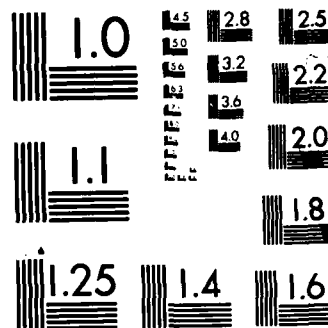


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A 10x10 grid of squares. The top-left square is missing, creating a shape that resembles a staircase or a corner. The grid consists of 10 rows and 10 columns. The first row has 9 squares (missing the first one). The second row has 10 squares. The third row has 10 squares. The fourth row has 10 squares. The fifth row has 10 squares. The sixth row has 10 squares. The seventh row has 10 squares. The eighth row has 10 squares. The ninth row has 10 squares. The tenth row has 10 squares.



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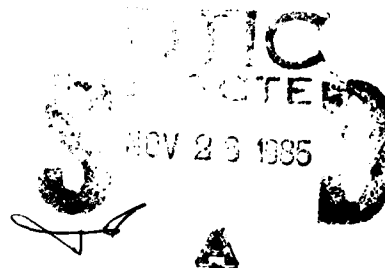
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MINIMIZATION OF A SIX VARIABLE BOOLEAN FUNCTION

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MAY 1985



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SECTION I: INTRODUCTION1.1 BACKGROUND

For many years now digital systems have been designed to perform specific functions. In the earlier years, the primary electronic element was vacuum tubes. Later came the advent of the transistor and recently the integrated circuit. Whether the system be composed of vacuum tubes, transistors, or integrated circuits, one of the major concerns in physically realizing the system is cost. The cost of a particular system equates to the number of logic elements in that system. Therefore, one of the aspects in designing digital systems is the problem of minimization. Given a function f , find the cheapest form f' such that f' denotes f .

Today, the cheapest form equates to the minimum number of integrated circuits, whether they be small-scale integration (SSI) circuits, medium-scale integration (MSI) circuits, large-scale integration (LSI) circuits or even the most recent, very large-scale integration (VLSI) circuits.

The task of realizing a boolean function of six or fewer variables is not unreasonable and can be done by hand using Karnaugh Maps. However, when attempting to minimize the number of integrated circuits required to realize a function with greater than five variables, the task becomes enormous for it involves methods which require a considerable amount of exhaustive searching. Some computer-

assisted tool is necessary to consider all the cases.

1.2 SCOPE OF THE MODEL

A function consisting of four variables can be realized in a single eight-input multiplexer. Three variables are "data select" lines while the fourth variable, or the binary constants 0 and 1, are applied to the eight input lines (I_0 through I_7). This is shown in Figure 1.1. Functions with five or more variables can be realized with multiplexer networks designed in two stages. In the case of a function with six variables, the function can be realized with eight four-input multiplexers (input-stage) feeding into a single eight-input multiplexer (output-stage). Figure 1.2 illustrates this design.

As mentioned previously, Karnaugh Maps can be used to aid in the realization of these functions. However, in the case of the six variable function, it would require evaluating twenty cases. These twenty cases are outlined and explained in Section II of this paper.

MINIZE is a computer program which can be used to aid in the minimization of a six variable combinational boolean function. This program has an interactive input section which allows the user to enter the number of minterms in the function and then the actual minterms (or elements that are equal to one). Output consists of the minimum number of four-input MSI's (input-stage multiplexers) needed to realize this function and their required inputs.

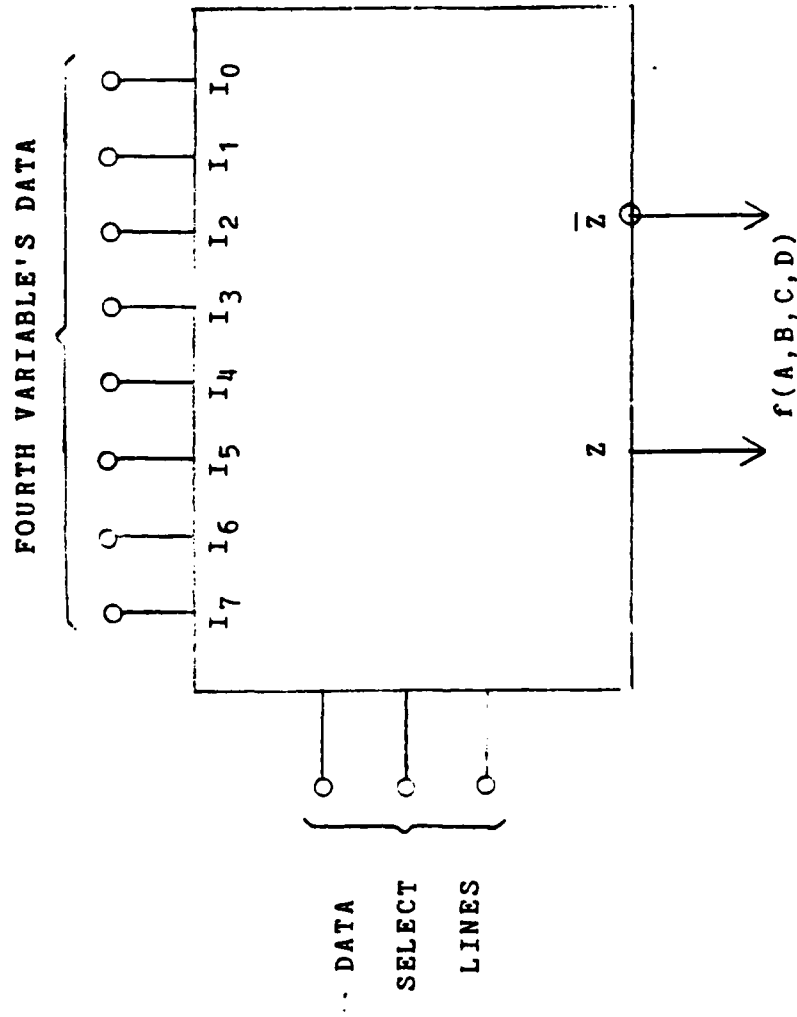


FIGURE 1.1 EIGHT-INPUT MULTIPLEXER USED TO REALIZE
A FOUR-VARIABLE FUNCTION.

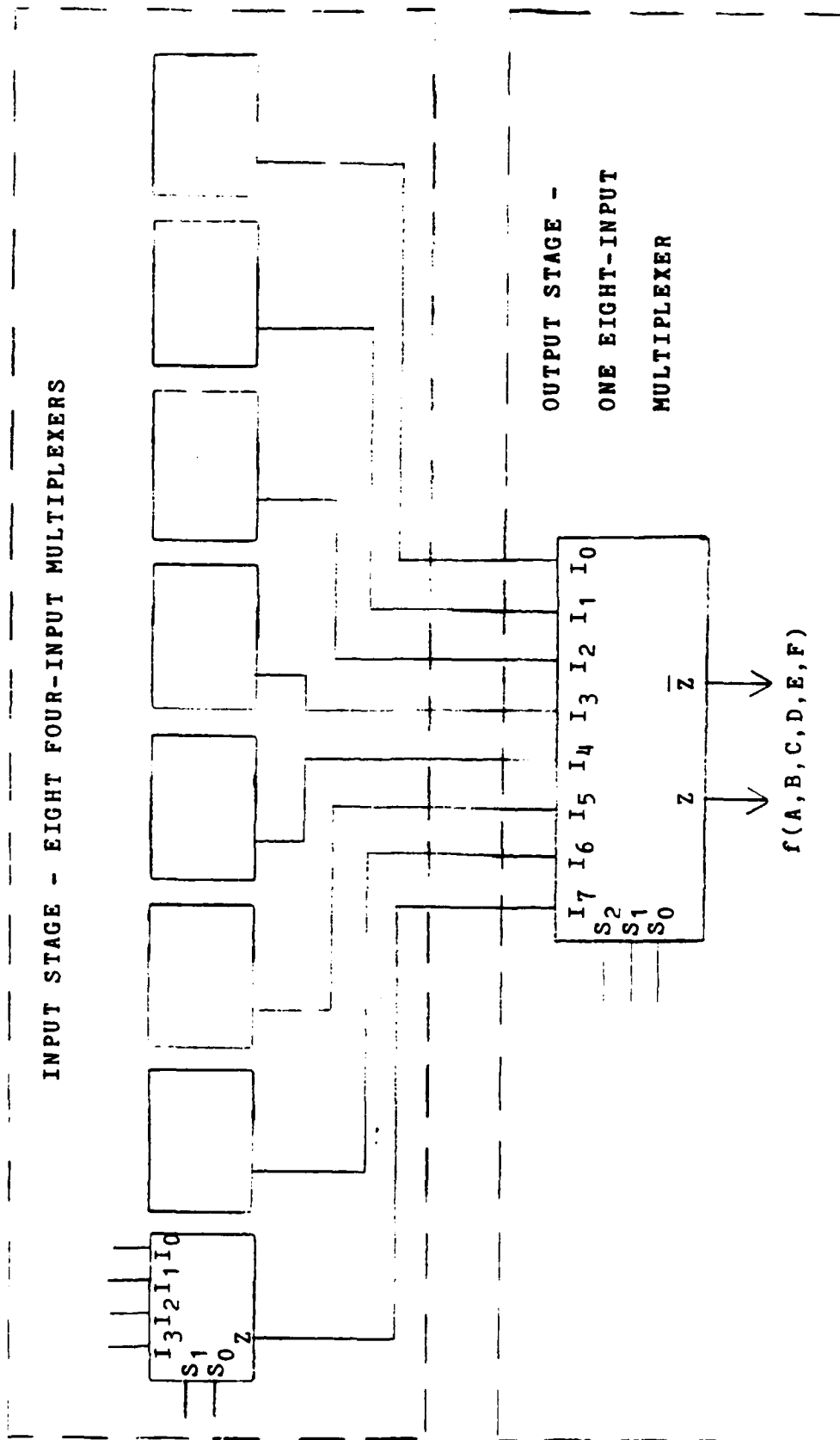


FIGURE 1.2 MULTIPLEXER NETWORK USED TO REALIZE A SIX-VARIABLE FUNCTION.

1.3 PURPOSE OF THE PAPER

The purpose of this paper is to describe the MINIZE program and to provide a user's manual. MINIZE is written in HP Basic for use on a Hewlett-Packard 9845B desktop computer with Advanced Programming capability.

Section ²~~II~~ describes the minimization process, along with the techniques used in the model. An example is presented to illustrate the method.

Section ³~~III~~ is the user's manual for the MINIZE program. This section outlines the inputs, outputs and operating instructions for the model.

Section ⁴~~IV~~ describes the program and each of its subroutines. Appendix A contains flowcharts of these routines.

A summary of the paper is provided in Section V.

SECTION II: MINIMIZATION METHOD2.1 OVERVIEW

This section describes the minimization process and the techniques used in the model MINIZE.

2.2 APPROACH

MINIZE uses the following method for reducing a six variable function. The process described here is only a slight modification of one presented in reference (1). This procedure can be described in the following series of steps for the function $f(A,B,C,D,E,F)$:

STEP 1: Divide the function into two parts ($g1=g1(A,B,C)$ and $g2=g2(D,E,F)$), thus reducing the six-variable function to two three-variable problems.

STEP 2: For each function element which is equal to one (minterm), factor out the variable values A,B,C to obtain the function $g2(D,E,F)$ of three variables.

STEP 3: Collect all terms of $g2(D,E,F)$ corresponding to each unique input combination of A,B,C.

STEP 4: Implement each $g2(D,E,F)$ term. This step is described in more detail in Example 1 presented in Section 2.2.1. This step is the realization of the input-stage.

At this point this function can be realized by eight

four-input input-stage multiplexers feeding into a single eight-input output-stage multiplexer as was shown in Figure 1.2. Now the inputs into the eight input-stage multiplexers must be examined to see if any can be eliminated in an effort to reduce this number of multiplexers.

STEP 5: Check the eight sets of four inputs for the following conditions. For each condition that is met, the required number of multiplexers can be reduced by one.

- a) All the inputs in the set equal zero. Then this set can be eliminated.
- b) All the inputs in the set equal one. Then this set can be eliminated.
- c) Two of the sets have identical inputs. Then one set can be eliminated.
- d) Two of the sets have inputs that are complements. Then one set can be eliminated.

STEP 6: Select another permutation of the original function $f(A,B,C,D,E,F)$ and repeat Steps 1-5 until the twenty permutations which provide different solutions of this function have been evaluated. These permutations and the rationale for them are described in Section 2.2.2.

When this process is complete MINIZE will output the minimum number of multiplexers needed and their required inputs in order to realize the given function.

2.2.1 EXAMPLE

The following example illustrates this minimization process.

Example 1: Given the following function and minterms, realize this function using the above minimization process.

$$f(A,B,C,D,E,F) = m(3,7,12,14,15,19,23,27,28,29, \\ 31,35,39,44,45,46,48,49,50,52, \\ 53,55,56,57,59)$$

Note: This example will only consider one permutation. The case where $g1=g1(A,B,C)$ and $g2=g2(D,E,F)$.

Table 2.1 is the list of ordered and collected minterms after performing Steps 1 through 3. Note that there are eight values for the function $g1=g1(A,B,C)$ (0-7).

Step 4 is to implement the function $g2=g2(D,E,F)$ for each value of $g1(A,B,C)$. For each group of minterms with the same value of $g1(A,B,C)$ (I value), separate the D and E arguments from F in the associated function $g2=g2(D,E,F)$. Then there are four possible values of the subfunction $g2a(D,E)$ (0-3). An F input must be determined for each of these four values. These F inputs can be found by following the next set of conditions.

A) If two minterms are present for a given

$g2a=g2a(D,E)$ ($F=0$ in one minterm and $F=1$ in the other), then the F input for this $g2a(D,E)$ value is one (1).

TABLE 2.1 ORDERED AND COLLECTED MINTERMS FOR EXAMPLE 1
FOR PERMUTATION A,B,C, D,E,F

<u>MINTERM</u>	<u>g1(A,B,C)</u>	<u>g2(D,E,F)</u>	<u>I VALUE*</u>
3	0 0 0	0 1 1	0
7	0 0 0	1 1 1	0
12	0 0 1	1 0 0	1
14	0 0 1	1 1 0	1
15	0 0 1	1 1 1	1
19	0 1 0	0 1 1	2
23	0 1 0	1 1 1	2
27	0 1 1	0 1 1	3
28	0 1 1	1 0 0	3
29	0 1 1	1 0 1	3
31	0 1 1	1 1 1	3
35	1 0 0	0 1 1	4
39	1 0 0	1 1 1	4
44	1 0 1	1 0 0	5
45	1 0 1	1 0 1	5
46	1 0 1	1 1 0	5
48	1 1 0	0 0 0	6
49	1 1 0	0 0 1	6
50	1 1 0	0 1 0	6
52	1 1 0	1 0 0	6
53	1 1 0	1 0 1	6
55	1 1 0	1 1 1	6
56	1 1 1	0 0 0	7
57	1 1 1	0 0 1	7
59	1 1 1	0 1 1	7

*value of g1(A,B,C)

B) If no minterms are present for the $g2a(D,E)$, then the F input for the $g2a(D,E)$ value is zero (0).

C) If only one minterm is present for the $g2a(D,E)$ subfunction then:

1) If $F=0$, then the F input is $\sim F$ for this $g2a(D,E)$ value.

2) If $F=1$, then the F input is F for this $g2a(D,E)$ value.

Table 2.2 presents the F inputs for each $g2a(D,E)$ value under each I value for Example 1.

TABLE 2.2 F INPUTS FOR EXAMPLE 1

<u>I VALUE</u>	<u>$g2a(D,E)$ VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	F	0	F
1	0	0	$\sim F$	1
2	0	F	0	F
3	0	F	1	F
4	0	F	0	F
5	0	C	1	$\sim F$
6	1	$\sim F$	1	F
7	1	F	0	0

Step 5 is to reduce this set of inputs. Note that I_0 , I_2 , and I_4 are all equivalent, so two sets can be eliminated (say I_0 and I_2). Therefore, the minimum number of multiplexers needed to realize this function for this permutation is six (eight minus two). Figure 2.1 graphically illustrates this realization.

2.2.2 PERMUTATIONS PROVIDING UNIQUE SOLUTIONS

This section outlines the twenty permutations that

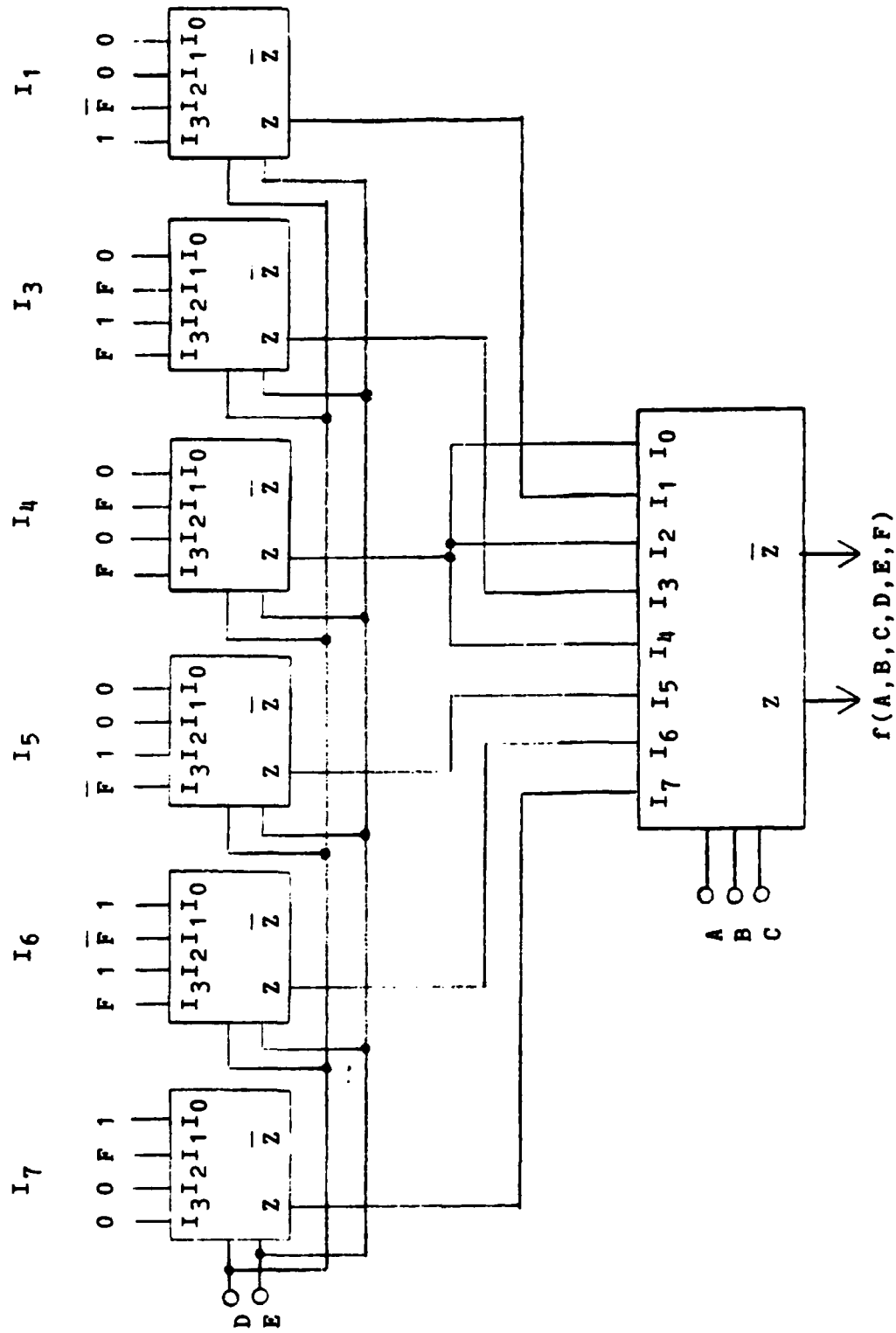


FIGURE 2.1 REALIZATION OF THE FUNCTION IN EXAMPLE 1.

provide unique solutions using this minimization process and presents the rationale behind why these are the only ones that need to be evaluated.

