

PROGRAM LIBRARY  
MATH ROUTINES

**PDP-8**



# **PDP-8**

## **PROGRAM LIBRARY**

### **MATH ROUTINES**

January, 1968

Order No. DEC-08-FFAA-D from Program Library, Maynard, Mass. Price \$ 1.50

Direct comments concerning this manual to Software Quality Control, Maynard, Mass.

DIGITAL EQUIPMENT CORPORATION • MAYNARD, MASSACHUSETTS

Reprinted  
September, 1967

Copyright 1968 by Digital Equipment Corporation

## CONTENTS

<u>Part</u>		<u>Page</u>
1.	Single-Precision Square Root DEC-08-FMAA-D . . . . .	1 - 1
2.	Single-Precision Signed Multiply Subroutine DEC-08-FMBA-D . . . . .	2 - 1
3.	Single-Precision Signed Divide Subroutine DEC-08-FMCA-D . . . . .	3 - 1
4.	Double-Precision Signed Multiply DEC-08-FMDA-D . . . . .	4 - 1
5.	Double-Precision Signed Divide Subroutine DEC-08-FMEA-D . . . . .	5 - 1
6.	Double-Precision Sine Subroutine DEC-08-FMFB-D . . . . .	6 - 1
7.	Double-Precision Cosine Subroutine DEC-08-FMGB-D . . . . .	7 - 1
8.	Four-Word Floating-Point Package DEC-08-FMHA-D . . . . .	8 - 1
9.	Logical Subroutines DEC-08-FMIA-D . . . . .	9 - 1
10.	Arithmetic Shift Subroutines DEC-08-FMJA-D . . . . .	10 - 1
11.	Logical Shift Subroutines DEC-08-FMKA-D . . . . .	11 - 1



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

$$(30 + N (25.5)) \mu\text{sec}$$

## 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
0201 3222
0202 3226
0203 1223
0204 3225
0205 1222
0206 /100
0207 1225
0210 7420
0211 5217
0212 2226
0213 3222
0214 1225
0215 1224
0216 5204
0217 7200
0220 1226
0221 5600
0222 0000
0223 /117
0224 /176
0225 0000
0226 0000

