PDP-8 FLOATING-POINT SYSTEM PROGRAMMING MANUAL

September 1965

DIGITAL EQUIPMENT CORPORATION • MAYNARD, MASSACHUSETTS

Reprinted January 1967
Reprinted June 1967
Reprinted November 1967

PREFACE

The PDP-8 comes to the user complete with an extensive selection of system programs and routines making the full data processing capability of the new computer immediately available to each user, eliminating many commonly experienced initial programming delays.

The programs described in these abstracts come from two sources, past programming effort on the PDP-5 computer, and present and continuing programming effort on the PDP-8. Thus the PDP-8 programming system takes advantage of the many man-years of program development and field testing by PDP-5 users.

Although in many cases PDP-8 programs originated as PDP-5 programs, all utility and functional program documentation is issued in a new, recursive format introduced with the PDP-8.

Programs written by users of either the PDP-5 or the PDP-8 and submitted to the users' library (DECUS - Digital Equipment Corporation Users' Society) are immediately available to PDP-8 users.

Consequently, users of either computer can take immediate advantage of the continuing program developments for the other.

CONTENTS

CONTENTS (continued)

CHAPTER 1

INTRODUCTION

The PDP-8 Floating-Point System enables the programmer to concentrate on the logic of his computation rather than on decimal points. The system maintains a constant number of significant digits throughout the computation, thereby enhancing the accuracy of the result.

Floating-point notation is particularly useful for computations involving numerous multiplications and divisions where magnitudes are likely to vary widely and where only crude predictions can be made as to the amount of variation involved. The main advantage of the PDP-8 Floating-Point System is derived from the ability to store very large or very small numbers by storing only the significant digits together with the exponent for that number. In an integral or fractional fixed-point machine, the programmer must either include all of the 0's between the significant digits and the decimal point (and in so doing loose considerable accuracy), or account for the point in each step of his programming.

The PDP-8 Floating-Point System is constructed as a self-contained package which includes its own input, arithmetic, and output routines. It allows the programmer to use floating-point arithmetic without having to construct his own arithmetic subroutines. For example, the polynomial:

$$Y = AX^3 + BX^2 + CX + D$$

may be programmed as follows (the variables X and Y, and the parameters A, B, C, and D are stored in registers of the same name):

```
......
JMS   I  7      /ENTER FLOATING PACKAGE
FGET  A         /LOAD PSEUDO AC
FMPY  X         /MULTIPLY
FADD  B         /ADD
FMPY  X         /MULTIPLY
FADD  C         /ADD
FMPY  X         /MULTIPLY
FADD  D         /ADD
FPUT  Y         /STORE
FEXT            /EXIT FLOATING PACKAGE
......
```

CHAPTER 2

FLOATING-POINT REPRESENTATION

A floating-point number consists of a mantissa and an exponent. For example, the decimal number 12 may be represented as:

$1200.0 \cdot 10^{-2}$
$120.00 \cdot 10^{-1}$
$12.000 \cdot 10^{0}$
$1.2000 \cdot 10^{1}$
$.12000 \cdot 10^{2}$
....
etc.

where the exponents are the numbers -2, -1, 0, etc.

Since the PDP-8 is a binary machine, floating-point numbers are stored as floating-point binary internally. For example, the binary number 110 (6 decimal) may be represented as:

....
$11000.0 \cdot 2^{-2}$ $(24 \cdot 1/4 = 6)$
$1100.00 \cdot 2^{-1}$ $(12 \cdot 1/2 = 6)$
$110.000 \cdot 2^{0}$ $(6 \cdot 1 = 6)$
$11.0000 \cdot 2^{1}$ $(3 \cdot 2 = 6)$
$1.10000 \cdot 2^{2}$ $(3/2 \cdot 4 = 6)$
$.110000 \cdot 2^{3}$ $(3/4 \cdot 8 = 6)$
....
etc.

Notice that the binary exponent is always a signed integer. The PDP-8 Floating-Point System uses the convention:

$$1/2 \leq |\,\text{MANTISSA}\,| < 1.$$

When this is true, the word is said to be normalized.

The value of the number is then:

$$\text{MANTISSA} \cdot 2^{\text{EXPONENT}}$$

where the MANTISSA is a signed quantity. The result of this convention is that more significant bits are retained. For example, the number .10 (decimal) is equal to:

$$|0.00\ 011\ 001\ 100\ |\ 110\ 011\ 001\ 100\ |\ 110\ 011\ 001\ 100\ 110\ \ldots.$$

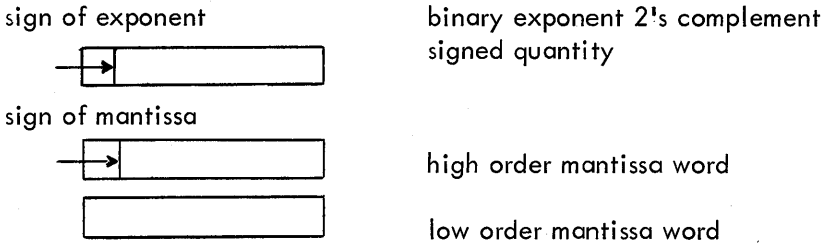
in binary.

When this word is stored in two 12-bit words (24 bits), the leading 0's are nonsignificant and only 20 bits of significance are maintained. If the number is rewritten as:

$$2^{-3}.|\ 0.11\ 001\ 100\ 110\ |\ 011\ 001\ 100\ 110\ |\ 011\ 001\ 100\ 110\ \ldots.$$

and the mantissa stored in two 12-bit words, 23 bits of significance are maintained.

The exponent is stored in a third word making a total of three words for storage.



The number .1 (decimal) would be stored as:

111 111 111 101 | 011001100110 | 011001100110

or written in octal:

7775 3146 3146

The address of this number would be considered 2146 if it were stored as follows:

2146/7775
2147/3146
2150/3146

The number −.1 would be:

7775
4631 (double precision 2's complement of mantissa)
4632

Since the mantissa is greater (in magnitude) than 1/2 and less than 1, its binary point is considered to be between bit 0 and bit 1 of the high order mantissa word.

Further examples:

12 (decimal)

$1100. = (2^4)\ (0.11000000000000000000000)$

would be stored as (written in octal):

0004

3000

0000

Octal	Decimal	Floating Binary		
-1	-1	0001	6000	0000
-10	-8	0004	6000	0000
.4	.5	0000	2000	0000
3	3	0002	3000	0000
14	12	0004	3000	0000
.2	.25	7777	2000	0000

Convert the decimal number 1.6 to PDP-8 floating-binary form for storage.

An easy method to convert a decimal fraction to an octal fraction is illustrated below:

```
   .6                 1.6(10) = 1.46314631(8)
 x 8
4) .8                       = 1.10011001100110011001101
 x 8
6) .4                       = (2^1) (0.11001100110011001100110)
 x 8
3) .2                       = 0001
 x 8
1) .6                         3146
    8
4) .8                         3146
    8
6) .4
    8
3) .2
    8
1) .6
```

ARITHMETIC

Since floating-point numbers are stored in a three-register format, the floating-point system uses a "psuedo" floating accumulator (FAC) which consists of three registers in the floating-point package: 44, 45, and 46. Register 44 contains the exponent; 45 and 46 contain the high and low order parts of the mantissa, respectively.

BASIC FLOATING-POINT COMMANDS

The basic floating-point commands include the following:

load floating accumulator
store floating accumulator
add to floating accumulator
subtract from floating accumulator
multiply by floating accumulator
divide into floating accumulator
normalize floating accumulator

All arithmetic operations are called through an interpreter. The command codes have a format that is almost identical to the format of the PDP-8 memory reference instruction, namely:

where the op code is from 000 to 111 or 0_8 - 7_8.

INTERPRETER

The interpreter contains, at all times, the address of the memory location containing the next pseudo instruction to be executed. This is initially stored when the program enters the interpreter using a JMS instruction. When the interpreter encounters an instruction with an op code of 0 and with bits 8-11 of the pseudo instruction equal to 0, it exits to the next memory location.

FLOATING-POINT INSTRUCTIONS

The floating-point instructions are:

Op Code	Mnemonic	Effect
1	FADD	Floating Addition Add the contents of the effective address to the floating accumulator.

2	FSUB	Floating Subtract Subtract the contents of the effect address from the floating accumulator.
3	FMPY	Floating Multiply Multiply the floating accumulator by the contents of the effective address.
4	FDIV	Floating Divide Divide the floating accumulator by the contents of the effecitve address.
5	FGET	Floating Get Load the floating accumulator with the contents of the effective address.
6	FPUT	Floating Put Store the contents of the floating accumulator at the locations specified by the effective address. The contents of the floating accumulator are unchanged.
7	FNOR	Floating Normalize Normalize the contents of the floating accumulator.

0 is decoded as follows:

Bits 8-11 = 0000	Floating Exit Return control to following instruction
= 0001	Floating Square Square the contents of the floating accumulator
= 0010	Floating Square Root Take the root of the absolute value of the floating accumulator
= 0011-1111	Expandable commands

This may be summarized:

FADD Y; 1000; C(FAC) + C(Y) → C(FAC)
FSUB Y; 2000; C(FAC) - C(Y) → C(FAC)
FMPY Y; 3000; C(FAC) × C(Y) → C(FAC)
FDIV Y; 4000; C(FAC) ÷ C(Y) → C(FAC)

} Result is normalized

FGET Y; 5000; C(Y) → C(FAC)

} C(Y) unchanged

FPUT Y; 6000; C(FAC) → C(Y)

FNOR ; 7000; C(FAC) normalized → C(FAC)

FEXT ; 0000; exit from interpreter to instruction following this command

SQUARE ; 0001; $C(FAC)^2$ → C(FAC)

SQROOT; 0002; $C(FAC)^{1/2}$ → C(FAC)

The assembler recognizes all of these mnemonics except for SQUARE and SQROOT which may be defined as:

```
SQUARE=0001
SQROOT=0002
```

The floating-point interpreter is entered with an effective JMS 5600.

For example:

```
SQROOT=0002
*7
 5600
*200
        JMS I 7     200/    4407
        FGET A      201/    5206
        SQROOT      202/    0002
        FPUT I B    203/    6611
        FEXT        204/    0000
        HLT         205/    7402
A,      0003        206/    0003
        2000        207/    2000
        0000        210/    0000
B,      300         211/    0300
$
```

When this program is started at 0200, it will halt at location 205. The state of the machine will be:

```
44/     0002
45/     2000        floating accumulator contains
46/     0000            2.0, i.e., (4.0)^1/2

206/    0003
207/    2000        register A contains 4.0
210/    0000

300/    0002
301/    2000        answer stored here
302/    0000
```

CHAPTER 3

FLOATING-POINT INPUT/OUTPUT

FLOATING-POINT INPUT

The basic floating-point package contains an input routine to read characters from the 33 ASR keyboard. Numbers are read in in decimal and converted to the internal floating-point binary format. Input format is floating decimal. The number 726.7 may be read in in any of the following forms:

```
726.7
.7267E3
.7267E+03
+7267E-1
etc.
```

Input is terminated when a character is typed that is not a part of this format. The conversion of "12.0." would be terminated on the second "." and the binary number:

```
000000000100        (octal 0004)
011000000000        (octal 3000)
000000000000        (octal 0000)
```

would be in the floating-point accumulator upon completion of the conversion.

Flags

There are several flags associated with the input routine that are useful to the programmer.

0056 This register is a switch that has the following meaning:

If C(56) = 0, do not type a line-feed after a carriage-return was read.
If C(56) = 7777, type a line-feed when a carriage-return is inputted.
This switch is initially set to 7777.

0057 This register contains the character that terminated the input conversion.

0060 This register contains 0000 if no input conversion was made; i.e., a space or other terminator was initially typed.

The input routine is entered with an effective JMS 7400. It returns control to the instruction following the calling JMS upon receipt of a terminator. The floating accumulator contains the input number in normalized floating-binary. Register 0057 contains the terminating character in ASCII, and C(0060) indicates whether or not there was a valid input.

For example:

```
*5
 7400
*7
 5600
*200
 JMS I 5        /INPUT ROUTINE
 JMS I 7        /CALL FLOATING POINT
 FPUT A
 FEXT
 JMS I 5
 JMS I 7
 FPUT B
 FEXT
 HLT
A, 0
   0
B, 0
   0
   0
$
```

When this program is started at 0200 and the following is typed:

```
X2.0Y
```

The program will halt at location 0210, and A and B will contain

```
A, 0
   0
   0          and C(57) = 0331, the second TERMINATOR
B, 0002
   2000
   0000
```

The first input was considered a 0 because a terminator "X" was inputted.

