EUR 5285 e

COMMISSION OF THE EUROPEAN COMMUNITIES

AN INTERACTIVE SYSTEM FOR THE AUTOMATIC LAYOUT OF PRINTED CIRCUIT BOARDS (ARAIGNEE)

by

M. COMBET, J. EDER, C. PAGNY

1974

Joint Nuclear Research Centre
Ispra Establishment — Italy

Technology Division

This report is on sale at the addresses listed on cover page 4

at the price of B.Fr. 120.—

Commission of the
European Communities
D.G. XIII - Scientific and Technical Information
and Information Management
29, rue Aldringen
L u x e m b o u r g

December 1974

EUR 5285 e

AN INTERACTIVE SYSTEM FOR THE AUTOMATIC LAYOUT OF PRINTED CIRCUIT BOARDS (ARAIGNEE)
by M. COMBET, J. EDER, C. PAGNY

Commission of the European Communities
Joint Nuclear Research Centre - Ispra Establishment (Italy)
Technology Division
Luxembourg, December 1974 - 34 Pages - 11 Figures - B.Fr. 120.—

A software package for the automatic layout of printed circuit boards is presented here. The programme permits an interaction of the user during the layout process. The automatic searching of paths can be interrupted at any step and convenient corrections can be inserted.

This procedure improves strongly the performance of the programme as far as the number of unresolved connections is concerned.

EUR 5285 e

AN INTERACTIVE SYSTEM FOR THE AUTOMATIC LAYOUT OF PRINTED CIRCUIT BOARDS (ARAIGNEE)
by M. COMBET, J. EDER, C. PAGNY

Commission of the European Communities
Joint Nuclear Research Centre - Ispra Establishment (Italy)
Technology Division
Luxembourg, December 1974 - 34 Pages - 11 Figures - B.Fr. 120.—

A software package for the automatic layout of printed circuit boards is presented here. The programme permits an interaction of the user during the layout process. The automatic searching of paths can be interrupted at any step and convenient corrections can be inserted.

This procedure improves strongly the performance of the programme as far as the number of unresolved connections is concerned.

EUR 5285 e

AN INTERACTIVE SYSTEM FOR THE AUTOMATIC LAYOUT OF PRINTED CIRCUIT BOARDS (ARAIGNEE)
by M. COMBET, J. EDER, C. PAGNY

Commission of the European Communities
Joint Nuclear Research Centre - Ispra Establishment (Italy)
Technology Division
Luxembourg, December 1974 - 34 Pages - 11 Figures - B.Fr. 120.—

A software package for the automatic layout of printed circuit boards is presented here. The programme permits an interaction of the user during the layout process. The automatic searching of paths can be interrupted at any step and convenient corrections can be inserted.

This procedure improves strongly the performance of the programme as far as the number of unresolved connections is concerned.

EUR 5285 e

COMMISSION OF THE EUROPEAN COMMUNITIES

AN INTERACTIVE SYSTEM FOR THE AUTOMATIC LAYOUT OF PRINTED CIRCUIT BOARDS (ARAIGNEE)

by

M. COMBET, J. EDER, C. PAGNY

1974

Joint Nuclear Research Centre
Ispra Establishment — Italy

Technology Division

ABSTRACT

A software package for the automatic layout of printed circuit boards is presented here. The programme permits an interaction of the user during the layout process. The automatic searching of paths can be interrupted at any step and convenient corrections can be inserted.

This procedure improves strongly the performance of the programme as far as the number of unresolved connections is concerned.

CONTENTS

AN INTERACTIVE SYSTEM FOR THE AUTOMATIC LAYOUT OF PRINTED CIRCUIT BOARDS (ARAIGNEE)

1. INTRODUCTION

One of the most time consuming jobs during the production of printed circuit boards is the preparation of the artwork. The layout of a board of medium size requires days or even weeks of concentrated work of a skilled draftsman. Time delays caused by the layout work are the bottleneck during the development of any kind of digital circuits.

Computer aided design is a powerful tool for reducing such efforts. However, to be useful, the system must be designed with a feasible man-machine interface which permits a simplified communication between operator and computer.

Based on the UCARDS[1] code a software package has been prepared which in its first version presented here permits a certain degree of conversation, e.g. the operator may interrupt the automatic searching of paths between components at any step, he may insert a convenient correction by means of an adequate statement (see below) and then continue the operation. This procedure can improve strongly the performance of the programme as far as the number of unresolved path-connections is concerned.

An example given in this report shows that a number of 22 paths not found by the programme in one run, is reduced to 7 with only one manual intervention.

2. IMPROVEMENT OF THE UCARD's PROGRAMME

The UCARD's programme - the only one available at Ispra - was developed in 1968. Therefore it does not contain in its component library complex elements like small and largescale integrated circuits etc. Furthermore, it does not respect modern circuit techniques like power supply busses and so on.

For these reasons a number of new commands have been inserted in the UCARD's vocabulary (it is supposed that the reader is familiar with the UCARD's language definition given in (1)):

INTEGRATED	- insertion of integrated circuits described with a minimum number of parameters
BUS	- insertion or deletion of paths with multiple connections
CALCOMP	- programme interface to the CALCOMP-plotter
STOP	- interruption of the programme execution after a predefined path number.

For the ROUTER-routine a new algorithm is applied which searches and selects the shortest connections. A new procedure called DYNAMIC UPDATING takes care of the handling of the STOP command, the updating and the correct restart of the programme.
In order to simplify the manipulation of data sets, the PSQ-facilities are used. A description of the control cards for the execution of ARAIGNEE and for the modification of the PSQ data sets will be given later on.

A number of errors found in the original UCARD's code have been

corrected, amongst them trivial errors like misprintings as XIØ against X10 and incompatibilities with library programmes. (IABS was replaced by LABS which calculates the absolute value for I*2 variables). A more serious error existed in the ORDER2-routine, where two statements (ORDE0046 and ORDE0055) were inverted).
In the COMPIL routine, the range of the pointer of the NSERT table was not limited, causing troubles with overflow.

3. SUBROUTINE ROUTER

The path-finding routine ROUTER is based now on an algorithm which is capable of doing the following:

- if more points have to be connected within one path, ROUTER calculates the distances and chooses the shortest path;
- every time a point must be connected with the I/O strip according to the "Arbitrary Nodes"-method, ROUTER selects the nearest point from the I/O strip;
- among all the connections "Arbitrary Nodes" to be realised, ROUTER selects the shortest first.

4. COMMAND STATEMENTS INTEGRATED, BUS

Format of the command:

$$\text{INTEGRATED/name,} \left\{ \begin{matrix} \text{T} \\ \text{B} \end{matrix} \right\} \text{, name of nodes, I, J, IDISP, INC, JNC}$$

where I, J are the coordinates of pin number 1

IDISP is a parameter defining one of four positions (see Fig. 1)

= 1 pin 1 left side, up

= 2 pin 1 left side, down

= 3 pin 1 right side, down

= 4 pin 1 right side, up

INC is the number of grid cells separating two adjacent pins (e. g. pin 1 and pin 2)

JNC is the number of grid cells separating two opposite pins (e. g. pin 1 and pin 14, resp. 16).

This statement which defines type and position of an integrated circuit is handled likewise as any other component descriptor.
The translating algorithm consists of two parts:

- analysis of the statement's parameters,
- calculation of all pin coordinates and insertion in the IDATA-vector of the general UCARD's component descriptor.

With the extensive use of integrated circuits a more convenient way to insert and delete paths became necessary than the commands INSERT PATH and DELETE PATH rendered possible. This will be shown in the following example:

The insertion of the path Nr. 64 represented in Fig. 2 requires the following UCARD command:

```
INSERT  PATH / T, 64.,20,3,17,3,T,64.,17,3,17,5,
               T,64.,17,5,13,5,T,64.,13,5,13,8,T,64.,13,8,10,8,
               T,64.,10,8,10,10
```

With the newly created BUS command all the redundant information may be omitted, thus

```
BUS / T, 64.,20,3,17,3,17,5,13,5,13,8,10,8,10,10
```

The improvement is obvious.

A further example concerning path Nr. 500, a typical line bus, is presented in Fig. 2:

BUS / T, 500., 20, 15, 17, 12, 13, 18, 10, 12, 7, 18, 3, 15, 5, 12, 1, 10, 5, 8, 1, 5,
3, 2, 5, 4, 8, 4, 8, 2

would be very difficult to translate into INSERT PATH statement.
If the points are written in the right order (e.g. the points X, Y, Z, V must be written within A(20, 15) and B(3, 15)), all segments are automatically and correctly generated by the routine COMPIL.

The BUS command can be used for deleting a complex path, too. In this case the path to be deleted is described in the same way as shown above but the path number must be absent. (E.g. to delete path Nr. 64, write

BUS / T, 20, 3, 17, 3, 17, 5, 13, 5, 13, 8, 10, 8, 10, 10)

5. DYNAMIC UPDATING

The UCARD system in its original version was conceived only for integral processing of layout jobs. No interaction during a run of the programme was possible.

With the introduction of integrated circuit packages this method showed serious drawbacks. As shown in Fig. 3, due to the in-line configuration of the IC-pins a path found by the UCARD strategy very easily surrounds a number of pins. Connections referring to these pins will be very difficult to realise and the probability of unresolvable connections will rise considerably.
With the original UCARD procedure the only remedy was to delete those disturbing paths and insert others after the complete processing.
In order to overcome these inconveniences, the dynamic updating was introduced. This method allows to stop the processing at any user-predefined level (path number), to correct the layout conveniently, deleting and inserting paths and to restart the programme from the point where it was interrupted.
The programme interrupt may be provoked by the user with the command

STOP / n

where n is an integer number defining the path number at which the interrupt shall occur.
If n=0 only updating will occur (searching of new paths is inhibited).

The following example presents a typical sequence of commands for multiple programme interrupts: (see also Figs. 9 and 10)

circuit descriptors
FILE / 1
ROUTE /
STOP / 64
EXIT /

The process will stop when encountering path numbers ≧ 64. The actual information will be stored in FILE 1 and can be retrieved at restart with the statement SEARCH / file number. Updatings can now be executed e.g. with the commands:

SEARCH / 1
UPDATE /
BUS / (inserting or deleting paths)
INSERT HØLE / ...
DELET HØLE / ...
RESTART / 1
STØP/ 75
EXIT /

The process is now interrupted at path number ≧ 75 and may be restarted in the same manner. If no further interrupt is desired, the following sequence may be used to obtain a draft at the CALCOMP:

RESTART / 1
CALCØMP /
DRAFT /
EXIT /

6. PROGRAMME HANDLING BY MEANS OF PSQ

The manipulating of this 11000 cards containing programme is greatly facilitated by the use of the PSQ-system (see (2)).

