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CONTENTS

1. Single Precision Square Root, DEC-08-FMAA-D

2. ABSTRACT

This subroutine will extract the square root of a single-precision integer. Given an input N ($0 \leq N < 2^{12}$), it will produce an integer K and a remainder R, such that $N = K^2 + R$.

3. REQUIREMENTS

3.1 Storage

This subroutine uses 23 (decimal) memory locations.

3.3 Equipment

Standard PDP-8

4. USAGE

4.1 Loading

The library tape that is supplied is a symbolic tape. It does not begin with an origin setting, although it does end with a dollar sign. The binary tape produced by assembling this tape, or the binary tape produced by assembling this tape with other tapes, is loaded with the Binary Loader.

4.2 Calling Sequence

This subroutine is called with an effective JMS SQRT with the argument in the accumulator. The subroutine returns control to the location following the JMS with the answer in the accumulator and with the remainder in the register tagged SQR1.

6. DESCRIPTION

6.2 Examples and/or Applications

The following program will illustrate the use of this subroutine:

```
400
        CLA
        TAD   X
        JMS   I        SQRTPT
        HLT

X,            0145     (1101     DECIMAL)
SQRTPT,       SQRT
```

This sample program will halt at location 403 with 0012 (octal) or 10 (decimal) in the accumulator. Register SQR1 (address 0222) will contain 0001, the remainder.

7. METHODS

7.2 Algorithm

The algorithm makes use of the fact that the sum of the odd integers is a square:

$$\sum_{K=1}^{N} (2K-1) = 2 \sum_{K=1}^{N} K - \sum_{K=1}^{N} 1 = 2\left(\frac{N}{2}\right)(N+1) - N = N^2$$

9. EXECUTION TIME

9.4 Timing Equation

If the answer is N, the time for the subroutine is

(30 + N (25.5)) μsec

10. PROGRAM

10.4 Program Listing

```
                        /DEC 08-FMAA-LA
                        /SQUARE ROOT ,...,.. ENTER WITH SQUARE IN AC
                        /                    EXITS WITH ROOT IN AC
                        /          ODD INTEGER METHOD
0200   0000             SQRT,      0
0201   3222                        DCA SQR1          /SAVE INPUT
0202   3226                        DCA ROOT          /0 TO ANSWER
0203   1223                        TAD SQR2          /-1; FIRST ATTEMPT
0204   3225             SQX,       DCA SQRD
0205   1222                        TAD SQR1          /COMPARE INPUT
0206   7100                        CLL               /WITH THIS TRY
0207   1225                        TAD SQRD
0210   7420                        SNL
0211   5217                        JMP SQRF          /TEST>INPUT; ALL DONE
0212   2226                        ISZ ROOT          /ADD +1 TO ANSWER
0213   3222                        DCA SQR1          /INPUT=INPUT-TEST
0214   1225                        TAD SQRD
0215   1224                        TAD SQR3          /TEST=TEST-2
0216   5204                        JMP SQX           /CONTINUE
0217   7200             SQRF,      CLA
0220   1226                        TAD ROOT          /FETCH ANSWER
0221   5600                        JMP I SQRT        /EXIT
0222   0000             SQR1,      0
0223   7777             SQR2,      -1
0224   7776             SQR3,      -2
0225   0000             SQRD,      0
0226   0000             ROOT,      0

                                   PAUSE

                             $



THERE ARE NO ERRORS



          SYMBOL TABLE

          ROOT       0226
          SQRD       0225
          SQRF       0217
          SQRT       0200
          SQR1       0222
          SQR2       0223
          SQR3       0224
          SQX        0204
```

1. Signed Multiply Subroutine - Single Precision, DEC-08-FMBA-D.

2. ABSTRACT

This subroutine forms a 22-bit signed product from 11-bit signed multiplier and multiplicand.

3. REQUIREMENTS

3.1 Storage

This subroutine uses 44 (decimal) memory locations.

4. USAGE

4.1 Loading

The library tape that is supplied is a symbolic tape. It does not begin with an origin setting, although it does end with a dollar sign. The binary tape produced by assembling this tape, or the binary tape produced by assembling this tape with other tapes, is loaded with the Binary Loader.

4.2 Calling Sequence

The subroutine is called by an effective JMS MULT. When the JMS is executed to enter the subroutine, the multiplier must be in the accumulator (AC). The location following the JMS must contain the multiplicand. The subroutine returns to the instruction immediately following the latter location with the most significant part of the product in the AC. The least significant part of the product is stored in location MP1.

6. DESCRIPTION

6.1 Discussion

Reference to the flow chart (11.1) will illustrate the following discussion.

6.1.1 On entry, the sign of the multiplier is tested, and if negative, the multiplier is made positive.

6.1.2 The multiplicand is obtained and tested for 0. If it equals 0, a jump to the exit is executed. Next the sign of the multiplicand is tested, and if it is negative, the multiplicand is made positive.

6.1.3 At this point, the content of the link is as follows:

Sign of Multiplier	Sign of Multiplicand	Link
0	0	0
0	1	1
1	0	1
1	1	0

andrepresents, therefore, the sign of the product.

6.1.4 The multiplication loop proper (tagged MP4) is entered. During this loop, the least significant half of the product shifts into the most significant end of MP1, while the multiplier shifts out the least significant end of MP1 and is lost. Note that the sign of the product is retained in MP1.

6.1.5 The sign of the product is tested. If positive, the subroutine exits. If negative, complementation of the product is performed before the exit.

6.2 Examples or Applications

Example (See 11.1 Flow Chart)

The C(Y) are tested. If C(Y) = 0, C(MP1) = C(MP5) = 0. If C(Y) $\neq$ 0, C(Y)→ C(MP2), C(MP5) are cleared and mulitplication is carried out as described below.

If $C(MP1)_{11}$ contains a 1, C(MP2) are added to C(MP5). The contents of MP5 and the MP1 are then shifted right one bit. If $C(MP1)_{11}$ = 0, the contents of MP5 and those of the MP1 are shifted right one bit.

For this example, assume that the registers MP1, MP5, and MP2 are five bits in length instead of 11. The following sequential steps occur in a multiply operation. The multiplicand is 9 and the multiplier is 4.

MP5	MP1	Y	Comments
00000	01001	00100	Initial contents of the register MP1 ready to be tested.
00100	01001		C(MP2) + C(MP5) → C(MP5) since C(MP1) is a 1.
00010	00100		C(MP5, MP1) rotated right one place. $C(MP1)_{11}$ is tested.
00001	00010		No addition, because $C(MP1)_{11}$ is 0. C(MP5, MP2) rotated right one bit and AC_{11} is tested.
00000	10001		No addition, $C(MP1)_{11}$ = 0, C(MP5, MP1) rotated right one bit. $C(MP1)_{11}$ is tested.
00100	10001		C(MP2) + C(MP5) → C(MP5) since $C(MP1)_{11}$ is a 1.
00010	01000		C(MP5, MP1) rotated right.
00001	00100		No addition, $C(MP1)_{11}$ = 0, C(MP5, MP1) rotated right one bit. Rotation counter indicates that the multiplication is complete since it has been reduced to 0.

6.3 Scaling

Upon entry the binary point is assumed to be located between bit positions 0 and 1 in both multiplier and multiplicand. Since there are 11 magnitude bits in each of the two factors, the product contains 22 magnitude bits.

The product is double signed; i.e., bit positions 0 and 1 of the most significant word of the product both contain the sign. The remaining ten bits of the most significant word of the product are magnitude bits.

The least significant word of the product is devoted entirely to magnitude.

If the binary points of the factors are as stated above, the binary point of the product will be located between bit positions 1 and 2 in the most significant position of the product.

On entry, multiplier and multiplicand must be 2s complement binary. After return, the product is contained in two words in 2s complement form.

For more information on binary scaling for fixed-point computers, see Application Note 501.

7. METHOD

7.1 Algorithm

The conventional algorithm is used. The least significant bit of the multiplier is tested. If it is equal to 1, the multiplicand is added to the developing product and this quantity is shifted right. If the least significant bit of the multiplier is 0, no addition is made before the shift. The process is repeated until all bits of the multiplier in order from least significant to most significant have been processed.

9. EXECUTION TIME

9.1 Minimum

When the subroutine discovers that the multiplicand is 0, it bypasses the multiplication loop. In this case, execution time is 25.5 μsec if the multiplier is positive and 27.0 μsec if the multiplier is negative.

9.2 Maximum

Maximum execution time occurs when the sign of the product is negative and the multipl consists (in binary) of all 1s. This time is approximately 350 μsec.

10. PROGRAM

10.4 Program Listing

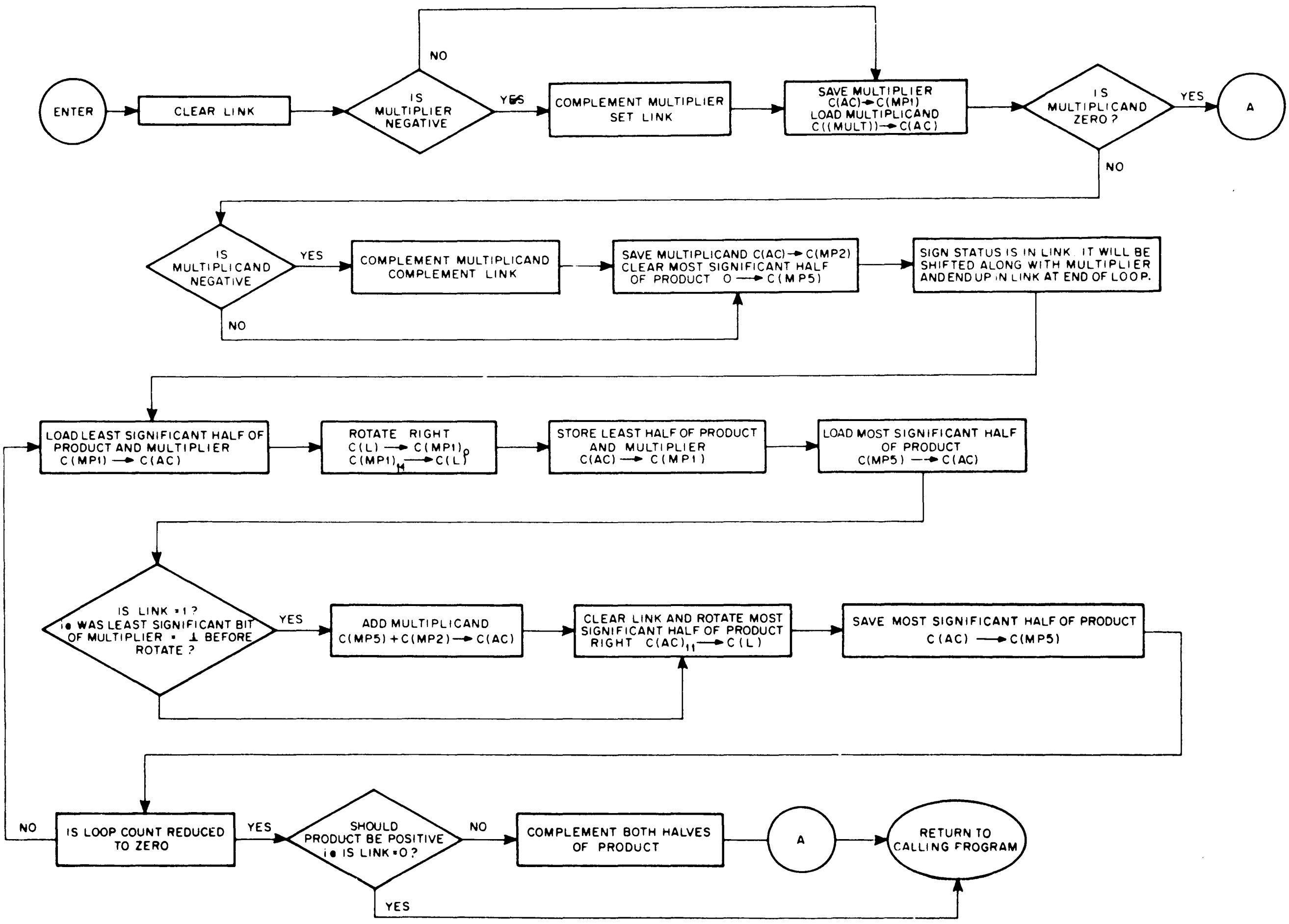
```
                                  /DEC-Ø8-FMBA
                                  /TWO'S COMPLEMENT SINGLE PRECISION MULTIPLY ROUTINE
                                  /RETURN HIGH ORDER PRODUCT IN AC, LOW IN MP1

Ø2ØØ   ØØØØ         MULT,     Ø
Ø2Ø1   71ØØ                   CLL
Ø2Ø2   751Ø                   SPA                 /TEST FOR NEGATIVE MULTIPLIER
Ø2Ø3   7Ø61                   CMA CML IAC
Ø2Ø4   325Ø                   DCA MP1             /STORE MULTIPLIER
Ø2Ø5   3251                   DCA MP5
Ø2Ø6   16ØØ                   TAD I MULT
Ø2Ø7   745Ø                   SNA                 /TEST FOR ZERO MULTIPLICAND
Ø21Ø   5234                   JMP MPSN+2     /JMP IF MULTIPLICAND=Ø
Ø211   751Ø                   SPA                 /TEST FOR NEGATIVE MULTIPLICAND
Ø212   7Ø61                   CMA CML IAC
Ø213   3252                   DCA MP2             /STORE MULTIPLICAND
Ø214   1247                   TAD THIR
Ø215   3253                   DCA MP3
Ø216   125Ø         MP4,      TAD MP1        /MULTIPLY LOOP PROPER
Ø217   7Ø1Ø                   RAR
Ø22Ø   325Ø                   DCA MP1
Ø221   1251                   TAD MP5
Ø222   743Ø                   SZL                 /TEST IF MULTIPLICAND SHOULD BE ADDED
Ø223   1252                   TAD MP2
Ø224   711Ø                   CLL RAR
Ø225   3251                   DCA MP5
Ø226   2253                   ISZ MP3             /TEST FOR END OF LOOP
Ø227   5216                   JMP MP4
Ø23Ø   125Ø                   TAD MP1
Ø231   7Ø1Ø                   RAR
Ø232   743Ø         MPSN,     SZL
Ø233   524Ø                   JMP COMP
Ø234   325Ø                   DCA MP1
Ø235   1251                   TAD MP5
Ø236   22ØØ         MPZ,      ISZ MULT            /EXIT TO CALLING PROGRAM
Ø237   56ØØ                   JMP I MULT
Ø24Ø   7141         COMP,     CMA CLL IAC         /COMPLEMENT PRODUCT
Ø241   325Ø                   DCA MP1
Ø242   1251                   TAD MP5
Ø243   7Ø4Ø                   CMA
Ø244   743Ø                   SZL
Ø245   7ØØ1                   IAC
Ø246   5236                   JMP MPZ
Ø247   7764         THIR,     7764                /ELEVEN IN DECIMAL
Ø25Ø   ØØØØ         MP1,      Ø
Ø251   ØØØØ         MP5,      Ø
Ø252   ØØØØ         MP2,      Ø
Ø253   ØØØØ         MP3,      Ø

                    PAUSE
```

SYMBOL TABLE

COMP	0240
MPSN	0232
MPZ	0236
MP1	0250
MP2	0252
MP3	0253
MP4	0216
MP5	0251
MULT	0200
THIR	0247

11. DIAGRAMS

11.1 Flow Chart



1. Single Precision Signed Divide Subroutine, DEC-08-FMCA-D

2. ABSTRACT

The Single-Precision Divide Subroutine will divide a 12-bit signed divisor into a 24-bit signed dividend to produce a 12-bit signed quotient and a 12-bit signed remainder.

3. REQUIREMENTS

3.1 Storage

This subroutine requires 62 (decimal) memory locations. It is provided in two forms: binary tape assembled with an origin of 0200, and a symbolic tape with no origin setting and ending with a dollar sign.

4. USAGE

4.1 Loading

This subroutine requires 62 (decimal) memory locations. It is provided as a symbolic tape with no origin setting and ending with a dollar sign.

4.2 Calling Sequence

The subroutine is called with an effective JMS DIVIDE. The accumulator contains the high-order bits of the dividend; the location following the JMS contains the low-order bits of the dividend; the location following this contains the divisor; and the subroutine returns to the following location with the quotient in the accumulator and the remainder in C(HDIVND). If a divide error has occurred, C(L) = 1 and the accumulator contains 0, otherwise C(L) = 0.

```
        TAD    HIGH D           /C(AC) = HIGH DIVIDEND
        JMS    I    DIVDP       /CALL DIVIDE
        LOWD                    /LOW DIVIDEND
        DIVSOR                  /DIVISOR
        HLT                     /C(AC) = QUOTIENT IF L = 0
DIVDP,  DIVIDE                  /(0200)
HIGHD,                          /HIGH DIVIDEND
```

4.5 Errors in Usage

There are two types of errors that may be encountered in using the divide subroutine, the first of which is tested by the routine. The divide may be represented as:

$$\frac{(\text{High-Order Dividend}) \cdot 2^{12} + \text{Low-Order Dividend}}{\text{Divisor}}$$

$$= \text{Quotient, Remainder}$$

or

$$(\text{High-Dividend}) \cdot 2^{12} + \text{Low-Dividend} = (\text{Quotient})\ (\text{Divisor}) + \text{Remainder}.$$

Since (Quotient) ≤ 3777(8), it is possible that a divisor and dividend are so specified that no quotient may be found that satisifies this identity. If High-Order Dividend ≥ Quotient, then the divide will not take place and C(L) will be 1. There are cases, however, that are not detected by this test. For example:

$$\frac{1777 \quad 7777}{2000}$$

Since (3777) (2000) + 3777 = 1000 1777, there is no possible quotient that when multiplied by the divisor will yield the dividend.

