MATH SUBR STORAGE POOL

DATE: March 1968

ID CODE: BRH

DRAWING: 391098 (Rev C)

LABEL: POOL

AUTHOR: STVL

SOURCE: SYM I Assembly Language

OBJECT: Relocatable

PURPOSE

There are two non-executable modules which are parts of the 703 MATH SUBROUTINES. One of these is a block of 19 locations used as storage by the various routines. Each location has a label. There are four locations labelled RET1, RET2, RET3 and RET4. These locations are used as temporary storage for the index register return location. There are ten locations labelled TMP1, ..., TMP9, TMP0. These are used as temporary storage by the executable routines. There are four locations labelled MNT1, ..., MNT4. These are used as a software register for Double Precision (MNT2, MNT3), for Floating (MNT1, MNT2, MNT3) and for Double Floating (MNT1, MNT2, MNT3, MNT4) arguments.

The label MNT0 refers to the same location as MNT1. There is one word labelled OVFL which is used as a flag to indicate overflow or underflow conditions.

The second non-executable module consists of a set of labelled constants used commonly by various math subroutines. Examples might be:

D1	which is a decimal 1,
B0	which is bit zero of a 16 bit word
M15R	which is a 15 bit mask, right adjusted

APPENDIX A

ASSEMBLY LISTING

of

MATH SUBR STORAGE CONSTANTS POOL

Drawing No.

391098 (Revision C)

ID Code

BRH

```
                                        2       'MATH SUBR STORAGE CONSTANTS POOL DN391098 C'                    BRH 0005
                                        3       *                                                               BRH 0006
                                        4       *                                                               BRH 0007
                                        5               BLK     MATH                                            BRH 0008
                                        6               LIBR    MNT2,MNT3                                       BRH 0009
0 000 0   8000  8000                    7       B0      D       X'8000'                                         BRH 0010
0 001 0   7FFF  7FFF                    8       M15R    D       X'7FFF'                                         BRH 0011
0 002 0   0001  0001                    9       D1      D       1                                               BRH 0012
0 003 0   0002  0002                    10      D2      D       2                                               BRH 0013
0 004 0   00FF  00FF                    11      D255    D       255                                             BRH 0014
0 005 0   0100  0100                    12      D256    D       256                                             BRH 0015
                                        13      *                                                               BRH 0016
0 006 0   0081  0081                    14      D129    D       129                                             BRH 0017
          0006  0006                    15      F1      EQU     D129                                            BRH 0018
0 007 0   4000  4000                    16      B1      D       X'4000'                                         BRH 0019
0 008 0   0000  0000                    17      D0      D       0                                               BRH 0020
0 009 0   0080  0080                    18      D128    D       128                                             BRH 0021
0 00A 0   FFFF  FFFF                    19      N1      D       -1                                              BRH 0022
0 00B 0   FF80  FF80                    20      N128    D       -128                                            BRH 0023
                                        21      *****************************************************           BRH 0024
0 00C 0   0000  0000                    22      OVFL    D       0       OVERFLOW UNDERFLOW FLAG                 BRH 0025
          000D  000D                    23      MNT0    EQU     $                                               BRH 0026
0 00D 0   0000  0000                    24      MNT1    D       0                                               BRH 0027
0 00E 0   0000  0000                    25      MNT2    D       0                                               BRH 0028
0 00F 0   0000  0000                    26      MNT3    D       0                                               BRH 0029
0 010 0   0000  0000                    27      MNT4    D       0                                               BRH 0030
0 011 0   0000  0000                    28      RET1    D       0                                               BRH 0031
0 012 0   0000  0000                    29      RET2    D       0                                               BRH 0032
0 013 0   0000  0000                    30      RET3    D       0                                               BRH 0033
0 014 0   0000  0000                    31      RET4    D       0                                               BRH 0034
0 015 0   0000  0000                    32      RET5    D       0                                               BRH 0035
0 016 0   0000  0000                    33      TMP1    D       0                                               BRH 0036
0 017 0   0000  0000                    34      TMP2    D       0                                               BRH 0037
0 018 0   0000  0000                    35      TMP3    D       0                                               BRH 0038
0 019 0   0000  0000                    36      TMP4    D       0                                               BRH 0039
0 01A 0   0000  0000                    37      TMP5    D       0                                               BRH 0040
0 01B 0   0000  0000                    38      TMP6    D       0                                               BRH 0041
0 01C 0   0000  0000                    39      TMP7    D       0                                               BRH 0042
0 01D 0   0000  0000                    40      TMP8    D       0                                               BRH 0043
0 01E 0   0000  0000                    41      TMP9    D       0                                               BRH 0044
0 01F 0   0000  0000                    42      TM10    D       0                                               BRH 0045
0 020 0   0000  0000                    43      TM11    D       0                                               BRH 0046
0 021 0   0000  0000                    44      TM12    D       0                                               BRH 0047
                                        45      *****************************************************           BRH 0048
                                        46              NTRY    OVFL                                            BRH 0049
                                        47              NTRY    MNT0,MNT1,MNT2,MNT3,MNT4                        BRH 0050
                                        48              NTRY    RET1,RET2,RET3,RET4,RET5                        BRH 0051
                                        49              NTRY    TMP1,TMP2,TMP3,TMP4,TMP5,TMP6,TMP7              BRH 0052
                                        50              NTRY    TMP8,TMP9,TM10,TM11,TM12                        BRH 0053
                                        51              NTRY    B0,B1,M15R                                      BRH 0054
                                        52              NTRY    D1,D2,D128,D129,D255,D256                       BRH 0055
                                        53              NTRY    F1,D0                                           BRH 0056
                                        54              NTRY    N1,N128                                         BRH 0057
```

