1620 GENERAL PROGRAM LIBRARY

Multiplication of Matrices with Variable Length Mantissa on the 1620

5.0.028

Multiplication of Matrices With Variable Length Mantissa on the 1620

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Annex

Brief Description

MULTIPLICATION OF MATRICES WITH VARIABLE

LENGTH MANTISSA ON 1620 (CARD)

a) Author : R. N. MENEGAUX
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b) Subroutine enabling to multiply two matrices with up to 45 digits of mantissa. The two matrices and the product matrix are together in core.

c) Needs at least the basic 1620 with indirect addressing and automatic division and asks for 1330 positions in itself.

d) A direct method is used

e) Operating time depends of the mantissa length

f) Written in SPS II Version II with variable length mantissa

g) Uses floating point subroutines

h) Numbers in floating point only

i) Trials with 10 x 10 (3 mn execution time) and 6 x 6 matrices

j) Language : English

k) None

l) This program and its documentation were written by an IBM employee. It was developed for a specific purpose and submitted for general distribution to interested parties in the hope that it might prove helpful to other members of the data processing community. The program and its documentation are essentially in the author's original form. IBM serves as the distribution agency in supplying this program. Questions concerning the use of the program should be directed to the author's attention.

Write up

MULTIPLICATION OF MATRICES WITH A

VARIABLE LENGTH MANTISSA ON THE

IBM 1620 (CARD)

DECK KEY

1 - Symbolic deck

We have used the numerotation of symbolic programmation sheets, i. e. 25 lines for one sheet. The sheet number is punched in columns 1-2, the line number in columns 3-4-5.

We have here :

Cards from 01 010 to 01 190	main program with the calling sequence
cards from 01 200 to 05 100	subroutine "MULT" in itself

2 - Assembled deck

The whole assembled deck is made of cards numbered sequentially from 00 000 to 00 106, punched in columns 76-80.

3 - Sample deck

There are two cards, including :

- the first, the M matric,
- the second, the N matrix.

GENERALITIES

a) Author : R. N. MENEGAUX
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b) Subroutine enabling to multiply two matrices (square of rectangular) previously stored in a variable length mantissa form (up to 45). A simple calling sequence is to be included in the main program. A third array must be given to store the product matrix. The initial matrices are left undamaged.

c) Requires indirect addressing and asks for 1330 positions of core without the necessary SPS II Version II Subroutines, and 20 K, 40 K or 60 K of core storage.

d) Multiplication is made from the formula giving every product element :

$$MN\ (I,\ J) = \sum_{K} M\ (K,\ J) \times N\ (I,\ K)$$

with I = column rank

and J = row rank

e) The execution time is proportional to the square of the mantissa length

f) Written is SPS II Version II with variable length mantissa

g) Uses floating point subroutines

h) Dimensions of possible matrices :

Let L be the length of the mantissa

M 1 and M 2 be the no. of columns and of rows of the lst matrix
N 1 and N 2 be the no. of columns and of rows of the 2nd matrix

As the no. of positions of core required is :

Subroutine itself	1330
Tables	400
Floating point subroutines SPS	2330
	4060

Then the formula is :

$$(M1 \times M2); + (N1 \times N2) + (N1 \times M2) = \frac{1}{L + 2}\ (\text{Memory-main prog. - 4060})$$

where "memory" = 20K, 40K or 60K
and "main prog. " is the place taken by the main program including the calling sequence.

- Note that the elements of every matrix are in floating point form only.
- The program uses 34 symbols.

i) Trials with two matrices of 10 x 10 and of 6 x 6, with a length of 16 positions mantissa (it took 3 mn for the 10 x 10 matrix).

II - MANUAL OPERATING

Does not occur.

