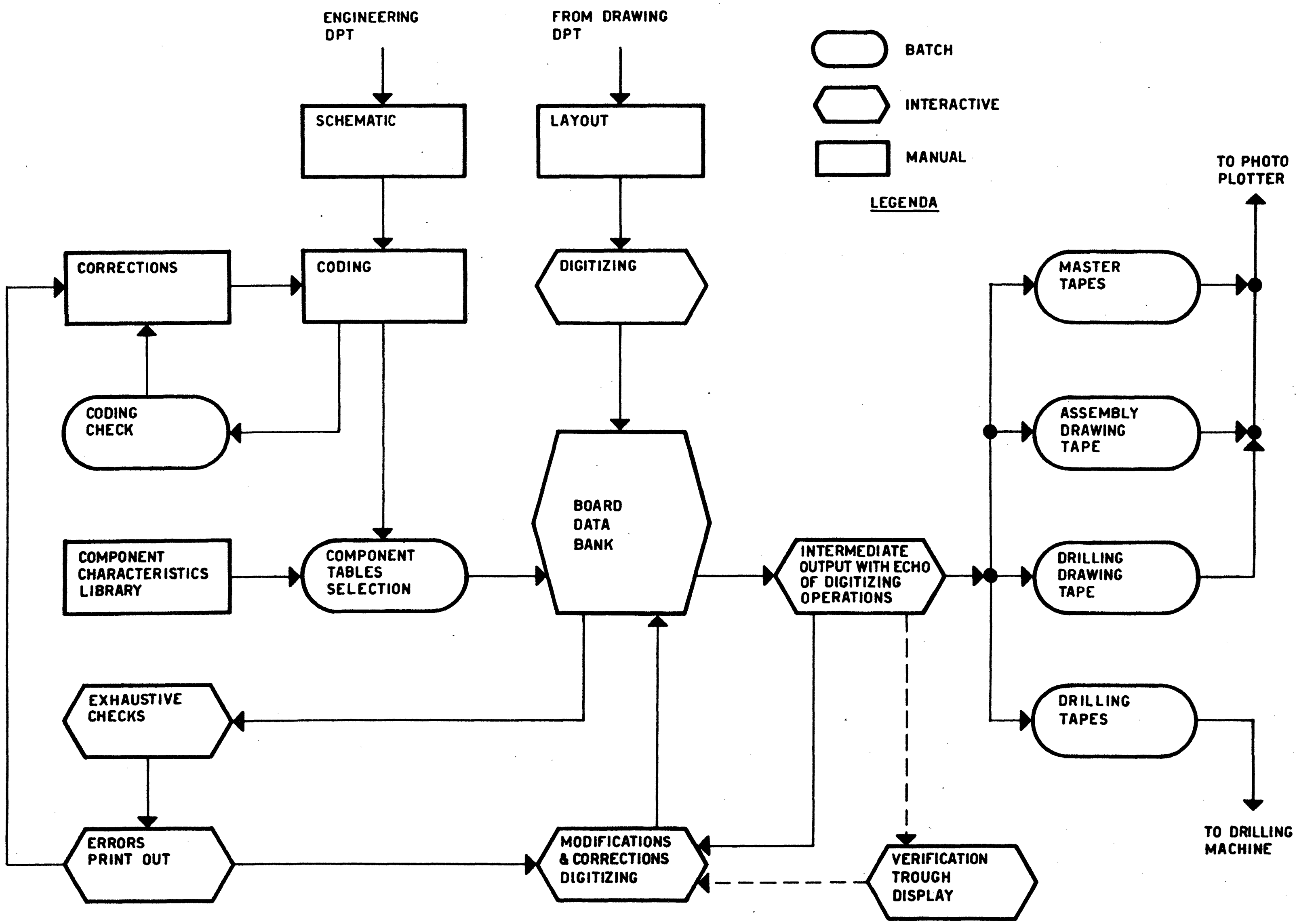


FIG. 5 FUNCTIONAL BLOCK DIAGRAM

- modification, correction, updating etc. (digitizing)
- output documentation production.

