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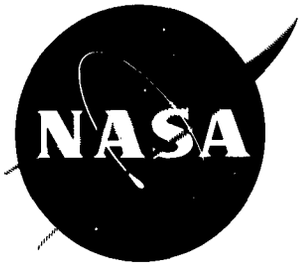

TECHNICAL NOTE

D-1078

FOURIER SERIES OPERATING PACKAGE

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON
December 1961

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D-1078

FOURIER SERIES OPERATING PACKAGE

by
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SUMMARY

This report presents a computer program for multiplying, adding, differentiating, integrating, "barring" and scalarly multiplying "literal" Fourier series as such, and for extracting the coefficients of specified terms.

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INTRODUCTION

The Hansen Satellite Theory as modified by Musen[1] involves various manipulations of "literal" Fourier series, as such, before final numerical evaluation. To program this formulation it is necessary to represent cosines, sines, and constants in a special manner and thus manipulate the various Fourier series.

SPECIAL REPRESENTATION OF A SINE, COSINE, OR CONSTANT

It was decided to represent any term, including the constant term, of the Fourier series we are concerned with by two consecutive eight-place floating-point words. The terms of this series have the general form

$$A_n \cos (iF + jE + kW + lU)$$

or

$$A_n \sin (iF + jE + kW + lU)$$

and the values of F, E, W, and U are not used until final numerical evaluation. The first eight-place floating-point word represents the coefficient A_n in an entirely standard manner. The second eight-place floating-point word represents the sine or cosine term of up to four arguments in an *artificial* manner.

[1]Musen, P., "A Modified Hansen's Theory as Applied to the Motion of Artificial Satellites," NASA Technical Note D-492, November 1960.

Consider a term such as $A_n \cos (iF + jE + kW + lU)$. Until this term is evaluated we are concerned only with the values of A_n, i, j, k, and l. The coefficient A_n is represented by the first of the two eight-digit floating-point words. The four coefficients of the arguments (i, j, k, and l) are each represented by two digits of the second eight-place floating-point word. The first two digits represent i and are normalized to 00; the next three pairs of digits represent j, k, and l, and are normalized to 50. Thus, the value of i may vary from 0 to 99, while j, k, and l may vary from -49 to +49. A cosine is denoted by a plus sign; a sine by a minus sign, that is, 1 cos (0F + 0E + 0W + 0U) or cos (0) becomes +10000000 + 01, +00505050 + 08. Any constant term can be represented as $A_n \cos (0)$. A few additional examples will be helpful (see also Appendix A):

Conventional	Special
1/4 cos (1F + 2E - 3W - 2U)	25000000 + 00, +01524748 + 08
1/4 sin (0F + 1E - 0W + 2U)	25000000 + 00, -00515052 + 08
1/4	25000000 + 00, +00505050 + 08
0	00000000 + 00, +00505050 + 08

The convention of having the first non-zero coefficient of the argument word positive was adopted. Cos(-x) becomes cos(x) and sin(-x) becomes -sin(x). Examples are:

(1/2) cos (0F - 3E + 1W + 0U) becomes (1/2) cos (0F + 3E - 1W + 0U)
and the special representation is 50000000 + 00, + 00534950 + 08

(1/2) sin (0F - 3E + 1W + 0U) becomes -(1/2) sin (0F + 3E - 1W + 0U)
and the special representation is -50000000 + 00 - 00534950 + 08.

The first location address of a series contains the number of terms of the series. A series of n terms would be represented by 2n + 1 words, the first of which would be the number n.

THE FOURIER OPERATING PACKAGE

The following series operations are performed by the Fourier Operating Package:

- Multiplication
- Addition and Subtraction
- Differentiation
- Integration
- Bar (Special operation used in the Hansen satellite theory)
- Scalar Multiplication
- Coefficient Extraction
- Series Evaluation

Multiplication

Multiplication of two series, where the terms are of the general form described earlier and the values of F, E, W, and U are not used until the final numerical evaluation, is according to the conventional trigonometric identities:

$$A \cos X \cdot B \cos Y = (AB/2) \cos (X+Y) + (AB/2) \cos (X-Y)$$
$$A \cos X \cdot B \sin Y = (AB/2) \sin (X+Y) - (AB/2) \sin (X-Y)$$
$$A \sin X \cdot B \cos Y = (AB/2) \sin (X+Y) + (AB/2) \sin (X-Y)$$
$$A \sin X \cdot B \sin Y = (AB/2) \cos (X+Y) + (AB/2) \cos (X-Y).$$

The Fourier Multiplication routine is composed of three major sections: the multiplier, the collapser, and the arranger.