This program could be written to ignore the non-numeric information as follows:

```
*5
    7400
*7
    5600
*200
    JMS I 5          /CALL INPUT ROUTINE
    TAD 60           /ANY VALID INPUT?
    SNA  CLA
    JMP .-3          /NO - IGNORE
    JMS I 7          /YES
    FPUT A           /STORE IT
    FEXT
    JMS I 5          /GET NEXT
    TAD 60
    SNA CLA          /VALID?
    JMP .-3          /NO - IGNORE
    JMS I 7          /YES
    FPUT B           /STORE IT
    FEXT
    HLT      /HALT
A,  0
    0
    0
B,  0
    0
    0
$
```

Register 57 may be used for integrating control characters into the input.

Rubout

There is one special input character, the rubout. If it is struck before an input delimiter, the input routine is restarted and previous numbers deleted.

For example, assume the input routine has been entered.

```
276 Rubout1T
```

The input routine would exit with 1 (decimal) in the floating accumulator or:

```
44/     0001
        2000
        0000
```

FLOATING-POINT OUTPUT

The basic floating-point package contains an output routine. Upon entry the contents of the floating accumulator are converted to floating-point decimal and typed out on the ASR 33 in the following format:

±0.XXXXXXXE±XX

For example, if the floating accumulator contained:

```
44/     0002
        2000
        0000
```

and the output routine were entered,

+0.2000000E+01

would be typed.

Entry

The output routine is entered by an effective JMS 7200. After outputting the contents of the floating accumulator, it returns control to the instruction following the calling JMS instruction. The contents of the floating accumulator are lost. The floating-output routine has a flag or program switch in location 0055 on page 0.

If C(0055) does not equal 0, type a carriage-return/line-feed following each output. This location initially contains 7777.

Program Example

```
/SOLVE THE QUADRATIC EQUATION
/AX2+BX+C=0 FOR VALUES
/OF A, B, C.          TYPE OUT ROOTS
SQROOT=0002
SQUARE=0001
*5      7400          /POINTER TO INPUT ROUTINE
        7200          /POINTER TO OUTPUT ROUTINE
        5600          /POINTER TO INTERPRETER
*200
            KCC
            TLS
BEGIN,      JMS I 5       /INPUT A
            JMS I 7       /ENTER INTERPRETER
```

```
        FMPY TWO    /2.0
        FPUT A      /STORE 2.0·A
        FEXT
        JMS I 5     /INPUT B
        JMS I 7     /ENTER INTERPRETER
        FPUT B      /STORE B
        FEXT
        JMS I 5     /INPUT C
        JMS I 7     /ENTER INTERPRETER
        FMPY TWO    /MULTIPLY BY 2.
        FMPY A      /MULTIPLY BY 2A
        FPUT TEMP   /4AC
        FGET B
        SQUARE      /B SQUARED
        FSUB TEMP   /B SQUARED -4AC
        SQROOT      /TAKE SQUARE ROOT
        FPUT TEMP   /STORE IT
        FGET B
        FMPY MIN1   /-1·B = — B
        FPUT B      /STORE
        FSUB TEMP   /-B—SQUARE ROOT
        FDIV A
        FEXT        /ANSWER IN FAC
        JMS I 6     /OUTPUT IT
        JMS I 7     /ENTER INTERPRETER
        FGET B      /-B
        FADD TEMP   /-B + SQUARE ROOT
        FDIV A
        FEXT        /ANSWER IN FAC
        JMS I 6     /OUTPUT IT
        JMP BEGIN   /CONTINUE
TWO,    0002        /CONSTANT 2.0
        2000
        0000
MIN1,   0001        /CONSTANT -1.0
        6000
        0000
TEMP,   0
        0
        0
A,      0
        0
        0
B,      0
        0
        0
C,      0
        0
        0
$
```

Both the input-conversion routine and the output-conversion routine use a typeout subroutine that contains the instructions:

```
...
TSF
JMP .-1
TLS
CLA
...
```

This means that the teleprinter flag must be set when these routines are entered or it must be in the process of typing. A TLS instruction can be put into the initialization section of a program.

THE BASIC PACKAGE

Subroutines

When the floating-point interpreter encounters a 0 op code, it further decodes bits 8-11. If these bits equal 0, the interpreter exits. If the bits are nonzero, they are used in a table look-up to specify the address of a subroutine. The called subroutine may use the floating-point interpreter, the input, or the output, but it may not use bits 8-11 to call another subroutine. The look-up table is on page 16 of the interpreter listing. For example, if the user wished to define a routine that negated the contents of the floating accumulator, the following steps would be taken:

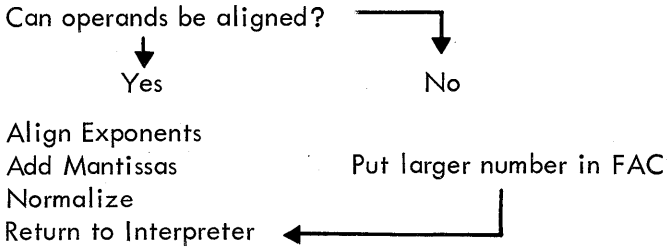
On page 6 of the interpreter listing, there is a routine to negate the floating accumulator. It is a subroutine and has, as entry point, the address 6000. If the negate subroutine were to be called by 0010 in the interpreter mode, the word 6000 would be placed in address 6554 of the calling table. Input and output could be called in the interpreter mode if 7400 were placed in 6555 (0011) and 7200 were placed in 6556 (0012).

```
NEGATE = 0010
INPUT  = 0011
OUTPUT = 0012
SQUARE = 0001
*7
 5600
 *200
  KCC
  TLS
  JMS I 7    /ENTER INTERPRETER
  INPUT      /CALL INPUT ROUTINE
  SQUARE     /SQUARE IT
  NEGATE     /CALL OUTPUT ROUTINE
  OUTPUT     /CALL OUTPUT ROUTINE
  FEXT       /EXIT
  HLT        /HALT
$
```

DESCRIPTION OF BASIC FUNCTION

Addition

Floating-point addition is carried out by first aligning the binary points of the two numbers. This is accomplished by scaling the smaller number to the right. Then the mantissas are both scaled right once so that overflow will not occur into the sign bit. A 2's complement addition of the mantissas is then made. The result is normalized and control returns to the interpreter. This may be represented as:



Subtraction

Floating-point subtraction is accomplished by negating the operand, and then calling the addition subprogram.

Negate Operand
Call Addition

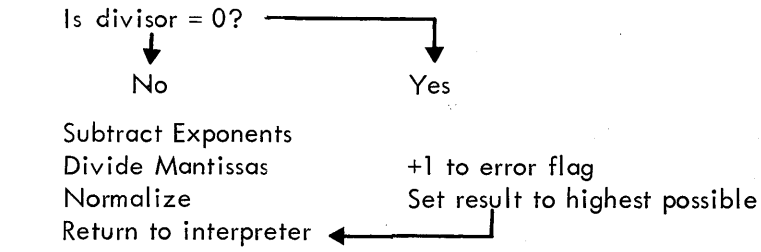
Multiplication

Floating-point multiplication is accomplished by adding the exponents together and then performing a double-precision multiplication. The result is normalized and control returns to the interpreter.

Add Exponents
Multiply Mantissas carrying result to 35 bits
Normalize
Return to Interpreter

Division

Floating-point division is accomplished by subtracting the exponent of the divisor from the exponent of the dividend. The mantissa is divided and the result is normalized. Control returns to the interpreter.

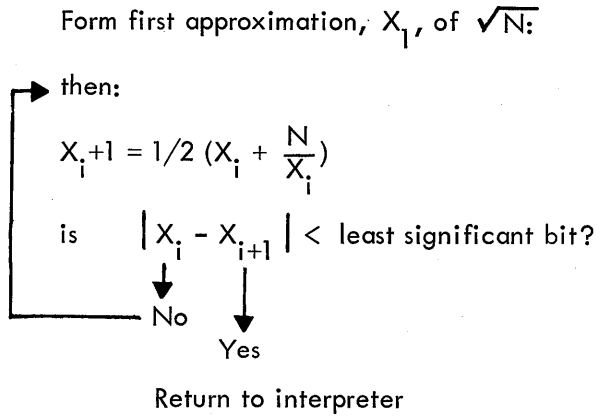


Square

The square routine calls the multiplication routine internally.

Square Root

The square root is calculated using Newton's method in which an initial approximation is made and then each succeeding approximation is calculated. The routine exits when two successive approximations are equal to within the least significant bit of the mantissas.



Error Flag

Division by 0 causes C(61) to be incremented by 1. The quotient is set to the highest positive number.

Attempting to extract the square of a negative number causes C(61) to be incremented by 1. The root of the absolute value is taken.

The contents of 61 are set to 0 at the beginning of each divide and square root operation.

SUMMARY OF BASIC PACKAGE

Entry Points

5600	Arithmetic Interpreter
7400	Floating Input
7200	Floating Output

NOTE: Both the input and the output routines require that register 7 contains the interpreter entry point: 5600.

Flags

55	If $\neq 0$, type carriage-return/line-feed after output.
56	If $\neq 0$, follow each input carriage-return by a line-feed.
57	Contains the input terminating character.
60	Equals 0 if no valid input.
61	Is nonzero if (a) divide by 0 or (b) square root of a negative number.

Commands

FADD	1000	Floating Add
FSUB	2000	Floating Subtract
FMPY	3000	Floating Multiply
FDIV	4000	Floating Divide
FGET	5000	Floating Get
FPUT	6000	Floating Put
FNOR	7000	Floating Normalize
FEXT	0000	Floating Exit
SQUARE	0001	Square
SQROOT	0002	Square Root
	0003	
	....	Expandable
	0017	

Storage

The floating accumulator is in registers:

44 - Exponent

45 - High Order Mantissa

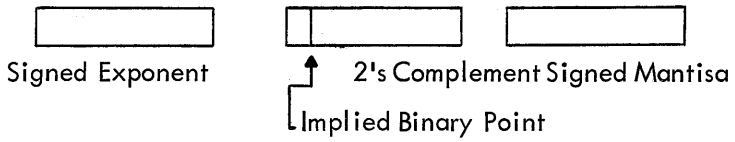
46 - Low Order Mantissa

The basic floating-point package (Digital 8-5A-S) uses memory locations:

7; 40-61; 5600-7577

FIXED TO FLOATING/FLOATING TO FIXED

Since the floating-point package stores numbers in the following format:



and since the exponent indicates where the real exponent is, this information may be used to either convert a floating-point number to fixed point or to convert a fixed-point number to floating point.

For example, assume that there is an integer in the accumulator that is less in magnitude than 2047. To float this number, the following sequence of steps may be employed:

```
            ...
            DCA 45      /PUT INTO HIGH-ORDER MANTISSA
            DCA 46      /PUT 0 INTO LOW-ORDER MANTISSA
            TAD C13     /11 (10) INTO
C,          DCA 44      /EXPONENT
            JMS I 7     /CALL INTERPRETER
            FNOR        /NORMALIZE
            FEXT        /LEAVE INTERPRETER
            ...
C13,        0013        /11 (DECIMAL)
```

At point C, we have set the binary point of the integer to the right end of the high order mantissa word, or eleven (decimal) locations to the right of the implicit binary point.

To float this number, the floating accumulator is scaled right until the exponent contains the location of the desired binary point. To fix the floating accumulator as an 11-bit signed integer, the following sequence of coding may be employed:

```
          ....
          CLA
          TAD 44          /FETCH EXPONENT
          SZA SMA         /IS THE NUMBER <1?
          JMP .+3         /NO:
          CLA             /YES:  FIX IT TO 0
          JMP DONE+1
          TAD M13         /NO:  SET BINARY POINT AT
          SNA             /11 (10) PLACES TO RIGHT OF CURRENT POINT
          JMP DONE        /IT IS ALREADY THERE:  ALL DONE
          SMA             /TEST TO SEE IF IT IS TOO LARGE
          JMP ERROR       /YES:  NUMBER >2**11
          DCA 44          /NO:  SET SCALE COUNT
GO,       CLL             /0 TO C(L)
          TAD 45          /FETCH MANTISSA
          SPA             /IS IT <0?
          CML             /YES:  PUT A 1 IN LEFT BIT
          RAR             /SCALE RIGHT
          DCA 45          /RESTORE IT
          ISZ 44          /TEST IF SHIFTED ENOUGH
          JMP 00          /NO:  CONTINUE
DONE,     TAD 45          /ANSWER IN C(AC)
          ....
          ....
M13,      -13             /-11 (DECIMAL)
```

This may be coded as a subroutine.

EXTENDED FLOATING-POINT PACKAGE

The extended floating-point package contains the following additional commands:

0003 Floating Sine
Take the sine of the angle in the floating accumulator (considered to be in radians) and leave the result in the floating accumulator.

0004 Floating Cosine
Take the cosine of the angle in the floating accumulator (considered to be in radians) and leave the result in the floating accumulator.

0005 Floating Arc Tangent
Take the arc tangent of the number in the floating accumulator and leave the result (in radians) in the floating accumulator.