SQR1, 0
DCA SQR1 /SAVE INPUT
DCA ROOT /0 TO ANSWER
TAD SQR2 /-1; FIRST ATTEMPT
SQR, DCA SQR0
TAD SQR1 /COMPARE INPUT
CLL /WITH THIS TRY
TAD SQR0
SNL
JMP SQRF /TEST>INPUT; ALL DONE
ISZ ROOT /ADD +1 TO ANSWER
DCA SQR1 /INPUT=INPUT-TEST
TAD SQR0
TAD SQR3 /TEST=TEST-2
JMP SQX /CONTINUE
SQRF, CLA
TAD ROOT /FETCH ANSWER
JMP I SQR1 /EXIT
SQR1, 0
SQR2, -1
SQR3, -2
SQR0, 0
ROOT, 0

```

PAUSE

\$

THERE ARE NO ERRORS

SYMBOL TABLE

ROOT	0226
SQR0	0225
SQRF	0217
SQR1	0200
SQR1	0222
SQR2	0223
SQR3	0224
SQR	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:

<u>Sign of Multiplier</u>	<u>Sign of Multiplicand</u>	<u>Link</u>
0	0	0
0	1	1
1	0	1
1	1	0

and represents, 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  $C(Y) \neq 0$ ,  $C(Y) \rightarrow C(MP2)$ ,  $C(MP5)$  are cleared and multiplication 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.

<u>MP5</u>	<u>MP1</u>	<u>Y</u>	<u>Comments</u>
00000	01001	00100	Initial contents of the register MP1 ready to be tested.
00100	01001		$C(MP2) + C(MP5) \rightarrow C(MP5)$ 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		$C(MP2) + C(MP5) \rightarrow C(MP5)$ 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  $\mu$ sec if the multiplier is positive and 27.0  $\mu$ sec if the multiplier is negative.

### 9.2 Maximum

Maximum execution time occurs when the sign of the product is negative and the multiplier consists (in binary) of all 1s. This time is approximately 350  $\mu$ sec.

## 10. PROGRAM

### 10.4 Program Listing

/DEC-08-FMBA

/TWO'S COMPLEMENT SINGLE PRECISION MULTIPLY ROUTINE

/RETURN HIGH ORDER PRODUCT IN AC, LOW IN MP1

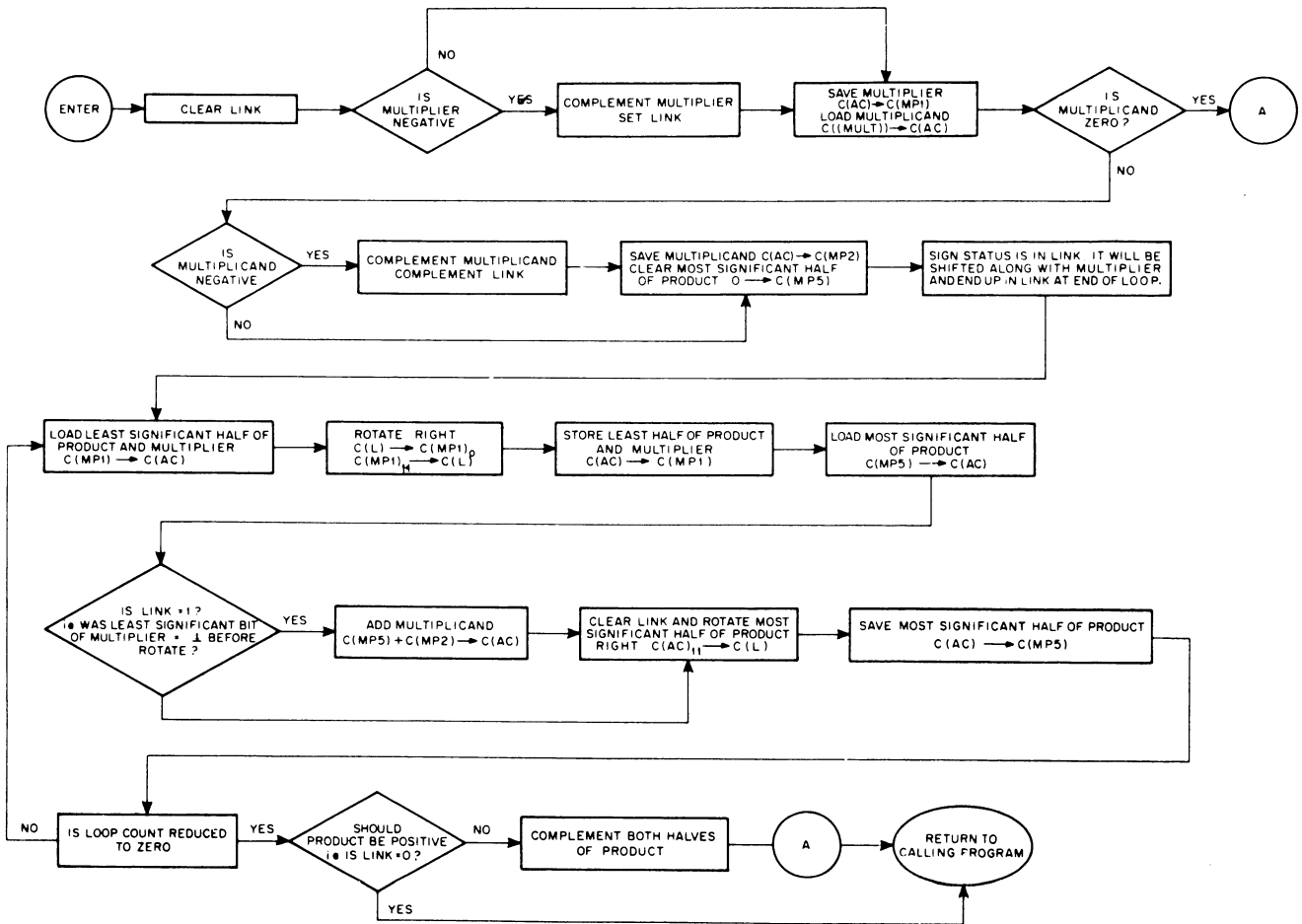
0200	0000	MULT,	0	
0201	7100		CLL	
0202	7510		SPA	/TEST FOR NEGATIVE MULTIPLIER
0203	7061		CMA CML IAC	
0204	3250		DCA MP1	/STORE MULTIPLIER
0205	3251		DCA MP5	
0206	1600		TAD I MUL1	
0207	7450		SNA	/TEST FOR ZERO MULTIPLICAND
0210	5234		JMP MP5N+2	/JMP IF MULTIPLICAND=0
0211	7510		SPA	/TEST FOR NEGATIVE MULTIPLICAND
0212	7061		CMA CML IAC	
0213	3252		DCA MP2	/STORE MULTIPLICAND
0214	1247		TAD THIR	
0215	3253		DCA MP3	
0216	1250	MP4,	TAD MP1	/MULTIPLY LOOP PROPER
0217	7010		RAR	
0220	3250		DCA MP1	
0221	1251		TAD MP5	
0222	7430		SZL	/TEST IF MULTIPLICAND SHOULD BE ADDED
0223	1252		TAD MP2	
0224	7110		CLL RAR	
0225	3251		DCA MP5	
0226	2253		ISZ MP3	/TEST FOR END OF LOOP
0227	5216		JMP MP4	
0230	1250		TAD MP1	
0231	7010		RAR	
0232	7430	MPSN,	SZL	
0233	5240		JMP COMP	
0234	3250		DCA MP1	
0235	1251		TAD MP5	
0236	2200	MPZ,	ISZ MUL1	/EXIT TO CALLING PROGRAM
0237	5600		JMP I MUL1	
0240	7141	COMP,	CMA CLL IAC	/COMPLEMENT PRODUCT
0241	3250		DCA MP1	
0242	1251		TAD MP5	
0243	7040		CMA	
0244	7430		SZL	
0245	7001		IAC	
0246	5236		JMP MPZ	
0247	7764	THIR,	7764	/ELEVEN IN DECIMAL
0250	0000	MP1,	0	
0251	0000	MP5,	0	
0252	0000	MP2,	0	
0253	0000	MP3,	0	
		PAUSE		

SYMBOL TABLE

CUMP	0240
MPSN	0232
MPZ	0236
MP1	0250
MP2	0252
MP3	0253
MP4	0216
MP5	0251
MULI	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:

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

= Quotient, Remainder

or

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

Since  $(\text{Quotient}) < 3777(8)$ , it is possible that a divisor and dividend are so specified that no quotient may be found that satisfies this identity. If  $\text{High-Order Dividend} \geq \text{Quotient}$ , 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:

$$\begin{array}{r} 1777 \ 7777 \\ \hline 2000 \end{array}$$

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.

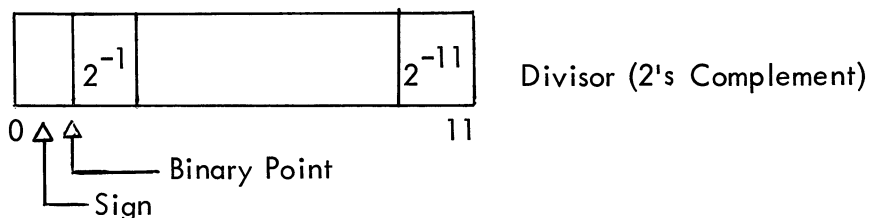
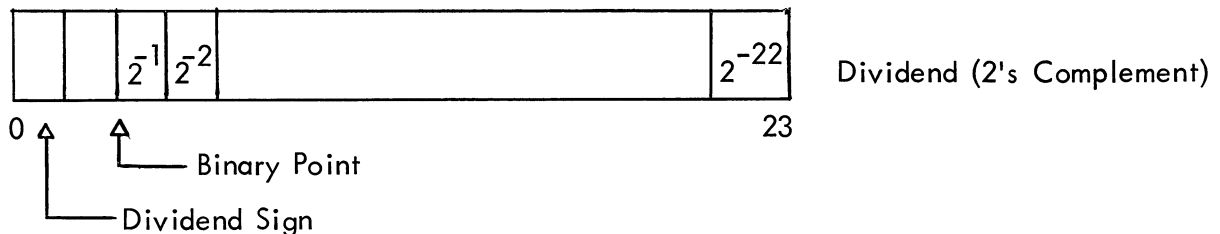
6. DESCRIPTION

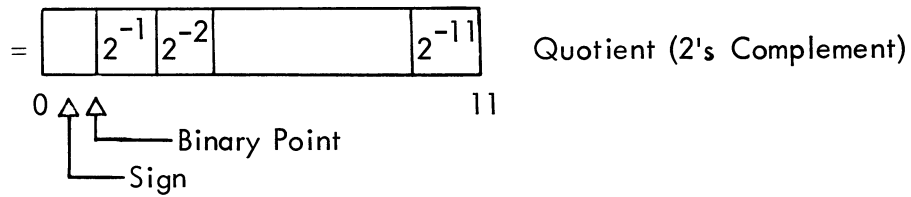
6.1 Discussion

The algorithm works by shifting the dividend left and comparing it with the divisor. If  $\text{Dividend} \geq \text{Divisor}$  then  $\text{Dividend} = \text{Dividend} - \text{Divisor}$ , 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:  $(\text{Dividend Sign}) \text{ XOR } (\text{Divisor Sign}) = (\text{Quotient Sign})$ .

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.





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

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

7. METHODS (See Above)

9. EXECUTION TIME

9.1 Minimum 58.5  $\mu$ sec (Divide Check)

- 
- 9.2        Maximum        478.5  $\mu$ sec
  - 9.3        Average          $\approx$  460  $\mu$ sec
  - 10.        PROGRAM
  - 10.4      Program Listing