Schematic coding

Component types and connections between component pins (signals) are described using on easy-to-learn man-oriented language (see example in figure 6). The components are named with standard symbols, i.e. U means I.C., R resistor, C capacitor etc.). The components are classified in

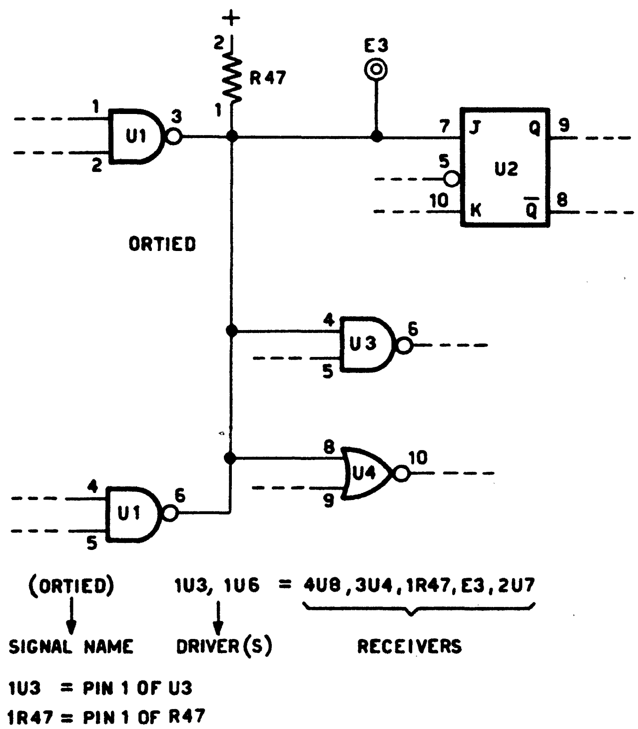


FIG. 6 SCHEMATIC CODING

groups, using a special coding letter according to the physical and topological characteristics i.e. pad size, pin hole size, distance between pins etc. A certain number of tables have therefore been predefined for all the possible usable components, forming a kind of component library.

Data structure

The previously defined encoded data are now loaded into the computer memory together with the selected component tables. The computer, while reading, checks the data and creates a data structure for the board. Diagnostic print outs (figure 7) can be produced.
The data structure contains two complementary information sets :

1) a component list which, for each board element, records the signal assigned to each pin;

2) a signal list which, for each signal, gives the chain of the interconnected pins.

These list are mutually accessible, in the sense that every item of each list contains pointers to related items of the other list. Provisions have been made to produce, at operator request a hard-copy of the input data, and/or a dump of the data structure. This feature can be very useful because it allows the above operations to be performed at a different time and by different people with respect to the following actions.

Component placing

As soon as the previous schematic data have been loaded, the system is ready to accept digitized layout information. The operator, by means of the probe and the keyboard, chooses a component name by pointing to alphanumeric characters of the menu and shows the components position on the layout drawing to the computer. Two coordinates are usually sufficient to indicate component position and orientation. The computer accepts this information, checks its validity and completion, computes coordinate values for every component pin and adds them to the board data base.
Information sent by the operator is echoed on a punched paper tape as soon as it is accepted and checked by the program.

Interconnecting digitizing

The printed circuit paths are digitized, grouped by signals.
The operator, starting from a component pin, follows the signal route, transmitting to the computer the coordinates of the end point of each segment. The keyboard is used by the operator to give the coordinates the following meanings :

- component pin
- feed-through hole
- path corner
- route branch

More over, when necessary, the layer must be specified. This process is continuously checked by the computer, which stores the accepted data in a buffer area. The teletype is used to print

