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SCAN AND ANALYSIS PROGRAM

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1. ABSTRACT

The program is an investigation of the possibility of using a graphic display for a highly efficient method of inputting graphic data.

The program is really divided into two parts. The first part scans the graphic data set as rectangular shaped elements or routings on a transparency. A digitized image of the transparency is obtained and displayed.

This image is then analyzed by the second part to obtain the desired symbols or routings.

2. INTRODUCTION

The program described here shows the possibility of using a graphic display for a highly efficient method of inputting graphic data with certain limitations.

The graphic data under consideration could be a logic diagram or plug-in board. To allow the analysis to be feasible the data is presented in two parts. The first part is the 'elements' which in the logic diagrams case will be the logic symbols and in the plug-in boards case will be the electrical elements (i.e. transistors or I. C. P) or connection pads. The second part of the data is the inter-connecting lines or routings.

The elements of the first part are presented as rectangular (or circular) shapes of various areas.

Basically the method is as follows:

A transparency with the elements data as in Figure 1 is put over the display tube. The light pen is held stationary some distance away from the display. The program proceeds to form a scan over the display tube and the light pen will 'see' an image of the transparency. This image is displayed back and forms the digitized information of the transparency. The program then processes this information by finding the co-ordinates of the origin of each rectangular shape and calculating the area which is used as a key to select a symbol and give the result as shown in Figure 2.

The next step is to scan the routings transparency and analyze the digitized information to form a result similar to Figure 3.

It should be noted that the construction of the light pen is such that the field of view is very limited. This can be increased by removing the shutter arrangement completely. The remaining difficulty is the sensitivity which is not enough to cover the loss in intensity when the light pen is put too far back from the display.

3. OPERATING INSTRUCTIONS

The starting address for the program is 4ØØ. On starting the program, a rectangle of side about 2" will appear on the display. Push Buttons (.P.B) Ø, 4, 5, 9 and 11 will be set ON.

The rectangle shows the area that the scan will cover. This is available and its size is controlled by P. B. 2 ⟶ 5 with P. B. 5 being the least significant. To choose a different size, P. B. 2 ⟶ 5 are set accordingly and the manual interrupt button (M. I.) is hit. This will set the X length value, a further hit will set the Y length value. The rectangle will be positioned centrally on the display irrespective of its dimensions. (Unless P. B. 7 is ON.)

The scanning scales for Y and X directions are set by P. B. 8, 9 and 10, 11 respectively. The settings take the binary values ØØ,Ø1, 1Ø,11 corresponding to hardware SC1, SC2, SC4, SC8 respectively. The scale is only noted when a M. I. hit is made. Different scales for X and Y could be chosen.

Having chosen the size and scale for scanning, P. B. Ø which is ON is pressed. This will clear P. B. Ø ⟶ 5 and set P. B. 6 ON (which locks the display cycles to the mains frequency) and starts scanning.

When the scanning ends an image of the transparency is displayed. This image can be scaled up or down by P. B. 8 ⟶ 11 and positioned at origin by P. B. 7. The image formed depends on Accumulator Switch Register Ø (ACØ) as described in Chapter 4.

The program can proceed to analyze the image as elements by hitting the space bar on the teletype. The method of analysis is described fully in Chapter 5. The speed of analysis can be slowed by putting P. B. 2 ⟶ 5 ON with 5 being the least significant. The results of the analysis depends on AC 1 ⟶ 4. Before the analysis proper is begun, a 'padding' routine is entered if AC4 is DOWN. This 'padding' fills up spurious missing points which should appear in the image after scanning is completed.

P. B. 1Ø,11 can be used for scaling the resulting symbols in X and Y direction simultaneously. (It should be noted that the scale chosen for X and Y directions before scanning should be the same as the final scale depends only on P. B. 1Ø,11.)

The symbols table can be displayed by putting P. B. Ø and 1 ON. The table is grouped in ascending order as in Figure 4.