```

/DEC-08-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

0200	0000	DIVIDE,	0	
0201	7100		ULL	
0202	7510		SPA	/DIVIDEND<0?
0203	7060		CMA CML	/YES COMPLEMENT AND SET C(L)
0204	3267		UCA HDIVND	/HIGH ORDER DIVIDEND
0205	7420		SNL	
0206	7040		CMA	
0207	3272		UCA SDVND	/SET DIVIDEND SIGN SWITCH
0210	1600		TAU I DIVIDE	/FETCH LOW ORDER DIVIDEND
0211	7430		SZL	
0212	7141		CMA ULL IAC	/YES: COMPLEMENT
0213	3270		UCA LDIVND	/LOW ORDER DIVIDEND
0214	7430		SZL	/CARRY?
0215	2267		ISZ HDIVND	/YES
0216	2200		ISZ DIVIDE	
0217	1600		TAU I DIVIDE	/FETCH DIVISOR
0220	7100		ULL	
0221	7500		SMA	
0222	7061		CMA CML IAC	/NEGATE IT
0223	3271		UCA DIVSOR	/SAVE DIVISOR
0224	7420		SNL	/WAS IT <0?
0225	7040		CMA	/YES: AC=-1
0226	1272		TAU SDVND	
0227	3273		UCA ANSWER	/ANSWER SIGN SWITCH
0230	7100		ULL	
0231	1271		TAU DIVSOR	/COMPARE DIVISOR
0232	1267		TAU HDIVND	/WITH DIVIDEND
0233	2200		ISZ DIVIDE	
0234	7630		SZL CLA	/OVER FLOW?
0235	5600		JMP I DIVIDE	/YES: DIVISOR<DIVIDEND

/PAGE 2

0236 1270  
0237 3274  
0240 5251

TAU M13  
UCA DIVCNT  
JMP DV2

/13 SHIFTS

/DIVIDE LOUP

0241 1267  
0242 7004  
0243 3267  
0244 1267  
0245 1271  
0246 7430  
0247 3267  
0250 7200  
0251 1270  
0252 7004  
0253 3270  
0254 2274  
0255 5241  
0256 1267  
0257 2272  
0260 7041  
0261 3267  
0262 1270  
0263 2273  
0264 7041  
0265 7100  
0266 5600

DV3, TAU HDIVND  
KAL  
UCA HDIVND  
TAU HDIVND  
TAU DIVSOR  
SZL  
UCA HDIVND  
CLA  
DV2, TAU LDIVND  
KAL  
UCA LDIVND  
ISZ DIVCNT  
JMP DV3  
TAU HDIVND  
ISZ SDVND  
CMA IAC  
UCA HDIVND  
TAU LDIVND  
ISZ ANSWER  
CMA IAC  
CLL  
JMP I DIVIDE

/DIVIDEND LEFT SHIFT

/COMPARE DIVISOR/DIVIDEND

/REMAINDER AFTER SUBTRACT

/QUOTIENT BITS

/ENTER HERE

/DONE 12?

/NO: CONTINUE

/REMAINDER

/DIVIDEND<0?

/YES

/QUOTIENT

/ANSWER<0?

/YES: NEGATE

/EXIT

0267 0000  
0270 0000  
0271 0000  
0272 0000  
0273 0000  
0274 0000  
0275 7763

HDIVND, 0  
LDIVND, 0  
DIVSOR, 0  
SDVND, 0  
ANSWER, 0  
DIVCNT, 0  
M13, -10

/-13(10)

5

SYMBOL TABLE

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

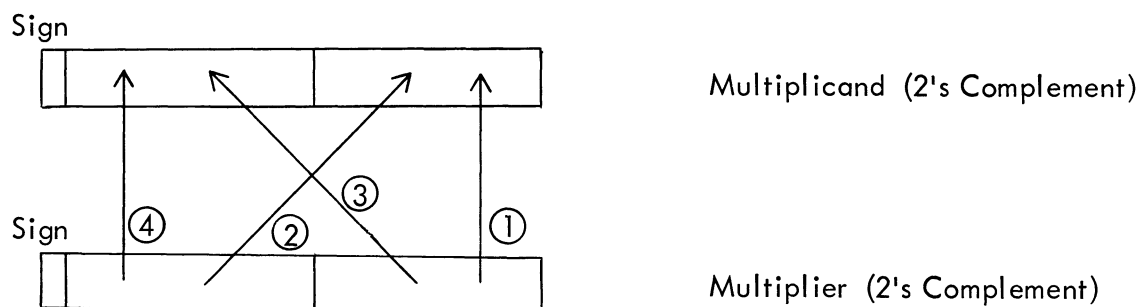
The signed double precision multiply routine is called by an effective JMS DMUL. The two locations following the JMS must contain the address of the high-order multiplicand and the address of the high-order multiplier respectively.

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.