The Multiplier

Two Fourier series such as

$$A_1A_1^* + A_2A_2^* + A_3A_3^* + \ldots + A_nA_n^* \qquad \text{(Series A)}$$

and

$$B_1B_1^* + B_2B_2^* + B_3B_3^* + \ldots + B_mB_m^* \qquad \text{(Series B)}$$

which are to be multiplied are arranged in descending order of the absolute values of the coefficients, that is,

$$|A_1| > |A_2| > |A_3| > \ldots > |A_n| \text{ and } |B_1| > |B_2| > |B_3| > \ldots > |B_m|$$

To facilitate further discussion, we shall denote any term in the A series $A_xA_x^*$, any term in the B series as $B_yB_y^*$, and any term in the resultant series by $C_zC_z^*$, where A_x, B_y and C_z are the coefficient words and A_x^*, B_y^*, and C_z^* are the argument words.

The multiplication of the A series by the B series proceeds as follows: The first term in the A series is multiplied by each term in the B series, then the second term in the A series is multiplied by each term in the B series, and so on until each term in the A series has been multiplied by each term in the B series. For example, $|A_xB_y|$ is compared with some numerical criterion e. If $|A_xB_y| > e$, then $C_zC_z^*$ and $C_{(z+1)}C_{(z+1)}^*$ are generated according to the trigonometric formulas already stated. If $|A_xB_y| \leq e$, then the value of y is examined. If $y > 1$ (i.e., B_y is any term other than the first term), A_x is replaced by $A_{(x+1)}$ and $A_{(x+1)}$ is multiplied by B_1. If $y = 1$, the multiplication of the two series is terminated since any further $A_{(x+1)}B_y$ will also be less than e. The multiplication process continues until $A_nA_n^*$ has been multiplied by $B_mB_m^*$ unless the numerical criterion or space limitations intervene.

The Collapser

Every multiplication generates two terms of two words each. The purpose of the collapser is to combine like argument terms. Each argument term C_z^* is compared with each other argument term previously generated and stored. If C_z^* equals any other argument term, the corresponding coefficient terms are added. Thus, there is no duplication of terms.

The Arranger

The final step in the multiplication is the arranging of the terms of the series. $|C_1|$ is compared with $|C_2|$, $|C_3|$, etc. If $|C_z| > |C_1|$, then C_1 is replaced by C_z and C_1^* is replaced by C_z^*. The process continues until the terms are arranged, in descending order, according to the absolute value of the coefficients.

Addition and Subtraction

Addition or subtraction of two Fourier series is primarily a process of comparing argument terms and adding the coefficients of like terms. A_1^* is compared successively with B_1^* through B_m^*, A_2^* with B_1^* through B_m^*, etc., until A_n^* has been compared with B_m^*. If $A_x^* = B_y^*$, the sum of the coefficients $(A_x + B_y)$ and the argument term A_x^* are stored, and B_y and B_y^* are replaced by zeros. If A_x^* does not equal any B_y^*, both A_x and A_x^* are stored. After all terms in the A series have been compared with all terms in the B series, the remaining B series terms are stored.

Subtraction is accomplished in like manner after changing the signs of each coefficient term in the B series. The resultant series in each case is processed through the arranger.

Differentiation

Differentiation, in this application, is with respect to the F variable. Thus,

$$\left(\frac{\partial}{\partial F}\right) A \sin (iF + jE + kW + lU) = iA \cos (iF + jE + kW + lU).$$

Example:

$$\left(\frac{\partial}{\partial F}\right) \sin (3F + 2E - 3W + U) = +3 \cos (3F + 2E - 3W + U)$$

and

$$\left(\frac{\partial}{\partial F}\right)[10000000 + 01, -03524751 + 08 \text{ becomes } +30000000 + 01, +03524751 + 08.$$

On completion of the differentiation, the resultant series is processed thru the arranger.

Integration

Integration, in this application, is with respect to E. However, W is also a function of E. Thus,

$$\int A \cos (iF + jE + kW + lU)dE = \frac{A}{c_1 j + c_2 k} \sin (iF + jE + kW + lU).$$

Example:

With $c_1 = 1$ and $c_2 = 1$,

$$\int[30000000 + 01, + 01525250 + 08]dE \text{ becomes } 75000000 + 00, -01525250 + 08.$$

The resultant integrated series is also processed through the arranger.