CODE	MEANING
CC	ILLEGAL CLASS IDENTIFIER
CN	ILLEGAL COMPONENT NUMBER
CP	ILLEGAL COMPONENT NAME
CS	LPE CONTROL STATEMENT ERROR
DD	COMPONENT DOUBLY DEFINED
DO	DATA BASE OVERFLOW
EN	END CONTROL STATEMENT ERROR
IL	ILLEGAL PIN NAME
PN	ILLEGAL PIN NUMBER
SC	SHORT CIRCUIT BETWEEN SIGNALS
SN	ILLEGAL SIGNALS NUMBER
SO	SIGNALS OVERFLOW
SP	ILLEGAL SEPARATOR
UN	COMPONENT UNDEFINED

FIG. 7. SCHEMATICS CODING DIAGNOSTICS

diagnostic messages as operator errors are detected (figure 8). As soon as a signal route is completely digitized, the program performs the following tasks :

- retrieves from the component section of the board data base the component pin whose coordinates match the contents of the first item of the buffer;
- reads out the associated signal code, and retrieves from the signal section the list of interconnected pins;
- copies pins coordinates into a second buffer;
- compares the contents of the two buffers looking for the complete match of the pins coordinates.

If the two buffers are identical, the digitised conn ection is punched out on the paper tape and the related pins are labelled in the data base. Should any difference be detected, a completely detailed diagnostic message is printed out (figure 9).

It must be pointed out that this necessity of absolute equivalence between the signal described by schematic coding and the signal created by the printed connection guarantees that all possible mistakes occurring along the working line are detected. Moreover, since no usable output is provided in case of errors, the draftsmen are compelled if any changes or updating of the logic are to be carried out, to modify both the input layout and schematic.

As soon as the operator finalizes the interconection description phase, the program checks that all coded signals have been digitized. All the missing signals are listed.

Correction and updating

These aspects of the system have been carefully studied because success of the automated system often depends on their efficient implementation.
It is quite obvious that, when modifications are required, only the information necessary for such changes is expected be introduced into the system.
This is also true for the system described here, but the procedure with which this is performed is not as straight forward as could be expected.
In fact, in order to save core, most of the digitizing data (i.e. printed wiring) are not retained in easily changeable locations (core) but punched out on paper tape.
However, since digitizing information is recorded in the same format as sent by the operator, it is possible to simulate and repeat all the operator actions by simply reading the punched paper tape into the computer. Of course the system also repeats the same operation printing the same diagnostics and punching eventually the same information. Because the system has been instructed to accept the same item (signal digitizing, component position, signal coding, etc.) only once, it is a very simple matter to feed the computer with updating data at the beginning of each phase before reading in the old data through the tape. Old data are automatically refused and/or corrected.

It is worthwhile to point out that this strategy offers the operator the outstanding facility to stop his work at any time and for any reason (including power off), without carrying out cumbersome recovery procedures (memory dumping).

Output documentation

The output tape of the digitizing phase is input to a post processing program, operating in batch mode.
This program produces the output documentation in the form of paper tapes which control the operation of a photo-plotter and of a N/C drilling machine.
The photo-plotter supplies the production artwork master, the drilling drawing (for inspection and customer documentation) and the assembly drawing (for customer documentation and semi-automatic component insertion machine).

PERFORMANCE AND RESULTS

There are presently three systems installed in our drawing department.
Each system comprises the basic configuration listed above plus an optional high speed serial printer.
There is also a multiconversion system used as a self-service centre based on the same minicomputer (16K), and comprising :

- paper tape reader
- paper tape punch
- magnetic unit
- card reader
- Tektronix 4010 graphic display with hard copy.

This fourth system, while not strictly necessary, is however convenient, as it frees all the other systems from batch activities. Punched cards are more easily modified than paper tape and a card-to-paper tape conversion has thus been provided.