0 021 0*******33 55 END BRH 0058

X-REF

```
DEF  0 000 0  B0
DEF  0 007 0  B1
DEF  0 008 0  D0
DEF  0 002 0  D1
DEF  0 009 0  D128
DEF  0 006 0  D129        0 007 0
DEF  0 003 0  D2
DEF  0 004 0  D255
DEF  0 005 0  D256
DEF  0 006 0  F.1         0 007 0
DEF  0 00D 0  MNT0        0 00D 0
DEF  0 00D 0  MNT1
LIB  0 00E 0  MNT2
LIB  0 00F 0  MNT3
DEF  0 010 0  MNT4
DEF  0 001 0  M1DR
DEF  0 00A 0  N1
DEF  0 008 0  N128
DEF  0 00C 0  OVFL
DEF  0 011 0  RET1
DEF  0 012 0  RET2
DEF  0 013 0  RET3
DEF  0 014 0  RET4
DEF  0 015 0  RET5
DEF  0 016 0  TMP1
DEF  0 017 0  TMP2
DEF  0 018 0  TMP3
DEF  0 019 0  TMP4
DEF  0 01A 0  TMP5
DEF  0 01B 0  TMP6
DEF  0 01C 0  TMP7
DEF  0 01D 0  TMP8
DEF  0 01E 0  TMP9
DEF  0 01F 0  TM10
DEF  0 020 0  TM11
DEF  0 021 0  TM12
```

NO ERRORS

CARDS	SYMBOLS	LITR	STACK
55	36	618	0	2

RAYTHEON

QUALITY SOFTWARE

700 PROGRAMMING SYSTEMS

SP MULTIPLY

DATE: March 1968

ID CODE: BLG

DRAWING: 390663 (Rev B)

LABEL: MPYS, MPYA

AUTHOR: JACQ

SOURCE: SYM I Assembly Language

OBJECT: Relocatable

PURPOSE

To multiply two single-word arguments and set their two-word product in the software pseudo-registers MNT2, MNT3. The high word of the product is stored in MNT2. The low word, always given a zero sign bit, is stored in MNT3 and is also left in the accumulator.

Arguments and product are in two's complement form.

USAGE

Calling Sequence

The routine will return to L+1 with the result in the Double Precision Register.

```
L     SMB   MPYS
L     JSX   MPYS
L+1   return
```

Argument Description

The two arguments must be in the hardware accumulator and the least significant half of the Double Precision Register, i.e., in MNT3.

Storage Requirements

External storage in RET1, TMP1, and the software registers MNT2, MNT3.

METHOD

Multiplicand and multiplier are selected so that the multiplicand to work with be positive. If both factors are negative, they are both converted to positive prior to the multiplication. The product is the accumulation of the shifted multiplicand for each bit found true in the multiplier. The multiplier is placed in the index register and each one of its bits is checked as it occupies the rightmost position. Both the multiplier and the accumulation already set in the accumulator are shifted to the right one bit at a time. When the sign bit comes under test, and if it is found negative, the multiplicand is subtracted from the accumulator, than giving a negative product.

ERROR CONDITIONS

Squaring -2^{15} (X'8000') will turn on the overflow flip flop.

RESTRICTIONS

Entries

MPYS, MPYA

MPYA is a special entry reserved to the multiple precision multiply subroutines.