For the normal execution of a layout job a standard deck with PSQ control cards has been prepared (Fig. 4). The user only has to insert the cards containing the parameters of its problem in the UCARD's language (see sample programme Figs. 9, 10).
A second deck of PSQ control cards is available for the case where temporary modifications of certain routines (in FORTRAN or in Assembler) are desired (Fig. 5). No permanent changement of the ARAIGNEE-code takes place.

If the ARAIGNEE data set has to be modified, the procedure shown in Fig. 6 can be applied.

7. SAMPLE PROGRAMME

Figs. 7 and 8 show the results for a practical layout problem, and Fig. 9 gives the respective input parameters.
Fig. 7 has been elaborated in one programme run without interventions by the operator. 17 connections could not be made by the programme.

Fig. 8 shows the same circuit. The programme was interrupted after path 69 and a correction of a number of connections was made (12 lines deleted and 14 new inserted, the parameter list for the corrections is given in Fig. 11).

After restart the programme was run without further interventions. Only 7 connections are still unresolved and have to be added by means of adequate statements.

8. ANNEX

Flow charts concerning the modifications of the original UCARD routines are given in the annex.

BIBLIOGRAPHY

(1) J.F. JAMISON; "Union Carbide Automatic Routing and Design System for printed circuit boards", Union Carbide - Rep. Nr. K 1736 CTC-4

(2) G. BUCCARI, C. DAOLIO, C. PIGNI, J. PIRE; "Sistema PSQ e file editor".

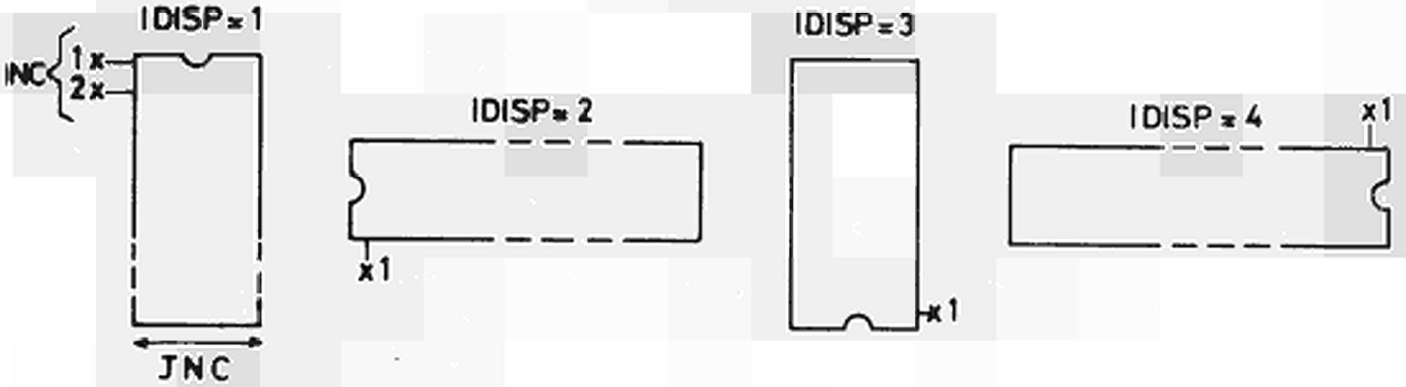


Fig. 1 - ORIENTATION OF INTEGRATED CIRCUIT PACKAGES

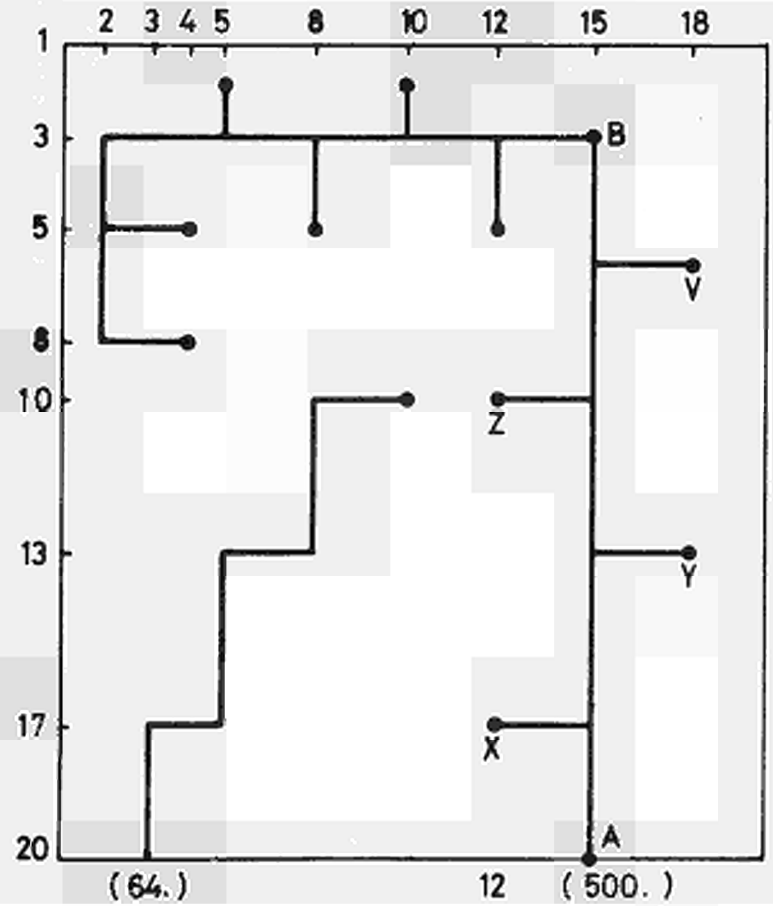


Fig. 2 - BUS CONNECTIONS

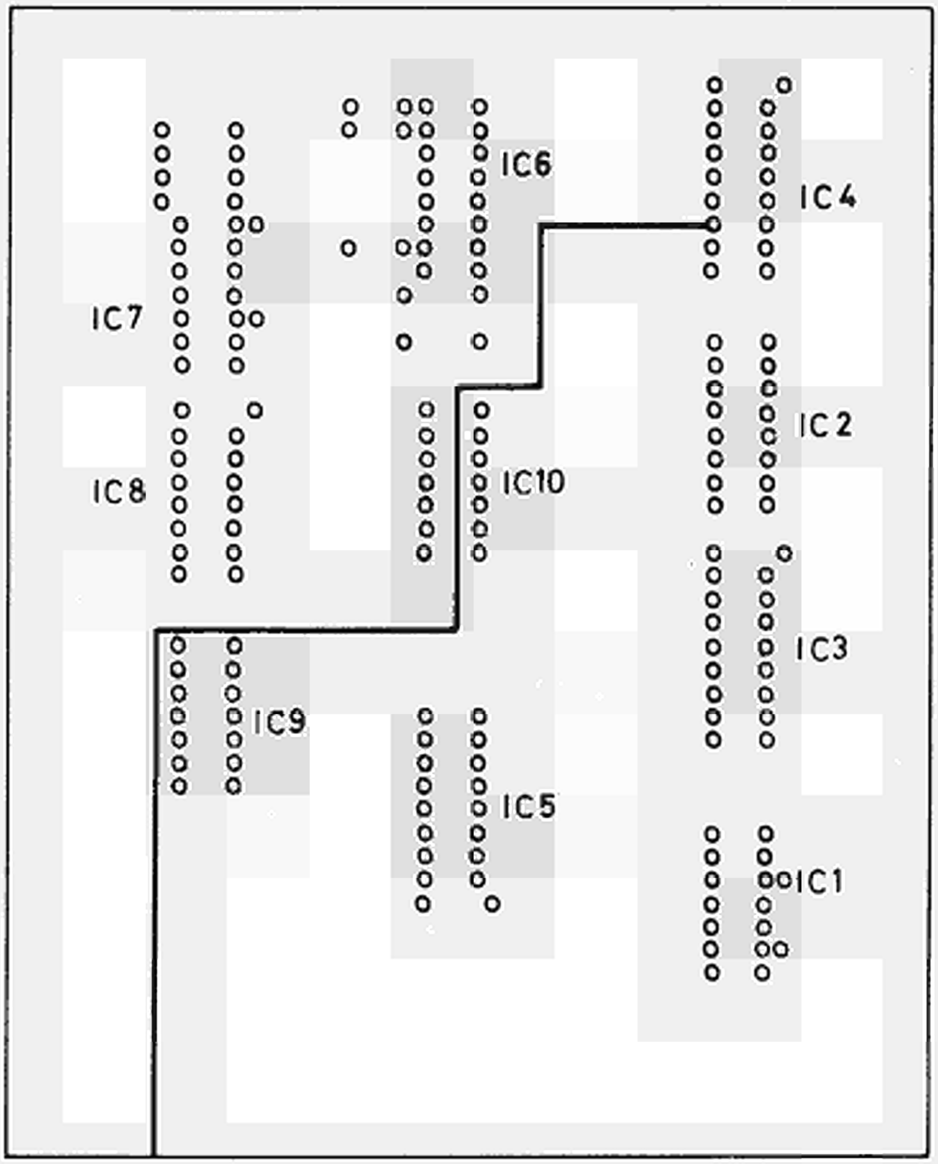


Fig. 3 - PATHS SURROUNDING IC-PINS

Fig. 4 - EXECUTION OF ARAIGNEE WITHOUT MODIFICATION

```
//       EXEC    PSQ
// FT02F001  DD  UNIT=SYSSQ, DSN=&A, DISP=(NEW, PASS), DCB=(RECFM=FB,
//          LRECL=80, BLKSIZE=800), SPACE=(CYL, (5, 1))
//GO. SYSIN  DD *
$OPEN, XXXXARAIGNEE
$TO=02
$F
$E
/*
//       EXEC   FTLG, OV=OVLY
//LKED. SYSIN  DD  DSN=&A, DISP=(OLD, DELETE, DELETE), UNIT=SYSSQ
/*
//GO. FT17F001  DD  UNIT=SYSSQ, DCB=(BLKSIZE=1200, RECFM=VS),
//       SPACE=(CYL, (2, 1))

     Same for FT17F002   FT17F003   FT17F004 ..... FT17F012
     Same for FT40F001   FT42F001   FT43F001 ..... FT50F001

//GO. FT41F001   DD   UNIT=3330, DSN=name of cylinder, VOL=SER=USER01,
//       DISP=OLD
//GO. FT16F001   DD   DUMMY (IF CALCOMP is not requested)
//GO. SYSUDUMP DD   SYSOUT=A
//GO. SYSIN      DD   *

     Programme statements
/*
```