If all permutations of the six variable function were necessary, then there would be 6! or 720 cases to consider. However, consider the following:

- 1) Say that the last three variables (function $g_2(D,E,F)$) were fixed and were not permuted. Then there would be six permutations of the function $f(A,B,C,D,E,F)$ (the six permutations of the function $g_1(A,B,C)$). When the minterms are grouped and collected by I value (the value of the function $g_1=g_1(A,B,C)$) for a particular permutation, then these same minterms would also be grouped together under any of these six permutations. Table 2.3 illustrates this for Example 1 for permutation B,A,C, D,E,F. Since the function $g_2(D,E,F)$ was fixed for all these permutations, then the calculated F inputs assigned would still be the same. They would just appear under a different I value. Since this does not affect the reduction process the set of F inputs can be reduced the same for all six permutations and the reduced number of multiplexers required would be the same.
- 2) Say that the first three elements are fixed (function $g_1=g_1(A,B,C)$). There would then be six permutations of the function $g_2=g_2(D,E,F)$. All

TABLE 2.3 COLLECTED MINTERMS FOR EXAMPLE 1 FOR
PERMUTATIONS (A,B,C, D,E,F) AND (B,A,C, D,E,F)

MIN- TERM S	PERMUTATION (A,B,C, D,E,F)			PERMUTATION (B,A,C, D,E,F)		
	<u>g1(A,B,C)</u>	<u>g2(D,E,F)</u>	<u>I</u> <u>VALUE</u>	<u>g1(B,A,C)</u>	<u>g2(D,E,F)</u>	<u>I</u> <u>VALUE</u>
3	0 0 0	0 1 1	0	0 0 0	0 1 1	0
7	0 0 0	1 1 1	0	0 0 0	1 1 1	0
12	0 0 1	1 0 0	1	0 0 1	1 0 0	1
14	0 0 1	1 1 0	1	0 0 1	1 1 0	1
15	0 0 1	1 1 1	1	0 0 1	1 1 1	1
19	0 1 0	0 1 1	2	1 0 0	0 1 1	4
23	0 1 0	1 1 1	2	1 0 0	1 1 1	4
27	0 1 1	0 1 1	3	1 0 1	0 1 1	5
28	0 1 1	1 0 0	3	1 0 1	1 0 0	5
29	0 1 1	1 0 1	3	1 0 1	1 0 1	5
31	0 1 1	1 1 1	3	1 0 1	1 1 1	5
35	1 0 0	0 1 1	4	0 1 0	0 1 1	2
39	1 0 0	1 1 1	4	0 1 0	1 1 1	2
44	1 0 1	1 0 0	5	0 1 1	1 0 0	3
45	1 0 1	1 0 1	5	0 1 1	1 0 1	3
46	1 0 1	1 1 0	5	0 1 1	1 1 0	3
48	1 1 0	0 0 0	6	1 1 0	0 0 0	6
49	1 1 0	0 0 1	6	1 1 0	0 0 1	6
50	1 1 0	0 1 0	6	1 1 0	0 1 0	6
52	1 1 0	1 0 0	6	1 1 0	1 0 0	6
53	1 1 0	1 0 1	6	1 1 0	1 0 1	6
55	1 1 0	1 1 1	6	1 1 0	1 1 1	6
56	1 1 1	0 0 0	7	1 1 1	0 0 0	7
57	1 1 1	0 0 1	7	1 1 1	0 0 1	7
59	1 1 1	0 1 1	7	1 1 1	0 1 1	7

these permutations would also require the same number of multiplexers when reduced. The following four cases explain why this is true.

Case 1: If all eight minterms for a given I value are present, then all F inputs for this I value are one (1). Any permutation of these eight minterms would still produce all eight elements, whose F inputs would also be all ones. In both cases this multiplexer can be eliminated.

Case 2: If no minterms for a given I value are present, then any permutation would still have F inputs all equal to zero. In both cases this multiplexer can be eliminated.

Case 3: If two I values have equivalent F inputs, then any permutation would still result in equivalent inputs. See Example 2a in Table 2.4.

Case 4: If two I values have complementary F inputs, then any permutation would still result in complementary inputs. See Example 2b in Table 2.4.

This means that there are thirty-six cases which result in the same number of required multiplexers (six permutations of $g1=g1(A,B,C)$ X six permutations of $g2=g2(D,E,F)$). Therefore, the number of permutations of the function $f(A,B,C,D,E,F)$ (divided into two functions

TABLE 2.4 EXAMPLES OF PERMUTATIONS

EXAMPLE 2a: Given the function $f(A,B,C,D,E,F) = \sum m(18,21,23,42,45,47)$, realize this function for the following permutations: 1) A,B,C, D,E,F and 2) A,B,C, F,D,E.

PERMUTATION 1g1=g1(A,B,C) g2=g2(D,E,F)

0 1 0	0 1 0
0 1 0	1 0 1
0 1 0	1 1 1
1 0 1	0 1 0
1 0 1	1 0 1
1 0 1	1 1 1

PERMUTATION 2g1=g1(A,B,C) g2=g2(F,D,E)

0 1 0	0 0 1
0 1 0	1 1 0
0 1 0	1 1 1
1 0 1	0 0 1
1 0 1	1 1 0
1 0 1	1 1 1

F INPUTS

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>
	0 1 2 3
0	ALL ZEROS
1	ALL ZEROS
2	0 ~F F F
3	ALL ZEROS
4	ALL ZEROS
5	0 ~F F F
6	ALL ZEROS
7	ALL ZEROS

F INPUTS

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>
	0 1 2 3
0	ALL ZEROS
1	ALL ZEROS
2	F 0 0 1
3	ALL ZEROS
4	ALL ZEROS
5	F 0 0 1
6	ALL ZEROS
7	ALL ZEROS

In both cases I_2 and I_5 are equivalent and only one multiplexer is needed to realize this function.

TABLE 2.4 EXAMPLES OF PERMUTATIONS (CONTINUED)

EXAMPLE 2b: Given the function $f(A,B,C,D,E,F) = \Sigma m(17,20,22,23,40,42,43,45)$, realize this function for the following permutations: 1) A,B,C, D,E,F and 2) A,B,C, F,D,E.

PERMUTATION 1g1=g1(A,B,C) g2=g2(D,E,F)

0 1 0	0 0 1
0 1 0	1 0 0
0 1 0	1 1 0
0 1 0	1 1 1
1 0 1	0 0 0
1 0 1	0 1 0
1 0 1	0 1 1
1 0 1	1 0 1

PERMUTATION 2g1=g1(A,B,C) g2=g2(F,D,E)

0 1 0	1 0 0
0 1 0	0 1 0
0 1 0	0 1 1
0 1 0	1 1 1
1 0 1	0 0 0
1 0 1	0 0 1
1 0 1	1 0 1
1 0 1	1 1 0

F INPUTS

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>
	0 1 2 3

0	ALL ZEROS
1	ALL ZEROS
2	F 0 ~F 1
3	ALL ZEROS
4	ALL ZEROS
5	~F 1 F 0
6	ALL ZEROS
7	ALL ZEROS

F INPUTS

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>
	0 1 2 3

0	ALL ZEROS
1	ALL ZEROS
2	0 1 ~F F
3	ALL ZEROS
4	ALL ZEROS
5	1 0 F ~F
6	ALL ZEROS
7	ALL ZEROS

In both cases I_2 and I_5 are complements and only one multiplexer is needed to realize this function.

$g1=g1(A,B,C)$ and $g2=g2(D,E,F)$) which result in different solutions to this minimization process is twenty (720/36). Table 2.5 lists these permutations.

Note that combination groups such as (A,B,C, D,E,F) and (D,E,F, A,B,C) do not result in the same number of multiplexers when they are reduced. Tables 2.6 and 2.7 perform the minimization process on Example 1 presented in Section 2.2.1 for the permutation where $g1=g1(D,E,F)$ and $g2=g2(A,B,C)$. In this case the set of F inputs for I_0 and I_1 are equivalent. Therefore, this particular permutation can be reduced by one multiplexer, whereas the first permutation considered in Table 2.1 was reduced by two multiplexers.

Appendix B contains a complete output for Example 1.

2.3 SUMMARY

This section describes the minimization method implemented in the MINIZE computer program. This process realizes a six variable boolean function in a minimum number of multiplexers. An example function is examined to aid the reader in understanding the process.

Also presented is a description of and rationale for the twenty permutations or cases that the program must consider in order to determine the minimum.

TABLE 2.5 PERMUTATIONS PROVIDING UNIQUE SOLUTIONS

<u>NUMBER</u>	<u>PERMUTATION</u>	<u>NUMBER</u>	<u>PERMUTATION</u>
1	ABC DEF	11	DEF ABC
2	ABD CEF	12	CEF ABD
3	ABE CDF	13	CDF ABE
4	ABF CDE	14	CDE ABF
5	ACD BEF	15	BEF ACD
6	ACE BDF	16	BDF ACE
7	ACF BDE	17	BDE ACF
8	ADE BCF	18	BCF ADE
9	ADF BCE	19	BCE ADF
10	AEF BCD	20	BCD AEF

TABLE 2.6 ORDERED MINTERMS OF EXAMPLE 1 FORPERMUTATION (D,E,F, A,B,C)

<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
DEFABC				
	000011	011000	000110	0
	000111	111000	000111	0
	001100	100001	001110	1
	001110	110001	001111	1
	001111	111001	010110	2
	010011	011010	011000	3
	010111	111010	011010	3
	011011	011011	011011	3
	011100	100011	011100	3
	011101	101011	011111	3
	011111	111011	100001	4
	100011	011100	100011	4
	100111	111100	100101	4
	101100	100101	100110	4
	101101	101101	101011	5
	101110	110101	101101	5
	110000	000110	101110	5
	110001	001110	110001	6
	110010	010110	110101	6
	110100	100110	111000	7
	110101	101110	111001	7
	110111	111110	111010	7
	111000	000111	111011	7
	111001	001111	111100	7
	111011	011111	111110	7

TABLE 2.7 F INPUTS FOR EXAMPLE 1 FOR
PERMUTATION (D,E,F, A,B,C)

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	1
1	0	0	0	1
2	0	0	0	$\sim F$
3	$\sim F$	1	$\sim F$	F
4	F	F	F	$\sim F$
5	0	F	F	$\sim F$
6	F	0	F	0
7	1	1	$\sim F$	$\sim F$

SECTION III: USER'S MANUAL3.1 OVERVIEW

This section describes the inputs and outputs of the MINIZE computer program. Instructions for operating the model are also presented.

3.2 INPUTS

The MINIZE program is an interactive program which prompts the user with questions on each of the necessary inputs or options available. Table 3.1 lists all these questions. A comment section in this table is provided to describe the options available to the user and any limitations on the responses.

3.3 OUTPUTS

The program's output begins with a printed hard copy of the entered minterms and their associated binary equivalent. Table 3.2 is an example of this printout for the function in Example 1.

At the end of the input section, the program will ask if the user wishes a list of the twenty permutations. If the user answers yes (Y), the program will print these permutations either on the CRT or the thermal printer, depending on the user-selected printout option. Table 2.5 is an example of this printout.

If the slow detailed version has been selected the program will print three tables for each of the twenty

TABLE 3.1 LIST OF INPUT QUESTIONS

<u>QUESTION NUMBER</u>	<u>QUESTION</u>	<u>COMMENT</u>
Q-1	Enter the number of minterms in this six variable function:	a) Integer b) $1 \leq \text{Number} \leq 64$
Q-2	Enter the minterms:	a) Integers b) $0 \leq \text{Minterm} \leq 63$ c) Each minterm must be unique Note: Minterms are then printed on the CRT
Q-3	Are these correct (Y or N)?	a) Y-if minterms correct b) N-if not correct (will return user to Q-1)
Q-4	Do you want to run the fast version or the slow detailed printout version (F=Fast or S=Slow)?	a) F-prints only current permutation number & minimum number of multiplexers required to date on the CRT (questions continue with Q-5)
If "S" is selected for Q-4, then:		b) S-prints intermediate results for each permutation and notes minimum to date on selected printout option: 16=CRT 0=Thermal printer
Q-4a	Do you want the detailed printout to appear on the CRT or do you want a hard copy (16=CRT 0=hard copy)?	
Q-5	Do you want to list the permutations (Y or N)?	a) Y-lists the 20 permutations b) N-does not
At the end of the program, after the current function has be evaluated:		
Q-6	Do you wish to evaluate another function (Y or N)?	a) Y-returns user to Q-1 b) N-ends program

TABLE 3.2 SAMPLE PRINTOUT OF THE ORIGINAL MINTERMS
WITH THEIR BINARY EQUIVALENT FOR EXAMPLE 1

LIST OF MINTERMS

<u>ORIGINAL MINTERM</u>	<u>BINARY EQUIVALENT</u>
3	000011
7	000111
12	001100
14	001110
15	001111
19	010011
23	010111
27	011011
28	011100
29	011101
31	011111
35	100011
39	100111
44	101100
45	101101
46	101110
48	110000
49	110001
50	110010
52	110100
53	110101
55	110111
56	111000
57	111001
59	111011

permutations. These tables will be printed on the user-selected printout option. Tables 3.3 through 3.5 contain sample printouts of each of these tables for the permutation A,B,C, D,E,F in Example 1.

The first table (Table 3.3) lists the following information:

- 1) the current permutation
- 2) the original minterms
- 3) the minterms after this permutation
- 4) the sorted minterms after this permutation (in ascending order), and
- 5) the I value for the rearranged minterm.

This table is then followed by the unreduced F inputs table for this permutation (Table 3.4). The third table for the permutation is then the reduced F inputs (Table 3.5).

If the fast output version is selected, the program displays on the CRT the permutation number that the program is currently evaluating, and the permutation number that so far can be realized in the minimum number of multiplexers. This minimum number of multiplexers required to date is also displayed. This display also appears on the CRT if the slow version is selected.

After all twenty permutations have been evaluated, MINIZE will print on the thermal printer the permutation that reduces to the minimum number of multiplexers necessary in order to realize the given function. The required inputs for this case are also printed. Table 3.6 is an example of

TABLE 3.3 SAMPLE PRINTOUT OF MINTERMS FOR PERMUTATIONA,B,C, D,E,F FOR EXAMPLE 1

<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
ABCDEF				
	000011	000011	000011	0
	000111	000111	000111	0
	001100	001100	001100	1
	001110	001110	001110	1
	001111	001111	001111	1
	010011	010011	010011	2
	010111	010111	010111	2
	011011	011011	011011	3
	011100	011100	011100	3
	011101	011101	011101	3
	011111	011111	011111	3
	100011	100011	100011	4
	100111	100111	100111	4
	101100	101100	101100	5
	101101	101101	101101	5
	101110	101110	101110	5
	110000	110000	110000	6
	110001	110001	110001	6
	110010	110010	110010	6
	110100	110100	110100	6
	110101	110101	110101	6
	110111	110111	110111	6
	111000	111000	111000	7
	111001	111001	111001	7
	111011	111011	111011	7

Note that in this case the minterms after this permutation are equal to the original minterms. Table 2.6 is another example of this type printout for permutation D,E,F, A,B,C.

TABLE 3.4 SAMPLE PRINTOUT OF THE UNREDUCED F INPUTSTABLE FOR PERMUTATION (A,B,C, D,E,F) FOR EXAMPLE 1UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	0	1	2	3
0	0	F	0	F
1	0	0	~F	1
2	0	F	0	F
3	0	F	1	F
4	0	F	0	F
5	0	0	1	~F
6	1	~F	1	F
7	1	F	0	0

TABLE 3.5 SAMPLE PRINTOUT OF THE REDUCED F INPUTSTABLE FOR PERMUTATION (A,B,C, D,E,F) FOR EXAMPLE 1REDUCED F MATRIX

MULTIPLEXERS= 6

	<u>g2a(D,E) VALUE</u>				
<u>I VALUE</u>	0	1	2	3	
0	THIS EQUIVALENT TO				I4
1	0	0	~F	1	
2	THIS EQUIVALENT TO				I4
3	0	F	1	F	
4	0	F	0	F	
5	0	0	1	~F	
6	1	~F	1	F	
7	1	F	0	0	

TABLE 3.6 SAMPLE PRINTOUT OF THE MINIMUM
FOR THE FUNCTION IN EXAMPLE 1

MINIMUM MULTIPLEXERS NEEDED IS 5

IT IS PERMUTATION NUMBER 20 WHICH IS THE FOLLOWING:

<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
BCDAEF				
	000011	000011	000011	0
	000111	001011	000111	0
	001100	011000	001011	1
	001110	011010	001111	1
	001111	011011	011000	3
	010011	100011	011010	3
	010111	101011	011011	3
	011011	110011	011100	3
	011100	111000	011101	3
	011101	111001	011110	3
	011111	111011	100011	4
	100011	000111	100100	4
	100111	001111	100101	4
	101100	011100	100110	4
	101101	011101	101011	5
	101110	011110	101100	5
	110000	100100	101101	5
	110001	100101	101111	5
	110010	100110	110011	6
	110100	101100	110100	6
	110101	101101	110101	6
	110111	101111	110111	6
	111000	110100	111000	7
	111001	110101	111001	7
	111011	110111	111011	7

THE INPUTS INTO THESE MULTIPLEXERS ARE AS FOLLOWS:

REDUCED F MATRIX

	<u>g2a(D,E) VALUE</u>				
<u>I VALUE</u>	0	1	2	3	
0	THIS EQUIVALENT TO				I1
1	0	F	0	F	
2	ALL VALUES = ZERO				
3	~F	1	1	~F	
4	0	F	1	~F	
5	THIS EQUIVALENT TO				I6
6	0	F	1	F	
7	1	F	0	0	

this printout for Example 1.

Appendix E contains a full detailed printout of all permutations for Example 1.

3.4 OPERATING INSTRUCTIONS

In order to run the MINIZE program, the user must perform the following steps on the HP9845B desktop computer:

- 1) Place the program tape in the right-hand tape reader.
- 2) Type LOAD "MINIZE" and press the EXECUTE key.
- 3) When the tape stops, press the RUN key.
- 4) Answer the prompted input questions.

The program can be stopped during execution by pressing the STOP key. To begin completely over again, press the STOP key twice and then the RUN key.

SECTION IV: PROGRAM DESCRIPTION4.1 OVERVIEW

This section describes the program MINIZE by providing an explanation of each of the subroutines.

Flowcharts of most of the routines can be found in Appendix A. Some routines are very short, so only an explanation of their purpose is given in this section. A complete listing of the program is provided in Appendix C.

4.2 PROGRAM MINIZE

This is the executive routine. It controls the calling order of all the subroutines and, at the end, prints the permutation which can be realized in a minimum number of 4-input multiplexers. It also prints the required inputs into these multiplexers.