Bar Operation

The bar operation is a special function in the Hansen Satellite Theory. It consists of adding the coefficient of the F argument to the coefficient of the E argument and substituting zero for the F coefficient. Thus,

A cos (iF + jE + kW + lU) after barring becomes A cos (0F + (i + j) E + kW + lU).

Example:

50000000 + 00, + 02534850 + 08 after barring becomes 50000000 + 0C, + 00554850 + 08.

Scalar Multiplication

Scalar multiplication is the multiplication of the coefficient A_n of each term by a constant.

Coefficient Extraction

In the Hansen Satellite Theory it is sometimes necessary to use the coefficient of some term of a Fourier series such as a sine 1F term, cosine 2E term, or the constant term of a series. Let us assume it is necessary to use the constant term. If there is a constant term in that series, it will be the multiplier of the cos (0), or in special form, that A_n word which multiplies 00505050 + 08. We successively compare each argument term in the series with cos (0) and extract that A_n which multiplies the argument term cos (0). If no argument term of the series is cos (0), a normalized zero (10000000 + 00 + 00000000 + 00 + 00505050 + 08), is printed.

Series Evaluation

The numerical values F, E, W, and U are only employed in the Series Evaluation Routine.

To evaluate a Fourier series, the numerical values of i, j, k, and l are multiplied by the numerical values of F, E, W, and U, and the sum iF + jE + kW + lU is determined. The sine or cosine of iF + jE + hW + lU is multiplied by the coefficient A and the terms are added.

CONCLUDING REMARKS

Appendix A is the special representation of a nine term series. Appendix B presents flow charts and Appendix C a listing of instructions for the program packages for multiplication (including the collapser and arranger), addition or subtraction, differentiation, integration, bar operation, scalar multiplication, coefficient extraction, and the evaluation of the final series. Because this program was written in Mystic Code for the IBM 709, an explanation of Mystic Code is given in Appendix D.

The Fourier operating package can be used with any theory that involves representations of functions by Fourier series. It can also be modified to operate with polynomials of the form $X^aY^bZ^cU^d$.

ACKNOWLEDGMENTS

The author is indebted to Messrs. R. G. Kelly and T. P. Gorman for their aid in the construction of the package and for the translation into Mystic Code and to Aileen Marlow for preparing the flow charts.

Appendix A

Nine Term Series in Standard and Special Form

The following is a nine term series presented in standard and in special form. Note that in the special form, the first location (address) contains the number of terms in the series.

Series in standard representation

.29467121 cos (0)
+.00010496334 cos (0F + 0E + 2W + 0U)
+.00005252596 sin (0F + 1E - 1W + 0U)
+.000019845618 cos (0F + 1E - 2W + 0U)
+.0000066329604 cos (0F + 1E + 2W + 0U)
+.0000020107054 cos (0F + 2E - 2W + 0U)
-.00000036004597 sin (0F + 0E + 1W + 0U)
-.000000055052357 sin (0F + 0E + 3W + 0U)
-.000000031090653 sin (0F + 1E + 1W + 0U)