0006 Floating Exponent
Raise e to the C(FAC) power. Leave the result in the floating accumulator.

0007 Floating Logarithm
Take the natural logarithm of the absolute value of the number in the floating accumulator.

Sine

The sine routine uses the following identities:

$$SIN(-X)=-SIN(X)$$

$$SIN(X)=SIN(2\pi N+F)=SIN(F)$$

where $0<F<2\pi$ and N is an integer:

$$SIN(\pi-F)=-SIN(F)$$

Using these identities, F is reduced to the range $-\pi/2<F<\pi/2$.

If $Y = 2F/\pi$ so that $-1<F<1$, then:

$$SIN(X)=(C_1F+C_3F^3+C_5F^5+C_7F^7+C_9F^9)$$

where:

$C_1 = 1.57079631847$

$C_3 = -0.64596371106$

$C_5 = +0.07968967928$

$C_7 = -0.00467376557$

$C_9 = +0.00015148419$

The sine subroutine is valid over the range:

$$-2\pi .2047<X<2\pi .2047$$

Cosine

The cosine routine uses the identity:

$$COS(X)=SIN(\pi/2-X)$$

It then uses the SINE routine.

Arc Tangent

The arc tangent routine uses the following identities:

$$ARCTAN(-X)=-ARCTAN(X)$$

IF $X>, 1$; then $ARCTAN(X)=\pi/2-ARCTAN(1/X)$

FOR $0<X<1$,

$$\text{ARCTAN}(X) = \frac{X(A_0+A_1X^2+A_2X^4)}{B_0+B_1,X^2+B_2X^4}$$

where:

$A_0 = +0.6402481953$

$A_1 = +0.4229908144$

$A_2 = +0.0264694361$

$B_0 = +0.6402487022$

$B_1 = +0.6363779373$

$B_2 = +0.1108328778$

The result is in the range:

$-\pi/2<\text{ARCTAN}(X)<\pi/2$

$-\infty<X<\infty$

Logarithm

The logarithm routine uses the identities:

For $X<1$;

$\text{LOG}(X)=\text{LOG}(2^N \cdot F)\ (1<F<2)$

$=N\text{LOG}(2)+\text{LOG}(F)$

$$\text{LOG}(1+Y)= \sum_{C=1}^{8} A_i Y^i$$

where:

$A_1 = +0.9999964239$

$A_2 = -0.4998741238$

$A_3 = +0.3317990258$

$A_4 = +0.2407338084$

$A_5 = +0.1676540711$

$A_6 = -0.0953293897$

$A_7 = +0.0360884937$

$A_8 = -0.0064553442$

for:

0<X<1, the identity:

LOG(X)=-LOG(1/X) is used.

Floating Exponent

The exponent routine uses the identity for X>0,

$$e^X = 2^{X \cdot \log_2 e} = 2^{N+F} = 2^N \cdot 2^F$$

where N is an integer and <F<1

$$2^F = 1 + \frac{2F}{A - F + BF^2 - \frac{C}{D+F^2}}$$

where:

$A = +9.95459578$

$B = +0.03465735903$

$C = +617.97226053$

$D = +87.417497202$

$\text{Log}_2 e = 1.4426950409$

If X<0

$$e^x = \frac{1}{e^{-x}}$$

Example, input A, B, and output:

$Y = \text{LOG}(\text{COS}(A/B) + \sqrt{A \cdot B})$

```
SQROOT=0002              /DEFINITIONS TO ASSEMBLER
COS=0004
LOG=0006

*5
  7400
  7200
  5600
/USES EXTENDED INTERPRETER
```

```
*200
KCC
TLS
BEGIN,  JMS I 5         /INPUT A
        JMS I 7         /ENTER INTERPRETER
        FPUT A          /STORE A
        FEXT            /EXIT
        JMS I 5         /INPUT B
        JMS I 7         /ENTER INTERPRETER
        FPUT B          /STORE B
        FMPY A          /A·B
        SQROOT          /EXTRACT ROOT
        FPUT TEMP       /STORE IT
        FGET A          /LOAD FAC WITH A
        FDIV B          /DIVIDE BY B
        COS             /TAKE COSINE
        FADD TEMP       /ADD
        LOG             /TAKE LOG.
        FEXT
        JMS I 6         /OUTPUT ANSWER
        JMP BEGIN
A,      0
        0
        0
B,      0
        0
        0
TEMP,   0
        0
        0
$
```

Output Controller

There is an additional routine available that formats floating-point output. It is available with both the basic floating-point package and the extended package.

The controller routine requires two parameters for output formatting. It is called by an effective JMS 7200. At this point:

C(62) = total number of digits to be outputted. If C(62)=0, output in E format.

C(AC) = number of digits to the right of the decimal point. If it equals 0, do not type a ".".

If the number in the floating accumulator is larger than the field width allows, "X's" will be typed. The sign is typed and leading 0's are suppressed.

Example: If the contents of the floating accumulator are 678.234 (decimal).

C(62)	C(AC)	Output
3	0	+ 678
4	0	+ 678
4	1	+ 678.2
5	2	+ 678.23
6	2	+ 678.23
3	2	+ 678.
2	0	+XX
0	1	+ 0.678234E+03

FLOATING POINT PACKAGE VERSIONS

Four versions of the floating-point package are available:

Digital 8-5A-S

This is the basic floating-point package. It consists of the input/output package and the basic arithmetic instructions. Its core limits are:

7; 40-61; 5600-7577

Digital 8-5B-S

This is the basic floating-point package with the output controller. Its limits are:

7; 40-62; 5400-7577

The output controller does not type a carriage-return/line-feed after output and, hence, the programmer must provide his own routine to do so. Because of the way in which the typeout routine in the floating-point packages are constructed, the user must construct similar typeout routines in order to avoid timing errors in the teleprinter. In other words, the floating-point package uses a routine similar to:

```
TSF
JMP .-1
TLS
```

to do its typing. The user must use a similar routine, i.e., one that waits for the teleprinter flag to be set before executing the TLS instruction.

Digital 8-5C-S

This is the basic floating-point package with the extended functions. In addition, two interpretive commands are provided for input and output. The additional interpretive commands are:

SINE	3
COSINE	4
ARCTANGENT	5
EXPONENTIAL	6
LOG	7
INPUT	13
OUTPUT	14

Its core limits are:

7; 40-61; 4757-7577

Using this package, the routine on page 3-14 and 3-15 for calculating:

Y=LOG(COS(A/B)+ $\sqrt{A \cdot B}$) may be rewritten as:

```
SQROOT=2
FCOS=4
FLOG=6
INPUT=13
OUTPUT=14
*7
 5600
*200
KCC
TLS
BEGIN,  JMS I 7     /CALL INTERPRETER
        INPUT       /READ A
        FPUT A      /STORE IT
        INPUT       /READ B
        FPUT B
        FMPY A      /A·B
        SQROOT
        FPUT TEMP   /(A·B)**.5
        FGET A
        FDIV B
        FCOS
        FADD TEMP
        FLOG
        OUTPUT
        FEXT
        JMP BEGIN
A,      0
        0
        0
B,      0
        0
        0
TEMP,   0
        0
        0
$
```

Digital 8-5D-S

This is the basic package, the output controller, and the extended functions. Its core limits are:

7; 40-62; 4557-7577

CHAPTER 4

PROGRAM LISTINGS

```
                    /FLOATING POINT ARITHMETIC INTERPRETER
                    *40
0040    0000    EX1,        0               /OPERAND STORAGE
0041    0000    AC1H,       0
0042    0000    AC1L,       0
0043    0000    OVER1,      0
0044    0000    EXP,        0               /F.A.
0045    0000    HORD,       0
0046    0000    LORD,       0
0047    0000    OVER2,      0
0050    0000    EXP1,       0
0051    0000    QUOL,       0
0052    0000    FPAC1,      0
0053    0000                0
0054    0000                0
                    *61
0061    0000    FLAG,       0               /ARITHMETIC ERROR FLAG
                    *5600
5600    0000    FPNT,       0
5601    7300                CLA CLL
5602    3043                DCA OVER1
5603    3047                DCA OVER2
5604    1600                TAD I FPNT      /GET NEXT INSTRUCTION
5605    3253                DCA JUMP
5606    1253                TAD JUMP
5607    0263                AND PAGENO      /GET PAGE BIT
5610    7650                SNA CLA         /PAGE ZERO?
5611    5214                JMP .+3         /YES
5612    1261                TAD MASK5       /NO
5613    0200                AND FPNT        /C(FPNT)0-4 CONTAINS PAGE BITS
5614    3256                DCA ADDR
5615    1262                TAD MASK7       /GET 7 BIT ADDRESS
5616    0253                AND JUMP
5617    1256                TAD ADDR
5620    3256                DCA ADDR
5621    1264                TAD INDRCT      /INDIRECT BIT=1?
5622    0253                AND JUMP
5623    7650                SNA CLA
5624    5227                JMP LOOP01      /NO-GO ON
5625    1656                TAD I ADDR      /YES DEFER
5626    3256                DCA ADDR
5627    2200    LOOP01,     ISZ FPNT
5630    1656                TAD I ADDR
5631    3040                DAC EX1         /EXPONENT
5632    1256                TAD ADDR
```

```
5633  3257          DCA SAVE
5634  2257          ISZ SAVE
5635  1657          TAD I SAVE
5636  3041          DCA AC1H        /HIGH ORDER MANTISSA
5637  2257          ISZ SAVE
5640  1657          TAD I SAVE
5641  3042          DAC AC1L        /LOW ORDER MANTISSA
5642  1253          TAD JUMP
5643  7106          CLL RTL
5644  7006          RTL
5645  0260          AND MASK3       /GET BITS 0-2, IE OPCODE
5646  1265          TAD TABLE       /LOOKUP IN TABLE
5647  3254          DCA JUMP2
5650  1654          TAD I JUMP2
5651  3254          DCA JUMP2
5652  5654          JMP I JUMP2     /GO THERE
5653  0000  JUMP,   0
5654  0000  JUMP2,  0
5655  0000  GO2,    0
5656  0000  ADDR,   0
5657  0000  SAVE,   0
5660  0017  MASK3,  0017
5661  7600  MASK5,  7600
5662  0177  MASK7,  0177
5663  0200  PAGENO, 0200
5664  0400  INDRCT, 0400
5665  5666  TABLE,  .+1
5666  5742          EXIT            /TABLE USED IN INTERPRETING
5667  5716          FLAD            /BITS 0-2 OF PSEUDO
5670  5737          FLSU            /INSTRUCTION
5671  5761          FLMY
5672  6305          FLDV            /IF OPCODE=0, GO TO EXIT
5673  5676          FLGT            /AND INTERPRET BITS 8-11
5674  5705          FLPT
5675  5773          NORF
5676  1040  FLGT,   TAD EX1         /FGET=5
5677  3044          DCA EXP
5700  1041          TAD AC1H
5701  3045          DCA HORD
5702  1042          TAD AC1L
5703  3046          DCA LORD
5704  5201          JMP FPNT+1
5705  1044  FLPT,   TAD EXP         /FPUT=6
5706  3656          DCA I ADDR
5707  2256          ISZ ADDR
5710  1045          TAD HORD
5711  3656          DCA I ADDR
5712  2256          ISZ ADDR
5713  1046          TAD LORD
5714  3656          DCA I ADDR
5715  5201          JMP FPNT+1
5716  4771  FLAD,   JMS I ALGN      /FLAD=1 - FIRST ALIGN EXPONENTS
5717  5201          JMP FPNT+1      /RETURN IF NO ALIGNMENT IS POSSIBLE
5720  4772          JMS I UNORM     /LARGER OF THE TWO IS IN F.A.
```

```
5721  7100          CLL
5722  1043          TAD OVER1       /TRIPLE PRECISION ADDITION
5723  1047          TAD OVER2       /SINCE BITS ARE SHIFTED
5724  3047          DCA OVER2       /RIGHT
5725  7004          RAL
5726  1042          TAD AC1L
5727  1046          TAD LORD
5730  3046          DCA LORD
5731  7004          RAL
5732  1041          TAD AC1H
5733  1045          TAD HORD
5734  3045          DCA HORD
5735  4770          JMS I NORM      /NORMALIZE THE RESULT
5736  5201          JMP FPNT+1

5737  4741  FLSU,   JMS I OPMINS    /FSUB=2 - NEGATE THE OPERAND
5740  5316          JMP FLAD        /ADD
5741  6400  OPMINS, MINUS2
5742  1253  EXIT,   TAD JUMP       /OPCODE=0
5743  0260          AND MASK3       /ARE BITS 8-11=0?
5744  7450          SNA
5745  5600          JMP I FPNT      /YES=FEXT
5746  1360          TAD ACON6       /LOOKUP ON TABLE
5747  3254          DCA JUMP2
5750  1654          TAD I JUMP2
5751  3254          DCA JUMP2
5752  1200          TAD FPNT
5753  3255          DCA GO2
5754  4654          JMS I JUMP2     /CALL AS A SUBROUTINE
5755  1255          TAD GO2         /RESTORE F.P. POINTER
5756  3200          DCA FPNT
5757  5201          JMP FPNT+1      /GET NEXT PSEUDO INSTRUCTION
5760  6544  ACON6,  TABLE6-1       /CALLING CAN BE TO A DEPTH ONE
5761  7201  FLMY,   CLA IAC        /FMPY=3
5762  1040          TAD EX1
5763  1044          TAD EXP         /ADD EXPONENTS TOGETHER
5764  3044          DCA EXP
5765  4767          JMS I MULT      /MULTIPLY
5766  5201          JMP FPNT+1
5767  6221  MULT,   DMULT
5770  6600  NORM,   DNORM
5771  6020  ALGN,   ALIGN
5772  6564  UNORM,  DUNORM
5773  4770  NORF,   JMS I NORM
5774  5201          JMP FPNT+1
            *6000
6000  0000  ACMINS, 0               /ROUTINE TO PERFORM
6001  7300          CLL CLA
6002  1047          TAD OVER2       /TRIPLE PRECISION NEGATION
6003  7041          CMA IAC         /OF FLOATING AC
6004  3047          DCA OVER2
6005  1046          TAD LORD
6006  7040          CMA
6007  7430          SZL
```

```
6010  7101          CLL IAC
6011  3046          DCA LORD
6012  1045          TAD HORD
6013  7040          CMA
6014  7430          SZL
6015  7101          CLL IAC
6016  3045          DCA HORD
6017  5600          JMP I ACMINS
6020  0000  ALIGN,  0              /SUBROUTINE TO ALIGN
6021  1045          TAD HORD       /BINARY POINTS FOR
6022  7640          SZA CLA        /ADD-SUBTRACT
6023  5227          JMP .+4
6024  1046          TAD LORD       /IS MANTISSA ZERO?
6025  7650          SNA CLA
6026  5337          JMP NOHERE     /YES
6027  1041          TAD AC1H       /IS OPERAND ZERO?
6030  7640          SZA CLA
6031  5235          JMP .+4
6032  1042          TAD AC1L
6033  7650          SNA CLA
6034  5620          JMP I ALIGN    /BOTH ARE ZERO-EXIT
6035  1040          TAD EX1
6036  7041          CMA IAC
6037  1044          TAD EXP
6040  7450          SNA            /ARE EXPONENTS EQUAL?
6041  5314          JMP DONE       /YES
6042  7500          SMA
6043  7041          CMA IAC
6044  3342          DCA AMOUNT
6045  1342          TAD AMOUNT
6046  1343          TAD TEST2
6047  7700          SMA CLA        /CAN EXPONENTS BE ALIGNED?
6050  5256          JMP .+6        /YES
6051  4316          JMS OUTGO      /NO
6052  7430          SZL
6053  1350          TAD TAG2
6054  1347          TAD TAG1
6055  5325          JMP NOGO
6056  4316          JMS OUTGO
6057  7420          SNL            /SET UP ADDRESSES
6060  1350          TAD TAG2
6061  1347          TAD TAG1
6062  3344          DCA TEST3
6063  1342          TAD AMOUNT
6064  7041          CMA IAC
6065  1744          TAD I TEST3
6066  3744          DCA I TEST3
6067  2344          ISZ TEST3
6070  1344          TAD TEST3
6071  3345          DCA TEST4
6072  2345          ISZ TEST4
6073  1345          TAD TEST4
6074  3346          DCA TEST5
6075  2346          ISZ TEST5
```

```
6076  7100  SHIFT,   CLL              /THIS ROUTINE DOES
6077  1744           TAD I TEST3      /THE ACUTAL SHIFTING
6100  7510           SPA
6101  7020           CML
6102  7010           RAR
6103  3744           DCA I TEST3
6104  1745           TAD I TEST4
6105  7010           RAR
6106  3745           DCA I TEST4
6107  1746           TAD I TEST5
6110  7010           RAR
6111  3746           DCA I TEST5
6112  2342           ISZ AMOUNT
6113  5276           JMP SHIFT
6114  2220  DONE,    ISZ ALIGN
6115  5620           JMP I ALIGN
6116  0000  OUTGO,   0                /DETERMINE WHICH TO SHIFT
6117  1040           TAD EX1
6120  7041           CMA IAC
6121  1044           TAD EXP
6122  7004           RAL
6123  7200           CLA
6124  5716           JMP I OUTGO
6125  3344  NOGO,    DCA TEST3        /CAN'T BE ALIGNED
6126  1744           TAD I TEST3      /LARGEST GOES INTO FAC
6127  3044           DCA EXP
6130  2344           ISZ TEST3
6131  1744           TAD I TEST3
6132  3045           DCA HORD
6133  2344           ISZ TEST3
6134  1744           TAD I TEST3
6135  3046           DCA LORD
6136  5620           JMP I ALIGN
6137  1040  NOHERE,  TAD EX1          /MANTISSA=0
6140  3044           DCA EXP
6141  5314           JMP DONE
6142  0000  AMOUNT,  0
6143  0030  TEST2,   0030
6144  0000  TEST3,   0
6145  0000  TEST4,   0
6146  0000  TEST5,   0
6147  0044  TAG1,    EXP
6150  7774  TAG2,    EX1-EXP
6151  5601  RETN2,   FPNT+1
6152  1362  ERROR1,  TAD GOOF         /DIVISION BY ZERO
6153  3044           DCA EXP          /SET TO LARGEST + VALUE
6154  1362           TAD GOOF
6155  3045           DCA HORD
6156  7040           CMA
6157  3046           DCA LORD
6160  2061           ISZ FLAG         /SET FLAG
6161  5751           JMP I RETN2
6162  3777  GOOF,    3777
```

```
6163  0000  SQUARE,  0
6164  4407           JMS I 0007
6165  6052           FPUT FPAC1
6166  3052           FMPY FPAC1
6167  0000           FEXT
6170  5763           JMP I SQUARE
6171  0000  EXIT6,   0              /DUMMY SUBROUTINE
6172  5771           JMP I EXIT6
      *6200
6200  0000  DIV1,    0              /SHIFT FAC RIGHT
6201  7300           CLA CLL
6202  1045           TAD HORD
6203  7510           SPA
6204  7120           CLL CML
6205  7010           RAR
6206  3045           DCA HORD
6207  1046           TAD LORD
6210  7010           RAR
6211  3046           DCA LORD
6212  1047           TAD OVER2
6213  7010           RAR
6214  3047           DCA OVER2
6215  7100           CLL
6216  2044           ISZ EXP
6217  7000           NOP
6220  5600           JMP I DIV1
6221  0000  DMULT,   0              /DOUBLE PRECISION MULTIPLY
6222  7300           CLA CLL        /SAVE PRODUCT TRIPLE PRECISION
6223  1363           TAD SMACLA
6224  3347           DCA SNSWIT     /CALLS A SINGLE PRECISION
6225  4336           JMS SIGN       /MULTIPLY 3 TIMES
6226  1042           TAD AC1L
6227  3756           DCA I MP2PT
6230  1046           TAD LORD
6231  4755           JMS I MP4PT
6232  7200           CLA
6233  1757           TAD I MP5PT
6234  3047           DCA OVER2
6235  1045           TAD HORD
6236  3756           DCA I MP2PT
6237  1042           TAD AC1L