4.3 SUBROUTINE INTRO

This routine introduces the user to the MINIZE program by printing the following on the CRT:

M I N I Z E

THIS PROGRAM WILL REALIZE A SIX VARIABLE COMBINATIONAL BOOLEAN FUNCTION $F(A,B,C,D,E,F)$ IN A MINIMUM NUMBER OF 4-INPUT MULTIPLEXERS. YOU WILL BE ASKED FOR THE NUMBER OF MINTERMS (OR ELEMENTS) AND THEN WHAT THESE MINTERMS ARE.

MINIZE WILL OUTPUT TO YOU THE MINIMUM NUMBER OF 4-INPUT MULTIPLEXERS YOU WILL NEED AND WHAT EACH OF THE INPUTS ARE INTO EACH MULTIPLEXER.

PRESS CONT WHEN YOU ARE READY.

4.4 SUBROUTINE READ-DATA

This routine initializes various arrays, variables and flags used throughout MINIZE. Table 4.1 lists some of these variables and arrays and their purpose.

4.5 SUBROUTINE GET-INPUTS

Subroutine Get-inputs prompts the user with questions on each of the required inputs and options available. Table 3.1 listed all of these questions.

Certain checks are made on some of the inputs, and as a result an error message may appear on the CRT. The flowchart of this subroutine in Appendix A has labeled the three different error messages by number. They are as follows:

Error Message #1: "NUMBER OF MINTERMS MUST BE BETWEEN
1 AND 64 INCLUSIVE."

Error Message #2: "MINTERMS MUST BE BETWEEN 0 AND 63
INCLUSIVE."

Error Message #3: "EACH MINTERM MUST BE UNIQUE."

4.6 SUBROUTINE ASSIGN-F-VALUES

This subroutine creates the unreduced F table by assigning all the F inputs (one for each $g2a(D,E)$ index under each I value). This is Step 4 in the minimization process, which is outlined in Section 2.2 and is described in more detail in Section 2.2.1.

TABLE 4.1 PARTIAL LIST OF DATA ARRAYS AND VARIABLES

<u>NAME</u>	<u>ARRAY/VARIABLE</u>	<u>TYPE</u>	<u>PURPOSE</u>
Perm	array	Integer	The 20 permutations to be evaluated (numeric values)
Alpha-perm\$	array	Alpha-numeric	The alpha-numeric values of the 20 permutations
Dividend	array	Integer	The powers of 2 necessary to calculate the binary equivalents
All1\$	variable	Alpha-numeric	Prints "ALL VALUES = ONE" message
All0\$	variable	Alpha-numeric	Prints "ALL VALUES = ZERO" message
Equiv\$	variable	Alpha-numeric	Prints "THIS EQUIVALENT TO" message
Compl\$	variable	Alpha-numeric	Prints "THIS COMPLEMENT OF" message
Numb\$	array	Alpha-numeric	Prints "I0" through "I7" for equiv/comple messages
Zero\$	variable	Alpha-numeric	Prints " 0 "
One\$	variable	Alpha-numeric	Prints " 1 "
Default\$	variable	Alpha-numeric	Prints " " (blanks)
Inp-f\$	variable	Alpha-numeric	Prints " F "
Inp-nf\$	variable	Alpha-numeric	Prints " ~F "
Min-mult	variable	Integer	Stores minimum number of multiplexers to date. Initialized to 9.
Min-where	variable	Integer	Stores minimum permutation number to date. Initialized to 0.

4.7 SUBROUTINE REDUCE

The unreduced F table is examined in this subroutine to determine if any of the multiplexers can be eliminated. This is Step 5 in the minimization process and is explained in Section 2.2. After examining the unreduced F table and creating the reduced F table, this subroutine then checks to see if this permutation requires fewer multiplexers than the minimum to date. If it does, this permutation and its reduced F inputs are then stored as the new minimum to date.

SECTION V: SUMMARY

This paper describes the MINIZE computer program, which is a minimization model that can be used to aid in the design and optimization of a digital system. The model is written in HP Basic for use on a Hewlett-Packard 9845B desktop computer with Advanced Programming capability.

An interactive input section allows the user to enter any six variable boolean function. MINIZE then evaluates this function according to the methods and procedures of a minimization process which realizes this function in a multiplexer network designed in two stages. The input-stage normally requires eight four-input multiplexers which then feed into an output-stage consisting of a single eight-input multiplexer. This computer model will attempt to reduce the number of input-stage multiplexers required.

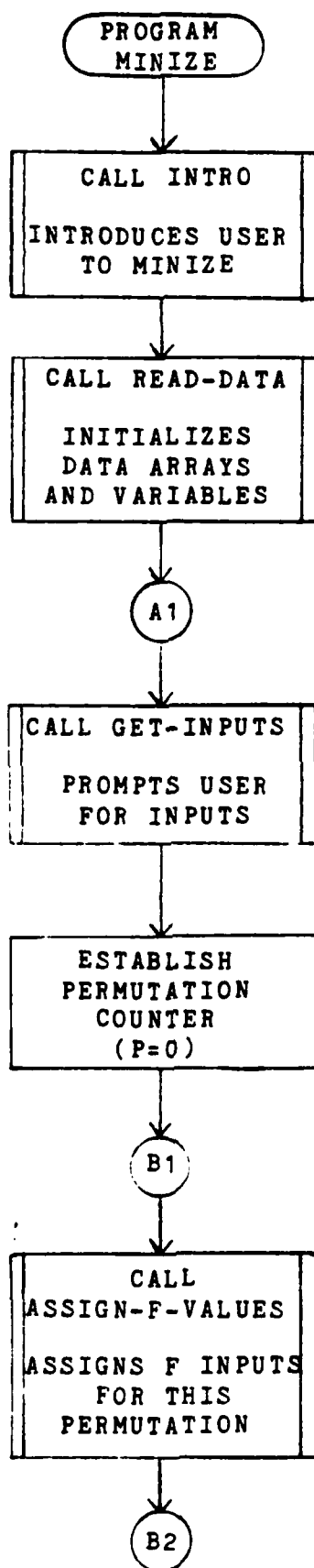
A description of the minimization process, along with a program description, user's guide, flowchart, listing and sample printout are all provided to aid both the reader and user.

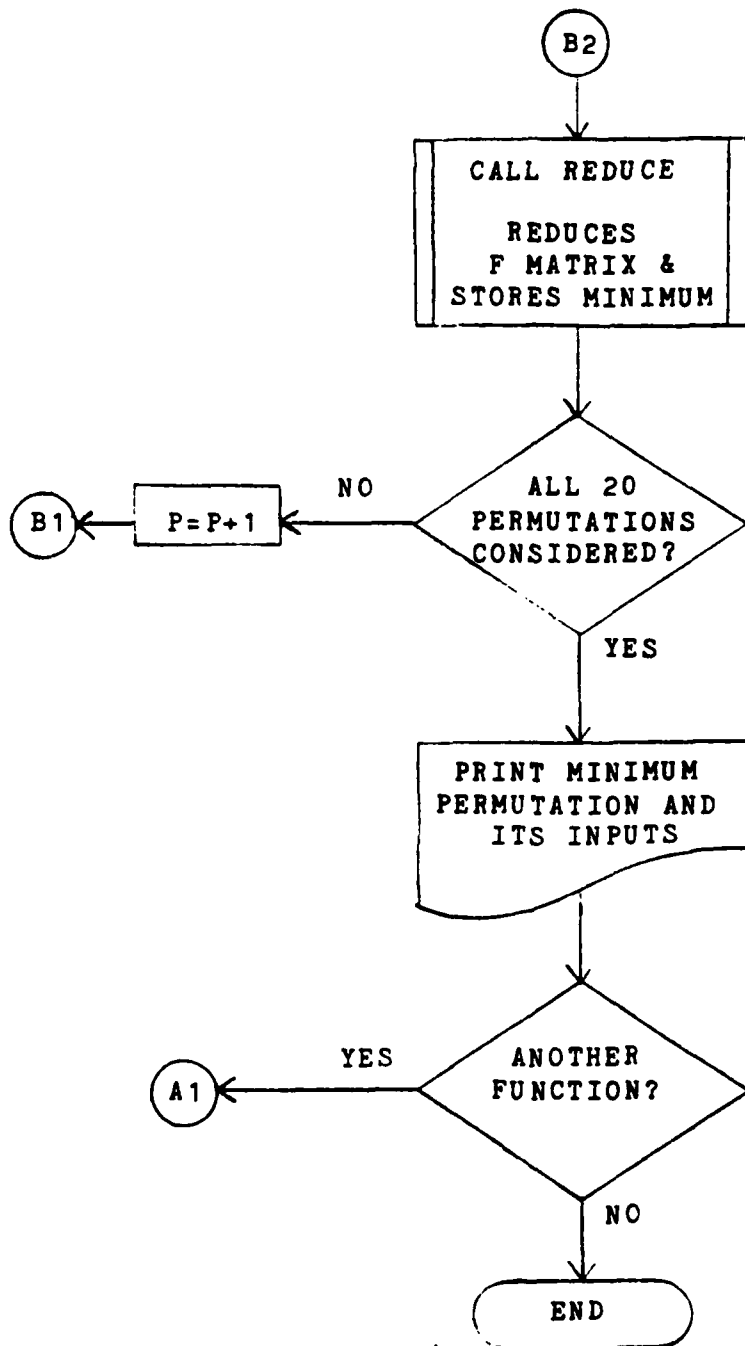
REFERENCES

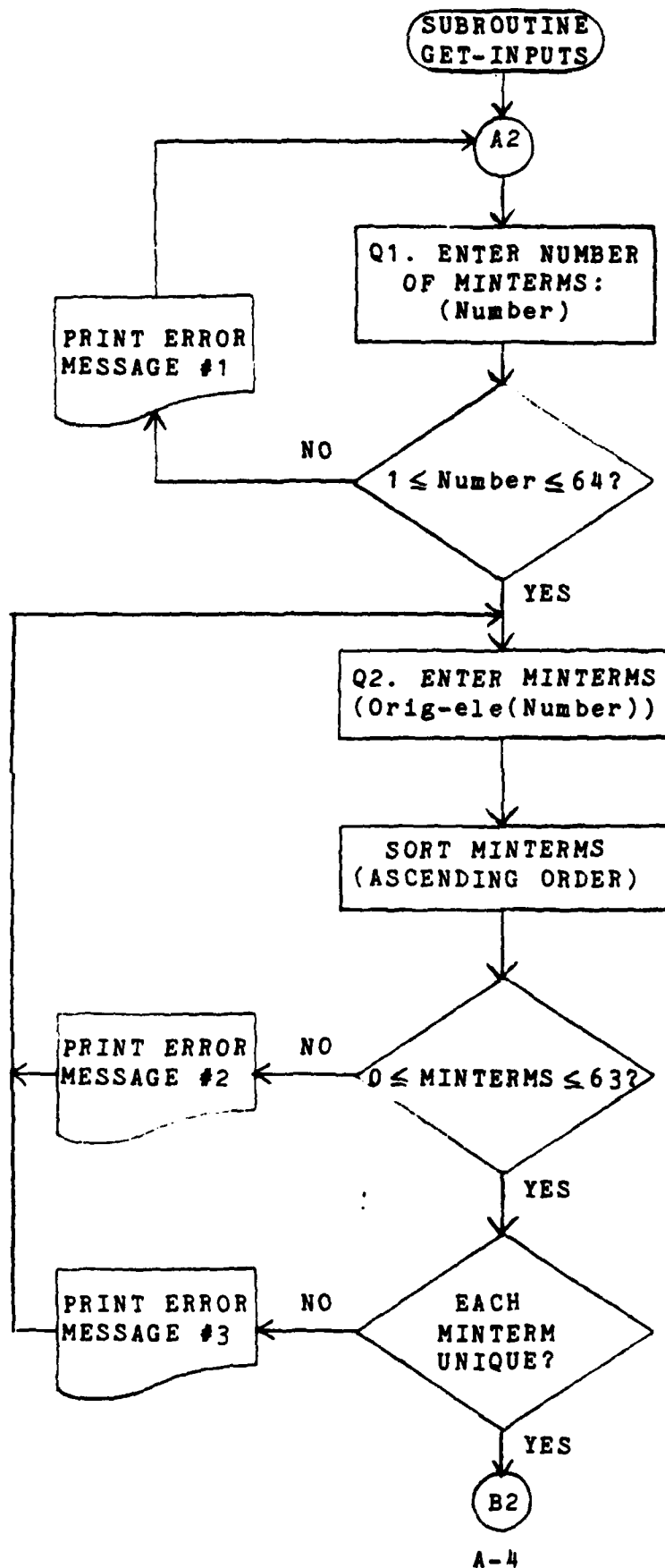
- (1) Barna, Arpad and Porat, Dan I., Integrated Circuits in Digital Electronics, John Wiley & Sons, New York, 1973.

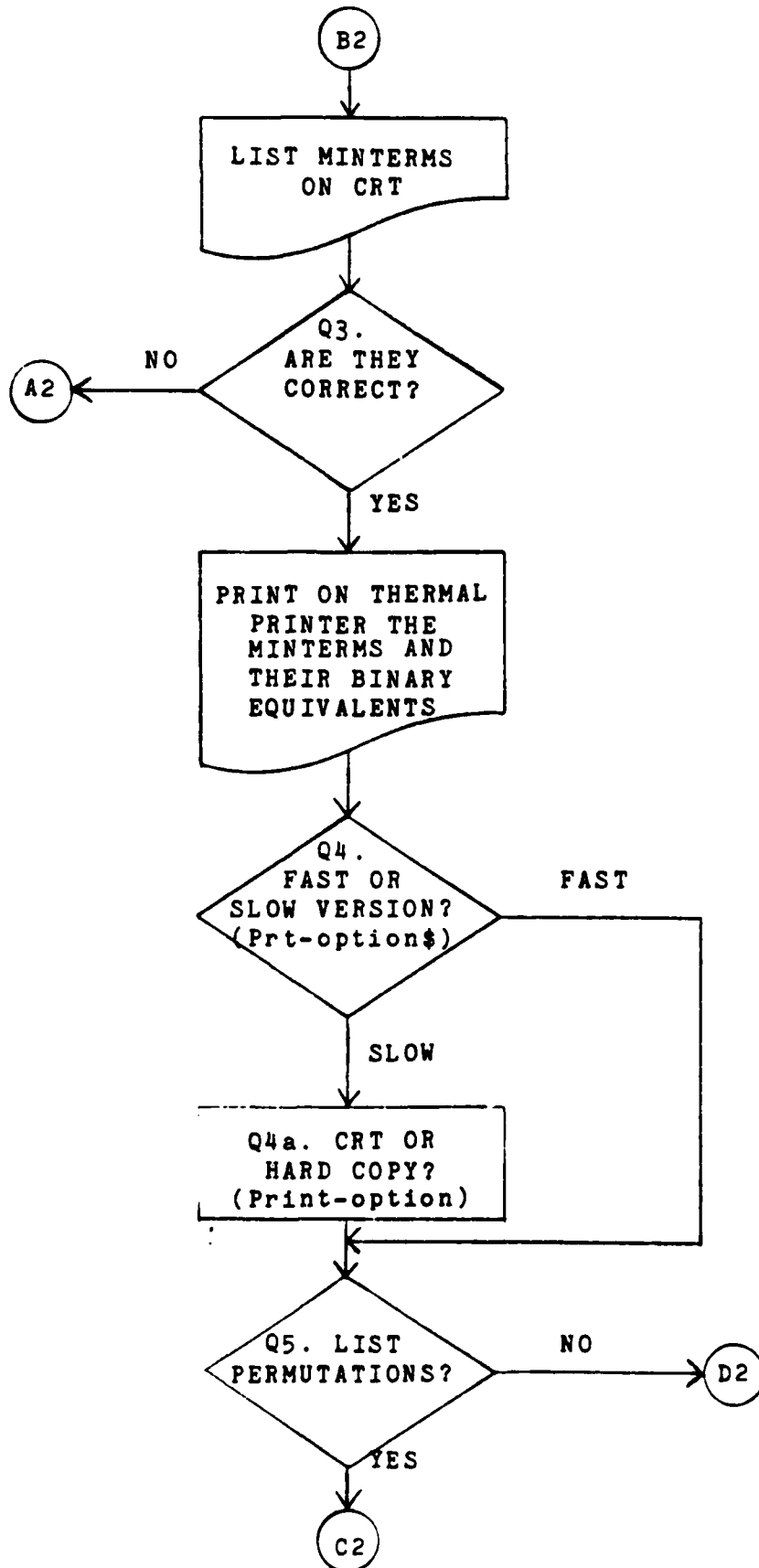
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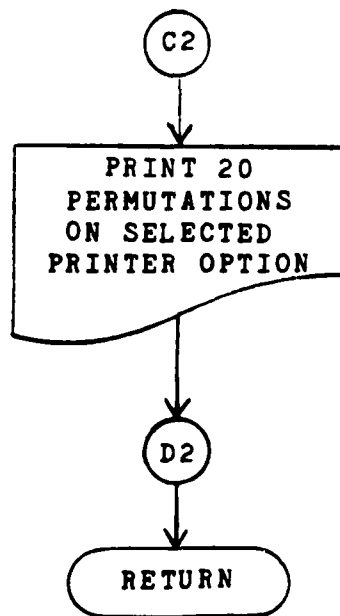
APPENDIX A:
FLOWCHARTS FOR MINIZE











SUBROUTINE
ASSIGN-F-VALUES

PRINT ON CRT
CURRENT
PERMUTATION
NUMBER

PRINT ON CRT
MINIMUM TO DATE
AND NUMBER OF
MULTIPLEXERS

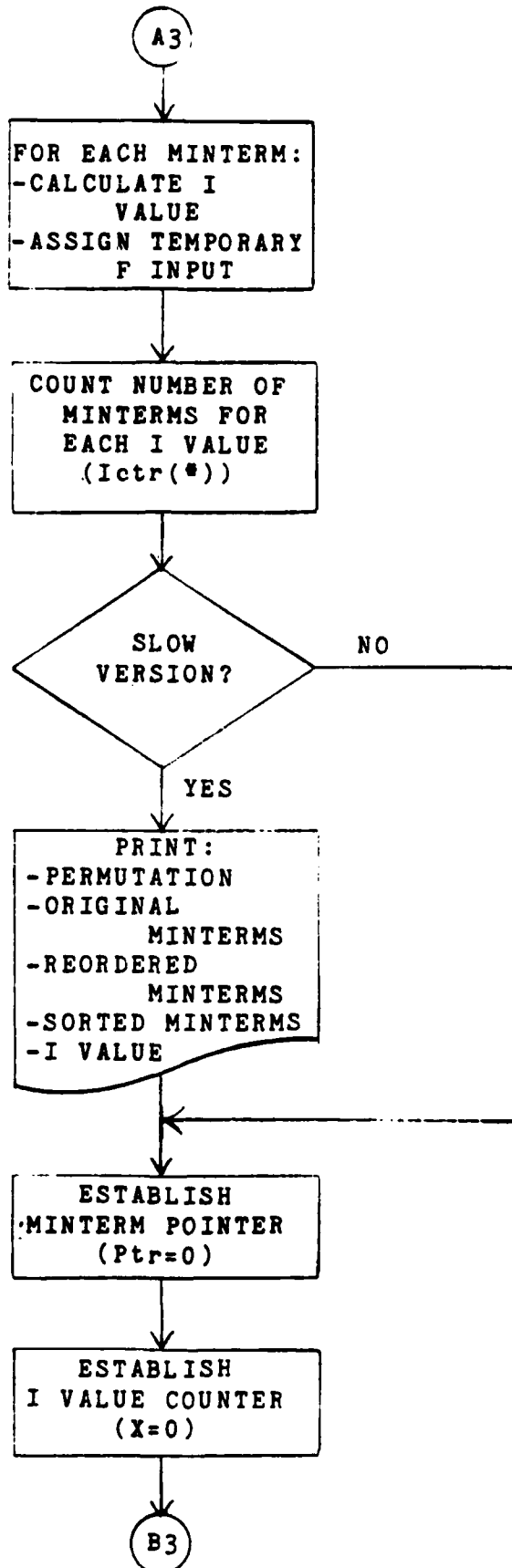
ASSIGN ORDERING
ARRAY THIS
PERMUTATION
(Point)