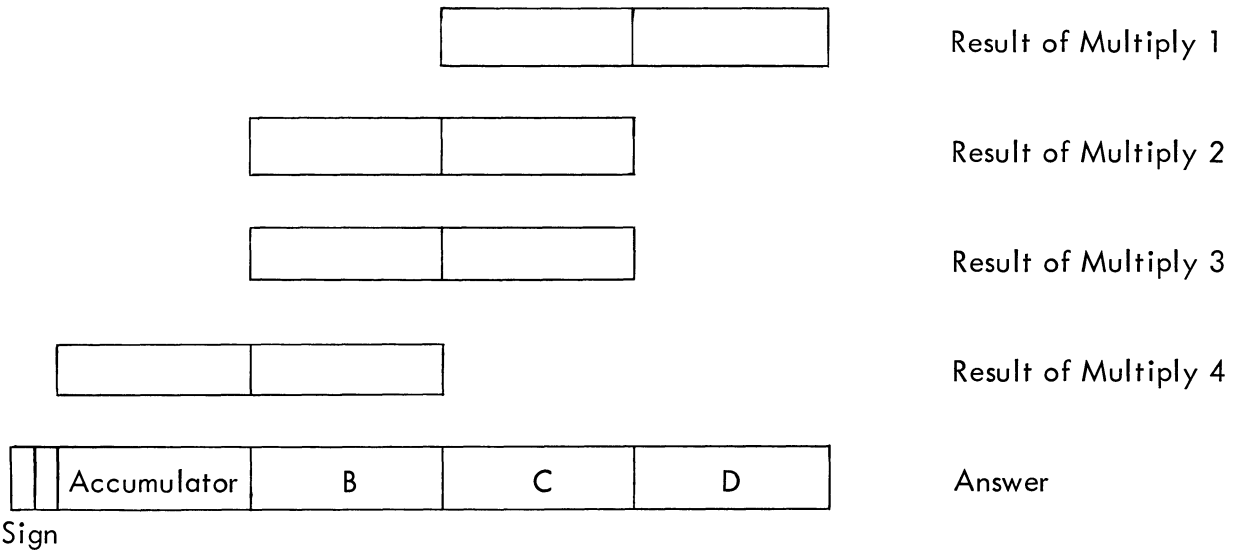
6. DESCRIPTION

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

$$(XXXX \ XXX.X) \quad (XXXX \ XXXX.)$$

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-08-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
DMJL,

```

0200	0000	0	
0201	7300	CLL CLA	
0202	1333	TAD RESI	/-2
0203	3332	DCA SIGNSW	/SET SIGN SWITCH
0204	4306	JMS TSIGN	/FETCH AND SET SIGN
0205	1337	TAD MLTH	/RESULT IN MLTH,MLTL
0206	3334	DCA MULIH	/HIGH ORDER MULTIPLICAND
0207	1336	TAD MLTL	
0210	3335	DCA MULIL	/LOW ORDER MULTIPLICAND
0211	4306	JMS TSIGN	/FETCH AND SET SIGN
0212	1335	TAD MULIL	/LOW ORDER MULTIPLICAND
0213	3301	DCA MP2	
0214	1336	TAD MLTL	/LOW ORDER MULTIPLIER
0215	4344	JMS MP4	/MULTIPLY
0216	3343	DCA D	/LOW ORDER
0217	1373	TAD MP5	
0220	3342	DCA C	/HIGH ORDER
0221	1334	TAD MULIH	/HIGH ORDER MULTIPLICAND
0222	3301	DCA MP2	
0223	1336	TAD MLTL	/LOW ORDER MULTIPLIER
0224	4344	JMS MP4	/MULTIPLY
0225	1342	TAD C	
0226	3342	DCA C	
0227	7004	RAL	/GET CARRY
0230	1373	TAD MP5	
0231	3341	DCA B	
0232	7004	RAL	/GET CARRY
0233	3340	DCA A	
0234	1335	TAD MULIL	/LOW ORDER MULTIPLICAND
0235	3301	DCA MP2	
0236	1337	TAD MLTH	/HIGH ORDER MULTIPLIER
0237	4344	JMS MP4	/MULTIPLY
0240	1342	TAD C	
0241	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 MLTH	/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
0301	0000		
0302	7040		
0303	7430		
0304	7101		
0305	5701		

MP2,  
COM,

0  
CMA  
SZL  
CLL IAC  
JMP I COM

```

/PAGE 3
MP1,
TSIGN,
0306 0000
0307 1600
0310 3340
0311 1/40
0312 7100
0313 7510
0314 7060
0315 3337
0316 2340
0317 1/40
0320 7430
0321 2332
0322 7000
0323 7430
0324 7141
0325 3336
0326 7430
0327 2337
0330 2200
0331 5/06

