Digital Equipment Corporation
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ADVANCED FOCAL

TECHNICAL SPECIFICATIONS

DEC-08-AJBB-DL

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TECHNICAL SPECIFICATIONS

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CONTENTS

CONTENTS (Cont)

CHAPTER 3
FOCAL USAGE

CONTENTS (Cont)

CONTENTS (Cont)

CHAPTER 5
ADDITIONAL FOCAL APPLICATIONS

CONTENTS (Cont)

ILLUSTRATIONS

ILLUSTRATIONS (Cont)

TABLES

CHAPTER 1
INTRODUCTION

FOCAL† is a service program for the PDP-8 family of computers, designed to help scientists, engineers, and students solve numerical problems.

The FOCAL[T.M.] language is used as a tool in a conversational mode; that is, the user creates his problem step by step, while sitting at the computer; when the steps of the problem have been completed, they can be executed and the results checked. Steps can be quickly changed, added or deleted.

One great advantage of a computer is that once a problem has been formulated, the machine can be made to repeat the same steps in the calculation over and over again. Until now, the job of generating the program was costly, time-consuming, and generally required the talents of a specialist called a programmer. For many modest jobs of computation, a person unfamiliar with computers and programming would use a desk calculator or slide rule to avoid the delays, expense, and bothersome detail of setting up his problem so that the programmer could understand it.

FOCAL circumvents these difficulties by providing a set of simplified techniques that permit the user to communicate directly with the computer. The user has the advantages of the computer put at his disposal without the requirement that he master the intricacies of machine language programming, since the FOCAL language consists of imperative English statements in standard mathematical notation.

FOCAL is flexible; commands may be abbreviated, and some may be concatenated within the same line. Each input string or line containing one or more commands is terminated by a carriage return.

A great deal of power has also been put into the editing properties of the command language. Normally, deletions, replacements, and insertions are taken care of by the line number which indicates the replacement or repositioning of lines. If single characters are to be changed within a FOCAL command line, it is not necessary to retype the entire string. The changes may be executed by using the MODIFY command. Thus, complex command strings may be modified quite easily.

In operation, the program indicates that it is ready to receive input by typing an asterisk. On-line command/input may be either direct (to be executed immediately) or indirect (to be stored and executed later) commands. An example of a direct command is

```
*TYPE  5*5*5,1   (User)
     =  125.000*  (PDP-8)
```

The final asterisk indicates that FOCAL is ready for its next command. All commands may be given in immediate mode (see Appendix A).

---

†Formulating On-Line Calculations in Algebraic Language (or FORmula CALculator)

[T.M.] Trademark of the Digital Equipment Corporation, Maynard, Mass.

Text input requires that a numerical digit, in the form ab.cd and within a range of 1.01 to 31.99, follow the * . The number to the left of the period is called the group number. The nonzero number to the right is called the specific line or step number. While keying in command/input strings, the rubout key and the left arrow may be used to delete single characters or to kill the entire line, respectively.

Since the command decoder is table driven, FOCAL can be modified by a small binary tape to understand foreign languages commands. (See Appendix F-2)

FOCAL is written especially for the educational and engineering markets and is intended to be used as a problem solving tool. It gives quick and concise reinforcement, minimizes turnaround time, and provides an unambiguous printed record.

FOCAL is also an extremely flexible, high accuracy, high resolution, general-purpose desk calculator and demonstration program.

This document describes the language, operating procedures for Disk Monitor and FOCAL; use of High Speed reader; addition of user function FNEW; and many other details of interest. Symbol tables, lists, and flow-charts are included.

There are also descriptions of the 10-digit overlay, 4 user overlay, and the complete graphics function.

CHAPTER 2
COMMANDS

2.1 TYPE, ASK

The TYPE and the ASK statements are used for output and input of literals, alphanumeric calculations, and formats. The simplest form of the TYPE statement is a command (e.g., TYPE A*1.4). This will cause the program to type =, evaluate the expression, and type out the result. Several expressions of this kind may be typed from the same statement if the expressions are each ended by commas.

The ASK statement is similar to the TYPE statement in form, but only single variable names can be used instead of expressions, and the user types in the values.

2.1.1 Literals

For output of literals, the user may enclose characters in quotation marks. The carriage return will automatically generate closing quotation marks. The bell may only be inserted during initial input, not via the MODIFY command.

2.1.2 Numerical Input Formats

Keyboard responses to ASK inputs may

a. have leading spaces

b. be preceded by + or - sign if desired or required

c. be in any fixed point or floating point format

d. be terminated by any terminating character, carriage return, or ALTMODE. It is recommanded, however, that the space be adopted as the conventional and general purpose input terminator. The ALTMODE is a special nonprinting terminator that may be used to synchronize the program with external events. For example, to insert special paper in the teletype before executing the program, type Ask A; GO and RETURN, then load the paper, and hit ALTMODE. The value of the variable used remains unchanged.

2.1.3 Alphanumeric Input Formats

Input data that is in response to an ASK command may take any format, may be signed or unsigned, and must be terminated by a legitimate terminating character (space, CR, comma, /, etc.). This means that alphabetic input may also be accepted by an ASK input command (see 3.4.9). This is done by a simple hash-coding technique so that the program can recognize keyboard responses by a single comparison. See example under the IF command for an illustration of how to program the

recognition of the user reply "WAIT". This is possible because the leading zero causes a character string to be interpreted as a number. (e.g.,

TYPE 0ANSWER = 0.26130E+22).

Any literal word containing the letter "E" twice in one input will cause the ASK statement to be terminated as the program interprets this letter as an exponent.

2.1.4 Special Characters

The exclamation point (!), percent (%), dollar sign ($), and the number sign (#) may be used next to quotation marks or by themselves. They cannot be used to terminate alphanumeric expressions. They may be used in either TYPE or ASK commands.

The TYPE statement precedes its numerical typeouts with an equal sign (=) before beginning the output conversation process. The ASK statement types a colon (:) when it is ready to receive keyboard data.

To type an expression before its results, the user may enclose the expression in question marks. This is a special use of the trace feature.

```
*TYPE   ?A*5.2?
 A*5.2=+10.40
 *
```

2.1.5 Print Positions

Carriage returns are not automatically supplied at the termination of a typeout. To supply carriage returns within a TYPE or ASK statement, the exclamation mark (!) is used. This is similar to the use of the slash in FORTRAN format statements.

Occasionally, it is desirable to return the carriage and type out again on the same line without giving a line feed. A number sign (#) returns the print mechanism to the left hand margin but does not feed the paper forward. This feature may be used to plot another variable along the same coordinate.

2.1.6 Symbol Table

TYPE $ (dollar sign) causes the contents of the symbol table to be typed out with the current values of all variables created. The symbol table is typed with subscripts and values in chronological order. The routine then returns as though a carriage return had been encountered in the TYPE statement, thereby terminating the TYPE command. Both the TYPE and the ASK statements may be followed by a semicolon (;) and other commands, unless a $ is in the string.

2.1.7 Output Formats

The output format may be changed within a TYPE statement by %X.YY, where X and YY are positive integers less than 31. X is equal to the total number of digits to be output and YY is equal to the number of digits to the right of the decimal point.

During output, leading zeroes are typed as spaces. If the number is larger than the field width indicates, FOCAL will convert to E format. E format is also specified by % alone. (Floating-point decimal: ±0.XXXXXXXE±Y, where E means "10 to the Yth power".) The current output format is retained until explicitly changed. If a number is too large for the current format, the E format is used temporarily.

2.1.8 Terminators

In the ASK statement, arguments are scanned by the GETARG Recursive Routine and may therefore be terminated by any legitimate terminating character (e.g., space, comma, *, etc.). In the TYPE statement, arguments are scanned by the EVAL Recursive Routine and must therefore be terminated by comma, semicolon, or carriage return. In either the TYPE or ASK statement, command arguments may be preceded by format control characters # ! ". Example:

```
*ASK ?A  B  C  ?
A :5, B :6 C :7↵ *
```

All commands except WRITE, RETURN, MODIFY, QUIT and ERASE may be combined on the same line if separated by a semicolon.

2.1.9 Off-Line Data Tapes (c.f., Section 4.5.3)

To prepare data tapes off-line, type the data word, the terminating space, and the "here-is" key. Use backspace and rubout to remove characters off-line.

2.1.10 Corrections

For editing input to an ASK command before the input has been terminated, the left arrow (←) is used.

2.1.11 Roundoff

Numbers to be typed out are rounded-off to the last significant digit to be printed (i.e., the rightmost digit of the requested format) or to the sixth significant digit, whichever is smaller.

2.2 DO

The DO command is used chiefly to form subroutines from single lines, groups of lines, or from the entire text buffer. Thus, the instruction DO 3.3 makes a subroutine of line 3.3. For a single line subroutine, control will be returned when the end of the line is encountered or when the line is otherwise terminated (e.g., by a RETURN statement, or in the case of TYPE, with the $).

One of the most useful features of a command language of this type is the ability to form subroutines out of entire groups. Thus, the statement DO 5 calls all of group 5 as a subroutine beginning with the first group 5 line number. Control will then proceed through the group numbers going from smaller to larger. A return or an exit is generated from this type of subroutine by using the word RETURN, or by encountering the end of that group, or by transferring control out of the group via a GOTO or IF command. Similarly, the entire text buffer may be used as a recursive subroutine by simply using DO or DO ALL.

The DO statement may be concatenated with other legitimate commands by terminating it with a semicolon. Thus, a single line may contain a number of subroutine calls. In this way, several forms of complex subroutine groupings may be tested from the console.

The number of DO commands which may be nested linearly or recursively is limited only by the amount of core storage remaining after inclusion of the text buffer and the variable storage.

NOTE

When a GOTO or IF statement is executed within a DO subroutine, control is transferred immediately to the object line of the GOTO command; that line will be executed and return made to the DO processor. If the next line number is within the group (if this is a group subroutine), it will be executed. If, however, a line number outside of that group is about to be executed, then a return will be made from the DO subroutine and if any of the DO command line remains, it will be processed.

2.3 EDITING AND TEXT MANIPULATION FACILITIES

2.3.1 Command-Input

A line number which has already been used and is reused in a new input will cause the new input to replace the line that previously had that number. Insertions are made at the appropriate point in a numerically-ordered string of lines. For example, line number 1.01 (the smallest line number) will be inserted in front of (or above) line number 1.1. The largest line number is 15.99.

2.3.2 ERASE

Removal of a single line may be made by using the ERASE command. For example, ERASE 2.2 will cause line 2.2 to be deleted. No error comment will be given if that line number does not exist. The command ERASE 3 or 3.0 will cause all of group 3 to be erased. To delete all of the text, one must type the words ERASE ALL.

ERASE, used alone, has the function of merely removing the variables. This may also be thought of as initializing the values of the variables to zero.

To examine a single line, type WRITE followed by the line number. For example, WRITE 3.3 will cause line 3.3 to be typed out with its line number on the Teletype. WRITE 4.0 will cause all of group four to be written on the Teletype. WRITE ALL will cause all of the text to be printed on the Teletype, left justified, with title and line numbers in numerical order.

2.3.3 MODIFY

When only a few characters of a particular line must be replaced, the MODIFY command is used to avoid replacing the entire line. For example, to change characters in line 5.41, type MODIFY 5.41. This command is terminated by a carriage return, and the program waits for the user to type that character at which he wishes to make changes or additions. The program will then type out the contents of that line until the search character is typed. (The search character is not echoed when it is first keyed in by the user.) The program will now accept input.

At this point, the user has seven options:

a. type in new characters in addition to the ones that have already been typed out;

b. type a form-feed; this will cause the search to proceed to the next occurrence, if any, of the search character;

c. type a bell which allows him to change the search character just as he did when first beginning to use the MODIFY command;

d. use the rubout key to delete characters going to the left;

e. type a left arrow to delete the line over to the left margin;

f. type a carriage return to terminate the line at that point and move the text to the right;

g. type line-feed to save the remainder of the line.

The ERASE ALL and MODIFY commands are generally used only in immediate mode, as these commands return to command mode upon completion. The reason for this is that internal pointers may be changed by these commands.

During command/input, the left arrow will delete the line numbers as well as the text. During the MODIFY command typing the left arrow will not delete the line number.

When the rubout key is struck, a backslash (\) is typed for each character that is deleted.

NOTE

Any modifications to the text will cause the variables to be deleted as if an ERASE command had been given. This is caused by the organization of the data structure. It is justified by the principle that a change of program probably means a change of variables as well.

2.4 FOR

This command is used for convenience in setting up program loops and iterations. The general format is:

FOR A = B, C, D;---.

The index A is initialized to the value B, then the command string following the semicolon is executed at least once. When the carriage return is encountered, the value of A is incremented by C and compared to the value of D. If A is less than or equal to D, then the command string after the semicolon is executed again. This process is repeated until A is greater than D.

Naturally, A must be a single variable; but B, C, and D may all be expressions, variables, or numbers. The computations involved in the FOR statement are done in floating point arithmetic. If comma and the value C are omitted, then it is assumed that the increment is one. For example:

SET B = 3; FOR I = 0, 10; TYPE B ↑ I, ! (power of 3)

2.5 IF

To provide transfer of control after a comparison, we have adopted the IF statement format from FORTRAN. The normal form of the IF statement contains the word IF, followed by a space, a parenthesized expression, and three line numbers separated from each other by commas. The program will GOTO the first line number if the expression is less than zero, the second line number if the statement has a value of zero, and the third line number if the value of the expression is greater than zero.

Alternative forms of the IF command are obtained by replacing the comma between the line numbers by a semicolon. In this case, if the condition is met which would normally cause the program to transfer to a line number past that position, then the remainder of the line will be executed. Example:

```
ASK REPLY
IF  (REPLY - 0WAIT) 6.4,  5.01;  RETURN
IF  (REPLY - 0YES) 6.3, 5.02; 6.3
```

NOTE

The IF command could occasionally fail to take the = 0 branch due to internal computation and truncation errors.

2.6 GOTO

This command causes control of the program to be transferred to the indicated line number. A specific line number must be given as the argument of the GOTO command. If command is initially handed to the program by means of an immediately executed GO, control will proceed from low numbered lines to higher numbered lines as is usual in a computer program. Control will be returned to command mode upon encountering a QUIT command, the end of the text, or a RETURN at the top level.

The operation of the GOTO is slightly more complicated when used in conjunction with a FOR or a DO statement. Its operation is perfectly straightforward when used with any other statement.

2.7 RETURN

The RETURN command is used to exit from DO subroutines. It is implemented internally by setting the current program counter to zero. When this situation is encountered by the DO statement it exits. (Refer to the DO command, Section 3.2.).

2.8 QUIT

A QUIT causes the program to return immediately to command/input mode, type *, and wait.

2.9 COMMENT

Beginning a command string with the letter C will cause the remainder of that line to be ignored so that comments may be inserted into the program.

2.10 CONTINUE

This word is used to indicate dummy lines. For example, it might be used to replace a line referenced elsewhere without changing those references to that line number.

2.11 SET

The SET command for arithmetic substitution is used for setting the value of a variable equal to the result of an expression. The SET statement may contain function calls, variable names, and

numerical literals on the right hand side of the equal sign. All of the usual arithmetic operations plus exponentiation, may be used with these operands. The priority of the operators is a standard system: +-/*↑. These, however, may be superseded by the use of parenthetical expressions. The SET statement may be terminated by either a carriage return or a semicolon, in which case it may be followed by additional commands. For example:

```
SET AA=B(5+<6+CONST>*ALPHA/[5/BETA]);GOTO 3.2
```

2.12 HIGH-SPEED READER

2.12.1 General

The asterisk (*) is also used as a flip-flop control over the selection of the input device to be used by a FOCAL program. (See the examples that follow.) An out-of-tape condition will return to low-speed reader input and change the status of the * flip-flop. An error condition, however, does not change that * flip-flop (see notes below).

For example, typing:

```
**
```

will read in a program tape or a series of immediate commands.

```
**;ASK  ABCDZ
```

will fill AB with data from tape. If tape is empty, control will return to command mode.

```
*1.1*; FOR I=1, 5; ASK AX(I)
*DO 1.1
```

If the tape contains fewer than 5 pieces of data, then remaining items are taken from keyboard. (See c below.)

2.12.2 Other Rules

a. * as a command may be concatenated with other processes [JMP (PROC):

(e.g., 01.30* ; ASK A, B;*)

b. If an out-of-tape condition is encountered while reading commands, then the input device is switched to keyboard and all is returned to normal. (This occurs when the user has no reader.) It is equivalent to receipt of a left arrow. [JMP (IBAR)].

c. If an out-of-tape condition occurs while executing an ASK command, then FOCAL responds as if the end of the command line (carriage return) has been reached. [ISZ PDLXR; POPJ]

Thus,

```
**; ASK A,B,C,D
```

produces:::(out of tape on C): and the user is back to normal mode.

However,

```
*ERASE
**; for I=1, 20; ASK A(I); TYPE I,!.
: = 1.0000
: = 2.0000
: = 3.0000
: (out of tape for I=4)
: (now accepting from keyboard) 123, = 5.0000
: 345, = 6.0000
: ?01.00 (Control-C typed)
* TYPE $
I @ (00) = 7.0000
A @ (01) = (data from tape)
A @ (02) = (data from tape)
A @ (03) = (data from tape)
A @ (04) = .0000
A @ (05) = 123.0000
*       A @ (06) = 345.000
```

d. When an error occurs from the reader (illegal command, etc.), the code will be typed out and input device control returned to the low-speed device. However, the device flip-flop (HSPSW) will still indicate that the reader is active. Consequently, it will be necessary to give two asterisks before the reader will be activated again.

```
**
*****?12.83   (Buffer full)
**
**
(reader now active again).
```

e. It is necessary to have a fairly long timing loop to detect the out-of-tape condition (slow readers, restart delays, etc.). As a result, the user of a PDP-8/S may encounter long delays if there is no high speed reader or when the reader is out of tape. However, the initial dialogue makes a correction for this when an 8/S is being used.

f. Since the reader operates with the interrupt on, one may use Control-C to return at once to keyboard input mode. A manual interrupt via Control-C (?01.00) or a console restart (?00.00) gives the same effect.

g. All commands, including "*" may be executed in immediate mode from the high speed reader. This has several beneficial results:

(1) Program tapes may be composed that are self-protecting and self-starting

```
ERASE ALL                          (protection)
01.10 ASK "Power of 2?"REPLY       (input indirect program)
01.30 TYPE 2 REPLY,!,GOTO 1.1
(etc)
GOTO 1.1                           (starting)
5, 3, 1                            (data)
```

This particular program is an infinite loop and must be stopped by a Control-C from the keyboard.

(2) Programs may chain themselves together.

```
ERASE ALL
3.4 TYPE "NUMBER 1"!!!; ASK A
3.5 *                          (indirect command)
*; GO                          (device restored to low speed and program
                               started)
```

The printout from this tape will be:

```
**          (START READER)
******      NUMBER 1
                    (Three lines accepted)
(Erase processed)
: (waiting for keyboard input)  (user)
```

(execution of 3.5 * at this point will reactivate the high speed reader).

(3) Immediate mode commands on the tape allow maximum storage for variables.

(4) If the interrupts are disabled by the patches shown in Section 4.5.3, then two tapes may be merged from both high- and low-speed readers by a resident FOCAL program.

2.13 THE FUNCTIONS

2.13.1 General

The functions are provided to give extended arithmetic capabilities and the potential for expansion to additional input/output devices. There are basically three types of functions. The first group contains integer parts, sign part, square root, fractional, and absolute value functions. The second group has the input/output for scope and analog/digital converter functions. The third group has extended arithmetic computations of trigonometric and exponential functions.

A function call consists of no more than four letters beginning with the letter F and followed by a parenthetical expression (e.g., FSGN (A-B *2)). This expression is evaluated before transferring to the function process itself.

2.13.2 Analog to Digital

a. Input

The function FADC(X) is used to take a reading from an analog-to-digital converter. The value of the function is a 12-bit integer reading. The argument "X" is the channel member (AX08) in decimal. Additional version of the ADC function could be designed to provide for synchronization by a clock or other means. (c.f., Chapter 5)

```
*SET A=FADC ( ) *5
```

b. Output

The scope function FDIS (expression, expression) is used to set and display an X-Y coordinate on a Model 34 Scope and scope interface. The value returned for each of these functions is the integer part of the second expression.

```
*SET Z = FDIS(X,X43/50)
```

2.13.3 Extended Functions

The extended arithmetic functions (FEXP, FLOG, FATN, FCOS, FSIN) are retained at the option of the user. They consume approximately 800 characters of text storage area. These arithmetic functions are adapted from the extended arithmetic functions of the three-word, floating point package.

2.13.4 Random Numbers

A simple random number generator is provided in the basic package as FRAN()! An expanded version could incorporate the random number generator from the DECUS library.

Functions for other devices are provided as overlay tapes (see Appendix H).

2.13.5 Standard Functions

a. Trigonometric Functions

All arguments are in radians

FSIN ( ) - the sine functions
FCOS ( ) - the cosine function
FATN ( ) - the arctangent

From these functions, the user may compute all other trigonometric functions. (See FOCAL User's Manual)

b. Logarithmic Functions

FLOG ( ) - log to the base e or Naperian base
FEXP ( ) - e to the power

c. Arithmetic Functions

FSQT ( ) - the square root
FSGN ( ) - one (1) with the sign of the argument
FABS ( ) - the absolute value
FITR ( ) - the next smaller integer part maximum of 1024

LOG_{10} (ARG) = LOG_e (ARG) *LOG_{10}(e)

LOG_{10} (e) = 0.434295

LOG_e (10) = 2.30258

e = 2.71828

where:

1 degree = .0174533 radians
1 radian = 57.2958 degrees

2.13.6 Using The Arctangent

An arctan function cycles between + π/2 and - π/2. Thus, to get a correct range for 0-2π radians from the expression FATN(Y/X), we must use the signs of X and Y.

X	Y	FATN(X/Y)
+	+	0-PI/2
-	+	PI/2 - PI
-	-	PI - 3*PI/2
+	-	3*PI/2 - PI*2

```
*GO


   INDEX     X       Y       FUNCTION          COMPUTED
=  0.00=   1.00=   0.00=   0.000000     =   0.000000
=  0.30=   0.96=   0.30=   0.300000     =   0.300000
=  0.60=   0.83=   0.57=   0.600000     =   0.600000
=  0.90=   0.62=   0.78=   0.900000     =   0.900000
=  1.20=   0.36=   0.93=   1.200000     =   1.200000
=  1.50=   0.07=   1.00=   1.500000     =   1.500000
=  1.80=-  0.23=   0.97=-  1.341600     =   1.800000
=  2.10=-  0.51=   0.86=-  1.041600     =   2.100000
=  2.40=-  0.74=   0.68=-  0.741595     =   2.400000
=  2.70=-  0.91=   0.43=-  0.441595     =   2.700000
=  3.00=-  0.99=   0.14=-  0.141595     =   3.000000
=  3.30=-  0.99=-  0.16=   0.158403     =   3.300000
=  3.60=-  0.90=-  0.44=   0.458402     =   3.600000
=  3.90=-  0.73=-  0.69=   0.758402     =   3.900000
=  4.20=-  0.49=-  0.87=   1.058400     =   4.200000
=  4.50=-  0.21=-  0.98=   1.358400     =   4.500000
=  4.80=   0.09=-  1.00=-  1.483200     =   4.800000
=  5.10=   0.38=-  0.93=-  1.183200     =   5.100000
=  5.40=   0.64=-  0.77=-  0.883196     =   5.400000
=  5.70=   0.84=-  0.55=-  0.583195     =   5.700000
=  6.00=   0.96=-  0.28=-  0.283198     =   6.000000
=  6.30=   1.00=   0.02=   0.016802     =   0.016802
=  6.60=   0.95=   0.31=   0.316803     =   0.316803
=  6.90=   0.82=   0.58=   0.616800     =   0.616800


C-FOCAL , 8/68

01.05 T !!!!"   INDEX     X      Y      FUNCTION          COMPUTED
01.10 FOR I=0,.3,7; TYPE !,%4.02,I;D 2
01.20 TYPE !!!!;WRITE ALL
01.30 QUIT

02.10 SET Y=FSIN(I); SET X=FCOS(I)
02.20 TYPE X,Y,%8.06,FATN(Y/<X+1E-10>); DO 13; TYPE "     " TH;

13.10 IF (X)13.3,13.2,13.3
13.20 SET X=1E-100
13.30 SET TH=FATN(FABS<Y/X>)
13.40 SET PI=3.141596
13.50 IF (Y) 13.6; IF (X) 13.7; RETURN
13.60 IF (X) 13.8;SET TH=PI+PI-TH; RETURN
13.70 SET TH=PI-TH; RETURN
13.80 SET TH=PI+TH; RETURN
*
```

2.13.7 Boolean Functions

TRUE is +1
FALSE is -1

```
*D  15
  A  B   AND   OR   NOR   XOR   CARRY   SUM
=-1=-1   =-1 =  -1    1=    1      =-1=-1
=-1= 1   =-1 =   1    1=   -1      =-1= 1
= 1=-1   =-1 =   1    1=   -1      =-1= 1
= 1= 1   = 1     1   -1=    1      = 1=-1
```

XOR is A*B
NOR is FSGN(-A-B)
OR is FSGN(A+B)
AND is FSGN(A+B-1)
NOT(A) is -A

The result of adding A and B is

CARRY = FSGN(A+B-1)
SUM   = -A*B

```
*
*WRITE 15
15.05 TYPE "  A  B   AND OR NOR XOR CARRY   SUM"!
15.10 FOR A=-1,2,1; FOR B=-1,2,1;TYPE A,B,"      "; DO  15.2
15.15 QUIT
15.20 TYPE FSGN(A+B-1),FSGN(A+B),FSGN(-A-B),A*B,"     "FSGN(A+B-1),-A*B,!
*
```

2.13.8 FNEW - A User Function

This function name may be used to call a machine language routine for any reason. (See Section 4.4.1)

2.14 THE LIBRARY COMMAND

The form and usage of this mass storage command will vary with the computer and FOCAL system used. (c.f., 4.6)

2.14.1 L-Command For Single User System

The command may be given in either direct or indirect mode. Execution of this command first causes the octal typeout of the contents of four FOCAL pointers: CFRS, BUFR, LASTV, and BOTTOM, respectively. The second action is to type out whatever characters follow the "L" to serve as operating instructions for the user. The third action is to turn off the interrupts and transfer to the Disk Monitor or 8-Library System by jumping to 7600.

The four octal numbers represent:

a. the start of text buffer,

b. the end of text buffer,

c. the end of the variable list,

d. the bottom of the push-down list.

These command features will permit optimum usage of available disk storage and be compatible with the Disk Monitor.