Other Routines

None

External Constants

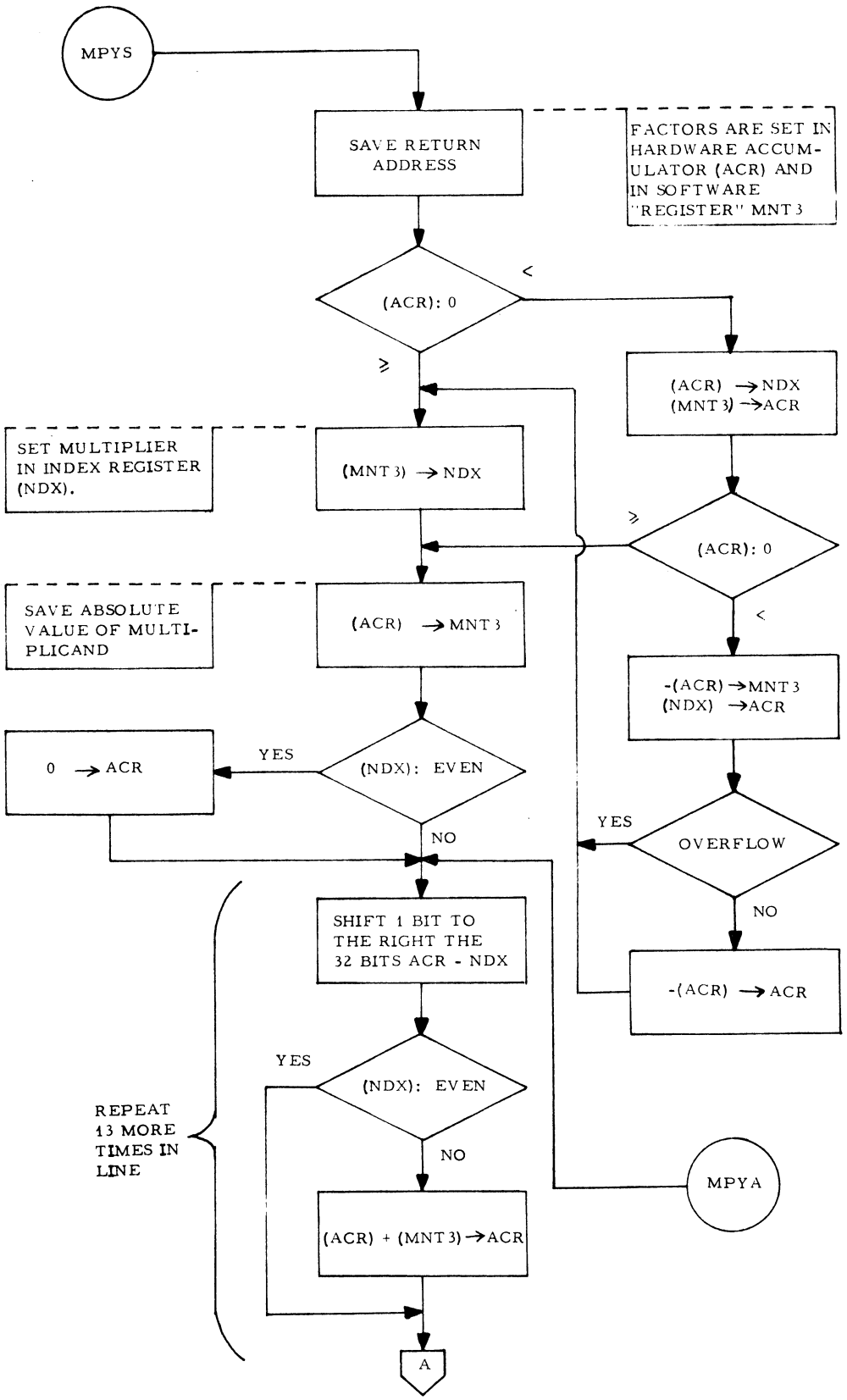
None

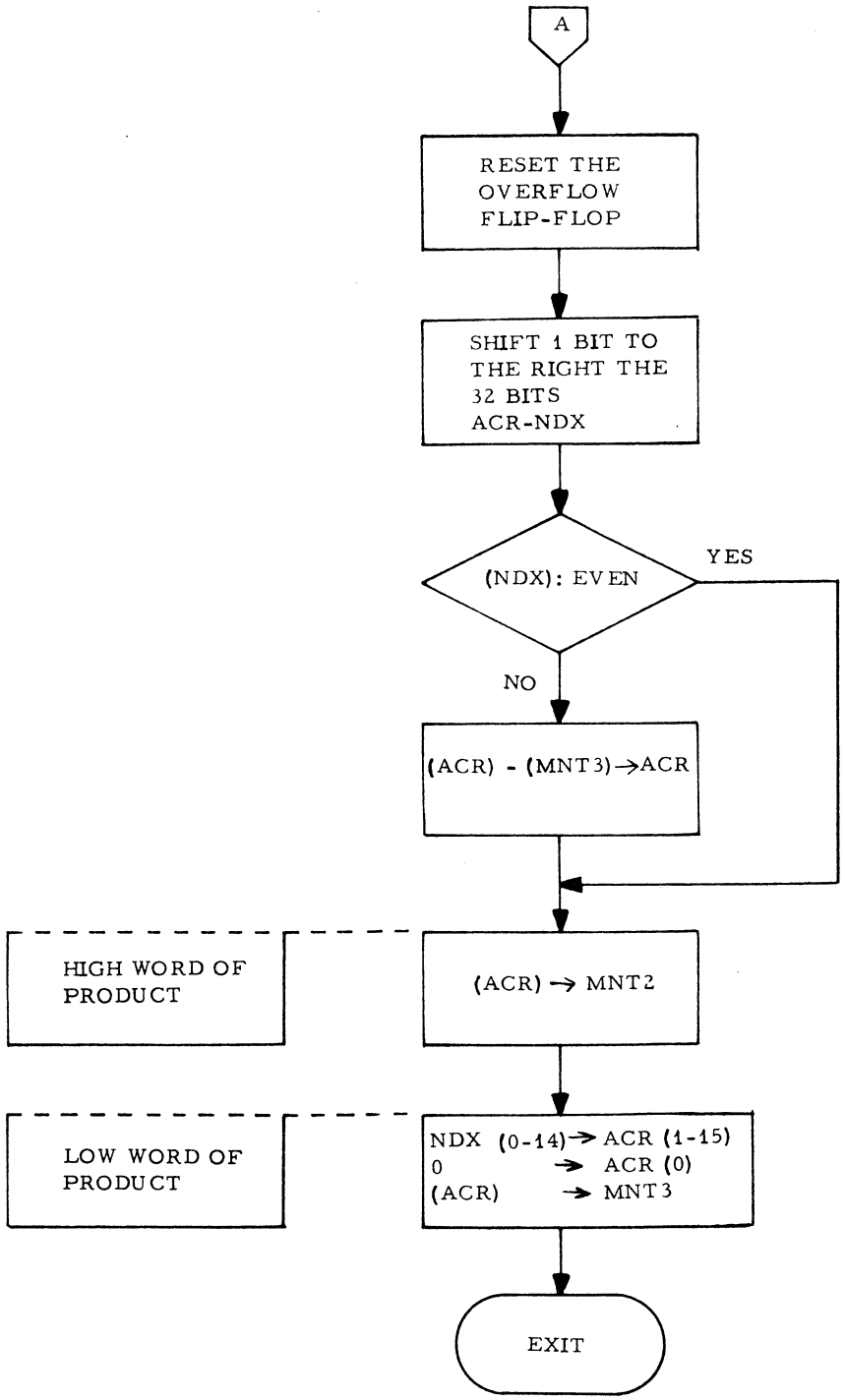
Space Used

71 words

Timing

Minimum - 65 cycles
Maximum - 105 cycles
Average - 84 cycles (any argument)
Average - 79 cycles (positive arguments)