If CALCOMP is requested, the DD cards definition must be:

```
//GO. FT16F001   DD   UNIT=TP9, VOLUME=(PRIVATE, SER=EU3068),
//          LABEL=(, , , OUT), DSNAME=Name,
//          DCB=(RECFM=VS, BLKSIZE=488, LRECL=484, DEN=2)
```

Programme size 300 Kbytes

Fig. 5 - EXECUTION OF ARAIGNEE WITH TEMPORARY MODIFICATIONS OF ROUTINES WRITTEN IN FORTRAN AND/OR ASSEMBLER

```
//      EXEC    PSQ
//FT02F001  DD  UNIT=SYSSQ, DSN=&A, DISP=(NEW, PASS), DCB=(RECFM=FB,
//          LRECL=80, BLKSIZE=800), SPACE=(CYL, (5, 1))
//GO.SYSIN  DD  *
$OPEN, XXXXARAIGNEE
$TO=02
$F
$E
/*
//      EXEC   FTGC
//CMP.SYSIN  DD  *

      Fortran routines

/*
//      EXEC   AHC
//CMP.SYSGO  DD  DSN=&LOADSET, DISP=(MOD, PASS, DELETE),
//      UNIT=SYSSQ, SPACE=(CYL, (3, 1), RLSE), DCB=(BLKSIZE=800)
//CMP.SYSIN  DD  *

      Assembler routines

/*
//     EXEC  FTLG, OV=OVLY
//LKED.SYSIN  DD  DSN=&LOADSET, DISP=(OLD, DELETE, DELETE),
//     UNIT=SYSSQ
//            DD DSN=&A, DISP=(OLD, DELETE, DELETE), UNIT=SYSSQ
//            DD * } (Only if overlay is not on PSQ file)
         overlay }
//GO.FT17F001  DD  UNIT=SYSSQ, DCB=(BLKSIZE=1200, RECFM=VS),
//     SPACE=(CYL, (2, 1))
```

The following cards are identical to the preceeding page

Programme size 300 Kbytes

Fig. 6 - MODIFICATION OF THE ROUTINES OF A PSQ DATA SET

COMPILATION AND CORRECTION OF BINARY DATA SET

```
//     EXEC    PSQ
//GO.FT01F001  DD  DSN=&DSFOR,DISP=(NEW,PASS,DELETE),UNIT=SYSSQ,
//     SPACE=(CYL,(1,1)),DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
//GO.FT02F001  DD  DSN=&DSASS,DISP=(NEW,PASS,DELETE),UNIT=SYSSQ,
//     SPACE=(CYL,(1,1)),DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
//GO.SYSIN  DD  *
$OPEN,XXXXFORTRAN              $UPDATE,XXXXFORTRAN
$TO=01                         $TO=01
$F                             $D,..............
$E                               corrections
                               $F
                               $E
$OPEN,XXXXASSEMBL              $UPDATE,XXXXASSEMBL
$TO=02                         $TO=02
$F                             $D,..............
$E                               corrections
                               $F
                               $E
/*
//     EXEC    FTGC
//CMP.SYSIN  DD  DSN=&DSFOR,DISP=(OLD,DELETE,DELETE),UNIT=SYSSQ
/*
//     EXEC    AHC
//CMP.SYSGO  DD  DSN=&LOADSET,DISP=(MOD,PASS,DELETE),UNIT=SYSSQ,
//     SPACE=(CYL,(3,1),RLSE),DCB=(BLKSIZE=800)
//CMP.SYSIN  DD  DSN=&DSASS,DISP=(OLD,DELETE,DELETE),UNIT=SYSSQ
/*
//     EXEC    PSQ
//GO.FT02F001  DD  DSN=&LOADSET,DISP=(OLD,DELETE,DELETE),
//     UNIT=SYSSQ,DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
//GO.SYSIN  DD  *
$GENERATE,XXXXARAIGNEE         $UPDATE,XXXXARAIGNEE
$PY                            $PY
$TI=03                         $TI=03
$F                             $F

     overlay                     overlay
$E                             $E
/*                             /*
```