CODE	FOLLOWED BY	DESCRIPTION	OPERATOR ACTION
B	-----	Menu coordinates expected	Send menu coordinated
D	Menu key decoded	Illegal menu key	Select one of the following: - TEXT - COMPONENT - PATHS - AREAS - END OF JOB
G	Four coordinates	Layout corners not aligned	Send again
M	-----	Illegal component name	Send correct component name or END OF PROCEDURE
N	-----	Component undefined	Send correct component name or END OF PROCEDURE
O	-----	Component previously digitized	Select override and send again
Q	-----	Illegal pin coordinates for dual-in-line component	Send again or END-OF PROCEDURE
S	-----	Path width expected	Select chosen path width
U	-----	No signal at this component pin	Check schematics
Z	List of digitized points	No complete match between signal and route	Digitize the complete route again or start a new route or send END OF PROCEDURE
X	-----	No side information for a route segment	Send side information

FIG. 8 SOME DIAGNOSTICS FOR WRONG TIPITIZING OPERATION

```
ROUTE 0015  SIGNAL 0192  DIGITIZED POINTS 08  PINS 03

COORDINATES    FUNCTIONS   PIN NAME         ERROR
+0390 +0240        M        13U10
+0406 +0240     R  C
+0406 +0216        C
+0390 +0216        C
+0406 +0212     T  C                  BRANCH POINT NOT ACKNOWLEDGED
+0406 +0180        F
+0406 +0136     E  M                  PIN UNDEFINED
+0422 +0136     R  M        04U21     BELONGS TO SIGNAL #0194

PINS OF SIGNAL 0192 NOT DIGITIZED

+0390 +0136                 11U20
```

FIG. 9 DIAGNOSTIC FOR SIGNAL-ROUTE MISMATCHING

Paper tape to magnetic tape conversion and v.v. is a fast and simple method of filing final data. The Tektronix unit is a cheap and fast device for verifying final punched paper tapes before driving the photo-plotter.
As far as cost and performance are concerned, these depend largely on one side from the type of organization, (country, wages, salaries, overheads, etc.) and on the other from the type of p.c. boards (size, component density, technology, etc.) produced.
In order to fix some data, let us consider one of our standard boards :

- sizes : 6x8 inches
- components : max 40 I.C. s plus some discrete ones
- connectors : 2
- I/O pins : 86+44
- component density : ≃ 1 I.C. per square inch

Results after six months of operation :

Through put (from a correct coding of the schematic to the final N/C tapes) : 1 board per shift per system.

Cost reduction : (schematic coding excluded) 50%
(schematic coding included) 30%.

Turn-around time reduction : (schematic coding included) 50%.

Payback period : (in our case) approximately corresponding to 250 boards.

Data shown in figure 10 are also interesting. It can be seen that the percentage of creative work, by use of the system, has increased from about 30% to 45% (schematic coding included) and to 60% (schematic coding excluded).

Personnel : the first operators were the draftsmen, of course, but we have since also trained skilled workers with satisfactory results. The system has been generally well-accepted. Some slight modifications were requested by the operators and added to the system.

Apart from the schematic coding, produced off-line by a special group of people, the whole system is handled by the operator, who has been trained to load the programs and to run the minicomputer. This fact, together with the possibility of seeing the results (through the TEKTRONIX display) are, according to the operators, two of the main reasons for job safisfaction.

CONCLUSION

A complete system for the generation of P.C.B. production documentation has been presented.

The system comprises a digitizer linked directly to the memory of a minicomputer, and offers, as a main advantage, fast detection and easily-made corrections of any errors and mistakes occurring during the working process in the drawing department. The flexibility and ease of operation in addition the low cost of the required equipment, allow purchase and exploitation also by small organizations.