MPYS
SAVE RETURN ADDRESS
FACTORS ARE SET IN HARDWARE ACCUMULATOR (ACR) AND IN SOFTWARE "REGISTER" MNT3
(ACR): 0
<
≥
(ACR) → NDX
(MNT3) → ACR
SET MULTIPLIER IN INDEX REGISTER (NDX).
(MNT3) → NDX
≥
(ACR): 0
SAVE ABSOLUTE VALUE OF MULTIPLICAND
(ACR) → MNT3
<
-(ACR) → MNT3
(NDX) → ACR
0 → ACR
YES
(NDX): EVEN
YES
OVERFLOW
NO
NO
SHIFT 1 BIT TO THE RIGHT THE 32 BITS ACR - NDX
-(ACR) → ACR
YES
(NDX): EVEN
REPEAT 13 MORE TIMES IN LINE
NO
MPYA
(ACR) + (MNT3) → ACR
A


A
RESET THE OVERFLOW FLIP-FLOP
SHIFT 1 BIT TO THE RIGHT THE 32 BITS ACR-NDX
(NDX): EVEN
YES
NO
(ACR) - (MNT3)→ACR
HIGH WORD OF PRODUCT
(ACR) → MNT2
LOW WORD OF PRODUCT
NDX (0-14)→ ACR (1-15)
0 → ACR (0)
(ACR) → MNT3
EXIT

APPENDIX A

ASSEMBLY LISTING

of

SP MULTIPLY

Drawing No.

390663 (Revision B)