After debugging a program, a typical user will execute ERASE and LIB. (This causes B and C to be equal in the 4K system.) He will then save the program and restart or call another program. (See Section 3.4.12)

Manual Chaining may also be done. For example, when a program reaches line 12.3, it may need to call another routine (as in a series of teaching programs, demos, or math subroutines). The user, however, must be given instructions on how to proceed:

```
12.30LIB    .CALL LES2
```

For example, execution of 12.3 may produce:

```
 3206
 3345
 3401
 4407
.CALL LES2
.CALL LES2                    [User types this]
.START
*
```

In the 8K Version, the text and variables are stored independently. For this reason, the 8K version can have different programs operating on the same data. (See Section 3.4.14)

2.14.2 LIBRA Command Specifications for Multi-User Systems*

Four modifiers of the LIBRARY command are implemented to allow automatic program storage, retrieval, and management in multi-user FOCAL. This extension to the FOCAL system is implemented under the segment name LIBRA and requires at least an 8K PDP-8 with one DF32.

The LIBRARY command and its variations are:

a. To save a program on disk,

```
LIBRA SAVE name )
```

Where "name" is a 1 to 4 character identifier and) is described in the FOCAL language specifications.

*Not completed

Errors:

(1) A program with an identical name has been found in the directory list

(2) Name missing from command

(3) Disk I/O error (non-recoverable)

b. To call a program on disk,

LIBRA CALL name)

Errors:

(1) No such program on directory list

(2) Name missing from command

(3) Disk I/O error (non-recoverable)

c. To delete a program from disk,

LIBRA DELETE name)

Errors:

(1) No such program name in directory list

(2) Name missing from command

(3) Disk I/O error

d. To list the directory

LIBRA LIST)

Errors:

(1) Disk I/O error

NOTE

This command will destroy any program by an effective "ERASE ALL".

The directory is printed ten across for as many lines as necessary.

2.14.3 DF32 FOCAL FILE STRUCTURE

Programs are stored in blocks 1600_8 words long. This allows 36 blocks of storage on one DF32 and a directory of 512 words or 256 entries. This directory is sufficient for the maximum DF32 configuration allowable on a PDP-8.

1. Disk 36 blocks
2. Disk 72 blocks
3. Disk 110 blocks
4. Disk 146 blocks

The directory is a linear list with a maximum size of 512 words (with 2 words/entry). Word position in the list corresponds to the block position on the disk. The blocks begin at location 1000_8 from the end of the directory and extend in increments of 1600_8 to the end of the disk. The end of the list is an entry of ones. Unused blocks are indicated by entries of all zeroes.

The LIBRARY functions swap users in the multiple user system. This diminishes the total number of blocks by the maximum number of allowed users. A disk program is required to clear the directory, and to set the maximum number of blocks available.

2.15 WRITE

The WRITE command is used to list the entire indirect program (WRITE ALL or W), specified groups, or single lines. When all text is printed, a leader-identifier is given at the top of the listing. This identifies which major version is being used for the particular indirect program. (FOCAL, 1969; 8K FOCAL @ 1969; 4-word @ 1969).

NOTE

The WRITE command disables the trace.

CHAPTER 3
FOCAL USAGE

3.1 REQUIREMENTS

Any 4K PDP-8 family computer with Teletype may be used with FOCAL: PDP-5, PDP-8, PDP-8/S, PDP-8/I, PDP-8/L, LAB-8, LINC-8, TSS-8, PDP-12.

3.2 LOADING PROCEDURE

a. The RIM or Read-In-Mode Loader must be in memory. (See RIM Loader Manual for a thorough discussion.)

b. The RIM Loader is used to load the Binary Loader. (See Binary Loader Manual for a complete description.)

c. The Binary Loader is used to load FOCAL.

d. Upon halting, press the CONTINUE key, since the program is loaded in two sections.

e. Place 200, the starting address of FOCAL, into the Switch Register when the complete tape has been loaded.

f. Press the LOAD ADDRESS key.

g. Press the START key.

h. The initial dialogue will begin.

3.3 INITIAL DIALOGUE

The program will identify the DEC 12-bit computer you are using and make appropriate corrections to itself. If the user determines that extra space is required, the program will permit rejection of extended functions.

FOCAL is ready for commands when it types *.

3.4 OPERATION

3.4.1 Restart Procedure

There are two methods to restart the system.

Method 1 - Type the character control/C at any time; (FOCAL acknowledges this by typing ?01.00).

Method 2 - a. Put 200 into the Switch Register
b. Press the STOP key
c. Press the LOAD ADDRESS key
d. Press the START key
e. The program will then type ?00.00 indicating a manual restart, and an asterisk indicating it is ready to receive input.

3.4.2 Keyboard Error Recovery

If an error is made while typing commands to FOCAL, one of the following methods may be used to recover:

a. Use the RUBOUT key on the teletype keyboard to erase the preceding character. The RUBOUT key echoes \ for each character removed.

b. Use the MODIFY command, with the modify control characters, to search the command string for any character in error and alter or delete that character.

c. Use Left Arrow to delete over to the left margin.

d. Use Left Arrow to delete input data.

3.4.3 Parentheses

The following parenthetical pairs may be used in any alphanumeric expression: parentheses, angle brackets (< >), and square brackets ([ ]). The program checks to see whether the proper matching terminator has been used at the correct level. Use of these terminators in different configurations provides additional clarity in reading alphanumeric expressions.

3.4.4 Trace Feature

A trace feature may be used to detect errors, follow program control, and create special formats. To implement the trace feature, insert a question mark into a command string at any point. Each succeeding character will then be typed out as it is interpreted until another question mark is encountered or until the program returns to command-input mode.

3.4.5 Variables, Functions and Numbers

A variable name consists of one or two alphanumeric characters, of which the first must be a letter. The second character may be A-Z, 0-9, ", '. Additional characters are ignored.

Function names are easily distinguished from variable names because they start with the letter F. A number always begins with a digit 0-9.

3.4.6 Error Diagnostics

Programming errors are indicated by an error diagnostic. The printout is in the form ?XX.XX @ GG.SS. The first number is a specific error number derived from the core address of the error call. The GG.SS is the number of the line, if any, of the text which contains the error.

The error diagnostic printouts are intended to be efficient yet informative and explicit. Used in conjunction with the trace feature, these will pinpoint errors precisely. (See Appendix B).

Example:

```
*DO 2.35?
 SET A=5/C + ?28.72   (Divide by zero, C=0)
*
```

3.4.7 Arithmetic Priorities

```
↑
*
/
+-
```

Operations of equal priority are executed from left to right (e.g., T 2↑3↑2=64 not 512).

3.4.8 ASCII data

ASCII input of A-Z has the values of 1-26 per digit per letter respectively, thus,

```
*ASK A; TYPE A
:Z=26.00
*A A; T A
:AZ = 36.00
```

This is also true for internal numerical constants like 0NO, 0YES, etc.

(See the IF command for an example of this feature.)

The technique may also be used to create a kind of associative memory:

```
*ASK    A; ASK GRADE (A)
:DICK     : 95
*ASK    A;TYPE GR(A)
:DICK     =95
```

3.4.9 Indirect Commands

If a Teletype line is prefixed by a line number, that line is not executed immediately, but is stored for later execution. Line numbers must be in the range 1.01 to 31.99. The numbers 0.0, 1.00, 2.00, 3, etc., are illegal line numbers and are used to indicate the entire group. The number to the left of the point is called the group number; the number to the right is called the step number. Execution of indirect commands is begun by an immediate GOTO of DO command. The GOTO command causes FOCAL to start the program by executing the command at a specified line number (e.g., GOTO 1.3). The GO command causes FOCAL to go to the lowest numbered line to begin executing the program and continues until it runs out of program text. FOCAL can automatically cross group boundaries.

3.5 SAVING FOCAL PROGRAMS

3.5.1 Paper Tape

To save a FOCAL symbolic text, type WRITE ALL, turn on the punch, type @ marks for leader-trailer, and type carriage return. When all of the program has been typed out, type additional @ marks for more leader-trailer, turn off the punch, and continue your conversation with the computer. (To save a FOCAL binary program, see Appendix C.1.)

3.5.2 LINC Tape (see Section 2.14.1; TC01 via 8-LIBRARY SYSTEM; PDP-12)

On LINC tape, load FOCAL program as follows:

a. Load FOCAL binary tape, execute Initial dialog, and call UPDATE.

```
NAME:        START
SA (OCTAL):     200
MEM LOCATIONS:  <4600,  7577 >;
```

b. Call UPDATE again.

```
NAME:        FOCAL
SA (OCTAL):     (none)
MEM LOCATIONS:  <0,   3377 >;
```

c. Calling Sequence:

```
FOCAL
START
*
```

d. Write the desired FOCAL routine.

e. Give an "L" command. Four octal numbers will be printed, and control will return to the Library System.

```
UPDATE

NAME:        (user's choice)
SA (OCTAL):     (none)
MEM LOCATIONS:  <0 ><(A),  (B) >;
  Where "(A)" and "(B)" mean the first and second octal numbers.
```

f. To call a program:

```
FOCAL
(user's choice)
START
*
```

3.5.3 Disk Monitor System (see Section 2.14.1)

a. Build the Disk System.

b. Load FOCAL into field zero.
(If the computer has 8K, use the binary loader in field 1.)
Alternate procedure: Use PIP to place the binary on disk. Then, use LOAD on the disk file. (This procedure is faster for a teletype, but uses more disk space.)

c. Load Address 200, START, and complete the initial dialogue.

d. Load Address 7600 and START.

e. Initialize the disk as follows:

```
.SAVE  START!4600-7577;200
.SAVE  FOCAL!0-3377;
```

f. Run FOCAL.

```
.)FOCAL
.)START

(Create Program)
```

g. Save program; return to disk Monitor by giving an L command.

```
.SAVE (name);0,(A) - (B)      [note saving page zero]
```

h. Run a program (after doing either step f or g).

```
.FOCAL )
.CALL  (name) )
.START ) [linefeed will not occur]
*(FOCAL ready)
```

i Steps g and h may be repeated.

3.5.4 Disk System and Extended Functions

To cope with configurations involving deletion of extended functions, proceed as follows:

a. Load FOCAL and start at 7600;

```
.SAVE START!4600-7577;200
.SAVE INIT:0,3200-4577;      [note saving page zero]
.CALL INIT
.START
[Dialogue, answer YES]
*L
.SAVE FOCAL!0-3377;
```

b. To reinitialize a system without some extended functions, type

```
.FOCAL
.CALL INIT
.START

[Dialogue, answer NO, YES, i.e., keep sine and cosine]
*L
.SAVE STNY!5200-7577;200
.
```

c. To create a system without any extended functions, type

```
.FOCAL
.CALL INIT
.START

[Dialogue, answer NO, NO]
*L
.SAVE STNN!5400-7577;200
```

d. Be sure to use the correct START command with each user program.

(1)

[to use no exponential function version]

```
.FOCAL
.CALL NEXP
.STNY
*
```

(2) or

[to use no cosine function version]

```
.FOCAL
.CALL NCOS
.STNN
*
```

3.5.5 Disk System and Extended Memory (see section 2.14.1)

Follow these operations to set up an 8K version of FOCAL on the disk:

```
[Build Disk System]
[Load FOCAL]
[Start at 200]
[Dialogue, answer questions.]
*L )
0100                    (A)
0121                    (B)
3217                    (C)
XXXX                    (D)
.SAVE ST8K! (D) -7577;200
.SAVE FCL8!  0 - 3177;
.SAVE NUL8: 10100; 10113
.
```

The SAVE command for a finished 8K FOCAL program is

```
.SAVE CODE:1(A) - 1(B); 10113
```

where (A) and (B) are the first and second four digit numbers typed out by the L-command. These are the field one bounds of the program text. The value of (D) will depend on the functions retained.

The variables, however, are in field zero. To save a set of data, type:

```
.SAVE DAT8:0;3200-(C);      [note saving page zero, field zero]
```

To set up a null program with a particular data set, type:

```
.FCL8
.CALL DAT8
.CALL NUL8
.ST8K
```

3.5.6 For 4-user FOCAL SAVE command, see Section 4.6.6.

3.5.7 EAE Patch for FOCAL, 1969

```
7203    3206    DCA    .+3
7204    1256    TAD    MP2
7205    7425    MQL    MUY
7206       0    0
7207    3253    DCA    MP5
7210    7501    MQA
7211    3255    DCA    MP3
7212    5227    SNP    .+15
```

CHAPTER 4
PROGRAM SPECIFICATIONS

4.1 MACHINE REQUIREMENTS

The minimum hardware configuration necessary to run this program is a 4K PDP-8 family computer with ASR-33.

Scope, an additional 4K memory, and high-speed reader and punch are available options.

Additional PT08s are added for extra users.

4.2 DESIGN SPECIFICATIONS

4.2.1 Design Goals

FOCAL is a conversational language and operating system for a basic PDP-8. It is designed to facilitate on-line editing and execution of symbolic programs. (For BNF description, see Appendix F.)

4.2.2 Input

The keyboard, low-speed reader, or high-speed reader may be used for input of program text and for commands to be executed immediately. Keyboard input is double buffered.

4.2.2.1 Input Format - See description of the commands in Chapter 2 for format information.

4.2.2.2 Character Set - Input and output characters are in ASCII teletype code. Interpretive operations are also done internally in expanded ASCII. The text buffer is packed two characters to a word as follows.

number = represented as: prints as
300 = not packed = ignored: @
301 - 336 = 01 - 36: A-Z
337 = not packed - edit control, kill line: ←.
240 - 276 = 40 - 76: symbols
277 = 37: ?.
340 - 376 = 7740 - 7776 (extended codes): non-printing
377 = not packed - edit control, delete preceding character; if a character is deleted, \ (backslash) is typed.
200 = not packed - ignored: leader-trailer
210 - 237 = 7701 - 7737: control characters
000 = not packed - ignored: blank tape.

4.2.3 Output

4.2.3.1 Output Format - See the TYPE and WRITE statements for format of output. The output character set is the same as that for input.

4.2.3.2 The Input/Output and Interrupt Processor - The purpose of the interrupt handler and the I/O buffers is to permit input and output to proceed asynchronously with calculations. This allows an optimal use of the computer time. When the interrupt handler finds that the teletype output flag has been raised, it clears that flag and looks to see whether there are any additional characters in the teletype output buffer to be printed. If there are, it takes the next character from the buffer, prints it, clears that location in the buffer, and moves the pointers. Separate pointers are maintained for both the interrupt processor and for the program output subroutine (XOUTL). If the interrupt handler finds that there are no more characters to be output on the Teletype, it will clear the teletype in-progress-switch (TELSW). If the interrupt handler does output another character, it sets TELSW to a nonzero value.

When the program desires to place characters in the buffer for the interrupt processor to print, it makes a call to XOUTL. This routine first checks to see if TELSW has been set. If TELSW is zero, no further interrupts are expected by the interrupt processor, and the output routine immediately types the character itself and sets TELSW to a nonzero value. Otherwise, if the interrupt processor is in motion, then the output routine places the character into the buffer and increments the pointer. If there is no room in the buffer for additional characters, the low-speed output routine waits until room is available. The keyboard input processors are similar in organization to the output routines except that no in-progress-switch is needed and the input is only double buffered.

Another advantage of the interrupt system is that it enables the user to stop program loops from the keyboard by typing Control C. The recovery routine will then reset the I/O pointers, type out the message code ?01.00, and return to command mode. Manual restart via the console switches also goes to the recovery routine, resets the pointers, and types out message code ?00.00. In fact, all error diagnostics go to the recovery routine. Error printing is withheld until prior printing is complete. Otherwise, on occasion, a full buffer could be dumped and the error message could be printed as many as 16 characters before it should have otherwise occurred. This would be misleading when using the trace mode to discover specific errors within a character string.

The recovery routine may also be called by the interrupt processor if it discovers that there is no more room in the keyboard buffer. For example, this could occur if the user continues to type on the keyboard while the program is making computations. Physical evidence of the error is indicated by failure of the computer to echo characters as the user types.

NOTE

This error could also occur when reading a paper tape program into the text buffer via the low-speed reader. If the output hardware is slower than the input hardware, more text is read in than is being read out of the buffer, resulting in failure of the program to empty the reader buffer as quickly as it is being filled up, since the program synchronizes the reading of the characters with sending them into the buffers. In other words, the program synchronizes its side of the I/O buffers, but the interrupt side of the I/O buffers proceeds at a rate determined by the hardware. To prevent this type of error with long input tapes, which were prepared off-line, carriage returns may be followed by some blank tape which is ignored by the input routines, thereby giving the output routine time to catch up. This is essentially a hardware problem since the program is unable to stop the low-speed reader.

4.2.4 Organization

4.2.4.1 Arithmetic Package - The arithmetic is done in the floating point system. The three-word floating point package allows six digits of accuracy plus the extended functions. The program will eventually use four words as an option. The exponential range is approximately ten to the six hundredth. Internal accuracy during computations is 6.924 decimal digits.

The four-word floating point system creates ten digits of accuracy, including roundoff. It does, however, require more storage for variables and for push-down list data.

4.2.4.2 Storage - The major components of the program occupy locations 1-3200. The remaining storage 3200 - 4600 is used for text storage, variable storage, and push-down storage, in that order. The text occupies approximately two characters per register. The variables occupy either five or six locations per variable depending on whether the three- or four-word option is utilized.

Remaining storage is allocated to the push-down list. Overflow will occur only when one of these lists exceeds the remaining storage. This could happen in the case of complex programs which have multiple levels or recursive subroutine calls. The push-down list contains three kinds of data. One of these is a single location for push-jump and pop-jump operations. The content of the accumulator is also pushed into the same list in a single register. The third type of push-down storage is floating point storage (see Appendix D).

This important storage allocation scheme permits flexibility in the trade off of text size, number of variables, and complexity of the program, rather than restricting the user to a fixed number of statements or characters, or to a fixed number of subroutine calls, or to a limited number of variables.

4.3 HARDWARE ERRORS

The 8/S will halt at location EXIT +6 if a parity error occurs.

4.4 INTERNAL ENVIRONMENT

4.4.1 Adding a User's Function;FNEW(Z) (c.f., Section 5.2)

The FOCAL system was designed to be easily interfaced for new hardware such as LAB-8, multiplexed ADCs real-time clocks, or to software such as a nonlinear function.

The information given below, the symbol table, the various lists, and a core layout are intended to be sufficient for all required modifications and patches. This symbolic approach ensures greater flexibility and compatibility with DEC modifications to FOCAL, other user's routines, and assembly via PAL III on a PDP-8.

Example: Suppose we had a scope routine to display characters at a given point on a scope. We will call this routine from FOCAL as function by FNEW (X, Y, SHOW). Here X and Y are expressions to be used as display coordinates for the start of SHOW.

a. First, patch the function branch table.

```
*FNTABF + 15
XFNEW
```

b. When control arrives at XFNEW, the X has already been evaluated.

```
XFNEW,    JMS     I     INTEGER    /make 12 bit integer
                                     in AC
          DXL                      /set X - coor.
          CLA
```

c. Now, test for the possibility of another argument.

```
          TAD               CHAR
          TAD               MCOMMA
          SZA               CLA
          JMP     I         EFUN3I   /no more
```

d. Move past the separating comma.

```
          GETC
          SPNOR
```

e. Evaluate the second argument.

```
        PUSHJ                       /this FNEW is
                        EVAL        /not recursive
        JMS     I       INTEGER
        DYS;CLA         /set Y and intensify
        SPNOR
        TAD             CHAR
        TAD             MCOMMA
        SZA             CLA
        JMP     I       EFUN3I
```

f. Now, pick up the single letters for display until the end of the function is reached.

```
DCHR,   GETC
        TAD             CHAR
        TAD             MRPAR
        SNA             CLA
        JMP     I       EFUN3I
```

Char. display routine called here; (for Tektronics Y002, it is simply PRINTC)

```
        JMP             DCHR
```

g. Definitions from the symbol table are available in Appendix E.

Summary:

a. User defined functions must leave their value, if any, in FLAC and return by a JMP I EFUN3I.

b. The contents of FLAC is converted to an integer in FLAC and in the AC by a JMS I INTEGER.

c. The floating point arithmetic interpreter is entered by JMS I 7.

(FOCAL uses its own version of the floating point package.)

d. The address of the user's function is placed by him in the FNTABF list.

e. Location BOTTOM contains the address of the last location to be used for storage. If BOTTOM is made to contain 4277, for example, then the user has from 4300 to 4577 for storage of the function processor. The user should achieve his function implementations using the information given here and in the symbol table without using the actual listing so that changes made by different users may be compatible and so that they may also be relocated easily should any changes be made by DEC. (see Section 4.5.1 for Core Utilization List)

f. The argument following the function name is evaluated and left in FLAC before control is transferred to the particular function handler. Since evaluation is terminated by either a comma (,) or a right parenthesis, a special function could have more than one argument.

Only in the case of multiple arguments does a user need to worry about saving his working machine language storage for a possible recursive use of his function. The contents

of the AC are saved by PUSHA and restored by POPA for this purpose. If there is another argument, it may be evaluated by PUSHJ; EVAL. Doing a PUSHJ; EVAL-1 is equivalent to

```
GETC;PUSHJ;EVAL.
```

4.4.2 Internal Subroutine Conventions

4.4.2.1 Calling Sequences - The (AC)=0 unless it contains information for the subroutines. Upon returns (AC)=0 unless it contains data.

There are six types of routines and subroutines used in the implementation of this program:

a. Normal subroutines called by an effective

```
JMS          SUBR1
```

which contain zero at their entry point

```
SUBR1,0
```

and a return by a

```
JMP     I    SUBR1
```

b. New instructions called by

```
PRNTLN       /(to print a line number)
```

and usually defined by

```
PRNTLN = JMS I.
XPRNT
```

where XPRNT is the entry point for a normal subroutine. These new instructions may have multiple returns/multiple arguments:

```
SORTJ                    /call;
        LIST6-1          /data list minus one;
        INLIST-LIST 6    /increment to branch table
                         /return if CHAR is not in LIST6
```

These new instruction subroutines often have implied arguments, e.g., GETC, READC, PACKC, TESTC, and SORTC all use the variable CHAR as their argument. The new instructions SORTJ and PRINTC use CHAR only if the AC is zero. If the AC is nonzero, then that value is used. Still others use only the AC for their argument: RTL6, TSTLPR, PUSHA, and TSTGRP, (see Appendix G).

c. Recursive routines called by

```
PUSHJ            /call
EVAL             /address
'                /return
```

where the address contains the first instruction of the routine. The return address is kept in the push-down list, and exit is made by use of

```
POPJ             /exit subroutine.
```

Such routines may call each other or themselves in any sequence and/or recursively by saving data on the push-down list. Others are EVAL, PROCESS, PROC, and GETVAR.

d. Command processor routines to handle specific command formats are called by

```
SORTJ                    /go to command
      COMLST-1
      COMGO-COMLST
ERROR 3                  /illegal command
```

The individual command routines use only new instructions and recursive routines. They may exit in one of three possible ways:

(1) POPJ - if C.R. is encountered or

(2) transfer to another command routine or

(3) transfer to START

e. Floating point groups of interpretive instructions similar to the following format:

```
FINT                     /enter floating interpreter (i.e., JAS I7)
FGET      FLARG
FMPY  I   PT1
.
EPUT      FLARG
FXIT                     /leave floating interpreter
```

f. Main processor modules to handle text input and keyboard commands. This routine could be "locked-out" by an instructor to protect and execute a stored or immediate command program repeatedly.

```
IBAR, INPUT X
```

Similarly, selected commands are easily deleted by the instructor by placing zero in the appropriate locations in COMLST.

Line number input and explicit replacements are "short circuited" by

```
GONE + 11, error 3
```

4.4.2.2 Subroutine Organization - Figure 4-1 illustrates the internal use of various subroutines. (c.f., Flow Charts in Appendix G).

4.4.3 Character Sorting

If a program must contend with a number of different characters (or 11-bit items) each of which can initiate different responses, simply look up the address of the action that corresponds to a given symbol or bit pattern. If the symbols do not form a continuum, the programmer must find the most efficient method for determining the corresponding address.

The method used in FOCAL is the table sort and branch. This method uses a subroutine to match up an input character with one member of a list of characters. The call to the subroutine is followed by

a. the address minus one of the list and

b. the difference between that list and a second list. The latter list contains the corresponding addresses. Thus, if a match is found in the first list, the difference is added to the address of that match to compute the address in the second list which contains the name of the action to be performed.

c. The next instruction to be executed if a match is not found.

In addition to being simple and concise, although more time consuming than other methods, this technique has another advantage that is especially useful in a PDP-8: the tables may be placed at page boundaries to take up the slack that often occurs at the end of a page. This results in a more efficient use of available core storage.

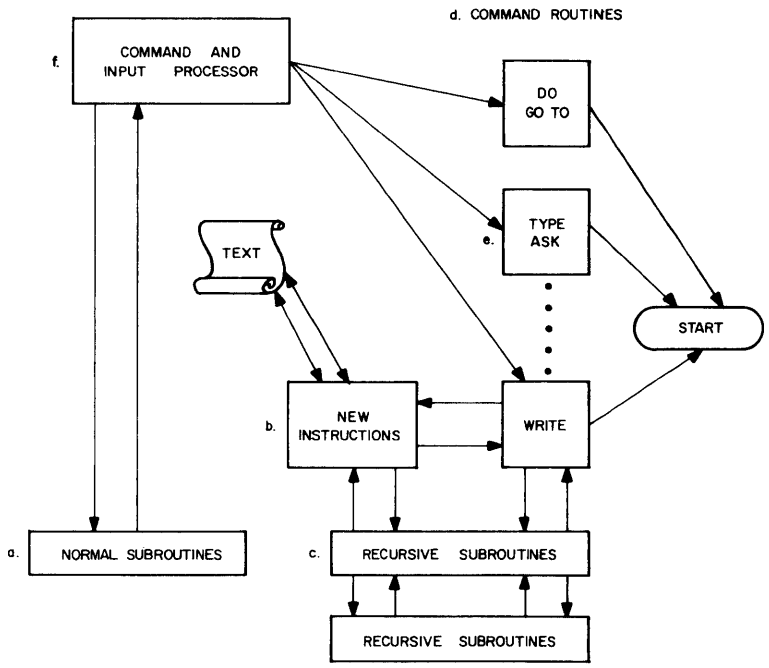


Figure 4-1

4.4.4 Language

The program is written in PAL III with floating point commands, as well as program-defined commands, implemented as subroutine calls. (see Appendix G) The program must be assembled using PAL10.