5. RESTRICTIONS

See Section 4.5.

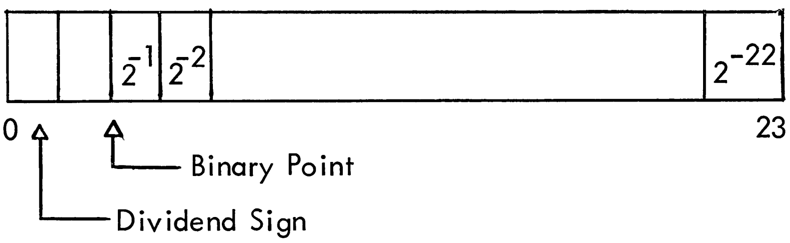
6. DESCRIPTION

6.1 Discussion

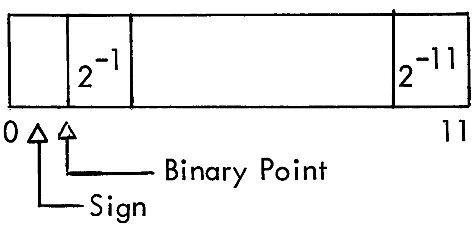
The algorithm works by shifting the dividend left and comparing it with the divisor. If Dividend ≥ Divisor then Dividend = Dividend-Divisor, and a bit is set in the quotient. This is repeated the proper number of times. The remainder will have the same sign as the dividend, and the quotient will be signed properly: (Dividend Sign) XOR (Divisor Sign) = (Quotient Sign).

6.3 Scaling

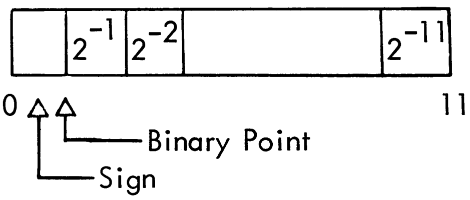
The Single-Precision Divide Subroutine is scaled analogous to the scaling of the Single-Precision Multiply Subroutine (DEC-08-FMBA, previously Digital-8-11-F). It may be thought of as either an integer divide or a fractional divide.



Dividend (2's Complement)



Divisor (2's Complement)

= 

Quotient (2's Complement)

If High-Order Dividend = HD
Low-Order Dividend = LD
Quotient = Q
Remainder = R
Divisor = D

$$\frac{HD \cdot 2^{12} + LD}{D} = Q, R$$

so that $Q \cdot D + R = (HD) \cdot 2^{12} + (LD)$

or

$$\frac{(HD \cdot 2^{12} + LD) \cdot 2^{-22}}{D \cdot 2^{-11}} = Q \cdot 2^{-11}, R \cdot 2^{-11}$$

Examples:

(a)

$$\frac{000\ 000\ 000\ 000\ 000\ 000\ 000\ 111}{000\ 000\ 000\ 011} = 000\ 000\ 000\ 010$$

Remainder = 000 000 000 001

$$\frac{7}{3} = 2,\ 1$$

(b)

$$\frac{000\ 100\ 000\ 000\ 000\ 000\ 000\ 000}{010\ 000\ 000\ 000} = 010\ 000\ 000\ 000$$

Remainder = 000 000 000 000

$$\frac{\frac{1}{4}}{\frac{1}{2}} = \frac{1}{2}$$

7. METHODS (See Above)

9. EXECUTION TIME

9.1 Minimum 58.5 μsec (Divide Check)

9.2	Maximum	478.5 μsec
9.3	Average	≈ 460 μsec

10. PROGRAM

10.4 Program Listing

```
                    /DEC-Ø8-FMCA-LA
                    /SIGNED SINGLE PRECISION DIVIDE SUBROUTINE
                    /CALLING SEQUENCE:
                    /         C(AC) CONTAINS HIGH ORDER DIVIDEND
                    /         JMS DIVIDE
                    /         LOW ORDER DIVIDEND
                    /         DIVISOR
                    /         RETURN: C(AC)=QUOTIENT; REMAINDER IN  HDIVND
                    /IF HIGH ORDER DIVIDEND IS EQUAL TO OR GREATER
                    /THAN THE DIVISOR; NO DIVISION TAKES PLACE AND C(L)=1

                    /PAGE 1

Ø2ØØ  ØØØØ          DIVIDE,   Ø
Ø2Ø1  71ØØ                    CLL
Ø2Ø2  751Ø                    SPA                 /DIVIDEND<Ø?
Ø2Ø3  7Ø6Ø                    CMA CML             /YES COMPLEMENT AND SET C(L)
Ø2Ø4  3267                    DCA HDIVND          /HIGH ORDER DIVIDEND
Ø2Ø5  742Ø                    SNL
Ø2Ø6  7Ø4Ø                    CMA
Ø2Ø7  3272                    DCA SDVND           /SET DIVIDEND SIGN SWITCH
Ø21Ø  16ØØ                    TAD I DIVIDE        /FETCH LOW ORDER DIVIDEND
Ø211  743Ø                    SZL
Ø212  7141                    CMA CLL IAC         /YES: COMPLEMENT
Ø213  327Ø                    DCA LDIVND          /LOW ORDER DIVIDEND
Ø214  743Ø                    SZL                 /CARRY?
Ø215  2267                    ISZ HDIVND          /YES
Ø216  22ØØ                    ISZ DIVIDE
Ø217  16ØØ                    TAD I DIVIDE        /FETCH DIVISOR
Ø22Ø  71ØØ                    CLL
Ø221  75ØØ                    SMA
Ø222  7Ø61                    CMA CML IAC         /NEGATE IT
Ø223  3271                    DCA DIVSOR          /SAVE DIVISOR
Ø224  742Ø                    SNL                 /WAS IT <Ø?
Ø225  7Ø4Ø                    CMA                 /YES: AC=-1
Ø226  1272                    TAD SDVND
Ø227  3273                    DCA SNSWER          /ANSWER SIGN SWITCH
Ø23Ø  71ØØ                    CLL
Ø231  1271                    TAD DIVSOR          /COMPARE DIVISOR
Ø232  1267                    TAD HDIVND          /WITH DIVIDEND
Ø233  22ØØ                    ISZ DIVIDE
Ø234  763Ø                    SZL CLA             /OVER FLOW?
Ø235  56ØØ                    JMP I DIVIDE        /YES: DIVISOR<DIVIDEND
```

```
                        /PAGE 2

0236   1275                   TAD M13              /13 SHIFTS
0237   3274                   DCA DIVCNT
0240   5251                   JMP DV2

                        /DIVIDE LOOP

0241   1267             DV3,  TAD HDIVND
0242   7004                   RAL
0243   3267                   DCA HDIVND           /DIVIDEND LEFT SHIFT
0244   1267                   TAD HDIVND
0245   1271                   TAD DIVSOR           /COMPARE DIVISOR:DIVIDEND
0246   7430                   SZL
0247   3267                   DCA HDIVND           /REMAINDER AFTER SUBTRACT
0250   7200                   CLA
0251   1270             DV2,  TAD LDIVND           /QUOTIENT BITS
0252   7004                   RAL                  /ENTER HERE
0253   3270                   DCA LDIVND
0254   2274                   ISZ DIVCNT           /DONE 12?
0255   5241                   JMP DV3              /NO: CONTINUE
0256   1267                   TAD HDIVND           /REMAINDER
0257   2272                   ISZ SDVND            /DIVIDEND<0?
0260   7041                   CMA IAC              /YES
0261   3267                   DCA HDIVND
0262   1270                   TAD LDIVND           /QUOTIENT
0263   2273                   ISZ SNSWER           /ANSWER<0?
0264   7041                   CMA IAC              /YES: NEGATE
0265   7100                   CLL
0266   5600                   JMP I DIVIDE         /EXIT

0267   0000             HDIVND, 0
0270   0000             LDIVND, 0
0271   0000             DIVSOR, 0
0272   0000             SDVND,  0
0273   0000             SNSWER, 0
0274   0000             DIVCNT, 0
0275   7763             M13,    -15            /-13(10)

                        $

SYMBOL TABLE

DIVCNT      0274
DIVIDE      0200
DIVSOR      0271
DV2         0251
DV3         0241
HDIVND      0267
LDIVND      0270
M13         0275
SDVND       0272
SNSWER      0273
```

1. Signed Double Precision Multiply, DEC-08-FMDA-D

2. ABSTRACT

This subroutine forms a 46-bit signed product from the 23-bit signed multiplier and multiplicand.

3. REQUIREMENTS

3.1 Storage

This subroutine uses 125 (decimal) memory locations.

4. USAGE

4.2 Calling Sequence

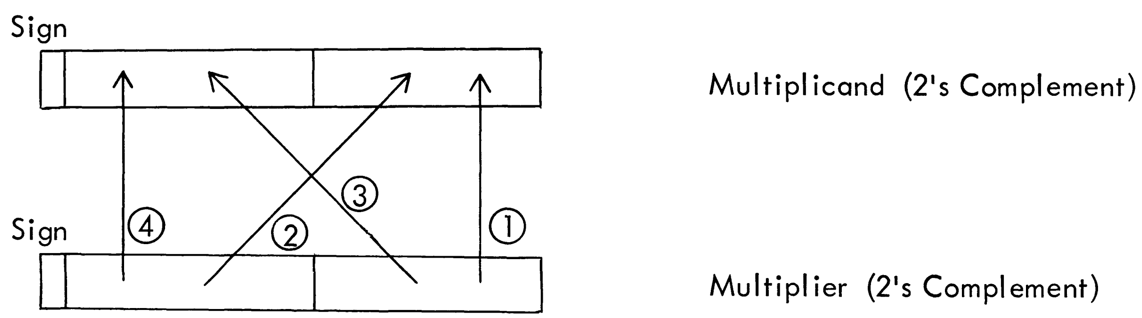
The signed double precision multiply routine is called by an effective JMS DMUL. The two locations following the JMS must contain the address of the high-order multiplicand and the address of the high-order multiplier respectively.

The subroutine will return to the instruction immediately following the latter location, with the most significant portion of the answer in the accumulator. The low order portions of the answer will be in registers (from high to low) B, C, and D.

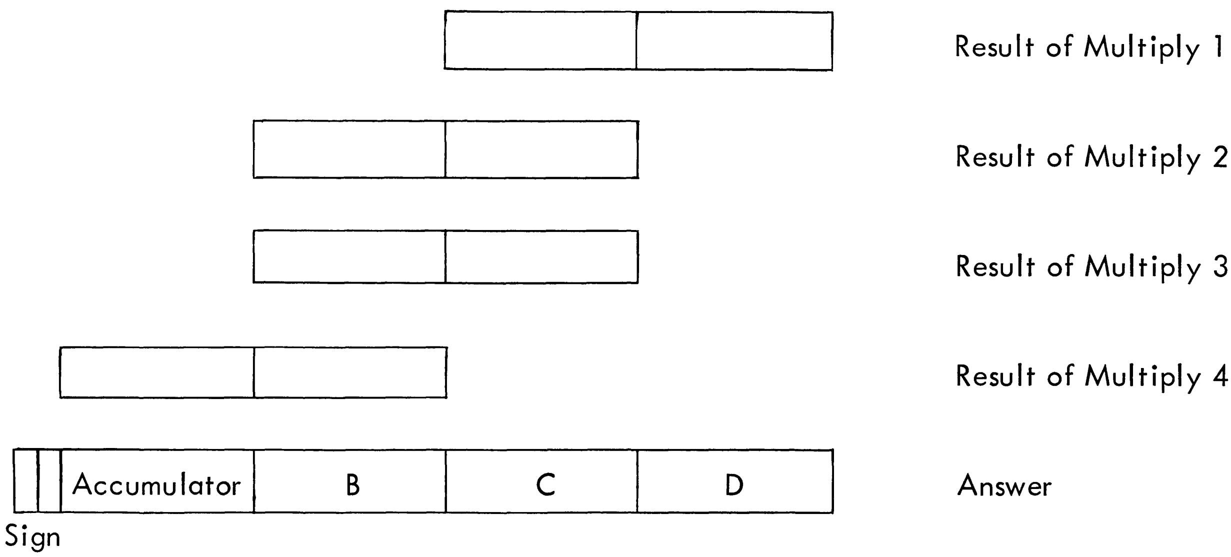
6. DESCRIPTION

6.1 Discussion

The double precision multiply routine calls a single precision multiply routine four times after the absolute values of the multiplier and multiplicand have been taken.



The results are added:



6.2 Examples

To multiply two double precision numbers which are located in registers tagged X and Y:

```
0400
            JMS   I   DMULTP
            X
            Y
            HLT
X,          0
            0
Y,          0
            0
DMULTP,     DMUL
```

If X and Y contained:

X	0000	0012	6000	0000
Y	0000	0012	3000	0000

The answers would be:

0000	0000	0000	0144	7200	0000	0000	0000
AC	B	C	D	AC	B	C	D

For further examples see the Double Precision Sine Routine, DEC-08-FMFA formerly Digital-8-16-F.

6.3 Scaling

Since there are 23 magnitude bits in both the multiplier and the multiplicand, the product will contain 46 magnitude bits. These are right justified in the AC and B, C, and D registers. Since the answer is in 2's complement form, the two sign bits are equal (redundant).

The multiply routine may be thought of as an integer multiplication, as a fraction multiplication, or as any combination of these. When the double precision multiply routine is given two 23-bit numbers, it produces a 46-bit product that is right justified. If the scaling is

(XXXX XXX.X) (XXXX XXXX.)

the scaling of the answer will be

XXXX XXXX XXXX XXX.X

The operands and the answer are in 2's complement form. Since only 46 bits of product may be produced and since the answer is right-justified, the two "sign" bits (0 and 1) are redundant.

7. METHODS

7.1 See the Single Precision Multiply Routine write-up, DEC-08-FMBA formerly Digital-8-11-F.

9. EXECUTION TIME

The execution time is a function of the number of 1's in the operands.

The maximum execution time is 1.605 msec. Average time will be around 1.4 msec.

10. PROGRAM

The subroutine occupies approximately one memory page and may be located on any page. The symbolic library tape does not start with an origin setting, but does end with a dollar sign.