Series in special representation

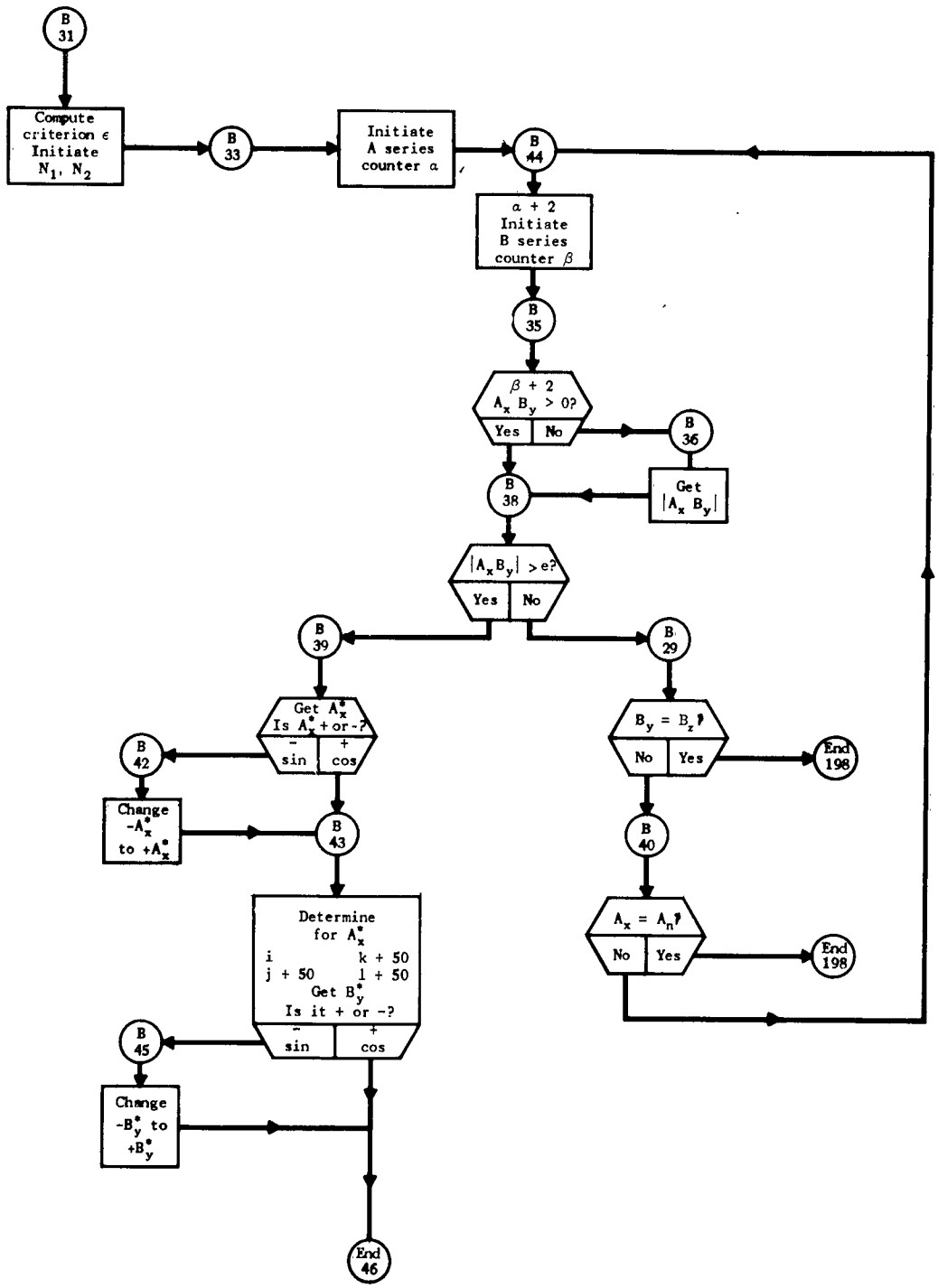
90000000 + 01
+29467127+00, +00505050+08
+10496334-03, +00505250+08
+52525962-04, -00514950+08
+19845618-04, +00514850+08
+66329604-05, +00515250+08
-20107054-05, +00524850+06
-36004597-06, -00505150+08
-55052357-07, -00505350+08
-31090653-07, -00515150+08