ID Code

BLG

```
                                 'SP MULTIPLY DN390663 B'
                                          ENDC
                                          TRUE   HARD=1
                                          ENDC
                                 *TO SELECT PROPER SEQUENCE SWITCH THE 2 'HARD' CARDS   BLG 0001
             0000   0000         HARD     EQU    0          SOFTWARE                    BLG 0002
                                          TRUE   HARD=2                                 BLG 0003
                                          ENDC                                          BLG 0005
                                 ****************************************************   BLG 0006
                                          BLK    MATH                                   BLG 0007
                                          LIBR   MPYS,MPYA                              BLG 0008
                                 * MULTIPLICAND IN ACCUMULATOR                          BLG 0009
                                 * MULTIPLIER   IN LOCATION 'B'                         BLG 0010
                                 * DOUBLE PRECISION PRODUCT TO SET IN 'A','B'           BLG 0011
                                 ****************************************************   BLG 0012
                                          TRUE   HARD=1                                 BLG 0013
                                          ENDC                                          BLG 0023
                                          TRUE   HARD=0                                 BLG 0024
                                 * SOFTWARE MULTIPLY                                    BLG 0025
             0000   0000         MPYS     EQU    $                                      BLG 0026
*   0 000 0  67FF   6 0 7FF               STX    RET1       SAVE RETURN                 BLG 0027
    0 001 0  0810   0810                  SAP               TEST SIGN OF MULTIPLICAND   BLG 0028
    0 002 0  103C   1 0 03C               JMP    NEG        NEGATIVE                    BLG 0029
*   0 003 0  97FF   9 0 7FF      MPY1     LDX    MNT3       PLACE MULTIPLIER IN INDEX   BLG 0030
*   0 004 0  7003   7 0 003      MPY2     STW    MNT3       SAVE MULTIPLICAND           BLG 0031
    0 005 0  0850   0850                  SXE               MULTIPLIER RIGHTMOST BIT    BLG 0032
    0 006 0  1008   1 0 008               JMP    $+2        TRUE - COUNT MULTIPLICAND   BLG 0033
    0 007 0  0100   0100                  CLR               FALSE - RESET COUNT         BLG 0034
             0008   0008         MPYA     EQU    $                                      BLG 0035
    0 008 0  0A21   0A2 1                 SRL D  1          GET TO MULTIPLIER NEXT BIT  BLG 0036
    0 009 0  0850   0850                  SXE                                           BLG 0037
*   0 00A 0  A004   A 0 004               ADD    MNT3                                   BLG 0038
    0 00B 0  0A21   0A2 1                 SRL D  1                                      BLG 0039
    0 00C 0  0850   0850                  SXE                                           BLG 0040
*   0 00D 0  A00A   A 0 00A               ADD    MNT3                                   BLG 0041
    0 00E 0  0A21   0A2 1                 SRL D  1                                      BLG 0042
    0 00F 0  0850   0850                  SXE                                           BLG 0043
*   0 010 0  A00D   A 0 00D               ADD    MNT3                                   BLG 0044
    0 011 0  0A21   0A2 1                 SRL D  1                                      BLG 0045
    0 012 0  0850   0850                  SXE                                           BLG 0046
*   0 013 0  A010   A 0 010               ADD    MNT3                                   BLG 0047
    0 014 0  0A21   0A2 1                 SRL D  1                                      BLG 0048
    0 015 0  0850   0850                  SXE                                           BLG 0049
*   0 016 0  A013   A 0 013               ADD    MNT3                                   BLG 0050
    0 017 0  0A21   0A2 1                 SRL D  1                                      BLG 0051
    0 018 0  0850   0850                  SXE                                           BLG 0052
*   0 019 0  A016   A 0 016               ADD    MNT3                                   BLG 0053
    0 01A 0  0A21   0A2 1                 SRL D  1                                      BLG 0054
    0 01B 0  0850   0850                  SXE                                           BLG 0055
*   0 01C 0  A019   A 0 019               ADD    MNT3                                   BLG 0056
    0 01D 0  0A21   0A2 1                 SRL D  1                                      BLG 0057
    0 01E 0  0850   0850                  SXE                                           BLG 0058
*   0 01F 0  A01C   A 0 01C               ADD    MNT3                                   BLG 0059
```

```
                0 020 0  0A21  0A2 1       67              SRL  D 1                                                  BLG 0060
                0 021 0  0850  0850        68              SXE                                                       BLG 0061
*               0 022 0  A01F  A 0 01F     69              ADD    MNT3                                               BLG 0062
                0 023 0  0A21  0A2 1       70              SRL  D 1                                                  BLG 0063
                0 024 0  0850  0850        71              SXE                                                       BLG 0064
*               0 025 0  A022  A 0 022     72              ADD    MNT3                                               BLG 0065
                0 026 0  0A21  0A2 1       73              SRL  D 1                                                  BLG 0066
                0 027 0  0850  0850        74              SXE                                                       BLG 0067
*               0 028 0  A025  A 0 025     75              ADD    MNT3                                               BLG 0068
                0 029 0  0A21  0A2 1       76              SRL  D 1                                                  BLG 0069
                0 02A 0  0850  0850        77              SXE                                                       BLG 0070
*               0 02B 0  A028  A 0 028     78              ADD    MNT3                                               BLG 0071
                0 02C 0  0A21  0A2 1       79              SRL  D 1                                                  BLG 0072
                0 02D 0  0850  0850        80              SXE                                                       BLG 0073
*               0 02E 0  A02B  A 0 02B     81              ADD    MNT3                                               BLG 0074
                0 02F 0  0A21  0A2 1       82              SRL  D 1                                                  BLG 0075
                0 030 0  0850  0850        83              SXE                                                       BLG 0076
*               0 031 0  A02E  A 0 02E     84              ADD    MNT3                                               BLG 0077
                0 032 0  0A21  0A2 1       85              SRL  D 1                                                  BLG 0078
                0 033 0  0910  091 0       86              SLA    0          CLEAR OVERFLOW TOGGLE                   BLG 0079
                0 034 0  0850  0850        87              SXE               ADOPTED SIGN OF MULTIPLIER              BLG 0080
*               0 035 0  B031  B 0 031     88              SUB    MNT3       MINUS - NEGATIVE PRODUCT                BLG 0081
*               0 036 0  77FF  7 0 7FF     89              STW    MNT2       STORE HIGHER WORD OF PRODUCT            BLG 0082
                0 037 0  0140  0140        90              CXA                                                       BLG 0083
                0 038 0  0A01  0A0 1       91              SRL    1                                                  BLG 0084
*               0 039 0  7035  7 0 035     92              STW    MNT3       STORE LOWER WORD OF PRODUCT             BLG 0085
*               0 03A 0  9000  9 0 000     93              LDX    RET1                                               BLG 0086
                0 03B 0  1800  1 1 000     94              JMP  * 0                                                  BLG 0087
                                           95      *                                                              BLG 0088
                0 03C 0  0130  0130        96      NEG     CAX                NEGATIVE MULTIPLIER                    BLG 0089
*               0 03D 0  8039  8 0 039     97              LDW    MNT3       GET THE OTHER FACTOR                    BLG 0090
                0 03E 0  0820  0820        98              SAM                                                       BLG 0091
                0 03F 0  1004  1 0 004     99              JMP    MPY2       POSITIVE - MULTIPLICAND                 BLG 0092
                0 040 0  0110  0110       100              CMP                BOTH FACTORS ARE NEGATIVE               BLG 0093
*               0 041 0  703D  7 0 03D    101              STW    MNT3       MULTIPLIER                              BLG 0094
                0 042 0  0140  0140       102              CXA                MULTIPLICAND                            BLG 0095
                0 043 0  08A0  08A0       103              SNO                NEGATIVE LIMIT IN MULTIPLIER            BLG 0096
                0 044 0  1003  1 0 003    104              JMP    MPY1       YES - WILL SET PRODUCT SIGN             BLG 0097
                0 045 0  0110  0110       105              CMP                                                       BLG 0098
                0 046 0  1003  1 0 003    106              JMP    MPY1                                               BLG 0099
                                          107              NTRY   MPYA                                               BLG 0100
                                          108              ENDC                                                      BLG 0101
                                          109      ********************************************************         BLG 0102
                                          110              NTRY   MPYS                                               BLG 0103
                0 046 0*******70          111              END                                                       BLG 0104
```

X-REF

```
    0000      HARD      0 000 0   0 000 0   0 000 0   0 000 0   0 000 0   0 000 0
EXT 0036      MNT2      0 036 0
EXT 0041      MNT3      0 003 0   0 004 0   0 00A 0   0 00D 0   0 010 0   0 013 0   0 016 0   0 019 0
                        0 01C 0   0 01F 0   0 022 0   0 025 0   0 028 0   0 028 0   0 02E 0   0 031 0
                        0 035 0   0 039 0   0 03D 0   0 041 0
LIB 0 008 0   MPYA      0 008 0
LIB 0 000 0   MPYS      0 000 0
    0 003 0   MPY1      0 044 0   0 046 0
    0 004 0   MPY2      0 03F 0
    0 03C 0   NEG       0 002 0
EXT 003A      RET1      0 000 0   0 03A 0
```

NO ERRORS

CARDS	SYMBOLS	LITR	STACK
111	9	624	0	6

DATE: March 1968

ID CODE: BLH

DRAWING: 390665 (Rev C)

LABEL: DIVS

AUTHOR: JACQ

SOURCE: SYM I Assembly Language

OBJECT: Relocatable

PURPOSE

To divide a two-word dividend by a single-word divisor, giving a single-word quotient in the software register MNT3, and a single-word remainder in the software register MNT2. The quotient is also duplicated in the accumulator.