10.4 Program Listing

```
                              /DEC-Ø8-FMDA-LA
                              /SIGNED DOUBLE PRECISION MULTIPLY ROUTINE
                              /CALLING SEQUENCE:
                              /       JMS DMUL
                              /       ADDRESS OF MULTIPLICAND(HIGH ORDER)
                              /       ADDRESS OF MULTIPLIER(HIGH ORDER)
                              /       RETURN, HIGH ORDER PRODUCT IN AC
                              /       NEXT HIGH TO LOW IN B,C,D
                              /PAGE 1
Ø2ØØ  ØØØØ                    DMUL,    Ø
Ø2Ø1  73ØØ                             CLL CLA
Ø2Ø2  1353                             TAD REST        /-2
Ø2Ø3  3352                             DCA SIGNSW      /SET SIGN SWITCH
Ø2Ø4  43Ø6                             JMS TSIGN       /FETCH AND SET SIGN
Ø2Ø5  1337                             TAD MLTH        /RESULT IN MLTH,MLTL
Ø2Ø6  3334                             DCA MULTH       /HIGH ORDER MULTIPLICAND
Ø2Ø7  1336                             TAD MLTL
Ø21Ø  3335                             DCA MULTL       /LOW ORDER MULTIPLICAND
Ø211  43Ø6                             JMS TSIGN       /FETCH AND SET SIGN
Ø212  1335                             TAD MULTL       /LOW ORDER MULTIPLICAND
Ø213  33Ø1                             DCA MP2
Ø214  1336                             TAD MLTL        /LOW ORDER MULTIPLIER
Ø215  4344                             JMS MP4         /MULTIPLY
Ø216  3343                             DCA D           /LOW ORDER
Ø217  1373                             TAD MP5
Ø22Ø  3342                             DCA C           /HIGH ORDER
Ø221  1334                             TAD MULTH       /HIGH ORDER MULTIPLICAND
Ø222  33Ø1                             DCA MP2
Ø223  1336                             TAD MLTL        /LOW ORDER MULTIPLIER
Ø224  4344                             JMS MP4         /MULTIPLY
Ø225  1342                             TAD C
Ø226  3342                             DCA C
Ø227  7ØØ4                             RAL             /GET CARRY
Ø23Ø  1373                             TAD MP5
Ø231  3341                             DCA B
Ø232  7ØØ4                             RAL             /GET CARRY
Ø233  334Ø                             DCA A
Ø234  1335                             TAD MULTL       /LOW ORDER MULTIPLICAND
Ø235  33Ø1                             DCA MP2
Ø236  1337                             TAD MLTH        /HIGH ORDER MULTIPLIER
Ø237  4344                             JMS MP4         /MULTIPLY
Ø24Ø  1342                             TAD C
Ø241  3342                             DCA C           /ADD
```

```
                    /PAGE 2

0242   7004              RAL                 /GET CARRY
0243   1373              TAD MP5
0244   1341              TAD B
0245   3341              DCA B
0246   7004              RAL                 /GET CARRY
0247   1340              TAD A
0250   3340              DCA A               /ADD
0251   1334              TAD MULTH           /HIGH ORDER MULTIPLICAND
0252   3301              DCA MP2
0253   1337              TAD MLTH            /HIGH ORDER MULTIPLIER
0254   4344              JMS MP4
0255   1341              TAD B
0256   3341              DCA B
0257   7004              RAL
0260   1373              TAD MP5
0261   1340              TAD A
0262   2332              ISZ SIGNSW          /ANSWER <0??
0263   5600              JMP I DMUL          /NO: EXIT
0264   3340              DCA A               /YES
0265   1343              TAD D
0266   7141              CMA CLL IAC         /NEGATE
0267   3343              DCA D
0270   1342              TAD C               /NEGATE
0271   4301              JMS COM
0272   3342              DCA C
0273   1341              TAD B
0274   4301              JMS COM             /NEGATE
0275   3341              DCA B
0276   1340              TAD A
0277   4301              JMS COM
0300   5600              JMP I DMUL          /EXIT

                  MP2,
0301   0000       COM,   0
0302   7040              CMA
0303   7430              SZL
0304   7101              CLL IAC
0305   5701              JMP I COM
```

```
                                /PAGE 3
                                MP1,
Ø3Ø6   ØØØØ                     TSIGN,   Ø
Ø3Ø7   16ØØ                              TAD I DMUL       /FETCH ADDRESS
Ø31Ø   334Ø                              DCA ADDRS
Ø311   174Ø                              TAD I ADDRS      /FETCH HIGH ORDER
Ø312   71ØØ                              CLL
Ø313   751Ø                              SPA              /IS IT <Ø?
Ø314   7Ø6Ø                              CMA CML          /YES: COMPLEMENT, SET LINK
Ø315   3337                              DCA MLTH
Ø316   234Ø                              ISZ ADDRS
Ø317   174Ø                              TAD I ADDRS      /FETCH LOW ORDER
Ø32Ø   743Ø                              SZL              /WAS IT <Ø?
Ø321   2332                              ISZ SIGNSW       /YES, ADD 1 TO SWITCH
Ø322   7ØØØ                              NOP
Ø323   743Ø                              SZL
Ø324   7141                              CMA CLL IAC      /COMPLEMENT, CLEAR LINK
Ø325   3336                              DCA MLTL
Ø326   743Ø                              SZL              /CARRY?
Ø327   2337                              ISZ MLTH         /YES
Ø33Ø   22ØØ                              ISZ DMUL
Ø331   57Ø6                              JMP I TSIGN      /EXIT ROUTINE

Ø332   ØØØØ                     SIGNSW,  Ø
Ø333   7776                     RESI,    -2
Ø334   ØØØØ                     MULIH,   Ø
Ø335   ØØØØ                     MULIL,   Ø
Ø336   ØØØØ                     MLTL,    Ø
Ø337   ØØØØ                     MLTH,    Ø
                                ADDRS,
Ø34Ø   ØØØØ                     A,       Ø
Ø341   ØØØØ                     B,       Ø
Ø342   ØØØØ                     C,       Ø
Ø343   ØØØØ                     D,       Ø
```

```
                              /PAGE 4

 0344  0000                   MP4,    0              /UNSIGNED MULTIPLY
 0345  3306                           DCA MP1
 0346  3373                           DCA MP5
 0347  1374                           TAD M12        /COUNT 12 BITS
 0350  3372                           DCA MP3
 0351  7100                           CLL
 0352  1306                           TAD MP1        /CARRY GOES INTO
 0353  7010                           RAR            /LEFT OF MP1
 0354  3306                           DCA MP1        /TEST MULTIPLIER BIT
 0355  1373                           TAD MP5
 0356  7420                           SNL            /A 1?
 0357  5362                           JMP .+3        /NO: DON'T ADD
 0360  7100                           CLL            /YES: ADD
 0361  1301                           TAD MP2
 0362  7010                           RAR
 0363  3373                           DCA MP5
 0364  2372                           ISZ MP3        /DONE 12 BITS?
 0365  5352                           JMP MP4+6      /NO: CARRY IS IN C(L)
 0366  1306                           TAD MP1        /YES: DONE
 0367  7010                           RAR
 0370  7100                           CLL
 0371  5744                           JMP I MP4      /EXIT

 0372  0000                   MP3,    0
 0373  0000                   MP5,    0
 0374  7764                   M12,    -14

                              PAUSE

SYMBOL TABLE

A         0340
ADDRS     0340
B         0341
C         0342
COM       0301
D         0343
DMUL      0200
MLTH      0337
MLTL      0336
MP1       0306
MP2       0301
MP3       0372
MP4       0344
MP5       0373
MULTH     0334
MULTL     0335
M12       0374
REST      0333
SIGNSW    0332
TSIGN     0306
```

1. Double Precision Signed Divide Subroutine, DEC-08-FMEA-D.

2. ABSTRACT

The Double-Precision Divide Subroutine will divide a 24-bit signed divisor into a 48-bit signed dividend to produce a 24-bit signed quotient and an unsigned remainder.

3. REQUIREMENTS

3.1 Storage

This subroutine requires 105 (decimal) memory locations. It is provided in two forms: a binary tape assembled with an origin of 0200 and, a symbolic tape with no origin setting.

4. USAGE

4.1 Loading

The subroutine is loaded with the Binary Loader (Digital-8-2-U). The symbolic is either assembled with the user program or separately with the proper origin setting.

4.2 Calling Sequence

The subroutine is called with an effective JMS DUBDIV with the address of the high-order word of the dividend (address of the dividend) in the accumulator, followed by the address of the high-order word of the divisor (address of the divisor). Control returns to the calling program at the address of the JMS plus 2.

```
        TAD     HIGH
        JMS     I       DDIVP
        LOW
        HLT
        .
        .
        .
DDIVP,  DUBDIV
HIGH,   . + 1           /ADDRESS OF DIVIDEND
        0               /DIVIDEND
        0
        0
        0
LOW,    0               /DIVISOR
        0
```

The high-order quotient is returned in the accumulator and the remaining bits of the answer are found as follows:

C(DIVND4) = Low-order quotient
C(DIVND1) = High-order remainder
C(DIVND2) = Low-order remainder

The quotient is signed, while the remainder is left unsigned.

4.5 Errors in Usage

Since the division process may be represented as:

$$\frac{\text{Dividend}}{\text{Divisor}} = \text{Quotient, Remainder}$$

such that:

Dividend = (Quotient) (Divisor) + Remainder

It is possible to specify a dividend and a divisor such that the quotient cannot be contained within the word size (in this case, 23 bits). If this is true, the results will be nonvalid. This condition is not tested by the Double-Precision Divide Subroutine. (For a more complete description, see DEC-08-FMCA, formerly Digital-8-12-F, Section 4.5.)

5. RESTRICTIONS

See Section 4.5.

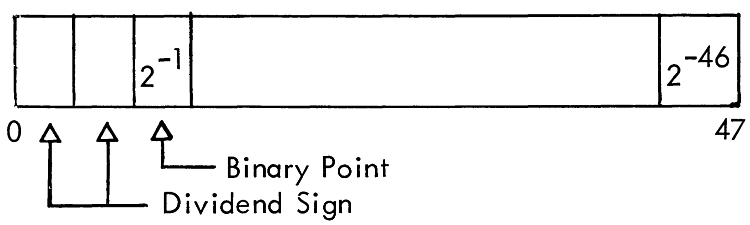
6. DESCRIPTION

6.1 Discussion

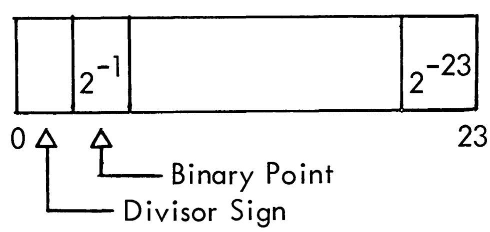
See DEC-08-FMCA, Section 6.1.

6.3 Scaling

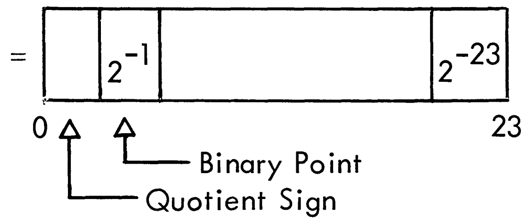
The Dobule-Precision Divide Subroutine is scaled analogous to the scaling of the Double-Precision Multiply Subroutine (DEC-08-FMDA, formerly Digital-8-13-F). It may be considered either an integer divide or a fractional divide.



Dividend (2's Complement)

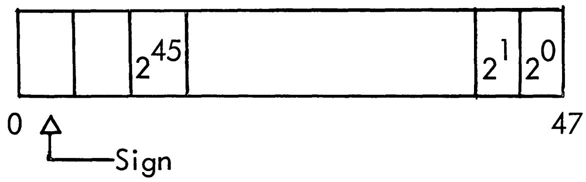


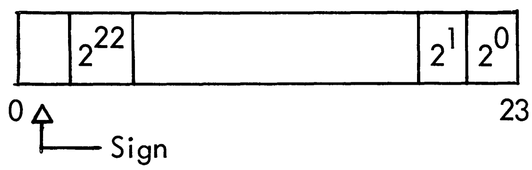
Divisor (2's Complement)

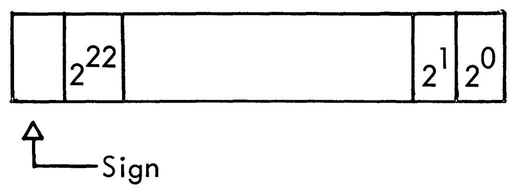


Quotient (2's Complement)

or







9. EXECUTION TIME

9.1 Minimum 1.424 msec

9.2 Maximum 1.705 msec

9.3 Average 1.65 msec

10. PROGRAM

10.4 Program Listing

```
                        /DEC-08-FMEA-LA
                        /DOUBLE PRECISION DIVIDE SUBROUTINE
                        /CALLING SEQUENCE:
                        /         C(AC)=ADDRESS OF HIGH ORDER DIVIDEND
                        /         JMS DUBDIV
                        /         ADDRESS OF HIGH ORDER DIVISOR
                        /         RETURN: C(AC)=HIGH ORDER QUOTIENT
                        /                 C(DIVND4)=LOW ORDER QUOTIENT
                        /                 C(DIVND1)=HIGH ORDER REMAINDER
                        /                 C(DIVND2)=LOW ORDER REMAINDER
                        /IF DIVISOR<DIVIDEND; RESULTS UNSPECIFIED

                        /PAGE 1

0200  0000              DUBDIV, 0
0201  3331                      DCA ADDRS           /DIVIDEND ADDRESS
0202  1343                      TAD REST            /-2
0203  3340                      DCA SIGNSW          /SET SIGN SWITCH
0204  1731                      TAD I ADDRS         /HIGH-ORDER DIVIDEND
0205  3332                      DCA DIVND1
0206  2331                      ISZ ADDRS
0207  1731                      TAD I ADDRS         /DIVIDEND
0210  3333                      DCA DIVND2
0211  2331                      ISZ ADDRS
0212  1731                      TAD I ADDRS         /DIVIDEND
0213  3334                      DCA DIVND3
0214  2331                      ISZ ADDRS
0215  1731                      TAD I ADDRS         /DIVIDEND
0216  3335                      DCA DIVND4
0217  1332                      TAD DIVND1          /DIVIDEND<0?
0220  7700                      SMA CLA
0221  5237                      JMP DIVGO1          /NO: CONTINUE
0222  2340                      ISZ SIGNSW          /YES: ADD 1 TO SWITCH
0223  1335                      TAD DIVND4
0224  7141                      CMA IAC CLL         /NEGATE DIVIDEND
0225  3335                      DCA DIVND4
0226  1334                      TAD DIVND3
0227  4344                      JMS COM
0230  3334                      DCA DIVND3
0231  1333                      TAD DIVND2
0232  4344                      JMS COM
0233  3333                      DCA DIVND2
0234  1332                      TAD DIVND1
0235  4344                      JMS COM
0236  3332                      DCA DIVND1
```

```
                              /PAGE 2

                              /FETCH DIVISOR
0237  1600                    DIVGO1,  TAD I DUBDIV
0240  2200                             ISZ DUBDIV
0241  3331                             DCA ADDRS         /ADDRESS OF DIVISOR
0242  1731                             TAD I ADDRS       /HIGH ORDER DIVISOR
0243  7100                             CLL
0244  7500                             SMA               /DIVISOR>0?
0245  7060                             CMA CML           /YES:NEGATE AND SET C(L)
0246  3336                             DCA HDIVSR
0247  2331                             ISZ ADDRS
0250  1731                             TAD I ADDRS       /LOW ORDER DIVISOR
0251  7420                             SNL
0252  2340                             ISZ SIGNSW        /ADD 1 TO SIGN SWITCH
0253  7000                             NOP
0254  7430                             SZL
0255  7141                             CMA IAC CLL       /COMPLEMENT
0256  3337                             DCA LDIVSR        /LOW ORDER DIVISOR
0257  7430                             SZL               /CARRY?
0260  2336                             ISZ HDIVSR        /YES
0261  1342                             TAD M25
0262  3341                             DCA DIVCNT        /SET DIVIDE COUNT=24
0263  7100                             CLL
0264  5307                             JMP DIV2
```

```
                            /PAGE 3

0265   1333     DIV3,       TAD DIVND2          /SHIFT HIGH DIVIDEND
0266   7004                 RAL                 /LEFT
0267   3333                 DCA DIVND2
0270   1332                 TAD DIVND1
0271   7004                 RAL
0272   3332                 DCA DIVND1
0273   1333                 TAD DIVND2          /COMPARE DIVISOR;
0274   1337                 TAD LDIVSR          /WITH DIVISOR
0275   3331                 DCA ADDRS
0276   7004                 RAL                 /GET CARRY
0277   1332                 TAD DIVND1
0300   1336                 TAD HDIVSR
0301   7420                 SNL
0302   5306                 JMP DIV2_1
0303   3332                 DCA DIVND1
0304   1331                 TAD ADDRS
0305   3333                 DCA DIVND2
0306   7200                 CLA
0307   1335     DIV2,       TAD DIVND4          /ROTATE LOW ORDER
0310   7004                 RAL                 /WORDS LEFT
0311   3335                 DCA DIVND4
0312   1334                 TAD DIVND3          /QUTOIENT BITS
0313   7004                 RAL
0314   3334                 DCA DIVND3          /ENTER FROM C(L)
0315   2341                 ISZ DIVCNT          /DONE 24?
0316   5265                 JMP DIV3            /NO: CONTINUE
0317   2340                 ISZ SIGNSW          /ANSWER<0?
0320   5327                 JMP OUT             /NO: EXIT
0321   1335                 TAD DIVND4          /YES
0322   7141                 CMA CLL IAC
0323   3335                 DCA DIVND4
0324   1334                 TAD DIVND3
0325   4344                 JMS COM
0326   5600                 JMP I DUBDIV
0327   1334     OUT,        TAD DIVND3
0330   5600                 JMP I DUBDIV
```

```
                                /PAGE 4

0331  0000                      ADDRS,    0
0332  0000                      DIVND1,   0
0333  0000                      DIVND2,   0
0334  0000                      DIVND3,   0
0335  0000                      DIVND4,   0
0336  0000                      HDIVSR,   0
0337  0000                      LDIVSR,   0
0340  0000                      SIGNSW,   0
0341  0000                      DIVCNT,   0
0342  7747                      M25,      -31                 /-25(10)
0343  7776                      REST,     -2

0344  0000                      COM,      0
0345  7040                                CMA
0346  7430                                SZL
0347  7101                                CLL IAC
0350  5744                                JMP I COM

                                          PAUSE
```

```
SYMBOL TABLE

ADDRS      0331
COM        0344
DIVCNT     0341
DIVGO1     0237
DIVND1     0332
DIVND2     0333
DIVND3     0334
DIVND4     0335
DIV2       0307
DIV3       0265
DUBDIV     0200
HDIVSR     0336
LDIVSR     0337
M25        0342
OUT        0327
REST       0343
SIGNSW     0340
```

12. REFERENCES

See DEC-08-FMDA, formerly Digital-8-13-F.