0332 0000
0333 7776
0334 0000
0335 0000
0336 0000
0337 0000

0340 0000
0341 0000
0342 0000
0343 0000

SIGNSW, 0
RESI, -2
MULIH, 0
MULIL, 0
MLTL, 0
MLTH, 0
ADDRS,
A, 0
B, 0
C, 0
D, 0

0
TAD I DMUL /FETCH ADDRESS
DCA ADDR5
TAD I ADDR5 /FETCH HIGH ORDER
CLL
SPA /IS IT <0?
CMA CML /YES: COMPLEMENT, SET LINK
DCA MLTH
ISZ ADDR5
TAD I ADDR5 /FETCH LOW ORDER
SZL /WAS IT <0?
ISZ SIGNSW /YES, ADD 1 TO SWITCH
NOP
SZL
CMA CLL IAC /COMPLEMENT, CLEAR LINK
DCA MLTL
SZL /CARRY?
ISZ MLTH /YES
ISZ DMUL
JMP I TSIGN /EXIT ROUTINE

```

/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
MULIH	0334
MULIL	0335
M12	0374
RESI	0333
SIGNS*	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:

$$\text{Dividend} = (\text{Quotient}) (\text{Divisor}) + \text{Remainder}$$

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.

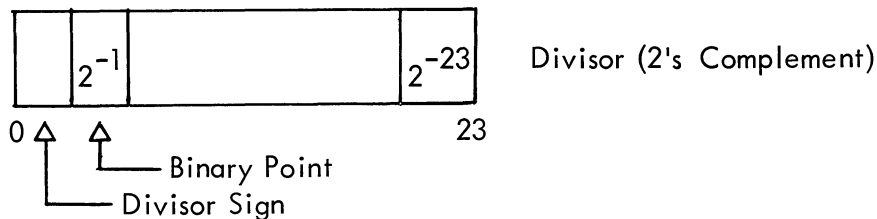
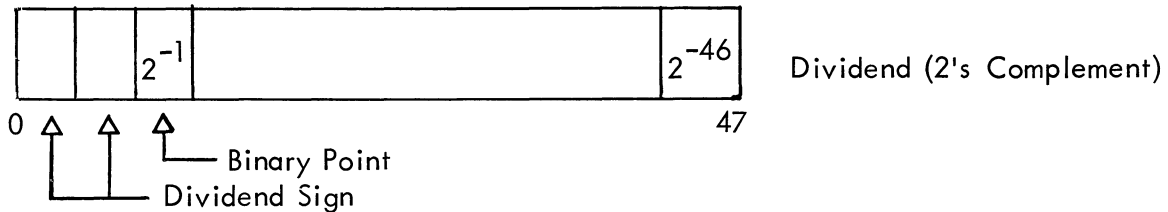
6. DESCRIPTION

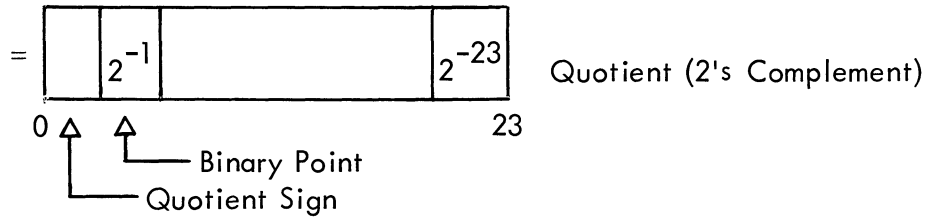
6.1 Discussion

See DEC-08-FMCA, Section 6.1.

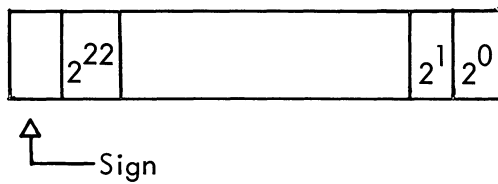
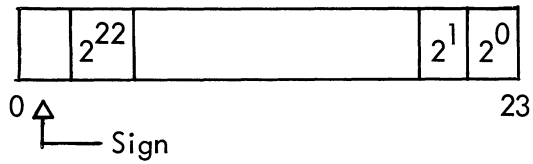
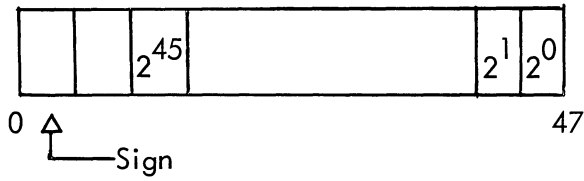
6.3 Scaling

The Double-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.





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	JUBDIV,	0	
0201	3331		DCA ADDR5	/DIVIDEND ADDRESS
0202	1343		TAD REST	/-2
0203	3340		DCA SIGNSW	/SET SIGN SWITCH
0204	1731		TAD I ADDR5	/HIGH-ORDER DIVIDEND
0205	3332		DCA DIVND1	
0206	2331		ISZ ADDR5	
0207	1731		TAD I ADDR5	/DIVIDEND
0210	3333		DCA DIVND2	
0211	2331		ISZ ADDR5	
0212	1731		TAD I ADDR5	/DIVIDEND
0213	3334		DCA DIVND3	
0214	2331		ISZ ADDR5	
0215	1731		TAD I ADDR5	/DIVIDEND
0216	3335		DCA DIVND4	
0217	1332		TAD DIVND1	/DIVIDEND<0?
0220	7700		SMA CLA	
0221	5237		JMP DIVG01	/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

/FEICH DIVISOR			
0237	1600	DIVG01, TAD I DUBDIV	
0240	2200	ISZ DUBDIV	
0241	3331	DCA ADDR5	/ADDRESS OF DIVISOR
0242	1/31	TAD I ADDR5	/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 ADDR5	
0250	1/31	TAD I ADDR5	/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	2330	ISZ HDIVSR	/YES
0261	1342	TAD M25	
0262	3341	DCA DIVCNI	/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 LDI VSR	/WITH DIVISOR
0275	3331		DCA ADDR5	
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 ADDR5	
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	/QUOTIENT BITS
0313	7004		RAL	
0314	3334		DCA DIVND3	/ENTER FROM C(L)
0315	2341		ISZ DIVCN1	/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	HUIVSR,	0	
0337	0000	LUIVSR,	0	
0340	0000	SIGNSW,	0	
0341	0000	DIVCNT,	0	
0342	7747	M25,	-31	/-25(10)
0343	7776	RESI,	-2	
0344	0000	CQM,	0	
0345	7040		CMA	
0346	7430		S&L	
0347	7101		CLL IAC	
0350	5744		JMP I CQM	

PAUSE

SYMBOL TABLE

ADDRS	0331
CQM	0344
DIVCNT	0341
DIVG01	0237
DIVND1	0332
DIVND2	0333
DIVND3	0334
DIVND4	0335
DIV2	0307
DIV3	0265
DOUBUV	0200
HUIVSR	0336
LUIVSR	0337
M25	0342
OUT	0327
RESI	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  $\text{Sin}(X)$  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)

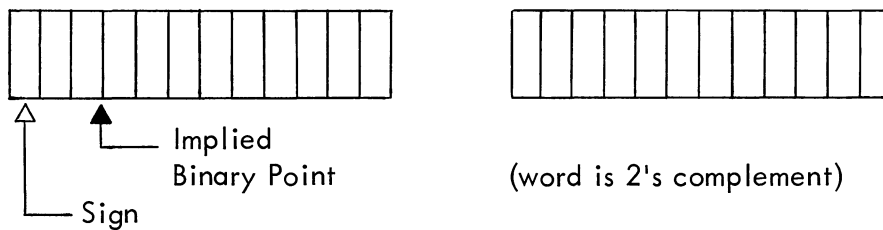
if  $X > \pi/2$        $\text{Sin}(X) = -\text{Sin}(X - \pi)$  (recursive call)  
 if  $X = \pi/2$        $\text{Sin}(\pi/2) = 1$   
 for  $0 < X < \pi/2$ ,

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

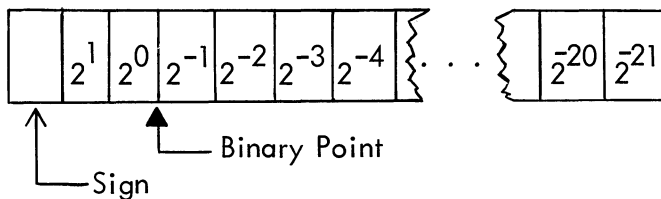
$$\text{Sin}(X) = F(C_1 + C_3F^2 + C_5F^4 + C_7F^6 + C_9F^8)$$

### 6.3 Scaling

The scaling for the argument is:



The binary weightings of the argument may be represented as:



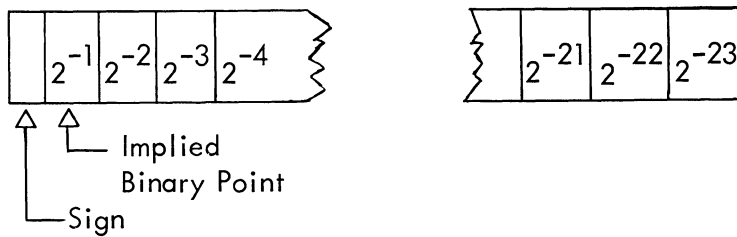
Thus, 1.5 radians would be:

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  $\pi$ : 70  $\mu$ sec

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-08-FMFB-PA
/DOUBLE PRECISION SINE
/POINTERS TO DEC-08-FMUA
0200 DMJL=200
0341 B=341
0342 C=342
0400 *400

0400 0000 DSIN, 0
0401 1600 TAD I DSIN /ADDRESS OF ARGUMENT
0402 3351 DCA TEMP
0403 1751 TAD I TEMP /HIGH ORDER
0404 3347 DCA X2
0405 2351 ISZ TEMP
0406 1751 TAD I TEMP /LOW ORDER
0407 3350 DCA X2+1
0410 2200 ISZ DSIN /FIX EXIT
0411 1200 TAD DSIN /SAVE ON PUSHDOWN LIST
0412 3763 DCA I PUSH
0413 2363 ISZ PUSH
0414 1347 TAD X2 /CHECK FOR ZERO
0415 7640 SZA CLA
0416 5233 JMP NEG
0417 1350 TAD X2+1
0420 7640 SZA CLA
0421 5233 JMP NEG /NO
0422 7200 CLA
0423 3754 DCA I PNTS /SIN(0)=0
0424 3755 DCA I PNTS+1
0425 7240 XIT1, CLA CMA /EXIT
0426 1363 TAD PUSH
0427 3363 DCA PUSH
0430 1763 TAD I PUSH
0431 3351 DCA TEMP
0432 5751 JMP I TEMP
0433 1347 NEG, TAD X2 /CHECK FOR NEGATIVE X
0434 7700 SMA CLA
0435 5261 JMP POS
0436 1350 TAD X2+1 /SIN(-X)=-SIN(X)
0437 7141 CLL CMA IAC
0440 3350 DCA X2+1
0441 1347 TAD X2
0442 7040 CMA
0443 7430 SXL
0444 7001 IAC
0445 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 MPI0+1
0503	3351		DCA TEMP
0504	7004		RAL
0505	1347		TAD X2
0506	1361		TAD MPI0
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 MPI0, 6333 /=(PI/2)
0562 6012 6012
0563 0564 PUSH, PUSH+1 / POINTER FOR PUSHDOWN LIST

```

/DEC-08-FMFB-PA

/PAGE 4

\*DSIN+200

0600	0600	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	

0656	7100	CLL	/ADD IN LAST CONSTANT
0657	1360	TAD	C1+1
0660	1342	TAD	ARG+1
0661	3342	DCA	ARG+1
0662	7004	RAL	/CARRY
0663	1341	TAD	ARG
0664	1357	TAD	C1
0665	3341	DCA	ARG
0666	4736	JMS	I DMTG
0667	0741	ARG	
0670	0743	X	
0671	4277	JMS	SCAL /PUT SCALING BACK TO ZERO
0672	4277	JMS	SCAL /GET RID OF SIGN BIT
0673	4312	JMS	ROUND
0674	0741	ARG	
0675	5676	JMP	I OUT
0676	0425	OUT,	XIT1
0677	0000	SCAL,	0 /ROUTINE TO ADJUST SCALING
0700	3350	DCA	TEM2
0701	1752	TAD	I CTG
0702	7104	CLL	RAL
0703	3752	DCA	I CTG
0704	1751	TAD	I BTG
0705	7004	RAL	
0706	3751	DCA	I BTG
0707	1350	TAD	TEM2
0710	7004	RAL	
0711	5677	JMP	I SCAL
0712	0000	ROUND,	0
0713	3347	DCA	TEM1
0714	1712	TAD	I ROUND /ADDRESS OF HIGH ORDER
0715	2312	ISZ	ROUND
0716	3350	DCA	TEM2
0717	1347	TAD	TEM1
0720	3750	DCA	I TEM2
0721	1350	TAD	TEM2
0722	7001	IAC	
0723	3347	DCA	TEM1
0724	1751	TAD	I BTG
0725	3747	DCA	I TEM1
0726	1752	TAD	I CTG
0727	7710	SPA	CLA /BIT 0=1??
0730	5712	JMP	I ROUND /NO; EXIT
0731	2747	ISZ	I TEM1 /YES; ROUND
0732	5712	JMP	I ROUND
0733	2750	ISZ	I TEM2 /CARRY
0734	7000	NOP	/RETURN SKIP OR NOT!!
0735	5712	JMP	I ROUND