Appendix B

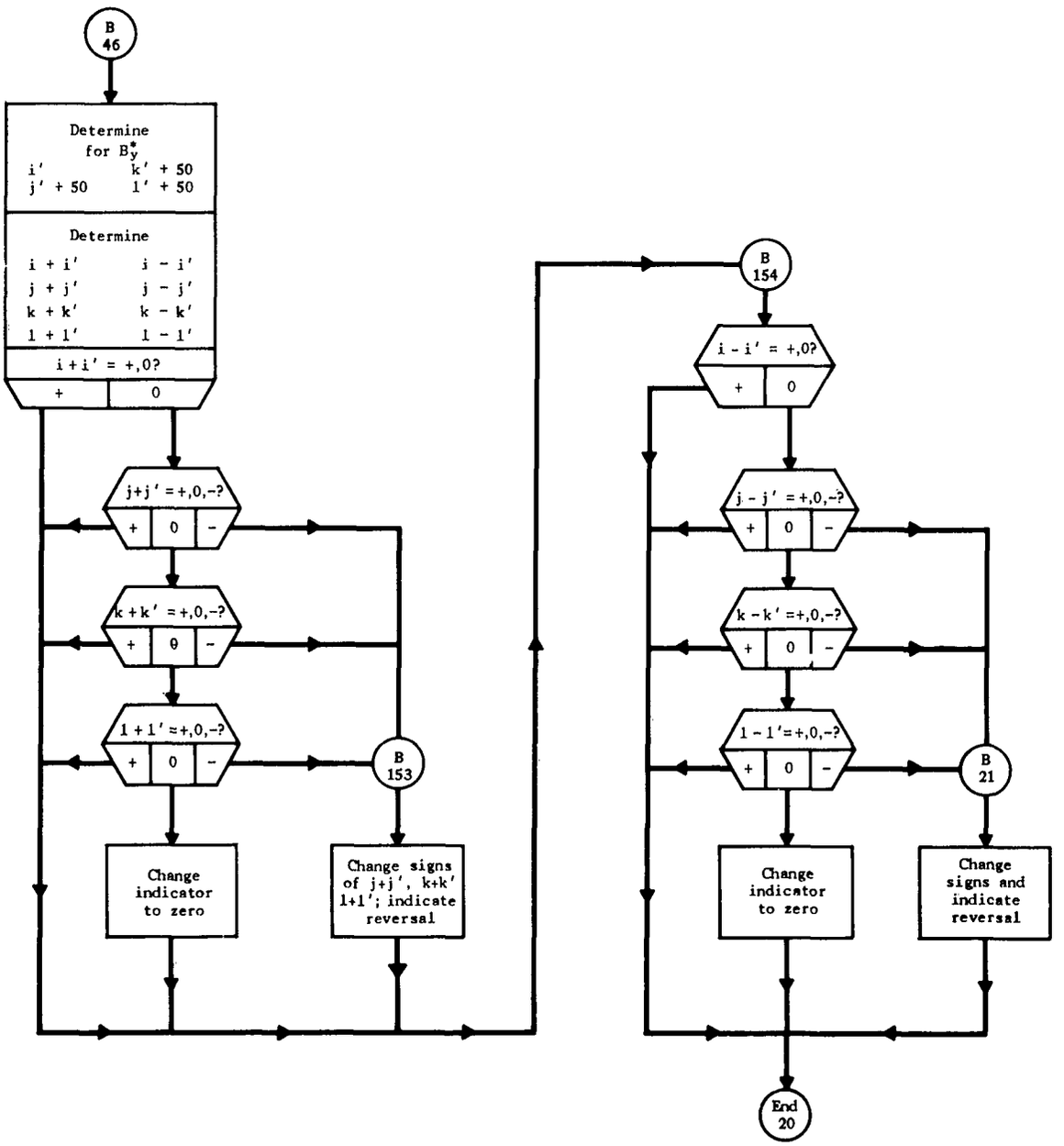
Flow Charts

The following are the flow charts for the operating packages for multiplication (including the collapser and the arranger), addition or subtraction, bar operation, differentiation, integration, and series evaluation.