1. Double-Precision Sine Subroutine, DEC-08-FMFB-D.

2. ABSTRACT

The Double-Precision Sine Subroutine will evaluate the function Sin(X) for $-4 < X < 4$ (X is in radians). The argument is a double-precision word, 2 bits representing the integer part and 21 bits representing the fractional part. The result is a 23-bit signed fraction $-1 < \text{Sin}(X) < 1$.

3. REQUIREMENTS

3.1 Storage

This subroutine uses 248 (decimal) memory locations.

3.2 Subprograms and/or Subroutines

The Double-Precision Multiply Subroutine (DEC-08-FMDA, formerly Digital-8-13-F) or EAE Version (Digital-8-23-F).

4. USAGE

4.2 Calling Sequence

The Double-Precision Sine Subroutine is called by an effective JMS DSIN followed by the address of the high-order word of the argument. Control returns to the calling program at the address of argument address + 1 with C(AC) = 0, C(L) = 0 and with the answer in registers ARG, ARG + 1. For example:

```
          JMS      I      DSINP
          ARGMNT
          HLT
          .
          .
          .
DSINP,    DSIN
ARGMNT,   1000
          0000
```

6. DESCRIPTION

6.1 Discussion

The input to the sine subroutine is considered to be in radians within the range $-4 < X < 4$. The subroutine is able to call itself recursively and does so when reducing the range of the argument to the first quadrant. The following identities are used:

if	$X = 0$	$\text{Sin}(0) = 0$
if	$X < 0$,	$\text{Sin}(-X) = -\text{Sin}(X)$ (recursive call)
if	$X < \pi$,	$\text{Sin}(X) = -\text{Sin}(X - \pi)$ (recursive call)

if	$X > \pi/2$	$\mathrm{Sin}(X) = -\mathrm{Sin}(X - \pi)$ (recursive call)
if	$X = \pi/2$	$\mathrm{Sin}(\pi/2) = 1$

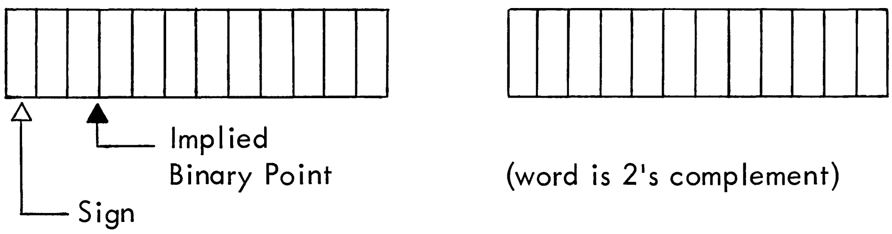
for $0 < X < \pi/2$,

$$F = \frac{2X}{\pi} \text{ so that } 0 < F < 1, \text{ then:}$$

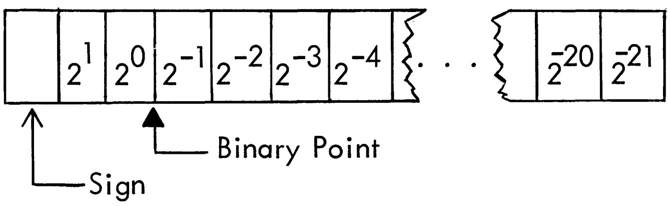
$$\mathrm{Sin}(X) = F(C_1 + C_3F^2 + C_5F^4 + C_7F^6 + C_9F^8)$$

6.3 Scaling

The scaling for the argument is:



The binary weightings of the argument may be represented as:



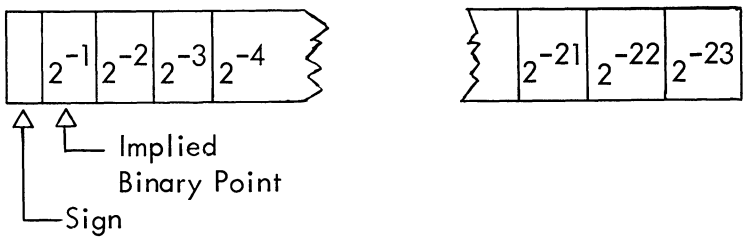
Thus, 1.5 radians would be:

001 100 000 000 000 000 000 000

and −1.5 radians would be:

110 100 000 000 000 000 000 000

The answer is a 23-bit signed fraction (2's complement) with the following binary weightings:



Thus if the answer were 0.75(10), it would appear as follows:

ARG	011 000 000 000
ARG+1	000 000 000 000

If the answer were −0.75(10), it would appear as:

ARG	101 000 000 000
ARG+1	000 000 000 000

7. METHODS

7.2 Algorithm

See Section 6.1.

9. EXECUTION TIME

9.1	Minimum	When the argument is a multiple of π: 70 μsec
9.2	Maximum	Without EAE: 10.6 msec With EAE: 2.78 msec
9.3	Average	Without EAE: 10.4 msec With EAE: 2.6 msec.

10. PROGRAM

10.1 Core Map

The Double-Precision Sine Subroutine, as listed, was assembled starting at 0400 (8). It assumes that the Double-Precision Multiply Subroutine (DEC-08-FMDA, formerly Digital-8-13-F) is in core starting at 0200. If the multiply subroutine is placed elsewhere, the pointers on page 1 of the program should be changed.

10.4 Program Listing

```
                        /DEC-Ø8-FMFB-PA
                        /DOUBLE PRECISION SINE
                        /POINTERS TO DEC-Ø8-FMUA
      Ø2ØØ              DMUL=2ØØ
      Ø341              B=341
      Ø342              C=342
      Ø4ØØ              *4ØØ

Ø4ØØ  ØØØØ              DSIN,   Ø
Ø4Ø1  16ØØ                      TAD I DSIN      /ADDRESS OF ARGUMENT
Ø4Ø2  3351                      DCA TEMP
Ø4Ø3  1751                      TAD I TEMP      /HIGH ORDER
Ø4Ø4  3347                      DCA X2
Ø4Ø5  2351                      ISZ TEMP
Ø4Ø6  1751                      TAD I TEMP      /LOW ORDER
Ø4Ø7  335Ø                      DCA X2+1
Ø41Ø  22ØØ                      ISZ DSIN        /FIX EXIT
Ø411  12ØØ                      TAD DSIN        /SAVE ON PUSHDOWN LIST
Ø412  3763                      DCA I PUSH
Ø413  2363                      ISZ PUSH
Ø414  1347                      TAD X2  /CHECK FOR ZERO
Ø415  764Ø                      SZA CLA
Ø416  5233                      JMP NEG
Ø417  135Ø                      TAD X2+1
Ø42Ø  764Ø                      SZA CLA
Ø421  5233                      JMP NEG /NO
Ø422  72ØØ                      CLA
Ø423  3754                      DCA I PNT3      /SIN(Ø)=Ø
Ø424  3755                      DCA I PNT3+1
Ø425  724Ø              XIT1,   CLA CMA /EXIT
Ø426  1363                      TAD PUSH
Ø427  3363                      DCA PUSH
Ø43Ø  1763                      TAD I PUSH
Ø431  3351                      DCA TEMP
Ø432  5751                      JMP I TEMP
Ø433  1347              NEG,    TAD X2  /CHECK FOR NEGATIVE X
Ø434  77ØØ                      SMA CLA
Ø435  5261                      JMP POS
Ø436  135Ø                      TAD X2+1        /SIN(-X)=-SIN(X)
Ø437  7141                      CLL CMA IAC
Ø44Ø  335Ø                      DCA X2+1
Ø441  1347                      TAD X2
Ø442  7Ø4Ø                      CMA
Ø443  743Ø                      SZL
Ø444  7ØØ1                      IAC
Ø445  3347                      DCA X2
```

```
                        /DEC-08-FMFB-PA
                        /PAGE 2
0446  4200                      JMS DSIN        /RECURSIVE CALL FOR SINE
0447  0547                      X2
0450  1755              XIT2,   TAD I PNT3+1    /NEGATE THE ANSWER
0451  7141                      CLL CMA IAC
0452  3755                      DCA I PNT3+1
0453  1754                      TAD I PNT3
0454  7040                      CMA
0455  7430                      SZL
0456  7001                      IAC
0457  3754                      DCA I PNT3
0460  5225                      JMP XIT1
0461  7100              POS,    CLL     /IS X<PI?
0462  1350                      TAD X2+1
0463  1360                      TAD MPI+1
0464  3351                      DCA TEMP
0465  7004                      RAL     /CARRY
0466  1347                      TAD X2
0467  1357                      TAD MPI
0470  7510                      SPA
0471  5300                      JMP PCHK
0472  3347                      DCA X2  /SIN(X)=-SIN(X-PI)
0473  1351                      TAD TEMP
0474  3350                      DCA X2+1
0475  4200                      JMS DSIN
0476  0547                      X2
0477  5250                      JMP XIT2
0500  7300              PCHK,   CLA CLL /IS X<PI/2?
0501  1350                      TAD X2+1
0502  1362                      TAD MPIO+1
0503  3351                      DCA TEMP
0504  7004                      RAL
0505  1347                      TAD X2
0506  1361                      TAD MPIO
0507  7510                      SPA
0510  5337                      JMP ALG
0511  7440                      SZA
0512  5324                      JMP P2NG
0513  1351                      TAD TEMP
0514  7440                      SZA
0515  5324                      JMP P2NG
0516  7140                      CMA CLL /SIN(PI/2)=1
0517  7010                      RAR
0520  3754                      DCA I PNT3
0521  7040                      CMA
0522  3755                      DCA I PNT3+1
0523  5225                      JMP XIT1
```

```
                        /DEC-08-FMFB-PA
                        /PAGE 3
0524  7300              P2NG,   CLL CLA
0525  1350                      TAD X2+1
0526  1360                      TAD MPI+1       /SIN(X)=-SIN(X-PI)
0527  3350                      DCA X2+1
0530  7004                      RAL
0531  1347                      TAD X2
0532  1357                      TAD MPI
0533  3347                      DCA X2
0534  4200                      JMS DSIN        /RECURSIVE CALL FOR SINE
0535  0547                      X2
0536  5250                      JMP XIT2
0537  7200              ALG,    CLA     /ALIGN SCALING FOR ALGORITHM
0540  1350                      TAD X2+1
0541  7104                      CLL RAL
0542  3753                      DCA I PNT2+1
0543  1347                      TAD X2
0544  7004                      RAL
0545  3752                      DCA I PNT2
0546  5756                      JMP I PNT4
                        /SYMBOLS AND CONSTANTS FOR THIS PAGE
0547  0000              X2,     0
0550  0000                      0
0551  0000              TEMP,   0
0552  0743              PNT2,   X
0553  0744                      X+1
0554  0741              PNT3,   ARG
0555  0742                      ARG+1
0556  0600              PNT4,   DALG
0557  4667              MPI,    4667    /-(PI)
0560  4023                      4023
0561  6333              MPIO,   6333    /-(PI/2)
0562  6012                      6012
0563  0564              PUSH,   PUSH+1  / POINTER FOR PUSHDOWN LIST
```

```
                        /DEC-08-FMFB-PA
                        /PAGE 4
      0600              *DSIN+200
0600  4736              DALG,   JMS I DMTG      /FORM (2/PI)*ARG
0601  0743                      X
0602  0755                      TOPI
0603  4277                      JMS SCAL        /GET RID OF EXTRA SIGN BIT
0604  4277                      JMS SCAL        /SCALING = 0 NOW
0605  4312                      JMS ROUND
0606  0743                      X
0607  4736                      JMS I DMTG      /GET X*X
0610  0743                      X
0611  0743                      X
0612  4277                      JMS SCAL        /GET RID OF EXTRA SIGN BIT
0613  4312                      JMS ROUND
0614  0737                      XSQR
0615  1353                      TAD FYX /INI
0616  3345                      DCA PNT /       T
0617  1354                      TAD FOUR        /       I
0620  3346                      DCA CHK /       A
0621  3341                      DCA ARG /       L
0622  3342                      DCA ARG+1       /       IZE
0623  7100              LOOP,   CLL
0624  1745                      TAD I PNT
0625  1342                      TAD ARG+1
0626  3342                      DCA ARG+1
0627  2345                      ISZ PNT
0630  7004                      RAL
0631  1341                      TAD ARG
0632  1745                      TAD I PNT
0633  3341                      DCA ARG
0634  2345                      ISZ PNT /INCREMENT POINTER FOR NEXT
0635  4736                      JMS I DMTG
0636  0741                      ARG
0637  0737                      XSQR
0640  4277                      JMS SCAL        /GET RID OF SIGN BIT
0641  4312                      JMS ROUND
0642  0741                      ARG
0643  2346                      ISZ CHK
0644  5223                      JMP LOOP
0645  7100                      CLL
0646  1341                      TAD ARG /SHIFT ARG 1 PLACE
0647  7510                      SPA
0650  7020                      CML
0651  7010                      RAR
0652  3341                      DCA ARG
0653  1342                      TAD ARG+1
0654  7010                      RAR
0655  3342                      DCA ARG+1
```

```
Ø656  71ØØ            CLL       /ADD IN LAST CONSTANT
Ø657  136Ø            TAD C1+1
Ø66Ø  1342            TAD ARG+1
Ø661  3342            DCA ARG+1
Ø662  7ØØ4            RAL       /CARRY
Ø663  1341            TAD ARG
Ø664  1357            TAD C1
Ø665  3341            DCA ARG
Ø666  4736            JMS I DMTG
Ø667  Ø741            ARG
Ø67Ø  Ø743            X
Ø671  4277            JMS SCAL          /PUT SCALING BACK TO ZERO
Ø672  4277            JMS SCAL          /GET RID OF SIGN BIT
Ø673  4312            JMS ROUND
Ø674  Ø741            ARG
Ø675  5676            JMP I OUT
Ø676  Ø425    OUT,    XIT1
Ø677  ØØØØ    SCAL,   Ø         /ROUTINE TO ADJUST SCALING
Ø7ØØ  335Ø            DCA TEM2
Ø7Ø1  1752            TAD I CTG
Ø7Ø2  71Ø4            CLL RAL
Ø7Ø3  3752            DCA I CTG
Ø7Ø4  1751            TAD I BTG
Ø7Ø5  7ØØ4            RAL
Ø7Ø6  3751            DCA I BTG
Ø7Ø7  135Ø            TAD TEM2
Ø71Ø  7ØØ4            RAL
Ø711  5677            JMP I SCAL
Ø712  ØØØØ    ROUND,  Ø
Ø713  3347            DCA TEM1
Ø714  1712            TAD I ROUND       /ADDRESS OF HIGH ORDER
Ø715  2312            ISZ ROUND
Ø716  335Ø            DCA TEM2
Ø717  1347            TAD TEM1
Ø72Ø  375Ø            DCA I TEM2
Ø721  135Ø            TAD TEM2
Ø722  7ØØ1            IAC
Ø723  3347            DCA TEM1
Ø724  1751            TAD I BTG
Ø725  3747            DCA I TEM1
Ø726  1752            TAD I CTG
Ø727  771Ø            SPA CLA /BIT Ø=1??
Ø73Ø  5712            JMP I ROUND       /NO; EXIT
Ø731  2747            ISZ I TEM1        /YES: ROUND
Ø732  5712            JMP I ROUND
Ø733  275Ø            ISZ I TEM2        /CARRY
Ø734  7ØØØ            NOP       /RETURN SKIP OR NOT!!
Ø735  5712            JMP I ROUND
```

```
                        /DEC-08-FMFB-PA
                        /PAGE 6
                        /SYMBOLS AND CONSTANTS
0736   0200             DMTG,    DMUL
0737   0000             XSQR,    0
0740   0000                      0
0741   0000             ARG,     0
0742   0000                      0
0743   0000             X,       0
0744   0000                      0
0745   0000             PNT,     0
0746   0000             CHK,     0
0747   0000             TEM1,    0
0750   0000             TEM2,    0
0751   0341             BTG,     B
0752   0342             CTG,     C
0753   0761             FYX,     C9
0754   7774             FOUR,    -4
0755   2427             TOPI,    2427     /2/PI
0756   6303                      6303
0757   3110             C1,      3110
0760   3755                      3755
0761   2367             C9,      2367     /C3-C9 STORED IN BACKWARDS ORDER
0762   0000                      0000
0763   3331             C7,      3331
0764   7766                      7766
0765   1505             C5,      1505
0766   0243                      0243
0767   0420             C3,      0420
0770   5325                      5325
                                 $
```

```
SYMBOL TABLE

ALG       0537
ARG       0741
B         0341
BTG       0751
C         0342
CHK       0746
CTG       0752
C1        0757
C3        0767
C5        0765
C7        0763
C9        0761
DALG      0600
DMTG      0736
DMUL      0200
DSIN      0400
FOUR      0754
FYX       0753
LOOP      0623
MPI       0557
MPIO      0561
NEG       0433
OUT       0676
PCHK      0500
PNT       0745
PNT2      0552
PNT3      0554
PNT4      0556
POS       0461
PUSH      0563
P2NG      0524
ROUND     0712
SCAL      0677
TEMP      0551
TEM1      0747
TEM2      0750
TOPI      0755
X         0743
XIT1      0425
XIT2      0450
XSQR      0737
X2        0547
```

1. Double-Precision Cosine Subroutine, DEC-08-FMGB-D

2 ABSTRACT

This subroutine will form the cosine of a double-precision argument (in radians). The input range is $-4 < X < 4$.