III - CALLING SEQUENCE

The calling sequence to be included in the main program is the following :

```
TFM LGM, xxxxx              ,,LENGTH OF MANTISSA
TFM NCOLM, xxxxx            ,,NO. OF COLUMNS OF MATRIX M
TFM NROWM, xxxxx            ,,NO. OF ROWS OF MATRIX M
TFM NCOLN, xxxxx            ,,NO. OF COLUMNS OF MATRIX N
TFM NROWN, xxxxx            ,,NO. OF ROWS OF MATRIX N
TFM ADM, xxxxx              ,,ADDRESS OF 1ST MATRIX M
TFM ADN, xxxxx              ,,ADDRESS OF 2ND MATRIX N
TFM ADMN, xxxxx             ,,ADDRESS OF PRODUCT MATRIX MN
TFM FMULT + 6,x + 48
TFM FERR + 6, x + 24
B     MULT
Error Return
Normal Return
```

So you must fill the following constants :
- "LGM" by the length of the mantissa (up to 45)
- "NCOLM" by the number of columns of the 1st matrix M
- "NROWM" by the number of rows of the 1st matrix M
- "NCOLN" by the number of columns of the 2nd matrix N
- "NROWN" by the number of rows of the 2nd matrix N
- "ADM" by the address (to the extreme right) of the first element of the first matrix M
- "ADN" like "ADM" for the 2nd matrix N
- "ADMN" like "ADM" for the product matrix MN you wish.

Note that those references and what they contain are not modified by the execution of the subroutine : they remain available at the end of the program.

Control will be given back to the second instruction following the last instruction of the calling sequence (here "B MULT"), if the multiplication of the matrices has been done normally.
If not, the following message will be printed :

"THE NO OF COLUMNS OF IST MATRIX IS NOT EQUAL TO THE NO. OF ROWS OF 2ND MATRIX"

then control will automatically be given back to the first instruction following the "B MULT", where a branch to an error procedure may be put.

No essential zeros have been considered in this subroutine.

The matrices to be multiplied together are supposed to be previously stored in sequence row by row from the left to the right. They will be left unchanged.

So the sequence must be :

```
Elements (I, J) with I = 1    J = 1
                then I = 1    J = 2
                ...............
                   I = 1    J = NCOLM
                   I = 2    J = 1
                   etc...
```

The program is provided in SPS II Version II form, to enable users to compile it with their own program (and their own length of mantissa).

TRIAL ON A SAMPLE PROBLEM

Let us multiply the following two matrices :

$$M = \begin{vmatrix} 1 & 2 \\ 3 & 4 \end{vmatrix} \qquad N = \begin{vmatrix} -2 & 1 \\ 3/2 & -1/2 \end{vmatrix}$$

Let us suppose the program including the calling sequence be :

```
DEBUT   NOP
        RNCD  10 000
        RNCD  11 000
        TFM   LGM  16
        TFM   NCOL M, 2
        TFM   N ROW M, 2
        TFM   NCOL N, 2
        TFM   N ROW N, 2
        TFM   A DM, 10017
        TFM   A DN, 11 017
```

```
        TFM      ADMN           12017
        TFM      FMULT + 6,       +48
        TFM      FERR   + 6,      +24
        B        MULT
        H                                   ( error return )
        TD       12 072, 400
        WNTY     12 000
        H                                   (end of the program)
        B        DEBUT
```

We add there the subroutine "MULT" itself, in its symbolic form.

Operating instructions :

The whole program is compiled in SPS II, Version II, with automatic division and variable length of mantissa (here, equal to 16) subroutine (Deck numbered 5). The two data matrices are called when the assembled program is loaded.

They have been punched on two cards under the following form :

```
1̄0000000000000000̄12̄0000000000000000̄13̄0000000000000000̄14̄0000000000000000̄1

2̄000000000000000̄0̄11̄0000000000000000̄11̄500000000000000̄0̄15̄000000000000000̄0̄0
```

The first matrix (M) is loaded in address 10000, the second matrix (N) in address 11000.