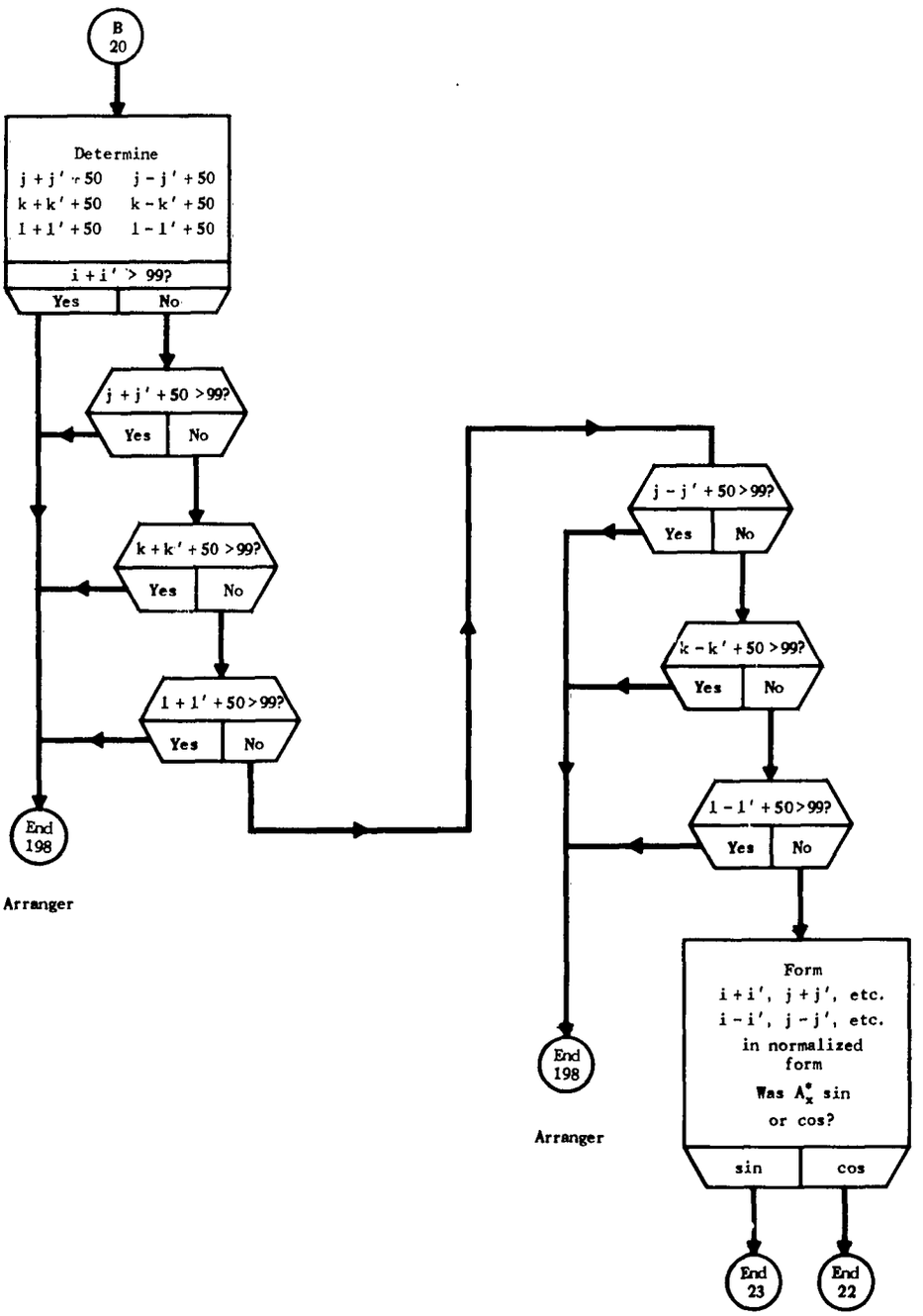
Flow Chart for Multiplication