6240  4755           JMS I MP4PT
6241  1047           TAD OVER2
6242  3047           DCA OVER2
6243  7004           RAL
6244  1757           TAD I MP5PT
6245  3367           DCA D
6246  7004           RAL
6247  3370           DCA KEEP
6250  1041           TAD AC1H
6251  3756           DCA I MP2PT
6252  1046           TAD LORD
6253  4755           JMS I MP4PT
```

```
6254  1047          TAD OVER2
6255  3047          DCA OVER2
6256  7004          RAL
6257  1757          TAD I MP5PT
6260  1367          TAD D
6261  3367          DCA D
6262  7004          RAL
6263  1370          TAD KEEP
6264  3370          DCA KEEP
6265  1045          TAD HORD
6266  3756          DCA I MP2PT
6267  1041          TAD AC1H
6270  4755          JMS I MP4PT
6271  1367          TAD D
6272  3046          DCA LORD
6273  7004          RAL
6274  1757          TAD I MP5PT
6275  1370          TAD KEEP
6276  3045          DCA HORD
6277  4760          JMS I NORMF
6300  3047          DCA OVER2
6301  2365          ISZ SGN
6302  5621          JMP I DMULT
6303  4773          JMS I MINS
6304  5621          JMP I DMULT
6305  1041  FLDV,   TAD AC1H
6306  7640          SZA CLA
6307  5313          JMP .+4
6310  1042          TAD AC1L
6311  7650          SNA CLA
6312  5774          JMP I ERROR     /DIVISION BY ZERO
6313  1040          TAD EX1
6314  7041          CMA IAC
6315  1044          TAD EXP
6316  7001          IAC
6317  3044          DCA EXP         /SUBTRACT EXPONENTS
6320  1362          TAD SPACLA
6321  3347          DCA SNSWIT
6322  4336          JMS SIGN        /SET UP SIGNS
6323  4761          JMS I DIVIDE    /DIVIDE
6324  1757          TAD I MP5PT
6325  1041          TAD AC1H        /ROUND OFF IN 23RD BIT
6326  7630          SZL CLA
6327  7001          IAC
6330  3042          DCA AC1L
6331  3041          DCA AC1H
6332  2365          ISZ SGN         /TEST SIGN
6333  4773          JMS I MINS      /NEGATE
6334  5735          JMP I .+1       /ADD ROUNDING
6335  5720          FLAD+2
6336  0000.  SIGN,   0             /TEST SIGN OF RESULT
6337  1366          TAD REST        /SET UP BY MULTIPLY AND
6340  3365          DCA SGN         /DIVIDE
```

```
6341  1045          TAD HORD
6342  7700          SMA CLA
6343  5346          JMP .+3
6344  4773          JMS I MINS
6345  2365          ISZ SGN
6346  1041          TAD AC1H
6347  7700  SNSWIT,  SMA CLA          /OR SPA CLA
6350  5736          JMP I SIGN
6351  4771          JMS I MINS2
6352  2365          ISZ SGN
6353  7000          NOP
6354  5736          JMP I SIGN
6355  6437  MP4PT,  MP4
6356  6471  MP2PT,  MP2
6357  6465  MP5PT,  MP5
6360  6600  NORMF,  DNORM
6361  6472  DIVIDE, DUBDIV
6362  7710  SPACLA, SPA CLA
6363  7700  SMACLA, SMA CLA
6364  5601  RETURN, FPNT+1
6365  0000  SGN,    0
6366  7776  REST,   7776
6367  0000  D,      0
6370  0000  KEEP,   0
6371  6400  MINS2,  MINUS2         /-AC1H,AC1L
6372  6420  RAR2,   DIV2           /AC1H,AC1L/2
6373  6000  MINS,   ACMINS
6374  6152  ERROR,  ERROR1
            *6400
6400  0000  MINUS2, 0               /NEGATE OPERAND
6401  7300          CLA CLL         /TRIPLE PRECISION
6402  1043          TAD OVER1
6403  7041          CMA IAC
6404  3043          DCA OVER1
6405  1042          TAD AC1L
6406  7040          CMA
6407  7430          SZL
6410  7101          CLL IAC
6411  3042          DCA AC1L
6412  1041          TAD AC1H
6413  7040          CMA
6414  7430          SZL
6415  7101          CLL IAC
6416  3041          DCA AC1H
6417  5600          JMP I MINUS2
6420  0000  DIV2,   0               /SHIFT OPERAND RIGHT
6421  7300          CLA CLL         /TRIPLE PRECISION
6422  1041          TAD AC1H
6423  7510          SPA
6424  7120          CLL CML
6425  7010          RAR
6426  3041          DCA AC1H
6427  1042          TAD AC1L
```

```
6430  7010          RAR
6431  3042          DCA AC1L
6432  1043          TAD OVER1
6433  7010          RAR
6434  3043          DCA OVER1
6435  7100          CLL
6436  5620          JMP I DIV2
6437  0000  MP4,     0               /SINGLE PRECISION MULTIPLY
6440  3266          DCA MP1         /12 BITS BY 12 BITS
6441  3265          DCA MP5
6442  1270          TAD THIR
6443  3267          DCA MP3
6444  7100          CLL
6445  1266          TAD MP1
6446  7010          RAR
6447  3266          DCA MP1
6450  1265          TAD MP5
6451  7420          SNL
6452  5255          JMP .+3
6453  7100          CLL
6454  1271          TAD MP2
6455  7010          RAR
6456  3265          DCA MP5
6457  2267          ISZ MP3
6460  5245          JMP MP4+6
6461  1266          TAD MP1
6462  7010          RAR
6463  7100          CLL
6464  5637          JMP I MP4
6465  0000  MP5,     0
6466  0000  MP1,     0
6467  0000  MP3,     0
6470  7764  THIR,    7764
6471  0000  MP2,     0
6472  0000  DUBDIV,  0               /DOUBLE PRECISION DIVIDE
6473  7300          CLA CLL
6474  3051          DCA QUOL
6475  1344          TAD MIF
6476  3267          DCA MP3
6477  5306          JMP DVX
6500  1046  DV3,     TAD LORD
6501  7004          RAL
6502  3046          DCA LORD
6503  1045          TAD HORD
6504  7004          RAL
6505  3045          DCA HORD
6506  1042  DVX,     TAD AC1L
6507  1046          TAD LORD
6510  3271          DCA MP2
6511  7004          RAL
6512  1045          TAD HORD
6513  1041          TAD AC1H
6514  7420          SNL
```

```
6515  5321          JMP DV2-1
6516  3045          DCA HORD
6517  1271          TAD MP2
6520  3046          DCA LORD
6521  7200          CLA
6522  1051  DV2,    TAD QUOL
6523  7004          RAL
6524  3051          DCA QUOL
6525  1047          TAD OVER2
6526  7004          RAL
6527  3047          DCA OVER2
6530  2267          ISZ MP3
6531  5300          JMP DV3
6532  1051          TAD QUOL
6533  3046          DCA LORD
6534  1045          TAD HORD
6535  7106          CLL RTL
6536  3265          DCA MP5
6537  1047          TAD OVER2
6540  3045          DCA HORD
6541  3047          DCA OVER2
6542  1265          TAD MP5
6543  5672          JMP I DUBDIV
6544  7751  MIF,    7751
6545  6163  TABLE6, SQUARE       /TABLE FOR INTERPRETATION
6546  6656          SQROOT       /OF BITS 8-11
6547  6171          EXIT6        /CONTAINS ABSOLUTE ADDRESSES
6550  6171          EXIT6        /OF PROGRAMS CALLED AS
6551  6171          EXIT6        /SUBROUTINES
6552  6171          EXIT6        /EXIT6=A DUMMY OR NOP
6553  6171          EXIT6
6554  6171          EXIT6
6555  6171          EXIT6
6556  6171          EXIT6
6557  6171          EXIT6
6560  6171          EXIT6
6561  6171          EXIT6
6562  6171          EXIT6
6563  6171          EXIT6
6564  0000  DUNORM, 0
6565  4220          JMS DIV2     /SHIFT OPERAND RIGHT
6566  4772          JMS I RAR1
6567  2040          ISZ EX1
6570  7000          NOP
6571  5764          JMP I DUNORM
6572  6200  RAR1,   DIV1
            *6600
6600  0000  DNORM,  0            /SUBROUTINE TO NORMALIZE
6601  7300          CLA CLL      /FLOATING ACCUMULATOR
6602  3255          DCA AMT1
6603  3254          DCA SIGN1
6604  1045          TAD HORD
6605  7510          SPA          /IS MANTISSA NEGATIVE?
```

```
6606  2254          ISZ SIGN1       /YES
6607  7640          SZA CLA         /IS MANTISSA=0?
6610  5217          JMP GO6         /NO
6611  1046          TAD LORD
6612  7640          SZA CLA
6613  5217          JMP GO6
6614  1047          TAD OVER2
6615  7650          SNA CLA
6616  5251          JMP EXIT2       /YES
6617  1254  GO6,    TAD SIGN1       /NO
6620  7640          SZA CLA         /NEGATIVE?
6621  4653          JMS I NEG       /YES
6622  1045  LOP,    TAD HORD        /WILL SHIFT BE TOO FAR?
6623  7104          RAL CLL
6624  7710          SPA CLA
6625  5241          JMP EXIT1       /YES
6626  1047          TAD OVER2
6627  7104          CLL RAL
6630  3047          DCA OVER2
6631  1046          TAD LORD        /NO SHIFT MANTISSA LEFT
6632  7004          RAL
6633  3046          DCA LORD
6634  1045          TAD HORD
6635  7004          RAL
6636  3045          DCA HORD
6637  2255          ISZ AMT1        /COUNT NO. OF TIMES SHIFTED
6640  5222          JMP LOP
6641  1255  EXIT1,  TAD AMT1        /CORRECT EXPONENT
6642  7041          CMA IAC
6643  1044          TAD EXP
6644  3044          DCA EXP
6645  1254          TAD SIGN1       /NEGATIVE?
6646  7640          SZA CLA
6647  4653          JMS I NEG       /YES
6650  5600          JMP I DNORM
6651  3044  EXIT2,  DCA EXP         /SET TO ZERO
6652  5600          JMP I DNORM
6653  6000  NEG,    ACMINS
6654  0000  SIGN1,  0
6655  0000  AMT1,   0
6656  0000  SQROOT, 0              /FLOATING SQUARE ROOT
6657  3362          DCA FLAG1       /TAKES ROOT OF ABSOLUTE
6660  4407          JMS I 007
6661  6052          FPUT FPAC1      /VALUE
6662  0000          FEXT            /NEWTON'S METHOD IS USED
6663  1045          TAD HORD
6664  7710          SPA CLA
6665  5351          JMP SQEND1      /NUMBER IS NEGATIVE
6666  1044          TAD EXP
6667  7100          CLL
6670  7510          SPA
6671  7020          CML
6672  7010          RAR
6673  3356          DCA ITER1       /MAKE FIRST APPROXIMATION
```

```
6674  7430            SZL
6675  2356            ISZ ITER1
6676  7000            NOP
6677  1361            TAD SQCON1
6700  3357            DCA ITER1+1
6701  3360            DCA ITER1+2
6702  1053            TAD FPAC1+1
6703  7640            SZA CLA
6704  5310            JMP CLCU
6705  1054            TAD FPAC1+2
6706  7650            SNA CLA
6707  5354            JMP SQEND       /NUMBER=0
6710  4407  CLCU,     JMS I 0007
6711  5052            FGET FPAC1
6712  4356            FDIV ITER1
6713  1356            FADD ITER1
6714  0000            FEXT
6715  7240            CLA CMA
6716  1044            TAD EXP
6717  3044            DCA EXP
6720  1044            TAD EXP
6721  7041            CMA IAC
6722  1356            TAD ITER1
6723  7640            SZA CLA         /ARE EXPONENTS EQUAL?
6724  5345            JMP ROOTGO      /NO
6725  1045            TAD HORD        /ARE HIGH-ORDER MANTISSAS EQUAL?
6726  7041            CMA IAC
6727  1357            TAD ITER1+1
6730  7640            SZA CLA
6731  5345            JMP ROOTGO      /NO
6732  1046            TAD LORD
6733  7041            CMA IAC
6734  1360            TAD ITER1+2     /DO LOW-ORDER MANTISSAS AGREE?
6735  7500            SMA
6736  7041            CMA IAC         /WITHIN ONE BIT?
6737  7001            IAC
6740  7710            SPA CLA
6741  5345            JMP ROOTGO      /NO
6742  1362            TAD FLAG1
6743  3061            DCA FLAG
6744  5656            JMP I SQROOT
6745  4407  ROOTGO,    JMS I 0007
6746  6356            FPUT ITER1
6747  0000            FEXT
6750  5310            JMP CLCU
6751  4653  SQEND1,    JMS I NEG       /NEGATE FAC
6752  2362            ISZ FLAG1
6753  5260            JMP SQROOT+2
6754  3044  SQEND,     DCA EXP
6755  5656            JMP I SQROOT
6756  0000  ITER1,     0
6757  0000            0
6760  0000            0
6761  3015  SQCON1,    3015
6762  0000  FLAG1,     0
```