Dumping from address 12000, we have the result :

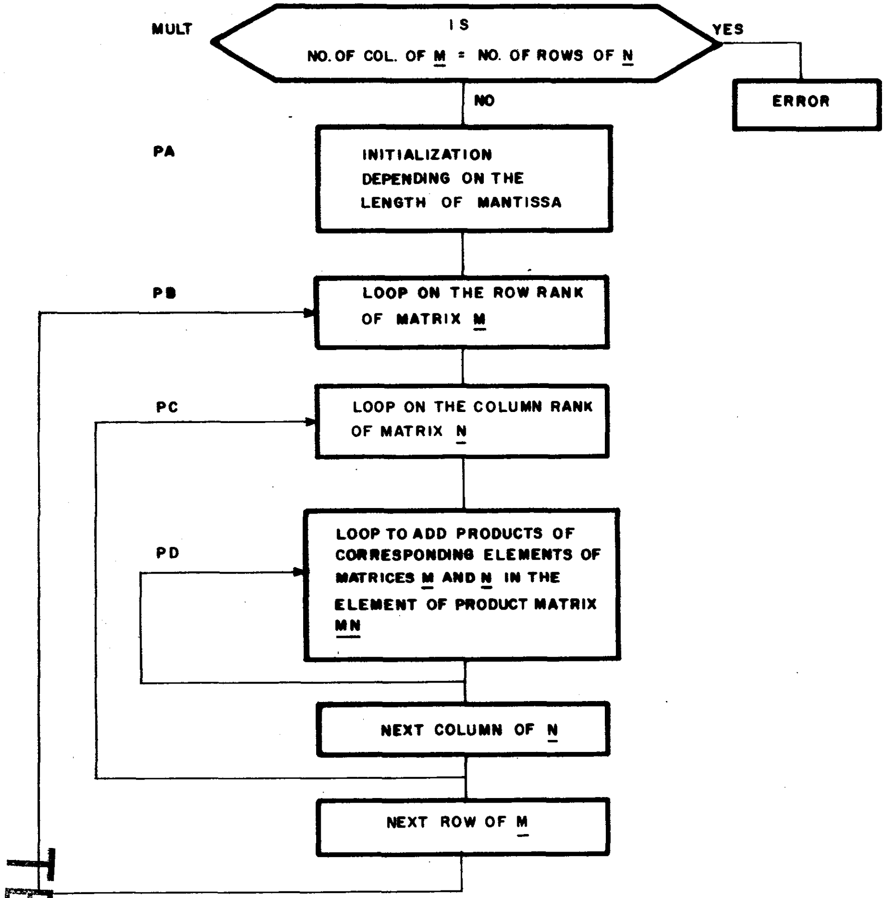
```
1̄0000000000000000̄10̄000000000000000̄9̄9̄0̄00000000000000̄0̄9̄9̄1̄0000000000000000̄1
```

which means matrix MN = $\begin{matrix} 1 & 0 \\ 0 & 1 \end{matrix}$, multiplication of the matrices M and N.

GENERAL FLOW CHART

cf. following chart.

FLOW CHART MULTIPLICATION OF MATRICES


MULT
IS
NO. OF COL. OF M = NO. OF ROWS OF N
YES
ERROR
NO
PA
INITIALIZATION DEPENDING ON THE LENGTH OF MANTISSA
PB
LOOP ON THE ROW RANK OF MATRIX M
PC
LOOP ON THE COLUMN RANK OF MATRIX N
PD
LOOP TO ADD PRODUCTS OF CORRESPONDING ELEMENTS OF MATRICES M AND N IN THE ELEMENT OF PRODUCT MATRIX MN
NEXT COLUMN OF N
NEXT ROW OF M