3. REQUIREMENTS

3.1 Storage

This subroutine requires 64 (decimal) memory locations.

3.2 Subprograms and/or Subroutines

This subroutine requires the Double-Precision Sine Subroutine (DEC-08-FMFB-D). The symbolic tape contains definitions that are used as intercommunication registers to the sine subroutine. If the sine subroutine is moved, these "pointers" must be changed.

3.3 Equipment

Standard PDP-8.

4. USAGE

4.1 Loading

The library tape that is supplied is a symbolic tape. It begins with an absolute origin setting and ends with a dollar sign. The binary tape produced by assembling this tape, or the binary tape produced by assembling this tape with other tapes, is loaded with the Binary Loader.

4.2 Calling Sequence

The Double-Precision Cosine Subroutine is called in a manner that is identical to the way in which the Double-Precision Sine Subroutine is called. For more complete information, see DEC-08-FMFB-D

5. RESTRICTIONS

See DEC-08-FMFB-D

6. DESCRIPTION

6.1 Discussion

The Double-Precision Cosine Subroutine uses the following identities:

If $X<0$; $COS(-X) = COS(X)$

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

This insures that the argument presented to the sine subroutine is in the proper range.

6.3 Scaling

See DEC-08-FMFB-D

7. METHODS

See DEC-08-FMFB-D

8. FORMAT

See DEC-08-FMFB-D

9. EXECUTION TIME

9.1 Minimum

The minimum time occurs when the argument is 0. In this case, time = 55.5 μsec.

9.3 Average

In general, the Double-Precision Cosine Subroutine takes from 75 μsec to 93 μsec longer than the Double-Precision Sine Subroutine (see DEC-08-FMFB-D).

10. PROGRAM

10.4 Program Listing

```
                        /DEC-Ø8-FMGB-PA
                        /DOUBLE PRECISION COSINE SUBROUTINE
                        /CALLS DEC-Ø8-FMFA
                        /POINTERS TO DEC-Ø8-FMFB FOLLOW
        Ø741            ARG=741
        Ø4ØØ            DSIN=4ØØ

        1ØØØ            *1ØØØ
1ØØØ    ØØØØ            DCOS,   Ø
1ØØ1    16ØØ                    TAD I DCOS      /FETCH ADDRESS OF
1ØØ2    3262                    DCA ADDRSS      /ARGUMENT
1ØØ3    1662                    TAD I ADDRSS    /FETCH HIGH ORDER
1ØØ4    3256                    DCA EX          /ARGUMENT
1ØØ5    2262                    ISZ ADDRSS      /INCREMENT ADDRESS POINTER
1ØØ6    1662                    TAD I ADDRSS    /FETCH LOW ORDER
1ØØ7    3257                    DCA EX+1        /ARGUMENT
1Ø1Ø    1256                    TAD EX          /IS ARGUMENT EQUAL
1Ø11    764Ø                    SZA CLA         /TO ZERO
1Ø12    5224                    JMP TSIGNN      /NO: TEST THE SIGN
1Ø13    1257                    TAD EX+1        /TEST LOW ORDER BITS
1Ø14    764Ø                    SZA CLA         /FOR ZERO
1Ø15    5224                    JMP TSIGNN      /NOT EQUAL TO ZERO
1Ø16    7Ø4Ø                    CMA
1Ø17    7Ø1Ø                    RAR
1Ø2Ø    366Ø                    DCA I ARGPNT
1Ø21    7Ø4Ø                    CMA
1Ø22    3661                    DCA I ARGPNT+1  /SET ANSWER TO 1
1Ø23    5254                    JMP EXIT
1Ø24    1256            TSIGNN, TAD EX          /SEE IF X>Ø
1Ø25    77ØØ                    SMA CLA
1Ø26    5237                    JMP ARGPOS      /ARGUMENT IS >Ø
1Ø27    1257                    TAD EX+1        /ARGUMENT IS <Ø
1Ø3Ø    7141                    CLL CMA IAC     /NEGATE IT
1Ø31    3257                    DCA EX+1
1Ø32    1256                    TAD EX
1Ø33    7Ø4Ø                    CMA
1Ø34    743Ø                    SZL
1Ø35    7ØØ1                    IAC
1Ø36    3256                    DCA EX
```

```
1037  7300            ARGPOS, CLL CLA
1040  1257                    TAD EX+1
1041  7041                    CMA IAC
1042  1265                    TAD PIOT+1          /SUBTRACT X FROM
1043  3257                    DCA EX+1            /PI/2
1044  1256                    TAD EX
1045  7040                    CMA
1046  7430                    SZL
1047  7001                    IAC
1050  1264                    TAD PIOT
1051  3256                    DCA EX
1052  4663                    JMS I DSINPT        /CALL SINE SUBROUTINE
1053  1056                    EX                  /ARGUMENT ADDRESS
1054  2200            EXIT,   ISZ DCOS            /RETURN TO CALL+1
1055  5600                    JMP I DCOS          /ANSWER IN ARG,ARG+1
1056  0000            EX,     0
1057  0000                    0
1060  0741            ARGPNT, ARG
1061  0742                    ARG+1
1062  0000            ADDRSS, 0
1063  0400            DSINPT, DSIN
1064  1444            PIOT,   1444
1065  1767                    1767

                      PAUSE
```

```
SYMBOL TABLE

ADDRSS    1062
ARG       0741
ARGPNT    1060
ARGPOS    1037
DCOS      1000
DSIN      0400
DSINPT    1063
EX        1056
EXIT      1054
PIOT      1064
TSIGNN    1024
```

12. REFERENCES

12.1 Other Library Programs

See Digital-8-16-F for further explanation of the calling sequence, timing, scaling, and algorithm.

1. Four-Word Floating-Point Package, DEC-08-FMHA-D.

2. ABSTRACT

This program is almost identical to the 3-word Floating-Point Package (Digital-8-5-S) except that accuracy is carried to 35 bits, and 4 12-bit words are used for storage.

3. REQUIREMENTS

3.1 Storage

This program occupies registers 7; 40-61; 5600-7577 (octal).

4. USAGE

4.1 Loading

Binary Loader (Digital-8-2-U) or DECtape System.

4.2 Calling Sequence

Identical to Digital-8-5-S.

5. RESTRICTIONS

See Digital-8-5-S.

6. DESCRIPTION

The floating accumulator resides in memory locations 44, 45, 46, and 47. The instructions FGET, FPUT use 4-word arguments (11-bit exponent + sign; 35-bit mantissa + sign). The 4-word package contains all operations except for square root (0002) and square (0001).

7. METHODS

See Digital-8-5-S.

8. FORMAT (Not Applicable)

9. EXECUTION TIME

9.3 Average

Execution times are very difficult to estimate as they greatly depend upon the data on which the floating-point package is operating. Generally speaking:

FADD	=	382 μsec + 42(N) where N is the number of shifts to align binary points.
FSUB	=	FADD time + 42 μsec
FDIV	=	3.4 msec (approximately)

FMPY	=	3.3 msec (approximately)
FGET	=	156 μsec
FPUT	=	172 μsec
FNOR	=	168 + N(42) μsec where N is number of shifts; +84 μsec if argument <0.
FEXT	=	140.5 μsec