4.5 NOTES

4.5.1 Core Utilization

NAMES	PLACE	SEGMENT
	0-15, 17-166	FOCAL (4K)
	167-175	8K
	176-2572	FOCAL (4K)
	2573-2577	8K
	2600-2724	(Interrupt Handler)
	2725-3117	FOCAL (4K)
IOBUF:	3120	(I/O Buffer)
COMEIN:	3140	(Command Buffer)
FRST:	3206	(Text Buffer)
BEGIN:	4420-4577	(Initialization)
	4430-4577	CLIN
FEXP:	4620-4776	(Extended Functions)
ARTN:	5000-5166	[11 free]
FCOS:	5200-5345	[32 free]
TGO:	5400-5577	[0 free]
DECONV:	5600-5773	[4 free]
FLOUTP:	6000-6157	(Output Conversion)
THISD:	6160-6176	8K
FLINTP:	6200-6317	(Input Conversion)
HREAD:	6320-6377	(High Speed Reader)
FPNT:	6400-7177	(floating interpreter)
MP4:	7200-7377	[none free]
XSQRT:	7400-7502	[FSQT( ) and format buffer]
LIBRARY:	7503-7556	(Single user L command)
XRTD:	7557-7576	8K
Storage of text is	3200-4577	14 functions
	3200-5177	11 functions
	3200-5377	9 functions

4.5.2 Extended Functions

Extended Functions may be reinitialized by loading in the second part of main program tape.

Functions are normally deleted by answering the questions asked when FOCAL is initiated. However, they may also be erased by changing location 0035 to 5377, and locations 401 through 0405 to 2725. Retaining the extended functions allows approximately 1200 characters of text or 170 variables (or any combination in the ratio of 7 characters to one variable). Deleting the extended functions allows approximately 1800 characters or 250 variables.

4.5.3 Error Printouts

Errors ?01.00
?00.00
and ?11.35

Because these errors are time dependent, they may be followed by nonexistant or false line number.

4.5.4 No Interrupts

To read data tapes without running the risk of Keyboard-Input-Buffer overflow (?11.35), it is necessary to remove the interrupt. This action means that Control-C will not work.

To run FOCAL without interrupts, change:

Loc/From	To
63/2676	1353
64/2666	2413
2732/6001	5336
2762/6046	7000

The high-speed punch will now run in parallel with the low-speed punch!

To run the high speed punch at top speed change:

1356/6041	6021

4.5.5 Operating HS Reader Without Interrupts

To run the high-speed reader without interrupts, make the above patches plus two more:

6324/1037	6011
6325/7700	7410

4.5.6 Non-Typing of Program Tapes During Loading

The "echo" feature for the ASR-33 may be suppressed by changing location 2163 to 7000 (from 4551). This will cause only asterisks to be typed as the tape is read. There will not be line feeds or carriage returns. (c.f., 4.7.3.4 for multi-user system)

Any output commands will be typed out in the usual manner, as will diagnostics, answers, etc. Entries from the keyboard will not be typed.

4.5.7 Explanation of NAGSW (Not All or Group Switch)

Since LINENO may be modified, a record is needed of whether a specific line number was given by XX.YY (where XX and YY are nonzero) or whether a group was indicated by XX or XX: or XX.00 or whether "ALL" text was indicated by either zero, less than one, or a non-numeric argument:

	NAGSW =
For one line	4000
For a group	0000
For all text	0001
Error	4001

PDP-8 code for testing NAGSW:

skip if

Or	One	All	Group
ONE	SMA	--	SMA SZA
ALL	--	SPA SNA	SNA
GROUP	SMA SZA	SPA SZA	SZA

4.5.8 Data Inaccuracies

The logical conclusion from the inequality $10^8 < 2^{27}$ is that the user can represent 8-digit decimal floating-point numbers accurately by 27-bit floating-point numbers. However, 28 significant bits are needed to represent some 8-digit numbers accurately. In general, we can show that if $10^p < 2^{q-1}$, then q significant bits are always enough for p-digit decimal accuracy. Finally, we can define a compact 27-bit floating-point representation that will give 28 significant bits, for numbers of practical importance.[1] In FOCAL, 23 bits are used giving 6.9 digit accuracy.

4.5.9 Eliminating = and : in I/O Formats

Leading equal signs and colons in I/O formats are omitted by making the following patch:

Loc/From	To
1216/4551	7600 /:
6002/4551	7600 /=

4.5.10 Estimating the Length of User's Program

FOCAL requires five words for each identifier stored in the symbol table and one word for each two characters of stored program. This may be calculated by

$$5s + \frac{c}{2} \cdot 1.01 = \text{length of user's program}$$

where s = Number of identifiers defined
c = Number of characters in indirect program

If the total program area or symbol table area becomes too large, FOCAL types an error message.

[1] Goldberg, B. "8-Digit Accuracy",
Communications of the ACM
Vol. 10, No. 2, February, 1967

FOCAL occupies core locations $1\text{-}3300_8$ and $4600_8\text{-}7576_8$. This leaves approximately 700_{10} locations for the user's program (indirect program, identifiers, and push-down list). The extended functions occupy locations 4600-5377. If the user decides not to retain the extended functions at load-time, there will be space left for approximately 1100_{10} characters for the user's program.

The L-command may be used to indicate how much core is available for the user.

4.6 FOCAL SYSTEMS

FOCAL systems are designed to take advantage of as many PDP-8 configurations as possible. With this in mind, the system source language is divided into segments which, when loaded together, fit the needs of a user and his particular configuration. Thus, when a user changes his configuration or requirements, he does not need to secure an entirely new FOCAL tape but only to load a new segment corresponding to the change in his configuration. The scheme used also has the advantage of simple maintenance, since changes are made to one source file for all possible systems and in some cases re-assembly of other segments is not needed.

Two source segments create a FOCAL system for a 4K PDP-8. Others are used to create a FOCAL system with (1) ten digit arithmetic, (2) 8K memory, and (3) circular and linear graphics.

The segments of the FOCAL system and their functions are listed in Table 4-1. The ASCII source segments FOCAL.ASC and FLOAT.ASC must be assembled with all configurations and the resulting binary segment, FOCAL.BIN, when loaded makes a one user FOCAL system for a 4K PDP-8.

The segment INIT.ASC is assembled alone, but when INIT.BIN is loaded with FOCAL.BIN into field zero it gives you the initial dialog. If the extended functions are to be retained, it is not necessary to load INIT at all. All corrections for machine type will be made anyway. After FOCAL is started and/or the dialog is completed the user may proceed to load other binary segments.

If a user has an 8K PDP-8 and wants to create a large program with extended precision arithmetic, he need only load FOCAL.BIN, start, and then load 4WORD.BIN, and 8K.BIN as indicated in Table 4-2. If he wants to share his PDP-8 with three other people, he just loads FOCAL.BIN and QUAD.BIN into field one and start.

Intra-references between segments is handled by small multiple assemblies, rather than a large assembly with conditionals for each possible system. For example, to obtain a binary copy of the segment QUAD.BIN, use PAL10 to assemble, QUAD.ASC, FOCAL.ASC, FLOAT.ASC. This assembly produces only the listing and binary files for QUAD which end with the PSEUDO-op's "XLIST" and "NOPUNCH". Tables 4-2 and 4-3 give the allowable combinations of the binary segments to produce legal configurations of the FOCAL system.

Table 4-1
FOCAL System Source Segments

ASCII Segment Name	Function	Description
FOCAL*	The interpreter & TTY I/O driver.	
FLOAT*	Modified Floating Point Package.	
4WORD	Extended precision overlay to FLOAT (give 10 digits).	(4.6.5)
8K	Allows one user to take advantage of an 8K PDP-8.	(4.6.4)
QUAD	Allows multiple users (up to 4) to use FOCAL or 8K PDP-8.	(4.6.6)
LIBRA†	Allows multiple users (up to 7) to run and save FOCAL programs on an 8K PDP-8 with disk.	(2.14.2)
CLIN	The user may have a scope to interact with FOCAL.	(5.8)
PENT	A variation of QUAD allowing five (5) users.	
INIT	The symbolic source for the initial dialog program.	

*These two segments must be assembled and loaded together for all configurations. They are separated for editing convenience.

†Not yet implemented.

Table 4-2
Allowable FOCAL Systems

1 - Must be loaded into field one
0 - Must be loaded into field zero
Y - Command may be used if disk system is built
N - Command is illegal
* - Command different

Binary Segment	Allowed Combinations & Subsets are indicated by entries in vertical columns	Minimum Hardware Required
FOCAL	0 0 0 0 1 1 1 1	4K
INIT (optional)	0 0 0 0	
4WORD	0 0 1 1	4K
8K	0 0	8K
QUAD or PENT (non-8/S)	0 0 0 0	8K/PT08s
LIBRA (non-8/S)	0 0	8K/PT08s/DF32
CLIN (optional)	0 1 1	Graphics Terminal
LIBRARY COMMAND (for disk monitor)	Y Y Y Y N N * *	DF32

FOCAL is always loaded first in the proper field.

Table 4-3
Variations for FOCAL Systems

Any combination of these three sets (2*2*4=16),

a.	b.	c.
8K overlay	Disk Monitor	No Dialogue
4K	No Disk	No ext. functions
		SINe, COSine only
		All ext. functions

or QUAD four-user system or PENT five-user system (PENT is obtained by a modified assembly of QUAD; see listing) may be used with

CLIN graphics (4)
4WORD overlay
Neither
Both

These are formed from only six sections of binary tapes.

The CLIN graphics function can be used for numerical control.

4K FOCAL can be run on the following DEC computers: 5, 8, 8/S, 8/I, 8/L, LINC-8, LAB-8, TSS-8, PDP-12.

a. Load FOCAL & INIT

b. do initial dialogue

c. load any or all of 4WORD, 8K, CLIN.

d. restart and use

4.6.1 FOCAL Systems Assembly

a. Systems programs

```
* ↑C
.RUN T PAL10
*FOCAL.BIN,FOCAL.LST←FOCAL.ZZL,FLOAT.ZZL
*QUAD.BIN,QUAD.LST←QUAD.ZZL,FOCAL.ZZL,FLOAT.ZZL
```

b. Initial dialogue

```
* ↑C
.RUN T PAL10
*INIT.BIN,INIT.LST←INIT.ZZL
*
```

c. Overlay routines

```
.R PAL10
*4WORD.BIN,4WORD.LST←4WORD.ZZL,FOCAL.ZZL,FLOAT.ZZL
*8K.BIN,8K.LST←8K.ZZL,FOCAL.ZZL,FLOAT.ZZL
*CLIN.BIN,CLIN.LST←CLIN.ZZL,FOCAL.ZZL,FLOAT.ZZL
*
```

4.6.2 FOCAL Binary Paper Tapes

```
.AS DSK D
DSK ASSIGNED
.AS PTP
PTP ASSIGNED
.R PIP
*PTP:←/ID:QUAD.BIN
*PTP:←/ID:4WORD.BIN,8K.BIN,CLIN.BIN
*PTP:←/ID:FOCAL.BIN,INIT.BIN
↑C
```

4.6.3 FOCAL Listings

```
*LPT:←D:QUAD.LST,4WORD.LST,8K.LST,CLIN.LST,INIT.LST,FOCAL.LST
*TTY:←/L DTAa:
58:  FREE BLOCKS LEFT
FOCAL    .ZZL
FLOAT    .ZZL
QUAD     .ZZL
4WORD    .ZZL
8K       .ZZL
CLIN     .ZZL
INIT     .ZZL
PAL10    .SAV
JR36
JR46
```

4.7 FOCAL SEGMENTS

4.7.1 8K Single User Overlay - 8K

To increase the size of program, the 8K overlay uses the upper 4K for storage of the user's source text. The maximum number of variables does not change as they are still stored in the lower 8K.

Load the overlay after doing the initial dialogue with the 4K version.

4.7.2 Extended Precision Overlay - 4Word

This overlay provides FOCAL with 10-digit accuracy when the 10th digit goes to enable. The overlay increases the number of words needed to store a number from three words to four words. The number of variables that may be stored is decreased accordingly.

Load the overlay after doing the initial dialogue with the 4K version.

4.7.2.1 Double Precision Multiply in Four-Word FOCAL

To multiply two numbers, the product of which is greater than ten digits and yet retain the least significant figures, use a double precision operation.

For example, to multiply:

M = 20243974

by

N = 69732824

let M0 = the 1st 4 digits of M and let M1 = the 2nd 4 digits of M. Similarly, N0 and N1 are the left and right halves of N.

Note the correction of an input error in the high order part of N.

```
*W
C-4WORD@1/69
14.10  ASK !,M0,M1,"*"N0,N1,!
14.20  SET A=M0*N0
14.30  SET B=N0*M1 + M0*N1
14.40  SET C=M1*N1
14.50  SET Z=FITR(C*1E-4)
14.60  SET C=C-Z*1E4
14.70  SET B=B+Z
14.80  SET Z=FITR(B*1E-4)
14.90  SET B=B-Z*1E4
14.99  TYPE !%8,A+Z,%4,B,C,!
*GO
:2024 :3974  *  :6928+6973  :2824
= 14116694= 7600= 2576
*
```

4.7.3 Four User Overlay - QUAD

QUAD allows an 8K PDP-8/I, -8/L with up to four teletypes to time-share FOCAL. In effect, each user has the equivalent of a 4K PDP-8 or PDP-12 with FOCAL. The QUAD overlay is located in the lower 4K, and the FOCAL interpreter is located in the upper 4K. Users are traded for one of three other users in the lower 4K. Swapping of users is based upon I/O waits and checkpoints in the FOCAL interpreter.

4.7.3.1 Four User Loading and Operating Procedure

a. Load 1st binary part into field one. (FOCAL.BIN)

b. Load 2nd binary part into field one. (QUAD.BIN)

c. Load address

7600
and START

.SAVE F4UB!0-2177,3000,3600,5400;200
.SAVE F4UA!0-13220, 14600-17577;

(Any errors made here may require reloading field zero.)

d. (Calling Sequence)

.F4UA
.F4UB

(If any problem occurs hit stop, record the PC and restart at 200 or reload.)

4.7.3.2 Swapping - At certain points in the FOCAL program it is a pure procedure. If swapping occurs at these times, then only 1K of impure data needs to be saved instead of 4K. This factor of four considerably improves system performance. Such a point is called a checkpoint.

Each time an operating program reaches a checkpoint the executive routine checks to see whether another user should be swapped in at that time.

This check is also made if the operating program goes into a state of waiting for input-output, except for output during use of trace.

4.7.3.3 Workload and Timing

a. Swapping is done on a demand (I/O wait) and a cooperative (checkpoint) basis. Therefore, no clock is needed. Not having a clock reduces system overhead by about ten percent.

b. Fully asynchronous I/O is backed up by large (over 16 characters) and uniform (easy to process) character buffers. Serial to parallel conversion of the bit stream is done in external hardware by PT08 line controllers. This reduces system load by 18 to 30 percent.

c. If each of eight user programs takes less than 100-17 msec to generate one 8-digit output string, then the system is barely output bound and no delay will be observed in response times. The 17 msec is average access time to the disk, and one TTY character takes 100 msec to be typed.

4.7.3.4 Special Controls - A control-R character (TAPE) suppresses echo of input tapes except for the line-feed. A control-T (NOT-TAPE) or Control-C restores the echo of input characters.

It is a good practice to punch a Control-R at the beginning of all off-line tapes. An alternative is simply to type Control-R manually before setting the low speed reader to RUN.

4.7.3.5 Dialogue - There is no initial dialogue with QUAD.

4.7.4 Graphics for Circles and Lines - CLIN

```
/CLIN - GRAPHICS OVERLAY FOR FOCAL,ZZK  PAL10   V133    14-MAR-69       16:01
                    /CLIN - GRAPHICS OVERLAY FOR FOCAL,ZZK


                    /FINITE DIFFERENCE EQUATION OF A CIRCLE - FOR FOCAL

                    /16.2 S P=X-X0;S Q=Y-Y0;S R=FSQT(Q*2+P*2)
                    /16.3 S Z=FNEW(6.3*R*C,P,Q,X0,Y0,S/R)
                    /16.4 S X0=X;S Y0=Y

                    /LINEAR DIFFERENCE EQUATION OF A LINE

                    /1'.1 D 16.2;S Z=FNEW(R,P/R,Q/R,X0,Y0,0);D 16.4

          6057      DXS=6057
          6053      DXL=6053
          6067      DYS=6067

          0035      *BOTTOM
     0035 4437              FCIN-1
          0407      *FNTABF+14
     0407 4440              FCIN

          4440      *4400+40

     4440 4453      FCIN,   JMS I INTEGER
     4441 7040              CMA
     4442 3342              DCA R           /SAVE THE POINT COUNT
     4443 1340              TAD XXP
     4444 3010              DCA AXIN        /START DATA POINTERS
     4445 1117              TAD M5          /FOR 5 MORE ITEMS
     4446 3316              DCA CT
     4447 4537      GETA,   PUSHJ           /COMPUTE EACH ARG,
     4450 1612                      EVAL-1
     4451 1044              TAD EXP         /FOUR FIXED POINT RESULTS
     4452 1341              TAD LP
     4453 3044              DCA EXP
     4454 4453              JMS I INTEGER
     4455 7200              CLA
     4456 1005              TAD P13         /SAVE UNNORMALIZED FORM
     4457 3410              DCA I AXIN
     4460 1045              TAD HORD
     4461 3410              DCA I AXIN
     4462 1046              TAD LORD
     4463 3410              DCA I AXIN
     4464 2316              ISZ CT          /TEST FOR END OF DATA
     4465 5247              JMP GETA
     4466 1046              TAD LORD        /TEST FOR CIRCLE OR LINE
     4467 7640              SZA CLA
     4470 5343              JMP XFCIR
```

```
4471  7100    XFLIN,  CLL             /VECTOR PLOT ALGORITHM
4472  1331            TAD X01
4473  1323            TAD P1
4474  3331            DCA X01
4475  7004            RAL
4476  1330            TAD X00
4477  1322            TAD P0
4510  6053            DXL             /(6317)- FOR LAB-8
4511  3330            DCA X00
4512  7110            CLL
4513  1334            TAD Y01
4514  1326            TAD Q1
4515  3334            DCA Y01
4516  7004            RAL
4517  1333            TAD Y00
4520  1325            TAD Q0
4521  6067            DYS             /(6307) - FOR LAB-8
4522  3333            DCA Y00
4523  2342            ISZ R
4524  5271            JMP XFLIN
4525  5535            JMP I EFUN3I
                ////
```

```
/TO DISPLAY A POINT X,Y:            SET Z=FDIS(X,Y)
/TO DRAW LINE X0,Y0 TO X,Y:         DO 17
/TO SET X0,Y0=X,Y:                  DO 16,4
/TO ERASE SCREEN :                  TYPE "(ERASE CODE)"
/TO RESET PRINT ORIGIN:             TYPE "(RESET CODE)"
/TO DRAW A CIRCLE ABOUT X0,Y0 STARTING AT X,Y
/AND GOING COUNTERCLOCKWISE FOR FRACTION
/OF A CIRCLE ALPHA :                SET S=+1;SET C=ALPHA;DO 16
/TO GO CLOCKWISE:                   SET S=-1;DO 16

/GROUPS 16 AND 17 CREATE OR USE THE VARIABLES
/X,Y,X0,Y0,Z,R,C,P,Q,K,AND S.
/S MAY BE REPLACED BY A 1 IF DESIRED.
```

```
4516  0000    CT,     0
4517  0000            0
4520  0000            0

4521  0000    PP,     0
4522  0000    P0,     0
4523  0000    P1,     0

4524  0000    QQ,     0
4525  0000    Q0,     0
4526  0000    Q1,     0

4527  0013    XX,     13
4530  0000    X00,    0
4531  0000    X01,    0

4532  0013    YY,     13
4533  0000    Y00,    0
4534  0000    Y01,    0

4535  0000    KK,     0
4536  0000            0
4537  0000            0

4540  4520    XXP,    PP-1
4541  0014    LP,     14
4542  0000    R,      0
```

```
/TO USE AN X-Y PLOTTER, CLIN IS NOT NEEDED; SIMPLY
/ADD THE FOLLOWING LINES TO GROUPS 16 AND 17 :

/16.25 S K=S/R
/16.30 F I=0,6.3*R*C;S P=P-Q*K;S Q=Q+P*K;S Z=FDIS(X0+P,Y0+Q)
/17.10 D 16.2;F I=0,R;S X0=X0+P/R;S Y0=Y0+Q/R;S Z=FDIS(X0,Y0)
/17.20 D 16.4

/THE ITERATION PARAMETER "I" MAY BE TAKEN IN GREATER INCREMENTS IF THE
/SCALE FACTOR IS ALSO CHANGED; I.E.
/17.10 DO 16.2;SET K=4/R
/17.15 FOR I=0,4,R;S X0=X0+K*P;S Y0=Y0+Q*K;S Z=FDIS(X0,Y0)
```

```
4543  4407    XFCIR,  FINT            /CIRCLE ALGORITHM
4544  0324            FGET QQ
4545  4335            FMUL KK
4546  6316            FPUT CT
4547  0321            FGET PP
4550  2316            FSUB CT
4551  6321            FPUT PP
4552  1327            FADD XX
4553  0000            FXIT
4554  4453            JMS I INTEGER
4555  6057            DXS             /(6317) - FOR LAB-8

4556  4407            FINT            /CLEARS AC
4557  0321            FGET PP
4560  4335            FMUL KK
4561  1324            FADD QQ
4562  6324            FPUT QQ
4563  1332            FADD YY
4564  0000            FXIT
4565  4453            JMS I INTEGER
4566  6067            DYS             /(6307) - FOR LAB-8
4567  7200            CLA

4570  2342            ISZ R
4571  5343            JMP XFCIR
4572  5535            JMP I EFUN3I


              NOPUNCH
      4600    PAGE
      0001    FIELD 1
              XLIST
```

4.8 FOCAL DEMONSTRATIONS

4.8.1 One-Line Function Plotting

This example demonstrates the use of FOCAL to present, in graphic form, some given function over a range of values. In this example, the function used is

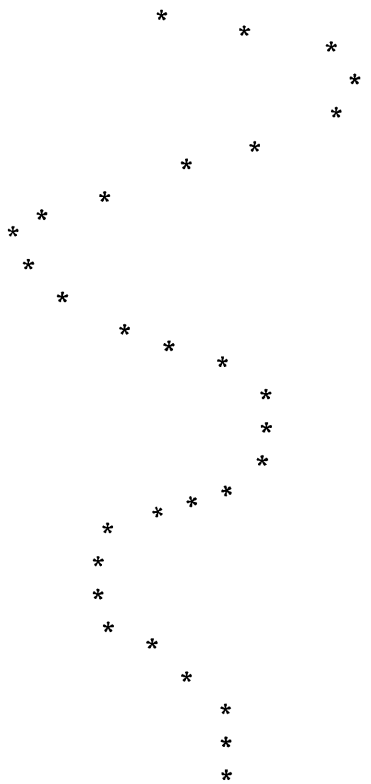
$$y = 30 + 15(\text{SIN}(x))e^{-.1x}$$

with x ranging from 0 to 15 in increments of .5. This damped sine wave has many physical applications, especially in electronics and mechanics (for example, in designing shock absorbers for automobiles).

In the actual coding of the example, the variables I and J were used in place of x and y, respectively; any two variables could have been used. The single line 08.01 contains a set of nested loops for I and J. The J loop types spaces horizontally for the y coordinate of the function; the I loop prints the * symbol and the carriage return and line feeds for the x coordinate. The function itself is used as the upper limit of the J loop showing the power of FOCAL commands.

The technique illustrated by this example can be used to plot any desired function. Although the * symbol was used here, any legal FOCAL character is acceptable.

```
08.01  F  I=0,.5,15; T "*",!;  F  J=0,30+15*FSIN(I)*FEXP <-.1*I >;T " "
*
*
*DO  8.01
*
```



4.8.2 How To Demonstrate FOCAL's Power Quickly

a. Load the program and start at 200.

b. Explain that the initial dialogue gives you options.

c. Try some other response like MAYBE ❯ .

d. Now answer YES ❯ .

e. The preceeding has demonstrated the interactive capabilities of the language and the compromises that it permits.

f. In a 4K machine (4096 words) FOCAL gives the user 15 functions and uses only 3K, leaving enough room to solve up to 6th order simultaneous equations.

g. The asterisk (*) means that FOCAL can now respond to your commands.

h. The basic command is TYPE:

```
*TYPE      5 ↑ 2 + FSQT (5) ❯
```

i. Now compute 5 factorial:

```
*SET       ALPHA=1
*FOR I=1, 5;  SET ALPHA=ALPH*I
```

j. The answer is ready when the next asterisk is typed out:

Then type

```
*TYPE      ALPHA
```

for the answer.

k. Now if you are using a PDP-8 or -8/I, demonstrate a large number:

```
*SET       A=1
*FOR       I=1,   300;  SET A=A*I
```

some time later

```
*TYPE A
= 0.395      615
```

l. Now generate a plot via a stored program:

```
*1.1 FOR  Y=0,  .5, 15;  TYPE ! ; DO2
*1.2 QUIT
*2.1 FOR  X=0,  12+10*FSIN(Y) ;  TYPE   "  "
*2.2 TYPE " * "
*GO
```

m. Now use the MODIFY Command to change 10* to FEXP (Y/6)* and try again.

4.9 FOCAL Versus BASIC

FOCAL is superior to BASIC, not only in terms of computing power and ease of use, but also in maximum use of the memory space, which is so often limited in small computer systems.

FOCAL contains all the power of BASIC, and in addition provides the following capabilities:

a. Control of the output format (i.e., precise figure location on a page and graphical representation);

b. An "immediate" mode, allowing the system to operate as a desk calculator and to execute simple problems without writing a program;

c. The capability of executing individual "stored program" statements in the immediate mode for debugging and verification;

d. Built-in symbolic editor capable of searching program statements for specified characters and inserting and deleting characters within a statement, thereby eliminating the retyping of the entire program statement;

e. Multiple statements may be grouped on each line for more logical ordering of the program;

f. True multiple level re-entrant subroutining capabilities;

g. A trace feature which types out selected segments of a program (as the program is executed) to pin point exactly where a program error occurred;

h. Commands may be abbreviated to one letter; this eliminates wasted typing time when writing a program and increases the available storage space for use by additional program statements;

i. Programs may be saved on disk and chained together;

j. Point plot displays, vector displays, X, Y plotters, and analog to digital converters may be operated by FOCAL; this capability can be used in an on-line, real-time fashion;

k. FOCAL SYSTEMS allow use of several hardware configurations: 8K, 10 digit, display, and multi-user.

CHAPTER 5
ADDITIONAL FOCAL APPLICATIONS

5.1 FOCAL FOR THE LAB-8

5.1.1 Standard

Two commands have been added to FOCAL to implement the A to D converter and the oscilloscope display on the AX08.

a. A to D Command:

FADC(N) where N is the channel number in decimal.