LISTING OF SYMBOLIC SAMPLE PROGRAM

```
01010DEBUT NOP                                                   MULT
01020      RNCD10000                                             MULT
01030      RNCD11000                                             MULT
01040      TFM LGM,16      ,,LENGTH OF MANTISSA                  MULT
01050      TFM NCOLM,2      ,,NO. OF COLUMNS OF MATRIX  M        MULT
01060      TFM NROWM,2     ,,NO. OF ROWS OF  MATRIX  M           MULT
01070      TFM NCOLN,2  ,,NO. OF COLUMNS OF MATRIX  N            MULT
01080      TFM NROWN,2     ,,NO. OF ROWS OF MATRIX  N            MULT
01090      TFM ADM,10017  ,,ADDRESS OF 1ST MATRIX  M             MULT
01100      TFM ADN,11017  ,,ADDRESS OF 2ND MATRIX  N             MULT
01110      TFM ADMN,12017 ,,ADDRESS OF PRODUCT MATRIX  MN        MULT
01120      TFM FMULT+6,*+48                                      MULT
01130      TFM FERR+6,*+24                                       MULT
01140      B   MULT                                              MULT
01150      H                                                     MULT
01160      TD  12072,400                                         MULT
01170      WNTY12000                                             MULT
01180      H                                                     MULT
01190      B   DEBUT                                             MULT
01200MULT  C   NCOLM,NROWN                                       MULT
01210      BE  PA                                                MULT
01220      RCTY                                                  MULT
01230      WATYMESSA                                             MULT
01240      RCTY                                                  MULT
01250FERR  B   0                                                 MULT
02010PA    TF  LGT,LGM                                           MULT
02020      AM  LGT,2,10                                          MULT
02030      M   NCOLM,LGT                                         MULT
```

```
02040       SF   95                                                MULT
02050       TF   N,99                                              MULT
02060       M    N,NROWM                                           MULT
02070       SF   95                                                MULT
02080       TF   NN,99                                             MULT
02090       M    NCOLN,LGT                                         MULT
02100       SF   95                                                MULT
02110       TF   NNN,99                                            MULT
02120       TF   AZER,AZERR                                        MULT
02130       SF   -AZER                                             MULT
02140       A    AZER,LGM                                          MULT
02150       AM   AZER,1,10                                         MULT
02160       TFM  -AZER,-99,10                                      MULT
02170       TF   AMEM,AMEMR                                        MULT
02180       SF   -AMEM                                             MULT
02190       A    AMEM,LGM                                          MULT
02200       AM   AMEM,1,10                                         MULT
02210       TFM  -AMEM,0,10                                        MULT
02220       TFM  I,0                                               MULT
02230PB     C    I,NNN                                             MULT
02240       BE   FMULT                                             MULT
02250       TFM  J,0                                               MULT
03010       TFM  JJ,0                                              MULT
03020PC     C    J,NN                                              MULT
03030       BE   PF                                                MULT
03040       TFM  K,0                                               MULT
03050       TFM  II,0                                              MULT
03060       TF   AC,ADMN                                           MULT
03070       A    AC,I                                              MULT
03080       A    AC,JJ                                             MULT
03090       TFLS-AC,-AZER                                          MULT
```

```
03100PD     C    K,N                                               MULT
03110       BE   PE                                                MULT
03120       TF   AM,ADM                                            MULT
03130       A    AM,K                                              MULT
03140       A    AM,J                                              MULT
03150       TF   AN,ADN                                            MULT
03160       A    AN,I                                              MULT
03170       A    AN,II                                             MULT
03180       TFLS-AMEM,-AM                                          MULT
03190       FM   -AMEM,-AN                                         MULT
03200       FA   -AC,-AMEM                                         MULT
03210       A    II,N                                              MULT
03220       A    K,LGT                                             MULT
03230       B    PD                                                MULT
03240PE     A    J,N                                               MULT
03250       A    JJ,NNN                                            MULT
04010       B    PC                                                MULT
04020PF     A    I,LGT                                             MULT
04030       B    PB                                                MULT
04040FMULT  B    0                                                 MULT
04050LGM    DC   5,00000                                           MULT
04060LGT    DC   5,00000                                           MULT
04070NCOLM  DC   5,00000                                           MULT
04080NROWM  DC   5,00000                                           MULT
04090NCOLN  DC   5,00000                                           MULT
04100NROWN  DC   5,00000                                           MULT
04110ADM    DC   5,00000                                           MULT
04120ADN    DC   5,00000                                           MULT
04130ADMN   DC   5,00000                                           MULT
```

```
04140AM     DC   5,00000                                                  MULT
04150AN     DC   5,00000                                                  MULT
04160AC     DC   5,00000                                                  MULT
04170N      DC   5,00000                                                  MULT
04180NN     DC   5,00000                                                  MULT
04190NNN    DC   5,00000                                                  MULT
04200I      DC   5,00000                                                  MULT
04210II     DC   5,00000                                                  MULT
04220J      DC   5,00000                                                  MULT
04230JJ     DC   5,00000                                                  MULT
04240K      DC   5,00000                                                  MULT
04250ZER    DC   1,0                                                      MULT
05010       DS   45                                                       MULT
05020AZERR  DSA  ZER                                                      MULT
05030AZER   DC   5,00000                                                  MULT
05040MEM    DC   1,0                                                      MULT
05050       DS   45                                                       MULT
05060AMEMR  DSA  MEM                                                      MULT
05070AMEM   DC   5,00000                                                  MULT
05080MESSA  DAC  49,THE NO. OF COLUMNS OF 1ST MATRIX IS NOT EQUAL TO ‡    MULT
05090       DAC  30,THE NO. OF ROWS OF 2ND MATRIX'                        MULT
05100       DENDDEBUT                                                     MULT
```