10. PROGRAM

10.4 Program Listing

```
                /4 WORD FLOATING POINT
                /ARITHMETIC INTERPRETER
                /PAGE 1

                *40
0040   0000     EX1,        0
0041   0000     HIGH1,      0
0042   0000     MID1,       0
0043   0000     LOW1,       0
0044   0000     EXP,        0
0045   0000     HORDER,     0
0046   0000     MIDDL,      0
0047   0000     LORDER,     0
0050   0000     OVER2,      0

0051   0000     OVER1,      0
                *61
0061   0000     FLAG,       0                /ARITHMETIC ERROR FLAG


                *5600
5600   0000     FPNT,       0
5601   7300                 CLA CLL
5602   3051                 DCA OVER1
5603   3050                 DCA OVER2
5604   1600                 TAD I FPNT           /GET INSTRUCTION
5605   3257                 DCA JUMP
5606   1257                 TAD JUMP
5607   0265                 AND PAGENO           /PAGE 0??
5610   7650                 SNA CLA
5611   5214                 JMP .+3              /YES
5612   1267                 TAD MASK5            /NO - GET PAGE BITS
5613   0200                 AND FPNT
5614   3262                 DCA ADDRS
5615   1270                 TAD MASK7            /GET 7 BIT ADDRESS
5616   0257                 AND JUMP
5617   1262                 TAD ADDRS
5620   3262                 DCA ADDRS
```

```
5621  1266            TAD INDRCT          /BIT3=1??
5622  0257            AND JUMP
5623  7650            SNA CLA
5624  5227            JMP LOOP01
5625  1662            TAD I ADDRS         /YES - DEFER
5626  3262            DCA ADDRS
5627  2200  LOOP01,   ISZ FPNT
5630  1662            TAD I ADDRS
5631  3040            DCA EX1             /EXPONENT
5632  1262            TAD ADDRS
5633  3263            DCA SAVE
5634  2263            ISZ SAVE
5635  1663            TAD I SAVE          /HIGH ORDER
5636  3041            DCA HIGH1
5637  2263            ISZ SAVE
5640  1663            TAD I SAVE
5641  3042            DCA MID1            /MIDDLE BITS
5642  2263            ISZ SAVE
5643  1663            TAD I SAVE
5644  3043            DCA LOW1            /LOWER BITS
5645  1257            TAD JUMP
5646  7106            CLL RTL
5647  7006            RTL
5650  0264            AND MASK3           /LOOK-UP ON TABLE
5651  1271            TAD TABLE
5652  3260            DCA JUMP2
5653  1660            TAD I JUMP2
5654  3260            DCA JUMP2
5655  4660            JMS I JUMP2         /EXECUTE
5656  5201            JMP FPNT+1          /GET NEXT
5657  0000  JUMP,     0
5660  0000  JUMP2,    0
5661  0000  GO2,      0
5662  0000  ADDRS,    0
5663  0000  SAVE,     0
5664  0017  MASK3,    0017
5665  0200  PAGENO,   0200
5666  0400  INDRCT,   0400
5667  7600  MASK5,    7600
5670  0177  MASK7,    0177
5671  5672  TABLE,    .+1
5672  5714            EXIT
5673  6000            FLAD
5674  6026            FLSU
5675  6367            FLMY
5676  6600            FLDV
5677  5702            FLGT
5700  5733            FLPT
5701  6200            FNORM
```

```
                  /FLOATING GET=5000
5702    0000      FLGT,     0
5703    1040                TAD EX1
5704    3044                DCA EXP
5705    1041                TAD HIGH1
5706    3045                DCA HORDER
5707    1042                TAD MID1
5710    3046                DCA MIDDL
5711    1043                TAD LOW1
5712    3047                DCA LORDER
5713    5201                JMP FPNT+1
                  /FLOATING EXIT OR SUBROUTINE=00XX
5714    0000      EXIT,     0
5715    1257                TAD JUMP
5716    0264                AND MASK3
5717    7450                SNA                    /BITS 8-11=0??
5720    5600                JMP I FPNT             /YES:FEXT
5721    1350                TAD TABLE6             /NO:LOOKUP BITS 8-11
5722    3260                DCA JUMP2              /ON SUBROUTINE TABLE
5723    1660                TAD I JUMP2
5724    3260                DCA JUMP2
5725    1200                TAD FPNT               /SAVE PSEUDO PC
5726    3261                DCA G02
5727    4660                JMS I JUMP2
5730    1261                TAD G02                /RESTORE PSEUDO PC
5731    3200                DCA FPNT
5732    5201                JMP FPNT+1             /RETURN
                  /FLOATING PUT=6000
5733    0000      FLPT,     0
5734    1044                TAD EXP
5735    3662                DCA I ADDRS
5736    1045                TAD HORDER
5737    2262                ISZ ADDRS
5740    3662                DCA I ADDRS
5741    1046                TAD MIDDL
5742    2262                ISZ ADDRS
5743    3662                DCA I ADDRS
5744    1047                TAD LORDER
5745    2262                ISZ ADDRS
5746    3662                DCA I ADDRS
5747    5201                JMP FPNT+1

5750    5750      TABLE6,   .                      /SUBROUTINE TABLE
5751    5770                EXIT6                  /ABSOLUTE ADDRESSES
5752    5770                EXIT6                  /OF SUBROUTINES
5753    5770                EXIT6
5754    5770                EXIT6
5755    5770                EXIT6                  /EXIT6=DUMMY OR NOP
5756    5770                EXIT6
```

```
5757   5770               EXIT6
5760   5770               EXIT6
5761   5770               EXIT6
5762   5770               EXIT6
5763   5770               EXIT6
5764   5770               EXIT6
5765   5770               EXIT6
5766   5770               EXIT6
5767   5770               EXIT6

5770   0000   EXIT6,      0
5771   5770               JMP I EXIT6

              /FLOATING ADD=1000
              *6000
6000   0000   FLAD,       0
6001   4231               JMS ALIGN         /ALIGN WORDS
6002   5600               JMP I FLAD        /NO ALIGNMENT
6003   4312               JMS SCALE
6004   7300               CLA CLL           /TRIPLE ADDITION
6005   1051               TAD OVER1
6006   1050               TAD OVER2
6007   3050               DCA OVER2
6010   7004               RAL               /CARRY
6011   1043               TAD LOW1
6012   1047               TAD LORDER
6013   3047               DCA LORDER
6014   7004               RAL
6015   1042               TAD MID1
6016   1046               TAD MIDDL
6017   3046               DCA MIDDL
6020   7004               RAL
6021   1041               TAD HIGH1
6022   1045               TAD HORDER
6023   3045               DCA HORDER
6024   4705               JMS I NORMAL
6025   5600               JMP I FLAD

              /FLOATING SUBTRACT=2000

6026   0000   FLSU,       0
6027   4706               JMS I OPMINS      /NEGATE OPERAND
5030   5201               JMP FLSUX         /ADD

              /ALIGN BINARY POINTS
6031   0000   ALIGN,      0
6032   1045               TAD HORDER
6033   7640               SZA CLA
6034   5240               JMP .+4
```

```
6035  1040            TAD EX1          /C(FAC)=0
6036  3044            DCA EXP
6037  5272            JMP DONE
6040  1041            TAD HIGH1
6041  7650            SNA CLA
6042  5631            JMP I ALIGN      /OPERAND=0
6043  1040            TAD EX1
6044  7041            CMA IAC
6045  1044            TAD EXP
6046  7450            SNA
6047  5272            JMP DONE         /EXPONENTS EQUAL - EXIT
6050  7500            SMA
6051  7041            CMA IAC
6052  3304            DCA AMOUNT       /NUMBER OF PLACES
6053  1304            TAD AMOUNT
6054  1307            TAD TEST1
6055  7710            SPA CLA
6056  5274            JMP NOGO         /NO SHIFTING POSSIBLE
6057  1040            TAD EX1
6060  7041            CMA IAC
6061  1044            TAD EXP
6062  7004            RAL
6063  7620            SNL CLA
6064  1310            TAD TCON1        /SHIFT OPERAND RIGHT
6065  1311            TAD TCON2        /SHIFT FAC RIGHT
6066  3303            DCA POINT
6067  4703            JMS I POINT
6070  2304            ISZ AMOUNT
6071  5267            JMP .-2
6072  2231  DONE,     ISZ ALIGN
6073  5631            JMP I ALIGN
6074  1040  NOGO,     TAD EX1
6075  7041            CMA IAC
6076  1044            TAD EXP
6077  7700            SMA CLA
6100  5631            JMP I ALIGN
6101  5702            JMP I .+1
6102  5703            FLGT+1
6103  0000  POINT,    0
6104  0000  AMOUNT,   0
6105  6200  NORMAL,   FNORM
6106  6306  OPMINS,   OPNEG
6107  0045  TEST1,    0045
6110  0023  TCON1,    SHFTOP-SHFTAC
6111  6116  TCON2,    SHFTAC
```

```
                /SCALE BOTH RIGHT
6112    0000    SCALE,      0
6113    4341                JMS SHFTOP
6114    4316                JMS SHFTAC
6115    5712                JMP I SCALE
                /SCALE FLOATING AC RIGHT
6116    0000    SHFTAC,     0
6117    7300                CLA CLL
6120    1045                TAD HORDER
6121    7510                SPA
6122    7020                CML
6123    7010                RAR
6124    3045                DCA HORDER
6125    1046                TAD MIDDL
6126    7010                RAR
6127    3046                DCA MIDDL
6130    1047                TAD LORDER
6131    7010                RAR
6132    3047                DCA LORDER
6133    1050                TAD OVER2
6134    7010                RAR
6135    3050                DCA OVER2
6136    2044                ISZ EXP
6137    7000                NOP
6140    5716                JMP I SHFTAC

                /SCALE OPERAND RIGHT
6141    0000    SHFTOP,     0
6142    7300                CLA CLL
6143    1041                TAD HIGH1
6144    7510                SPA
6145    7020                CML
6146    7010                RAR
6147    3041                DCA HIGH1
6150    1042                TAD MID1
6151    7010                RAR
6152    3042                DCA MID1
6153    1043                TAD LOW1
6154    7010                RAR
6155    3043                DCA LOW1
6156    1051                TAD OVER1
6157    7010                RAR
6160    3051                DCA OVER1
6161    2040                ISZ EX1
6162    7000                NOP
6163    5741                JMP I SHFTOP
6164    4200     FLSUX,     JMS FLAD
6165    5626                JMP I FLUX
```

```
                /NORMALIZE FLOATING ACCUMULATOR
                *6200
6200    0000    FNORM,      0
6201    7300                CLA CLL
6202    3361                DCA MP1                 /0 # OF SHIFTS
6203    3363                DCA MP3                 /RESET SWITCH
6204    1045                TAD HORDER
6205    7510                SPA                     /INPUT<0
6206    2363                ISZ MP3                 /YES-SET SWITCH
6207    7640                SZA CLA                 /FAC=0?
6210    5224                JMP GO6                 /NO
6211    1046                TAD MIDDL
6212    7640                SZA CLA
6213    5224                JMP GO6
6214    1047                TAD LORDER
6215    7640                SZA CLA
6216    5224                JMP GO6                 /NO
6217    1050                TAD OVER2
6220    7640                SZA CLA
6221    5224                JMP GO6                 /NO
6222    3044                DCA EXP                 /YES
6223    5600                JMP I FNORM             /EXIT
6224    1363    GO6,        TAD MP3
6225    7640                SZA CLA                 /WAS INPUT <0
6226    4261                JMS ACNEG               /YES
6227    1045    SHIFT,      TAD HORDER
6230    7104                CLL RAL
6231    7710                SPA CLA                 /TOO FAR?
6232    5251                JMP NOREXT              /YES:EXIT ROUTINE
6233    1050                TAD OVER2               /NO
6234    7104                CLL RAL
6235    3050                DCA OVER2               /SHIFT LEFT
6236    1047                TAD LORDER
6237    7004                RAL
6240    3047                DCA LORDER
6241    1046                TAD MIDDL
6242    7004                RAL
6243    3046                DCA MIDDL
6244    1045                TAD HORDER
6245    7004                RAL
6246    3045                DCA HORDER
6247    2361                ISZ MP1                 /ADD 1 TO COUNT
6250    5227                JMP SHIFT               /CONTINUE
6251    1361    NOREXT,     TAD MP1                 /SUBTRACT COUNT FROM
6252    7041                CMA IAC                 /EXPONENT
6253    1044                TAD EXP
6254    3044                DCA EXP
6255    1363                TAD MP3                 /WAS INPUT<0??
6256    7640                SZA CLA
6257    4261                JMS ACNEG               /YES
6260    5600                JMP I FNORM             /EXIT
```

```
                /NEGATE FLOATING AC
6261  ØØØØ  ACNEG,    Ø
6262  73ØØ            CLA CLL
6263  105Ø            TAD OVER2
6264  7Ø41            CMA IAC
6265  3Ø5Ø            DCA OVER2
6266  1Ø47            TAD LORDER
6267  7Ø4Ø            CMA
627Ø  743Ø            SZL
6271  71Ø1            CLL IAC
6272  3Ø47            DCA LORDER
6273  1Ø46            TAD MIDDL
6274  7Ø4Ø            CMA
6275  743Ø            SZL
6276  71Ø1            CLL IAC
6277  3Ø46            DCA MIDDL
63ØØ  1Ø45            TAD HORDER
63Ø1  7Ø4Ø            CMA
63Ø2  743Ø            SZL
63Ø3  71Ø1            CLL IAC
63Ø4  3Ø45            DCA HORDER
63Ø5  5661            JMP I ACNEG
                /NEGATE OPERAND

63Ø6  ØØØØ  OPNEG,    Ø
63Ø7  73ØØ            CLA CLL
631Ø  1Ø51            TAD OVER1
6311  7Ø41            CMA IAC
6312  3Ø51            DCA OVER1
6313  1Ø43            TAD LOW1
6314  7Ø4Ø            CMA
6315  743Ø            SZL
6316  71Ø1            CLL IAC
6317  3Ø43            DCA LOW1
632Ø  1Ø42            TAD MID1
6321  7Ø4Ø            CMA
6322  743Ø            SZL
6323  71Ø1            CLL IAC
6324  3Ø42            DCA MID1
6325  1Ø41            TAD HIGH1
6326  7Ø4Ø            CMA
6327  743Ø            SZL
633Ø  71Ø1            CLL IAC
6331  3Ø41            DCA HIGH1
6332  57Ø6            JMP I OPNEG
```

```
6333   0000   MULTIP,    0
6334   3361              DCA MP1
6335   3364              DCA MPSCON
6336   1365              TAD THIR
6337   3363              DCA MP3
6340   7100              CLL
6341   1361              TAD MP1
6342   7010              RAR
6343   3361              DCA MP1
6344   1364              TAD MPSCON
6345   7420              SNL
6346   5351              JMP .+3
6347   7100              CLL
6350   1362              TAD MP2CON
6351   7010              RAR
6352   3364              DCA MPSCON
6353   2363              ISZ MP3
6354   5341              JMP MULTIP+6
6355   1361              TAD MP1
6356   7010              RAR
6357   7100              CLL
6360   5733              JMP I MULTIP
6361   0000   MP1,       0
6362   0000   MP2CON,    0
6363   0000   MP3,       0
6364   0000   MPSCON,    0
6365   7764   THIR,      -14
6366   6400   FMULT1,    FMULT
6367   0000   FLMY,      0
6370   4766              JMS I FMULT1
6371   4200              JMS FNORM
6372   3050              DCA OVER2
6373   2777              ISZ I SIGN1
6374   5767              JMP I FLMY
6375   4261              JMS ACNEG
6376   5767              JMP I FLMY
6377   6750   SIGN1,     SGNTST

              *6400
              /FLOATING MULTIPLY
              /(A*2↑24+B*2↑12+C)*(D*2↑24+E*2↑12+F)
6400   0000   FMULT,     0
6401   7201              CLA IAC
6402   1040              TAD EX1
6403   1044              TAD EXP
6404   3044              DCA EXP               /ADD EXPONENTS
6405   1377              TAD SMACLA
6406   3772              DCA I SGNSW           /SET UP SIGN ROUTINE
6407   4773              JMS I SIGNP           /GO THERE
```

```
6410   1043        TAD LOW1
6411   3775        DCA I MP2
6412   1047        TAD LORDER         /C*F
6413   4774        JMS I DMULT
6414   7200        CLA
6415   1776        TAD I MP5
6416   3371        DCA MUL5
6417   1046        TAD MIDDL
6420   3775        DCA I MP2
6421   1043        TAD LOW1           /B*F
6422   4774        JMS I DMULT
6423   1371        TAD MUL5
6424   3371        DCA MUL5
6425   7004        RAL
6426   1776        TAD I MP5
6427   3370        DCA MUL4
6430   7004        RAL
6431   3367        DCA MUL3
6432   1042        TAD MID1
6433   3775        DCA I MP2
6434   1047        TAD LORDER         /C*E
6435   4774        JMS I DMULT
6436   1371        TAD MUL5
6437   3371        DCA MUL5
6440   7004        RAL
6441   1370        TAD MUL4
6442   1776        TAD I MP5
6443   3370        DCA MUL4
6444   7004        RAL
6445   1367        TAD MUL3
6446   3367        DCA MUL3
6447   1045        TAD HORDER
6450   3775        DCA I MP2
6451   1043        TAD LOW1           /A*F
6452   4774        JMS I DMULT
6453   1370        TAD MUL4
6454   3370        DCA MUL4
6455   7004        RAL
6456   1367        TAD MUL3
6457   1776        TAD I MP5
6460   3367        DCA MUL3
6461   7004        RAL
6462   3366        DCA MUL2
6463   1041        TAD HIGH1
6464   3775        DCA I MP2
6465   1047        TAD LORDER         /D*C
6466   4774        JMS I DMULT
6467   1370        TAD MUL4
6470   3370        DCA MUL4
6471   7004        RAL
```

```
6472  1367   TAD MUL3
6473  1776   TAD I MP5
6474  3367   DCA MUL3
6475  7004   RAL
6476  1366   TAD MUL2
6477  3366   DCA MUL2
6500  1046   TAD MIDDL
6501  3775   DCA I MP2
6502  1042   TAD MID1          /B*D
6503  4774   JMS I DMULT
6504  1370   TAD MUL4
6505  3370   DCA MUL4
6506  7004   RAL
6507  1367   TAD MUL3
6510  1776   TAD I MP5
6511  3367   DCA MUL3
6512  7004   RAL
6513  1366   TAD MUL2
6514  3366   DCA MUL2
6515  1045   TAD HORDER
6516  3775   DCA I MP2
6517  1042   TAD MID1          /A*E
6520  4774   JMS I DMULT
6521  1367   TAD MUL3
6522  3367   DCA MUL3
6523  7004   RAL
6524  1366   TAD MUL2
6525  1776   TAD I MP5
6526  3366   DCA MUL2
6527  7004   RAL
6530  3365   DCA MUL1
6531  1041   TAD HIGH1
6532  3775   DCA I MP2
6533  1046   TAD MIDDL         /B*D
6534  4774   JMS I DMULT
6535  1367   TAD MUL3
6536  3367   DCA MUL3
6537  7004   RAL
6540  1366   TAD MUL2
6541  1776   TAD I MP5
6542  3366   DCA MUL2
6543  7004   RAL
6544  1365   TAD MUL1
6545  3365   DCA MUL1
6546  1045   TAD HORDER
6547  3775   DCA I MP2
6550  1041   TAD HIGH1         /A*D
6551  4774   JMS I DMULT
6552  1366   TAD MUL2
```

```
6553  3046                DCA MIDDL
6554  7004                RAL
6555  1365                TAD MUL1
6556  1776                TAD I MP5
6557  3045                DCA HORDER
6560  1367                TAD MUL3
6561  3047                DCA LORDER
6562  1370                TAD MUL4
6563  3050                DCA OVER2
6564  5600                JMP I FMULT
6565  0000  MUL1,         0
6566  0000  MUL2,         0
6567  0000  MUL3,         0
6570  0000  MUL4,         0
6571  0000  MUL5,         0
6572  6740  SGNSW,        SGNSWT
6573  6727  SIGNP,        SIGNCL
6574  6333  DMULT,        MULTIP
6575  6362  MP2,          MP2CON
6576  6364  MP5,          MPSCON
6577  7700  SMACLA,       SMA CLA

            /FLOATING DIVIDE=4000
            *6600
6600  0000  FLDV,         0
6601  1040                TAD EX1               /SUBTRACT EXPONENTS
6602  7041                CMA IAC
6603  1044                TAD EXP
6604  7001                IAC
6605  3044                DCA EXP
6606  1326                TAD SPACLA
6607  3340                DCA SGNSWT
6610  4327                JMS SIGNCL            /SET UP SIGNS
6611  1041                TAD HIGH1
6612  7650                SNA CLA               /DIVISOR=0?
6613  5303                JMP DVER              /YES - ERROR
6614  7300                CLA CLL
6615  3320                DCA QUOL
6616  3321                DCA QUOH
6617  1325                TAD MIF
6620  3324                DCA DIVCNT
6621  5233                JMP DVX
6622  1047  DV3,          TAD LORDER
6623  7004                RAL
6624  3047                DCA LORDER
6625  1046                TAD MIDDL
6626  7004                RAL
```

```
6627  3046         DCA MIDDL
6630  1045         TAD HORDER
6631  7004         RAL
6632  3045         DCA HORDER
6633  1043  DVX,   TAD LOW1        /PARTIAL SUBTRACT
6634  1047         TAD LORDER
6635  3322         DCA DTEM1
6636  7004         RAL
6637  1042         TAD MID1
6640  1046         TAD MIDDL
6641  3323         DCA DTEM2
6642  7004         RAL
6643  1041         TAD HIGH1
6644  1045         TAD HORDER
6645  7420         SNL             /DIVISOR<DIVIDEND?
6646  5254         JMP DV2-1       /NO
6647  3045         DCA HORDER      /YES:C(L)=QUOTIENT BIT
6650  1323         TAD DTEM2
6651  3046         DCA MIDDL
6652  1322         TAD DTEM1
6653  3047         DCA LORDER
6654  7200         CLA
6655  1320  DV2,   TAD QUOL        /SHIFT BIT INTO
6656  7004         RAL             /QUOTIENT
6657  3320         DCA QUOL
6660  1321         TAD QUOH
6661  7004         RAL
6662  3321         DCA QUOH
6663  1050         TAD OVER2
6664  7004         RAL
6665  3050         DCA OVER2
6666  2324         ISZ DIVCNT      /DONE?
6667  5222         JMP DV3         /NO
6670  1320         TAD QUOL
6671  3047         DCA LORDER
6672  1321         TAD QUOH
6673  3046         DCA MIDDL
6674  1050         TAD OVER2
6675  3045         DCA HORDER
6676  3050         DCA OVER2
6677  4717         JMS I NORMIT
6700  2350  DEXIT, ISZ SGNTST
6701  4746         JMS I FACNEG
6702  5600         JMP I FLDV
```

```
6703  7240  DVER,     CLA CMA           /DIVIDE ERROR
6704  3047            DCA LORDER
6705  7240            CLA CMA
6706  3046            DCA MIDDL
6707  7040            CMA
6710  7110            CLL RAR
6711  3045            DCA HORDER
6712  1045            TAD HORDER
6713  3044            DCA EXP
6714  2061            ISZ FLAG
6715  7000            NOP
6716  5300            JMP DEXIT

6717  6200  NORMIT,   FNORM
6720  0000  QUOL,     0
6721  0000  QUOH,     0
6722  0000  DTEM1,    0
6723  0000  DTEM2,    0
6724  0000  DIVCNT,   0
6725  7735  MIF,      -43               /STEP COUNT
6726  7710  SPACLA,   SPA CLA

            /TEST SIGN SUBROUTINE

6727  0000  SIGNCL,   0
6730  1351            TAD RESTOR
6731  3350            DCA SGNTST
6732  1045            TAD HORDER
6733  7700            SMA CLA
6734  5337            JMP .+3
6735  4746            JMS I FACNEG
6736  2350            ISZ SGNTST
6737  1041            TAD HIGH1
6740  7700  SGNSWT,   SMA CLA           /OR SPA CLA
6741  5727            JMP I SIGNCL
6742  4747            JMS I OPNEGS
6743  2350            ISZ SGNTST
6744  7000            NOP
6745  5727            JMP I SIGNCL

6746  6261  FACNEG,   ACNEG
6747  6306  OPNEGS,   OPNEG
6750  0000  SGNTST,   0
6751  7776  RESTOR,   -2
```