To proceed with the program the M. I. button is hit. This will set the program to pre-scanning state. The routings transparency may now be positioned and P. B. Ø pressed to commence scanning. At the end of the scan an image of the routings is displayed. The analysis of the routings image will commence on hitting any key on the teletype other than space bar. The first step in this analysis is the 'padding' routine if AC4 is DOWN. The method of analysis is discussed in Chapter 5. The result of this analysis is dependent on the setting of five constants. At the end of the analysis the resulting routes and symbols from the previous scan are displayed. If P. B. 1 is set ON, the routings will not be displayed.

The M. I. button may be pressed now to take the program to pre-scanning state. A complete scan and analysis of routings may take place again. The displayed result will contain the original symbols and previous routings.

The above step may be repeated for routings only till the display file buffer is full. An elements scan and analysis will start with a cleared display file.

The control of P. B. and A. C. on the program is shown in Chapter 7.

4. SCANNING AND IMAGE FORMATION

Scanning is always started from the bottom left hand corner of the rectangle. A spot is displayed with full intensity and repeated on the same position twice to obtain full intensity of light emission. A note is then made whether the light pen 'saw' this spot. The spot is then moved one raster point to the right and the above procedure followed.

The above raster point move depends on the scale setting of P. B. 8 and 9. The above step is repeated until the full length of X side of rectangle is covered. The point is then moved one raster point up (according to scale setting of P. B. 1Ø,11) and taken back to the start of X side of rectangle.

If while the scanning was in progress the light pen state changed from 'see' to 'no see' then a vector of length equal to the number of points seen is deposited in the scan display file which starts at absolute core location $1ØØØØ_{(8)}$. This has intensity bit set if ACØ is UP. If the change of state was from 'no see' to 'see' then a similar vector is put in the display file with intensity bit not set if ACØ is UP. If ACØ is DOWN, the setting of the intensity bit is reversed. Hence ACØ acts in the role of forming positive or negative images of transparency.

If the end of X side of rectangle is reached then a vector is put accordingly in the display file and a PJMP call is inserted to move the beam up and back to start of X side.

The scan display file will continuously fill memory field 1 until the limit set at 76ØØ. is reached, the scan will then terminate and resulting image displayed.

An estimate of the size of the display file required for any transparency can be made since for every X side scan the total number of words required is twice the total number of visible and invisible vectors. This is repeated for every step in Y direction with the addition of two words for the PJMP call for Y step.

The limit is set in core location PCHNO1 (which is ØØØ6 in memory field Ø) and may be altered if required.

5. ELEMENTS ANALYSIS

Figure 5A shows a typical scaled up image of a rectangular element. The missing points (shown as circles) seem to appear in certain cases. A routine is entered if AC4 is down to amend this situation. The routine forms a continuous visible vector from any set of visible vectors which subtend an invisible vector. The maximum length of this invisible vector is set at $3_{(8)}$ in FK (Address ØØØ5 in memory field Ø. It is possible to see this taking place in 'slow motion' by putting P. B. 2 ⟶ 5 ON with P. B. 5 being the least significant.

Figure 5B shows the result of this 'padding'.

The analysis for the elements proceeds with PB.2 ⟶ 5 having same effect as described above. The display file in memory Field 1 is looked at from the start for the first vector with its intensity bit set. The Y value is noted and the minimum X and maximum X values of the intensified points are noted. (X min, X max in Figure 5B). The intensity bit for this vector is removed to make it invisible. The next visible vector is then found from the display file and its Xmin, is checked to see if it is within ± 6 points from the previous Xmin. If it is within the set limits, the current Xmin, Xmax over-write the previous set. If Xmin was not within ± 6 points then the check is made for Xmax. If this fails, then a check is made to see if the current visible vector completely encloses the previous Xmin, Xmax or if the Xmin, Xmax completely enclose the current visible vector (e.g. in Figure 5B lines X_1-X_2 and X_3-X_4 respectively).

As the intensity bit of each visible vector which passes one of the above 4 conditions is removed the number of points contained in it is summed up to form the total area of the element.