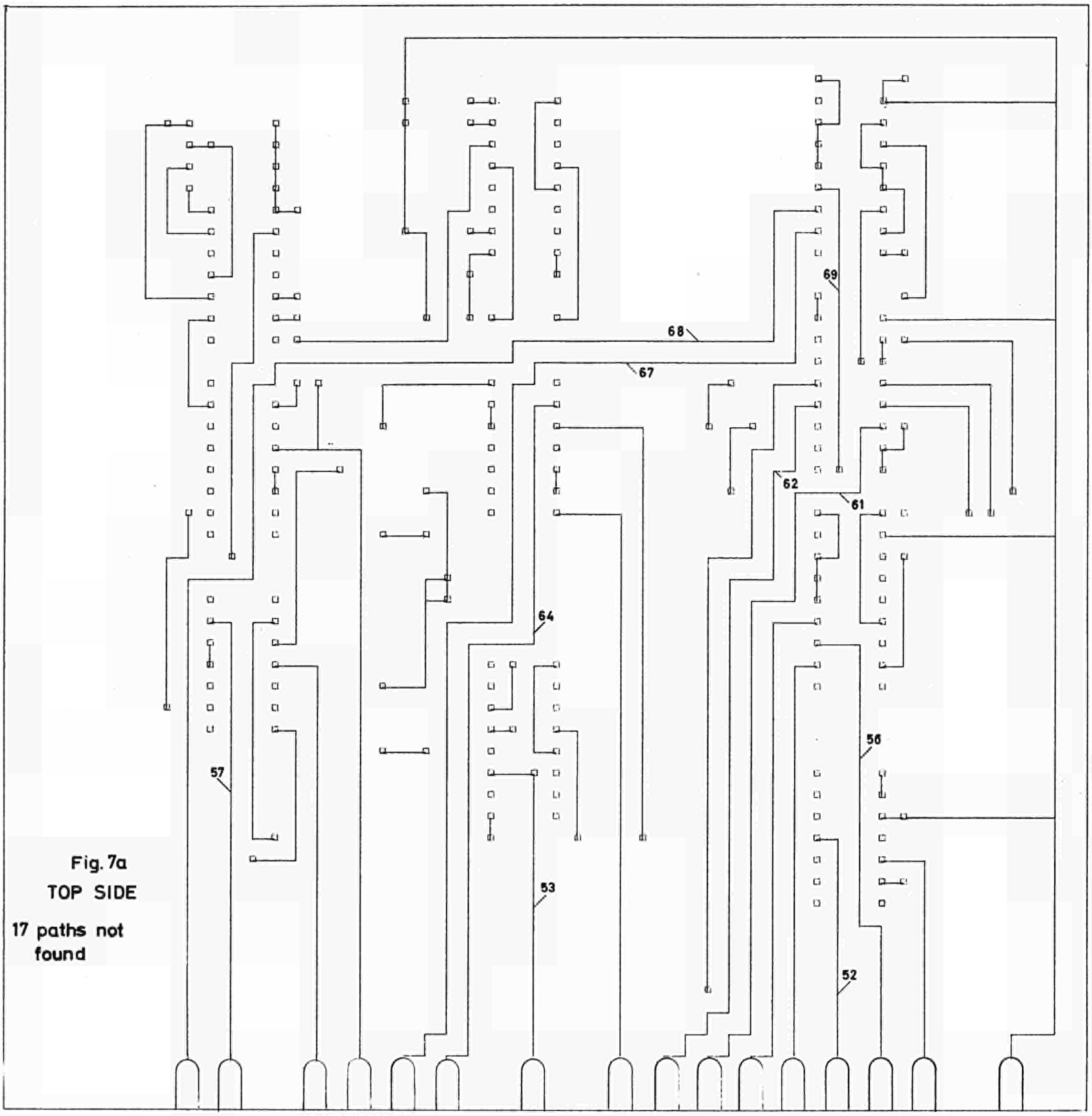


Fig. 7a
TOP SIDE
17 paths not found

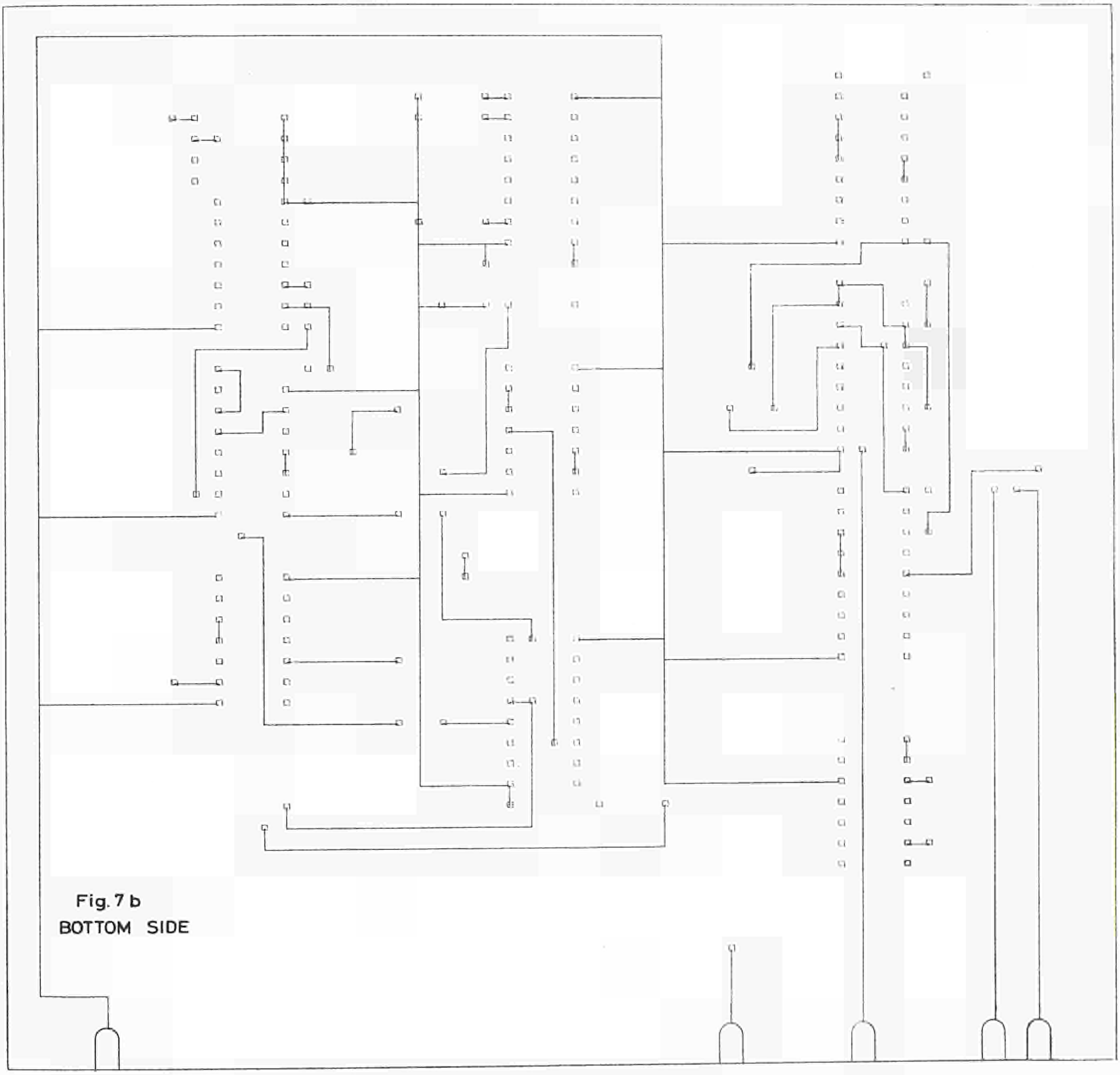
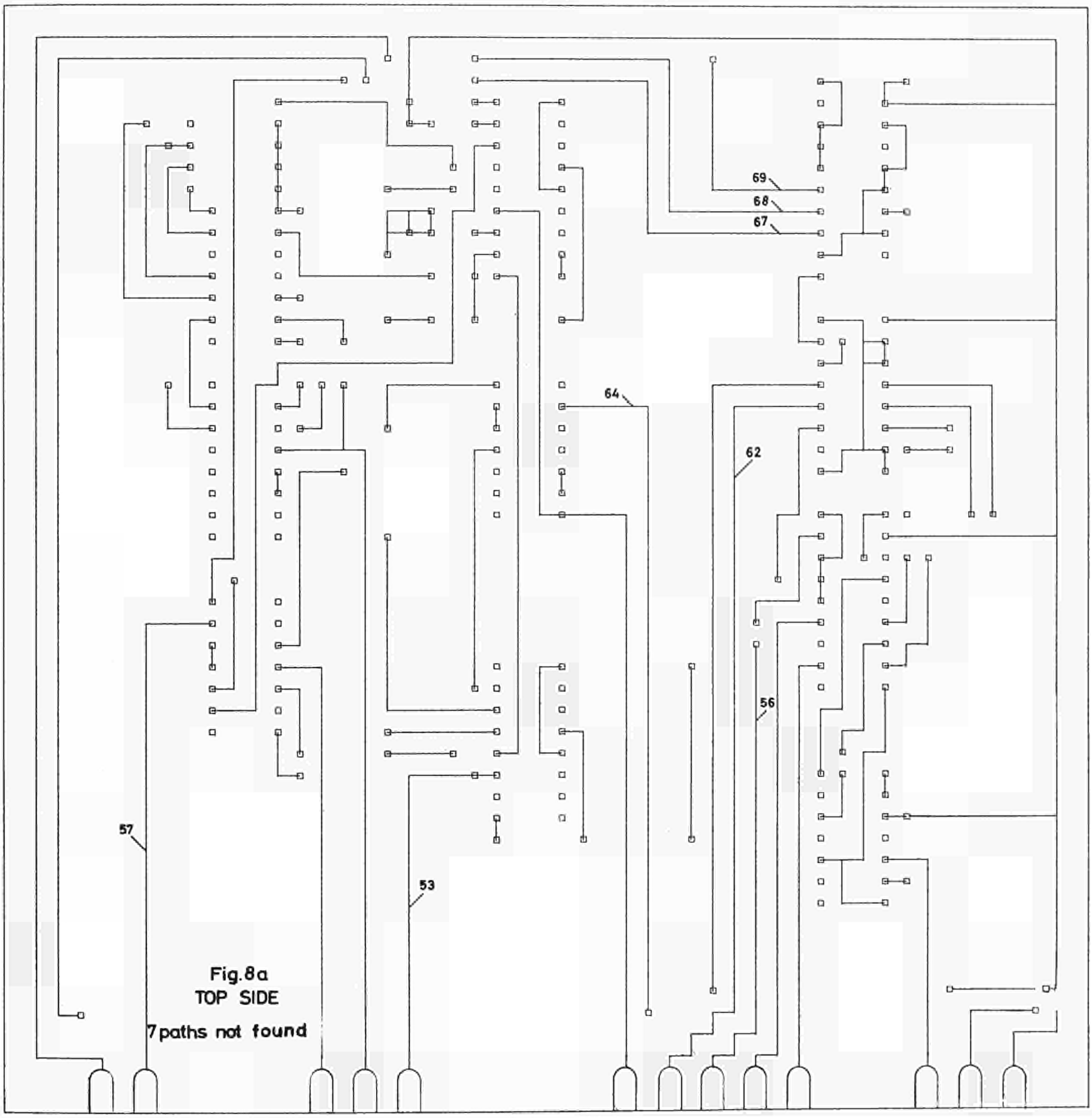


Fig. 7 b
BOTTOM SIDE

```
THE FOLLOWING CONNECTIONS COULD NOT BE MADE
IC1      1 TO IC1     12          HNET=  0.0TNET=10.0
IC1     12 TO IC3      9          HNET=  0.0TNET=10.0
IC1      7 TO IC1     10          HNET=  0.0TNET=10.0
IC1      8 TO IC3     14          HNET=  0.0TNET=10.0
IC1      9 TO IC3     11          HNET=  0.0TNET=10.0
IC1     11 TO IC3      1          HNET=  0.0TNET=10.0
IC2      6 TO IC3     13          HNET=  0.0TNET=10.0
IC2      7 TO IC3     15          HNET=  0.0TNET=10.0
IC3     15 TO IC4      1          HNET=  0.0TNET=10.0
IC3     16 TO R2       2          HNET=  0.0TNET=10.0
IC4      8 TO IC4     10          HNET=  0.0TNET=10.0
IC6     13 TO IC9      1          HNET=  0.0TNET=10.0
IC6     14 TO IC10     1          HNET=  0.0TNET=10.0
IC8      1 TO IC9      5          HNET=  0.0TNET=10.0
IC7      8 TO IC8      9          HNET=  0.0TNET=10.0
IC7     12 TO IC9      2          HNET=  0.0TNET=10.0
IC9      9 TO IC10     4          HNET=  0.0TNET=10.0
```