The command:

```
SET Z = FADC(28)
```

gives the variable Z a value of octal channel 34 depending on the position of the upper righthand potentiometer. The other 3 knobs are channels 29, 30 and 31. A subroutine in FOCAL to read the A to D in volts is as follows:

```
15.1  ASK CHAN;C-0,1,2,3
15.2  SET X=FADC(28+CH)
15.3  IF (X-256)15.Y,15.4;SET X=X-4096
15.4  SET X=X/255
```

The input variable is CH for values of 0 to 3, and the output variable is X with values ±/volt.

b. Display Command:

The display command has been modified to use only one statement to define X and Y.

```
SET Z = FDIS(X,Y).
```

will display a point on the oscilloscope screen defined by points X and Y. X can range between 0-511 and Y from -255 to +255. The variable Z is a dummy. (It is given the value of the integer part of Y.). (c.f., Section 5.8 for circle and sector algorithms.)

CAUTION

Since the ADC of the AX08 hardware is an integral part of the display logic, using both display and A and D, may result in splatter of the Y direction of the oscilloscope screen.

5.1.2 Additional (Possible) FOCAL Functions for AX-08

FADC (n): Converts (decimal) channel n. Returns result of conversion.

FDIS (x,y): Loads display X and Y; intensifies point.

FTIM (n): Delays n RC clock pulses (n < 4096)
Returns # of 100 μs increments since last used.
Xtal clock interrupt is enabled.
Interrupt servicing for Xtal clock as follows:

```
SKXK
JMP OTHERS
CLXK
ISF TIME +1
JMP .+3
ISF TIME
NOP
ION
JMP I 0
```

Clock flag servicing will tie up 20% of processor time.

When FTIM is called, do the following sequence:

```
        TAD (1002)    /enable Xtal clock, start RC clock
        OTEN
        get n
        SNA
        JMP XTIME
        CMA IAC
        DCA RCNTR
        CLRK
        SKRK
        JMP    .-1
        ISZ    RCNTR
        RMP    .-4
XTIME,  PUT TIME, TIME +1 in FLAC
        DCA TIME
        DCA TIME +1
        return to FOCAL
```

FNEW (a, b, c)

a = 0: Turn on relays indicated by b ($b \leq 7$)
Turn off relays indicated by c ($c \leq 7$)
as follows:

```
get b
RAL; RTL
AND (70
OTEN
get c
RTL; RAL
AND (70
CMA
ZTEN
CLA
return to FOCAL
```

a = 1: "and" external register with mask
b: mask (octal)
c: ignored

```
                    Get characters of b
                    interpret as octal #
                    DCA XMASK
                    XRIN
                    AND MASK
                    XRCL
                    CMA JAC
                    TAD MASK
                    SNA CLA
                    IAC
                    store in FLAC
                    return to FOCAL
```

a = 2: "or" external register with mask
b: mask (octal)
c: ignored

```
                    get characters of b
                    interpret as octal #
                    DCA XMASK
                    XRIN
                    AND MASK
                    XRCL
                    SZA CLA
                    IAC
                    store in FLAC
                    return to FOCAL
```

5.2 FNEW FOR DATA ARRAYS*

A new function for 8-K FOCAL is available which uses field one to store data arrays in floating double precision, single precision, and signed integer format. This facility is added to FOCAL via the function call FNEW. The function may be called recursively to any level, and all of the features of FOCAL are retained. In addition an ERASE or ERASE ALL command will not wipe out the array. Hence, variables may be stored for use in successive programs.

5.2.1 Storage Requirements

Fits into unused locations in floating point package

5.2.2 Usage

5.2.2.1 Loading - Load after FOCAL has been loaded into the machine (and the initial dialogue is executed). Load the first part of the overlay using the Big Loader. If a single precision floating array is desired press CONTINUE. A patch should now be read in to allow a 1980 element array in

*Originated by University of Georgia, program not supported by DEC.

single precision floating point. If an integer array (maximum number = 3047) is desired press CONTINUE. A patch will now be read in to allow a 3965 element signed integer array.

Restart FOCAL at 200.

5.2.2.2 Calling Sequence - To store a variable Z as array element J:

```
* S X=FNEW (J,Z)
      or
* 4.3 S X=FNEW (J,Z)
```

In addition, X will be set equal to Z.

To call the array element K and set Z equal to this element:

```
* S Z=FNEW(K)
```

i.e., if there is only one argument the instruction is interpreted as a "GET". If there are two arguments it is interpreted as a "PUT".

5.2.3 Recursive Calling

The function FNEW may be called recursively at any level. viz.

```
* S Z=FNEW  [J, FNEW(J+10)]
```

sets Z=FNEW(J+10) and stores FNEW(J+10) in array element J.

```
* 3.2 S Z=FDIS (J*1000) , FDIS(FNEW(J)*NORM)
```

the arguments may be any arithmetic expression. The following are valid:

```
* S Z=FNEW (J*10-3, FEXP(X^2)*Y)
* S Z=FNEW (J,FNEW (K)*FEXP(FNEW(L)))
```

5.2.4 Restrictions

Double precision floating:	$0 \leq J \leq 1320$	(23 bits of significance)
Single precision floating:	$0 \leq J \leq 1979$	(11 bits of significance)
Integer Array:	$0 \leq J \leq 3965$	(11 bits of significance)
	$\lvert Z \rvert \leq 2047$	

5.2.5 Description

The function FNEW protects the binary loader in upper core. The function checks to see if J is too large, but does not check to see if Z is larger than 2047 in the integer array case (c.f., array overlay).

The user, of course, may subdivide this array into any number of smaller arrays, keeping track of his own indices.

5.3 DYNAMIC INTERRUPT PROCESSING VIA FOCAL, 1969

This simple patch allows real-time interrupts to initiate execution of a specific FOCAL subroutine (e.g. Group 31) which gains control (i.e., D031) when an interrupt occurs from an external device. The FOCAL subroutine could sample various channels of the A/D converter, set a few constants, then turn off the interrupt, and return to the main FOCAL program. The main FOCAL program will carry out the analysis or output of data during the time between these external device interrupts. The external device could even be an animal and the time between interrupts will be asynchronous and long (between 1 and 1000 seconds), or the external device will be a clock, in which case the time between interrupts will probably not be less than 100 ms or greater than 1 sec.

```
/patch to interrupt processor
(tag assignments from symbol table)
*EXIT                   /replaces H.S. Reader*
    IOT1                /skip if device
    JMP.+3
    NOP                 /"HINBUF" is cleared
*PC1                    /checkpoint in main program
    JMP  I 175          /  valid for 8K, also
*167
    DIPCHK              /Dynamic Interrupt Check
*HINBUF
    1                   /initialized to non-zero
*HREAD
DIPCHK,TAD HINBUF
       SZA  CLA
       POPJ
       TAD  PC          /save FOCAL register
       PUSHA
       TAD SPCLN        /(your group #)
       DCA LINENO
       DCA NAGSW
       ISZ HINBUF
       PUSHJ
          DO+1
       POPA
       DCA PC
       POPJ
SPCLN, 7600             /(group 31)
```

The routine in group 31 returns control by "RETURN". This feature does not operate until main program is started. It will operate during execution of a direct command.

5.4 SIMULTANEOUS EQUATIONS' SOLUTIONS

This program will work with a set of simultaneous linear equations (in 4K. FOCAL 6 equations is the limit) and output the solutions. To do this the program requests a value "L", the number of equations and variables to be processed. The program then requests the coefficients and constants for each equation, in a matrix like format. The solution values are typed out in a column with the names "X(0)" through "X(L-1)". The program is available through DECUS.

5.5 FAST FOURIER TRANSFORMS PROGRAMS

The FAST FOURIER TRANSFORMS Program is designed to accept samples of a complex wave pattern as input and, through a FOURIER analysis, describe its component sine and cosine waves in terms of amplitudes and frequencies.

The user inputs a number "N", which must be a power of two, (in 4K. FOCAL, "4" is the limit) and which describes the number of samples to be used in the analysis. Next the samples, which are wave height measurements taken at regular intervals, are requested. Output is in the form of two columns (side by side), the left of which describes the cosine wave components while right hand column describes the sine wave components.

It should be noted that because the number of samples is always a power of two, the number of complex multiplications is cut drastically. For this reason computation time is also greatly reduced.

NOTE

In order to use this program, the extra extended function FX(A,B) must be loaded into memory via the BIN loader.

FAST FOURIER TRANSFORMS

```
W
C-FOCAL.,1968
01.08 A "POWER OF 2 ",NU
01.10 S  N=2 ↑NU;S  TP=2*3.14159/N
01.18 S  S=N/2:,  L=1;S Q=S-1;S H=1-NU
01.20 F  I10,N-1;A !;A !,XR(I);S XI(I)=0
01.22 S  SR=XR(Q+S)+XR(Q);S XR(Q+S)=XR(Q)-XR(Q+S);S XR(Q)=SR
01.24 I  (Q) 1.26,1.26;S Q=Q-1;G 1.22
01.26 I  (L-NU) 1.28,1.54,1.28
01.28 S  L=L+1;S  S=S/2;S  H=H+1;S  P=N-1;S  Z=1/(2↑(-H) )
01.32 S  C=1
01.34 S  U=FITR(P*Z);S  K=FX(NU,U)*TP
01.36 S  CO=FCOS(K);S  SN=FSIN(K)
01.38 S  GR=CO*XR(P)+SN*XI(P);S  GI=CO*XI(P)-SN*XR(P)
```

```
01.40 S  Q=P-S;S  SR=GR+XR(Q);S  SI=GI+XI(Q);S  XR(Q)=XR(Q)-GR
01.42 S  XI(Q)=XI(Q)-GI;S  XR(P)=SR:,  XI(P)=SI
01.46 S  P=P-1;  I (-FABS[C-S])  1.48;  I (P-S+1)  1.52,1.26,1.52
01.48 S  C=C+1;G 1.34
01.52 S  P=P-S;G  1.32
01.54 F  I=0,N-1;S  K=FX(NU,I);T  !,%3.2,2*XR(K)/N,"                ",2*XI(K)/N
*
*C-TRANSFORM OF INTERFERENCE PATTERN FORMED BY MIXING A SINE
*C-WAVE OF AMPLITUDE 1.0 AND A COSINE WAVE OF AMPLITUDE 1.5
*
*GO
POWER OF 2 :3
:1.5
:1.768
:1
:-.353
:-1.5
:-1.768
:-1
:.353
+=0.00          =+0.00
=+1.50          =-1.00
=+0.00          =+0.00
=+0.00          =-0.00
=+0.00          =+0.00
=+0.00          =+0.00
=+0.00          =+0.00
=+1.50          =+1.00*
*
```

```
                /FNEW(u,v)  for FFT
                *BOTTOM
                    4377
                *FNTABF+1Y
                    XFX
                *4400
              XFX, JMS  I  INTEGER
                Dca  U
                PUSHJ
                    EVAL-1
                JMS  I  INTEGER
                CIA
                DCA   T2
                DCA   LORD/low order
                TAD   U
                CLL   RAR
                DCA   U
                TAD     LORD
                RAL
                DCA     LORD
                ISZ     T2
                JMP     .-7
                JMP  I  EFUN3I
```

5.6 TRAVEL VOUCHER TO EXPENSE VOUCHER CONVERSION PROGRAM

Though FOCAL is not a business oriented language the use of FOCAL in business applications is not impossible. Such a use is seen in the TRAVEL VOUCHER TO EXPENSE VOUCHER CONVERSION program with which the user may ease the task of reporting his expenses after a business trip.

Working from the input of the number of the days using the expense account and the categorized input of the expenses encountered (all amounts must be entered in terms of cents rather than dollars) during that period, the computer tallies and itemizes

a. the daily expenses and

b. the totals of the expenses over the entire period.

The data, thus summarized, are very easily transcribed onto an employee expense voucher.

TRAVEL VOUCHER TO EXPENSE VOUCHER
CONVERSION PROGRAM

C-FOCAL., 1969

```
01.01   T !! "EXPENSE ACCOUNTER (TYPE ALL AMOUNTS IN PENNIES)"
01.05   ERASE
01.10   ASK %6.02,!"HOW MANY DAYS?" DAYS,!
01.20   IF (DAYS) 1.1,1.1; FOR I=1,DAYS; DO 5
01.40T  !! " THE TRIP TOTALS ARE";F  I=1,30;T " "
01.41T  "GRAND"!
01.60   SET LO=LT; SET ME=ET
01.70   SET OJ=OT; SET MI=MT;  DO 7
01.80   TYPE "  $"!!!!!!
01.90G  1.05

05.10   ASK !!!"BRKFST " B1
05.20   ASK !"LUNCH " B2
05.30   ASK !"DINNER " B3
05.40   ASK !"SNACKS " B4
05.50   ASK !"MILES TRAVELED ? "B5;  SET B5=B5*9;  TYPE " $ B5/100; DO 6
05.60   ASK !"HOTEL " B6
05.70   ASK !"OTHER " B7
05.73   ASK !"TELE " B8
05.75   A !"TAXI  "C1
05.76A  !"PARKN "C2
05.77A  !"TOLL "C3
05.85   ASK !"MISC. " B9
05.90   TYPE !"THE DAILY TOTALS ARE"!
05.91   SET LO=B6;  SET ME=B1+B2+B3+B4
05.92   SET OJ=B5+C1;  SET MI=B9+B8+B7+C2+C3
05.93   TYPE "DAY NO.";  DO 7.1
05.94   TYPE  !%3,I,"  "; DO 7.2;  DO 7.3
05.95   SET LT=LT+LO;  SET ET=ET+ME
05.96   SET OT=OT+OJ;  SET MT=MT+MI
```

```
06.10   ASK " MISC. TRAV.  ? "B6; SET B5=B5+B6
07.10T  "     LODGING     MEALS   OTHER TRAV.   MISC.      TOTAL
07.15 T !
07.20T   %8.02,LO/100,"   "ME/100,"   "OJ/100,"   "MI/100,"
07.30 T (LO+ME+OJ+MI)/100
*
*
*G

EXPENSE ACCOUNTER (TYPE ALL AMOUNTS IN PENNIES)
HOW MANY DAYS? :2

BRKFST   :150
LUNCH    :170
DINNER   :645
SNACKS   :35
MILES TRAVELED  ? :36
        $ =+ 3.24   MISC. TRAV.  ? :0

HOTEL    :1400
OTHER    :0
TELE     :40
TAXI     :0
PARKN    :250
TOLL     :0
MISC.    :0
THE DAILY TOTALS ARE
DAY NO.      LODGING     MEALS      OTHER TRAV.     MISC        TOTAL
=+     1  =+       14.00   =+ 10.00 =+     3.24    =+   2.90  =+     30.14

BRKFST   :98
LUNCH    :192
DINNER   :650
SNACKS   :30
MILES TRAVELED   ? :23
 $ =+    2.07     MISC. TRAV.   ? :0
HOTEL    :1400
OTHER    :398
TELE     :285
TAXI     :0
PARKN    :250
TOLL     :0
MISC.    :0
THE DAILY TOTALS ARE
DAY NO.      LODGING     MEALS      OTHER TRAV.     MISC        TOTAL
=+   2     =+       14.00   =+ 9.70   =+    2.07       =+ 9.33   =+   35.10

THE TRIP TOTALS ARE                                                GRAND
        LODGING          MEALS      OTHER TRAV.     MISC        TOTAL
 =+     28.00       =+       19.70   =+      5.31    =+ 12.23   =+   65.24  $
```

5.7 TWINS DEMO

The TWINS DEMO Program is an interesting experiment in the applications of plotting with a visual scope display unit. It must be noted that several functions must be loaded into memory before this program will operate. This program is an integral part of curve fitting. The Twins Demo requires V68/I Control with Tektronix 611 Scope. (i.e., 340 control)

TWINS DEMO

```
W
C-FOCAL., 1969
01.05S    A=FDIS ( ) +FDXS () +FNEW(2) + FNEW (256)
01.10S    A=.2;S SW=19
01.70F    T=0,.05,6.284;S T2=T+3.14159/4;DO 1.8;DO 15
01.75     G 2.1
01.80S    R=4*FSIN(T) +4;S X=8+R*FCOS(T2);S Y=32+R*FSIN(T2)
02.10     F Y=28.5,A,32;S K=( (Y-30.5)/1.5) ↑ 2;S X=9-(K*K-K);DO 15
03.10     F X=7.4,A,10.5;S Y=26.5-( (X-9) ↑2)/2;DO 15
04.10     S X=10.5;F Y=17,2*A,24.8;DO 15
05.10     F X=7 .2*A,8;S Y=22-7*(X-7); DO 15
06.10 F   X=10.5,A,15;S Y=26-FSOT(5*(X-10) );DO 15
07.10 F   X=11.5,A,14.5;D 8.5
07.20 F   X=14.5,.2*A,15;D 8.5
08.10 F   X=3,A,4.6;DO 8.4
08.20 F   X=11,A,12;DO 8.4
08.30     G 9.1
08.40     S K=X-7;S Y=12+(K*K)/4;DO 15
08.50S    Y-21-FSQT(6.25-(X-12.5) ↑2);D 15
08.60S    Y=(X-7) ↑2-1;D 15
08.70S    X-5+FSIN(3.14159*(Y-12)/7);D 15
09.10 F   Y=0,2*A,16;S X=12-( (Y-8) ↑2)/64;DO 15
10.10 F   X=2,A,4.5;S K=X-3;S Y=K*(K*(.47*K-.5)+1.03)+26;DO 15
11.10 F   X=2,(.2*A),2.85;D 8.6
11.20 F   X=4.7,.2*A,6;D 8.6
12.10F    Y=4.5,2*A,12;D 8.7
12.20F    Y=15,2*A,25;D 8.7
13.10F    X=5.3,.3*A,6;S Y=-7*(X-6);DO 15
14.10F    Y=12,2*A,24;S K=( (Y-15.5)/11) ↑2;S X=5.5+12.5*(K*K-K);DO 15
14.20F    Y=4,2*A,12;S K=Y-8.5;S X=8.1-FSQT(27-K*K);DO 15
14.30R
```

NOTE

Group 15 must be supplied to scale X, Y and call appropriate display for the device. (c.f., Section 5.8)

APPENDIX A
FOCAL COMMAND SUMMARY

Command	Abbr	Example of Form	Explanation
TYPE	T	TYPE FSQT (AL ↑ 3+FSQT (B))	Evaluates expression, types out =, and result in current output format.
		TYPE "TEXT STRING"!	Types text. Use ! to generate carriage return line feed.
WRITE	W	WRITE ALL	FOCAL prints the entire indirect program.
		WRITE 1	FOCAL types out all group 1 lines.
		WRITE 1.1	FOCAL prints line 1.1
IF	I	IF (X) 1.2,1.3,1.4;	Where X is identifier or expression.

Control is transferred to the first, second, or third line number if (X) is less than, equal to, or greater than zero respectively. If the semicolon is encountered prematurely then the remainder of the line is executed.

MODIFY	M	MODIFY 1.15	Enables editing of characters on line 1.15

The next character typed becomes the search character. FOCAL will position itself after the search character; then the user may

a. type new text, or
b. form-feed to go to the next occurrence, or
c. bell to change the search character, or
d. rubout to delete backwards, or
e. left arrow to kill backwards, or
f. carriage return to end the line, or
g. line-feed to save the rest of the line.

QUIT	Q	QUIT or * or control-C	Returns control to user.
RETURN	R	RETURN	Terminates DO subroutines
SET	S	SET A = 5/B * SCALE(3)	Substitution statement
ASK	A	ASK ALPHA (I + 2 * J)	FOCAL types a colon for each variable; the user types a value to define each variable.

Command	Abbr	Example of Form	Explanation
COMMENT	C	C - compute area	If a line begins with the letter C, the remainder of the line will be ignored.
CONTINUE	C	C - ignore temporarily	
DO	D	DO 4.14	Execute line 4.14; return
		DO 4	Execute all group 4 lines, return when group is expanded or when a RETURN is encountered.
		DO ALL	Execute entire indirect text as a subroutine.
ERASE	E	ERASE	Erases the symbol table.
		ERASE 2	Erases all group 2 lines.
		ERASE 2.1	Deletes line 2.1.
		ERASE ALL	Deletes all user text.
FOR	F	FOR I = x,y,z; TYPE I	The command string following the semicolon is executed for each value; x,y,z are constants, variables, or expressions. x=initial value of I, y=value added to I until I is greater than z. y is assumed =1 if omitted.
GO	G	GO	Starts indirect program at lowest numbered line number.
GOTO	G	GOTO 3.4	Starts indirect program at line 3.4

C - The Fourteen (14) Functions are

FSQT ( ) - Square Root
FABS ( ) - Absolute Value
FSGN ( ) - Sign Part of the Expression
FITR ( ) - Integer Part of the Expression
FRAN ( ) - A Noise Generator
FEXP ( ) - Natural Base to the Power
FSIN ( ) and - FCOS ( ), FATN ( ) - Trig Functions
FLOG ( ) - Naperian Log
FDIS (X,Y) - Scope Functions
FADC ( ) - Analog to Digital Input Function
FNEW ( ) - User Function
FX ( ) - Extra User Function

APPENDIX B

ERROR DIAGNOSTICS*

Table B-1
Error Diagnostics of FOCAL, 1969

Location	Code	Meaning
	?00.00	Manual Start given from console.
	?01.00	Interrupt from keyboard via control-C.
0250	?01.40	Illegal step or line number used.
0316	?01.78	Group number is too large.
0340	?01.96	Double periods found in a line number.
0351	?01.:5	Line number is too large.
0362	?01.;4	Group zero is an illegal line number.
0440	?02.32	Nonexistant Group referenced by 'DO'.
0464	?02.52	Nonexistant line referenced by 'DO'.
0517	?02.79	Storage was filled by push-down list.
0605	?03.05	Nonexistant line used after 'GOTO' or 'IF'.
0634	?03.28	Illegal command used.
1047	?04.34	Left of "=" in error in 'FOR' or 'SET'.
1064	?04.52	Excess right terminators encountered.
1074	?04.60	Illegal terminator in 'FOR' command.
1147	?04.:3	Missing argument in Display command.
1260	?05.48	Bad argument to 'MODIFY'.
1406	?06.06	Illegal use of function or number.
1466	?06.54	Storage is filled by variables.
1626	?07.22	Operator missing in expression or double 'E'.
1646	?07.38	No operator used before parenthesis.
1755	?07.:9	No argument given after function call.
1764	?07.;6	Illegal function name or double operators used.
2057	?08.47	Parenthesis do not match.
2213	?09.11	Bad argument in 'ERASE'.
2551	?10.:5	Storage was filled by text.
2643	?11.35	Input buffer has overflowed.
5042	?20.34	Logarithm of zero requested.
5644	?23.36	Literal number is too large.
6543	?26.99	↑ Power is too large or negative.
7111	?28.73	Division by zero requested.
7405	?30.05	Imaginary square roots required.
	?31.<7	Illegal character, unavailable command, or unavailable function used.

*The above diagnostics apply only to the version of FOCAL, 1969, issued on tape DEC-08-AJAE-B

B.1 OBTAINING ERROR CODES VIA ODT36

To obtain error codes via ODT36, proceed as follows:

a. Start ODT at 3600.

b. User types underlined letters:

(change, from, to)

4320/1357	1275 (line feed)	
4321/4745	3067 (line feed)	(LINENO)
4322/1675	4552 (line feed)	(PRNTLN)
4323/4246	7000 (carriage return)	
63/2676	1355 (C.R.)	(OUTDEV, OUTL)

c. then

M 7777	7777 (line feed)	
4273/0001	4400 (C.R.)	
4565W	(ERROR 2)	

Calling addresses and error codes will be printed here. The first two and last error codes (00.00,01.00,31.<7) are always the same.

APPENDIX C
EXPLANATION OF NEW INSTRUCTIONS

C.1 NEW INSTRUCTIONS (see Table C-1)

C.1.1 Push Down List Instructions

The user's push down list begins at the start of the floating point package and grows up toward the last variable. The initial value of the push down list pointer is contained in location "BOTTOM". The pointer is kept in an auto-index labeled "PDLXR". The instructions used to manage the list are given below:

PUSHA	places the contents of the AC onto the list as the current entry
POPA	adds the current entry of the push down list to the AC,
PUSHF	saves a group of data, normally a floating point entry. This instruction is followed by a pointer to a 3 word (or 4 word) group of data. These 3 or 4 words are placed on the push down list as the current entry.
POPF	restores a 3 or 4 word group of data from the current entry on the push down list according to the pointer which follows the instruction. The location "MFLT" contains either -3 or -4 and determines the number of words affected by "PUSHF" and "POPF".
PUSHJ	calls subroutine which is pointed to by the word following the instruction. The return address is placed on the push down list as the current entry.
POPJ	the current entry is used as a return address from a subroutine.

C.1.2 Character Handling Instructions

These instructions are used to pick-up, save, and print characters for processing by FOCAL. Characters are fetched from the user's storage area or from the ASR-33 input buffer. Character conversion between 8 and 6 bits and the trace feature are handled by these routines.

PRINTC	is used to print a character. If the AC is zero upon entry then the character in "CHAR" is printed. If the AC is non-zero, then the contents of the AC is printed.
READC	Reads a character from the user's input buffer (ASR-33 input) and echos all characters except line feeds and rubouts. The character is placed into "CHAR".
PACKC	places the 8-bit character in "CHAR" into the user's storage area. If the character is a rubout the previous character is deleted from the user's area and a back-slash is echoed via "PRINTC". The character is

converted into 6-bit code. The auto index "AXIN" and the flip-flop "XCTIN" are pointers to the user's storage area.

GETC — this instruction fetches the next character from the right or left side of the word pointed to by "AXOUT" and "XCT" and places it into "CHAR". If a question mark character is detected the dump switch "DMPSW" is flipped. If the dump switch is on then the character in "CHAR" is printed via "PRINTC".

SPNOR — Blanks and leading zeroes are ignored by repeated calls to "GETC".

C.1.3 Character Testing Routines

These guide the interpreter through the source text. They are testing routines used throughout FOCAL in interpreting the program and in other instances.

SORTC — the character in "CHAR" is classified according to an ASCII list which is pointed to by the location following the instruction. If the character is found in the list an exit is made to the location following the list pointer. If no character is found exit is made to the second location following the list pointer. If the character was found in the list then "SORTCN" contains the position relative to zero in the list searched. The list is terminated by a negative word.

SORTJ — the character in "CHAR" or in the AC is classified according to a list as per "SORTC". If the character is found in the ASCII list, then a jump to an address is made from a second list. The second list is pointed to by the 2nd location following call. If the character is not found then exit is made as per "SORTC". "SORTCN" is not changed, however.