ACMINS	6000	FLPT	5705	NORMF	6360
ACON6	5760	FLSU	5737	OPMINS	5741
AC1H	0041	FPAC1	0052	OUTGO	6116
AC1L	0042	FPNT	5600	OVER1	0043
ADDR	5656	GOOF	6162	OVER2	0047
ALGN	5771	GO2	5655	PAGENO	5663
ALIGN	6020	GO6	6617	QUOL	0051
AMOUNT	6142	HORD	0045	RAR1	6572
AMT1	6655	INDRCT	5664	RAR2	6372
CLCU	6710	ITER1	6756	REST	6366
D	6367	JUMP	5653	RETN2	6151
DIVIDE	6361	JUMP2	5654	RETURN	6364
DIV1	6200	KEEP	6370	ROOTGO	6745
DIV2	6420	LOOP01	5627	SAVE	5657
DMULT	6221	LOP	6622	SGN	6365
DNORM	6600	LORD	0046	SHIFT	6076
DONE	6114	MASK3	5660	SIGN	6336
DUBDIV	6472	MASK5	5661	SIGN1	6654
DUNORM	6564	MASK7	5662	SMACLA	6363
DVX	6506	MIF	6544	SNSWIT	6347
DV2	6522	MINS	6373	SPACLA	6362
DV3	6500	MINS2	6371	SQCON1	6761
ERROR	6374	MINUS2	6400	SQEND	6754
ERROR1	6152	MP1	6466	SQEND1	6751
EXIT	5742	MP2	6471	SQROOT	6656
EXIT1	6641	MP2PT	6356	SQUARE	6163
EXIT2	6651	MP3	6467	TABLE	5665
EXIT6	6171	MP4	6437	TABLE6	6545
EXP	0044	MP4PT	6355	TAG1	6147
EXP1	0050	MP5	6465	TAG2	6150
EX1	0040	MP5PT	6357	TEST2	6143
FLAD	5716	MULT	5767	TEST3	6144
FLAG	0061	NEG	6653	TEST4	6145
FLAG1	6762	NOGO	6125	TEST5	6146
FLDV	6305	NOHERE	6137	THIR	6470
FLGT	5676	NORF	5773	UNORM	5772
FLMY	5761	NORM	5770		

```
                /FLOATING POINT I/O ROUTINES
                /REQUIRES FLOATING POINT INTERPRETER
                /ENTRY AT 0007

                *7
0007  5600  FPNT,     5600

                *44
0044  0000  EXPONT,   0
0045  0000  HORDER,   0
0046  0000  LORDER,   0

                *52
0052  0000  FPAC1,    0
0053  0000            0
0054  0000            0
0055  7777  SWIT1,    7777        /IF = 0, NO CR-LF AFTER OUTPUT
0056  7777  SWIT2,    7777        /IF = 0, NO LF AFTER CR IN INPUT
0057  0000  CHAR,     0           /CONTAINS LAST CHARACTER READ
0060  0000  DSWIT,    0           /= 0 IF NO CONVERSION TOOK PLACE

                *6767
6767  0000  PRCHAR,   0
6770  1056            TAD SWIT2
6771  7650            SNA CLA
6772  5767            JMP I PRCHAR
6773  1377            TAD LFED
6774  4776            JMS I OPUT
6775  5767            JMP I PRCHAR
6776  7344  OPUT,     OUT
6777  0212  LFED,     0212
```

```
                /DOUBLE PRECISION DECIMAL-BINARY
                /INPUT AND CONVERSION
                *7000

7000  0000  DECONV,   0
7001  7200            CLA                     /INITIALIZE MANTISSA
7002  3045            DCA HORDER
7003  3046            DCA LORDER
7004  3265            DCA SIGN
7005  3266            DCA DNUMBR
7006  4342            JMS INPUT
7007  1336            TAD PLUS                /TEST FOR SIGN
7010  7450            SNA
7011  5217            JMP DECON
7012  1335            TAD MINUS
7013  7440            SZA
7014  5220            JMP .+4
7015  7240            CLA CMA
7016  3265            DCA SIGN                /IF-, SET SWITCH
7017  4342  DECON,     JMS INPUT
7020  7200            CLA
7021  1057            TAD CHAR                /IS IT A DIGIT
7022  1337            TAD MIN9
7023  7500            SMA
7024  5600            JMP I DECONV            /NO
7025  1340            TAD PLUS12
7026  7510            SPA
7027  5600            JMP I DECONV            /NO
7030  3263            DCA DIGIT               /YES
7031  1045            TAD HORDER
7032  0341            AND MASK                /OVERFLOW?
7033  7440            SZA
7034  5217            JMP DECON               /YES-IGNORE
7035  2060            ISZ DSWIT
7036  2266            ISZ DNUMBR              /INDEX NUMBER OF DIGITS
7037  4241            JMS MULT10
7040  5217            JMP DECON               /CONTINUE
7041  0000  MULT10,    0                       /ROUTINE TO MULTIPLY
7042  1046            TAD LORDER             /DOUBLE PRECISION WORD
7043  3261            DCA LTEMP               /BY TEN (DECIMAL)
7044  1045            TAD HORDER              /REMAIN=REMAINDER
7045  3262            DCA HTEMP
7046  3264            DCA REMAIN
7047  4267            JMS MULT2               /CALL SUBROUTINE TO
7050  4267            JMS MULT2               /MULTIPLY BY TWO
7051  4303            JMS DUBLAD              /CALL DOUBLE ADD
7052  4267            JMS MULT2
7053  1263            TAD DIGIT               /ADD LAST DIGIT RECEIVED
7054  3261            DCA LTEMP
7055  3262            DCA HTEMP
7056  4303            JMS DUBLAD
7057  1264            TAD REMAIN              /EXIT WITH REMAINDER
7060  5641            JMP I MULT10            /IN AC

7061  0000  LTEMP,    0                       /DOUBLE PRECISION WORD
7062  0000  HTEMP,    0
7063  0000  DIGIT,    0                       /STORAGE FOR DIGIT
7064  0000  REMAIN,   0
7065  0000  SIGN,     0                       /=0 IF PLUS: =7777 IF MINUS
7066  0000  DNUMBR,   0                       /=NUMBER OF DIGITS
7067  0000  MULT2,    0                       /MULTIPLY LORDER, HORDER BY 2
```

```
7070  7300            CLA CLL
7071  1046            TAD LORDER
7072  7004            RAL
7073  3046            DCA LORDER
7074  1045            TAD HORDER
7075  7004            RAL
7076  3045            DCA HORDER
7077  1264            TAD REMAIN
7100  7004            RAL
7101  3264            DCA REMAIN
7102  5667            JMP I MULT2
7103  0000  DUBLAD,    0                       /DOUBLE PRECISION ADDITION
7104  7300            CLA CLL
7105  1046            TAD LORDER
7106  1261            TAD LTEMP
7107  3046            DCA LORDER
7110  7004            RAL
7111  1045            TAD HORDER
7112  1262            TAD HTEMP
7113  3045            DCA HORDER
7114  7004            RAL
7115  1264            TAD REMAIN
7116  3264            DCA REMAIN
7117  5703            JMP I DUBLAD
7120  0000  MSIGN,     0                       /ROUTINE TO FORM
7121  7300            CLA CLL                 /2'S COMPLEMENT IF
7122  2265            ISZ SIGN                /MINUS
7123  5720            JMP I MSIGN             /SIGN=0000: EXIT
7124  1046            TAD LORDER
7125  7041            CMA IAC
7126  3046            DCA LORDER
7127  1045            TAD HORDER
7130  7040            CMA
7131  7430            SZL
7132  7001            IAC
7133  3045            DCA HORDER
7134  5720            JMP I MSIGN

7135  7776  MINUS,     253-255                 /TEST FOR SIGN
7136  7525  PLUS,      -253
7137  7506  MIN9,      -272                    /TEST FOR DIGIT
7140  0012  PLUS12,    272-260
7141  7600  MASK,      7600                    /TEST FOR OVERFLOW
            /INPUT A CHARACTER, IF CR, TEST
            /INPUT SWITCH TO SEE IF LF SHOULD
            /BE TYPED. IF RUBOUT, RESTART INPUT
7142  0000  INPUT,     0                       /INPUT A CHARACTER
7143  7200            CLA
7144  6031            KSF
7145  5344            JMP .-1
7146  6036            KRB
7147  3057            DCA CHAR
7150  1057            TAD CHAR
7151  4766            JMS I OUTPUT
7152  1057            TAD CHAR
7153  7450            SNA
7154  5343            JMP INPUT+1             /IGNORE BLANKS
7155  1370            TAD MRBOUT
7156  7450            SNA
7157  5767            JMP I RESTRT            /RUBOUT-RESTART INPUT
7160  1371            TAD MINCR
```

```
7161  7650            SNA CLA
7162  4765            JMS I PRINT          /CR - SEE IF TO BE FOLLOWED
7163  1057            TAD CHAR             /BY LF
7164  5742            JMP I INPUT          /EXIT ROUTINE

7165  6767  PRINT,    PRCHAR
7166  7344  OUTPUT,   OUT
7167  7401  RESTRT,   FLINTP+1
7170  7401  MRBOUT,   -377
7171  0162  MINCR,    377-215


              /FLOATING OUTPUT "E" FORMAT
              /USES:     TSF
              /          JMP .-1
              /          TLS
              *7200
7200  0000  FLOUTP,    0
7201  4217            JMS FOUTCN           /CONVERT MANTISSA AND OUTPUT
7202  1324            TAD BEXP
7203  3044            DCA EXPONT
7204  1343            TAD CHE
7205  4344            JMS OUT
7206  4737            JMS I FEXPPT         /CONVERT EXPONENT AND OUTPUT
7207  1055            TAD SWIT1            /PRINT CR-LF?
7210  7650            SNA CLA
7211  5600            JMP I FLOUTP         /NO-EXIT
7212  1341            TAD CARRTN /YES
7213  4344            JMS OUT
7214  1342            TAD LNFEED
7215  4344            JMS OUT
7216  5600            JMP I FLOUTP         /EXIT
              /THIS WHOLE SUBROUTINE MAY BE ALTERED TO BUFFER
              /THE OUTPUT DIGITS : CHANGE JMS OUTDG TO DCA I 10, ETC.
7217  0000  FOUTCN,    0
7220  7300            CLA CLL
7221  1045            TAD HORDER           /NUMBER>0??
7222  7710            SPA CLA
7223  7220            CLA CML              /NO SET LINK
7224  1327            TAD SPLUS            /YES
7225  7430            SZL
7226  1330            TAD SMINUS /NO
7227  4344            JMS OUT
7230  4352            JMS OUTDG            /OUTPUT "0"
7231  1331            TAD PERIOD
7232  4344            JMS OUT              /OUTPUT "."
7233  7300            CLA CLL
7234  1045            TAD HORDER
7235  7700            SMA CLA
7236  5242            JMP FGO1
7237  7040            CMA                  /NUMBER IS NEGATIVE
7240  3733            DCA I SNPT           /NEGATE
7241  4732            JMS I MSNPT
7242  7240  FGO1,     CLA CMA              /SUBTRACT 1 FROM BINARY EXPONENT
7243  1044            TAD EXPONT           /COMPENSATE AT FGO4
7244  3044            DCA EXPONT
7245  3324            DCA BEXP             /INITIALIZE DECIMAL EXPONENT
7246  1044  FGO2,     TAD EXPONT           /IS -4<EXPONENT<-1
7247  7500            SMA
7250  5263            JMP FGO3             /TOO LARGE: MULTIPLY BY 1/10
7251  1326            TAD FOUR
```

```
7252  7700            SMA CLA
7253  5270            JMP FGO4
7254  4407            JMS I FPNT          /TOO SMALL-TIMES TEN
7255  3740            FMPY I TENPT        /TEN
7256  0000            FEXT
7257  7240            CLA CMA
7260  1324            TAD BEXP
7261  3324            DCA BEXP
7262  5246            JMP FGO2
7263  4407  FGO3,     JMS I FPNT
7264  3372            FMPY C.10           /ONE TENTH
7265  0000            FEXT
7266  2324            ISZ BEXP
7267  5246            JMP FGO2
7270  3734  FGO4,     DCA I DPT           /MULTIPLY BY TWO
7271  4736            JMS I M2PT          /IE.SHIFT LEFT
7272  4735            JMS I M10PT         /MULTIPLY BY TEN
7273  7410            SKP
7274  4357  FGO5A,    JMS DIVTWO          /COMPENSATE FOR
7275  2044            ISZ EXPONT          /BINARY EXPONENT
7276  5274            JMP FGO5A
7277  7450            SNA                 /IS FIRST DIGIT A ZERO
7300  5311            JMP FGO7            /YES, IGNORE
7301  4352  FGO6,     JMS OUTDG           /MULTIPLICATIONS YIELD
7302  1325            TAD MINUS7          /DECIMAL DIGITS AS HIGH
7303  3044            DCA EXPONT          /ORDER REMAINDERS
7304  4735  FGO6A,    JMS I M10PT         /IE. .672X10=6+.72.. ETC
7305  4352            JMS OUTDG
7306  2044            ISZ EXPONT          /7 DIGITS OUTPUT??
7307  5304            JMP FGO6A           /NO: CONTINUE
7310  5617            JMP I FOUTCN        /YES:EXIT

7311  7240  FGO7,     CLA CMA             /IGNORE FIRST DIGIT
7312  1324            TAD BEXP            /SUBTRACT 1 FROM
7313  3324            DCA BEXP            /DECIMAL EXPONENT
7314  1045            TAD HORDER
7315  7640            SZA CLA
7316  5322            JMP .+4             /IS MANTISSA ZERO?
7317  1046            TAD LORDER
7320  7650            SNA CLA
7321  3324            DCA BEXP            /YES:EXP=0
7322  7240            CLA CMA
7323  5302            JMP FGO6+1

7324  0000  BEXP,     0                   /CONTAINS DECIMAL EXPONENT
7325  7772  MINUS7,   7772                /NUMBER OF DIGTS OUTPUT
7326  0004  FOUR,     0004
7327  0253  SPLUS,    253
7330  0002  SMINUS,   255-253
7331  0256  PERIOD,   256
7332  7120  MSNPT,    MSIGN
7333  7065  SNPT,     SIGN                /POINTERS
7334  7063  DPT,      DIGIT
7335  7041  M10PT,    MULT10
7336  7067  M2PT,     MULT2
7337  7522  FEXPPT,   FEXC
7340  7504  TENPT,    TEN
7341  0215  CARRTN,   0215
7342  0212  LNFEED,   0212
7343  0305  CHE,      305
```

```
7344  0000  OUT,      0                       /OUTPUT ONE ASCII CHARACTER
7345  6041            TSF
7346  5345            JMP .-1
7347  6046            TLS
7350  7200            CLA
7351  5744            JMP I OUT

7352  0000  OUTDG,    0                       /OUTPUT ONE DIGIT
7353  1356            TAD C260
7354  4344            JMS OUT
7355  5752            JMP I OUTDG

7356  0260  C260,     0260

7357  0000  DIVTWO,   0                       /DIVIDE BY TWO IE.
7360  7110            CLL RAR                 /ROTATE RIGHT
7361  3344            DCA OUT                 /TEMPORARY STORAGE
7362  1045            TAD HORDER
7363  7010            RAR
7364  3045            DCA HORDER
7365  1046            TAD LORDER
7366  7010            RAR
7367  3046            DCA LORDER
7370  1344            TAD OUT
7371  5757            JMP I DIVTWO
7372  7775  C.10,     7775                    /CONSTANT .10 USED IN
7373  3146            3146                    /FLOATING OUTPUT-PROVIDES
7374  3147            3147
      /FLOATING POINT INPUT
      *7400
7400  0000  FLINTP,   0
7401  7240            CLA CMA                 /INITIALIZE "PERIOD SWITCH"
7402  3313            DCA PRSW
7403  3060            DCA DSWIT
7404  4716            JMS I DPCVPT            /7777 = NO PERIOD
7405  7200            CLA
7406  1057            TAD CHAR
7407  1312            TAD PER
7410  7640            SZA CLA
7411  5220            JMP FIG01
7412  1313            TAD PRSW                /PERIOD FOUND
7413  7650            SNA CLA                 /SECOND PERIOD
7414  5222            JMP FIG02               /YES,TERMINATE
7415  3721            DCA I DPN               /NO - SET NUMBER OF DIGITS TO 0
7416  3313            DCA PRSW                /SET PERIOD SWITCH TO 0
7417  5717            JMP I DPCSPT            /CONVERT REST OF STRING

7420  1313  FIG01,    TAD PRSW                /PERIOD READ IN PREVIOUSLY?
7421  7650            SNA CLA
7422  1721  FIG02,    TAD I DPN               /YES:-NUMBER OF DIGITS IN SEXP
7423  7041            CMA IAC                 /NO
7424  3314            DCA SEXP
7425  4720            JMS I MSGNPT            /TEST SIGN
7426  1311  FIG03,    TAD C27
7427  3044            DCA EXPONT
7430  4407            JMS I FPNT              /NORMALIZE F.P. NUMBER
7431  7000            FNOR
7432  6052            FPUT FPAC1              /SAVE NUMBER
7433  0000            FEXT
7434  1057            TAD CHAR
7435  1310            TAD MINUSE
```

```
7436  7640            SZA CLA                 /"E" READ IN?
7437  5252            JMP ENDFI               /NO
7440  4716            JMS I DPCVPT            /YES - CONVERT DECIMAL EXPONENT
7441  4720            JMS I MSGNPT            /TEST SIGN
7442  1045            TAD HORDER              /EXPONENT TOO LARGE??
7443  7510            SPA
7444  7001            IAC
7445  7640            SZA CLA
7446  5277            JMP EXCESS              /YES
7447  1046            TAD LORDER              /NO:DECIMAL POINT IS
7450  1314            TAD SEXP                /C(SEXP)PLACES TO RIGHT
7451  3314            DCA SEXP                /OF LAST DIGIT
                /END OF FLOATING POINT INPUT
                /COMPENSATE FOR DECIMAL EXPONENTS

7452  4407  ENDFI,    JMS I FPNT              /RESTORE MANTISSA
7453  5052            FGET FPAC1
7454  0000            FEXT
7455  1314            TAD SEXP
7456  7450            SNA
7457  5600            JMP I FLINTP
7460  7700            SMA CLA
7461  5270            JMP FIGO4
7462  4407            JMS I FPNT              /. IS TO THE LEFT:
7463  3707            FMPY I PC.10            /TIMES .1000
7464  0000            FEXT
7465  2314            ISZ SEXP
7466  5255            JMP ENDFI+3
7467  5600            JMP I FLINTP

7470  4407  FIGO4,    JMS I FPNT              /. IS TO THE RIGHT:
7471  3304            FMPY TEN                /MULTIPLY BY 10
7472  0000            FEXT
7473  7240            CLA CMA
7474  1314            TAD SEXP
7475  3314            DCA SEXP
7476  5255            JMP ENDFI+3
7477  1315  EXCESS,   TAD C3777
7500  3044            DCA EXPONT
7501  1315            TAD C3777
7502  3045            DCA HORDER
7503  5600            JMP I FLINTP
7504  0004  TEN,       0004
7505  2400            2400
7506  0000            0000
7507  7372  PC.10,     C.10                    /.10
7510  7473  MINUSE,    -305
7511  0027  C27,       0027
7512  7522  PER,       -256
7513  0000  PRSW,      0
7514  0000  SEXP,      0                       /CONTAINS DECIMAL EXPONENT