Fig.7c


69
68
67
64
62
56
57
53
Fig.8a
TOP SIDE
7 paths not found

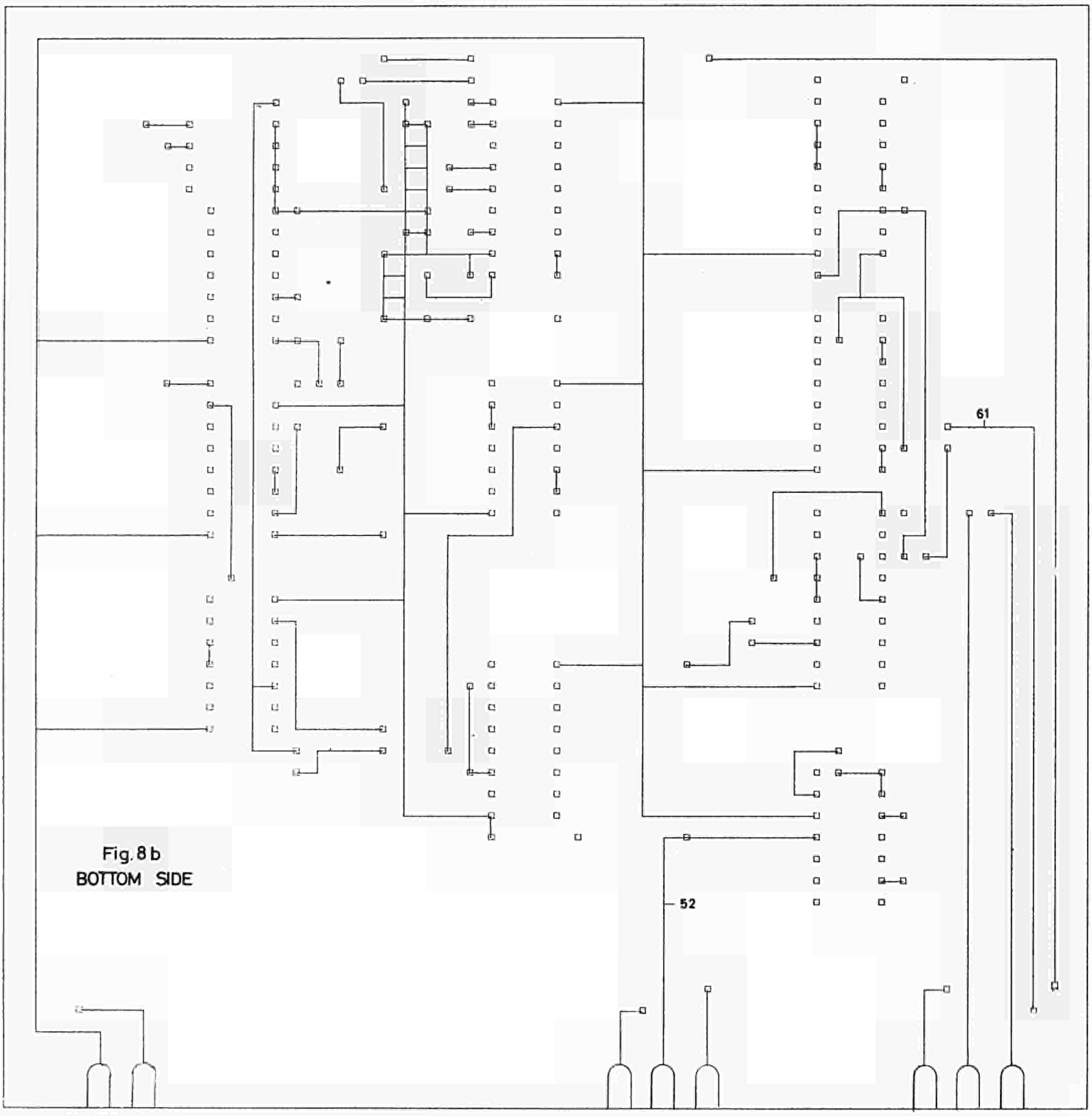


Fig. 8 b
BOTTOM SIDE

```
THE FOLLOWING CONNECTIONS COULD NOT BE MADE
IC3     13 TO IC4    14        HNET= 0.0TNET=10.0
IC2      7 TO IC3    15        HNET= 0.0TNET=10.0
IC3     15 TO IC4     1        HNET= 0.0TNET=10.0
IC3     16 TO R2      2        HNET= 0.0TNET=10.0
IC7     12 TO IC9     2        HNET= 0.0TNET=10.0
IC8      3 TO IC8    13        HNET= 0.0TNET=10.0
IC9      9 TO IC10    4        HNET= 0.0TNET=10.0
```

Fig. 8c

THE FOLLOWING IS A LIST OF DATA INPUT

```
TITLE/    INTEGRATED CIRCUITS
FILE / 1
GRID SIZE/50,50
CELL SIZE/.1
IO HEIGHT/.1
FRAME /50.,0.,0.,0.,0.,51.,50.,51.
IO STRIP/1.5,1.5,2 ,1.,22
FAILURE LIMIT/99
SCALE/0.5
PUNCH OPTION/OFF
PREDEFINE/
BUS/B,500.,50,5,48,5,48,2,34,9 ,25,9 ,16,9 ,2,2,2,30,5,27,12,37,              CONT
           18,27,22,37,31,27,32,37,38,37,38,30
BUS/T,501.,50,47,48,47,48,49,38,43,25,42,15,42,5,42,2,49,2,19,5,19
BUS/B,501.,5,19,10,14,12,22,19,14,24,22,28,14,38,22,38,19
ARBITRARYNOD/3,9,11,12,13,16,17,23,24,25,37,48,60,58,71,74,30,31,32
DEFINE/
ONE SIDED IO/BS,B,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,                    CONT
           50,7,50,9,50,11,50,13,50,15,50,17,50,19,50,21,50,23,50,25,         CONT
           50,27,50,29,50,31,50,33,50,35,50,37,50,39,50,41,50,43,50,45,50,47
ONE SIDED IO/TS,T,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,                    CONT
           50,5,50,7,50,9,50,11,50,13,50,15,50,17,50,19,50,21,50,23,50,25,    CONT
           50,27,50,29,50,31,50,33,50,35,50,37,50,39,50,41,50,43,50,45
INTEGRATED/IC1,T,1,2,3,80,5,6,6,7,8,6,9,1,81,4,                       42,41,3,1,3
INTEGRATED/IC2,T,10,14,15,16,17,18,19,10,10,10,11,12,13,10,10,20,     15,38,1,1,3
INTEGRATED/IC3,T,9,22,22,22,23,24,25,25,1,15,8,14,18,7,19,21,         25,38,1,1,3
INTEGRATED/IC4,T,19,29,29,29,30,31,32,27,15,27,14,27,27,18,27,28,      5,38,1,1,3
INTEGRATED/IC5,T,82,83,84,33,39,85,86,33,87,88,34,35,36,37,89,38,     38,26,3,1,3
INTEGRATED/IC6,T,40,90,91,41,42,92,93,41,43,44,45,46,47,48,49,50,     12,26,3,1,3
INTEGRATED/IC7,T,51,52,94,53,54,55,56,57,58,59,95,60,36,61,           10,10,1,1,3
INTEGRATED/IC8,T,55,62,63,96,97,98,65,34,57,64,64,58,63,66,           19,10,1,1,3
INTEGRATED/IC9,T,47,60,67,67,55,45,75,70,59,46,74,73,35,77,           28,10,1,1,3
INTEGRATED/IC10,T,48,68,68,69,70,71,76,73,72,72,37,99,100,78,         24,26,3,1,3
RESISTOR/R1,T,2,5,41,42,38,42
RESISTOR/R2,T,22,21,24,38,24,42
RESISTOR/R3,T,29,28,4,38,4,42
RESISTOR/R4,T,39,38,39,27,39,23
RESISTOR/R6,T,42,50,15,26,15,22
RESISTOR/R7,T,43,50,5,22,5,19
RESISTOR/R8,T,44,50,6,22,6,19
RESISTOR/R9,T,49,50,11,22,11,19
RESISTOR/R11,T,52,61,8,9,8,13
RESISTOR/R5,T,62,66,18,10,18,14
RESISTOR/R10,T,51,61,9,9,9,13
RESISTOR/R12,T,53,61,7,9,7,13
RESISTOR/R13,T,54,61,6,9,6,13
RESISTOR/R14,T,59,61,14,14,10,14
RESISTOR/R15,T,60,50,13,26,13,22
ROUTE/
DRAFT/
STOP/69
EXIT/
```

Fig. 9 - INPUT PARAMETERS FOR SAMBLE LAYOOT

```
UPDATE/
BUS/T,39,39,50,39
BUS/T,36,23,36,25,50,25
BUS/T,30,39,30,40,43,40,43,41,50,41
BUS/T,29,10,29,11,50,11
BUS/T,20,40,23,40,23,37,28,37,28,35,48,35,48,34,49,34,49,33,50,33
BUS/T,19,37,22,37,22,36,27,36,27,34
BUS/T,19,25,30,25,30,22,49,22,49,21,50,21
BUS/T,18,38,18,36,21,36,21,35,26,35,26,33
BUS/T,11,37,17,37,17,25,18,25,18,24,29,24,29,21,48,21,48,20,49,20,49,19,     CONT
                    50,19
BUS/T,10,38,10,36,16,36,16,24,17,24,17,13,18,13,18,12,27,12,27,9,50,9
BUS/T,9,39,22,39
BUS/B,22,39,50,39
BUS/B,52.,39,38,39,31,50,31
BUS/T,53.,36,23,36,19,50,19
BUS/B,56.,30,38,30,35
BUS/T,56.,30,35,48,35,48,34,49,34,49,33,50,33
BUS/T,57.,29,10,29,7,50,7
BUS/T,61.,20,41,20,44
BUS/B,61.,20,44,20,48,47,48
BUS/T,61.,47,48,47,45,50,45
BUS/T,62.,19,37,19,34,30,34
BUS/T,64.,19,26,19,30,47,30
BUS/B,64.,47,30,47,29,50,29
BUS/T,65.,18,38,18,33,30,33
BUS/T,67.,11,38,11,30,4,30,4,22
BUS/B,67.,4,22,4,17
BUS/T,67.,4,17,3,17,3,3,47,3,47,4
BUS/B,67.,47,4,47,7,50,7
BUS/T,68.,10,38,10,31,3,31,3,22
BUS/B,68.,3,22,3,18
BUS/T,68.,3,18,2,18,2,2,49,2,49,5,50,5
BUS/T,69.,9,38,9,33,3,33
BUS/B,69.,3,33,3,49,46,49
BUS/T,69.,46,49,46,44
BUS/B,69.,46,44,46,43,50,43
DELETE HOLE/22,39
INSERTHOLE/30,35,20,44,47,48,47,30,4,22,4,17,47,4,3,22,3,18,3,33,46,49,46,44
RESTART/1
DRAFT /
EXIT /
```