TESTC — this instruction fetches the next non-space and classifies it as a terminator, number, function, or letter. The instruction then skips zero, one, two or three cells accordingly.

TESTN — "CHAR" is classified according to whether it is a period (no skip), number (skip two), or other (skip one). If "CHAR" is a number then its binary value is in "SORTCN".

TSTLPR — This instruction skips the next instruction if the AC contains a left parenthesis.

C.1.4 Line Number Handling Instructions

This group is used in manipulating line data and line numbers.

TSTGRP	If the group of the line number in the AC is equal to the group on the line in "LINENO" the next instruction is skipped.
PRNTLN	the coded line in "LINENO" is printed as a decimal fraction with group number and the step number separated by a decimal point.
GETLN	"SPNOR" is called and a line number is built in "LINENO" via calls to "GETC". "NAGSW" is set to indicate whether the line number was a group, line, or "ALL" designator.
FINDLN	the line number coded in "LINENO" is searched for in the user's text area. If the line is found, the auto-index "AXOUT" and "XCT" are set to point to the line's text and an instruction is skipped. If the line is not found, the pointer "AXOUT" is set to point to the next higher line and no instructions are skipped. "THISLN" points to the line found on the next larger line and "LASTLN" points to the previous/less line.
ENDLN	"ENDLN" links the line in the user's storage area to the rest of his text. It uses the result of the "FINDLN" instruction to accomplish this. The new end of the user's buffer is set-up in "AXIN". This command is used for insertion of new text, reconnecting after a deletion, and reconnection after Modify.

Table C-1
New Instructions

```
PUSHJ = JMS I  .                    /RECURSIVE SUBROUTINE CALL
          XPUSHJ
POPA = TAD  I POLXR                 /RESTORE AC
POPJ  = JMP  I  .                   /SUBROUTINE RETURN
          XPUPJ
PUSHA = JMS I  .                    /SAVE AC
          XPUSHA
PUSHF = JMS I  .                    /SAVE GROUP OF DATA
          PD2
POPF = JMS  I  .                    /RESTORE GROUP
          PD3
GETC = JMS I  .                     /UNPACK A CHARACTER
          UTRA
PACKC = JMS I  .                    /PACK A CHARACTER
          PACBUF
SORTJ = JMS I  .                    /SORT AND BRANCH ON AC OR CHAR
          SORTB
/NUMERICAL LIST -1
/ADDRESS LIST - NUMERICAL LIST
```

Table C-1 (Cont)
New Instructions

```
SORTC = JMS I  .          /SORT CHAR
        XSORTC
PRINTC = JMS  I  .        /PRINT AC OR CHAR
        OUT
READC = JMS I  .          /READ ASR-33 INTO CHAR AND PRINT IT
        CHIN
PRNTLN = JMS I  .         /PRINT C (LINENO)
        XPRNT
GETLN = JMS  I  .         /UNPACK AND FORM A LINENUMBER
        XGETLN
FINDLN = JMS  I  .        /SEARCH FOR A GIVEN LINE
        XFIND
ENDLN = JMS  I  L         /INSERT LINE POINTERS
        XENDLN
RTL6 = JMS     I  .       /ROTATE LEFT SIX
        XRTL6
SPNOR = JMS  I  .         /IGNORE SPACE AND LEADING ZEROS
        XSPNOR
TESTN = JMS  I  .         /PERIOD:  OTHER:  NUMBER
        XTESTN
TSTLPR = JMS  I  .        /SKIP IS 5 < SORTCN < 11 (I . E . AN L-PAR)
        LPRTST
TSTGRP = JMS  I  .        /SKIP IF G(AC) = G (LINENO)
        GRPTST
TESTC = JMS  I  .         /TERM; NUMBER;  FUNCTION;  LETTER
        XTESTC
ERROR2 = JMS  I  .        /EXCESS SOMETHING ERROR
ERROR3 = JMS  I  .        /MISCELLANEOUS ERROR
ERROR4 = JMS  I  .        /FORMAT ERROR
        ERR2
```

APPENDIX D

FOCAL CORE LAYOUT

Table D-1
Focal Core Layout-Usage

Mnemonics	What
ZERO	
START	FOCAL PROPER
BUFBEG	BUFFER AREA
BEGIN	INITIAL DIALOGUE
FEXP (BET 2+ 3) ARTN (FLAG 3 +1) FCOS	EXTENDED FUNCTIONS
(FLOA + 11) (TEMPO + 1) DECONV	OUTPUT CONVERSION
(INFIX +5) FLOUTP (OUTOG+4) FLINTP	INPUT-OUTPUT ROUTINES
(P43+1) FPNT ACMINS (RAR1+1) DNORM	FLOATING-POINT INTERPRETER
(BUFFER + 10) BINARY (RIM)	LOADERS

Table D-2
Detailed FOCAL Core Layout

Miscellaneous
Numbers
Floating-Point Working Area
Constants
New Instruction Pointers
Variables

START

Command/Input
Line Read Routine
'DO' Routine
Push-POP Routines
'GOTO' and 'WRITE' and Misc.
'IF', "SET", 'FOR' and Misc.
'ASK', 'TYPE', 'MODIFY'

"GETARG" - Recursive Routine
"SPNOR", "TESTN", "POPJ"
'RETRUN'
"EVAL" - Recursive Routine
OPNEXT - read operator
ARGNXT - read operand
ETERM - evaluate terminator
FLOP - floating operations called
ENUM - number processor
EFUN - function processor
ELPAR - left parens processor
EFUN3 - function returns
"DELETE" - Recursive Routine
DOK - group delete
DONE - garbage collection
"FINDLN" - Normal Routine
Find exact match or next larger
'ERASE' command processor
"GETC" - unpack text and trace
"ENDLN", "PRNTLN"
I/O Subroutines
Interrupt Processor
ERROR Processor
"PACKC" - pack text
Rubout routine

Table D-2 (Cont)

*3120		I/O Buffer Command Buffer Text Buffer Begins
TEXT/VARIABLES/./PUSHDOWNLIST	*4400 -	Once-Only Code SELF-START CLEAR ALL FLAGS TYPE MESSAGE
	*3600	ODT-JR (for X-FUN)
	*4600	ODT-JR (for dialogue)

Floating Point Routines
(c.f., Section 4.5.2)

*4600	Extended Functions
*5400	I/O Controller
*6400	Interpreter
*7600	Binary Loader or 8-SYS LIB Bootstrap or Disk Monitor Bootstrap
*7756	Rim Loader
End of Field Zero	
Field One Command Buffer	Extended Text Storage

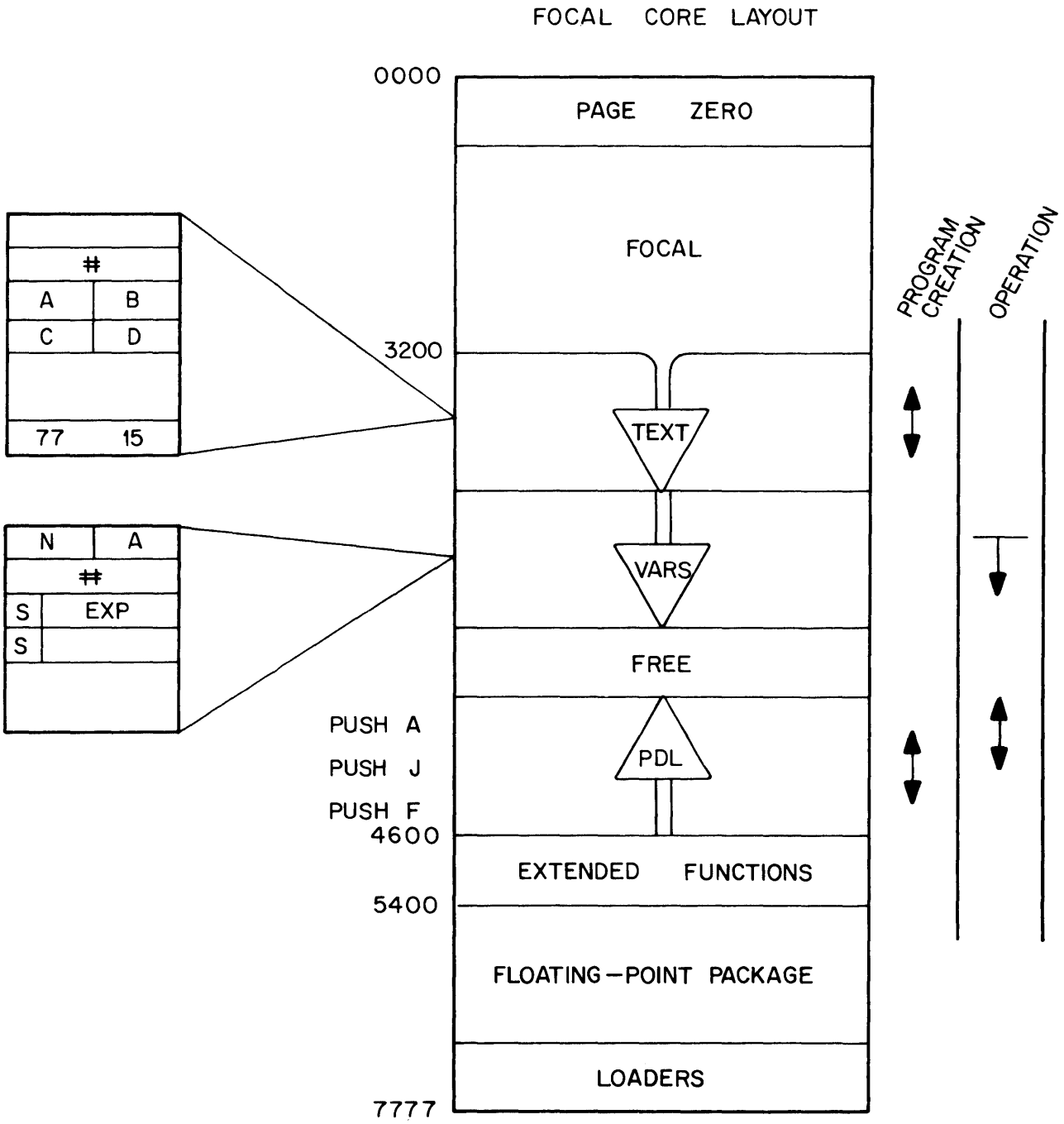


Figure D-1 FOCAL Core Layout
Dynamic Storage

APPENDIX E

SYMBOL TABLE AND OTHER TABLES/LISTS

E.1 SYMBOL TABLE

/FOCAL.ZZM PAL1[illegible] V515 10-APR-69 19:38 PAGE 121

A	0045	BFXX	4556	COMEIN	3140	DUBDIV	7261				
ABSOL	6751	BMOVE	1255	COMEOU	3206	DUBLAD	5733				
ABSOL2	6153	BOTTOM	0035	COMGO	1163	DUMLN2	2012				
ABSOL3	7375	BUFBEG	3217	COMLST	0774	DV3	7267				
ABSOLV	5571	BUFFER	7470	COMMEN	0614	E	0042				
AC1H	0041	BUFR	0060	CON1	5037	EBELL	0512				
AC1L	0042	BUFRS	1300	CONTIN	1147	ECALL	1601				
ACMINS	6673	BUFRSP	3045	CONTN	0076	ECCR	2630				
ACTING	0701	BUFST	5531	CSTAR	0225	ECHO	0454				
ACTION	4420	C	0047	CTABS	0353	ECHOLS	1624				
ACTIVE	0037	C100	0006	D	0041	EFOP	0056				
ACTVP	1143	C140	2554	DATUM	7102	EFUN	1743				
ADD	0061	C144	6140	DATUMA	7252	EFUN2	1754				
ADDR	0040	C200	0123	DCONP	6303	EFUN3	2017				
ADONE	6673	C200M	0065	DCONT	0471	EFUN3I	0136				
AF	4677	C260	0113	DCOUNT	6143	ELPAR	1763				
ALF1	4760	C3	5346	DDTJP	0004	END	0134				
ALF2	4763	C5	5342	DEBGSW	0026	ENDFI	6243				
ALFZ	4755	C7	5336	DECK	0040	ENDLN	4556				
ALGN	6570	C9	5332	DECKP	0107	ENDT	0135				
ALIGN	6623	CCR	0077	DECON	5627	ENUM	1732				
ALIST	1372	CDF	7000	DECONV	5600	EOUT	0474				
ALISTP	0072	CDF1	6211	DECP	5533	EP7	0052				
ALPHA	1436	CEX1	6504	DECR	5521	EPAR	1710				
AMOUNT	6722	CEXP	6503	DELETE	4565	EPAR2	1765				
ARCALG	4732	CF	4705	DF	4710	ER5	4555				
ARCRTN	5024	CFRS	0133	DGRP	0425	ERASE	2204				
ARGNXT	1723	CFRSX	0137	DGRP1	0441	ERG	2225				
ARTN	5000	CHAR	0066	DIG	5543	ERL	2222				
ASHFT	6665	CHARM	0026	DIGIT	5713	ERR2	2726				
ASK	1202	CHIN	2155	DIGITS	0006	ERROR2	4566				
ATEI	4465	CHKCNT	1053	DIV1	5754	ERROR3	4566				
ATES	4513	CHKCON	1052	DIV2	6757	ERROR4	4566				
ATLIST	1570	CHRT	6133	DIVIDE	7150	ERROR5	2725				
ATSW	0056	CIA	7041	DLISTP	0100	ERT	2214				
AXIN	0010	CIF	6202	DMDONE	7063	ERV	2217				
AXOUT	0017	CIF1	6212	DMPSW	0100	ERVX	2237				
B	0046	CLA	7200	DMULT	7004	ESCA	2532				
BACK	5503	CLCU	7427	DMULT4	7036	ETERM	1647				
BASER	0616	CLF	0076	DNORM	7335	ETERM1	1627				
BASES	1540	CLL	7100	DNUMBR	5714	ETERM2	1655				
BASEX	0617	CMA	7040	DO	0420	ETERMN	1644				
BDUMP	0071	CML	7020	DOK	2111	EVAL	1613				
BEGIN	4371	CNTR	0057	DONE	2127	EX1	0040				
BELLX	0534	CNTRLC	0324	DOONE	0463	EXASK	2662				
BEND	4442	CNTRLX	0331	DOUBLE	0127	EXCHCK	1037				
BET1	4771	CNTRM	0024	DPCVPT	6302	EXCHE	1072				
BET2	4774	CNTRT	0032	DPN	6305	EXCHEC	2615				
BETA	0010	CODET	0044	DPT	6145	EXGO	1007				
BETZ	4766	COL	1255	DSAVE	5640	EXGON	1215				
BF	4702	COMBOT	0226	DTABLE	0070	EXIT	2646				
BFX	4557	COMBUF	0132	DTST	5647	EXIT1	5034				

EXIT2	5302		FLOUT	5556		HOLD	0036		KINT	2625
EXIT3	7363		FLOUTP	6000		HOLDI	1276		KRB	6036
EXITJ	2661		FLPT	6465		HOLDO	1277		KSF	6031
EXMOD	2657		FLSU	6505		HORD	0045		KSF1	6401
EXP	0044		FLTONE	2405		HREAD	6321		KSF2	6421
EXPRIN	2600		FLTXR	0014		HREAD2	6324		KSF3	6441
EXPRN	1060		FLTXR2	0015		HSGO	6364		KSF4	6461
EXPRNT	1000		FLTZER	2407		HSP	0273		L1	5126
EXRD	1014		FM12	6142		HSPSW	6375		L2	5131
EXREAD	2605		FNEG	5163		HSPX	6361		L3	5134
EXRED	1054		FNOR	7000		HSR	0273		L4	5137
EXSWP	1142		FNPT	4554		HSWITC	6343		L8A	4550
EXTR	2313		FNTARF	0374		HTST	6376		L8AX	4553
F	0043		FNTARL	2165		I33	2414		L8AY	4552
FCONT	1171		FOR	1041		IAC	7001		L8B	4551
FCOS	5200		FOUTPU	0130		IBAR	0212		LASTLN	0025
FCOUNT	5535		FPAC1	7474		IBUFI	0106		LASTOP	0055
FEND3	2267		FPNT	6400		IBUFO	0105		LASTV	0031
FEXP	4620		FPRNT	5465		IECALL	1037		LCON	0371
FEXT	0000		FRST	3206		IF	1013		LG2E	4713
FGO2	6011		FRSTX	3215		IF1	1035		LIBRAR	7503
FGO3	6027		FSIN	5205		IF3	1025		LINENO	0067
FGO4	6034		FXIT	0000		IGNOR	0217		LIST3	0077
FGO5	6070		G8L	4466		IGNORE	0447		LIST6	0072
FIGO1	6221		GECALL	1460		ILIST	0771		LIST7	0074
FIGO4	6261		GEND	2334		IN	5513		LISTGO	1370
FINCR	1065		GERR	0340		INBUF	0034		LISTL	0023
FINDLN	4555		GET1	2330		INDEV	0064		LISTP	1165
FINDN	2246		GET3	2345		INDRCT	6463		LOG2	5157
FINFIN	1137		GETARG	1403		INFIX	2401		LOG5	5142
FINKP	1133		GETC	4545		INITL	3001		LOG6	5145
FINPUT	7131		GETLN	4554		INITL4	3011		LOG7	5150
FINT	4407		GETSGN	1045		INLIST	0570		LOG8	5153
FISW	0052		GETVAR	1407		INORM	6307		LOOKUP	4571
FIX	6724		GEXIT	0352		INPUT	0756		LOOP01	6431
FIXM	6753		GFND1	1505		INPUTX	0271		LORD	0046
FLAC	0044		GINC	0070		INSUR	0036		LP7	7556
FLAD	6506		GLIST	1377		INTEGE	0053		LPRTST	2035
FLAG1	5162		GO	5021		INTRPM	0201		M100	0101
FLAG2	4725		GOCR	0451		INTRPT	2603		M10PT	6147
FLARG	2030		GONE	0232		IOBUF	3120		M11	0121
FLARGP	0125		GOTO	0603		IOF	6002		M12	2413
FLDV	7107		GRPTST	0744		ION	6001		M137	2357
FLEX	6515		GS1	1437		IOTX	0110		M140	2556
FLGT	6467		GS2	1461		IPART	1040		M144	6137
FLIMIT	1075		GS3	1441		IRETM	0227		M2	0111
FLINTP	6200		GS4	1454		ITABLE	6573		M20	0105
FLIST1	0577		GSERCH	1426		ITER1	7470		M200	0064
FLIST2	0574		GTEM	0021		JUMP	6462		M20M	0056
FLMY	6563		GZERR	0362		K5	5525		M240	0114
FLOG	5040		HINBUF	0037		KEY	0321		M240M	3046
FLOP	1674		HLT	7402		KEYX	0447		M260	1526

```
M271    1527    NEGP    4724    P       0000    PDP     4562
M4      6141    NEWU    0042    P10     0053    PDP5    4570
M40     2356    NEXT0   1146    P100    0342    PDP5X   4463
M40M    0057    NEXTU   1145    P1000   0046    PDP8I   4567
M4M     0061    NL1     7301    P13     0005    PEQ     6135
M5      0120    NL2     7326    P14     0706    PER     0102
M6M     1162    NL2000  7332    P140    0532    PI      5312
M77     0103    NL3777  7350    P17     0107    PI2     5036
MBREAK  2602    NL4000  7330    P177    0106    PIOT    5316
MC200   0446    NL5777  7352    P17M    0054    PLCE    5536
MCOM    1136    NL7775  7346    P2      4566    PLS     6026
MCR     0116    NL7776  7344    P20     0055    PM2000  1144
MCRM    0063    NOECHO  0465    P2000   0373    PNTR    0031
MD      5526    NOP     7000    P27     6750    POPA    1413
MDECK   0043    NORF    6513    P277    0110    POPF    4544
MEQ     1135    NORM    6567    P2M     0707    POPJ    5541
MF      0602    NORMF   7147    P3      2034    PPTEN   6144
MFLT    0117    NOUSRS  0073    P337    0075    PRINTC  4551
MIF     7260    NOX     6675    P37     0062    PRINTD  7550
MINE    5662    NOX1    6711    P377    2553    PRNT    2442
MINSKI  0051    NOX2    6704    P4      0060    PRNT2   3114
MINUS2  7153    O1      4370    P40     2552    PRNT8   7527
MINUSA  0112    O2      4561    P4000   0124    PRNTI   6132
MINUSE  6301    O4      4412    P43     6310    PRNTLN  4553
MINUSZ  5663    O5      4563    P6777   0050    PROC    0611
MLISTP  0077    O6      4564    P7      4565    PROCES  0610
MOD     5215    OBUF0   0104    P7000   0047    PSIN    0165
MODIFY  1256    OBUFI   0103    P7576   0764    PT1     0030
MOVE15  1232    OBUFO   0102    P7600   0104    PTCH    0126
MOVE20  1243    OFFDEC  4422    P77     0122    PTEN    6275
MP1     7254    OM12    5530    P7700   0101    PTEST   1457
MP11    0575    ONDECK  4421    P7740   0372    PUSHA   4542
MP177   0445    ONE     4716    P7750   0763    PUSHF   4543
MP2     7256    OOUT    4544    P7757   0051    PUSHJ   4540
MP3     7255    OP      3115    P77M    0045    R6      5441
MP4     7200    OPMINS  6565    PA1     2524    RAL     7004
MP5     7253    OPNEXT  1622    PACBUF  2502    RANO    1530
MP6     7210    OPTABL  1731    PACKC   4546    RAR     7010
MPER    0115    OPTR0   2663    PACKST  0027    RAR1    6571
MPLUS   5664    OPTRI   2665    PACX    2530    RAR2    6572
MQ      0035    OPTRO   2664    PALG    5261    RDIV    0152
MQA     7501    OPUT    5532    PARITY  0302    READC   4552
MRO     0444    OTHER   0215    PARTES  2047    RECOVR  2740
MSPACE  5665    OUT     2465    PC      0022    RECOVX  2761
MULDIV  7101    OUTA    5536    PC1     0614    REMAIN  5712
MULT    6566    OUTCR   2476    PCHECK  5245    REPT    6146
MULT10  5667    OUTDEV  0063    PCHK    0510    RESOL   6752
MULT2   5715    OUTDG   6154    PCK1    2535    RESOL3  7376
MULTY   4752    OUTL    1354    PCM     0101    RESOL5  6304
MX      0533    OUTX    2475    PD2     0534    RESOLV  7173
MZERO   0067    OVER1   0043    PD3     0554    RESTAR  0003
NAGSW   0065    OVER2   0047    PDLXR   0013    RESTOR  0304
```

RESTP	6377	SNL	7420	TEST?	4561	XABS	2014
RESUME	2623	SORTR	1314	TEXT?	1610	XACTIO	0643
RET	5452	SORTC	4550	TEXT?	2075	XADC	1343
RETRN	1563	SORTCN	0054	TEXTE	0017	XB	2655
RETURN	5536	SORTJ	4547	TEXTPM	0074	XBUF	0516
REVIT	7146	SPA	7510	TGO	5400	XCOM	0620
RFC	6014	SPECIA	6777	THIR	7257	XCT	0020
RMF	6244	SPL	7000	THISLN	0023	XCTIN	0062
RND2	5527	SPLAT	3051	THISOP	0024	XDECK	0600
ROOTGO	7461	SPNOR	4560	TINTR	1241	XDELET	2062
ROT	2557	SQCON1	7467	TLIST	1400	XDYS	1142
ROUND	6151	SQEND	7465	TLIST2	1404	XENDLN	2360
RRR	6012	SRETN	0261	TLIST3	2377	XF	4560
RSF	6011	SRNLST	1363	TLS	6046	XFIND	2242
RTL	7006	START	0177	TPC	6044	XGETLN	0302
RTL6	4557	STARTL	5064	TQUOT	1232	XI33	2666
RTR	7012	STARTV	0060	TRAD	6573	XIN	6306
RUB1	3004	SUBS	1517	TRC1	1163	XINPUT	5666
RUB2	3042	SZA	7440	TRC2	1164	XINT	1160
RUB3	3030	SZL	7430	TSF	6041	XKEY	0412
RUB4	3037	T	0000	TSF1	6411	XOUTL	2676
RUB5	3041	T1	0032	TSF2	6431	XPOPJ	1565
RUBIT	2555	T12	4426	TSF3	6451	XPR	1062
SAC	0033	T2	0071	TSF4	6471	XPR2	1064
SADR	6150	T2U	2624	TSTGBP	4563	XPRNT	2425
SAVAC	2600	T3	0033	TSTLBR	4562	XPRNTI	1013
SAVE	3751	TABLE	6464	TTY	0322	XPUSHA	0477
SAVLK	2601	TAG1	6723	TTYPE	0347	XPUSHJ	0521
SBAR	1302	TASK	1204	TWO	4721	XR10	0010
SCHAR	1273	TASK4	1253	TWOPT	5306	XR11	0011
SCONT	1270	TCE	6042	TYPE	1203	XR12	0012
SCOUNT	5534	TCRLF	1251	TYPE2	1226	XR13	0013
SET	1041	TCRLF2	1246	UNDECK	0633	XRAN	1553
SETW	0527	TDUMP	3052	UPAR	0066	XRAR2	7365
SETWI	0023	TELSW	0016	USERNO	0041	XRSTAR	0312
SEX	1340	TELSW1	0275	USERTS	1210	XRT	0011
SEXC	0740	TELSW2	0276	UTF	2276	XRT2	0012
SFOUND	1306	TELSW3	0277	UTO	2375	XRTL6	0413
SGOT	1312	TELSW4	0300	UTRA	2274	XSGN	2010
SIGN	7124	TELSW5	0301	UTX	2316	XSORTC	0721
SIGNF	2050	TEM	5156	VAL	0032	XSPNOR	1517
SILENT	0343	TEMP	4726	WALL	0664	XSQ2	4676
SIN	2662	TEMPM	0025	WORDS	0003	XSQR	5326
SING	0471	TEMPT	0027	WRITE	0635	XSQRT	7400
SINGLE	2636	TEMPX	0030	WTEST2	0653	XT3	0717
SKP	7410	TEN	6271	WTESTG	0667	XTDUMP	0535
SLK	0034	TENPT	6152	WX	0673	XTESTC	0700
SMA	7500	TERMS	1770	X	5322	XTESTN	1533
SMIN	6136	TEST2	6736	X1	5035	XTTX	0727
SMP	6101	TEST4	7366	X2	4675	XTTY	0710
SMSP	6134	TESTA	0322	XA	2656	XXTTY	0742
SNA	7450	TESTC	4564			XYZ	2451

```
/FOCAL,ƵƵM      PAL1Ø   V515    1Ø-APR-69       19:38   PAGE 121-4
        ƵERO    6520

 ERRORS DETECTED: Ø
 RUN-TIME:  32 SECONDS
 6K CORE USED
```