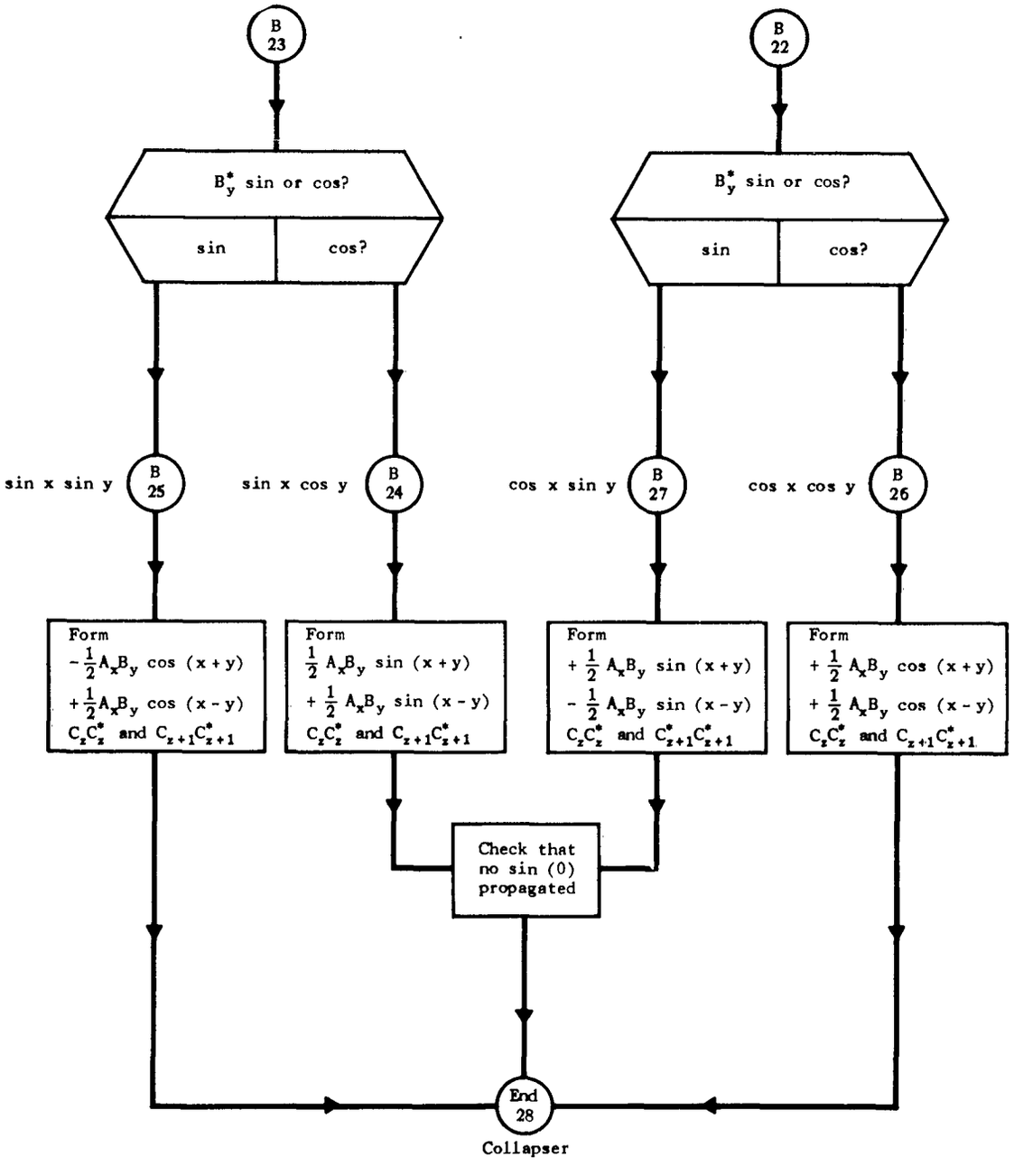
Flow Chart for Multiplication (Continued)