Fig. 10 UPDATED PARAMETERS

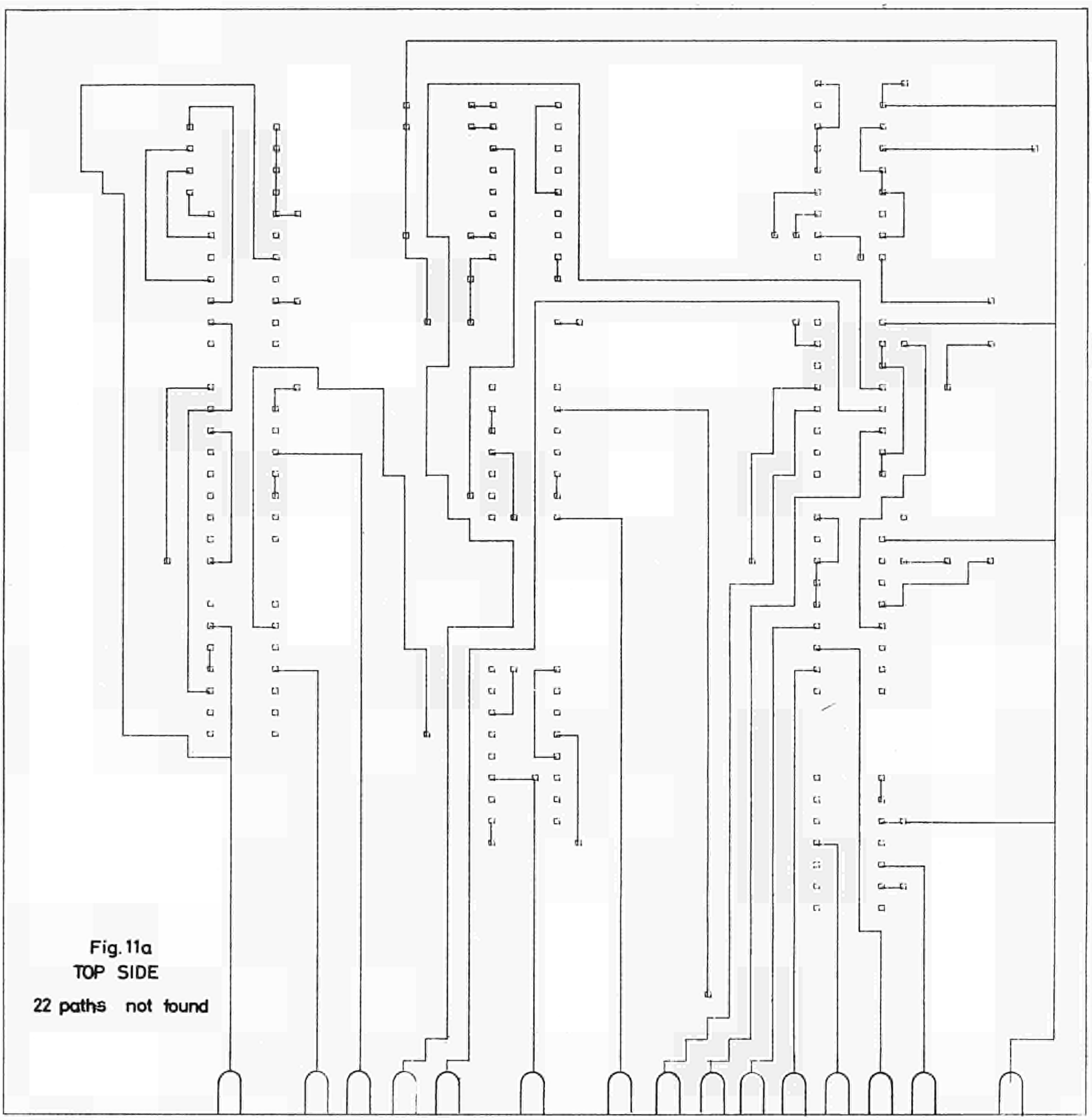


Fig. 11a
TOP SIDE
22 paths not found

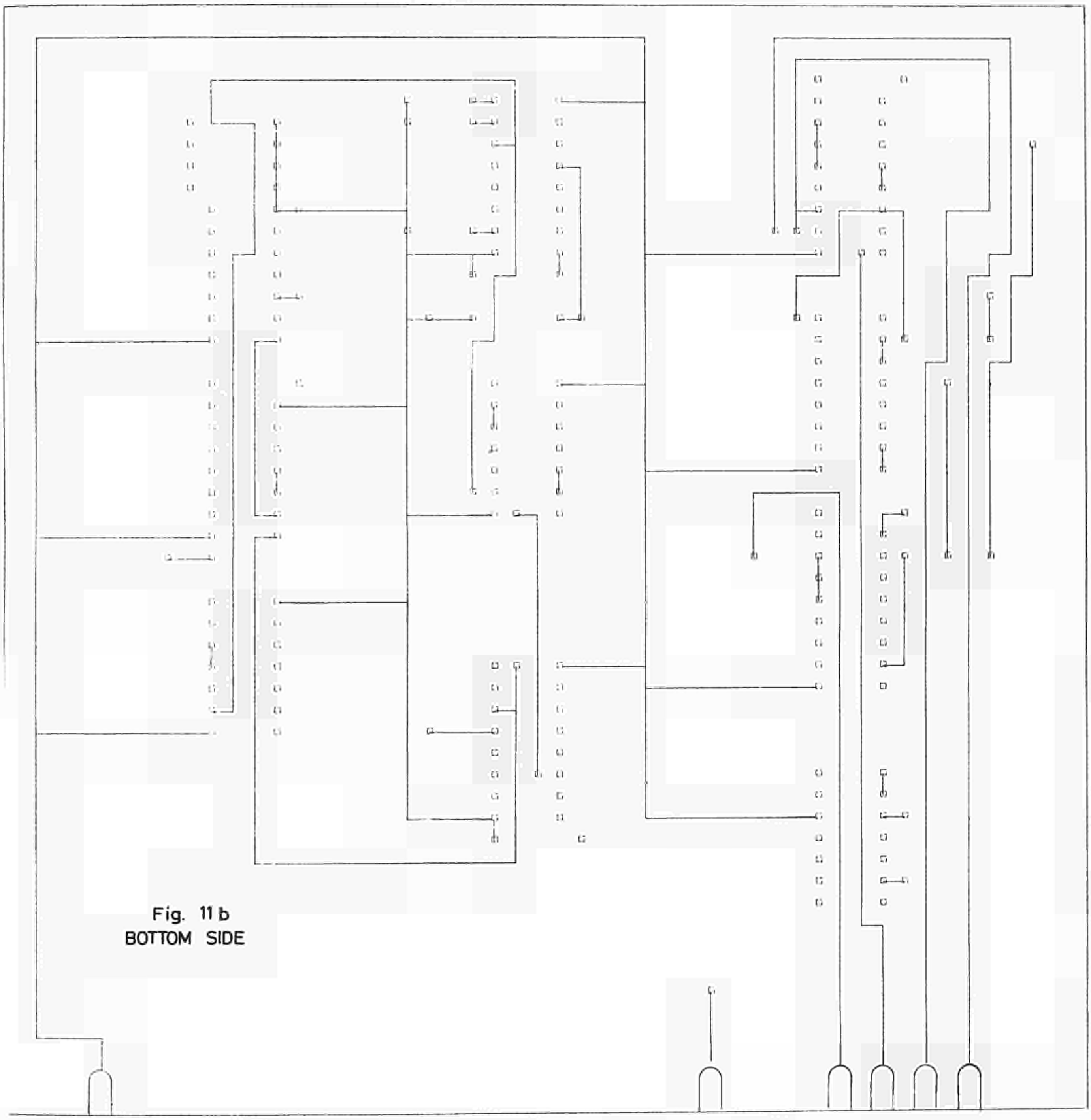
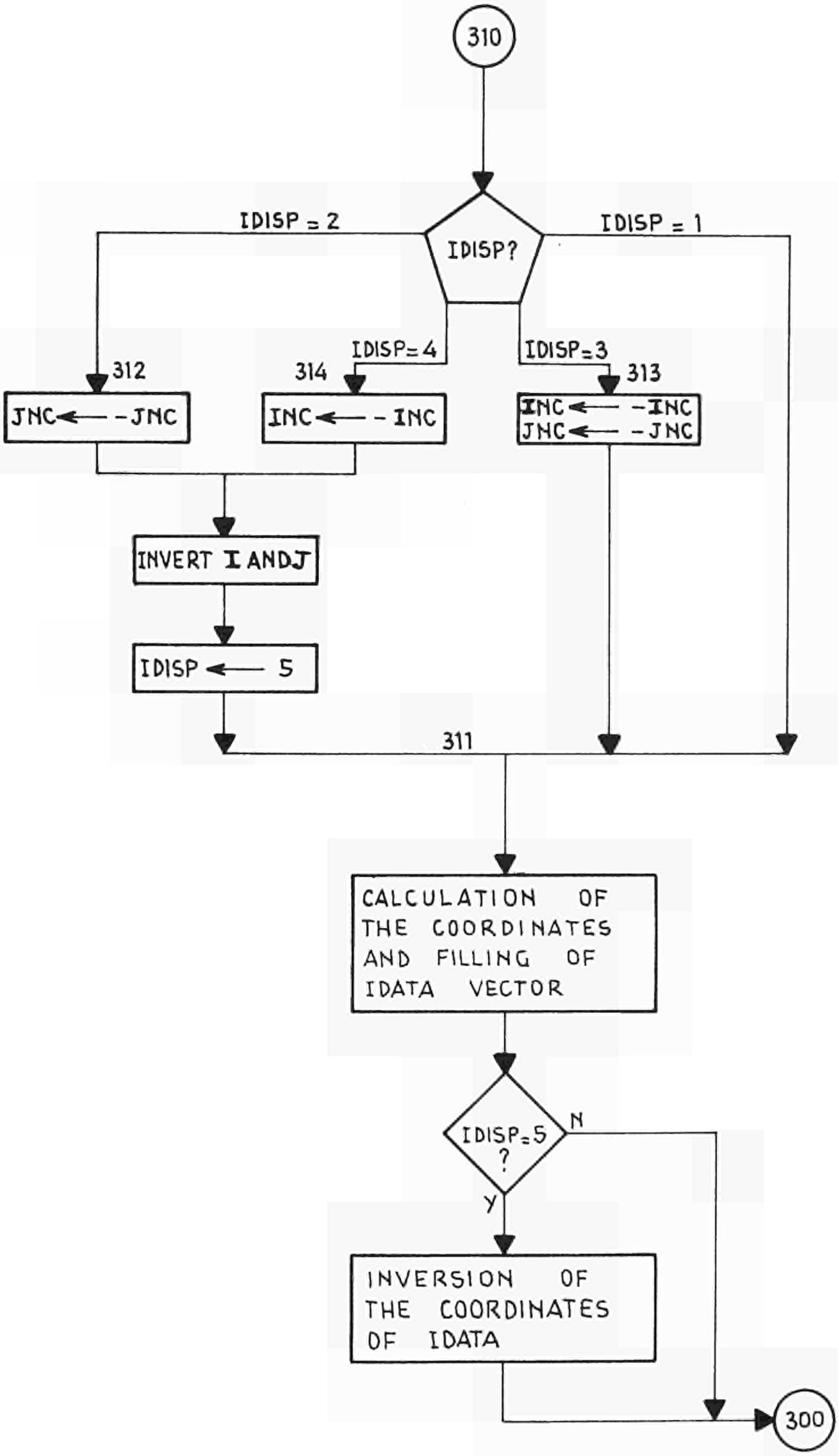