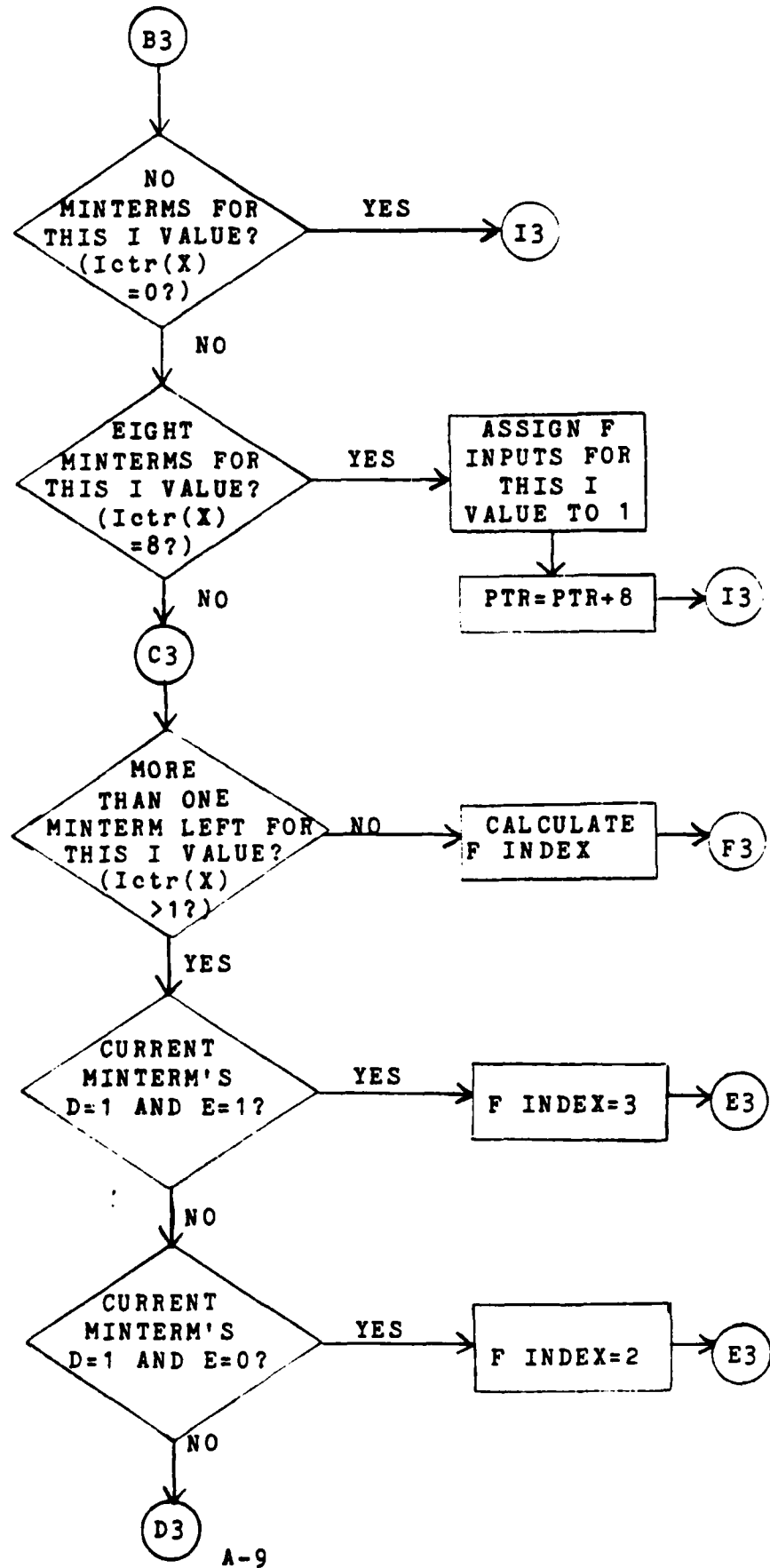
INITIALIZE
ARRAYS AND
VARIABLES

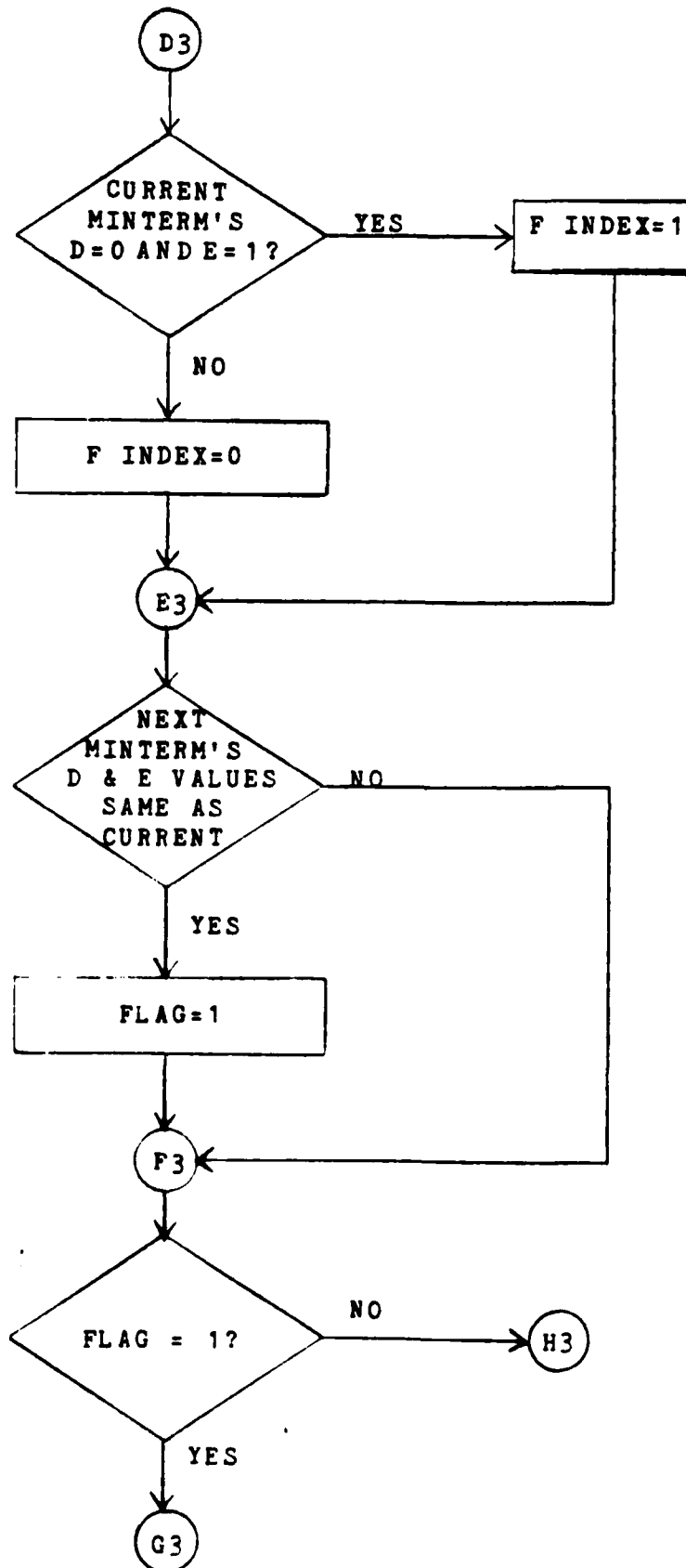
REORDER MINTERMS
FOR THIS
PERMUTATION
BY Point