ACNEG	6261
ADDRS	5662
ALIGN	6Ø31
AMOUNT	61Ø4
DEXIT	67ØØ
DIVCNT	6724
DMULT	6574
DONE	6Ø72
DTEM1	6722
DTEM2	6723
DVER	67Ø3
DVX	6633
DV2	6655
DV3	6622
EXIT	5714
EXIT6	577Ø
EXP	ØØ44
EX1	ØØ4Ø
FACNEG	6746
FLAD	6ØØØ
FLAG	ØØ61
FLDV	66ØØ
FLGT	57Ø2
FLMY	6367
FLPT	5733
FLSU	6Ø26
FMULT	64ØØ
FMULT1	6366
FNORM	62ØØ
FPNT	56ØØ
GO2	5661
GO6	6224
HIGH1	ØØ41
HORDER	ØØ45
INDRCT	5666
JUMP	5657
JUMP2	566Ø
LOOPØ1	5627
LORDER	ØØ47
LOW1	ØØ43
MASK3	5664
MASK5	5667
MASK7	567Ø
MIDDL	ØØ46
MID1	ØØ42
MIF	6725
MPSCON	6364
MP1	6361
MP2	6575
MP2CON	6362
MP3	6363
MP5	6576
MULTIP	6333
MUL1	6565
MUL2	6566
MUL3	6567
MUL4	657Ø
MUL5	6571
NOGO	6Ø74
NOREXT	6251
NORMAL	61Ø5
NORMIT	6717
OPMINS	61Ø6
OPNEG	63Ø6
OPNEGS	6747
OVER1	ØØ51
OVER2	ØØ5Ø
PAGENO	5665
POINT	61Ø3
QUOH	6721
QUOL	672Ø
RESTOR	6751
SAVE	5663
SCALE	6112
SGNSW	6572
SGNSWT	674Ø
SGNTST	675Ø
SHFTAC	6116
SHFTOP	6141
SHIFT	6227
SIGNCL	6727
SIGNP	6573
SIGN1	6377
SMACLA	6577
SPACLA	6726
TABLE	5671
TABLE6	575Ø
TCON1	611Ø
TCON2	6111
TEST1	61Ø7
THIR	6365

```
              /4/17/65-HB-DEC
              /4 WORD
              /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   MIDDL,     0
0047   0000   LORDER,    0

              *52
0052   0000   FPAC1,     0
0053   0000              0
0054   0000              0
0055   0000              0
0056   7777   SWIT1,     7777       /IF = 0, NO CR-LF AFTER OUTPUT
0057   7777   SWIT2,     7777       /IF = 0, NO LF AFTER CR IN INPUT
0060   0000   CHAR,      0          /CONTAINS LAST CHARACTER READ
0061   0000   DSWIT,     0          /= 0 IF NO CONVERSION TOOK PLACE

              *6767
6767   0000   PRCHAR,    0
6770   1057              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   7345   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 MIDDL
7004   3047              DCA LORDER
7005   3266              DCA SIGN
7006   3267              DCA DNUMBR
7007   4350              JMS INPUT
```

```
7Ø1Ø  134Ø            TAD PLUS        /TEST FOR SIGN
7Ø11  745Ø            SNA
7Ø12  522Ø            JMP DECON
7Ø13  1337            TAD MINUS
7Ø14  744Ø            SZA
7Ø15  5221            JMP .+4
7Ø16  724Ø            CLA CMA
7Ø17  3266            DCA SIGN        /IF-, SET SWITCH
7Ø2Ø  435Ø  DECON,    JMS INPUT
7Ø21  72ØØ            CLA
7Ø22  1Ø6Ø            TAD CHAR        /IS IT A DIGIT
7Ø23  1341            TAD MIN9
7Ø24  75ØØ            SMA
7Ø25  56ØØ            JMP I DECONV    /NO
7Ø26  1342            TAD PLUS12
7Ø27  751Ø            SPA
7Ø3Ø  56ØØ            JMP I DECONV    /NO
7Ø31  3265            DCA DIGIT       /YES
7Ø32  1Ø45            TAD HORDER
7Ø33  Ø343            AND MASK        /OVERFLOW?
7Ø34  744Ø            SZA
7Ø35  522Ø            JMP DECON       /YES-IGNORE
7Ø36  2Ø61            ISZ DSWIT
7Ø37  2267            ISZ DNUMBR      /INDEX NUMBER OF DIGITS
7Ø4Ø  4242            JMS MULT1Ø
7Ø41  522Ø            JMP DECON       /CONTINUE
7Ø42  ØØØØ  MULT1Ø,   Ø               /ROUTINE TO MULIPLY
7Ø43  1Ø47            TAD LORDER     /DOUBLE PRECISION WORD
7Ø44  3Ø43            DCA 43          /BY TEN (DECIMAL)
7Ø45  1Ø46            TAD MIDDL
7Ø46  3Ø42            DCA 42
7Ø47  1Ø45            TAD HORDER      /REMAIN=REMAINDER
7Ø5Ø  3Ø41            DCA 41
7Ø51  3Ø4Ø            DCA 4Ø
7Ø52  427Ø            JMS MULT2       /CALL SUBROUTINE TO
7Ø53  427Ø            JMS MULT2       /MULTIPLY BY TWO
7Ø54  43Ø7            JMS DUBLAD      /CALL DOUBLE ADD
7Ø55  427Ø            JMS MULT2
7Ø56  1265            TAD DIGIT       /ADD LAST DIGIT RECEIVED
7Ø57  3Ø43            DCA 43
7Ø6Ø  3Ø42            DCA 42
7Ø61  3Ø41            DCA 41
7Ø62  43Ø7            JMS DUBLAD
7Ø63  1Ø4Ø            TAD 4Ø          /EXIT WITH REMAINDER
7Ø64  5642            JMP I MULT1Ø    /IN AC

7Ø65  ØØØØ  DIGIT,    Ø               /STORAGE FOR DIGIT
7Ø66  ØØØØ  SIGN,     Ø               /=Ø IF PLUS: =7777 IF MINUS
7Ø67  ØØØØ  DNUMBR,   Ø               /=NUMBER OF DIGITS
7Ø7Ø  ØØØØ  MULT2,    Ø               /MULTIPLY LORDER, HORDER BY 2
```

```
7Ø71   73ØØ             CLA CLL
7Ø72   1Ø47             TAD LORDER
7Ø73   7ØØ4             RAL
7Ø74   3Ø47             DCA LORDER
7Ø75   1Ø46             TAD MIDDL
7Ø76   7ØØ4             RAL
7Ø77   3Ø46             DCA MIDDL
71ØØ   1Ø45             TAD HORDER
71Ø1   7ØØ4             RAL
71Ø2   3Ø45             DCA HORDER
71Ø3   1Ø4Ø             TAD 4Ø
71Ø4   7ØØ4             RAL
71Ø5   3Ø4Ø             DCA 4Ø
71Ø6   567Ø             JMP I MULT2
71Ø7   ØØØØ  DUBLAD,    Ø                    /DOUBLE PRECISION ADDITION
711Ø   73ØØ             CLA CLL
7111   1Ø47             TAD LORDER
7112   1Ø43             TAD 43
7113   3Ø47             DCA LORDER
7114   7ØØ4             RAL
7115   1Ø46             TAD MIDDL
7116   1Ø42             TAD 42
7117   3Ø46             DCA MIDDL
712Ø   7ØØ4             RAL
7121   1Ø45             TAD HORDER
7122   1Ø41             TAD 41
7123   3Ø45             DCA HORDER
7124   7ØØ4             RAL
7125   1Ø4Ø             TAD 4Ø
7126   3Ø4Ø             DCA 4Ø
7127   57Ø7             JMP I DUBLAD
713Ø   ØØØØ  MSIGN,     Ø                    /ROUTINE TO FORM
7131   73ØØ             CLA CLL              /2'S COMPLEMENT
7132   2266             ISZ SIGN             /IF C(SIGN)=7777
7133   573Ø             JMP I MSIGN
7134   4736             JMS I .+2
7135   573Ø             JMP I MSIGN
7136   6261             6261                 /"ACNEG" IN INTERPRETER

7137   7776  MINUS,     253-255              /TEST FOR SIGN
714Ø   7525  PLUS,      -253
7141   75Ø6  MIN9,      -272                 /TEST FOR DIGIT
7142   ØØ12  PLUS12,    272-26Ø
7143   76ØØ  MASK,      76ØØ                 /TEST FOR OVERFLOW
7144   7775  C.1Ø,      7775
7145   3146             3146
                            7146   3146          3146
7147   3147             3147
```

```
                 /INPUT A CHARACTER, IF CR, TEST
                 /INPUT SWITCH TO SEE IF LF SHOULD
                 /BE TYPED. IF RUBOUT, RESTART INPUT
7150  0000  INPUT,      0                        /INPUT A CHARACTER
7151  7200              CLA
7152  6031              KSF
7153  5352              JMP .-1
7154  6036              KRB
7155  3060              DCA CHAR
7156  1060              TAD CHAR
7157  4774              JMS I OUTPUT
7160  1060              TAD CHAR
7161  7450              SNA
7162  5351              JMP INPUT+1              /IGNORE BLANKS
7163  1376              TAD MRBOUT
7164  7450              SNA
7165  5775              JMP I RESTRT             /RUBOUT-RESTART INPUT
7166  1377              TAD MINCR
7167  7650              SNA CLA
7170  4773              JMS I PRINT              /CR - SEE IF TO BE FOLLOWED
7171  1060              TAD CHAR                 /BY LF
7172  5750              JMP I INPUT              /EXIT ROUTINE

7173  6767  PRINT,      PRCHAR
7174  7345  OUTPUT,     OUT
7175  7401  RESTRT,     FLINTP+1
7176  7401  MRBOUT,     -377
7177  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  4345              JMS OUT
7206  4737              JMS I FEXPPT             /CONVERT EXPONENT AND OUTPUT
7207  1056              TAD SWIT1                /PRINT CR-LF?
7210  7650              SNA CLA
7211  5600              JMP I FLOUTP             /NO-EXIT
7212  1341              TAD CARRTN               /YES
7213  4345              JMS OUT
7214  1342              TAD LNFEED
7215  4345              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 1Ø, ETC.
7217  ØØØØ  FOUTCN,    Ø
722Ø  73ØØ             CLA CLL
7221  1Ø45             TAD HORDER            /NUMBER>Ø??
7222  771Ø             SPA CLA
7223  722Ø             CLA CML               /NO SET LINK
7224  1327             TAD SPLUS             /YES
7225  743Ø             SZL
7226  133Ø             TAD SMINUS            /NO
7227  4345             JMS OUT
723Ø  4353             JMS OUTDG             /OUTPUT "Ø"
7231  1331             TAD PERIOD
7232  4345             JMS OUT               /OUTPUT "."
7233  73ØØ             CLA CLL
7234  1Ø45             TAD HORDER
7235  77ØØ             SMA CLA
7236  5242             JMP FG01
7237  7Ø4Ø             CMA                   /NUMBER IS NEGATIVE
724Ø  3733             DCA I SNPT            /NEGATE
7241  4732             JMS I MSNPT
7242  724Ø  FG01,      CLA CMA               /SUBTRACT 1 FROM BINARY EXPON
7243  1Ø44             TAD EXPONT            /COMPENSATE AT FG04
7244  3Ø44             DCA EXPONT
7245  3324             DCA BEXP              /INITIALIZE DECIMAL EXPONENT
7246  1Ø44  FG02,      TAD EXPONT            /IS -4<EXPONENT<-1
7247  75ØØ             SMA
725Ø  5263             JMP FG03              /TOO LARGE: MULTIPLY BY 1/1Ø
7251  1326             TAD FOUR
7252  77ØØ             SMA CLA
7253  527Ø             JMP FG04
7254  44Ø7             JMS I FPNT            /TOO SMALL-TIMES TEN
7255  374Ø             FMPY I TENPT          /TEN
7256  ØØØØ             FEXT
7257  724Ø             CLA CMA
726Ø  1324             TAD BEXP
7261  3324             DCA BEXP
7262  5246             JMP FG02
7263  44Ø7  FG03,      JMS I FPNT
7264  3744             FMPY I PRC.1Ø         /ONE TENTH
7265  ØØØØ             FEXT
7266  2324             ISZ BEXP
7267  5246             JMP FG02
```

```
7270  3734  FG04,     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  4360  FG05A,    JMS DIVTWO        /COMPENSATE FOR
7275  2044            ISZ EXPONT        /BINARY EXPONENT
7276  5274            JMP FG05A
7277  7450            SNA               /IS FIRST DIGIT A ZERO
7300  5311            JMP FG07          /YES, IGNORE
7301  4353  FG06,     JMS OUTDG         /MULTIPLICATIONS YIELD
7302  1325            TAD MINUS7        /DECIMAL DIGITS AS HIGH
7303  3044            DCA EXPONT        /ORDER REMAINDERS
7304  4735  FG06A,    JMS I M10PT       /IE. .672X10=6+.72.. ETC
7305  4353            JMS OUTDG
7306  2044            ISZ EXPONT        /7 DIGITS OUTPUT??
7307  5304            JMP FG06A         /NO: CONTINUE
7310  5617            JMP I FOUTCN      /YES:EXIT

7311  7240  FG07,     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  1047            TAD LORDER
7320  7650            SNA CLA
7321  3324            DCA BEXP          /YES:EXP=0
7322  7240            CLA CMA
7323  5302            JMP FG06+1

7324  0000  BEXP,     0                 /CONTAINS DECIMAL EXPONENT
7325  7767  MINUS7,   -11               /NUMBER OF DIGITS OUTPUT
7326  0004  FOUR,     0004
7327  0253  SPLUS,    253
7330  0002  SMINUS,   255-253
7331  0256  PERIOD,   256
7332  7130  MSNPT,    MSIGN
7333  7066  SNPT,     SIGN              /POINTERS
7334  7065  DPT,      DIGIT
7335  7042  M10PT,    MULT10
7336  7070  M2PT,     MULT2
7337  7523  FEXPPT,   FEXC
7340  7504  TENPT,    TEN
7341  0215  CARRTN,   0215
7342  0212  LNFEED,   0212
7343  0305  CHE,      305
7344  7144  PRC.10,   C.10
```

```
7345  0000  OUT,      0                  /OUTPUT ONE ASCII CHARACTER
7346  6041            TSF
7347  5346            JMP .-1
7350  6046            TLS
7351  7200            CLA
7352  5745            JMP I OUT

7353  0000  OUTDG,    0                  /OUTPUT ONE DIGIT
7354  1357            TAD C260
7355  4345            JMS OUT
7356  5753            JMP I OUTDG

7357  0260  C260,     0260

7360  0000  DIVTWO,   0                  /DIVIDE BY TWO IE.
7361  7110            CLL RAR            /ROTATE RIGHT
7362  3345            DCA OUT            /TEMPORARY STORAGE
7363  1045            TAD HORDER
7364  7010            RAR
7365  3045            DCA HORDER
7366  1046            TAD MIDDL
7367  7010            RAR
7370  3046            DCA MIDDL
7371  1047            TAD LORDER
7372  7010            RAR
7373  3047            DCA LORDER
7374  1345            TAD OUT
7375  5760            JMP I DIVTWO

            /FLOATING POINT INPUT
            *7400
7400  0000  FLINTP,   0
7401  7240            CLA CMA            /INITIALIZE "PERIOD SWITCH"
7402  3314            DCA PRSW
7403  3061            DCA DSWIT
7404  4717            JMS I DPCVPT       /7777 = NO PERIOD
7405  7200            CLA
7406  1060            TAD CHAR
7407  1313            TAD PER
7410  7640            SZA CLA
7411  5220            JMP FIGO1
7412  1314            TAD PRSW           /PERIOD FOUND
7413  7650            SNA CLA            /SECOND PERIOD
7414  5222            JMP FIGO2          /YES,TERMINATE
7415  3722            DCA I DPN          /NO - SET NUMBER OF DIGITS TO
7416  3314            DCA PRSW           /SET PERIOD SWITCH TO 0
7417  5720            JMP I DPCSPT       /CONVERT REST OF STRING
```

```
7420  1314  FIGO1,     TAD PRSW          /PERIOD READ IN PREVIOUSLY?
7421  7650             SNA CLA
7422  1722  FIGO2,     TAD I DPN         /YES:-NUMBER OF DIGITS IN SER
7423  7041             CMA IAC           /NO
7424  3315             DCA SEXP
7425  4721             JMS I MSGNPT      /TEST SIGN
7426  1312  FIGO3,     TAD C43
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  1060             TAD CHAR
7435  1311             TAD MINUSE
7436  7640             SZA CLA           /"E" READ IN?
7437  5252             JMP ENDFI         /NO
7440  4717             JMS I DPCVPT      /YES - CONVERT DECIMAL EXPONE
7441  4721             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  1047             TAD LORDER        /NO:DECIMAL POINT IS
7450  1315             TAD SEXP          /C(SEXP)PLACES TO RIGHT
7451  3315             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  1315             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  3710             FMPY I PC.10      /TIMES .1000
7464  0000             FEXT
7465  2315             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  1315            TAD SEXP
7475  3315            DCA SEXP
7476  5255            JMP ENDFI+3
7477  1316  EXCESS,   TAD C3777
7500  3044            DCA EXPONT
7501  1316            TAD C3777
7502  3045            DCA HORDER
7503  5600            JMP I FLINTP
7504  0004  TEN,      0004
7505  2400            2400
7506  0000            0000
7507  0000            0000
7510  7144  PC.10,    C.10                 /.10
7511  7473  MINUSE,   -305
7512  0043  C43,      0043
7513  7522  PER,      -256
7514  0000  PRSW,     0
7515  0000  SEXP,     0                    /CONTAINS DECIMAL EXPONENT
7516  3777  C3777,    3777

7517  7000  DPCVPT,   DECONV
7520  7020  DPCSPT,   DECON
7521  7130  MSGNPT,   MSIGN
7522  7067  DPN,      DNUMBR

            /OUTPUT THE EXPONENT

7523  0000  FEXC,     0
7524  7300            CLA CLL
7525  1044            TAD EXPONT
7526  7510            SPA
7527  7061            CMA IAC CML
7530  3044            DCA EXPONT
7531  1367            TAD C253
7532  7430            SZL
7533  1370            TAD C255
7534  4775            JMS I DGPT
7535  3045            DCA HORDER
7536  1044            TAD EXPONT
7537  2045            ISZ HORDER
7540  1371            TAD M144
7541  7500            SMA
7542  5337            JMP .-3
```

```
7543  1372              TAD C144
7544  3044              DCA EXPONT
7545  7040              CMA
7546  1045              TAD HORDER
7547  7440              SZA
7550  4775              JMS I DGPT
7551  3045              DCA HORDER
7552  1044              TAD EXPONT
7553  2045              ISZ HORDER
7554  1373              TAD M12
7555  7500              SMA
7556  5353              JMP .-3
7557  1374              TAD C12
7560  3047              DCA LORDER
7561  7240              CLA CMA
7562  1045              TAD HORDER
7563  4775              JMS I DGPT
7564  1047              TAD LORDER
7565  4775              JMS I DGPT
7566  5723              JMP I FEXC

7567  7773  C253,       0253-260
7570  0002  C255,       255-253
7571  7634  M144,       7634
7572  0144  C144,       0144
7573  7766  M12,        7766
7574  0012  C12,        0012
7575  7353  DGPT,       OUTDG


BEXP     7324
CARRTN   7341
CHAR     0060
CHE      7343
C.10     7144
C12      7574
C144     7572
C253     7567
C255     7570
C260     7357
C3777    7516
C43      7512
DECON    7020
DECONV   7000
DGPT     7575
DIGIT    7065
DIVTWO   7360
DNUMBR   7067
DPCSPT   7520
```