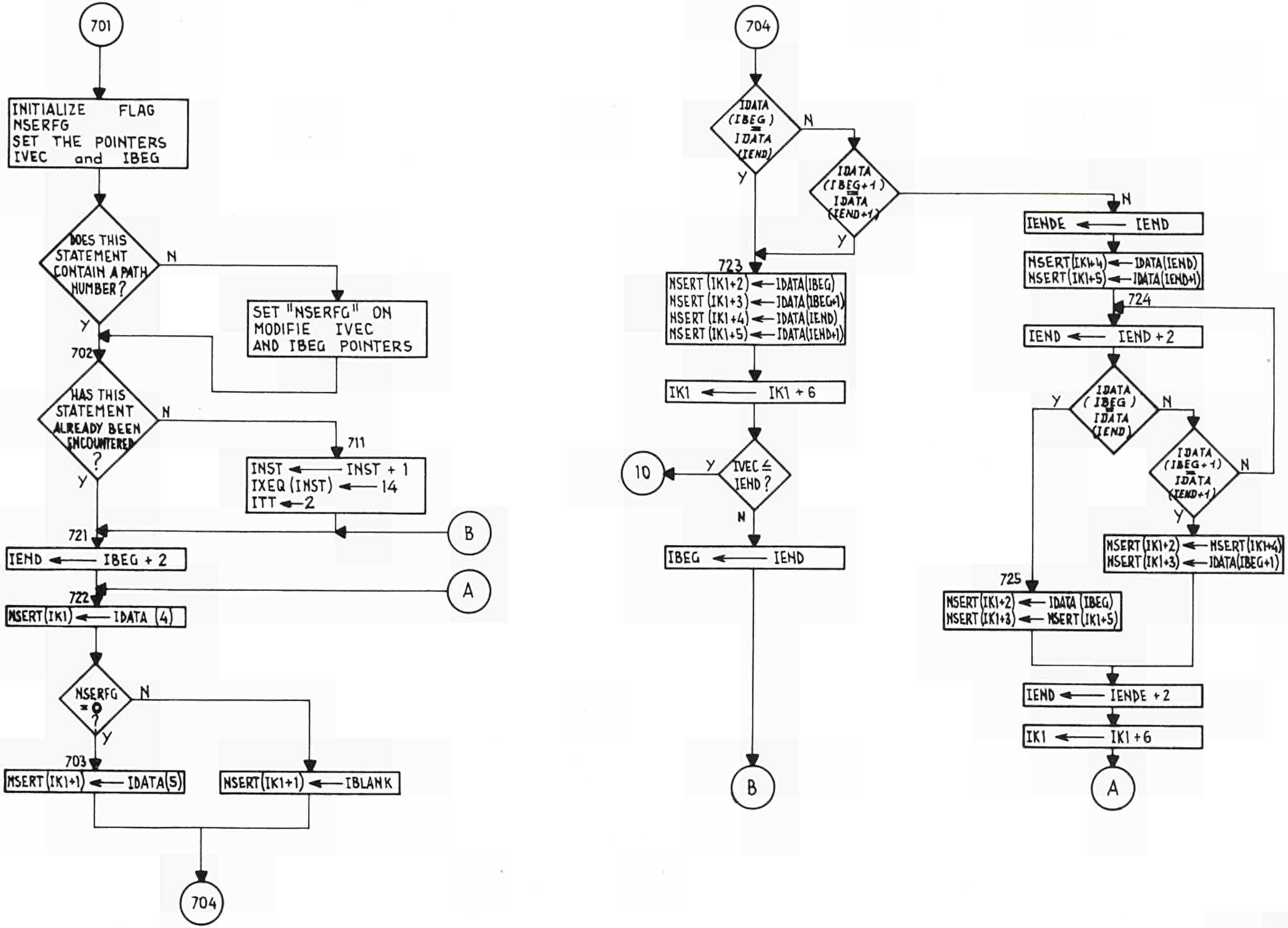
Fig. 11 b
BOTTOM SIDE

```
THE FOLLOWING CONNECTIONS COULD NOT BE MADE
IC1       1 TO IC1      12          HNET= 0,OTNET=10.0
IC1      12 TO IC3       9          HNET= 0,OTNET=10.0
IC1       7 TO IC1      10          HNET= 0,OTNET=10.0
IC1       8 TO IC3      14          HNET= 0,OTNET=10.0
IC1       9 TO IC3      11          HNET= 0,OTNET=10.0
IC1      11 TO IC3       1          HNET= 0,OTNET=10.0
IC2       1 TO IC2      15          HNET= 0,OTNET=10.0
IC2       9 TO IC2       8          HNET= 0,OTNET=10.0
IC2       3 TO IC4       9          HNET= 0,OTNET=10.0
IC2       6 TO IC3      13          HNET= 0,OTNET=10.0
IC2       7 TO IC3      15          HNET= 0,OTNET=10.0
IC3      15 TO IC4       1          HNET= 0,OTNET=10.0
IC4       8 TO IC4      10          HNET= 0,OTNET=10.0
IC5      13 TO IC7      13          HNET= 0,OTNET=10.0
IC6      12 TO IC9      10          HNET= 0,OTNET=10.0
IC6      13 TO IC9       1          HNET= 0,OTNET=10.0
IC6      14 TO IC10      1          HNET= 0,OTNET=10.0
IC7       9 TO IC8      12          HNET= 0,OTNET=10.0
IC8       3 TO IC8      13          HNET= 0,OTNET=10.0
IC9       8 TO IC10      5          HNET= 0,OTNET=10.0
IC9       9 TO IC10      4          HNET= 0,OTNET=10.0
IC9      12 TO IC10      8          HNET= 0,OTNET=10.0
```