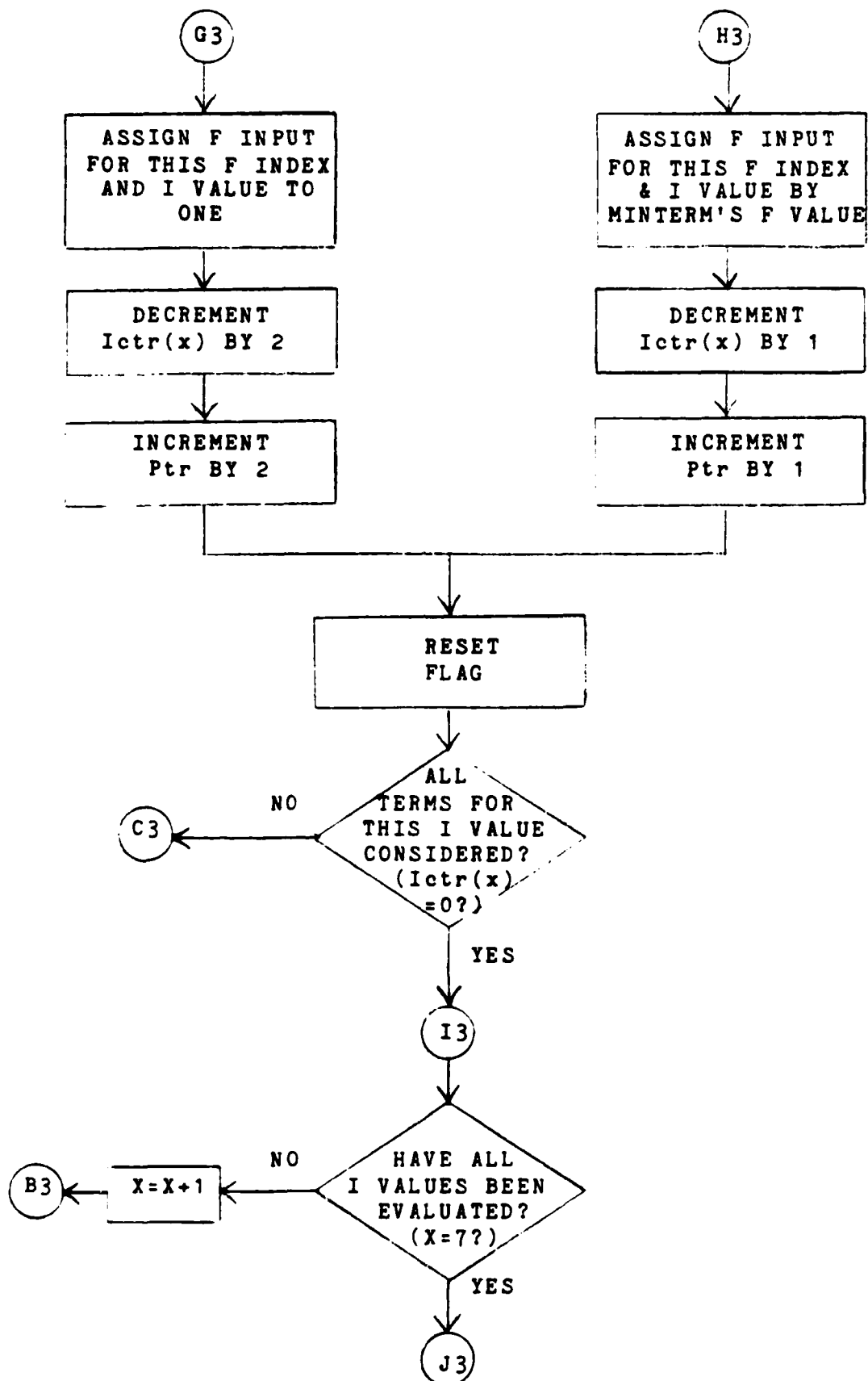
SORT REORDERED
MINTERMS

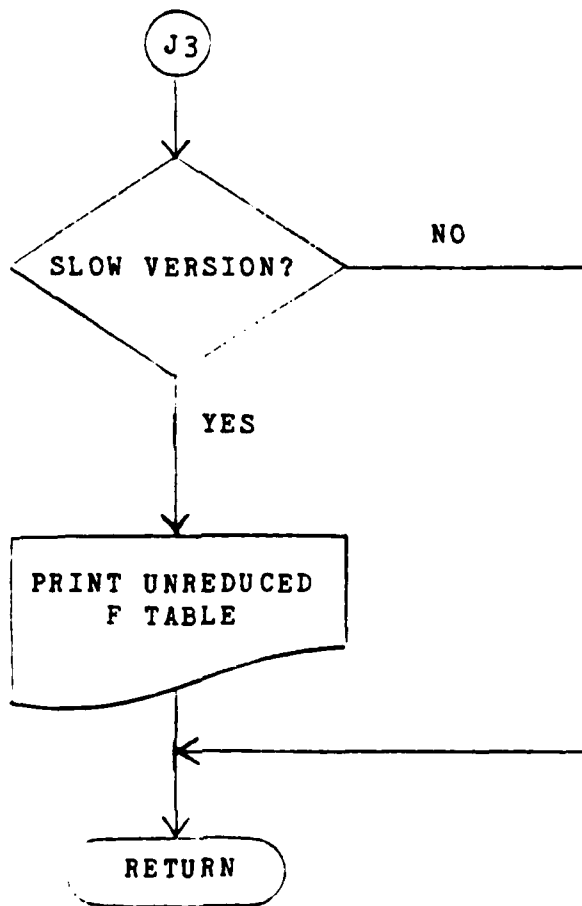
A3

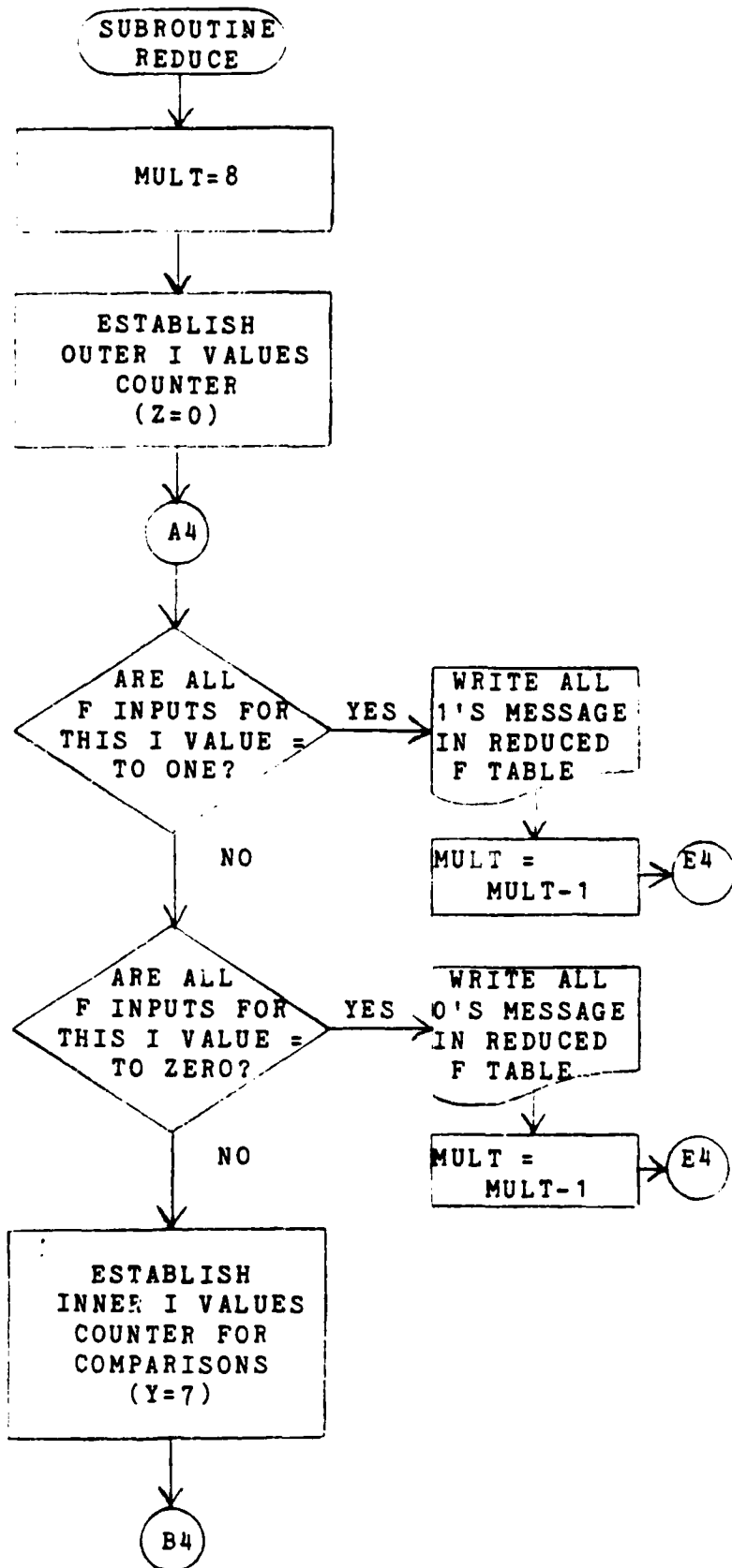


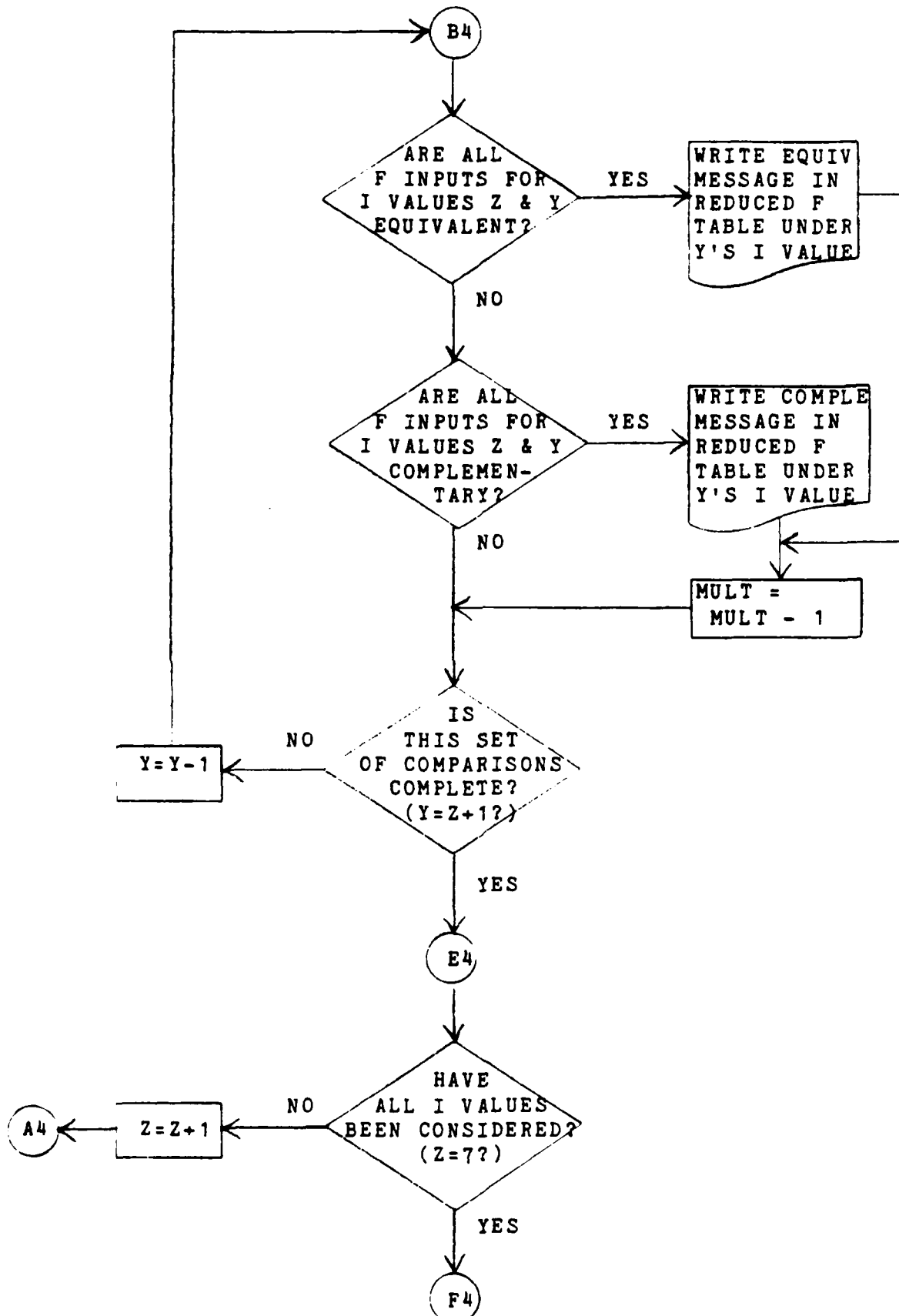


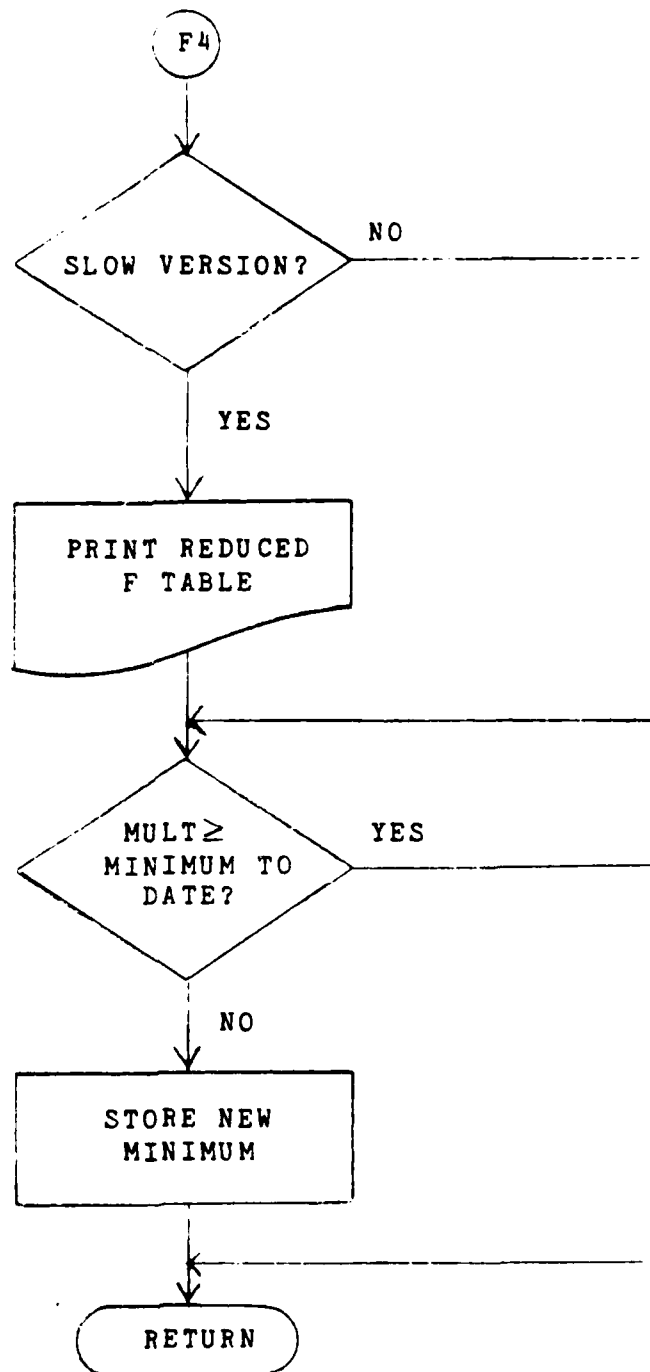












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APPENDIX B:
COMPLETE DETAILED OUTPUT FOR THE
FUNCTION IN EXAMPLE 1

LIST OF MINTERMS

<u>ORIGINAL MINTERM</u>	<u>BINARY EQUIVALENT</u>
3	000011
7	000111
12	001100
14	001110
15	001111
19	010011
23	010111
27	011011
28	011100
29	011101
31	011111
35	100011
39	100111
44	101100
45	101101
46	101110
48	110000
49	110001
50	110010
52	110100
53	110101
55	110111
56	111000
57	111001
59	111011

LIST OF PERMUTATIONS

<u>NUMBER</u>	<u>PERMUTATION</u>	<u>NUMBER</u>	<u>PERMUTATION</u>
1	ABCDEF	11	DEFABC
2	ABDCEF	12	CEFABD
3	ABECDF	13	CDFABE
4	ABFCDE	14	CDEABF
5	ACDBEF	15	BEFACD
6	ACEBDF	16	BDFACE
7	ACFBDE	17	BDEACF
8	ADEBCF	18	BCFADE
9	ADFBCE	19	BCEADF
10	AEFBCD	20	BCDAEF

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<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
ABCDEF				
	000011	000011	000011	0
	000111	000111	000111	0
	001100	001100	001100	1
	001110	001110	001110	1
	001111	001111	001111	1
	010011	010011	010011	2
	010111	010111	010111	2
	011011	011011	011011	3
	011100	011100	011100	3
	011101	011101	011101	3
	011111	011111	011111	3
	100011	100011	100011	4
	100111	100111	100111	4
	101100	101100	101100	5
	101101	101101	101101	5
	101110	101110	101110	5
	110000	110000	110000	6
	110001	110001	110001	6
	110010	110010	110010	6
	110100	110100	110100	6
	110101	110101	110101	6
	110111	110111	110111	6
	111000	111000	111000	7
	111001	111001	111001	7
	111011	111011	111011	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	F	0	F
1	0	0	$\sim$ F	1
2	0	F	0	F
3	0	F	1	F
4	0	F	0	F
5	0	0	1	$\sim$ F
6	1	$\sim$ F	1	F
7	1	F	0	0

REDUCED F MATRIX

MULTIPLEXERS=6

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	THIS EQUIVALENT TO			
1	0	0	$\sim$ F	1
2	THIS EQUIVALENT TO			
3	0	F	1	F
4	0	F	0	F
5	0	0	1	$\sim$ F
6	1	$\sim$ F	1	F
7	1	F	0	0

THIS IS A NEW MINIMUM: ABCDEF

MULTIPLEXERS = 6

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<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
ABDCEF	000011	000011	000011	0
	000111	001011	001011	1
	001100	001100	001100	1
	001110	001110	001110	1
	001111	001111	001111	1
	010011	010011	010011	2
	010111	011011	010111	2
	011011	010111	011011	3
	011100	011100	011100	3
	011101	011101	011101	3
	011111	011111	011111	3
	100011	100011	100011	4
	100111	101011	101011	5
	101100	101100	101100	5
	101101	101101	101101	5
	101110	101110	101110	5
	110000	110000	110000	6
	110001	110001	110001	6
	110010	110010	110010	6
	110100	111000	110100	6
	110101	111001	110101	6
	110111	111011	110111	6
	111000	110100	111000	7
	111001	110101	111001	7
	111011	110111	111011	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	F	0	0
1	0	F	$\sim$ F	1
2	0	F	0	F
3	0	F	1	F
4	0	F	0	0
5	0	F	1	$\sim$ F
6	1	$\sim$ F	1	F
7	1	F	0	0

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	THIS EQUIVALENT TO 14			
1	0	F	$\sim$ F	1
2	0	F	0	F
3	0	F	1	F
4	0	F	0	0
5	0	F	1	$\sim$ F
6	1	$\sim$ F	1	F
7	1	F	0	0

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<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
ABECDF				
	000011	001001	000110	0
	000111	001011	001001	1
	001100	000110	001011	1
	001110	001110	001110	1
	001111	001111	001111	1
	010011	011001	010110	2
	010111	011011	010111	2
	011011	011101	011001	3
	011100	010110	011011	3
	011101	010111	011101	3
	011111	011111	011111	3
	100011	101001	100110	4
	100111	101011	100111	4
	101100	100110	101001	5
	101101	100111	101011	5
	101110	101110	101110	5
	110000	110000	110000	6
	110001	110001	110001	6
	110010	111000	110010	6
	110100	110010	110011	6
	110101	110011	110100	6
	110111	111011	110101	6
	111000	110100	111000	7
	111001	110101	111011	7
	111011	111101	111101	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	$\sim F$
1	F	F	0	1
2	0	0	0	1
3	F	F	F	F
4	0	0	0	1
5	F	F	0	$\sim F$
6	1	1	1	0
7	$\sim F$	F	F	0

REDUCED F MATRIX

MULTIPLEXERS-6

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	$\sim F$
1	F	F	0	1
2	THIS COMPLEMENT OF			
3	F	F	F	F
4	THIS COMPLEMENT OF			
5	F	F	0	$\sim F$
6	1	1	1	0
7	$\sim F$	F	F	0

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<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
ABFCDE				
	000011	001001	000110	0
	000111	001011	000111	0
	001100	000110	001001	1
	001110	000111	001011	1
	001111	001111	001111	1
	010011	011001	010110	2
	010111	011011	011001	3
	011011	011101	011011	3
	011100	010110	011101	3
	011101	011110	011110	3
	011111	011111	011111	3
	100011	101001	100110	4
	100111	101011	100111	4
	101100	100110	101001	5
	101101	101110	101011	5
	101110	100111	101110	5
	110000	110000	110000	6
	110001	111000	110001	6
	110010	110001	110010	6
	110100	110010	110100	6
	110101	111010	111000	7
	110111	111011	111010	7
	111000	110100	111011	7
	111001	111100	111100	7
	111011	111101	111101	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	1
1	F	F	0	F
2	0	0	0	$\sim$ F
3	F	F	F	1
4	0	0	0	1
5	F	F	0	$\sim$ F
6	1	$\sim$ F	$\sim$ F	0
7	$\sim$ F	1	1	0

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	THIS EQUIVALENT TO 14			
1	F	F	0	F
2	0	0	0	$\sim$ F
3	F	F	F	1
4	0	0	0	1
5	F	F	0	$\sim$ F
6	1	$\sim$ F	$\sim$ F	0
7	$\sim$ F	1	1	0

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<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
ACDBEF	000011	000011	000011	0
	000111	001011	000111	0
	001100	011000	001011	1
	001110	011010	001111	1
	001111	011011	010111	2
	010011	000111	011000	3
	010111	001111	011010	3
	011011	010111	011011	3
	011100	011100	011100	3
	011101	011101	011101	3
	011111	011111	011111	3
	100011	100011	100011	4
	100111	101011	100100	4
	101100	111000	100101	4
	101101	111001	100110	4
	101110	111010	101011	5
	110000	100100	101100	5
	110001	100101	101101	5
	110010	100110	101111	5
	110100	101100	110100	6
	110101	101101	110101	6
	110111	101111	110111	6
	111000	110100	111000	7
	111001	110101	111001	7
	111011	110111	111010	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	F	0	F
1	0	F	0	F
2	0	0	0	F
3	$\sim$ F	1	1	F
4	0	F	1	$\sim$ F
5	0	F	1	F
6	0	0	1	F
7	1	$\sim$ F	0	0

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	THIS EQUIVALENT TO 11			
1	0	F	0	F
2	0	0	0	F
3	$\sim$ F	1	1	F
4	0	F	1	$\sim$ F
5	0	F	1	F
6	0	0	1	F
7	1	$\sim$ F	0	0

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<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
ACEBDF				
	000011	001001	001001	1
	000111	001011	001011	1
	001100	010010	001101	1
	001110	011010	001111	1
	001111	011011	010010	2
	010011	001101	010110	2
	010111	001111	010111	2
	011011	011101	011010	3
	011100	010110	011011	3
	011101	010111	011101	3
	011111	011111	011111	3
	100011	101001	100100	4
	100111	101011	100101	4
	101100	110010	100110	4
	101101	110011	100111	4
	101110	111010	101001	5
	110000	100100	101011	5
	110001	100101	101100	5
	110010	101100	101111	5
	110100	100110	110010	6
	110101	100111	110011	6
	110111	101111	110100	6
	111000	110100	110101	6
	111001	110101	111010	7
	111011	111101	111101	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	0
1	F	F	F	F
2	0	$\sim$ F	0	1
3	0	1	F	F
4	0	0	1	1
5	F	F	$\sim$ F	F
6	0	1	1	0
7	0	$\sim$ F	F	0

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	ALL VALUES = ZERO			
1	F	F	F	F
2	0	$\sim$ F	0	1
3	0	1	F	F
4	0	0	1	1
5	F	F	$\sim$ F	F
6	0	1	1	0
7	0	$\sim$ F	F	0

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<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
ACFBDE				
	000011	001001	001001	1
	000111	001011	001011	1
	001100	010010	001101	1
	001110	010011	001111	1
	001111	011011	010010	2
	010011	001101	010011	2
	010111	001111	010110	2
	011011	011101	011011	3
	011100	010110	011101	3
	011101	011110	011110	3
	011111	011111	011111	3
	100011	101001	100100	4
	100111	101011	100101	4
	101100	110010	100110	4
	101101	111010	101001	5
	101110	110011	101011	5
	110000	100100	101100	5
	110001	101100	101110	5
	110010	100101	101111	5
	110100	100110	110010	6
	110101	101110	110011	6
	110111	101111	110100	6
	111000	110100	111010	7
	111001	111100	111100	7
	111011	111101	111101	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	0
1	F	F	F	F
2	0	1	0	$\sim$ F
3	0	F	F	1
4	0	0	1	$\sim$ F
5	F	F	$\sim$ F	1
6	0	1	$\sim$ F	0
7	0	$\sim$ F	1	0

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	ALL VALUES = ZERO			
1	F	F	F	F
2	0	1	0	$\sim$ F
3	0	F	F	1
4	0	0	1	$\sim$ F
5	F	F	$\sim$ F	1
6	0	1	$\sim$ F	0
7	0	$\sim$ F	1	0

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<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
ADEBCF				
	000011	001001	001001	1
	000111	011001	001101	1
	001100	010010	001111	1
	001110	011010	010010	2
	001111	011011	010110	2
	010011	001101	010111	2
	010111	011101	011001	3
	011011	001111	011010	3
	011100	010110	011011	3
	011101	010111	011101	3
	011111	011111	011111	3
	100011	101001	100100	4
	100111	111001	100101	4
	101100	110010	100110	4
	101101	110011	100111	4
	101110	111010	101001	5
	110000	100100	101100	5
	110001	100101	101111	5
	110010	101100	110010	6
	110100	110100	110011	6
	110101	110101	110100	6
	110111	111101	110101	6
	111000	100110	111001	7
	111001	100111	111010	7
	111011	101111	111101	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	0
1	F	0	F	F
2	0	$\sim$ F	0	1
3	F	1	F	F
4	0	0	1	1
5	F	0	$\sim$ F	F
6	0	1	1	0
7	F	$\sim$ F	F	0

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	ALL VALUES = ZERO			
1	F	0	F	F
2	0	$\sim$ F	0	1
3	F	1	F	F
4	0	0	1	1
5	F	0	$\sim$ F	F
6	0	1	1	0
7	F	$\sim$ F	F	0

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<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
ADFBCE				
	000011	001001	001001	1
	000111	011001	001101	1
	001100	010010	001111	1
	001110	010011	010010	2
	001111	011011	010011	2
	010011	001101	010110	2
	010111	011101	011001	3
	011011	001111	011011	3
	011100	010110	011101	3
	011101	011110	011110	3
	011111	011111	011111	3
	100011	101001	100100	4
	100111	111001	100101	4
	101100	110010	100110	4
	101101	111010	101001	5
	101110	110011	101100	5
	110000	100100	101110	5
	110001	101100	101111	5
	110010	100101	110010	6
	110100	110100	110011	6
	110101	111100	110100	6
	110111	111101	111001	7
	111000	100110	111010	7
	111001	101110	111100	7
	111011	101111	111101	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	0
1	F	0	F	F
2	0	1	0	$\sim$ F
3	F	F	F	1
4	0	0	1	$\sim$ F
5	F	0	$\sim$ F	1
6	0	1	$\sim$ F	0
7	F	$\sim$ F	1	0

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	ALL VALUES = ZERO			
1	F	0	F	F
2	0	1	0	$\sim$ F
3	F	F	F	1
4	0	0	1	$\sim$ F
5	F	0	$\sim$ F	1
6	0	1	$\sim$ F	0
7	F	$\sim$ F	1	0

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<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
AEFBCD	000011	011000	000011	0
	000111	011001	000111	0
	001100	000011	001111	1
	001110	010011	010011	2
	001111	011011	011000	3
	010011	011100	011001	3
	010111	011101	011011	3
	011011	011110	011100	3
	011100	000111	011101	3
	011101	001111	011110	3
	011111	011111	011111	3
	100011	111000	100011	4
	100111	111001	100100	4
	101100	100011	100101	4
	101101	101011	100110	4
	101110	110011	101011	5
	110000	100100	101100	5
	110001	101100	101101	5
	110010	110100	101110	5
	110100	100101	110011	6
	110101	101101	110100	6
	110111	111101	111000	7
	111000	100110	111001	7
	111001	101110	111101	7
	111011	111110	111110	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	F	0	F
1	0	0	0	F
2	0	F	0	0
3	1	F	1	1
4	0	F	1	$\sim$ F
5	0	F	1	$\sim$ F
6	0	F	$\sim$ F	0
7	1	0	F	$\sim$ F

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	F	0	F
1	0	0	0	F
2	0	F	0	0
3	1	F	1	1
4	THIS EQUIVALENT TO 15			
5	0	F	1	$\sim$ F
6	0	F	$\sim$ F	0
7	1	0	F	$\sim$ F

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<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
DEFABC				
	000011	011000	000110	0
	000111	111000	000111	0
	001100	100001	001110	1
	001110	110001	001111	1
	001111	111001	010110	2
	010011	011010	011000	3
	010111	111010	011010	3
	011011	011011	011011	3
	011100	100011	011100	3
	011101	101011	011111	3
	011111	111011	100001	4
	100011	011100	100011	4
	100111	111100	100101	4
	101100	100101	100110	4
	101101	101101	101011	5
	101110	110101	101101	5
	110000	000110	101110	5
	110001	001110	110001	6
	110010	010110	110101	6
	110100	100110	111000	7
	110101	101110	111001	7
	110111	111110	111010	7
	111000	000111	111011	7
	111001	001111	111100	7
	111011	011111	111110	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	1
1	0	0	0	1
2	0	0	0	$\sim F$
3	$\sim F$	1	$\sim F$	F
4	F	F	F	$\sim F$
5	0	F	F	$\sim F$
6	F	0	F	0
7	1	1	$\sim F$	$\sim F$

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	THIS	EQUIVALENT	TO	11
1	0	0	0	1
2	0	0	0	$\sim F$
3	$\sim F$	1	$\sim F$	F
4	F	F	F	$\sim F$
5	0	F	F	$\sim F$
6	F	0	F	0
7	1	1	$\sim F$	$\sim F$