USAGE

Calling Sequence

```
      SMB  DIVS
L     JSX  DIVS
L+1   return
```

The routine will return to L+1.

Argument Description

The divisor must be placed in the hardware accumulator. The dividend must be set in the software registers MNT2, MNT3. In order to conform with the hardware divide, the routine accepts any setting in the sign bit of the lower word (the standard double precision format requires the second sign bit to be zero). Both arguments are in two's complement form.

Storage Requirements

External storage in RET1, TMP1, TMP2, TMP3, and the software registers MNT2, MNT3.

METHOD

The signs of the arguments are saved. When negative, the arguments are converted to their absolute value. The quotient is obtained bit by bit from left to right in an algorithm where the divisor is repeatedly subtacted if it fits, first into the most significant half of the dividend, then into the successive remainders. The contents of the accumulator and index registers are each time shifted one bit position to the left, then the next quotient bit is set true in the rightmost position of the index register for each effective subtraction. The final remainder is set to the original sign of the dividend and stored in MNT2. The quotient is set to its proper sign and stored in MNT3.

ERROR CONDITIONS

Any time the divisor is not found greater in magnitude than the dividend high word, the overflow flip flop is turned on. The arguments are left unaltered upon exit.

RESTRICTIONS

Entries

DIVS

Other Routines

None

External Constants

D1 (= 1)
D2 (= 2)
B0 (X'8000')
M15R (X'7FFF')

Space Used

73 words

Timing

Minimum -	149 cycles
Maximum -	193 cycles
Average	171 cycles
Average (positive arguments)	164 cycles

APPENDIX A

ASSEMBLY LISTING

of

SP DIVIDE

Drawing No.

390665 (Revision B)