	INSPECTION	CREATIVE	COPYING	TRAVELLING	TOTAL
MANUAL	33	30	32	5	100
DIGITIZER WITH CHECK	13 (10)	61 (45)	22 (36)	4 (9)	100

Figures in hours

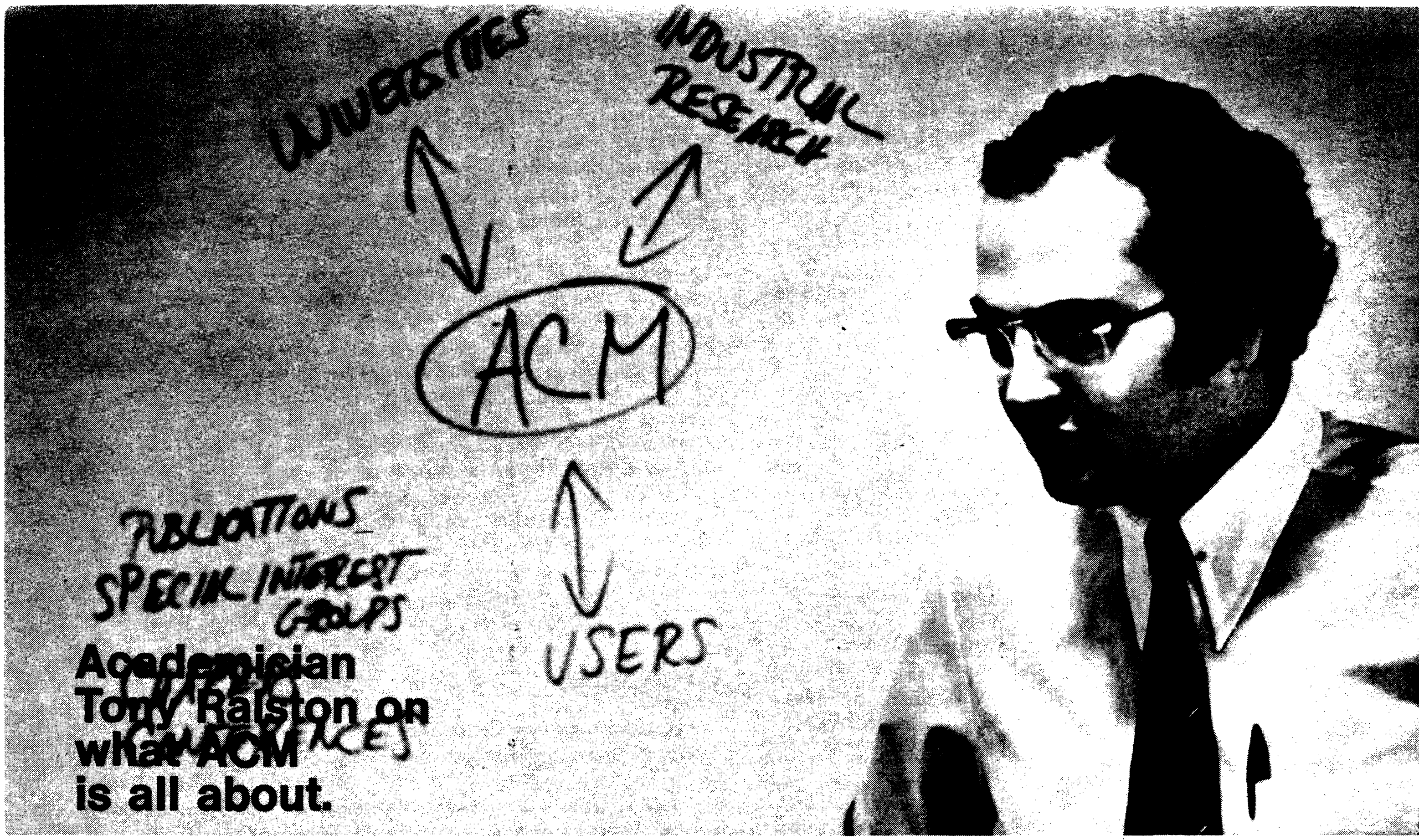
Figures in (-) if schematics coding is excluded

	INSPECTION	CREATIVE	COPYING	TRAVELLING	TOTAL
MANUAL	45	12	31	12	100
DIGITIZER WITH CHECK	27 (18)	36 (24)	27 (53)	10 (5)	100

Figures in days

Figures in (-) if schematics coding is excluded

Fig. 10. PERCENTAGES OF THE WORKING PROCESS PER DESIGN PHASES



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