E.2 OTHER TABLES AND LISTS

```
                    /LIST OF FUNCTION ADDRESSES, (NAMES ARE IN "FNTABL")

          0373      FNTABF=,
0373      2014                XABS    /ABS    -ABSOLUTE VALUE
0374      2010                XSGN    /SGN    -SIGN PART
0375      1161                XINT    /ITR    -INTEGER PART
0376      1143                XDYS    /DIS    -DISPLAY AND INTENSIFY
0377      1553                XRAN    /RAN    -RANDOM NUMBER
0400      1344                XADC    /ADC    -READ ANALOG TO DIGITAL CONVERTER
0401      5000                ARTN    /ATN    -
0402      4620                FEXP    /EXP    -EXPONENTIAL FUNCTIONS
0403      5040                FLOG    /LOG    -
0404      5205                FSIN    /SIN    -TRIG FUNCTIONS
0405      5200                FCOS    /COS    -
0406      7400                XSQRT   /SQT    -SQUARE ROOT
0407      2725                ERROR5  /NEW    -USER DEFINED FUNCTIONS
0410      2725                ERROR5  /COM    -
0411      2725                ERROR5  /X      -

0412      0000      XRTL6,    0       /ROTATE AC LEFT SIX - "RTL6"
0413      7106                CLL RTL
0414      7006                RTL
0415      7006                RTL
0416      5612                JMP I XRTL6



                              /ENGLISH_FRENCH
          0775      COMLST=,  /COMMAND DECODING LIST
0775      0323                323     /SET    - ORGANIZE
0776      0306                306     /FOR    - QUAND
0777      0311                311     /IF     - SI
1000      0304                304     /DO     - FAIZ
1001      0307                307     /GOTO   - VA
1002      0303                303     /COMMENT- COMMENTE
1003      0301                301     /ASK    - DEMANDE
1004      0324                324     /TYPE   - TAPE
1005      0314                314     /LIBRARY- ENTREPOSE
1006      0305                305     /ERASE  - BIFFE
1007      0327                327     /WRITE  - INSCRIS
1010      0315                315     /MODIFY - MODIFIE
1011      0321                321     /QUIT   - ARRETE
1012      0322                322     /RETURN - RETOURNE
1013      0212                212     /(ASTERISK)=EXPANDABLE COMMAND
```

```
      1164     COMGO=, /COMMAND ROUTINE ADDRESSES
1164  1042             SET
1165  1042             FOR
1166  1014             IF
1167  0417             DO
1170  0604             GOTO            /(REFERENCED)
1171  0615             COMMENT
1172  1203             ASK
1173  1204             TYPE
1174  7503             LIBRARY
1175  2204             ERASE
1176  0636             WRITE
1177  1257             MODIFY
1200  0177             START   /RETURN TO COMMAND MODE VIA 'QUIT'
1201  1563             RETRN
1202  6361             HSPX    /ACTIVATE THE HIGH SPEED READER
```

```
      2165     FNTABL=,
2165  2533             2533    /ABS
2166  2650             2650    /SGN
2167  2636             2636    /ITR
2170  2565             2565    /DIS
2171  2630             2630    /RAN
2172  2517             2517    /ADC
2173  2572             2572    /ATN
2174  2624             2624    /EXP
2175  2625             2625    /LOG
2176  2654             2654    /SIN    /LIST OF CODED FUNCTION NAMES
2177  2575             2575    /COS
2200  2702             2702    /SQT
2201  2631             2631    /NEW
2202  2567             2567    /COM
2203  0330             0330    /X
```

```
                    /CONTROL TABLE

0354  0451          IGNORE          /L,T,
      0355          CTABS=,
0355  0456          ECHO                    /↑A-HOME
0356  0333          CNTRLX                  /↑B
0357  0326          CNTRLC                  /C-END OF MESSAGE
0360  0333          CNTRLX                  /D
0361  0333          CNTRLX                  /E
0362  0333          CNTRLX                  /F
0363  0456          ECHO                    /G - BELL
0364  0333          CNTRLX                  /H
0365  0333          CNTRLX                  /I
0366  0467          NOECHO                  /J - LF,
0367  0333          CNTRLX                  /K
0370  0467          NOECHO                  /L -FF,
0371  0453          GOCR                    /M -C,R,
0372  0333          CNTRLX                  /N -
0373  0333          CNTRLX                  /O
0374  0333          CNTRLX                  /P
0375  0333          CNTRLX                  /Q
0376  0345          SILENT                  /R-TAPE
0377  0333          CNTRLX                  /S- (7000) - FOR DEBUGGING
0400  0351          TTYPE                   /T-NOT TAPE
0401  0333          CNTRLX                  /U
0402  0333          CNTRLX                  /V
0403  0333          CNTRLX                  /W -E,O,MEDIA
0404  0456          ECHO                    /X-ERASE
0405  0333          CNTRLX                  /Y
0406  0333          CNTRLX                  /Z
0407  0451          IGNORE                  /[
0410  0451          IGNORE                  /\
0411  0451          IGNORE                  /]
0412  0456          ECHO                    /UPAR -
0413  0453          GOCR                    /LEPTAR=GORO
```

```
4WORD (10 DIGIT) OVERLAY FOR FOCAL.ZZK PAL10   V133    14-MAR-69  15:54

                        /4WORD (10 DIGIT) OVERLAY FOR FOCAL,ZZK

                0004    WORDS=4
                0012    DIGITS=12

                0052    *FISW
          0052  0000            0

                0070    *GINC
          0070  0006            WORDS+2
                0116    *MFLT
          0116  7774            -WORDS
                3210    *FRST+2
          3210  0355    TEXT @C-4WORD@
          3211  6427
          3212  1722
          3213  0400
                5526    *MU
          5526  7766            -DIGITS /EXTENDED LENGTH OF OUTPUT FORMAT
          5527  0013            DIGITS+1/RND2

                5310    *TWOPI+2
          5310  3755            3755    /CORRECT CONSTANTS
                5314    *PI+2
          5314  3755            3755
                5320    *PIOT+2
          5320  3755            3755

                6143    *DCOUNT
          6143  7765            -DIGITS-1
                6277    *PTEN+2
          6277  3146            3146    /CONSTANT ONE

                6402    *FPNT+2
          6402  7410            SKP     /DO NOT CLEAR OVERFLOW WORDS
                6540    *ZERO+20
          6540  7000            NOP
                6736    *TEST2
          6736  0043            43

                7036    *DMULT4
          7036  3275            DCA DATUM+5
                7105    *MULDIV+4
          7105  7000            NOP
                7072    *DMDONE+7
          7072  7000            NOP
```

```
          7260    *MIF

 7260     7735            -43

          7271    *DV3+2
 7271     1043            TAD OVER1
 7272     1047            TAD OVER2
 7273     3253            DCA MP5
 7274     7004            RAL
 7275     1042            TAD AC1L        /COMBINE ONE POSITION AND
 7276     1046            TAD LORD
 7277     3256            DCA MP2         /SAVE RESULT
 7300     7004            RAL
 7301     1045            TAD HORD        /ADD OVERFLOW
 7302     1041            TAD AC1H
 7303     7420            SNL             /SKIP IF OVERFLOW
 7304     5312            JMP .+6
 7305     3045            DCA HORD        /UPDATE FLAC
 7306     1253            TAD MP5
 7307     3047            DCA OVER2
 7310     1256            TAD MP2
 7311     3046            DCA LORD
 7312     7200            CLA             /CLEAR ACCUMULATOR
 7313     1254            TAD MP1         /SAVE OVERFLOW BITS CIRCULARLY
 7314     7004            RAL
 7315     3254            DCA MP1
 7316     1200            TAD MP4
 7317     7004            RAL
 7320     3200            DCA MP4
 7321     1335            TAD DNORM



                          NOPUNCH
          0001            FIELD 1
                          XLIST
```

```
                    /8K  OVERLAY FOR FOCAL,ZZK

                    /TEXT IS IN FIELD 1; VARIABLES AND POL ARE IN FIELD 0

                    /,SAVE ST8K!(D)-7577;200
                    /,SAVE FCL8!0-3377;
                    /,SAVE NUL8:10100;10113
                    /,SAVE NAM8:10100-(8);10113


          6201      CDF=6201

          2010      T=10

          0000      P=0

          0000      FIELD 0


          0100      LINE0=100
          0022      *PC
    0022  0000                0
          0031      *LASTV
    0031  3206                COMEOUT
          0060      *BUFR
    0060  0126                LINE1
          0131      *COMBUF
    0131  0010                10
          0132      *CFRS
    0132  0100                LINE0
          0134      *ENDT
    0134  0126                LINE1
          0166      *166
    0166  2565      DPC,      ROT+5     /PC
    0167  6160      DTHIS,    THISD     /THISLN
    0170  6173      DPT1,     PT1D      /PT1
    0171  7557      DXRT,     XRTD      /(TAD I XRT)
    0172  7564      DAXIN,    AXIND     /(DCA I AXIN)
    0173  2572      DAXOUT,   AXOUTD    /(TAD I AXOUT)
    0174  0120      DLIB,     DLIB8     /LINK FOR 8K L-COMMAND
```

```
                    ////////////////////////////////////////

                    FIELD 1

          0001      *0000
0000      0000              0         /ZERO PC
0001      0000              0
0002      0000              0         /TDUMP DATA
0003      0000              0
0004      0000              0
0005      5051              5051
0006      0060              BUFR
0007      0126              LINE1

          0100      *LINE0
0100      0000              0
0101      0000              0
0102      0355    TEXT @C-8K FOCAL @
0103      7013
0104      4006
0105      1703
0106      0114
0107      4000
0110      6171              6171
0111      6671              6671
0112      7715              7715

0113      6201    ST8K,     CDF P     /START 8K USER FILE AT THIS ADDRESS
0114      1007              TAD 7
0115      3406              DCA I 6
0116      6202              CIF P
0117      5525              JMP I RLIB
0120      6002    DLIB8,    IOF
0121      1406              TAD I 6
0122      3007              DCA 7
0123      6203              CIF CDF P
0124      5525              JMP I ,+1
0125      7600    RLIB,     7600      /RETURN TO DISK MONITOR,
          0126    LINE1=,



          0000    FIELD 0
          0000    *0000
0000      0000              0

                  NOPUNCH
                  XLIST
```

APPENDIX F

FOCAL SYNTAX

Table F-1
Syntax in Backus Normal Form

<immediate command> : : = <program statement> C.R.
<indirect command> : : = <line #> <program statement> C.R.

<line #> : : = <group no.> · <line no.>

<group no.> : : = 1-31

<line no.> : : = 01-99 | 1-9

<program statement> : : = <command> |

<command> <space> <arguments> | <command string> |

<program statement>; <program statement>

<command> : : = WRITE | DO | ERASE | GO | GOTO

<arguments> : : = ALL | <line #> | <group no.>

<command string> : : = <type statement> | <Library statement> |

<Ask statement> | <If statement>
<Modify statement> | <Set statement>
<For statement> | QUIT | RETURN | COMMENT | CONTINUE

<Set statement> : : = SET <space> <variable> = <expression>

<For statement> : : = FOR <space> <variable> = <expression>,

<expression>, <expression>; <program statement> |

FOR <space> <variable> = <expression>, <expression>;
<program statement>

<If statement> : : = IF <space> <subscript> <line #>; |

IF <space> <subscript> <line #>, <line #>; |

IF <space> <subscript> <line #>, <line #>, <line #>

<Ask statement> : : = ASK <space> <Ask arguments>

<Ask arguments> : : = <operand>, <Ask arguments> |

! <Ask arguments> | # <Ask arguments> | % <format code>, <Ask arguments> |

" <character string> " <Ask arguments> | <null> |

<operand> <space> | $

<format code> : : = <line #> | <null> | <group no.>

<Library statement> : : =

LIBRARY <space> <Library Command>

<space> <file NAME>

<Library Command> : : = CALL | SAVE | DELETE | LIST

<character string > : : = <null > | <character > <character string >

<character > : : = a-z | <digit > | <special symbols >

<digit > : : = 1-9 | 0

<terminator > : : = <space > | , | ; | C.R.

<not space > : : = <null > | <character >

<special symbols > : : = & | ' | : | @

<leader-trailer > : : = @ | [200] | <null >

<File name > : : = <character string >

<data list > : : = <variable > | <variable >, <data list >

<Type statement > : : = TYPE <space > <Type arguments >

<Type Arguments > : : = <Ask arguments > | <expression > |

<Type arguments >, <Type arguments >

<Modify statement > : : = MODIFY <space > <line # >

This command is then followed by keyboard input characters defined as <search character >
plus
<null > | <character string > | <control character > |
<character string > <control characters >

<control charcter > : : = [bell] <search character > |
[form] | [line-feed] | C.R. |

[↑C] | ← | [rub-out]

<Variable > : : = <letter > | <letter > <character > |
<Variable > <subscript >

<Subscript > : : = <left paren > <expression > <right paren >

<operand > : : = <variable > | <constant > | <subscript > | <function >

<left paren > : : = < | (| [
<right paren > : : = >) |]
<expression > : : = <unary > <operand > | <operand > |

<expression > <operator > <expression >

<unary > : : = + | -

<operator > : : = ↑ | * | / | + | -

<Function > : : = F <function code > <subscript >

<function code > : : = SIN | COS | LOG | ATN | EXP
SQT | ADC | DIS | ITR |
ABS | SGN | RAN | NEW |

NOTE

Spaces are ignored except when required.

Table F-2
FOCAL Commands In French

Commandments Francais Pour Le Calculateur Electronique "IGOR"

	English	French	Letter
1.	SET	ORGANIZE	O
2.	FOR	QUAND	Q
3.	IF	SI	S
4.	DO	FAIS	F
5.	GOTO	VA	V
6.	COMMENT	COMMENTE	C
7.	ASK	DEMANDE	D
8.	TYPE	TAPE	T
9.	LIBRARY	ENTREPOSE	E
10.	ERASE	BIFFE	B
11.	WRITE	INSCRIS	I
12.	MODIFY	MODIFIE	M
13.	QUIT	ARRETE	A
14.	RETURN	RETOURNE	R

CE N'EST PAS PARFAIT
MAIS "IGOR" EST INTELLIGENT
IL COMPRENDRA

NOTE

"IGOR" refers to PDP-8/I

APPENDIX G
ILLUSTRATIONS

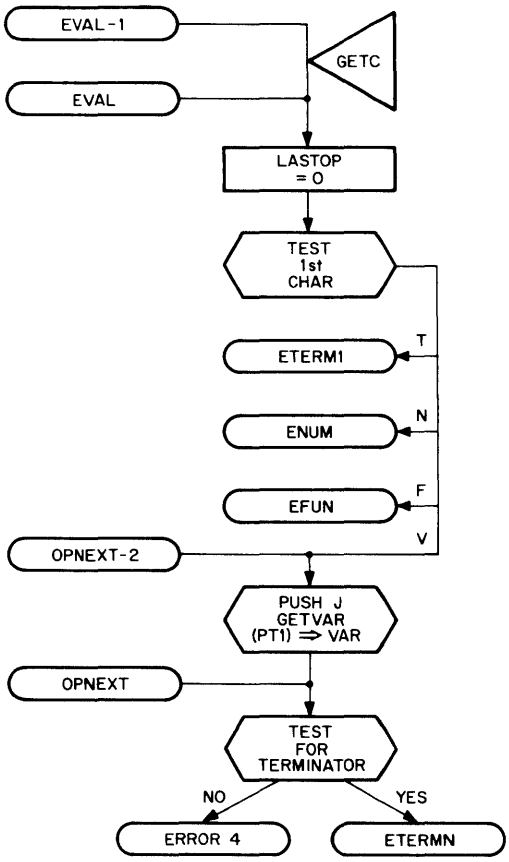


Figure G-1 (Sheet 1) Arithmetic Evaluation

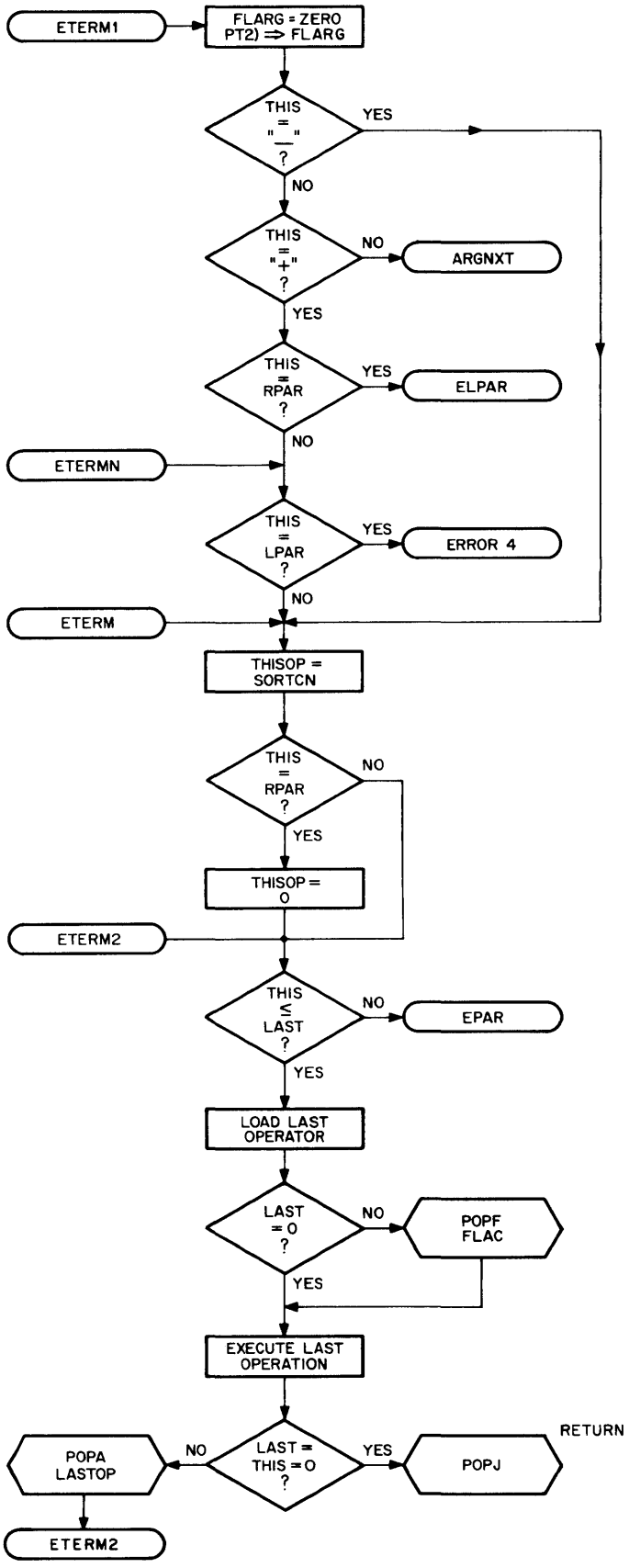
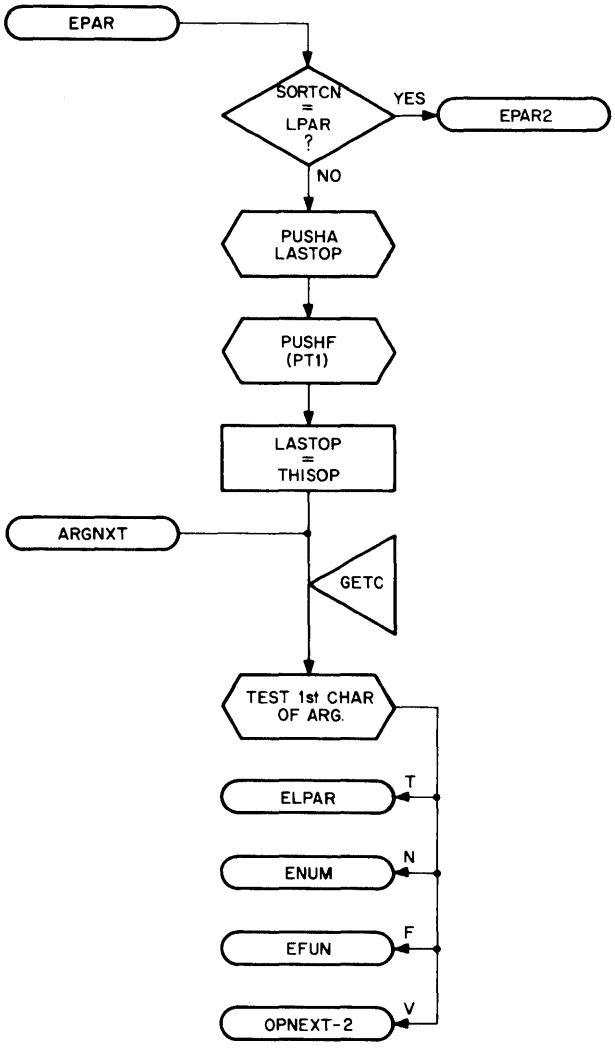
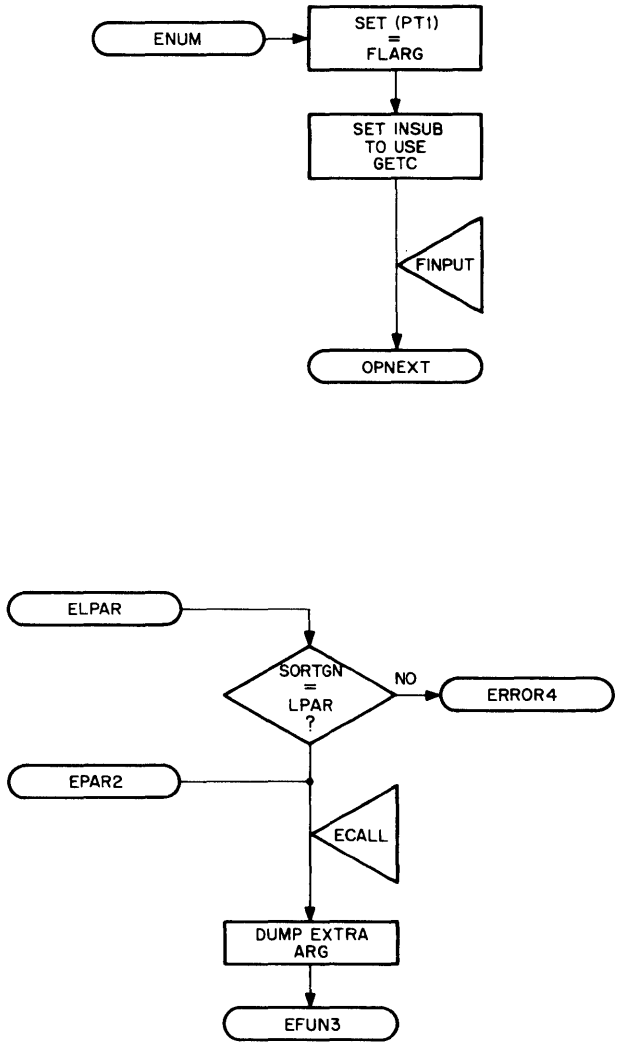


Figure G-1 (Sheet 2) Arithmetic Evaluation



Analysis of Operands



Analysis of Sub-Expressions and Constants

Figure G-1 (Sheet 3) Arithmetic Evaluation

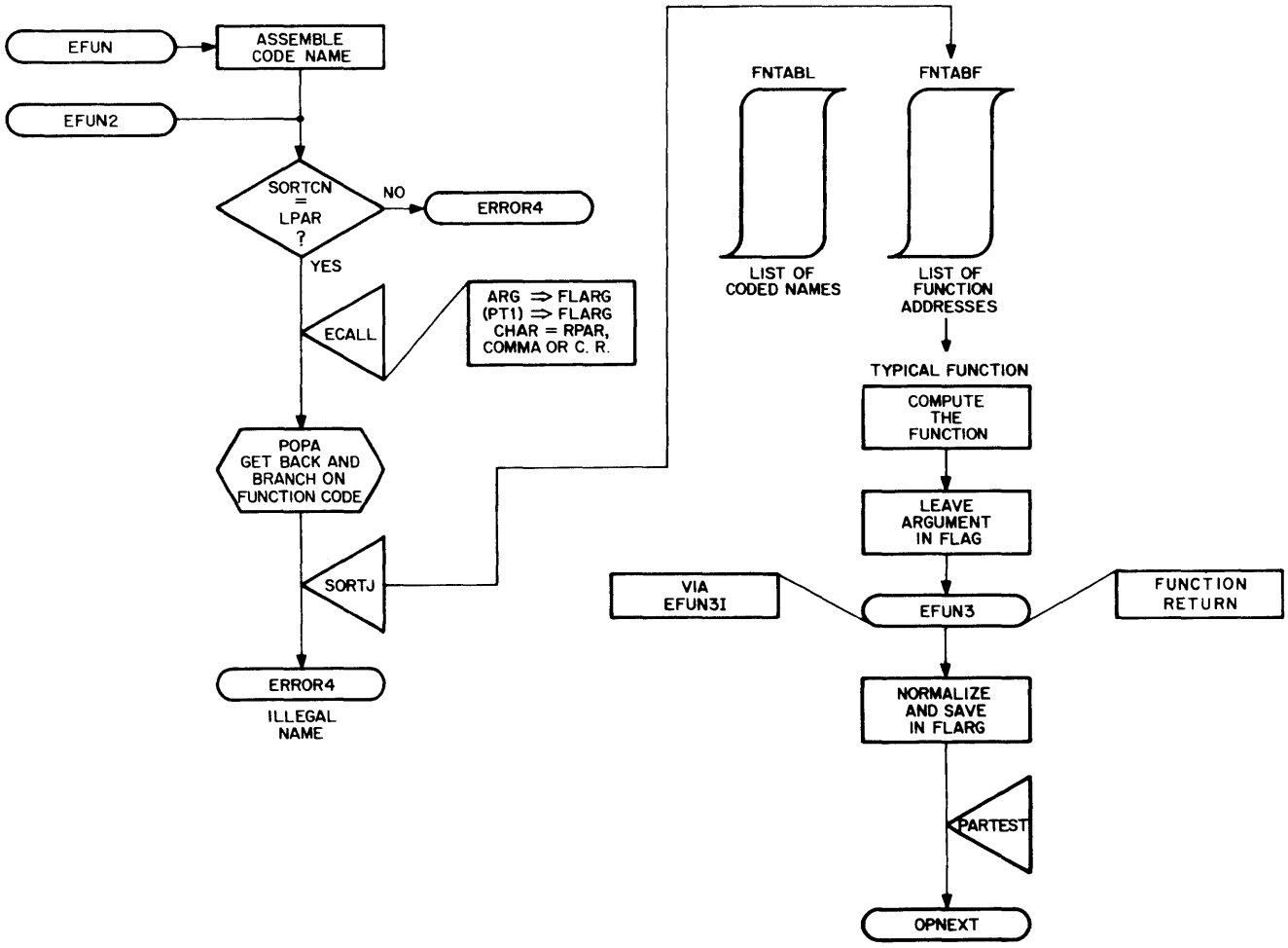


Figure G-1 (Sheet 4) Arithmetic Evaluation (Analysis of Functions)