LISTING OF THE ASSEMBLED SAMPLE PROGRAM

```
360007200500360020100500440001200276260005900274250001100000260009000269      -0000
2600075002643100000002002600114002742500000000011490001200000                 -0001
41000000000036100000050036110000050160142б-00161601436-0002‡0-1-0402-0462 -0002
1601441-00021601446-00021601451-00021601456J00171601461J1017‡0-1-0462-0522 -0003
1601466J20171601416-05821600696-05704900630000004800000000‡0-1-0522-0582 -0004
2512072004003812000001004800000000004900402000002401436014S1‡0-1-0582-0642 -0005
4600702012003400000001023901635001003400000001024900000000000‡0-1-0642-0702 -0006
2601431014261101431000-22301436014313200095000002601486000 99‡0-1-0702-0762 -0007
2301486014413200095000002601491000992301446014313200095C0000‡0-1-0762-0822 -0008
26014960009926015770157232015 7P00000210157701426110157700C-1‡0-1-0822-0882 -0009
160157P000RR26016330162832016 3L0000021016330142611016 33000-1‡0-1-0882-0942 -0010
160163L000-01601501-00002401501014964601410012001601511-0000‡0-1-0942-1002 -0011
1601516-000024015110149146013860120016C1521-00001601506-0000‡0-1-1002-1062 -0012
2601431014662101481015012101481015161601863-11214901832C0000‡0-1-1062-1122 -0013
-148J-157P‡                                               1-1-1117-1127 -0014
2401521014864601350012002601471014562101471015212101471C1511‡0-1-1128-1188 -0015
2601476014612101476015012101476015C61601863-1247490183200000‡0-1-1188-1248 -0016
-163L-147J‡                                               1-1-1243-1253 -0017
1601863-127749018120000‡                                  0-1-1254-1278 -0018
-163L-147C‡                                               1-1-1273-1283 -0019
1601863-130749017920000‡                                  0-1-1284-1308 -0020
-148J-163L‡                                               1-1-1303-1313 -0021
21015060148621015210143149011280000210151101486210151601496‡0-1-1314-1374 -0022
49010140000210150101431490096600000490000000000‡          0-1-1374-1422 -0023
-0000-0000-0000-0000-0000-0000-0000-0000-0000-0000-0000-0000‡1-1-1422-1482 -0024
-0000-0000-0000-0000-0000-0000-0000-0000-‡                1-1-1482-1523 -0025
-1522‡                                                    1-1-1568-1573 -0026
-0000-‡                                                   1-1-1573-1579 -0027
```

```
-1578‡                                                         1-1-1624-1629 -0028
-0000348450055560300564600435653645455620056460071626 3‡       1-1-1629-1684 -0029
005441635949670049620055566300455864415300635600‡              1-1-1684-1732 -0030
0348450055560300564600595666620056460072554400544163594967 0‡  1-1-1732-1792 -0031
26019190000044019080191933019190000026019190191R4901864000 0‡0-1-1852-1912 -0032
2602509000002601955019191201955000-2260250700000150221100002‡0-1-1908-1968 -0033
2601991018632602262000001101863000-52602027018632602083000 00‡0-1-1968-2028 -0034
44020720208333020830000026020830208L490202800000‡              0-1-2028-2076 -0035
2602654000002602119020831202119000-2260265200000260228601863‡0-1-2072-2132 -0036
44021760226233022620000026022620226K490213200000‡              0-1-2132-2180 -0037
2602274022621202274000-21102286000-01202211000-14702248012000‡0-1-2176-2236 -0038
150221100002490000000000‡                                      0-1-2236-2260 -0039
26000000250926000000025074900000000-00‡                        0-1-2256-2292 -0040
‡                                                              1-1-2291-2292 -0041
38022820010043023280040148-26520265316025090000R92602507028 62‡0-1-2292-2352 -0042
490242000000‡                                                  0-1-2352-2364 -0043
38022820010044023960040148J00001000016025090000RR2602507 02907‡0-1-2360-2420 -0044
49000000000‡                                                   0-1-2420-2432 -0045
380228200100480-1-2-0020‡                                      0-1-2428-2452 -0046
‡                                                              1-1-2451-2452 -0047
49000000000‡                                                   0-1-2452-2464 -0048
‡                                                              1-1-2510-2511 -0049
‡                                                              1-1-2655-2656 -0050
-0000000000000000000000000000000000000000000000‡               1-1-2657-2705 -0051
J0‡                                                            1-1-2656-2658 -0052