/DEC-08-FMFB-PA  
 /PAGE 6  
 /SYMBOLS AND CONSTANTS

0736 0200  
 0737 0000  
 0740 0000  
 0741 0000  
 0742 0000  
 0743 0000  
 0744 0000  
 0745 0000  
 0746 0000  
 0747 0000  
 0750 0000  
 0751 0341  
 0752 0342  
 0753 0761  
 0754 7774  
 0755 2427  
 0756 6303  
 0757 3110  
 0760 3755  
 0761 2367  
 0762 0000  
 0763 3331  
 0764 7766  
 0765 1505  
 0766 0243  
 0767 0420  
 0770 5325

DMTG, DMUL  
 XSQR, 0  
 0  
 ARG, 0  
 0  
 X, 0  
 0  
 PNT, 0  
 CHK, 0  
 TEM1, 0  
 TEM2, 0  
 BTG, B  
 CTG, C  
 FYX, C9  
 FOUR, -4  
 TOP1, 2427  
 6303  
 C1, 3110  
 3755  
 C9, 2367  
 0000  
 C7, 3331  
 7766  
 C5, 1505  
 0243  
 C3, 0420  
 5325  
 \$

/2/PI

/C3-C9 STORED IN BACKWARDS ORDER

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
TUPI	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  $X < 0$ ;  $\text{COS}(-X) = \text{COS}(X)$

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

- 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  $\mu$ sec.
  - 9.3       Average  
          In general, the Double-Precision Cosine Subroutine takes from 75  $\mu$ sec to 93  $\mu$ sec longer than the Double-Precision Sine Subroutine (see DEC-08-FMFB-D).
  - 10.       PROGRAM
  - 10.4      Program Listing

```

/DEC-08-FMGB-PA
/DOUBLE PRECISION COSINE SUBROUTINE
/CALLS DEC-08-FMFA
/POINTERS TO DEC-08-FMFB FOLLOW
ARG=741
DSIN=400

```

```

0741
0400

1000 1000
1001 0000
1002 1600
1003 3262
1004 1662
1005 3256
1006 2262
1007 1662
1010 3257
1011 1256
1012 7640
1013 5224
1014 1257
1015 7640
1016 5224
1017 7040
1020 7010
1021 3660
1022 7040
1023 3661
1024 5254
1025 1256
1026 7700
1027 5237
1030 1257
1031 7141
1032 3257
1033 1256
1034 7040
1035 7430
1036 7001
1036 3256

*1000
DCOS, 0
TAD I DCOS /FETCH ADDRESS OF
DCA ADDRSS /ARGUMENT
TAD I ADDRSS /FETCH HIGH ORDER
DCA EX /ARGUMENT
ISZ ADDRSS /INCREMENT ADDRESS POINTER
TAD I ADDRSS /FETCH LOW ORDER
DCA EX+1 /ARGUMENT
TAD EX /IS ARGUMENT EQUAL
SZA CLA /TO ZERO
JMP TSIGNN /NO: TEST THE SIGN
TAD EX+1 /TEST LOW ORDER BITS
SZA CLA /FOR ZERO
JMP TSIGNN /NOT EQUAL TO ZERO
CMA
RAR
DCA I ARGPNT
CMA
DCA I ARGPNT+1 /SET ANSWER TO 1
JMP EXIT
TSIGNN, TAD EX /SEE IF X>0
SMA CLA
JMP ARGPOS /ARGUMENT IS >0
TAD EX+1 /ARGUMENT IS <0
CLL CMA IAC /NEGATE IT
DCA EX+1
TAD EX
CMA
SZL
IAC
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 $\mu$ sec + 42(N) where N is the number of shifts to align binary points.
FSUB	=	FADD time + 42 $\mu$ sec
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 MIDDLE, 0
0047 0000 LORDER, 0
0050 0000 OVER2,   0

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

*5500
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 ADDR5
5615 1270          TAD MASK7        /GET 7 BIT ADDRESS
5616 0257          AND JUMP
5617 1262          TAD ADDR5
5620 3262          DCA ADDR5

```

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 EXI	/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 MIDDLE
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 PJT=6000
5733 0000 FLPT, 0
5734 1044 TAD EXP
5735 3662 DCA I ADDR5
5736 1045 TAD HORDER
5737 2262 ISZ ADDR5
5740 3662 DCA I ADDR5
5741 1046 TAD MIDDLE
5742 2262 ISZ ADDR5
5743 3662 DCA I ADDR5
5744 1047 TAD LORDER
5745 2262 ISZ ADDR5
5746 3662 DCA I ADDR5
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 MIDDLE		
6017	3046	DCA MIDDLE		
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 OPINS		/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 EXI	/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 EXI	
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 EXI	
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 EXI	
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 MIDDLE
6126	7010		RAR
6127	3046		DCA MIDDLE
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

\*5200

6200	0000	FNORM,	0	
6201	7300		CLA CLL	
6202	3361		DCA MPI	/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 G06	/NO
6211	1046		TAD MIDDLE	
6212	7640		SZA CLA	
6213	5224		JMP G06	
6214	1047		TAD LORDER	
6215	7640		SZA CLA	
6216	5224		JMP G06	/NO
6217	1050		TAD OVER2	
6220	7640		SZA CLA	
6221	5224		JMP G06	/NO
6222	3044		DCA EXP	/YES
6223	5600		JMP I FNORM	/EXIT
6224	1363	G06,	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 MIDDLE	
6242	7004		RAL	
6243	3046		DCA MIDDLE	
6244	1045		TAD HORDER	
6245	7004		RAL	
6246	3045		DCA HORDER	
6247	2361		ISZ MPI	/ADD 1 TO COUNT
6250	5227		JMP SHIFT	/CONTINUE
6251	1361	NOREXT,	TAD MPI	/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	0000	ACNEG,	Ø
6262	7300		CLA CLL
6263	1050		TAD OVER2
6264	7041		CMA IAC
6265	3050		DCA OVER2
6266	1047		TAD LORDER
6267	7040		CMA
6270	7430		SZL
6271	7101		CLL IAC
6272	3047		DCA LORDER
6273	1046		TAD MIDDLE
6274	7040		CMA
6275	7430		SZL
6276	7101		CLL IAC
6277	3046		DCA MIDDLE
6300	1045		TAD HORDER
6301	7040		CMA
6302	7430		SZL
6303	7101		CLL IAC
6304	3045		DCA HORDER
6305	5661		JMP I ACNEG