7515  3777  C3777,     3777

7516  7000  DPCVPT,    DECONV
7517  7017  DPCSPT,    DECON
7520  7120  MSGNPT,    MSIGN
7521  7066  DPN,       DNUMBR
                /OUTPUT THE EXPONENT

7522  0000  FEXC,      0
7523  7300            CLA CLL
```

```
7524  1044            TAD EXPONT
7525  7510            SPA
7526  7061            CMA IAC CML
7527  3044            DCA EXPONT
7530  1366            TAD C253
7531  7430            SZL
7532  1367            TAD C255
7533  4774            JMS I DGPT
7534  3045            DCA HORDER
7535  1044            TAD EXPONT
7536  2045            ISZ HORDER
7537  1370            TAD M144
7540  7500            SMA
7541  5336            JMP .-3
7542  1371            TAD C144
7543  3044            DCA EXPONT
7544  7040            CMA
7545  1045            TAD HORDER
7546  7440            SZA
7547  4774            JMS I DGPT
7550  3045            DCA HORDER
7551  1044            TAD EXPONT
7552  2045            ISZ HORDER
7553  1372            TAD M12
7554  7500            SMA
7555  5352            JMP .-3
7556  1373            TAD C12
7557  3046            DCA LORDER
7560  7240            CLA CMA
7561  1045            TAD HORDER
7562  4774            JMS I DGPT
7563  1046            TAD LORDER
7564  4774            JMS I DGPT
7565  5722            JMP I FEXC

7566  7773  C253,     0253-260
7567  0002  C255,     255-253
7570  7634  M144,     7634
7571  0144  C144,     0144
7572  7766  M12,      7766
7573  0012  C12,      0012
7574  7352  DGPT,     OUTDG
```

```
BEXP     7324
CARRTN   7341
CHAR     0057
CHE      7343
C.10     7372
C12      7573
C144     7571
C253     7566
C255     7567
C260     7356
C27      7511
C3777    7515
DECON    7017
DECONV   7000
DGPT     7574
DIGIT    7063
DIVTWO   7357
DNUMBR   7066
DPCSPT   7517
DPCVPT   7516
DPN      7521
DPT      7334
DSWIT    0060
DUBLAD   7103
ENDFI    7452
EXCESS   7477
EXPONT   0044
FEXC     7522
FEXPPT   7337
FGO1     7242
FGO2     7246
FGO3     7263
FGO4     7270
FGO5A    7274
FGO6     7301
FGO6A    7304
FGO7     7311
FIGO1    7420
FIGO2    7422
FIGO3    7426
FIGO4    7470
FLINTP   7400
FLOUTP   7200
FOUR     7326
FOUTCN   7217
FPAC1    0052
FPNT     0007
HORDER   0045
HTEMP    7062
INPUT    7142
LFED     6777
LNFEED   7342
LORDER   0046
LTEMP    7061
MASK     7141
MINCR    7171
MINUS    7135
MINUSE   7510
MINUS7   7325
MIN9     7137
MRBOUT   7170
MSGNPT   7520
MSIGN    7120
MSNPT    7332
MULT10   7041
MULT2    7067
M10PT    7335
M12      7572
M144     7570
M2PT     7336
OPUT     6776
OUT      7344
OUTDG    7352
OUTPUT   7166
PC.10    7507
PER      7512
PERIOD   7331
PLUS     7136
PLUS12   7140
PRCHAR   6767
PRINT    7165
PRSW     7513
REMAIN   7064
RESTRT   7167
SEXP     7514
SIGN     7065
SMINUS   7330
SNPT     7333
SPLUS    7327
SWIT1    0055
SWIT2    0056
TEN      7504
TENPT    7340
```

```
                    EXTENDED FUNCTIONS
                /FLOATING POINT PACKAGE

                GETSGN=TAD 45
                CLFPNT=JMS I 7

                /FLOATING POINT EXPONENTIAL

                *5000
5000  0000      FEXP,     0
5001  1045                GETSGN
5002  7710                SPA CLA
5003  4310                JMS FNEG
5004  3304                DCA SIGN              /C(SIGN)=-1 IF X<0
5005  4407                CLFPNT
5006  3273                FMPY LG2E
5007  6315                FPUT X
5010  0000                FEXT
5011  4706                JMS I FIXIT
5012  1045                GETSGN
5013  3305                DCA FLAG2
5014  4707                JMS I FLOAT
5015  4407                CLFPNT
5016  6320                FPUT XSQR
5017  5315                FGET X
5020  2320                FSUB XSQR
5021  6315                FPUT X
5022  3315                FMPY X
5023  6320                FPUT XSQR
5024  1270                FADD D
5025  6323                FPUT TEMP
5026  5265                FGET C
5027  4323                FDIV TEMP
5030  2315                FSUB X
5031  1257                FADD A
5032  6323                FPUT TEMP
5033  5262                FGET B
5034  3320                FMPY XSQR
5035  1323                FADD TEMP
5036  6323                FPUT TEMP
5037  5315                FGET X
5040  4323                FDIV TEMP
5041  3301                FMPY TWO
5042  1276                FADD ONE
5043  0000                FEXT
5044  1305                TAD FLAG2
5045  1044                TAD 44
5046  3044                DCA 44
5047  2304                ISZ SIGN
5050  5600                JMP I FEXP
5051  4407                CLFPNT
5052  6315                FPUT X
5053  5276                FGET ONE
5054  4315                FDIV X
5055  0000                FEXT
5056  5600                JMP I FEXP
                /CONSTANTS FOR FEXP

5057  0004      A,        0004
5060  2372                2372
5061  1402                1402
```

```
5062  7774  B,        7774
5063  2157            2157
5064  5157            5157
5065  0012  C,        0012
5066  5454            5454
5067  0343            0343
5070  0007  D,        0007
5071  2566            2566
5072  5341            5341
5073  0001  LG2E,      0001
5074  2705            2705
5075  2435            2435
5076  0001  ONE,       0001
5077  2000            2000
5100  0000            0000
5101  0002  TWO,       0002
5102  2000            2000
5103  0000            0000
5104  0000  SIGN,      0
5105  0000  FLAG2,     0
5106  4757  FIXIT,     FIX
5107  5563  FLOAT,     FLOA
            /NEGATION SUBROUTINE
5110  0000  FNEG,      0
5111  4714            JMS I ACMINS          /CALL SUBROUTINE IN
5112  7240            CLA CMA               /INTERPRETER
5113  5710            JMP I FNEG
5114  6000  ACMINS,    6000                  /POINTER TO INTERPRETER

            /TEMPORARY STORAGE
5115  0000  X,         0
5116  0000            0
5117  0000            0
5120  0000  XSQR,      0
5121  0000            0
5122  0000            0
5123  0000  TEMP,      0
5124  0000            0
5125  0000            0
5126  0000  ZER,       0
5127  0000            0
5130  0000            0
            /MAIN ALGORITHM FOR ARCTANGENT
5131  4407  ARCALG,    CLFPNT
5132  5315            FGET X
5133  3315            FMPY X
5134  6320            FPUT XSQR
5135  3373            FMPY BET2
5136  1370            FADD BET1
5137  3320            FMPY XSQR
5140  1365            FADD BETZ
5141  6323            FPUT TEMP
5142  5362            FGET ALF2
5143  3320            FMPY XSQR
5144  1357            FADD ALF1
5145  3320            FMPY XSQR
5146  1354            FADD ALFZ
5147  3315            FMPY X
5150  4323            FDIV TEMP
5151  0000            FEXT
5152  5753            JMP I .+1
5153  5226            ARCRTN
```

```
                /CONSTANTS - FLOATING ARC TANGENT
5154  0000      ALFZ,     0000
5155  2437                2437
5156  1643                1643
5157  7777      ALF1,     7777
5160  3304                3304
5161  4434                4434
5162  7773      ALF2,     7773
5163  3306                3306
5164  5454                5454
5165  0000      BETZ,     0000
5166  2437                2437
5167  1646                1646
5170  0000      BET1,     0000
5171  2427                2427
5172  2323                2323
5173  7775      BET2,     7775
5174  3427                3427
5175  7052                7052
                /FLOATING POINT ARC TANGENT
                *5200
5200  0000      ARTN,     0
5201  1045                GETSGN
5202  7710                SPA CLA
5203  4642                JMS I NEGIT
5204  3243                DCA FLAG1
5205  4407                CLFPNT
5206  6644                FPUT I X1
5207  5644                FGET I X1
5210  2645                FSUB I CON1
5211  0000                FEXT
5212  1045                GETSGN
5213  7710                SPA CLA
5214  5223                JMP GO
5215  4407                CLFPNT
5216  5645                FGET I CON1
5217  4644                FDIV I X1
5220  6644                FPUT I X1
5221  0000                FEXT
5222  7240                CLA CMA
5223  3251      GO,       DCA FLOG          /FLAG
5224  5625                JMP I .+1         /CALL ALGORITHM
5225  5131                ARCALG
5226  2251      ARCRTN,   ISZ FLOG          /RETURN HERE
5227  5235                JMP EXIT
5230  4407                CLFPNT
5231  6644                FPUT I X1
5232  5246                FGET PIOT
5233  2644                FSUB I X1
5234  0000                FEXT
5235  2243      EXIT,     ISZ FLAG1
5236  5600                JMP I ARTN
5237  4642                JMS I NEGIT
5240  7200                CLA
5241  5600                JMP I ARTN
                /CONSTANTS FOR ARCTANGENT

5242  5110      NEGIT,    FNEG
5243  0000      FLAG1,    0
5244  5115      X1,       X
5245  5076      CON1,     ONE
```

```
5246  0001  PIOT,     0001
5247  3110            3110
5250  3755            3755
            /FLOATING LOGARITHM

5251  0000  FLOG,     0
5252  1045            GETSGN
5253  7440            SZA
5254  5261            JMP OK
5255  4407            CLFPNT                  /INDICATE ERROR
5256  4775            FDIV I ZERO             /DIVIDE BY ZERO
5257  0000            FEXT
5260  5651            JMP I FLOG
5261  7710  OK,       SPA CLA
5262  4642            JMS I NEGIT
5263  4407            CLFPNT
5264  6774            FPUT I TEM
5265  2645            FSUB I CON1
5266  0000            FEXT
5267  1045            GETSGN
5270  7450            SNA
5271  5350            JMP ZERGO
5272  7710            SPA CLA
5273  5341            JMP INVERT
5274  3243  START,    DCA FLAG1
5275  7040            CMA
5276  1774            TAD I TEM
5277  3045            DCA 45
5300  4777            JMS I FLOATP
5301  4407            CLFPNT
5302  3776            FMPY I LOG2
5303  6644            FPUT I X1
5304  0000            FEXT
5305  7001            IAC
5306  3774            DCA I TEM
5307  4407            CLFPNT
5310  5774            FGET I TEM
5311  2645            FSUB I CON1
5312  6774            FPUT I TEM
5313  3773            FMPY I L8
5314  1772            FADD I L7
5315  3774            FMPY I TEM
5316  1771            FADD I L6
5317  3774            FMPY I TEM
5320  1770            FADD I L5
5321  3774            FMPY I TEM
5322  1365            FADD L4
5323  3774            FMPY I TEM
5324  1362            FADD L3
5325  3774            FMPY I TEM
5326  1357            FADD L2
5327  3774            FMPY I TEM
5330  1354            FADD L1
5331  3774            FMPY I TEM
5332  1644            FADD I X1
5333  0000            FEXT
5334  2243            ISZ FLAG1
5335  5651            JMP I FLOG
5336  4642            JMS I NEGIT
5337  7200            CLA
5340  5651            JMP I FLOG
```

```
5341  4407  INVERT,   CLFPNT
5342  5645            FGET I CON1
5343  4774            FDIV I TEM
5344  6774            FPUT I TEM
5345  0000            FEXT
5346  7240            CLA CMA
5347  5274            JMP START
5350  4407  ZERGO,    CLFPNT
5351  5775            FGET I ZERO
5352  0000            FEXT
5353  5651            JMP I FLOG
5354  0000  L1,       0000
5355  3777            3777
5356  7742            7742
5357  7777  L2,       7777
5360  4000            4000
5361  4100            4100
5362  7777  L3,       7777
5363  2517            2517
5364  0307            0307
5365  7776  L4,       7776
5366  4113            4113
5367  7211            7211
5370  5547  L5,       LOG5
5371  5552  L6,       LOG6
5372  5555  L7,       LOG7
5373  5560  L8,       LOG8
5374  5123  TEM,      TEMP
5375  5126  ZERO,     ZER
5376  5544  LOG2,     LOGE2
5377  5563  FLOATP,   FLOA
            /FLOATING POINT SINE
            *5400
5400  0000  FSIN,     0
5401  1045            GETSGN              /X>0?
5402  7740            SMA SZA CLA
5403  5210            JMP MOD             /YES
5404  1045            GETSGN
5405  7700            SMA CLA             /NO  X=0?
5406  5600            JMP I FSIN          /YES SIN(0)=0
5407  4741            JMS I NEGT          /NO:SIN(-X)=-SIN(X)
5410  3343  MOD,      DCA PNTR            /REDUCE X MODULO 2 PI
5411  4407            CLFPNT
5412  4315            FDIV TWOPI
5413  6724            FPUT I XSQ2
5414  0000            FEXT
5415  4742            JMS I FIXR
5416  4363            JMS FLOA
5417  4407            CLFPNT
5420  6723            FPUT I X2
5421  5724            FGET I XSQ2
5422  2723            FSUB I X2
5423  3315            FMPY TWOPI
5424  6723            FPUT I X2
5425  2320            FSUB PI             /X<PI?
5426  0000            FEXT
5427  1045            GETSGN
5430  7710            SPA CLA
5431  5241            JMP PCHECK          /YES
5432  4407            CLFPNT              /NO SIN(X-PI)=-SIN(X)
5433  6723            FPUT I X2
5434  0000            FEXT
```

```
5435  1343            TAD PNTR
5436  7650            SNA CLA
5437  7040            CMA
5440  3343            DCA PNTR
5441  4407  PCHECK,   CLFPNT                /X<PI/2?
5442  5723            FGET I X2
5443  2714            FSUB I PI2
5444  0000            FEXT
5445  1045            GETSGN
5446  7710            SPA CLA
5447  5255            JMP PALG              /YES
5450  4407            CLFPNT                /NO
5451  5320            FGET PI               /SIN(X)=SIN(PI-X)
5452  2723            FSUB I X2
5453  6723            FPUT I X2
5454  0000            FEXT

5455  4407  PALG,     CLFPNT
5456  5723            FGET I X2
5457  4714            FDIV I PI2
5460  6723            FPUT I X2
5461  3723            FMPY I X2
5462  6724            FPUT I XSQ2
5463  5325            FGET C9
5464  3724            FMPY I XSQ2
5465  1330            FADD C7
5466  3724            FMPY I XSQ2
5467  1333            FADD C5
5470  3724            FMPY I XSQ2
5471  1336            FADD C3
5472  3724            FMPY I XSQ2
5473  1714            FADD I PI2
5474  3723            FMPY I X2
5475  0000            FEXT
5476  2343            ISZ PNTR
5477  5600            JMP I FSIN
5500  4741            JMS I NEGT
5501  7200            CLA
5502  5600            JMP I FSIN
                /FLOATING POINT COSINE

5503  0000  FCOS,     0
5504  4407            CLFPNT                /COS(X)=SIN(PI/2-X)
5505  6723            FPUT I X2
5506  5714            FGET I PI2
5507  2723            FSUB I X2
5510  0000            FEXT
5511  1303            TAD FCOS
5512  3200            DCA FSIN
5513  5201            JMP FSIN+1

                /CONSTANTS AND POINTERS

5514  5246  PI2,      PIOT                  /PI/2
5515  0003  TWOPI,    0003
5516  3110            3110
5517  3755            3755
5520  0002  PI,       0002
5521  3110            3110
5522  3755            3755
5523  5115  X2,       X
5524  5120  XSQ2,     XSQR
```

```
                /SINE CONSTANTS
5525  7764  C9,       7764
5526  2366            2366
5527  5735            5735
5530  7771  C7,       7771
5531  5466            5466
5532  6317            6317
5533  7775  C5,       7775
5534  2431            2431
5535  5053            5053
5536  0000  C3,       0000
5537  5325            5325
5540  0420            0420
5541  5110  NEGT,     FNEG
5542  4757  FIXR,     FIX
5543  0000  PNTR,     0

                /LOGARITHM CONSTANTS

5544  0000  LOGE2,    0000
5545  2613            2613
5546  4414            4414
5547  7776  LOG5,     7776
5550  2535            2535
5551  3301            3301
5552  7775  LOG6,     7775
5553  4746            4746
5554  0771            0771
5555  7774  LOG7,     7774
5556  2236            2236
5557  4304            4304
5560  7771  LOG8,     7771
5561  4544            4544
5562  1735            1735
                /FLOAT C(45)
5563  0000  FLOA,     0
5564  7300            CLA CLL
5565  3046            DCA 46
5566  1374            TAD C13
5567  3044            DCA 44
5570  4407            CLFPNT
5571  7000            FNOR
5572  0000            FEXT
5573  5763            JMP I FLOA
5574  0013  C13,      0013
                *4757
                /FIX C(FAC)
4757  0000  FIX,      0
4760  1044            TAD 44
4761  7540            SMA SZA
4762  5365            JMP .+3
4763  7200            CLA
4764  5375            JMP FIXEND
4765  1377            TAD M13
4766  3044            DCA 44
4767  1044  LOOP,     TAD 44
4770  7700            SMA CLA
4771  5757            JMP I FIX
4772  4774            JMS I .+2
4773  5367            JMP LOOP
4774  6200            6200                    /DIVI IN INTERPRETER
```

```
4775  3045  FIXEND,   DCA 45
4776  5757            JMP I FIX
4777  7765  M13,      -13
```