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<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
CEFABD				
	000011	011000	000110	0
	000111	011001	000111	0
	001100	100001	001110	1
	001110	110001	001111	1
	001111	111001	010110	2
	010011	011010	011000	3
	010111	011011	011001	3
	011011	111010	011010	3
	011100	100011	011011	3
	011101	101011	011100	3
	011111	111011	011101	3
	100011	011100	011111	3
	100111	011101	100001	4
	101100	100101	100011	4
	101101	101101	100101	4
	101110	110101	100110	4
	110000	000110	101011	5
	110001	001110	101101	5
	110010	010110	101110	5
	110100	000111	110001	6
	110101	001111	110101	6
	110111	011111	111001	7
	111000	100110	111010	7
	111001	101110	111011	7
	111011	111110	111110	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g_{2a}(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	1
1	0	0	0	1
2	0	0	0	$\sim F$
3	1	1	1	F
4	F	F	F	$\sim F$
5	0	F	F	$\sim F$
6	F	0	F	0
7	F	1	0	$\sim F$

REDUCED F MATRIX

MULTIPLEXERS=6

<u>I VALUE</u>	<u>g_{2a}(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	THIS EQUIVALENT TO			
1	0	0	0	1
2	THIS COMPLEMENT OF			
3	1	1	1	F
4	F	F	F	$\sim F$
5	0	F	F	$\sim F$
6	F	0	F	0
7	F	1	0	$\sim F$

<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
CDFABE				
	000011	001001	000110	0
	000111	011001	000111	0
	001100	110000	001001	1
	001110	110001	001011	1
	001111	111001	001101	1
	010011	001011	001110	1
	010111	011011	010110	2
	011011	101011	011001	3
	011100	110010	011011	3
	011101	111010	011101	3
	011111	111011	011110	3
	100011	001101	011111	3
	100111	011101	100110	4
	101100	110100	101011	5
	101101	111100	101110	5
	101110	110101	101111	5
	110000	000110	110000	6
	110001	001110	110001	6
	110010	000111	110010	6
	110100	010110	110100	6
	110101	011110	110101	6
	110111	011111	111001	7
	111000	100110	111010	7
	111001	101110	111011	7
	111011	101111	111100	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	1
1	F	F	F	$\sim$ F
2	0	0	0	$\sim$ F
3	F	F	F	1
4	0	0	0	$\sim$ F
5	0	F	0	1
6	1	$\sim$ F	1	0
7	F	1	$\sim$ F	0

REDUCED F MATRIX

MULTIPLEXERS=6

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	1
1	F	F	F	$\sim$ F
2	THIS EQUIVALENT TO			
3	F	F	F	1
4	0	0	0	$\sim$ F
5	THIS COMPLEMENT OF			
6	1	$\sim$ F	1	0
7	F	1	$\sim$ F	0

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<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
CDEABF				
	000011	001001	000110	0
	000111	011001	000111	0
	001100	110000	001001	1
	001110	111000	001011	1
	001111	111001	001101	1
	010011	001011	001110	1
	010111	011011	010110	2
	011011	101011	010111	2
	011100	110010	011001	3
	011101	110011	011011	3
	011111	111011	011101	3
	100011	001101	011111	3
	100111	011101	100110	4
	101100	110100	100111	4
	101101	110101	101011	5
	101110	111100	101111	5
	110000	000110	110000	6
	110001	000111	110010	6
	110010	001110	110011	6
	110100	010110	110100	6
	110101	010111	110101	6
	110111	011111	111000	7
	111000	100110	111001	7
	111001	100111	111011	7
	111011	101111	111100	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	1
1	F	F	F	$\sim$ F
2	0	0	0	1
3	F	F	F	F
4	0	0	0	1
5	0	F	0	F
6	$\sim$ F	1	1	0
7	1	F	$\sim$ F	0

REDUCED F MATRIX

MULTIPLEXERS-6

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	THIS EQUIVALENT TO			
1	F	F	F	$\sim$ F
2	THIS EQUIVALENT TO			
3	F	F	F	F
4	0	0	0	1
5	0	F	0	F
6	$\sim$ F	1	1	0
7	1	F	$\sim$ F	0

NADC-85135-20

<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
BEFACD				
	000011	011000	000011	0
	000111	011001	000111	0
	001100	000011	001111	1
	001110	010011	010011	2
	001111	011011	010111	2
	010011	111000	011000	3
	010111	111001	011001	3
	011011	111010	011011	3
	011100	100011	011100	3
	011101	101011	011101	3
	011111	111011	100011	4
	100011	011100	100100	4
	100111	011101	100101	4
	101100	000111	100110	4
	101101	001111	101011	5
	101110	010111	101100	5
	110000	100100	101101	5
	110001	101100	101110	5
	110010	110100	110100	6
	110100	100101	111000	7
	110101	101101	111001	7
	110111	111101	111010	7
	111000	100110	111011	7
	111001	101110	111101	7
	111011	111110	111110	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	F	0	F
1	0	0	0	F
2	0	F	0	F
3	1	F	1	0
4	0	F	1	$\sim$ F
5	0	F	1	$\sim$ F
6	0	0	$\sim$ F	0
7	1	1	F	$\sim$ F

REDUCED F MATRIX

MULTIPLEXERS=6

	<u>g_{2a}(D,E) VALUE</u>				
<u>I VALUE</u>	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	
0	THIS	EQUIVALENT	TO		I 2
1	0	0	0	F	
2	0	F	0	F	
3	1	F	1	0	
4	THIS	EQUIVALENT	TO		I 5
5	0	F	1	$\sim$ F	
6	0	0	$\sim$ F	0	
7	1	1	F	$\sim$ F	

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<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
BDFACE				
	000011	001001	001001	1
	000111	011001	001101	1
	001100	010010	010010	2
	001110	010011	010011	2
	001111	011011	010110	2
	010011	101001	010111	2
	010111	111001	011001	3
	011011	101011	011011	3
	011100	110010	011101	3
	011101	111010	011110	3
	011111	111011	100100	4
	100011	001101	100101	4
	100111	011101	100110	4
	101100	010110	101001	5
	101101	011110	101011	5
	101110	010111	101100	5
	110000	100100	101110	5
	110001	101100	101111	5
	110010	100101	110010	6
	110100	110100	110100	6
	110101	111100	111001	7
	110111	111101	111010	7
	111000	100110	111011	7
	111001	101110	111100	7
	111011	101111	111101	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g_{2a}(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	0
1	F	0	F	0
2	0	1	0	1
3	F	F	F	$\sim$ F
4	0	0	1	$\sim$ F
5	F	F	$\sim$ F	1
6	0	$\sim$ F	$\sim$ F	0
7	F	1	1	0

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g_{2a}(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	ALL VALUES = ZERO			
1	F	0	F	0
2	0	1	0	1
3	F	F	F	$\sim$ F
4	0	0	1	$\sim$ F
5	F	F	$\sim$ F	1
6	0	$\sim$ F	$\sim$ F	0
7	F	1	1	0

NADC-85135-20

<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
BDEACF				
	000011	001001	001001	1
	000111	011001	001101	1
	001100	010010	010010	2
	001110	011010	010110	2
	001111	011011	010111	2
	010011	101001	011001	3
	010111	111001	011010	3
	011011	101011	011011	3
	011100	110010	011101	3
	011101	110011	011110	3
	011111	111011	100100	4
	100011	001101	100101	4
	100111	011101	100110	4
	101100	010110	100111	4
	101101	010111	101001	5
	101110	011110	101011	5
	110000	100100	101100	5
	110001	100101	101111	5
	110010	101100	110010	6
	110100	110100	110011	6
	110101	110101	110100	6
	110111	111101	110101	6
	111000	100110	111001	7
	111001	100111	111011	7
	111011	101111	111101	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g_{2a}(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	0
1	F	0	F	0
2	0	$\sim$ F	0	1
3	F	1	F	$\sim$ F
4	0	0	1	1
5	F	F	$\sim$ F	F
6	0	1	1	0
7	F	F	F	0

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g_{2a}(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	ALL VALUES = ZERO			
1	F	0	F	0
2	0	$\sim$ F	0	1
3	F	1	F	$\sim$ F
4	0	0	1	1
5	F	F	$\sim$ F	F
6	0	1	1	0
7	F	F	F	0

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<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
BCFADE				
	000011	001001	001001	1
	000111	001011	001011	1
	001100	010010	001101	1
	001110	010011	001111	1
	001111	011011	010010	2
	010011	101001	010011	2
	010111	101011	010110	2
	011011	111001	010111	2
	011100	110010	011011	3
	011101	111010	011110	3
	011111	111011	100100	4
	100011	001101	100101	4
	100111	001111	100110	4
	101100	010110	101001	5
	101101	011110	101011	5
	101110	010111	101100	5
	110000	100100	101110	5
	110001	101100	101111	5
	110010	100101	110010	6
	110100	100110	110100	6
	110101	101110	111001	7
	110111	101111	111010	7
	111000	110100	111011	7
	111001	111100	111100	7
	111011	111101	111101	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	0
1	F	F	F	F
2	0	1	0	1
3	0	F	0	$\overline{F}$
4	0	0	1	$\overline{F}$
5	F	F	$\overline{F}$	1
6	0	$\overline{F}$	$\overline{F}$	0
7	F	1	1	0

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	ALL VALUES = ZERO			
1	F	F	F	F
2	0	1	0	1
3	0	F	0	$\overline{F}$
4	0	0	1	$\overline{F}$
5	F	F	$\overline{F}$	1
6	0	$\overline{F}$	$\overline{F}$	0
7	F	1	1	0

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<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
BCEADF				
	000011	001001	001001	1
	000111	001011	001011	1
	001100	010010	001101	1
	001110	011010	001111	1
	001111	011011	010010	2
	010011	101001	010110	2
	010111	101011	010111	2
	011011	111001	011010	3
	011100	110010	011011	3
	011101	110011	011110	3
	011111	111011	100100	4
	100011	001101	100101	4
	100111	001111	100110	4
	101100	010110	100111	4
	101101	010111	101001	5
	101110	011110	101011	5
	110000	100100	101100	5
	110001	100101	101111	5
	110010	101100	110010	6
	110100	100110	110011	6
	110101	100111	110100	6
	110111	101111	110101	6
	111000	110100	111001	7
	111001	110101	111011	7
	111011	111101	111101	7

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	0	0	0
1	F	F	F	F
2	0	$\sim$ F	0	1
3	0	1	0	$\sim$ F
4	0	0	1	1
5	F	F	$\sim$ F	F
6	0	1	1	0
7	F	F	F	0

REDUCED F MATRIX

MULTIPLEXERS=7

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	ALL VALUES = ZERO			
1	F	F	F	F
2	0	$\sim$ F	0	1
3	0	1	0	$\sim$ F
4	0	0	1	1
5	F	F	$\sim$ F	F
6	0	1	1	0
7	F	F	F	0

<u>PERMUTATION</u>	<u>ORIGINAL</u> <u>MINTERM</u>	<u>MINTERMS AFTER</u> <u>PERMUTATION</u>	<u>ORDERED</u> <u>MINTERMS</u>	<u>I VALUE</u>
BCDAEF				
	000011	000011	000011	0
	000111	001011	000111	0
	001100	011000	001011	1
	001110	011010	001111	1
	001111	011011	011000	3
	010011	100011	011010	3
	010111	101011	011011	3
	011011	110011	011100	3
	011100	111000	011101	3
	011101	111001	011110	3
	011111	111011	100011	4
	100011	000111	100100	4
	100111	001111	100101	4
	101100	011100	100110	4
	101101	011101	101011	5
	101110	011110	101100	5
	110000	100100	101101	5
	110001	100101	101111	5
	110010	100110	110011	6
	110100	101100	110100	6
	110101	101101	110101	6
	110111	101111	110111	6
	111000	110100	111000	7
	111001	110101	111001	7
	111011	110111	111011	7

AD-A161 718

MINIMIZATION OF A SIX VARIABLE BOOLEAN FUNCTION(U)
NAVAL AIR DEVELOPMENT CENTER WARMINSTER PA SYSTEMS
DIRECTORATE L M KOCH MAY 85 NADC-85135-20

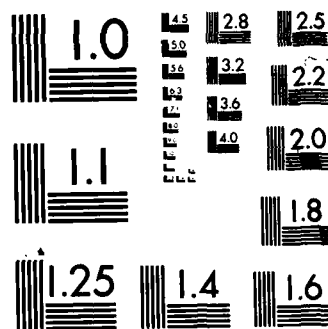
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UNCLASSIFIED

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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

UNREDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	0	F	0	F
1	0	F	0	F
2	0	0	0	0
3	$\sim$ F	1	1	$\sim$ F
4	0	F	1	$\sim$ F
5	0	F	1	F
6	0	F	1	F
7	1	F	0	0

REDUCED F MATRIX

MULTIPLEXERS=5

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	THIS EQUIVALENT TO 11			
1	0	F	0	F
2	ALL VALUES = ZERO			
3	$\sim$ F	1	1	$\sim$ F
4	0	F	1	$\sim$ F
5	THIS EQUIVALENT TO 16			
6	0	F	1	F
7	1	F	0	0

THIS IS A NEW MINIMUM: BCDAEF

MULTIPLEXERS = 5

MINIMUM MULTIPLEXERS NEEDED IS 5

IT IS PERMUTATION NUMBER 20 WHICH IS THE FOLLOWING:

<u>PERMUTATION</u>	<u>ORIGINAL MINTERM</u>	<u>MINTERMS AFTER PERMUTATION</u>	<u>ORDERED MINTERMS</u>	<u>I VALUE</u>
BCDAEF				
	000011	000011	000011	0
	000111	001011	000111	0
	001100	011000	001011	1
	001110	011010	001111	1
	001111	011011	011000	3
	010011	100011	011010	3
	010111	101011	011011	3
	011011	110011	011100	3
	011100	111000	011101	3
	011101	111001	011110	3
	011111	111011	100011	4
	100011	000111	100100	4
	100111	001111	100101	4
	101100	011100	100110	4
	101101	011101	101011	5
	101110	011110	101100	5
	110000	100100	101101	5
	110001	100101	101111	5
	110010	100110	110011	6
	110100	101100	110100	6
	110101	101101	110101	6
	110111	101111	110111	6
	111000	110100	111000	7
	111001	110101	111001	7
	111011	110111	111011	7

THE INPUTS INTO THESE MULTIPLEXERS ARE AS FOLLOWS:

REDUCED F MATRIX

<u>I VALUE</u>	<u>g2a(D,E) VALUE</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
0	THIS EQUIVALENT TO 11			
1	0	F	0	F
2	ALL VALUES = ZERO			
3	$\sim$ F	1	1	$\sim$ F
4	0	F	1	$\sim$ F
5	THIS EQUIVALENT TO 16			
6	0	F	1	F
7	1	F	0	0

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APPENDIX C:
MINIZE PROGRAM LISTING

```

10 ! *****
20 !
30 !           PROGRAM   MINIZE
40 !
50 !
60 !     THIS PROGRAM WILL REALIZE A SIX VARIABLE FUNCTION IN A
70 !     MINIMUM NUMBER OF 4-INPUT MULTIPLEXERS FOR A COMBINATIONAL
80 !     CIRCUIT.
90 !
100 !    WRITTEN BY:  LORRAINE M. KOCH
110 !                NAVAL AIR DEVELOPMENT CENTER
120 !                WARMINSTER, PA  18974
130 !                (215) 441-1595
140 !
150 !
160 !    DATE:  DECEMBER 1984
170 !
180 ! *****
190 !
200 !  OPTION BASE 0
210 !  COM Orig_ele(63),Orig_array(63,5),Bin_equiv(63,5),Number
220 !  COM Min_mult,Min_i_inp$(7,3),Mult,Min_where
230 !  COM Perm(19,5),Alpha_perm$(19,5)
240 !  COM Work_array(63,5),F$(7,3),I(63),Ictr(7),Point(5),Tempf$(63)
250 !  COM Zero$,One$,Defalt$,Inp_f$,Inp_nf$
260 !  COM All1$,All0$,Equiv$,Comple$,Numb$(7),Prt_opt$,Print_option
270 !  COM Temp_array(63,5),Dividend(5)
280 !  COM Min_work(63,5),Min_temp(63,5),Min_i(63)
290 !  INTEGER X,Y,P
300 !
310 ! *****
320 !
330 !    CALL TO INTRO SUBROUTINE INTRODUCES THE USER TO THIS PROGRAM
340 !
350 ! *****
360 !
370 !  CALL Intro
380 !
390 ! *****
400 !
410 !    CALL TO READ_DATA SUBROUTINE INITIALIZES CERTAIN VARIABLES AND
420 !    SOME DATA ARRAYS.
430 !
440 ! *****
450 !
460 !  CALL Read_data
470 !
480 ! *****
490 !
500 !    CALL TO GET_INPUTS PROMPTS THE USER WITH QUESTIONS ON ALL THE
510 !    NECESSARY INPUTS AND OPTIONS AVAILABLE.
520 !
530 ! *****
540 !

```

```

550 Inputs:  !
560 CALL Get_inputs
570 !
580 ! *****
590 !
600 !           THIS SECTION IS THE HEART OF THIS PROGRAM
610 !
620 ! INDEX P CONTROLS THE PROCESS THROUGH ALL 20 PERMUTATIONS.
630 !
640 !
650 ! ASSIGN_F_VALUES - ASSIGNS THE F INPUTS FOR EACH g2a(D,E) INDEX VALUE
660 !                   UNDER EACH I VALUE FOR THE PERMUTATION THAT IS PASSED.
670 !
680 ! REDUCE          - EVALUATES THE F INPUTS MATRIX AND TRIES TO REDUCE THE
690 !                   NUMBER OF MULTIPLEXERS NEEDED TO REALIZE THIS CASE.
700 !                   THIS ROUTINE ALSO CHECKS AND STORES THE MINIMUM TO DATE
710 !
720 !
730 ! P = THE PERMUTATION NUMBER WE ARE CURRENTLY WORKING ON
740 !
750 ! *****
760 !
770   FOR P=0 TO 19
780       CALL Assign_f_values(P)
790       CALL Reduce(P)
800   NEXT P
810 !
820 ! *****
830 !
840 !           WE ARE FINISHED
850 !
860 !   NOW WE WILL PRINTOUT THE MINIMUM NUMBER OF MULTIPLEXERS
870 !   NEEDED TO REALIZE THIS FUNCTION AND ALSO THEIR REQUIRED
880 !   INPUTS.
890 !
900 ! *****
910 !
920   PRINTER IS 0
930   BEEP
940   PRINT PAGE
950   PRINT LIN(3)
960   PRINT "           MINIMUM MULTIPLEXERS NEEDED IS";Min_mult
970   PRINT
980   PRINT USING "10X,K,K,2D,K,K";"IT IS PERMU","TATION NUMBER ";Min_where;" WH
ICH IS"," THE FOLLOWING: "
990   Indx=Min_where-1
1000  PRINT
1010 !
1020 ! *****
1030 !
1040 ! PRINT THE ORIG , TEMP AND WORK ARRAY OF THE MINIMUM
1050 !
1060 ! *****
1070 !