/NEGATE OPERAND

		OPNEG,	Ø
6306	0000		CLA CLL
6307	7300		TAD OVER1
6310	1051		CMA IAC
6311	7041		DCA OVER1
6312	3051		TAD LOW1
6313	1043		CMA
6314	7040		SZL
6315	7430		CLL IAC
6316	7101		DCA LOW1
6317	3043		TAD MID1
6320	1042		CMA
6321	7040		SZL
6322	7430		CLL IAC
6323	7101		DCA MID1
6324	3042		TAD HIGH1
6325	1041		CMA
6326	7040		SZL
6327	7430		CLL IAC
6330	7101		DCA HIGH1
6331	3041		JMP I OPNEG
6332	5706		

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
6405	1377		TAD SMACLA
6406	3772		DCA I SGNSW
6407	4773		JMS I SIGNP

/ADD EXPONENTS

/SET UP SIGN ROUTINE

/GO THERE

6410	1045	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 MIDDLE	
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 MIDDLE	
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 MIDDLE	/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 MIDDLE
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,	MP5CON
6577	7700	SMA CLA,	SMA CLA

/FLOATING DIVIDE=4000

\*6600

6600	0000	FLDV,	0
6601	1040		TAD EXI
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
6611	1041		TAD HIGH1
6612	7650		SNA CLA
6613	5303		JMP DVER
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 MIDDLE
6626	7004		RAL

/SUBTRACT EXPONENTS

/SET UP SIGNS

/DIVISOR=0?

/YES - ERROR

6627	3046		DCA MIDDLE	
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 MIDI	
6640	1046		TAD MIDDLE	
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 MIDDLE	
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 MIDDLE	
6674	1050		TAD OVER2	
6675	3045		DCA HORDER	
6676	3050		DCA OVER2	
6677	4717		JMS I NORMIT	
6700	2350	DEXIT,	ISZ SGNST	
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 MIDDLE	
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	MPSCON	6364
ADDRS	5662	MP1	6361
ALIGN	6031	MP2	6575
AMOUNT	6104	MP2CON	6362
DEXIT	6700	MP3	6363
DIVCNT	6724	MP5	6576
DMULT	6574	MULTIP	6333
DONE	6072	MUL1	6565
STEM1	6722	MUL2	6566
STEM2	6723	MUL3	6567
DVER	6703	MUL4	6570
DVX	6633	MUL5	6571
DV2	6655	NOGO	6074
DV3	6622	NOREXT	6251
EXIT	5714	NORMAL	6105
EXIT6	5770	NORMIT	6717
EXP	0044	OPMINS	6106
EX1	0040	OPNEG	6306
FACNEG	6746	OPNEGS	6747
FLAD	6000	OVER1	0051
FLAG	0061	OVER2	0050
FLDV	6600	PAGENO	5665
FLGT	5702	POINT	6103
FLMY	6367	QUOH	6721
FLPT	5733	QUOL	6720
FLSU	6026	RESTOR	6751
FMULT	6400	SAVE	5663
FMULT1	6366	SCALE	6112
FNORM	6200	SGNSW	6572
FPNT	5600	SGNSWT	6740
G02	5661	SGNTST	6750
G06	6224	SHFTAC	6116
HIGH1	0041	SHFTOP	6141
HORDER	0045	SHIFT	6227
INDRCT	5666	SIGNCL	6727
JUMP	5657	SIGNP	6573
JUMP2	5660	SIGNI	6377
LOOP01	5627	SMACLA	6577
LORDER	0047	SPACLA	6726
LOW1	0043	TABLE	5671
MASK3	5664	TABLE6	5750
MASK5	5667	TCO1	6110
MASK7	5670	TCO2	6111
MIDDLE	0046	TEST1	6107
MID1	0042	THIR	6365
MIF	6725		

/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 MIDDLE,    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
0767 0000 PRCHAR,    0
0770 1057           TAD SWIT2
0771 7650           SNA CLA
0772 5767           JMP I PRCHAR
0773 1377           TAD LFED
0774 4776           JMS I OPUT
0775 5767           JMP I PRCHAR
0776 7345 OPUT,      OUT
0777 0212 LFED,      0212
  
```

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