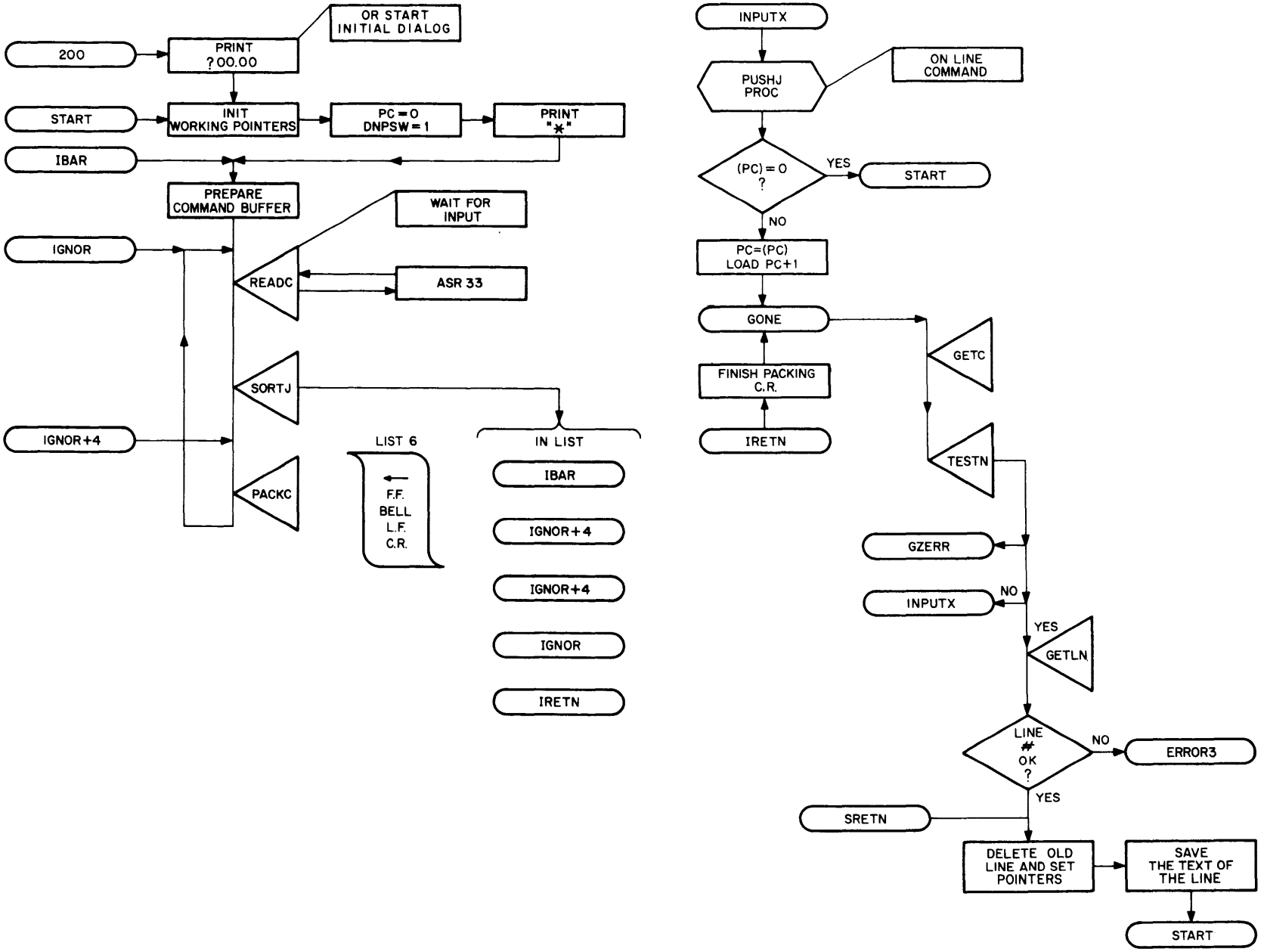


Figure G-2 Command/Input

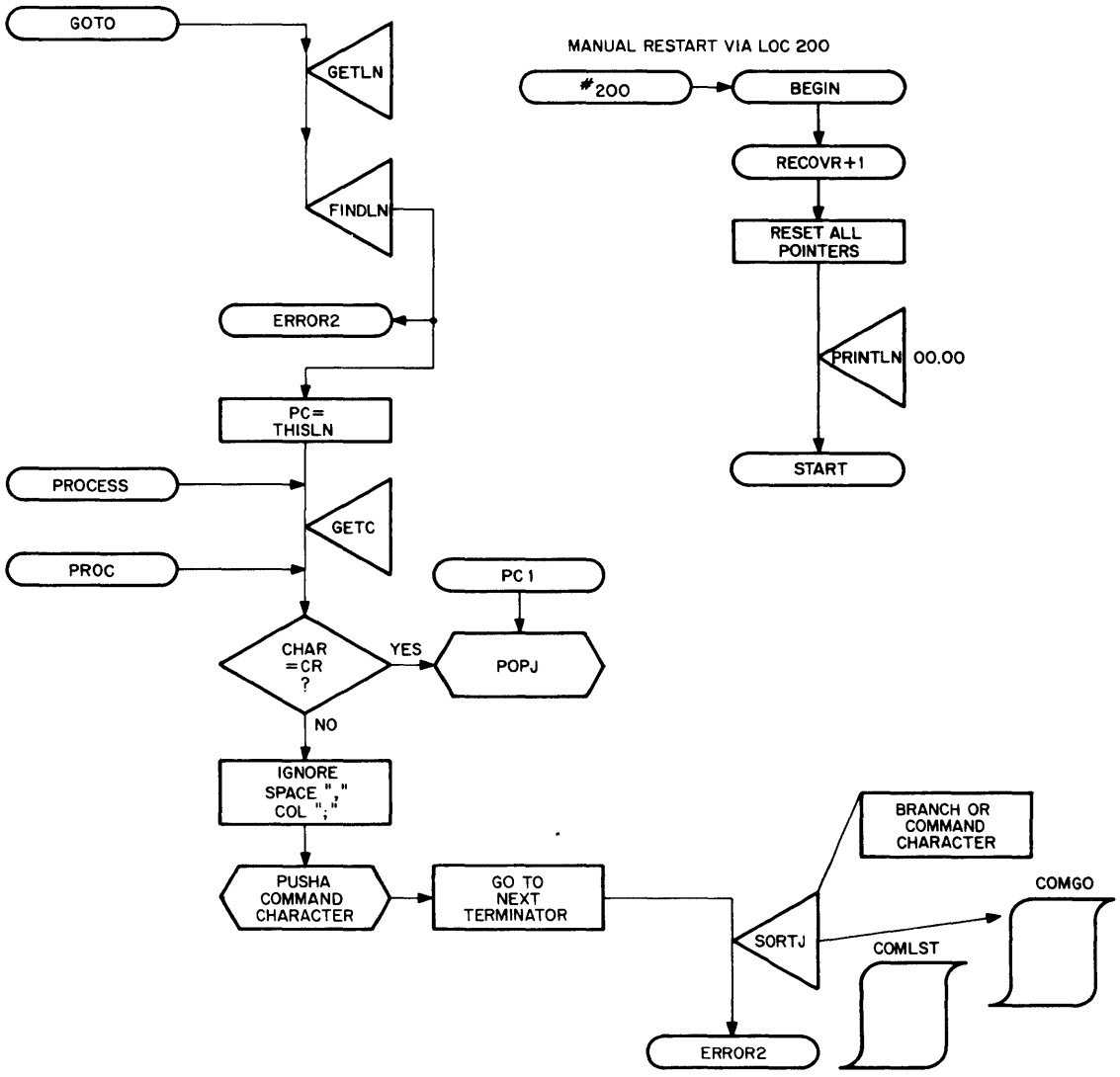


Figure G-3 Main Control and Transfer

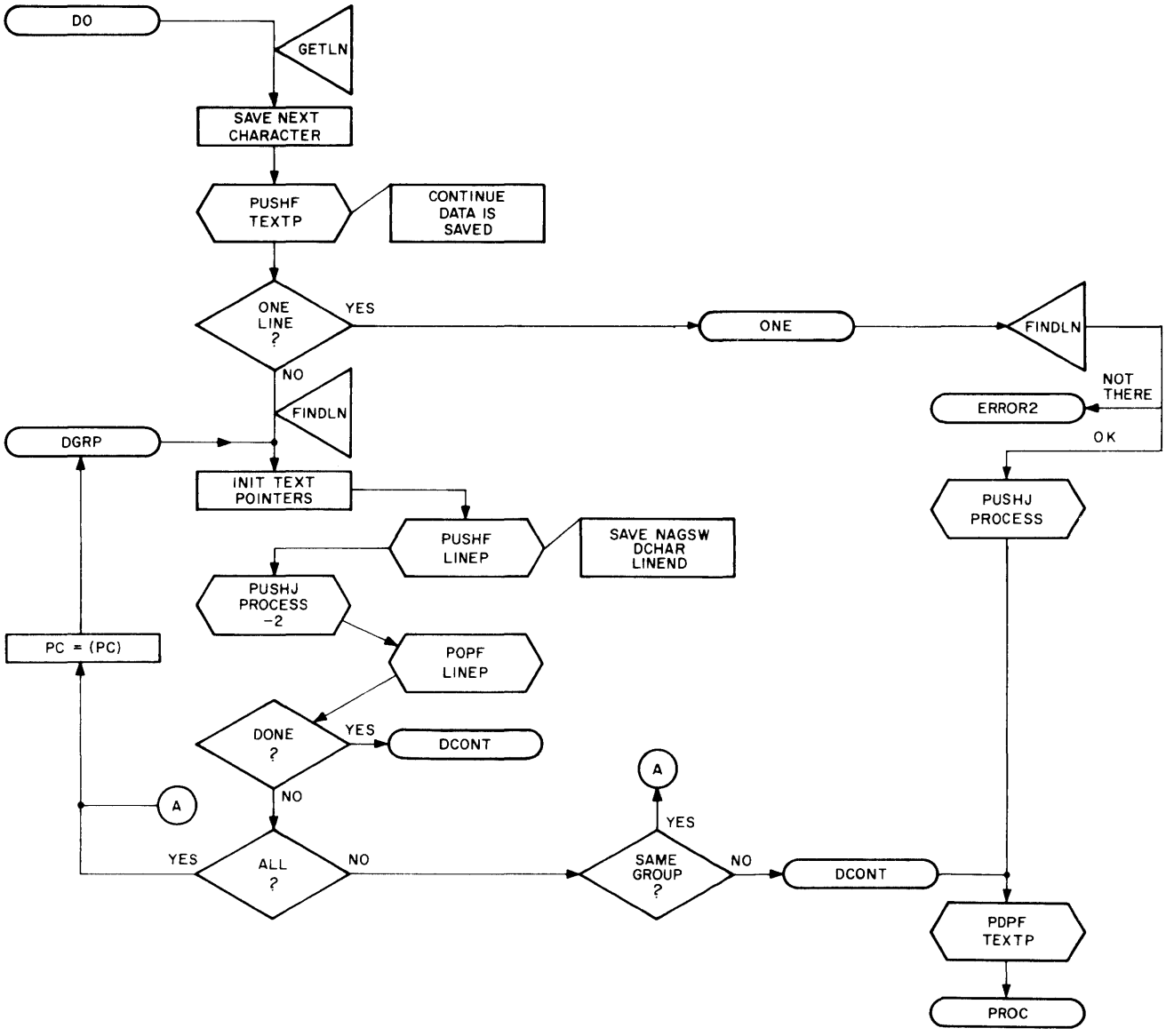


Figure G-4 DO Command

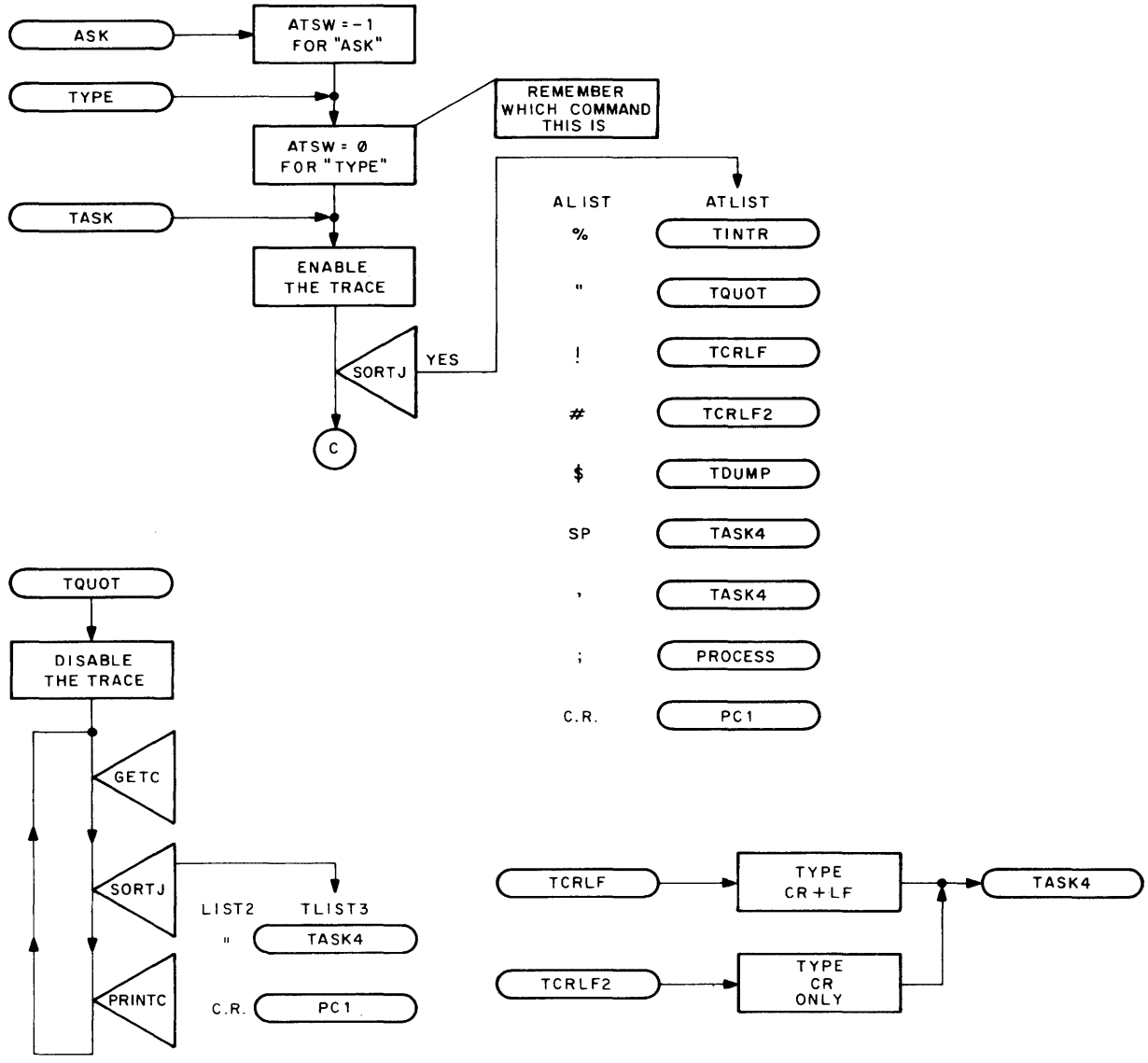


Figure G-5 (Sheet 1) Input/Output Commands

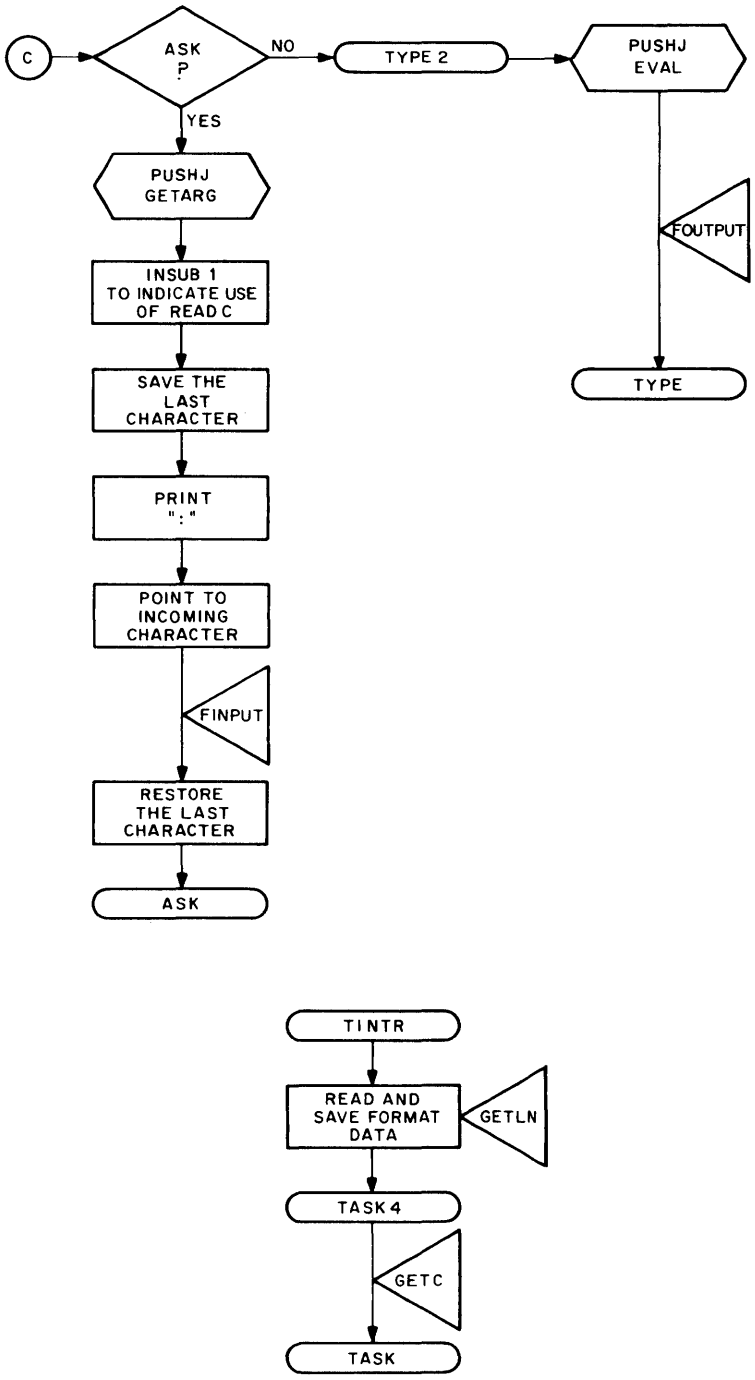


Figure G-5 (Sheet 2) Input/Output Commands

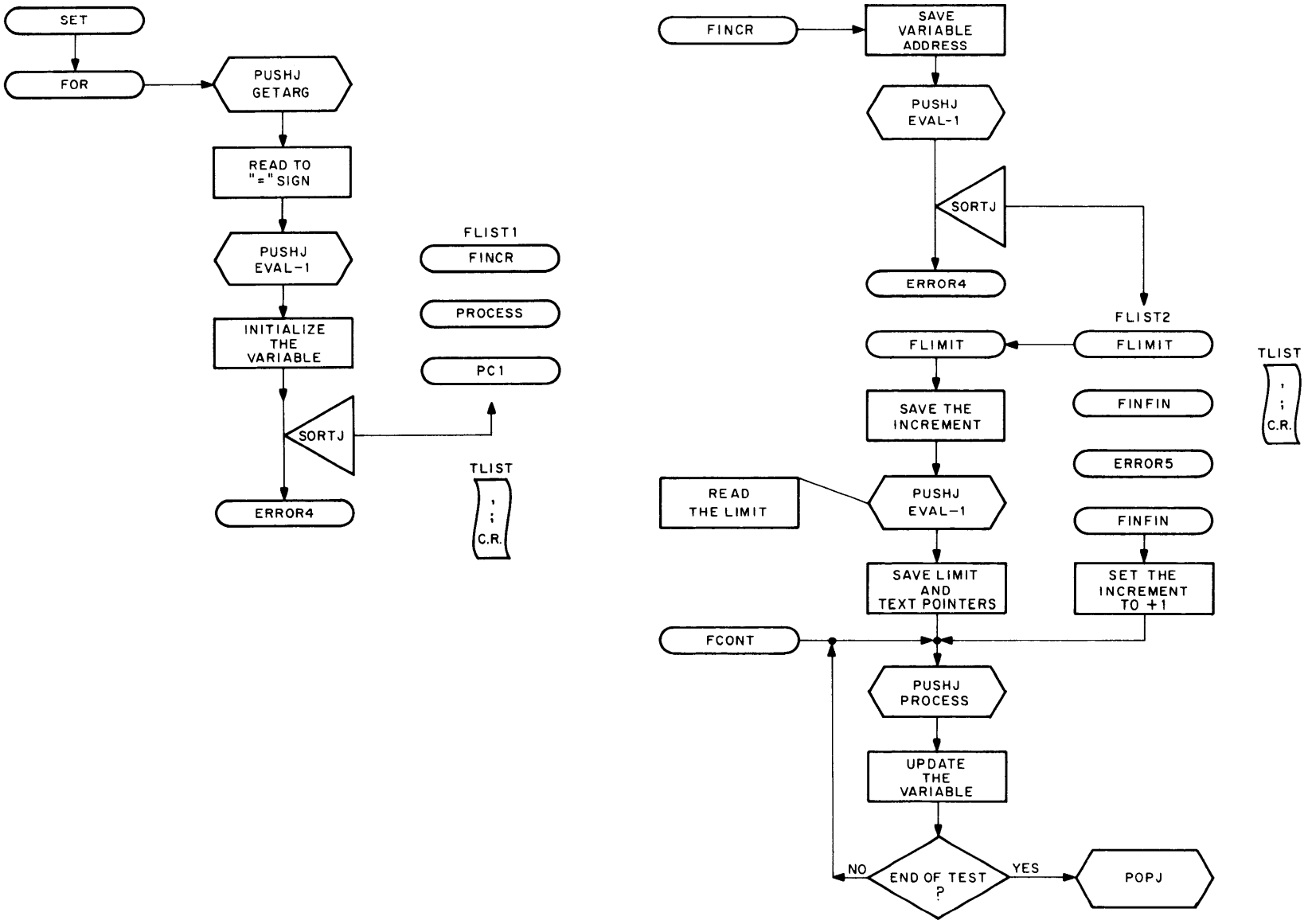


Figure G-6 Iteration Control

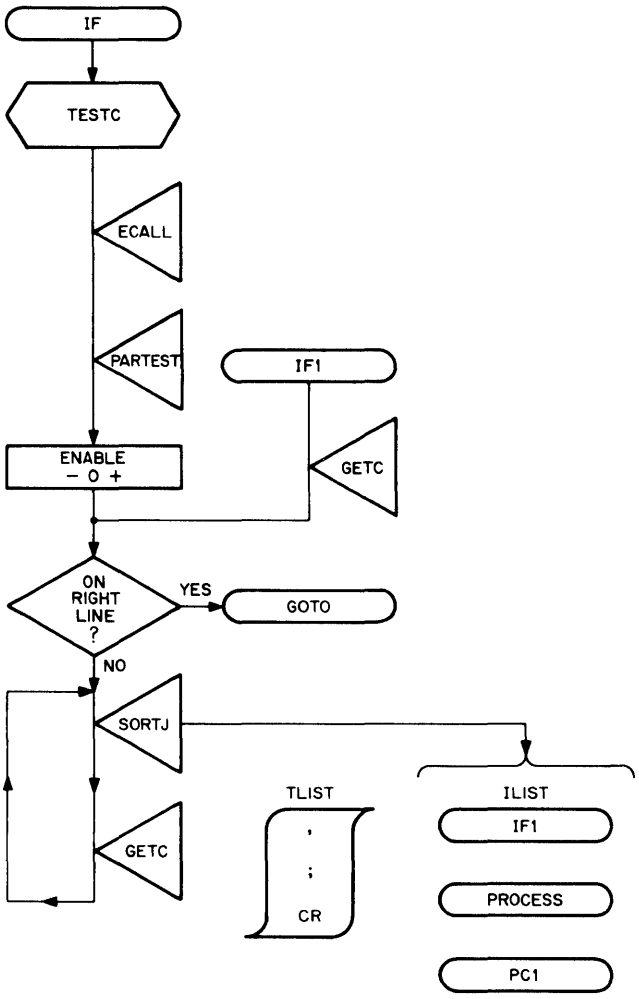


Figure G-7 Conditional Branch Command

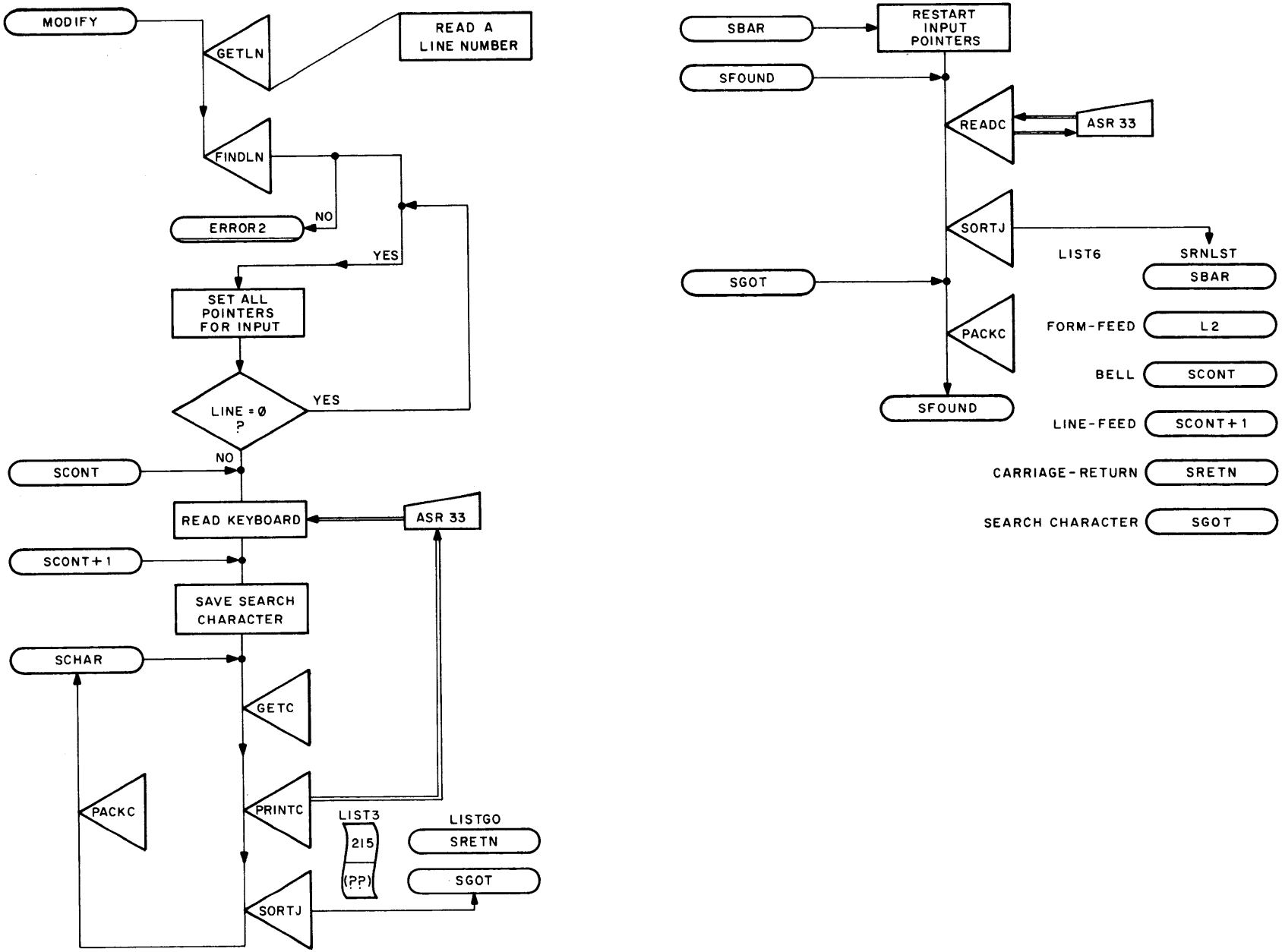


Figure G-8 Character Editing