A	5057
ACMINS	5114
ALFZ	5154
ALF1	5157
ALF2	5162
ARCALG	5131
ARCRTN	5226
ARTN	5200
B	5062
BETZ	5165
BET1	5170
BET2	5173
C	5065
CLFPNT	4407
CON1	5245
C13	5574
C3	5536
C5	5533
C7	5530
C9	5525
D	5070
EXIT	5235
FCOS	5503
FEXP	5000
FIX	4757
FIXEND	4775
FIXIT	5106
FIXR	5542
FLAG1	5243
FLAG2	5105
FLOA	5563
FLOAT	5107
FLOATP	5377
FLOG	5251
FNEG	5110
FSIN	5400
GETSGN	1045
GO	5223
INVERT	5341
LG2E	5073
LOGE2	5544
LOG2	5376
LOG5	5547
LOG6	5552
LOG7	5555
LOG8	5560
LOOP	4767
L1	5354
L2	5357
L3	5362
L4	5365
L5	5370
L6	5371
L7	5372
L8	5373
MOD	5410
M13	4777
NEGIT	5242
NEGT	5541
OK	5261
ONE	5076
PALG	5455
PCHECK	5441
PI	5520
PIOT	5246
PI2	5514
PNTR	5543
SIGN	5104
START	5274
TEM	5374
TEMP	5123
TWO	5101
TWOPI	5515
X	5115
XSQR	5120
XSQ2	5524
X1	5244
X2	5523
ZER	5126
ZERGO	5350
ZERO	5375

```
                /FLOATING OUTPUT PROGRAM
                /IF(62)=0, THEN OUTPUT IN E FORMAT
                /ELSE, C(62)=NUMBER OF DIGITS
                /C(AC)=NUMBER OF PLACES TO RIGHT OF .
                /IF C(AC)=0, THEN DON'T OUTPUT POINT
                /SIGN AND . NOT COUNTED IN OUTPUT
                /CONTENTS OF 15 LOST DURING OPERATION

                *7201
7201    4777            JMS I 7377 /ALTERATIONS FLOATING OUTPUT
7202    4217            JMS 7217
7203    1324            TAD 7324
7204    4776            JMS I 7376

                *7207
7207    7200            CLA


                *7227
7227    3415            DCA I 15
7230    7000            NOP
7231    7000            NOP
7232    7000            NOP

                *7301
7301    3415            DCA I 15

                *7305
7305    3415            DCA I 15

                *7376
7376    5412            TGO
7377    5400            EDIT
                *5400
5400    0000    EDIT,   0
5401    3352            DCA SAC
5402    1062            TAD 62
5403    7041            CMA IAC
5404    3347            DCA COUNT1
5405    1357            TAD M8
5406    3350            DCA COUNT2
5407    1363            TAD SAD1
5410    3015            DCA 15
5411    5600            JMP I EDIT
5412    0000    TGO,    0
5413    3044            DCA 44
5414    1363            TAD SAD1
5415    3015            DCA 15
5416    1415            TAD I 15
5417    4761            JMS I OUT1
5420    1062            TAD 62
5421    7650            SNA CLA
5422    5327            JMP EFORM
5423    2212            ISZ TGO
5424    2212            ISZ TGO
5425    1044    TRYAGN, TAD 44
5426    7510            SPA
5427    5300            JMP MINS
5430    1352            TAD SAC
5431    7041            CMA IAC
5432    1062            TAD 62
```

```
5433  7510          SPA
5434  5266          JMP ERR
5435  7450          SNA
5436  5245          JMP G01
5437  7041          CMA IAC
5440  3351          DCA CNTR
5441  1353          TAD SPCE
5442  4321          JMS OUT
5443  2351          ISZ CNTR
5444  5241          JMP .-3

5445  1044  G01,     TAD 44
5446  7041          CMA IAC
5447  7450          SNA
5450  5256          JMP G02
5451  3351          DCA CNTR
5452  4337          JMS GET
5453  4321          JMS OUT
5454  2351          ISZ CNTR
5455  5252          JMP .-3

5456  1352  G02,     TAD SAC
5457  7650          SNA CLA
5460  5263          JMP .+3
5461  1354          TAD PERIOD
5462  4761          JMS I OUT1
5463  4337          JMS GET
5464  4321          JMS OUT
5465  5263          JMP .-2
5466  1352  ERR,     TAD SAC
5467  7700          SMA CLA
5470  5274    .     JMP ERGO
5471  1356          TAD CHX
5472  4321          JMS OUT
5473  5271          JMP .-2

5474  7240  ERGO,    CLA CMA
5475  1352          TAD SAC
5476  3352          DCA SAC
5477  5225          JMP TRYAGN

5500  7200  MINS,    CLA
5501  1062          TAD 62
5502  7041          CMA IAC
5503  1352          TAD SAC
5504  7450          SNA
5505  5313          JMP G03
5506  3351          DCA CNTR
5507  1353          TAD SPCE
5510  4321          JMS OUT
5511  2351          ISZ CNTR
5512  5307          JMP .-3

5513  1354  G03,     TAD PERIOD
5514  4761          JMS I OUT1
5515  4321          JMS OUT
5516  2044          ISZ 44
5517  5315          JMP .-2
5520  5263          JMP G02+5
5521  0000  OUT,     0
5522  4762          JMS I OUT2
```

```
5523  2347             ISZ COUNT1
5524  5721             JMP I OUT
5525  1355             TAD CHE
5526  5612             JMP I TGO

5527  4762  EFORM,     JMS I OUT2
5530  1354             TAD PERIOD
5531  4761             JMS I OUT1
5532  1360             TAD M7
5533  3347             DCA COUNT1
5534  4337             JMS GET
5535  4321             JMS OUT
5536  5334             JMP .-2

5537  0000  GET,       0
5540  2350             ISZ COUNT2
5541  5345             JMP .+4
5542  7240             CLA CMA
5543  3350             DCA COUNT2
5544  5737             JMP I GET
5545  1415             TAD I 15
5546  5737             JMP I GET
5547  0000  COUNT1,     0
5550  0000  COUNT2,     0
5551  0000  CNTR,       0
5552  0000  SAC,        0
5553  7760  SPCE,       240-260
5554  0256  PERIOD,     256
5555  0305  CHE,        305
5556  0050  CHX,        330-260
5557  7770  M8,         -10
5560  7771  M7,         -7
5561  7344  OUT1,       7344
5562  7352  OUT2,       7352
5563  5563  SAD1,       BUFFER-1
            BUFFER,
BUFFER  5564
CHE     5555
CHX     5556
CNTR    5551
COUNT1  5547
COUNT2  5550
EDIT    5400
EFORM   5527
ERGO    5474
ERR     5466
GET     5537
GO1     5445
GO2     5456
GO3     5513
MINS    5500
M7      5560
M8      5557
OUT     5521
OUT1    5561
OUT2    5562
PERIOD  5554
SAC     5552
SAD1    5563
SPCE    5553
TGO     5412
TRYAGN  5425
```