DPCVPT	7517
DPN	7522
DPT	7334
DSWIT	ØØ61
DUBLAD	71Ø7
ENDFI	7452
EXCESS	7477
EXPONT	ØØ44
FEXC	7523
FEXPPT	7337
FG01	7242
FG02	7246
FG03	7263
FG04	727Ø
FG05A	7274
FG06	73Ø1
FG06A	73Ø4
FG07	7311
FIG01	742Ø
FIG02	7422
FIG03	7426
FIG04	747Ø
FLINTP	74ØØ
FLOUTP	72ØØ
FOUR	7326
FOUTCN	7217
FPAC1	ØØ52
FPNT	ØØØ7
HORDER	ØØ45
INPUT	715Ø
LFED	6777
LNFEED	7342
LORDER	ØØ47
MASK	7143
MIDDL	ØØ46
MINCR	7177
MINUS	7137
MINUSE	7511
MINUS7	7325
MIN9	7141
MRBOUT	7176
MSGNPT	7521
MSIGN	713Ø
MSNPT	7332
MULT1Ø	7Ø42
MULT2	7Ø7Ø
M1ØPT	7335
M12	7573
M144	7571
M2PT	7336
OPUT	6776
OUT	7345
OUTDG	7353
OUTPUT	7174
PC.1Ø	751Ø
PER	7513
PERIOD	7331
PLUS	714Ø
PLUS12	7142
PRCHAR	6767
PRC.1Ø	7344
PRINT	7173
PRSW	7514
RESTRT	7175
SEXP	7515
SIGN	7Ø66
SMINUS	733Ø
SNPT	7333
SPLUS	7327
SWIT1	ØØ56
SWIT2	ØØ57
TEN	75Ø4
TENPT	734Ø

11. DIAGRAMS (Not Applicable)

12 REFERENCES

See Digital-8-5-S.

1. Logical Subroutines, DEC-08-FMIA-D.

2. ABSTRACT

Subroutines for performing the logical operations of inclusive and exclusive OR are presented as a package.

3. REQUIREMENTS

3.1 Storage

Inclusive OR requires 12 (decimal) core locations. Exclusive OR requires 14 (decimal) locations.

3.3 Equipment

Basic PDP-8

4. USAGE

4.1 Loading

The subroutines may be placed in memory by means of the Binary Loader. See Digital-8-2-U-Rim for a complete description of this loader and its use.

4.2 Calling Sequence

Both subroutines are called by a JMS instruction with one argument in the accumulator. The location following the calling JMS contains the address of the second argument. Both subroutines return to the location following that containing the latter address with the result in the AC.

6. DESCRIPTION

6.1 Discussion

These subroutines supplement the AND and CMA hardware instructions in the performance of logical operations. Note that the result of the exclusive OR is the complement of the logical operation termed the "biconditional."

6.2 Examples

Truth tables for these functions are as follows. Depending on the values of corresponding bits in A and B, the associated bit of the result conforms to the following truth tables:

AND			Inclusive OR			Exclusive OR			Biconditional		
A	B	Result	A	B	Result	A	B	Result	A	B	Result
0	0	0	0	0	0	0	0	0	0	0	1
0	1	0	0	1	1	0	1	1	0	1	0
1	0	0	1	0	1	1	0	1	1	0	0
1	1	1	1	1	1	1	1	0	1	1	1

Or for complete data words

Inclusive OR		Exclusive OR	
A	011 010 111 001	A	011 010 111 001
B	010 110 101 100	B	010 110 101 101
Result	011 110 111 101	Result	001 100 010 100

9. EXECUTION TIME

9.2 Maximum

Execution time is actually fixed for these subroutines. Inclusive OR requires precisely 32.0 microseconds. Exclusive OR requires exactly 46.0 microseconds.

10. PROGRAM

10.4 Program Listing

A listing of both subroutines with INCOR stored in 0200 is as follows:

```
                        /LOGICAL SUBROUTINES
                        /ENTER WITH A IN AC
                        /ADDRESS OF B FOLLOWS CALLING JMS
                        /RETURN WITH RESULT IN AC TO
                        /LOCATION FOLLOWING THAT HOLDING ADDRESS

0200    0000    INCOR,      0                   /INCLUSIVE OR
0201    3226                DCA   TEMPY1
0202    1600                TAD I INCOR
0203    3227                DCA   TEMPY2
0204    1627                TAD I TEMPY2
0205    7040                CMA
0206    0226                AND   TEMPY1
```

```
0207    1627               TAD I  TEMPY2
0210    2200               ISZ    INCOR
0211    5600               JMP I  INCOR
0212    0000    EXCOR,     0                 /EXCLUSIVE OR
0213    3226               DCA    TEMPY1
0214    1612               TAD I  EXCOR
0215    3227               DCA    TEMPY2
0216    1226               TAD    TEMPY1
0217    0627               AND I  TEMPY2
0220    7041               CIA
0221    7104               CLL  RAL
0222    1226               TAD    TEMPY1
0223    1627               TAD I  TEMPY2
0224    2212               ISZ    EXCOR
0225    5612               JMP I  EXCOR
0226    0000    TEMPY1,    0
0227    0000    TEMPY2,    0
```

1. Arithmetic Shift Subroutines, DEC-08-FMJA-D.

2. ABSTRACT

Four basic subroutines, shift right and shift left each at both single and double precision, are presented as a package. These are arithmetic shifts.

3. REQUIREMENTS

3.1 Storage

Core storage required for these subroutines is as follows in decimal:

	Shift Left	Shift Right
Single Precision	12	15
Double Precision	24	27

3.3 Equipment

Basic PDP-8

4. USAGE

4.1 Loading

These subroutines may be loaded using the Binary Loader. See Digital-8-2-U-Rim for a complete description of this loader.

4.2 Calling Sequence

All four subroutines are called with -N (the 2's complement form of N) in the accumulator. N is a binary integer specifying the number of bit positions the data words are to be shifted.

In the location following the calling JMS instruction is an address which in the case of the single-precision subroutines is the address of the data to be shifted. In the case of the double-precision subroutines, this address is that of the most significant portion of the data. The least significant portion of the data must be located in the address following that of the most significant portion.

These subroutines will return to the address following that of the calling JMS plus two. Upon exit, the AC will hold the shifted data in the case of single-precision shifts. In the case of double-precision shifts, the AC will hold the most significant portion of the result while the least significant portion of the result will be stored in location LSH.

4.5 Errors

It is possible by specifying too large an N to shift data completely out of a computer word or words in the case of single-precision shifts or double-precision shifts, respectively. These subroutines do not test for this eventuallity.

6. DESCRIPTION

6.1 Discussion

These subroutines are arithmetic shift subroutines. By this is meant that in the case of any shift, bits shifted "out" of the register are lost. In the case of left shifts, bits moving into the least significant bit position are always 0. In the case of right shifts, bits moving into the most significant bit position (the sign) bits are 0 if the original data was positive but are 1 if the original data was negative.

6.2 Examples

The following examples illustrate the nature of the single-precision shift process. In each example, a shift of four bits is shown:

		Right	Left
Positive	Data	000 010 100 100	000 000 111 101
	Result	000 000 001 010	001 111 010 000
Negative	Data	111 111 010 100	111 110 000 101
	Result	111 111 111 101	100 001 010 000

6.3 Scaling

Shift right and shift left operations are the fundamental means by which numerical data is scaled in fixed-point computers.

For more information on numerical binary scaling for fixed-point computers, see Application Note 801.

9. EXECUTION TIMES

9.3 Timing Equations

Time needed for a given shift may be calculated from the following equations.

9.3.1 Single-Precision Shift Left - Time in microseconds = 22.4 + 6.4N

9.3.2 Single-Precision Shift Right - For positive data, time in microseconds = 22.4 + 9.6N. For negative data, time in microseconds = 22.4 + 11.2N.

9.3.3 Double-Precision Shift Left - Time in microseconds = 40.0 + 20.8N

9.3.4 Double-Precision Shift Right - For positive data, time in microseconds = 40.0 + 24.0N. For negative data, time in microseconds = 40.0 + 25.6N.

10. PROGRAM

10.4 Program Listing

A listing of all four subroutines with SPSL located at 0600 is as follows:

```
                /SHIFT RIGHT SHIFT LEFT SUBROUTINES
                /SINGLE AND DOUBLE PRECISION
                /SHIFTS ARE ARITHMETIC RATHER THAN LOGICAL
                /BITS SHIFTED OUT OF REGISTER ARE LOST
                /DURING LEFT SHIFTS ZEROS ENTER LEAST SIG. BIT
                /DURING POSITIVE RIGHT SHIFTS ZEROS ENTER MOST SIG. BIT
                /DURING NEGATIVE RIGHT SHIFTS SIGN IS PROPAGATED
                /ENTER WITH -N IN AC
                /CALLING SEQUENCE : JMS SPSL OR SPSR OR DPSL OR DPSR
                /                           ADDRESS OF DATA
                /                           RETURN, RESULT IN AC FOR SINGLE
                /                                   RESULT (MSB) IN AC FOR DOUBLE
                /                                   RESULT (LSB) IN LSH FOR DOUBLE
                *600
0600    0000    SPSL,   0
0601    3302            DCA CNTR        /SINGLE PRECISION SHIFT LEFT
0602    1600            TAD I SPSL
0603    3303            DCA ADDR
0604    1703            TAD I ADDR
0605    2200            ISZ SPSL
0606    7104            CLL RAL
0607    2302            ISZ CNTR
0610    5206            JMP .-2
0611    5600            JMP I SPSL
0612    0000    SPSR,   0
0613    3302            DCA CNTR        /SINGLE PRECISION SHIFT RIGHT
0614    1612            TAD I SPSR
0615    3303            DCA ADDR
0616    1703            TAD I ADDR
0617    2212            ISZ SPSR
0620    7100            CLL
0621    7510            SPA
0622    7020            CML
0623    7010            RAR
0624    2302            ISZ CNTR
0625    5220            JMP .-5
0626    5612            JMP I SPSR
```

```
0627   0000   DPSL,   0
0630   3302           DCA CNTR      /DOUBLE PRECISION SHIFT LEFT
0631   1627           TAD I DPSL
0632   3303           DCA ADDR
0633   1703           TAD I ADDR
0634   3304           DCA MSH       /MOST SIGNIFICANT HALF
0635   2303           ISZ ADDR
0636   1703           TAD I ADDR
0637   3305           DCA LSH       /LEAST SIGNIFICANT HALF
0640   2227           ISZ DPSL
0641   1305           TAD LSH       /SHIFT LEFT
0642   7104           CLL RAL
0643   3305           DCA LSH
0644   1304           TAD MSH
0645   7004           RAL
0646   3304           DCA MSH
0647   2302           ISZ CNTR
0650   5241           JMP .-7
0651   1304           TAD MSH
0652   5627           JMP I DPSL
0653   0000   DPSR,   0
0654   3302           DCA CNTR      /DOUBLE PRECISION SHIFT RIGHT
0655   1653           TAD I DPSR
0656   3303           DCA ADDR
0657   1703           TAD I ADDR
0660   3304           DCA MSH       /MOST SIGNIFICANT HALF
0661   2303           ISZ ADDR
0662   1703           TAD I ADDR
0663   3305           DCA LSH       /LEAST SIGNIFICANT HALF
0664   2253           ISZ DPSR
0665   1304           TAD MSH       /SHIFT RIGHT
0666   7100           CLL
0667   7510           SPA
0670   7020           CML
0671   7010           RAR
0672   3304           DCA MSH
0673   1305           TAD LSH
0674   7010           RAR
0675   3305           DCA LSH
0676   2302           ISZ CNTR
0677   5265           JMP .-12
```

```
0700    1304            TAD MSH
0701    5653            JMP I DPSR
0702    0000    CNTR,   0
0703    0000    ADDR,   0
0704    0000    MSH,    0
0705    0000    LSH,    0
ADDR       0703
CNTR       0702
DPSL       0627
DPSR       0653
LSH        0705
MSH        0704
SPSL       0600
SPSR       0612
```

1. Logical Shift Subroutines, DEC-08-FMKA-D.

2. ABSTRACT

Two basic subroutines, shift right at both single and double precision are presented as a package. The shifts are logical in nature.

3. REQUIREMENTS

3.1 Storage

Core storage required for these subroutines is 12 (decimal) locations for single precision and 24 (decimal) locations for double precision.

3.3 Equipment

Basic PDP-8

4. USAGE

4.1 Loading

These subroutines may be loaded using the Binary Loader. See Digital-8-2-U-Rim for a complete description of this loader.

4.2 Calling Sequence

Call with -N (the 2's complement form of N) in the accumulator. N is a binary integer specifying the number of bit positions the data word is to be shifted

In the location following the calling JMS is the address of the data in the case of single precision. For double precision this location contains the address of the most significant portion of the data which must be stored in two consecutive words.

The subroutines return to the location following that containing the data address.

For single precision the result is in the accumulator upon return. For double precision the most significant part of the result is in the accumulator on return while the balance of the result is in location LESTSG.

4.5 Errors

It is quite possible by specifying too large an N effectively to shift data completely out of a computer word or words.

6. DESCRIPTION

6.1 Discussion

These subroutines are logical shift subroutines. It is important to note that there is no difference between arithmetic and logical shifts in the case of left shifts. Consequently only two new subroutines in addition to those described in Digital-8-8-U-Sym are required to supply all logical shifts.

Logical right shifts are defined as those in which bits shifted "out" of the least significant bit position are lost. Bits moving into the most significant bit position are always 0.

6.3 Examples

The following examples illustrate the nature of the single-precision logical right shift. In each example, a shift of four bits is shown.

Data	Result
000 010 111 000	000 000 001 011
111 010 000 000	000 011 101 000

9. EXECUTION TIMES

9.3 Timing Equations

Time needed for a given shift may be calculated from the following equations.

9.3.1 Single-Precision Logical Right Shift - Time in microseconds = 22.4 + 6.4N.

9.3.2 Double-Precision Logical Right Shift - Time in microseconds = 36.8 + 24.0N.

10. PROGRAM

10.4 Program Listing

A listing of both subroutines with LSRSP located in 0200 is as follows:

```
                /LOGICAL SHIFT RIGHT SUBROUTINES
                /SINGLE AND DOUBLE PRECISION
                /ENTER WITH -N IN AC
                /DATA ADDRESS FOLLOWS CALLING JMS
                /RETURN WITH DATA IN AC
                /MOST SIGNIFICANT PART FOR DOUBLE
                /LEAST SIG. PART FOR DOUBLE IN LESTSG
0200  0000         LSRSP,    0                /SINGLE PRECISION
0201  3236                   DCA TIMES
0202  1600                   TAD I LSRSP
0203  3237                   DCA COMMUN
```

```
0204   1637             TAD I COMMUN
0205   7110             CLL RAR           /SHIFT LOOP
0206   2236             ISZ TIMES
0207   5205             JMP .-2
0210   2200             ISZ LSRSP         /EXIT
0211   5600             JMP I LSRSP
0212   0000   LSRDP,    0                 /DOUBLE PRECISION
0213   3236             DCA TIMES
0214   1612             TAD I LSRDP
0215   3237             DCA COMMUN
0216   1637             TAD I COMMUN
0217   3240             DCA MOSTSG
0220   2237             ISZ COMMUN
0221   1637             TAD I COMMUN
0222   3241             DCA LESTSG
0223   1240   SHIFT,    TAD MOSTSG        /SHIFT LOOP
0224   7110             CLL RAR
0225   3240             DCA MOSTSG
0226   1241             TAD LESTSG
0227   7010             RAR
0230   3241             DCA LESTSG
0231   2236             ISZ TIMES
0232   5223             JMP SHIFT
0233   1240             TAD MOSTSG        /EXIT
0234   2212             ISZ LSRDP
0235   5612             JMP I LSRDP
0236          TIMES,    0
0237          COMMUN,   0
0240          MOSTSG,   0
0241          LESTSG,   0
```

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