J5707963267948966192313216916397514420985846996‡               1-1-2705-2752 -0053
M3429448190325182765112891891660508229439700580‡               1-1-2752-2799 -0054
K30258509299404568401799145468436420760110148862‡              1-1-2799-2847 -0055
R999999999999999999999999999999999999999999999‡                1-1-2847-2892 -0056
-00000000000000000000000000000000000000000000000‡              1-1-2940-2988 -0057
-000000000000000000000000000000000000000000000000‡             1-1-2892-2941 -0058
```

```
                                                                           00059
     017921602254-3008‡                                     0J1-1792-1804 R0060
                                                                           00061
     0180449018523‡                                         0J1-1804-1812 R0062
                                                                           00063
     018121602254-3708‡                                     0J1-1812-1824 R0064
                                                                           00065
     0182449018523‡                                         0J1-1824-1832 R0066
1603086-3088490302000000‡                                   0-1-2988-3012 -0067
1603086-31321602426-348446030440140015024910000-150263600000-‡0-1-3008-3068 -0068
1602290000-0490000000000‡                                   0-1-3068-3092 -0069
440312002652330265200000490313200000‡                       0-1-3088-3124 -0070
32026520000430316402492310249202637490350800000‡            0-1-3120-3168 -0071
430318402637490350800000‡                                   0-1-3164-3188 -0072
1503377000011603387-2652240250902654460328001100460337601200‡0-1-3184-3244 -0073
310254002492310249202637‡                                   0-1-3244-3268 -0074
3102637025402202654025094603508014001402654000JN470350801300‡0-1-3268-3328 -0075
210338702654440336402652150337700002330263700000210250700000‡0-1-3328-3388 -0076
160350700-12250344702507470352801400260250702506330249300000‡0-1-3388-3448 -0077
15024920000J1102509000-146076880140044035080344732025070000 0‡0-1-3448-3508 -0078
1102507000-0490225600000‡                                   0-1-3508-3532 -0079
430352002492460239601200330250700000‡                       0-1-3528-3564 -0080
3202493000002603563025093102492024932502507-18511203563000-1‡0-1-3564-3624 -0081
260250903563430365602492490356400000‡                       0-1-3624-3660 -0082
470348401400250229003507490236000000‡                       0-1-3656-3692 -0083
250229003506490229200000‡                                   0-1-3688-3712 -0084
1603086-3740160383700-124903928000000‡                      0-1-3708-3744 -0085
2302507026522503447000994602396012001603507 00-3443038840068‡0-1-3740-3800 -0086
1604079-00841202654000-14703860014001202509000-1‡           0-1-3800-3848 -0087
```

```
1602654000RR4304100038353200069000002102509026544904068000C0‡0-1-3848-3908 -0088
1603086-3960160383700J111604079-00832600099029244903020C00000‡0-1-3904-3964 -0089
2800083025072900083026524604120014002503447000834303812000067‡0-1-3960-4020 -0090
46023960120032000680000016035070 0-56220250902654260250700082‡0-1-4020-4080 -0091
440347202509490365600000‡                                   0-1-4080-4104 -0092
1604079-0082490404400000‡                                   0-1-4100-4124 -0093
15022900000071602458-2440490242800000‡                      0-1-4120-4156 -0094
                                                                          00095
     01832T60225 4-4152‡                                    0J1-1832-1844 R0096
                                                                          00097
     0184449019563‡                                         0J1-1844-1852 R0098
26025090265426025070265249022560000‡                        0-1-4152-4188 -0099
00000   L600000005004900000‡                                -8-0096-0115 -0100
360010000500360017200500360024400500360031600500360000000500             -0101
0000000000001020304000204060800030609021004080216100500151C200602181 4200‡ -0102
704112820080614223009081726300000000000506070809001214161815181124272024 2‡ -0103
82236352035304540363248445532494653604846546275445362718012345678912345 6‡ -0104
789-23456789-J3456789-JK456789-JKL56789-JKLM6789-JKLMN789-JKLMN089-JKLMN‡ -0105
M800000000049-04020P9-JKLMNOPQ‡     L1003880001 9M90000000000M90003600000  -0106
```