ID Code

BLH (Revision B)

```
                               3    'SP DIVIDE DN390665 B'
                               4              ENDC
                               5              TRUE   HARD=1
                               7              ENDC
                               8    *TO SELECT PROPER SEQUENCE SWITCH THE 2 'HARD' CARDS       BLH 0001
              0000  0000       9    HARD      EQU    0        SOFTWARE                         BLH 0002
                              10              TRUE   HARD=2                                    BLH 0003
                              12              ENDC                                             BLH 0005
                              13    ***************************************************        BLH 0006
                              14              BLK    MATH                                      BLH 0007
                              15              LIBR   DIVS                                      BLH 0008
                              16    * DIVISOR IN ACCUMULATOR                                   BLH 0009
                              17    * DOUBLE PRECISION DIVIDEND IN LOCATIONS 'A','B'           BLH 0010
                              18    * QUOTIENT TO SET IN ACCUMULATOR                           BLH 0011
                              19    *          TO DUPLICATE IN LOCATION 'B'                    BLH 0012
                              20    * REMAINDER TO SET IN LOCATION 'A'                         BLH 0013
                              21    * NOTE - OVERFLOW TOGGLE SET ON OVERFLOW CONDITIONS,       BLH 0014
                              22    *          IN WHICH CASE THE DATA ARE LEFT UNALTERED.      BLH 0015
                              23    ***************************************************        BLH 0016
                              24              TRUE   HARD=1                                    BLH 0017
                              42              ENDC                                             BLH 0035
                              43              TRUE   HARD=0                                    BLH 0036
                              44    * SOFTWARE DIVIDE                                          BLH 0037
              0000  0000      45    DIVS      EQU    $                                         BLH 0038
*  0 000 0    67FF  6 0 7FF   46              STX    RET1     SAVE RETURN                      BLH 0039
*  0 001 0    77FF  7 0 7FF   47              STW    TMP3     SAVE DIVISOR                     BLH 0040
   0 002 0    0810  0810      48              SAP                                              BLH 0041
   0 003 0    0110  0110      49              CMP             USE A POSITIVE DIVISOR           BLH 0042
*  0 004 0    A7FF  A 0 7FF   50              ADD    B0       REVERSE SIGN BIT                 BLH 0043
*  0 005 0    77FF  7 0 7FF   51              STW    TMP2                                      BLH 0044
*  0 006 0    87FF  8 0 7FF   52              LDW    D2       SET LOOP COUNT                   BLH 0045
*  0 007 0    77FF  7 0 7FF   53              STW    TMP1                                      BLH 0046
*  0 008 0    97FF  9 0 7FF   54              LDX    MNT3     DIVIDEND LOW WORD                BLH 0047
   0 009 0    0A31  0A3 1     55              SLL D  1        SQUEEZE OUT LOWER SIGN BIT       BLH 0048
*  0 00A 0    87FF  8 0 7FF   56              LDW    MNT2     DIVIDEND HIGH WORD               BLH 0049
   0 00B 0    0810  0810      57              SAP                                              BLH 0050
   0 00C 0    103C  1 0 03C   58              JMP    NEG                                       BLH 0051
*  0 00D 0    B005  B 0 005   59    POS       SUB    TMP2     POSITIVE DIVIDEND                BLH 0052
   0 00E 0    0810  0810      60              SAP             CHECK MAGNITUDE                  BLH 0053
   0 00F 0    1047  1 0 047   61              JMP    DIV0                                      BLH 0054
*  0 010 0    A00D  A 0 00D   62    DIV1      ADD    TMP2                                      BLH 0055
   0 011 0    1014  1 0 014   63              JMP    DIVB     ENTER LOOP                       BLH 0056
*  0 012 0    6007  6 0 007   64    DIVL      STX    TMP1     SAVE LOOP COUNT                  BLH 0057
*  0 013 0    9008  9 0 008   65              LDX    MNT3                                      BLH 0058
   0 014 0    0A71  0A7 1     66    DIVB      SLC D  1                                         BLH 0059
*  0 015 0    B010  B 0 010   67              SUB    TMP2                                      BLH 0060
   0 016 0    0820  0820      68              SAM                                              BLH 0061
*  0 017 0    A015  A 0 015   69              ADD    TMP2                                      BLH 0062
   0 018 0    0A71  0A7 1     70              SLC D  1                                         BLH 0063
*  0 019 0    B017  B 0 017   71              SUB    TMP2                                      BLH 0064
   0 01A 0    0820  0820      72              SAM                                              BLH 0065
*  0 01B 0    A019  A 0 019   73              ADD    TMP2                                      BLH 0066
   0 01C 0    0A71  0A7 1     74              SLC D  1                                         BLH 0067
```

```
*  0 01D 0  B01B  B 0 01B    75          SUB   TMP2                              BLH 0068
   0 01E 0  0820  0820       76          SAM                                     BLH 0069
*  0 01F 0  A01D  A 0 01D    77          ADD   TMP2                              BLH 0070
   0 020 0  0A71  0A7 1      78          SLC D 1                                 BLH 0071
*  0 021 0  B01F  B 0 01F    79          SUB   TMP2                              BLH 0072
   0 022 0  0820  0820       80          SAM                                     BLH 0073
*  0 023 0  A021  A 0 021    81          ADD   TMP2                              BLH 0074
   0 024 0  0A71  0A7 1      82          SLC D 1                                 BLH 0075
*  0 025 0  B023  B 0 023    83          SUB   TMP2                              BLH 0076
   0 026 0  0820  0820       84          SAM                                     BLH 0077
*  0 027 0  A025  A 0 025    85          ADD   TMP2                              BLH 0078
*  0 028 0  6013  6 0 013    86          STX   MNT3                              BLH 0079
*  0 029 0  9012  9 0 012    87          LDX   TMP1                              BLH 0080
   0 02A 0  0501  05 01      88          DXS   1      DECREMENT LOOP COUNT       BLH 0081
   0 02B 0  1012  1 0 012    89          JMP   DIVL   NOT DONE - KEEP IN LOOP    BLH 0082
*  0 02C 0  9028  9 0 028    90          LDX   MNT3                              BLH 0083
   0 02D 0  0A71  0A7 1      91          SLC D 1      DONE - POSITION QUOTIENT   BLH 0084
   0 02E 0  0A01  0A0 1      92          SRL   1             POSITION REMAINDER  BLH 0085
   0 02F 0  0400  04 00      93          IXS   0      SIGN OF DIVIDEND           BLH 0086
   0 030 0  0110  0110       94          CMP          TO GIVE TO REMAINDER       BLH 0087
*  0 031 0  700A  7 0 00A    95          STW   MNT2   STORE REMAINDER            BLH 0088
   0 032 0  0140  0140       96          CXA                                     BLH 0089
*  0 033 0  D001  D 0 001    97          ORE   TMP3   SIGN OF QUOTIENT           BLH 0090
*  0 034 0  A004  A 0 004    98          ADD   B0     SAVE IN OVERFLOW TOGGLE    BLH 0091
   0 035 0  0140  0140       99          CXA                                     BLH 0092
*  0 036 0  E7FF  E 0 7FF   100          AND   M15R   CLEAN QUOTIENT             BLH 0093
   0 037 0  08A0  08A0      101          SNO                                     BLH 0094
   0 038 0  0110  0110      102          CMP                                     BLH 0095
*  0 039 0  702C  7 0 02C   103          STW   MNT3   STORE QUOTIENT             BLH 0096
*  0 03A 0  9000  9 0 000   104    DIVX  LDX   RET1                              BLH 0097
   0 03B 0  1800  1 1 000   105          JMP * 0                                 BLH 0098
   0 03C 0  0140  0140      106    NEG   CXA          NEGATIVE DIVIDEND          BLH 0099
   0 03D 0  0110  0110      107          CMP          WORK ABSOLUTE VALUE        BLH 0100
   0 03E 0  0130  0130      108          CAX                                     BLH 0101
   0 03F 0  0800  0800      109          SAZ                                     BLH 0102
*  0 040 0  87FF  8 0 7FF   110          LDW   D1                                BLH 0103
*  0 041 0  A031  A 0 031   111          ADD   MNT2                              BLH 0104
   0 042 0  0110  0110      112          CMP                                     BLH 0105
*  0 043 0  B027  B 0 027   113          SUB   TMP2                              BLH 0106
*  0 044 0  D034  D 0 034   114          ORE   B0     KEEP SIGN BIT OF DIVIDEND  BLH 0107
   0 045 0  0810  0810      115          SAP          CHECK MAGNITUDE            BLH 0108
   0 046 0  1010  1 0 010   116          JMP   DIV1                              BLH 0109
*  0 047 0  8033  8 0 033   117    DIVO  LDW   TMP3   OVERFLOW - RESTORE DIVISOR BLH 0110
   0 048 0  103A  1 0 03A   118          JMP   DIVX                              BLH 0111
                            119          ENDC                                    BLH 0112
                            120    ***************************************************  BLH 0113
                            121          NTRY  DIVS                              BLH 0114
   0 048 0*******72         122          END                                     BLH 0115
```