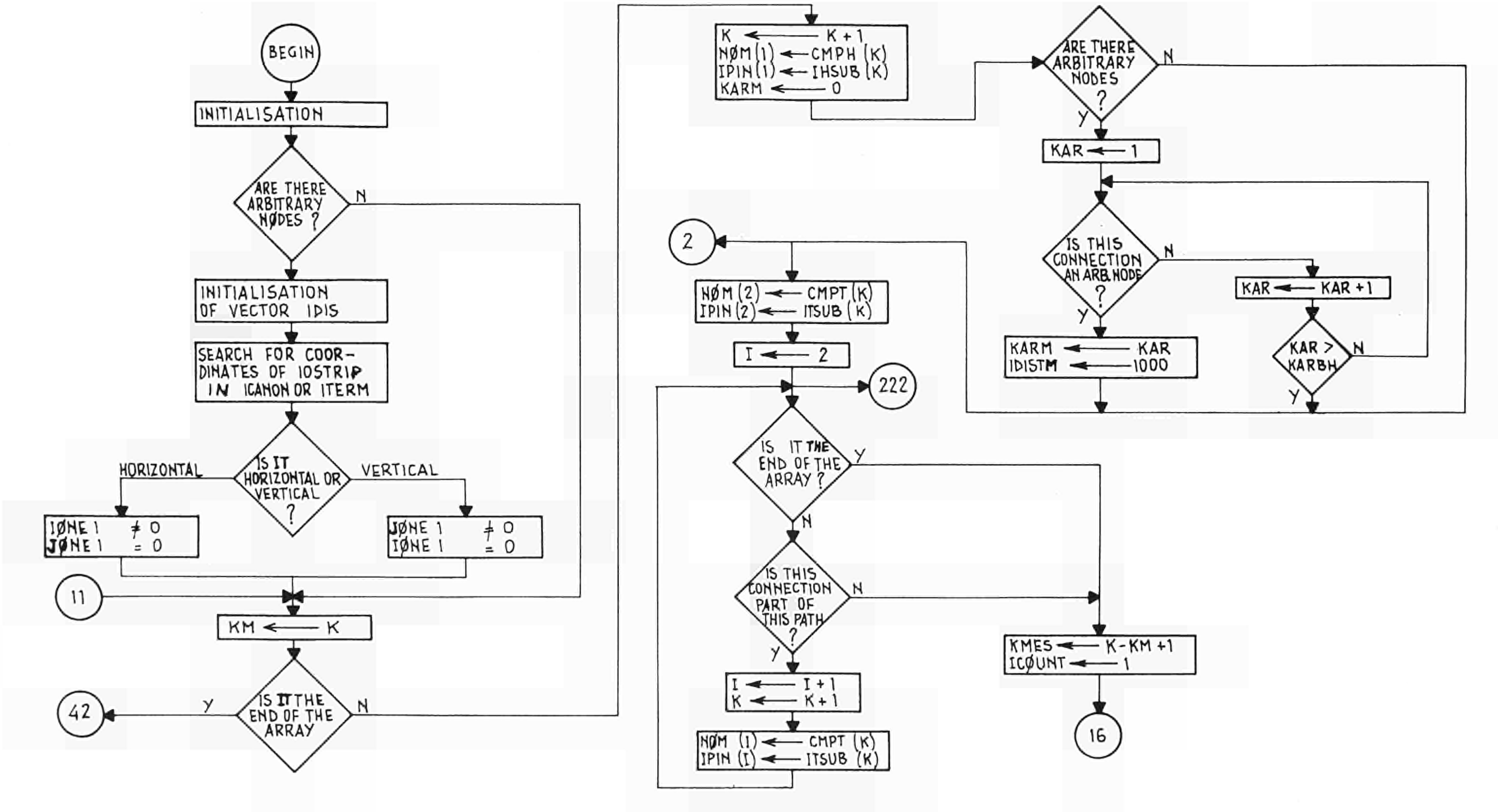
Fig. 11c



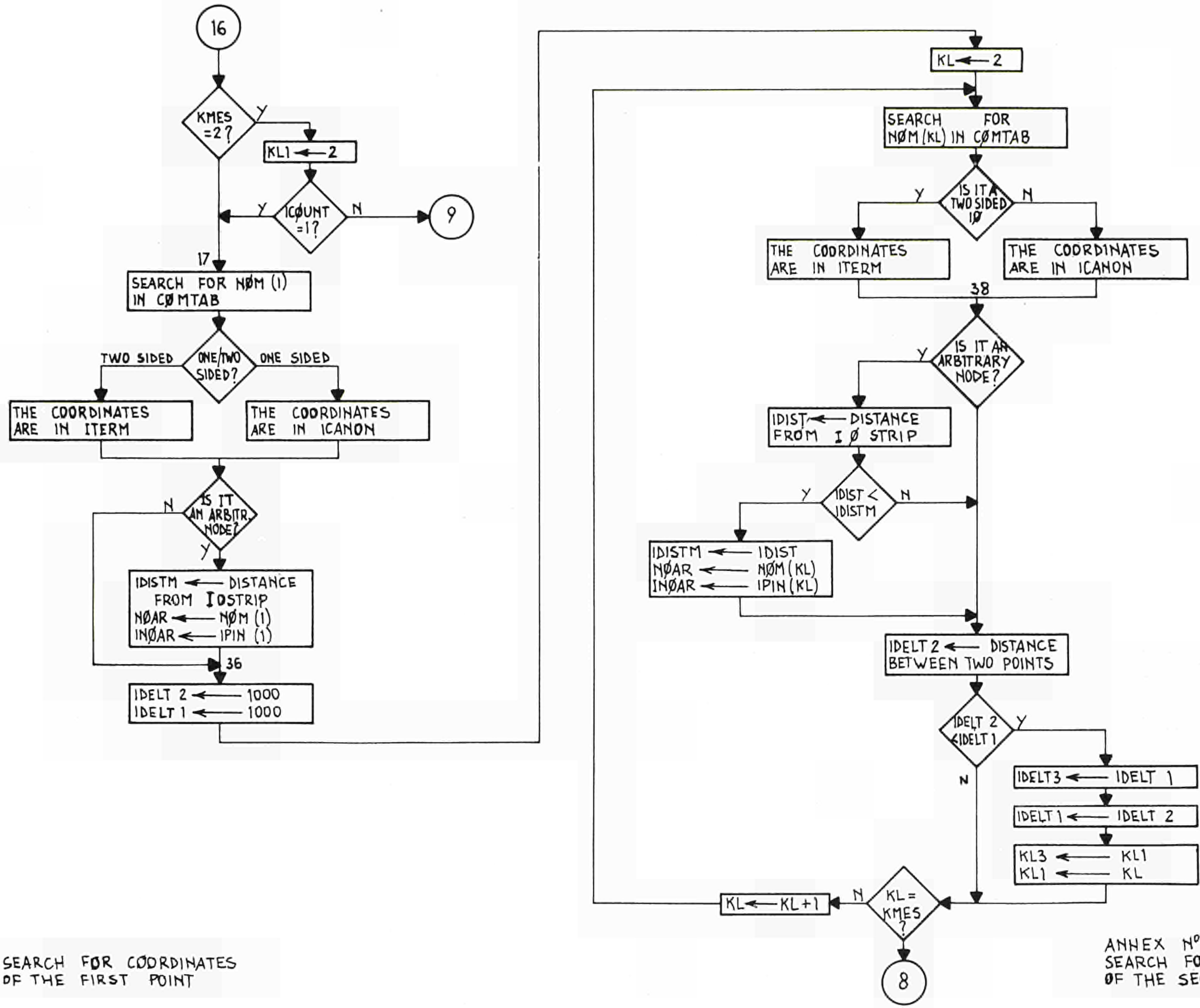
ANNEX N° 1
CØMPIL
STATEMENT
INTEGRATED/



ANNEX N° 2
COMPIL
STATEMENT
BUS/

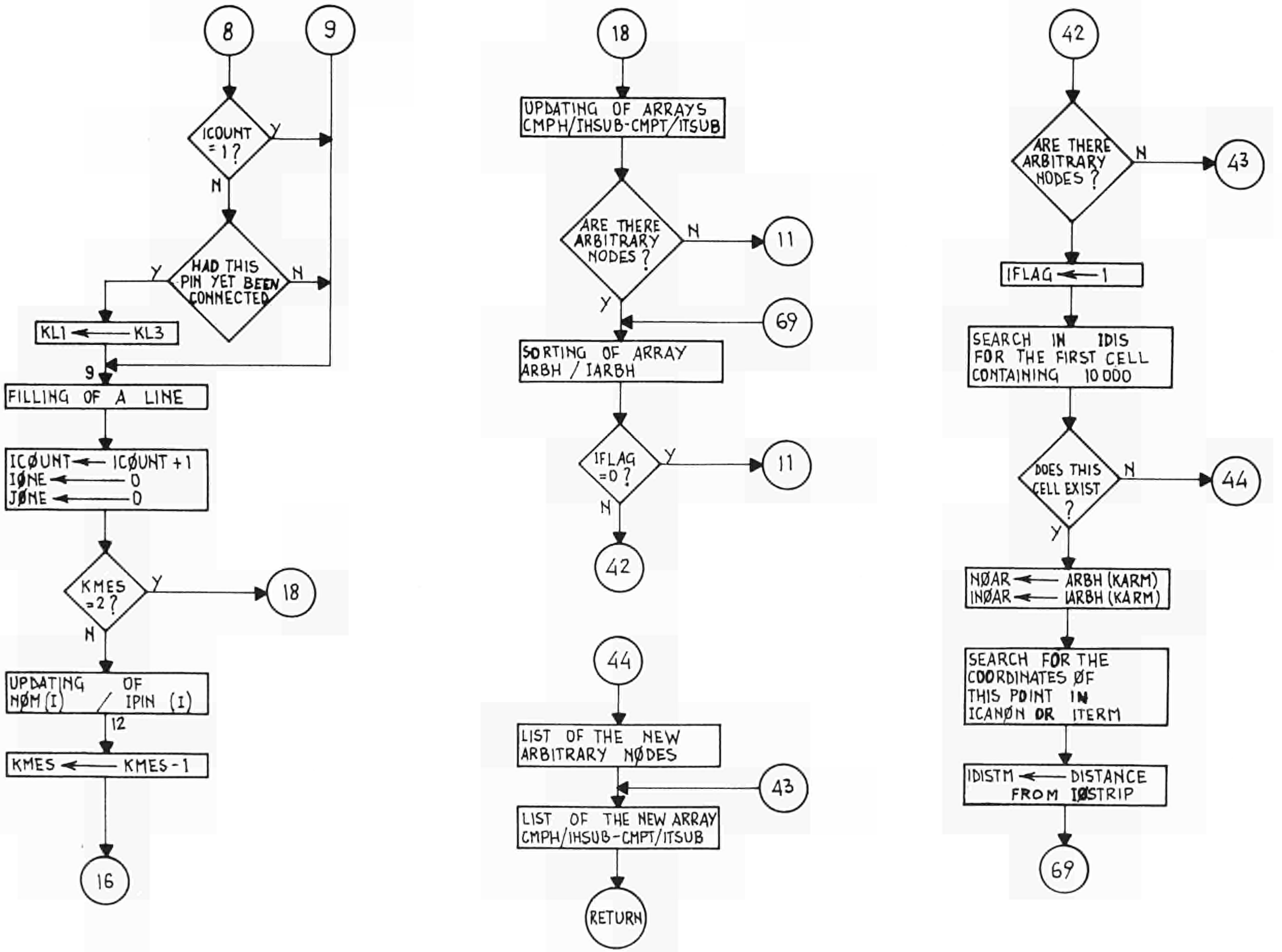


ANNEX N° 3
SEARCH FOR ARBYTRARY NODES AND
BEGIN TO FILL NØM (I)
IPIN (I)



SEARCH FOR COORDINATES
OF THE FIRST POINT

ANNEX N° 3
SEARCH FOR COORDINATES
OF THE SECOND POINT



ANNEX N° 3
FILLING OF THE ARRAYS
TH/ITH - TT/ITT

NOTICE TO THE READER

All scientific and technical reports published by the Commission of the European Communities are announced in the monthly periodical **"euro-abstracts".** For subscription (1 year: BF.1025) or free specimen copies please write to :

Office for Official Publications
of the European Communities
Boîte postale 1003
Luxembourg
(Grand-Duchy of Luxembourg)

To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

Alfred Nobel

SALES OFFICES

The Office for Official Publications sells all documents published by the Commission of the European Communities at the addresses listed below, at the price giyen on cover. When ordring, specify clearly the exact reference and the title of the document.

UNITED KINGDOM

H.M. Stationery Office
P.O. Box 569
London S.E. 1 — Tel. 01-928 69 77, ext. 365

BELGIUM

Moniteur belge — Belgisch Staatsblad
Rue de Louvain 40-42 — Leuvenseweg 40-42
1000 Bruxelles – 1000 Brussel — Tel. 512 00 26
CCP 50-80 — Postgiro 50-80

Agency :
Librairie européenne — Europese Boekhandel
Rue de la Loi 244 — Wetstraat 244
1049 Bruxelles – 1049 Brussel

DENMARK

J.H. Schultz — Boghandel
Møntergade 19
DK 1116 København K — Tel. 14 11 95

FRANCE

Service de vente en France des publications des Communautés européennes — Journal officiel
26, rue Desaix — 75 732 Paris - Cédex 15e
Tel (1) 306 51 00 — CCP Paris 23-96

GERMANY (FR)

Verlag Bundesanzeiger
5 Köln 1 — Postfach 108 006
Tel. (0221) 21 03 48
Telex: Anzeiger Bonn 08 882 595
Postscheckkonto 834 00 Köln

GRAND DUCHY OF LUXEMBOURG

Office for Official Publications of the European Communities
Boîte postale 1003 — Luxembourg
Tel. 49 00 81 — CCP 191-90
Compte courant bancaire: BIL 8-109/6003/300

IRELAND

Stationery Office — The Controller
Beggar's Bush
Dublin 4 — Tel. 76 54 01

ITALY

Libreria dello Stato
Piazza G. Verdi 10
00198 Roma — Tel. (6) 85 08
CCP 1/2640

NETHERLANDS

Staatsdrukkerij- en uitgeverijbedrijf
Christoffel Plantijnstraat
's-Gravenhage — Tel. (070) 81 45 11
Postgiro 42 53 00

UNITED STATES OF AMERICA

European Community Information Service
2100 M Street, N.W
Suite 707
Washington, D.C., 20 037 — Tel. 296 51 31

SWITZERLAND

Librairie Payot
6 rue Grenus
1211 Genève — Tel. 31 89 50
CCP 12-236 Genève

SWEDEN

Librairie C.E. Fritze
2, Fredsgatan
Stockholm 16
Post Giro 193, Bank Giro 73/4015

SPAIN

Libreria Mundi-Prensa
Castelló 37
Madrid 1 — Tel. 275 51 31

OTHER COUNTRIES

Office for Official Publications of the European Communities
Boîte postale 1003 — Luxembourg
Tel. 49 00 81 — CCP 191-90
Compte courant bancaire: BIL 8-109/6003/300

OFFICE FOR OFFICIAL PUBLICATIONS OF THE EUROPEAN COMMUNITIES
Boîte postale 1003 — Luxembourg 6760

CDNA05285ENC