LIST OF REFERENCES OF SAMPLE PROGRAM

```
310000300002RS

SPS PROCESSOR  FOR 1620/1710 CARD I/O SYSTEM,DATED 1/1/1962


END OF PASSI


LOAD SUBROUTINES
ENTER MANTISSA LENGTH 16RS


END OF PASSII
00402   DEBUT   00630   MULT    00690   FERR    00702   PA      00966   PB
01014   PC      01128   PD      01350   PE      01386   PF      01410   FMULT
01426   LGM     01431   LGT     01436   NCOLM   01441   NROWM   01446   NCOLN
01451   NROWN   01456   ADM     01461   ADN     01466   ADMN    01471   AM
01476   AN      01481   AC      01486   N       01491   NN      01496   NNN
01501   I       01506   II      01511   J       01516   JJ      01521   K
01522   ZER     01572   AZERR   01577   AZER    01578   MEM     01628   AMEMR
01633   AMEM    01635   MESSA
```

```
310000300002RS
```

INPUT SAMPLE PROBLEM

```
1̅000000000000000000̅12̅000000000000000000̅13̅000000000000000000̅14̅000000000000000000̅1

2̅00000000000000000̅0̅11̅000000000000000000̅11̅50000000000000000̅15̅00000000000000000̅0̅0̅
```

OUTPUT DUMP OF THE SAMPLE PROBLEM

4900402

```
1̅000000000000000000̅10̅000000000000000009̅9̅0̅00000000000000000̅9̅9̅1̅000000000000000000̅1
```