```

```

1080 PRINT "                                ORIGINAL  MINTERMS AFTER  ORDERED
      "
1090 PRINT "          PERMUTATION  MINTERM      PERMUTATION  MINTERMS
      I VALUE"
1100 PRINT USING "13X,6(K)";Alpha_perm$(Indx,5),Alpha_perm$(Indx,4),Alpha_perm$(Indx,3),Alpha_perm$(Indx,2),Alpha_perm$(Indx,1),Alpha_perm$(Indx,0)
1120 FOR X=0 TO Number
1130     PRINT USING "#,K";"                                "
1140     FOR Y=5 TO 0 STEP -1
1150         PRINT USING "#,D";Orig_array(X,Y)
1160     NEXT Y
1170     PRINT USING "#,K";"                                "
1180     FOR Y=5 TO 0 STEP -1
1190         PRINT USING "#,D";Min_temp(X,Y)
1200     NEXT Y
1210     PRINT USING "#,K";"                                "
1220     FOR Y=5 TO 0 STEP -1
1230         PRINT USING "#,D";Min_work(X,Y)
1240     NEXT Y
1250     PRINT USING "8X,D";Min_i(X)
1260 NEXT X
1270 PRINT LIN(2)
1280 IF Number>=30 THEN PRINT PAGE
1290 PRINT "          THE INPUTS INTO THESE MULTIPLEXERS ARE AS FOLLOWS:"
1300 PRINT
1310 PRINT "          REDUCED F MATRIX"
1320 PRINT
1330 PRINT "          g2s(D,E) VALUE      "
1340 PRINT "          I VALUE      0      1      2      3      "
1350 FOR X=0 TO 7
1360     PRINT USING "17X,D,8X,K,K,K,K";X,Min_i_inp$(X,0),Min_i_inp$(X,1),Min_i_inp$(X,2),Min_i_inp$(X,3)
1370 NEXT X
1380 !
1390 ! *****
1400 !
1410 ! DOES THE USER WISH TO EVALUATE ANOTHER FUNCTION.  IF SO, GO BACK TO THE
1420 ! THE GET_INPUTS SUBROUTINE AND BEGIN AGAIN.
1430 !
1440 ! *****
1450 !
1460 PRINTER IS 16
1470 PRINT PAGE
1480 Rsvp$="N"
1490 INPUT "Q-6.  DO YOU WISH TO EVALUATE ANOTHER FUNCTION ( Y OR N )?"
,Rsvp$
1500 IF Rsvp$<>"Y" THEN GOTO 1560
1510 Again$="Y"
1511 Min_mult=9
1512 Min_where=0
1520 GOTO Inputs
1530 !
1540 !
1550 BEEP
1560 PRINT " PROGRAM END "
1570 STOP
1580 !

```

```

1590 !
1600 ! *****
1610 !
1620 !             INTRO SUBROUTINE
1630 !
1640 !             INTRO SUBROUTINE INTRODUCES THE USER TO MINIZE
1650 !
1660 ! *****
1670 !
1680 SUB Intro
1690 !
1700 PRINTER IS 16
1710 PRINT
1720 PRINT "                M I N I Z E      "
1730 PRINT LIN(2)
1740 PRINT "                THIS PROGRAM WILL REALIZE A SIX VARIABLE COMBINATIONAL
"
1750 PRINT "                BOOLEAN FUNCTION F(A,B,C,D,E,F) IN A MINIMUM NUMBER OF "
1760 PRINT "                4-INPUT MULTIPLEXERS. YOU WILL BE ASKED FOR THE NUMBER OF "
1770 PRINT "                MINTERMS (OR ELEMENTS) AND THEN WHAT THESE MINTERMS ARE."
1780 PRINT
1790 PRINT "                MINIZE WILL OUTPUT TO YOU THE MINIMUM NUMBER OF 4-INPUT"
1800 PRINT "                MULTIPLEXERS YOU WILL NEED AND WHAT EACH OF THE INPUTS ARE"
1810 PRINT "                INTO EACH MULTIPLEXER."
1820 PRINT LIN(5)
1830 PRINT " PRESS  CONT  WHEN YOU ARE READY."
1840 PAUSE
1850 SUBEND
1860 !
1870 ! *****
1880 !
1890 !             READ_DATA SUBROUTINE
1900 !
1910 ! THE READ_DATA SUBROUTINE INITIALIZES CERTAIN DATA ARRAYS AND VARIABLES.
1920 !
1930 !             PERM ARRAY - STORES THE 20 PERMUTATIONS
1940 !             DIVIDEND ARRAY - STORES POWERS OF 2 TO COMPUTE BINARY EQUIVALENTS
1950 !             MIN_MULT - STORES MINIMUM NUMBER OF MULTIPLEXERS REQUIRED
1960 !                     TO DATE
1970 !             MIN_WHERE - STORES PERMUTATION NUMER OF MINIMUM TO DATE
1980 !
1990 !             THE ALPHA-NUMERIC ARRAYS STORE MESSAGES USED IN CALCULATING
2000 !                     THE UNREDUCED AND REDUCED F INPUTS MATRICES.
2010 !
2020 ! *****
2030 !
2040 SUB Read_data
2050 OPTION BASE 0
2060 COM Orig_ele(*),Orig_array(*),Bin_equiv(*),Number
2070 COM Min_mult,Min_i_inp$(*),Mult,Min_where
2080 COM Perm(*),Alpha_perm$(*)
2090 COM Work_array(*),F$(*),I(*),Ictr(*),Point(*),Tempf$(*)
2100 COM Zero$,One$,Default$,Inp_f$,Inp_nf$
2110 COM All1$,All0$,Equiv$,Comple$,Numb$(*),Prt_opt$,Print_option
2120 COM Temp_array(*),Dividend(*)
2130 COM Min_work(*),Min_temp(*),Min_i(*)

```

```

2140 INTEGER Perm,Dividend
2150 !
2160 DATA 0,1,2,3,4,5,      A,B,C,D,E,F
2170 DATA 0,1,3,2,4,5,      A,B,D,C,E,F
2180 DATA 0,2,3,1,4,5,      A,B,E,C,D,F
2190 DATA 1,2,3,0,4,5,      A,B,F,C,D,E
2200 DATA 0,1,4,2,3,5,      A,C,D,B,E,F
2210 DATA 0,2,4,1,3,5,      A,C,E,B,D,F
2220 DATA 1,2,4,0,3,5,      A,C,F,B,D,E
2230 DATA 0,3,4,1,2,5,      A,D,E,B,C,F
2240 DATA 1,3,4,0,2,5,      A,D,F,B,C,E
2250 DATA 2,3,4,0,1,5,      A,E,F,B,C,D
2260 !
2270 !
2280 DATA 3,4,5,0,1,2,      D,E,F,A,B,C
2290 DATA 2,4,5,0,1,3,      C,E,F,A,B,D
2300 DATA 1,4,5,0,2,3,      C,D,F,A,B,E
2310 DATA 0,4,5,1,2,3,      C,D,E,A,B,F
2320 DATA 2,3,5,0,1,4,      B,E,F,A,C,D
2330 DATA 1,3,5,0,2,4,      B,D,F,A,C,E
2340 DATA 0,3,5,1,2,4,      B,D,E,A,C,F
2350 DATA 1,2,5,0,3,4,      B,C,F,A,D,E
2360 DATA 0,2,5,1,3,4,      B,C,E,A,D,F
2370 DATA 0,1,5,2,3,4,      B,C,D,A,E,F
2380 FOR X=0 TO 19
2390     FOR Y1=0 TO 5
2400         READ Perm(X,Y1)
2410     NEXT Y1
2420     FOR Y2=5 TO 0 STEP -1
2430         READ Alpha_perm$(X,Y2)
2440     NEXT Y2
2450 NEXT X
2460 !
2470 DATA 1,2,4,8,16,32
2480 MAT READ Dividend
2490 !
2500 DATA " ALL VALUES = ONE"
2510 DATA " ALL VALUES = ZERO"
2520 DATA "THIS EQUIVALENT TO"
2530 DATA "THIS COMPLEMENT OF"
2540 READ All1$,All0$,Equiv$,Comple$
2550 !
2560 DATA "I0","I1","I2","I3","I4","I5","I6","I7"
2570 READ Numb$(0),Numb$(1),Numb$(2),Numb$(3),Numb$(4),Numb$(5),Numb$(6),Numb$(
7)
2580 !
2590 Again$="N"
2600 Zero$=" 0 "
2610 One$=" 1 "
2620 Default$=" "
2630 Inp_f$=" F "
2640 Inp_nf$=" ~F "
2650 Min_mult=9
2660 Min_where=0
2670 SUBEND
2680 !

```

```

2690 ! *****
2700 !
2710 !             GET_INPUTS SUBROUTINE
2720 !
2730 !     USER DEFINED INPUTS:  1) NUMBER = NUMBER OF MINTERMS IN THIS 6 VARIABLE
2740 !                           FUNCTION ( MIN=1, MAX=64 )
2750 !                           2) ORIG_ELE(63) = THE ACTUAL MINTERMS UP TO A
2760 !                               MAXIMUM OF 63; MINIMUM OF 0
2770 !
2780 ! *****
2790 !
2800 SUB Get_inputs
2810 OPTION BASE 0
2820 COM Orig_ele(*),Orig_array(*),Bin_equiv(*),Number
2830 COM Min_mult,Min_i_inp$(*),Mult,Min_where
2840 COM Perm(*),Alpha_perm$(*)
2850 COM Work_array(*),F$(*),I(*),Ictr(*),Point(*),Tempf$(*)
2860 COM Zero$,One$,Defalt$,Inp_f$,Inp_nf$
2870 COM All1$,All0$,Equiv$,Comple$,Numb$(*),Prt_opt$,Print_option
2880 COM Temp_array(*),Dividend(*)
2890 COM Min_work(*),Min_temp(*),Min_i(*)
2900 INTEGER Orig_ele,Orig_array,Temp,X,Y,Z,Z1
2910 PRINTER IS 16
2920 PRINT PAGE
2930 MAT Orig_ele=ZER
2940 Number=0
2950 INPUT "Q-1.  ENTER THE NUMBER OF MINTERMS IN THIS 6 VARIABLE FUNCTION:",Nu
mber
2960 PRINT LIN(3)
2970 IF (Number<=64) AND (Number>=1) THEN GOTO 3010
2980 BEEP
2990 PRINT "NUMBER OF MINTERMS MUST BE BETWEEN 1 AND 64 INCLUSIVE"
3000 GOTO 2950
3010 Number=Number-1
3020 REDIM Orig_ele(Number)
3030 INPUT "Q-2.  ENTER THE MINTERMS:",Orig_ele(*)
3040 MAT SORT Orig_ele(*)
3050 IF (Orig_ele(0)>=0) AND (Orig_ele(Number)<=63) THEN GOTO 3090
3060 BEEP
3070 PRINT "MINTERMS MUST BE BETWEEN 0 AND 63 INCLUSIVE"
3080 GOTO 3030
3090 FOR X=0 TO Number-1
3100     IF Orig_ele(X)=Orig_ele(X+1) THEN GOTO 3130
3110 NEXT X
3120 GOTO 3160
3130 PRINT " EACH MINTERM MUST BE UNIQUE"
3140 BEEP
3150 GOTO 3030
3160 PRINT LIN(3)
3170 PRINT "LIST OF MINTERMS IS:",Orig_ele(*)
3180 PRINT LIN(3)
3190 Rsvp$="Y"
3200 INPUT "Q-3.  ARE THESE CORRECT ( Y OR N )?",Rsvp$
3210 IF Rsvp$<>"Y" THEN GOTO 2920
3220 !

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```

3230 ! *****
3240 !
3250 !             ASSIGN THESE MINTERMS THEIR BINARY EQUIVALENT
3260 !
3270 !     ORIG_ARRAY(63,5)=CONTAINS BINARY EQUIVALENT OF THE ORIGINAL
3280 !             MINTERMS
3290 !
3300 ! *****
3310 !
3320 REDIM Orig_array(Number,5)
3330 PRINTER IS 0
3340 PRINT PAGE
3341 PRINT LIN(4)
3342 PRINT "
3343 PRINT
3350 PRINT "
3360 FOR X=0 TO Number
3370 PRINT USING "#,27X,2D,16X";Orig_ele(X)
3380 Temp=Orig_ele(X)
3390     FOR Y=5 TO 0 STEP -1
3400         Orig_array(X,Y)=INT(Temp/Dividend(Y))
3410         Temp=Temp MOD Dividend(Y)
3420         PRINT USING "#,D";Orig_array(X,Y)
3430     NEXT Y
3440 PRINT
3450 NEXT X
3460 PRINTER IS 16
3470 !
3480 ! *****
3490 !
3500 !     THIS SECTION ALLOWS THE USER TO SELECT THE TYPE OF PRINTOUT
3510 !     THAT IS DESIRED.  THE DETAILED PRINTOUT WILL RUN CONSIDERABLY
3520 !     SLOWER.
3530 !
3540 !             PRT_OPT$ - F=FAST VERSION OR S=SLOW DETAILED VERSION
3550 !             PRINT_OPTION$ - 16=PRINTS EVERYTHING ON THE CRT OR
3560 !                             0=PRINTS EVERYTHING ON THE THERMAL PRINTER
3570 !
3580 ! *****
3590 !
3600 Prt_opt$="F"
3610 Print_option=16
3620 PRINT "Q-4. DO YOU WANT TO RUN THE FAST VERSION OR THE SLOW DETAILED"
3630 PRINT "
3640 INPUT Prt_opt$
3650 IF Prt_opt$="F" THEN GOTO 3710
3660 PRINT LIN(3)
3670 PRINT "Q-4a. DO YOU WANT THE DETAILED PRINTOUT TO APPEAR ON THE CRT OR"
3680 PRINT "
3690 INPUT Print_option
3700 !
3710 ! *****
3720 !
3730 !     THIS SECTION ASKS THE USER IF THEY WISH TO LIST THE PERMUTATIONS.
3740 !

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3750 !   IF YES, THE 20 PERMUTATIONS ARE PRINTED ON THE DESIRED PRINTOUT
3760 !       OPTION.
3770 !
3780 ! *****
3790 !
3800 PRINT LIN(4)
3810 INPUT "Q-5. DO YOU WANT TO LIST THE PERMUTATIONS ( Y OR N )?",Rsvp$
3820 PRINTER IS Print_option
3830 IF Rsvp$<>"Y" THEN GOTO 4070
3840 PRINT LIN(4)
3850 IF Number>40 THEN PRINT PAGE
3851 PRINT "                                LIST OF PERMUTATIONS"
3852 PRINT
3860 PRINT "                NUMBER      PERMUTATION                NUMBER      PERMU
TATION"
3870 FOR Z=0 TO 9
3880 PRINT USING "#,12X,3D,11X";Z+1
3890 FOR Z1=5 TO 0 STEP -1
3900 PRINT USING "#,K";Alpha_perm$(Z,Z1)
3910 NEXT Z1
3920 PRINT USING "#,11X,3D,11X";Z+11
3930 FOR Z1=5 TO 0 STEP -1
3940 PRINT USING "#,K";Alpha_perm$(Z+10,Z1)
3950 NEXT Z1
3960 PRINT
3970 NEXT Z
3980 !
3990 ! *****
4000 !
4010 ! REDIMENSION THE ARRAYS FOR THE CURRENT NUMBER OF MINTERMS
4020 !
4030 ! *****
4040 !
4050 REDIM Work_array(Number,5),Min_work(Number,5),Min_temp(Number,5)
4060 REDIM Min_i(Number),Temp_array(Number,5),Tempf$(Number)
4070 SUBEND
4080 !
4090 ! *****
4100 !
4110 ! ASSIGN_F_VALUES SUBROUTINE
4120 !
4130 !
4140 ! THIS SUBROUTINE ASSIGNS THE F INPUTS TO THE F$ MATRIX
4150 ! FOR THE CURRENT PERMUTATION. THERE IS ONE F INPUT FOR
4160 ! EACH g2a(D,E) INDEX UNDER EACH I VALUE.
4170 !
4180 ! *****
4190 !
4200 SUB Assign_f_values(INTEGER Indx1)
4210 OPTION BASE 0
4220 COM Orig_ele(*),Orig_array(*),Bin_equiv(*),Number
4230 COM Min_mult,Min_i_inp$(*),Mult,Min_where
4240 COM Perm(*),Alpha_perm$(*)
4250 COM Work_array(*),F$(*),I(*),Ictr(*),Point(*),Tempf$(*)
4260 COM Zero$,One$,Defalt$,Inp_f$,Inp_nf$