The limit of 6 points is set in PK (Address ØØØØ in memory Field Ø). As the procedure is repeated the most minimum X and maximum Y are found. (X'min, X'max in Figure 5B.) When a complete X length of rectangle is checked and none of the above 4 conditions is satisfied or when the end of display file in memory Field 1 is reached then it is assumed that the end of the element is reached.

The program now creates a new display file starting at address $2476_{(8)}$ in memory Field Ø for the result of the above analysis. This file will consist of a PJMP call to the invisible vector which positioned the scanning area centrally on the display. This is followed by an invisible vector from origin of scanning rectangle to X'min, Y. The next step depends on AC 3. If it is UP, then the vectors to draw a rectangular shape for the minimum and maximum values in X and Y for the element are put in the display file. The two vectors which are at the origin of this rectangle are invisible. The calculated area of the element is then divided by ($1ØØ_8$) and a character is displayed at the origin of the rectangle which is the integer value of the above division. This integer is taken modulo (Ø ⟶ 9, A ⟶ U).

If AC 3 is DOWN, then the integer obtained after the total area is divided by $1ØØ_{(8)}$ is used to form the address for the PJMP call to the symbol in Figure 4 taken as modulo($16_{1Ø}$). Each of these symbols has a □ to show its origin.

If AC 1 is UP then no display file is created unless the above integer value is non-zero. This in effect suppresses isolated points.

If AC 2 is up then the area is doubled before division takes place.

It should be noted that the above 4 conditions will analyze circular shapes as well or in fact any shape with a smoothly varying perimeter. The value in PK sets the limiting condition.

The program will pass through the image file in Field 1 repeatedly until all elements have been analyzed and a corresponding display file in Field Ø created. The analysis may be stopped at any time by hitting M. I. which sets the pre-scan state.

Figure 1

Figure 2

Figure 3

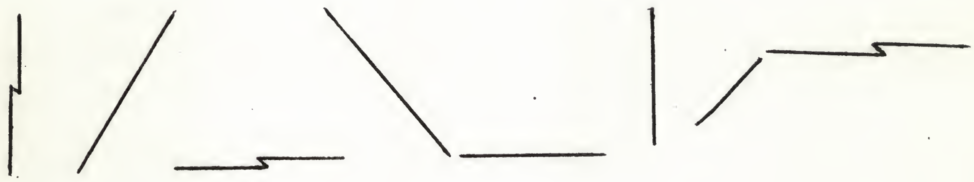

Figure 4

```
16

11   12   13   14   15

6    7    8    9    10

1    2    3    4    5
```

Figure 5A

```
  . . . . . . . . . . . . .
  . . . . . . . . . . . . .
        . . . . . .
  . . . . . . . . . . . . .
  . . 0 . . . . . 0 . . . .
  . . . . 0 0 . . . . 0 0 .
    . . . . . . . . . . . . . .
. . . . . . . . . . . .
  . . . . . . . . . . . . .
```

Figure 5B

```
           . . . . . . . . . . . . .
      X1   . . . . . . . . . . . . .  X2
                 . . . . . .
      X3   . . . . . . . . . . . . .  X4
           . . . . . . . . . . . . .
           . . . . . . . . . . . . .
             . . . . . . . . . . . . . .  X'Max
X'Min  . . . . . . . . . . . .
    XMin   . . . . . . . . . . . . .  XMax
```

6. ROUTING ANALYSIS

This enters the 'padding' routine if AC 4 is DOWN and proceeds to look at the display file in Field 1 as in the elements analysis. The first visible vector encountered is checked to find if its length is greater than $14_{(8)}$. If it is then the vector is taken to be part of a horizontal route and a marker is set to this mode. The above length is specified in RVV (Address ØØØ2 in Field Ø), and typically should be greater than the maximum width of a vertical or diagonal route.