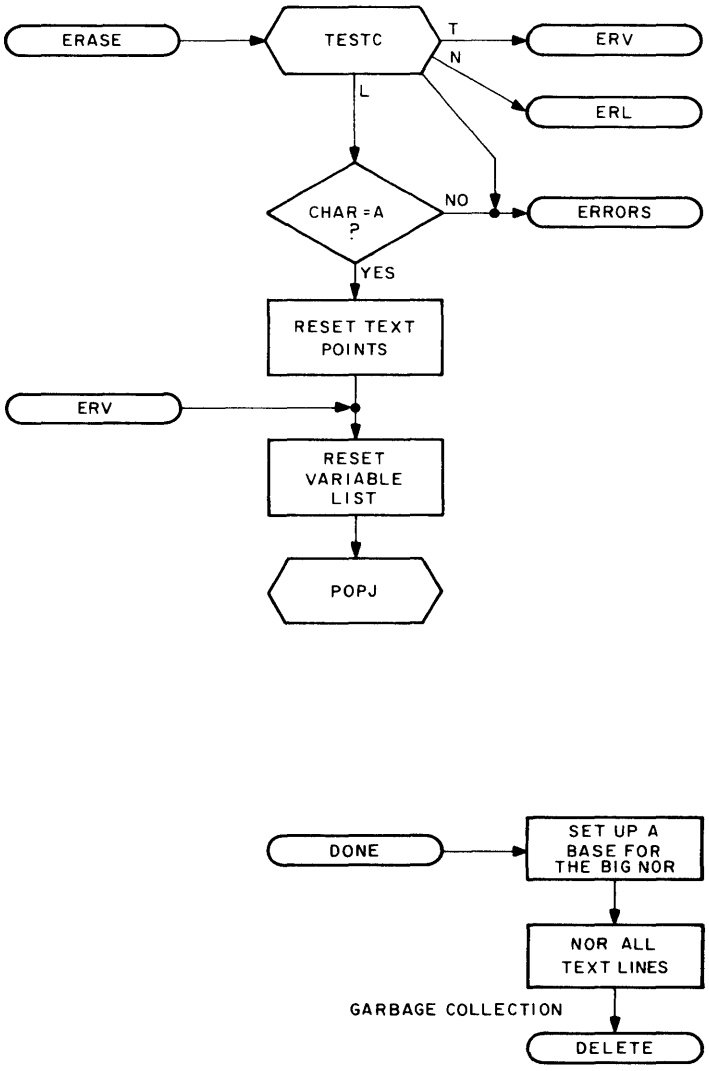


Figure G-9 (Sheet 1) ERASE and Delete

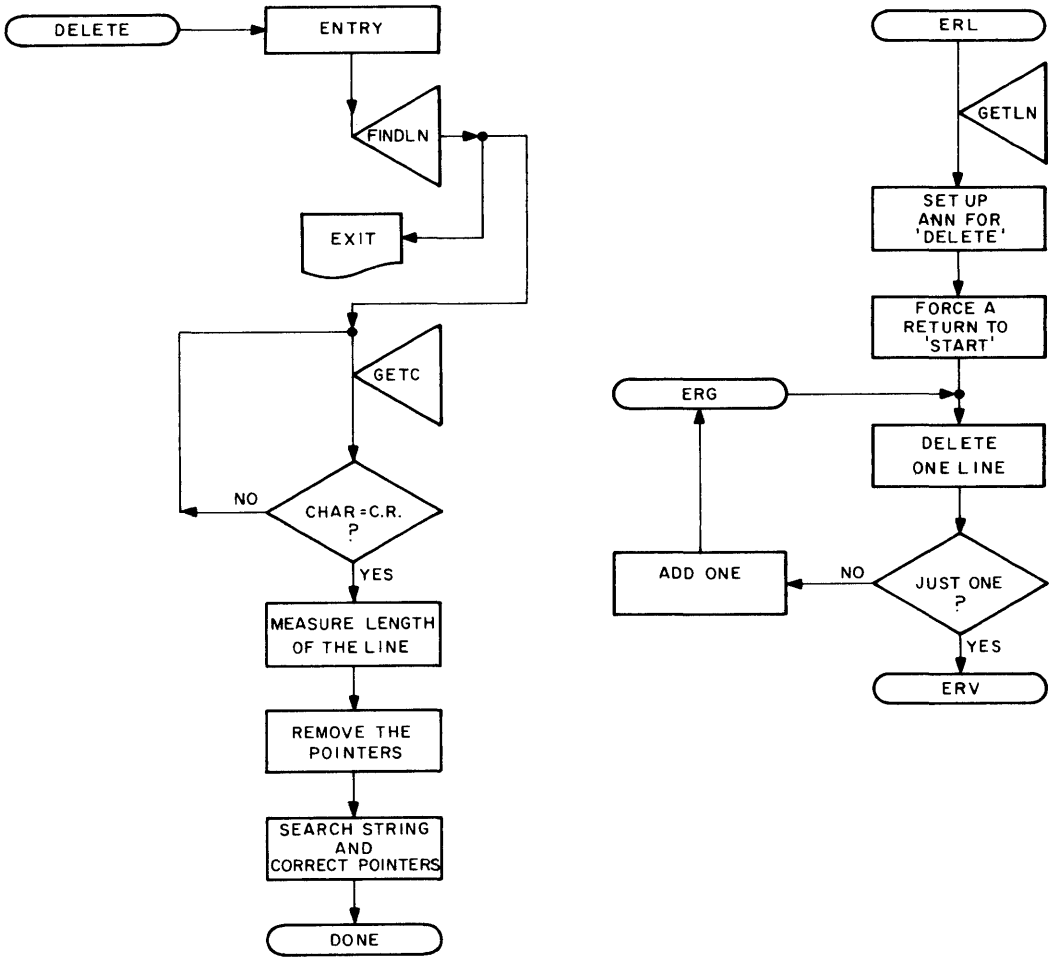


Figure G-9 (Sheet 2) ERASE and Delete

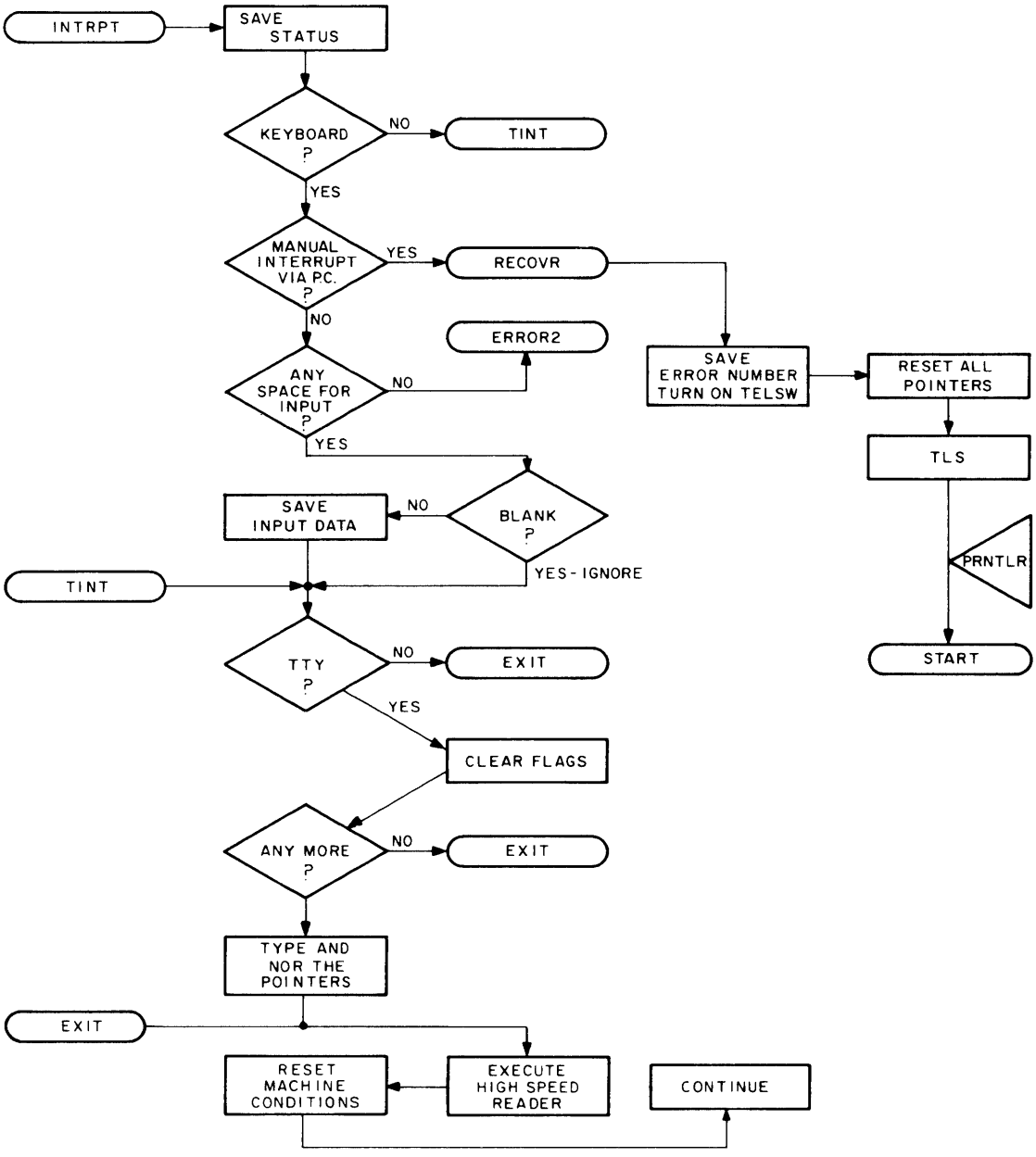


Figure G-10 (Sheet 1) Interrupt Handler

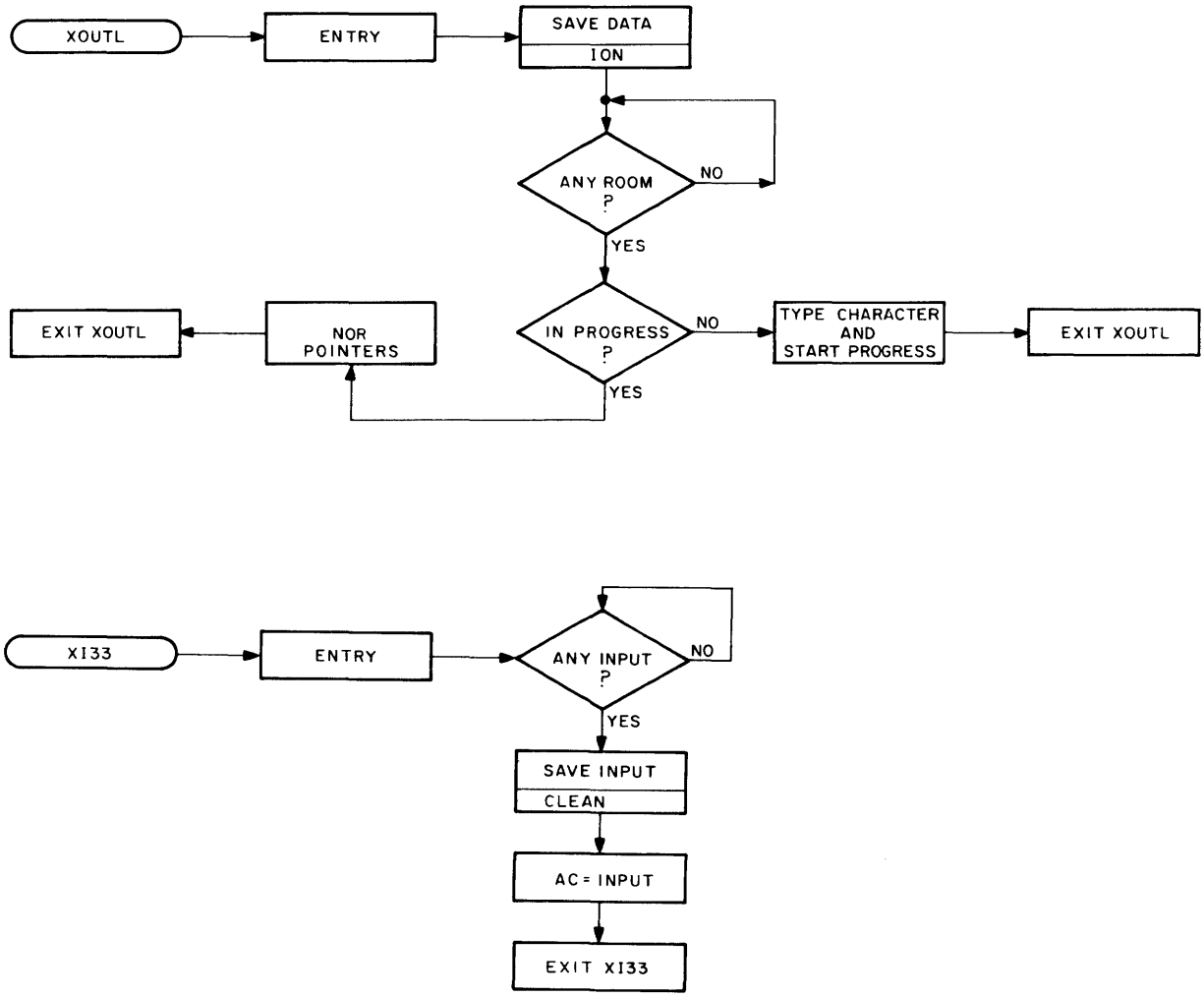


Figure G-10 (Sheet 2) Interrupt Handler

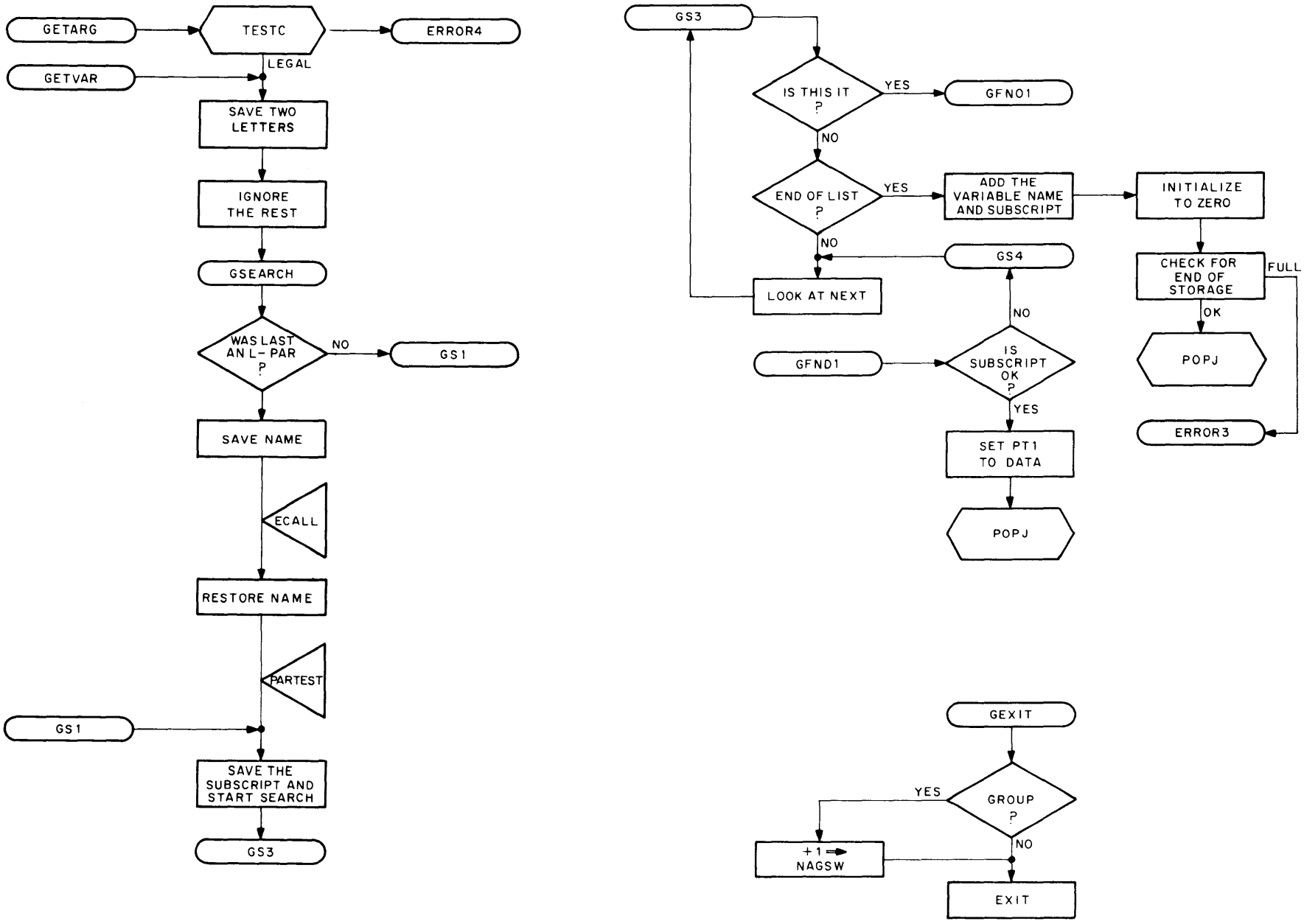


Figure G-11 Variable Look-up and Enter

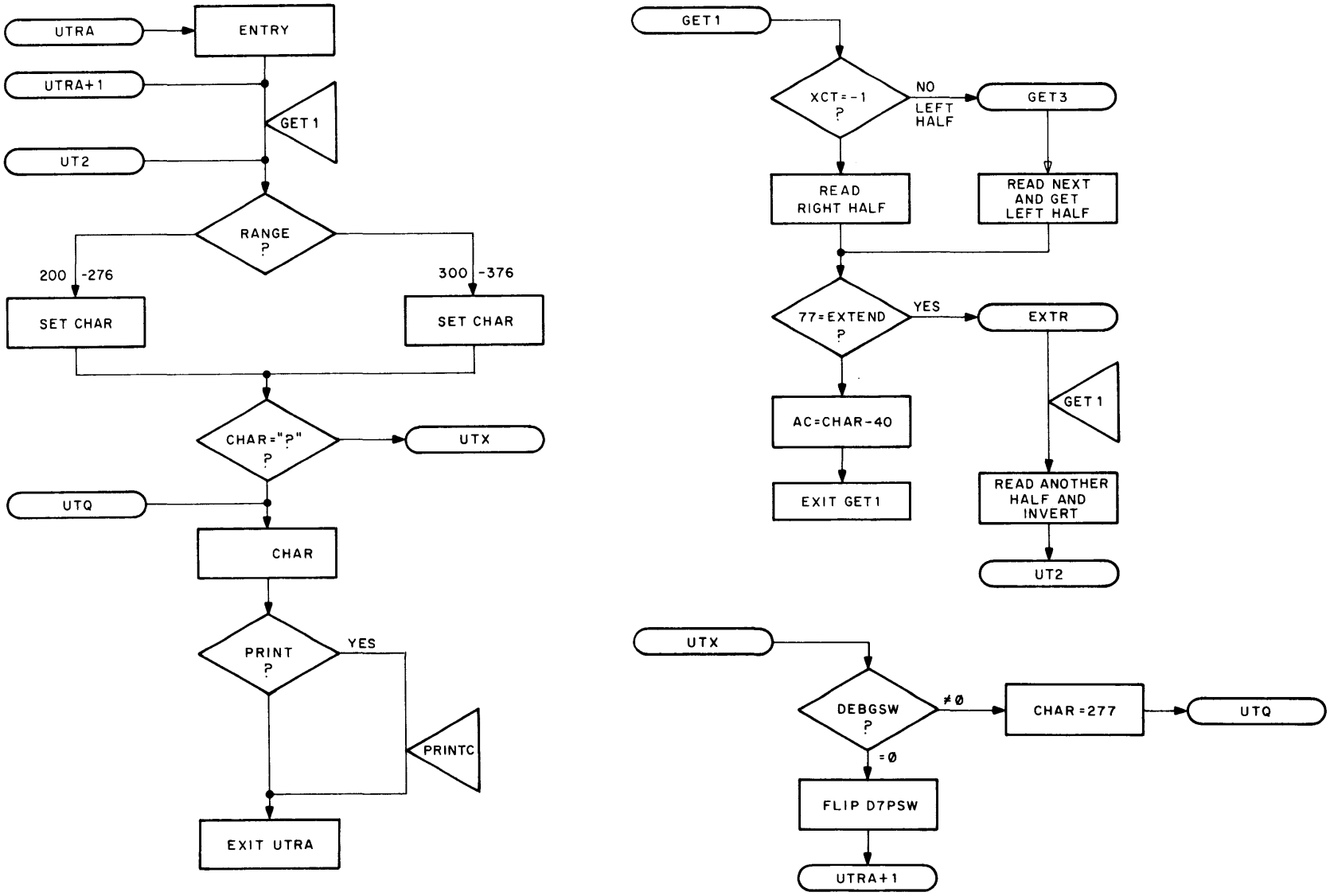


Figure G-12 Character Unpacking

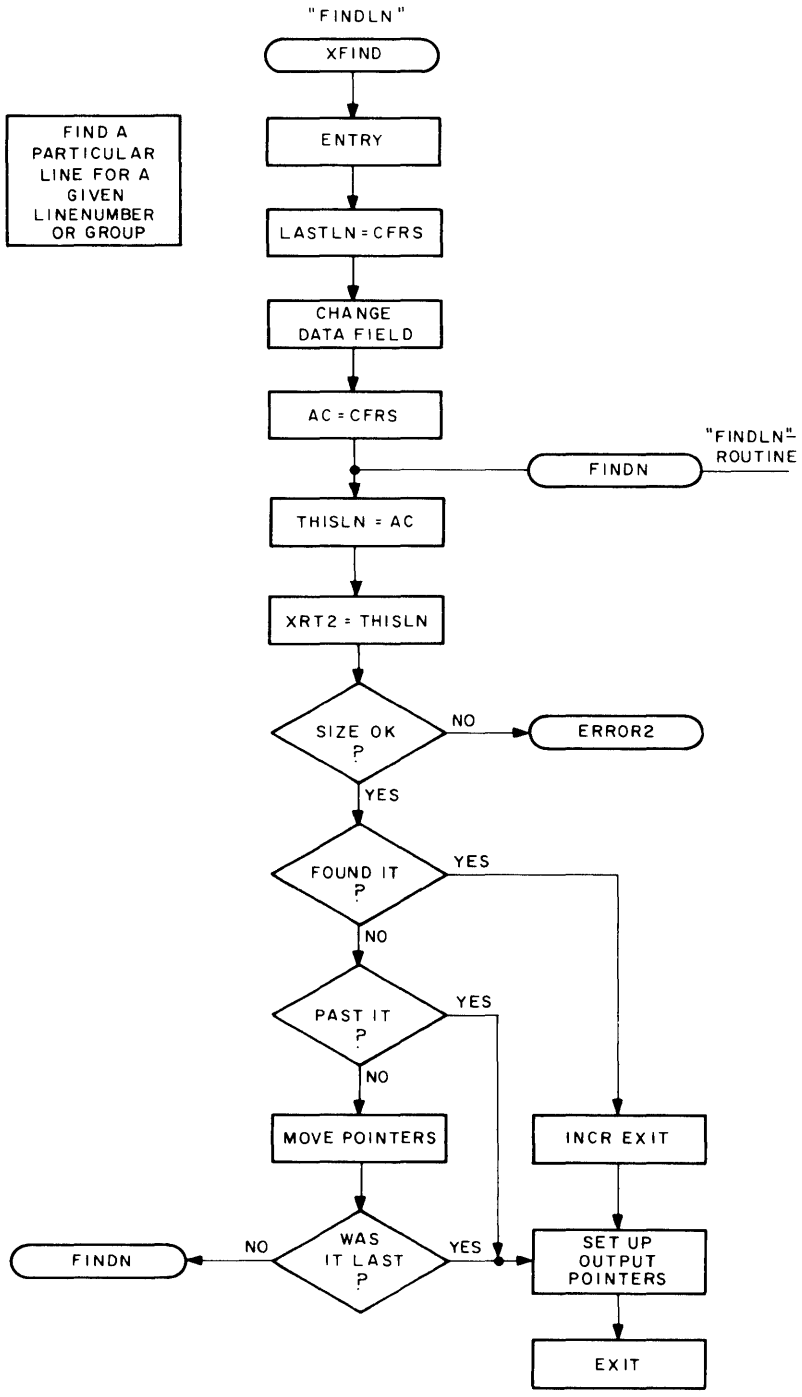


Figure G-13 "FINDLN" Routine

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