X-REF

```
EXT 0044      B0          0 004 0    0 034 0    0 044 0
    0 014 0   DIVB        0 011 0
    0 012 0   DIVL        0 02B 0
    0 047 0   DIVØ        0 00F 0
LIB 0 000 0   DIVS        0 000 0
    0 03A 0   DIVX        0 048 0
    0 010 0   DIV1        0 046 0
EXT 0040      D1          0 040 0
EXT 0006      D2          0 006 0
    0000      HARD        0 000 0    0 000 0    0 000 0    0 000 0    0 000 0    0 000 0
EXT 0041      MNT2        0 00A 0    0 031 0    0 041 0
EXT 0039      MNT3        0 008 0    0 013 0    0 028 0    0 02C 0    0 039 0
EXT 0036      M15R        0 036 0
    0 03C 0   NEG         0 00C 0
    0 00D 0   PØS
EXT 003A      RET1        0 000 0    0 03A 0
EXT 0029      TMP1        0 007 0    0 012 0    0 029 0
EXT 0043      TMP2        0 005 0    0 00D 0    0 010 0    0 015 0    0 017 0    0 019 0    0 01B 0    0 01D 0
                          0 01F 0    0 021 0    0 023 0    0 025 0    0 027 0    0 043 0
EXT 0047      TMP3        0 001 0    0 033 0    0 047 0
```

NØ ERRØRS

CARDS	SHMBØLS	LITR	STACK
122	19	622	0	2

SP CUMULATIVE MULTIPLY

DATE: March 1968

ID CODE: BRJ

DRAWING: 391101

LABEL: ACMY

AUTHOR: JACQ

SOURCE: SYM I Assembly Language

OBJECT: Relocatable

PURPOSE

To add a one-word number to the product of two one-word numbers.

USAGE

Calling Sequence

```
L-1   SMB     ACMY
L     JSX     ACMY
L+1   Return
```

Argument Description

The argument to add to the product is in the software register MNT2. The two factors of the product are in the software register MNT3 and in the hardware accumulator. All three arguments must be positive.

Storage Requirements

External storage RET1, MNT2, MNT3

METHOD

The multiplier is moved from the accumulator to the index register, the contents of MNT2 is set in the accumulator. Using the contents of MNT3 as the multiplicand, the multiplication is initialized, then control is transferred to the multiply routine (MPYS) at entry point MPYA.

RESTRICTIONS

Usage

Strictly restricted to positive arguments.

Entry

ACMY

Other Routines

MPYS

External Constants

None

Space Used

6 words

Timing

78 $\pm$ 14 cycles

APPENDIX A

ASSEMBLY LISTING

of

SP CUMULATIVE MULTIPLY

Drawing No.	ID Code
391101	BRJ

```
                                    3      'SP CUMULATIVE MULTIPLY DN391101
                                    4              ENDC
                                    5              TRUE  HARD=1
                                    7              ENDC
                                    8      *TO SELECT PROPER SEQUENCE SWITCH THE 2 'HARD' CARDS                BRJ 0001
                    0000  0000      9      HARD    EQU   0        SOFTWARE                                    BRJ 0002
                                   10              TRUE  HARD=2                                               BRJ 0003
                                   12              ENDC                                                      BRJ 0005
                                   13      ***********************************************************       BRJ 0006
                                   14              BLK   MATH                                                BRJ 0007
                                   15              LIBR  ACMY                                                BRJ 0008
                                   16      * ADD CONTENTS OF 'MNT2' TO PRODUCT                               BRJ 0009
                                   17      * ROUTINE ONLY GOOD WITH POSITIVE VALUES                          BRJ 0010
                                   18      ***********************************************************       BRJ 0011
                                   19              TRUE  HARD=1                                              BRJ 0012
                                   33              ENDC                                                      BRJ 0026
                                   34              TRUE  HARD=0                                              BRJ 0027
                                   35      * SOFTWARE MULTIPLY                                               BRJ 0028
                    0000  0000     36      ACMY    EQU   $                                                   BRJ 0029
*     0 000 0  67FF  6 0 7FF       37              STX   RET1     SAVE RETURN                                 BRJ 0030
      0 001 0  0130  0130          38              CAX           MULTIPLIER                                  BRJ 0031
*     0 002 0  87FF  8 0 7FF       39              LDW   MNT2     TO ADD TO COMING PRODUCT                    BRJ 0032
      0 003 0  0850  0850          40              SXE                                                       BRJ 0033
*     0 004 0  A7FF  A 0 7FF       41              ADD   MNT3                                                BRJ 0034
*     0 005 0  17FF  1 0 7FF       42              JMP   MPYA     ENTER MPY ROUTINE                          BRJ 0035
                                   43              ENDC                                                      BRJ 0036
                                   44      ***********************************************************       BRJ 0037
                                   45              NTRY  ACMY                                                BRJ 0038
      0 005 0*******5              46              END                                                       BRJ 0039
```

X-REF

```
LIB 0 000 0  ACMY      0 000 0
    0000     HARD      0 000 0    0 000 0    0 000 0    0 000 0    0 000 0    0 000 0
EXT 0002     MNT2      0 002 0
EXT 0004     MNT3      0 004 0
EXT 0005     MPYA      0 005 0
EXT 0000     RET1      0 000 0
```

NO ERRORS

```
CARDS  SYMBOLS   LITR  STACK
46     6         625   0     2
```