```

7000 0000 DECONV,    0
7001 7200           CLA           /INITIALIZE MANISSA
7002 3045           DCA HORDER
7003 3046           DCA MIDDLE
7004 3047           DCA LORDER
7005 3266           DCA SIGN
7006 3267           DCA DNUMBR
7007 4350           JMS INPUT
  
```

7010	1340		TAD PLUS	/TEST FOR SIGN
7011	7450		SNA	
7012	5220		JMP DECON	
7013	1337		TAD MINUS	
7014	7440		SZA	
7015	5221		JMP .+4	
7016	7240		CLA CMA	
7017	3266		DCA SIGN	/IF-, SET SWITCH
7020	4350	DECON,	JMS INPUT	
7021	7200		CLA	
7022	1060		TAD CHAR	/IS IT A DIGIT
7023	1341		TAD MIN9	
7024	7500		SMA	
7025	5600		JMP I DECONV	/NO
7026	1342		TAD PLUS12	
7027	7510		SPA	
7030	5600		JMP I DECONV	/NO
7031	3265		DCA DIGIT	/YES
7032	1045		TAD HORDER	
7033	0343		AND MASK	/OVERFLOW?
7034	7440		SZA	
7035	5220		JMP DECON	/YES-IGNORE
7036	2061		ISZ DSWIT	
7037	2267		ISZ DNUMBR	/INDEX NUMBER OF DIGITS
7040	4242		JMS MULT10	
7041	5220		JMP DECON	/CONTINUE
7042	0000	MULT10,	0	/ROUTINE TO MULTIPLY
7043	1047		TAD LORDER	/DOUBLE PRECISION WORD
7044	3043		DCA 43	/BY TEN (DECIMAL)
7045	1046		TAD MIDL	
7046	3042		DCA 42	
7047	1045		TAD HORDER	/REMAIN=REMAINDER
7050	3041		DCA 41	
7051	3040		DCA 40	
7052	4270		JMS MULT2	/CALL SUBROUTINE TO
7053	4270		JMS MULT2	/MULTIPLY BY TWO
7054	4307		JMS DUBLAD	/CALL DOUBLE ADD
7055	4270		JMS MULT2	
7056	1265		TAD DIGIT	/ADD LAST DIGIT RECEIVED
7057	3043		DCA 43	
7060	3042		DCA 42	
7061	3041		DCA 41	
7062	4307		JMS DUBLAD	
7063	1040		TAD 40	/EXIT WITH REMAINDER
7064	5642		JMP I MULT10	/IN AC
7065	0000	DIGIT,	0	/STORAGE FOR DIGIT
7066	0000	SIGN,	0	/=0 IF PLUS: =7777 IF MINUS
7067	0000	DNUMBR,	0	/=NUMBER OF DIGITS
7070	0000	MULT2,	0	/MULTIPLY LORDER, HORDER BY 2

7071	7300		CLA CLL	
7072	1047		TAD LORDER	
7073	7004		RAL	
7074	3047		DCA LORDER	
7075	1046		TAD MIDDLE	
7076	7004		RAL	
7077	3046		DCA MIDDLE	
7100	1045		TAD HORDER	
7101	7004		RAL	
7102	3045		DCA HORDER	
7103	1040		TAD 40	
7104	7004		RAL	
7105	3040		DCA 40	
7106	5670		JMP I MULT2	
7107	0000	DUBLAD,	0	/DOUBLE PRECISION ADDITION
7110	7300		CLA CLL	
7111	1047		TAD LORDER	
7112	1043		TAD 43	
7113	3047		DCA LORDER	
7114	7004		RAL	
7115	1046		TAD MIDDLE	
7116	1042		TAD 42	
7117	3046		DCA MIDDLE	
7120	7004		RAL	
7121	1045		TAD HORDER	
7122	1041		TAD 41	
7123	3045		DCA HORDER	
7124	7004		RAL	
7125	1040		TAD 40	
7126	3040		DCA 40	
7127	5707		JMP I DUBLAD	
7130	0000	MSIGN,	0	/ROUTINE TO FORM
7131	7300		CLA CLL	/2'S COMPLEMENT
7132	2266		1SZ SIGN	/IF C(SIGN)=7777
7133	5730		JMP I MSIGN	
7134	4736		JMS I .+2	
7135	5730		JMP I MSIGN	
7136	6261		6261	/"ACNEG" IN INTERPRETER
7137	7776	MINUS,	253-255	/TEST FOR SIGN
7140	7525	PLUS,	-253	
7141	7506	MIN9,	-272	/TEST FOR DIGIT
7142	0012	PLUS12,	272-260	
7143	7600	MASK,	7600	/TEST FOR OVERFLOW
7144	7775	C.10,	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 CARRIN /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 10, ETC.  
 FOUTCN, 0

7217	0000		CLA CLL	
7220	7300		TAD HORDER	/NUMBER>0??
7221	1045		SPA CLA	
7222	7710		CLA CML	/NO SET LINK
7223	7220		TAD SPLUS	/YES
7224	1327		SZL	
7225	7430		TAD SMINUS	/NO
7226	1330		JMS OUT	
7227	4345		JMS OUTDG	/OUTPUT "0"
7230	4353		TAD PERIOD	
7231	1331		JMS OUT	/OUTPUT "."
7232	4345		CLA CLL	
7233	7300		TAD HORDER	
7234	1045		SMA CLA	
7235	7700		JMP FG01	
7236	5242		CMA	/NUMBER IS NEGATIVE
7237	7040		DCA I SNPT	/NEGATE
7240	3733		JMS I MSNPT	
7241	4732		CLA CMA	/SUBTRACT 1 FROM BINARY EXPON
7242	7240	FG01,	TAD EXPONT	/COMPENSATE AT FG04
7243	1044		DCA EXPONT	
7244	3044		DCA BEXP	/INITIALIZE DECIMAL EXPONENT
7245	3324		TAD EXPONT	/IS -4<EXPONENT<-1
7246	1044	FG02,	SMA	
7247	7500		JMP FG03	/TOO LARGE: MULTIPLY BY 1/10
7250	5263		TAD FOJR	
7251	1326		SMA CLA	
7252	7700		JMP FG04	
7253	5270		JMS I FPNT	/TOO SMALL-TIMES TEN
7254	4407		FMPY I TENPT	/TEN
7255	3740		FEXT	
7256	0000		CLA CMA	
7257	7240		TAD BEXP	
7260	1324		DCA BEXP	
7261	3324		JMP FG02	
7262	5245		JMS I FPNT	
7263	4407	FG03,	FMPY I PRC.10	/ONE TENTH
7264	3744		FEXT	
7265	0000		ISZ BEXP	
7266	2324		JMP FG02	
7267	5246			

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 OJTDG	/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 FOJTCN	/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,	0305	
7344	7144	PRC.10,	C.10	

7345	0000	OUT,	0	/OUTPUT ONE ASCII CHARACTER
7346	6041		TSF	
7347	5346		JMP .-1	
7350	6046		ILS	
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 MIDDLE	
7367	7010		RAR	
7370	3046		DCA MIDDLE	
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 FIG01	
7412	1314		TAD PRSW	/PERIOD FOUND
7413	7650		SNA CLA	/SECOND PERIOD
7414	5222		JMP FIG02	/YES, TERMINATE
7415	3722		DCA I DPN	/NO - SET NUMBER OF DIGITS TO 0
7416	3314		DCA PRSW	/SET PERIOD SWITCH TO 0
7417	5720		JMP I DPCSPT	/CONVERT REST OF STRING

7420	1314	FIG01,	TAD PRSW	/PERIOD READ IN PREVIOUSLY?
7421	7650		SNA CLA	
7422	1722	FIG02,	TAD I DPN	/YES:-NUMBER OF DIGITS IN SER
7423	7041		CMA IAC	/NO
7424	3315		DCA SEXP	
7425	4721	FIG03,	JMS I MSGNPT	/TEST SIGN
7426	1312		TAD C43	
7427	3044		DCA EXPONT	
7430	4407		JMS I FPNT	/NORMALIZE F.P. NUMBER
7431	7000		FNOR	
7432	6052		FPUT FPACI	/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 FPACI	
7454	0000		FEXT	
7455	1315		TAD SEXP	
7456	7450		SNA	
7457	5600		JMP I FLINTP	
7460	7700		SMA CLA	
7461	5270		JMP FIG04	
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	FIG04,	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 FXEC

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
CHR	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	MINUSE	7511
DPN	7522	MINUS7	7325
DPI	7334	MIN9	7141
DSWIT	0061	MRBOUT	7176
DUBLAD	7107	MSGNPT	7521
ENDFI	7452	MSIGN	7130
EXCESS	7477	MSNPT	7332
EXPONT	0044	MULT10	7042
FEAC	7523	MULT2	7070
FEXPPT	7337	MI0PT	7335
FG01	7242	MI2	7573
FG02	7246	MI44	7571
FG03	7263	M2PT	7336
FG04	7270	OPUT	6776
FG05A	7274	OUT	7345
FG06	7301	OUTDG	7353
FG06A	7304	OUTPUT	7174
FG07	7311	PC.10	7510
FIG01	7420	PER	7513
FIG02	7422	PERIOD	7331
FIG03	7426	PLUS	7140
FIG04	7470	PLUS12	7142
FLINTP	7400	PRCHAR	6767
FLOUTP	7200	PRC.10	7344
FOUR	7326	PRINT	7173
FOUTCN	7217	PRSW	7514
FPAC1	0052	RESTRT	7175
FPNT	0007	SEXP	7515
HORDER	0045	SIGN	7066
INPUT	7150	SMINUS	7330
LFED	6777	SNPT	7333
LNFEED	7342	SPLUS	7327
LORDER	0047	SWIT1	0056
MASK	7143	SWIT2	0057
MIDDL	0046	TEN	7504
MINCR	7177	TENPT	7340
MINUS	7137		

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:

<u>AND</u>			<u>Inclusive OR</u>			<u>Exclusive OR</u>			<u>Biconditional</u>		
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

<u>Inclusive OR</u>			<u>Exclusive OR</u>		
A	011 010 111 001		A	011 010 111 001	
B	010 110 101 100		B	010 110 101 101	
Result	<u>011 110 111 101</u>		Result	<u>001 100 010 100</u>	

## 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:

	<u>Shift Left</u>	<u>Shift Right</u>
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 eventuality.

## 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:

		<u>Right</u>	<u>Left</u>
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.

<u>Data</u>	<u>Result</u>
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	





**digital**

**DIGITAL EQUIPMENT CORPORATION • MAYNARD, MASSACHUSETTS**