The analysis then proceeds to check if the next visible vector begins, ends, is wholly contained or contains wholly the saved Xmin, Xmax. If any of the above 4 conditions are satisfied and the length of the vector is greater than the value in RVV, then the analysis continues. When a complete X side of rectangle is traversed and the above two conditions are not satisfied, then the display file in memory Field Ø is updated to show a vector equal in length and height to the horizontal route image in length and width.

If the length of the visible vector is less than RVV then the search through the display file continues and the next visible vector is checked to see if its start AND end are within ± 4. This value is set in RK (Address ØØØ1 in memory Field Ø).

Eight steps in Y are taken and then the current Xmin is compared with Xmin 8 steps previously. If the difference is ± 4 then it is assumed that the route is in the vertical direction, and a marker is set accordingly.

If the difference is greater than + 4 then it is assumed that the route is diagonal with X increasing as Y is stepped. A marker is set to signify this mode. If the difference is less than -4 then the route is diagonal with X decreasing as Y is stepped. Similarly a marker is set.

The forward scan of 8 is set in RLB as a NEGATIVE number (Address ØØØ3 in Field Ø). The difference limit of 4 is set in R2. (Address ØØØ4 in Field Ø).

The analysis continues once one of the above markers have been set. A comparison is made after 8 steps (or the value set in RLB) to insure that the direction of routing has not changed.

If the direction has changed, then a corresponding line is created in the display file in Field Ø. This has its end at the co-ordinates of the previous 8 steps.

If the end of the route is reached or it merges into a horizontal route, then a corresponding vector is added to the display file in memory Field Ø. This vector will not be put in the display file if it is not in horizontal mode and its Y length is less than 4. This value of 4 is set as a NEGATIVE value in RVG (Address ØØØ7 in Field Ø).

The above analysis is repeated until all the routings have been processed, or the display file in Field Ø reaches its limit at $56ØØ_{(8)}$.

It is important to note that the diagonal routes should be at an angle of 45° or within ± 15 of 45°. This variation from 45° or the vertical is directly related to the values of RLB and R2.

A route at an intermediate angle will alter between the vertical and the diagonal modes.

7. MISCELLANEOUS

a-PB CONTROL

Display Table START SCAN	Symbol Display Routing	'SLOW MOTION' ANALYSIS RECTANGLE SIZE			
Ø	1	2	3	4	5
6	7	8	9	1Ø	11
LOCK TO MAINS	SET TO ORIGIN OF DISPLAY	X SCALE		& SCALE	

b-A.C. CONTROL

-VE IMAGE	IGNORE Ø AREA	DOUBLE AREA	FORM CHARACTERS	NO PADDING
Ø	1	2	3	4
+VE IMAGE			FORM SYMBOLS	PADDING ENTERED

c-MEMORY USE

The program occupies core locations Ø ⟶ 2475 in memory Field Ø. Memory Field 1 is used entirely for the display file of the scan. Core locations 2476 ⟶ 56ØØ are used for the display file of the analysis. 6ØØØ ⟶ 6777 are used for display files of the permanent symbols table. 7ØØØ ⟶ 7577 contains the character generator dispatch table and routines.

If the display processor does not have the LOCK ON MAINS facility then core location Ø6Ø4 in Field Ø should be changed to 3ØØØ$_{(8)}$. This will actually increase the scanning speed but will cause a slight distortion.

d-RELEVANT CONSTANTS

NAME	ABSOLUTE LOCATION	CURRENT VALUE	CONTROL
PK	ØØØØ	6	Difference limit for element analysis
RK	ØØØ1	4	Difference limit for routing analysis
RVV	ØØØ2	14	Minimum size for a horizontal route
RLB	ØØØ3	777Ø	FORWARD SCAN SIZE
R2	ØØØ4	4	Limit for vertical or diagonal test
FK	ØØØ5	3	Maximum size for padding invisible points
PCHNO1	ØØØ6	76ØØ	Maximum size of scan display file in Field 1
RVG	ØØØ7	7774	Vertical or diagonal routes ignore limit