```

```

4270 COM All1$,All0$,Equiv$,Comple$,Numb$(*),Prt_opt$,Print_option
4280 COM Temp_array(*),Dividend(*)
4290 COM Min_work(*),Min_temp(*),Min_i(*)
4300 INTEGER Where,Point,Perm,I,Ictr,Work_array,Orig_array,Temp_array,Ptr
4310 INTEGER Findex,X,Y
4320 PRINTER IS 16
4330 !
4340 ! *****
4350 !
4360 ! DISPLAY ON THE CRT THE MINIMUM TO DATE AND THE CURRENT PERMUTATION #
4370 !
4380 ! *****
4390 !
4400 Where=Indxl
4410 PRINT CHR$(27)&"m"
4420 PRINT PAGE
4430 PRINT USING "K,DDD,K,K,D";"PERMUTATION ",Min_where," IS THE MINIMUM-","---
MULTIPLEXORS = ",Min_mult
4440 PRINT
4450 PRINT "THE PROGRAM IS CURRENTLY WORKING ON PERMUTATION ";Where+1
4460 PRINT CHR$(27)&"l"
4470 PRINTER IS Print_option
4480 !
4490 ! *****
4500 !
4510 ! ASSIGN POINT ARRAY TO THE CURRENT PERMUTATION AND INITIALIZE ARRAYS
4520 !
4530 ! *****
4540 !
4550 FOR X=0 TO 5
4560     Point(X)=Perm(Indxl,X)
4570 NEXT X
4580 FOR X=0 TO 7
4590     FOR Y=0 TO 3
4600         F$(X,Y)=Zero$
4610     NEXT Y
4620 NEXT X
4630 FOR X=0 TO Number
4640     Tempf$(X)=Default$
4650 NEXT X
4660 MAT I=ZER
4670 MAT Ictr=ZER
4680 !
4690 ! *****
4700 !
4710 ! COPY ORIG_ARRAY TO WORK_ARRAY AND REORDER WORK_ARRAY ACCORDING TO THE
4720 ! CURRENT PERMUTATION. THEN SORT THE WORK_ARRAY.
4730 !
4740 ! *****
4750 !
4760 MAT Work_array=Orig_array
4770 MAT REORDER Work_array BY Point,2
4780 MAT Temp_array=Work_array
4790 MAT SORT Work_array(*,5),(*,4),(*,3),(*,2),(*,1),(*,0)
4800 PRINT LIN(2)
4810 !

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```

4820 | *****
4830 |
4840 | COUNT THE NUMBER OF MINTERMS FOR EACH I VALUE (0 THROUGH 7)
4850 |     THIS IS THE FUNCTION gl=gl(A,B,C).
4860 |
4870 | ALSO FILL TEMPFS$ ARRAY WITH VALUE OF LAST ELEMENT (F)
4880 |
4890 | *****
4900 |
4910 | FOR X=0 TO Number
4920 |     I(X)=Work_array(X,5)*4+Work_array(X,4)*2+Work_array(X,3)
4930 |     Ictr(I(X))=Ictr(I(X))+1
4940 |     Tempf$(X)=Inp_f$
4950 |     IF Work_array(X,0)=0 THEN Tempf$(X)=Inp_nf$
4960 | NEXT X
4970 |
4980 | *****
4990 |
5000 | IF THE DETAILED PRINTOUT HAS BEEN SELECTED, THEN PRINT:
5010 |
5020 |     POINT = THE CURRENT PERMUTATION
5030 |     ORIG_ARRAY = ORIGINAL MINTERMS
5040 |     TEMP_ARRAY = WORKING ARRAY AFTER THIS PERMUTATION
5050 |     WORK_ARRAY = SORTED WORKING ARRAY
5060 |     I VALUE = VALUE OF THE FUNCTION gl=gl(A,B,C) WHICH IS THE
5070 |               FIRST THREE VALUES OF THE REORDERED MINTERM
5080 |
5090 | *****
5100 |
5110 | IF Prt_opt$ <> "S" THEN GOTO 5330
5120 | PRINT PAGE
5121 | PRINT LIN(3)
5130 | PRINT "                                ORIGINAL   MINTERMS AFTER   ORDERED
5140 | PRINT "                                PERMUTATION MINTERM   PERMUTATION   MINTERMS
5150 | PRINT USING "13X,6(K)";Alpha_perm$(Indx1,5),Alpha_perm$(Indx1,4),Alpha_per
5160 | m$(Indx1,3),Alpha_perm$(Indx1,2),Alpha_perm$(Indx1,1),Alpha_perm$(Indx1,0)
5170 | FOR X=0 TO Number
5180 | PRINT USING "#,K";"                                "
5190 |     FOR Y=5 TO 0 STEP -1
5200 |         PRINT USING "#,D";Orig_array(X,Y)
5210 |     NEXT Y
5220 | PRINT USING "#,K";"                                "
5230 |     FOR Y=5 TO 0 STEP -1
5240 |         PRINT USING "#,D";Temp_array(X,Y)
5250 |     NEXT Y
5260 | PRINT USING "#,K";"                                "
5270 |     FOR Y=5 TO 0 STEP -1
5280 |         PRINT USING "#,D";Work_array(X,Y)
5290 |     NEXT Y
5300 | PRINT USING "8X,D";I(X)
5310 | NEXT X
5320 | PRINT
5330 |
5340 | *****
5350 |

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5360 ! NOW WE WILL CALCULATE THE F$ MATRIX OF INPUTS FOR THIS PERMUTATION.
5370 ! WE WILL BEGIN TO COMPUTE THE F MATRIX BY CHECKING THE ICTR ARRAY
5380 ! AND COMPARING TWO MINTERMS AT A TIME TO DETERMINE THE F INPUT FOR
5390 ! EACH F INDEX UNDER EACH I VALUE.
5400 !
5410 !     DEFINITION OF TERMS
5420 !
5430 !     I VALUE = g1(A,B,C) VALUE
5440 !     F INDEX = g2a(D,E) VALUE
5450 !     F$ MATRIX = CONTAINS THE F INPUTS; ONE FOR EACH F INDEX UNDER EACH
5460 !                 I VALUE
5470 ! IF THEIR IS ONLY ONE MINTERM FOR A PARTICULAR F INDEX AND I VALUE,
5480 ! THE F INPUT ASSIGNED IS DEPENDENT OF THE MINTERM'S F ARGUMENT (F VALUE).
5490 !     F INPUT = " F " (VARIABLE INP_F$) IF MINTERM'S F VALUE IS 1 OR
5500 !               = "~F " (VARIABLE INP_NF$) IF MINTERM'S F VALUE IS 0.
5510 !
5520 !     METHOD
5530 !
5540 ! IF ICTR(X)=0 THEN THERE ARE NO MINTERMS WITH THIS I VALUE.
5550 !     THE F INPUTS FOR ALL INDICES SHOULD BE ASSIGNED TO 0.
5560 !     F$ MATRIX IS INITIALIZED TO ZERO.
5570 !     -1 THEN THERE IS ONLY ONE MINTERM LEFT FOR THIS I
5580 !     VALUE SO ASSIGN F INPUT ACCORDING TO THIS MINTERM'S
5590 !     F VALUE FOR THE MINTERM'S F INDEX FOR THIS I VALUE.
5600 !     -2 THEN THERE ARE TWO MINTERMS FOR THIS I VALUE; MUST
5610 !     CHECK WHAT F INDEX CURRENT MINTERM IS AND SEE
5620 !     IF THE NEXT MINTERM'S IS THE SAME.
5630 !     -3-7 THEN MUST CHECK THE NEXT TWO MINTERMS TO SEE IF THE
5640 !     F INDEX OF CURRENT IS THE SAME AS NEXT
5650 !     -8 THEN ALL MINTERMS FOR THIS I VALUE, SO F INPUTS FOR ALL
5660 !     INDICES SHOULD BE ASSIGNED 1 FOR THIS I VALUE.
5670 !
5680 !
5690 !     PTR = POINTER INTO THE WORK_ARRAY OF ALL THE MINTERMS REORDERED
5700 !     AND SORTED FOR THIS PERMUTATION.
5710 !     X = CONTROLS THE COUNTER THROUGH ALL THE I VALUES OF THE F$ MATRIX
5720 !     FINDEX = VARIABLE THAT GETS ASSIGNED THE CURRENT MINTERM'S F INDEX VALUE.
5730 !
5740 ! *****
5750 !
5760 ! Ptr=0
5770 ! Flag$=Default$
5780 ! FOR X=0 TO 7
5790 !     IF Ictr(X)=0 THEN Next_x
5800 !     IF Ictr(X)<8 THEN Cont1
5810 !         ! HERE THERE IS ALL 8 MINTERMS FOR THIS I VALUE; MUST ASSIGN
5820 !         ! ALL F INDICES = 1
5830 !         FOR Y=0 TO 3
5840 !             F$(X,Y)=One$
5850 !         NEXT Y
5860 !         Ptr=Ptr+8
5870 !         GOTO Next_x
5880 ! Cont1: !
5890 !     IF Ictr(X)>1 THEN GOTO Ckindx
5900 !     ! HERE THERE IS ONLY ONE ELEMENT LEFT. WE MUST FILL THE

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5910      ! APPROPRIATE INDEX OF THE F MATRIX WITH THE F VALUE.
5920      Findex=INT(Work_array(Ptr,2)*2+Work_array(Ptr,1))
5930      GOTO Assign
5940 Ckindx: ! HERE THERE IS AT LEAST 2 MINTERMS WITH THIS I VALUE;
5950      !      FIND THE CURRENT F INDEX WE ARE WORKING ON
5960      IF (Work_array(Ptr,2)=1) AND (Work_array(Ptr,1)=1) THEN GOTO F3
5970      IF Work_array(Ptr,2)=1 THEN GOTO F2
5980      IF Work_array(Ptr,1)=1 THEN GOTO F1
5990 F0: Findex=0
6000      ! BOTH D AND E VALUES FOR THIS ELEMENT ARE ZERO
6010      ! NOW CHECK IF NEXT MINTERM'S D AND E VALUES ARE ZERO
6020      ! IF YES, FLAG IS SET - OTHERWISE ASSIGN ROUTINE WILL ASSIGN
6030      ! THE F MATRIX THE APPROPRIATE F INPUT ACCORDING TO THE CURRENT
6040      ! MINTERM'S F VALUE (TEMPF$ ARRAY)
6050      IF (Work_array(Ptr+1,2)=0) AND (Work_array(Ptr+1,1)=0) THEN Flag$=One$
6060      GOTO Assign
6070 F1: Findex=1
6080      ! D VALUE IS 0 , E VALUE IS 1
6090      ! CHECK IF NEXT MINTERM HAS THE SAME D AND E VALUES
6100      IF (Work_array(Ptr+1,2)=0) AND (Work_array(Ptr+1,1)=1) THEN Flag$=One$
6110      GOTO Assign
6120 F2: Findex=2
6130      ! D VALUE IS 1 , E VALUE IS 0
6140      ! CHECK IF NEXT MINTERM HAS THE SAME D AND E VALUES
6150      IF (Work_array(Ptr+1,2)=1) AND (Work_array(Ptr+1,1)=0) THEN Flag$=One$
6160      GOTO Assign
6170 F3: Findex=3
6180      ! D VALUE IS 1 , E VALUE IS 1
6190      ! CHECK IF NEXT MINTERM HAS THE SAME D AND E VALUES
6200      IF (Work_array(Ptr+1,2)=1) AND (Work_array(Ptr+1,1)=1) THEN Flag$=One$
6210      !
6220      ! *****
6230      !
6240      ! THIS ROUTINE WILL ASSIGN THE APPROPRIATE F INPUT INTO THE F MATRIX
6250      ! FOR THE CURRENT F INDEX AND I VALUE.
6260      !
6270      ! *****
6280      !
6290 Assign: IF Flag$=Default$ THEN GOTO Only1
6300      ! HERE THERE ARE TWO MINTERMS WITH THE SAME F INDEX SO ASSIGN
6310      ! F MATRIX = 1 FOR THIS F INDEX AND I VALUE. FLAG HAS BEEN ASSIGNED THIS
6320      ! VALUE.
6330      ! DECREMENT/INCREMENT COUNTER AND POINTER BY 2
6340      F$(X,Findex)=Flag$
6350      Ictr(X)=Ictr(X)-2
6360      Ptr=Ptr+2
6370      Flag$=Default$
6380      GOTO Ckend
6390 Only1: ! HERE THERE IS ONLY ONE MINTERM WITH THIS F INDEX SO ASSIGN
6400      ! F MATRIX THE APPROPRIATE F INPUT BASED ON THE MINTERM'S F VALUE.
6410      ! DECREMENT/INCREMENT COUNTER AND POINTER BY 1
6420      F$(X,Findex)=Tempf$(Ptr)
6430      Ictr(X)=Ictr(X)-1
6440      Ptr=Ptr+1
6450 Ckend: ! CHECK TO SEE IF ANY MORE MINTERMS WITH THIS I VALUE

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6460      ! IF CTR NOT ZERO THEN CONTINUE WITH THIS I VALUE AND
6470      ! CONTINUE FILLING F MATRIX WITH REQUIRED INPUTS.
6480      ! IF CTR = 0 THEN NO MORE MINTERMS FOR THIS I VALUE -
6490      ! SO GO ON TO NEXT I VALUE.
6500 !
6510      IF Ictr(X)>0 THEN GOTO Cont1
6520 !
6530 Next_x:  NEXT X
6540 !
6550 ! *****
6560 !
6570 ! IF THE DETAILED PRINTOUT OPTION HAS BEEN SELECTED THEN PRINTOUT
6580 !     THE F MATRIX FOR THIS CASE
6590 !
6600 ! *****
6610 !
6620 IF Prt_opt$<>"S" THEN GOTO 6720
6640 IF Number>=24 THEN PRINT PAGE
6645 PRINT LIN(3)
6650 PRINT "                                UNREDUCED F MATRIX"
6660 PRINT
6670 PRINT "                                g2a(D,E) VALUE    "
6680 PRINT "                                I VALUE      0    1    2    3    "
6690 FOR X=0 TO 7
6700     PRINT USING "18X,D,8X,K,K,K,K";X,F$(X,0),F$(X,1),F$(X,2),F$(X,3)
6710 NEXT X
6720 SUBEND
6730 !
6740 ! *****
6750 !
6760 !                                REDUCE SUBROUTINE
6770 !
6780 ! NOW ALL THE I VALUES HAVE BEEN EVALUATED AND THE F MATRIX OF
6790 ! ALL THE REQUIRED INPUTS HAS BEEN ASSIGNED FOR THIS PERMUTATION.
6800 ! WE MUST NOW COMPARE THESE F MATRIX VALUES TO SEE IF WE CAN
6810 ! REDUCE THE REQUIRED NUMBER OF MULTIPLEXERS NEEDED TO REALIZE
6820 ! THIS CASE.
6830 !
6840 ! *****
6850 !
6860 SUB Reduce(INTEGER Where)
6870 OPTION BASE 0
6880 COM Orig_ele(*),Orig_array(*),Bin_equiv(*),Number
6890 COM Min_mult,Min_i_inp$(*),Mult,Min_where
6900 COM Perm(*),Alpha_perm$(*)
6910 COM Work_array(*),F$(*),I(*),Ictr(*),Point(*),Tempf$(*)
6920 COM Zero$,One$,Default$,Inp_f$,Inp_nf$
6930 COM All1$,All10$,Equiv$,Comple$,Numb$(*),Prt_opt$,Print_option
6940 COM Temp_array(*),Dividend(*)
6950 COM Min_work(*),Min_temp(*),Min_i(*)
6960 INTEGER X,Z,Blanks,Y
6970 !
6980 ! *****
6990 !
7000 ! Z CONTROLS THE COUNTER THROUGH ALL THE I VALUES OF THE F MATRIX

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7010 !
7020 ! WE CAN REDUCE IF: 1) ALL F INPUTS FOR AN I VALUE ARE EQUAL TO 1
7030 !                      2) ALL F INPUTS FOR AN I VALUE ARE EQUAL TO 0
7040 !                      3) F INPUTS FOR TWO DIFFERENT I VALUES ARE IDENTICAL
7050 !                      4) F INPUTS FOR TWO DIFFERENT I VALUES ARE COMPLEMENTS
7060 !
7070 ! *****
7080 !
7090 Mult=8
7100 FOR Z=0 TO 7
7110 Ckone: ! CHECK IF ALL F INPUTS FOR THIS I VALUE ARE = 1.
7120 ! IF YES, THEN WE CAN REDUCE THE NUMBER OF REQUIRED
7130 ! MULTIPLEXERS BY 1.
7140 FOR X=0 TO 3
7150 IF F$(Z,X)<>One$ THEN GOTO Ckzero
7160 NEXT X
7170 ! HERE ALL F INPUTS = 1 - REDUCE MULTIPLEXERS COUNTER
7180 Mult=Mult-1
7190 F$(Z,0)=A111$
7200 Blanks=3
7210 GOTO Clearf
7220 Ckzero: ! CHECK IF ALL F INPUTS FOR THIS I VALUE ARE = 0.
7230 ! IF YES, THEN WE CAN REDUCE THE NUMBER OF REQUIRED
7240 ! MULTIPLEXERS BY 1.
7250 FOR X=0 TO 3
7260 IF F$(Z,X)<>Zero$ THEN GOTO Ckcont
7270 NEXT X
7280 ! HERE ALL F INPUTS = 0 - REDUCE MULTIPLEXERS COUNTER
7290 Mult=Mult-1
7300 F$(Z,0)=A110$
7310 Blanks=3
7320 GOTO Clearf
7330 Ckcont: ! CONTINUE COMPARING EACH SET OF INPUTS FOR EACH I VALUE
7340 FOR Y=7 TO Z+1 STEP -1
7350 Ckeqv: ! CHECK IF THESE TWO ARE EQUIVALENT
7360 ! IF YES, THEN REDUCE THE NUMBER OF MULTIPLEXERS BY 1.
7370 FOR X=0 TO 3
7380 IF F$(Z,X)<>F$(Y,X) THEN GOTO Ckcomp
7390 NEXT X
7400 ! HERE THESE TWO I'S INPUTS ARE EQUIVALENT - REDUCE.
7410 ! PUT MESSAGE UNDER Z'S I VALUE AND ELIMINATE THIS
7420 ! MULTIPLEXER.
7430 Mult=Mult-1
7440 F$(Z,0)=Equiv$
7450 F$(Z,3)=Numb$(Y)
7460 Blanks=2
7470 GOTO Clearf
7480 Ckcomp: ! CHECK IF THESE TWO ARE COMPLEMENTS
7490 ! IF YES, THEN REDUCE THE NUMBER OF MULTIPLEXERS BY 1.
7500 FOR X=0 TO 3
7510 IF (F$(Z,X)=One$) AND (F$(Y,X)<>Zero$) THEN GOTO Next_y
7520 IF (F$(Z,X)=Zero$) AND (F$(Y,X)<>One$) THEN GOTO Next_y
7530 IF (F$(Z,X)=Inp_f$) AND (F$(Y,X)<>Inp_nf$) THEN GOTO Next_y
7540 IF (F$(Z,X)=Inp_nf$) AND (F$(Y,X)<>Inp_f$) THEN GOTO Next_y
7550 NEXT X

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7560      ! HERE THESE TWO I'S VALUES ARE COMPLEMENTS - REDUCE.
7570      ! PUT MESSAGE UNDER Z'S I VALUE AND ELIMINATE THIS
7580      ! MULTIPLEXER.
7590      Mult=Mult-1
7600      F$(2,0)=Comple$
7610      F$(2,3)=Numb$(Y)
7620      Blanks=2
7630 Clearf: ! HERE WE HAVE REDUCED - CLEAR REST OF F MATRIX FOR THIS I VALUE
7640      FOR X=1 TO Blanks
7650          F$(2,X)=" "
7660      NEXT X
7670      GOTO Next_z
7680 Next_y: NEXT Y      ! SO FAR THIS IS A UNIQUE I VALUE
7690                      ! IF WE REACH THE END OF THIS Y LOOP THEN THIS IS A
7700                      ! UNIQUE I VALUE AND THE F MATRIX REMAINS AS ASSIGNED.
7710 Next_z: NEXT Z      ! CHECK NEXT I VALUE
7720 !
7730 ! *****
7740 !
7750 ! IF THE DETAILED PRINTOUT OPTION IS SELECTED THEN PRINT OUT
7760 !     THE REDUCED F MATRIX FOR THIS CASE
7770 !
7780 ! *****
7790 !
7800 IF Prt_opt$<>"S" THEN GOTO 8070
7810 PRINT LIN(3)
7820 PRINT "                                REDUCED F MATRIX          MULTIPLEXERS=";Mul
7830 PRINT
7840 PRINT "                                g2a(D,E) VALUE          "
7850 PRINT "                                1 VALUE          0    1    2    3    "
7860 FOR X=0 TO 7
7870     PRINT USING "18X,D,8X,K,K,K,K";X,F$(X,0),F$(X,1),F$(X,2),F$(X,3)
7880 NEXT X
7890 !
7900 ! *****
7910 !
7920 ! CHECK IF THIS PERMUTATION'S REDUCED F$ MATRIX REQUIRES LESS
7930 ! MULTIPLEXERS THAN THE MINIMUM TO DATE. IF YES, STORE THE
7940 ! INFORMATION FOR THIS CASE.
7950 !
7960 !     MIN_WHERE = MINIMUM PERMUTATION NUMBER
7970 !     MIN_MULT  = MINIMUM NUMBER OF MULTIPLEXERS REQUIRED
7980 !     MIN_I_INP = REDUCED F MATRIX INPUTS FOR MINIMUM
7990 !     MIN_TEMP  = WORKING_ARRAY OF MINIMUM BEFORE SORTED
8000 !     MIN_WORK  = WORKING_ARRAY OF MINIMUM AFTER SORTED
8010 !     MIN_I     = I VALUES OF THE REORDERED MINTERMS FOR THE MINIMUM
8020 !
8030 ! RETURN TO GET THE NEXT PERMUTATION.
8040 !
8050 ! *****
8060 !
8070 IF Mult>=Min_mult THEN GOTO 8240
8080 ! THIS IS A NEW MINIMUM
8081 PRINT LIN(2)

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8090 PRINT USING "#,43X,K,K";"THIS IS A"," NEW MINIMUM:"
8100 PRINT USING "3X,6(K)";Alpha_perm$(Where,5),Alpha_perm$(Where,4),Alpha_perm
$(Where,3),Alpha_perm$(Where,2),Alpha_perm$(Where,1),Alpha_perm$(Where,0)
8110 PRINT
8120 PRINT USING "43X,K,3D";"MULTIPLEXERS = ";Mult
8130 Min_where=Where+1
8140 MAT Min_temp=Temp_array
8150 MAT Min_work=Work_array
8160 MAT Min_i=I
8170 FOR X=0 TO 7
8180     FOR Y=0 TO 3
8190         Min_i_inp$(X,Y)=F$(X,Y)
8200     NEXT Y
8210 NEXT X
8220 Min_mult=Mult
8230 WAIT 2000
8240 SUBEND
8250 !
8260 END
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