Flow Chart for Multiplication (Continued)

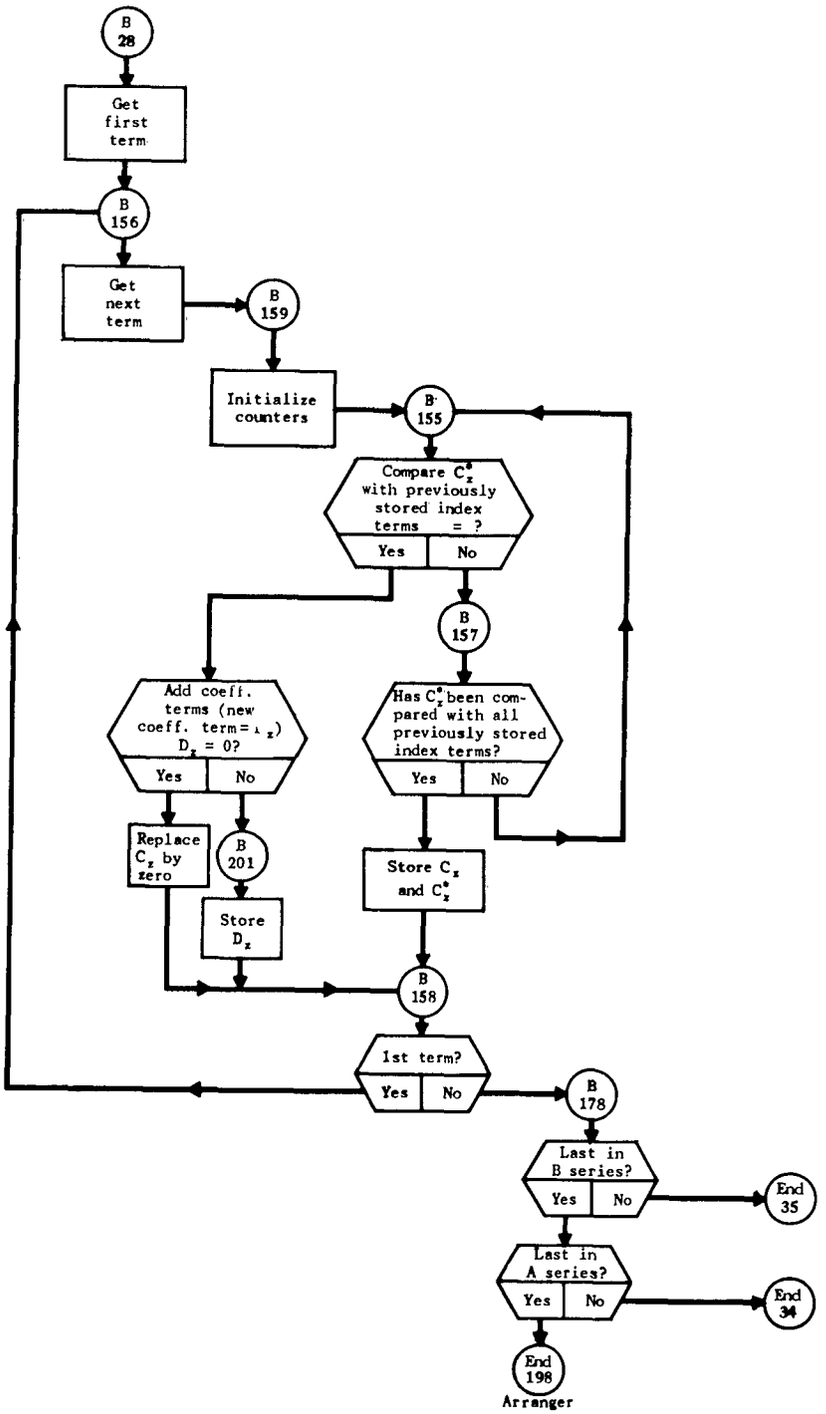


Flow Chart for Multiplication (Continued)



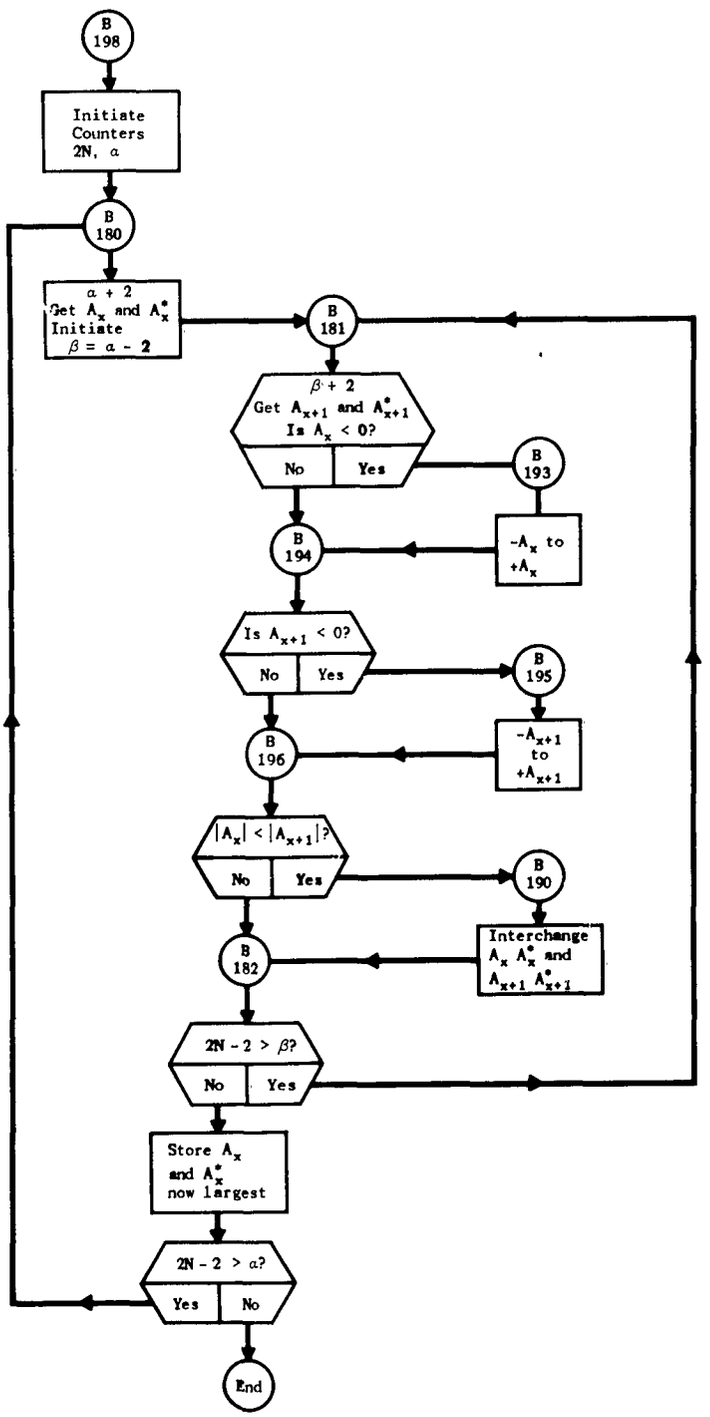
Flow Chart for Multiplication (Continued)

Collapser

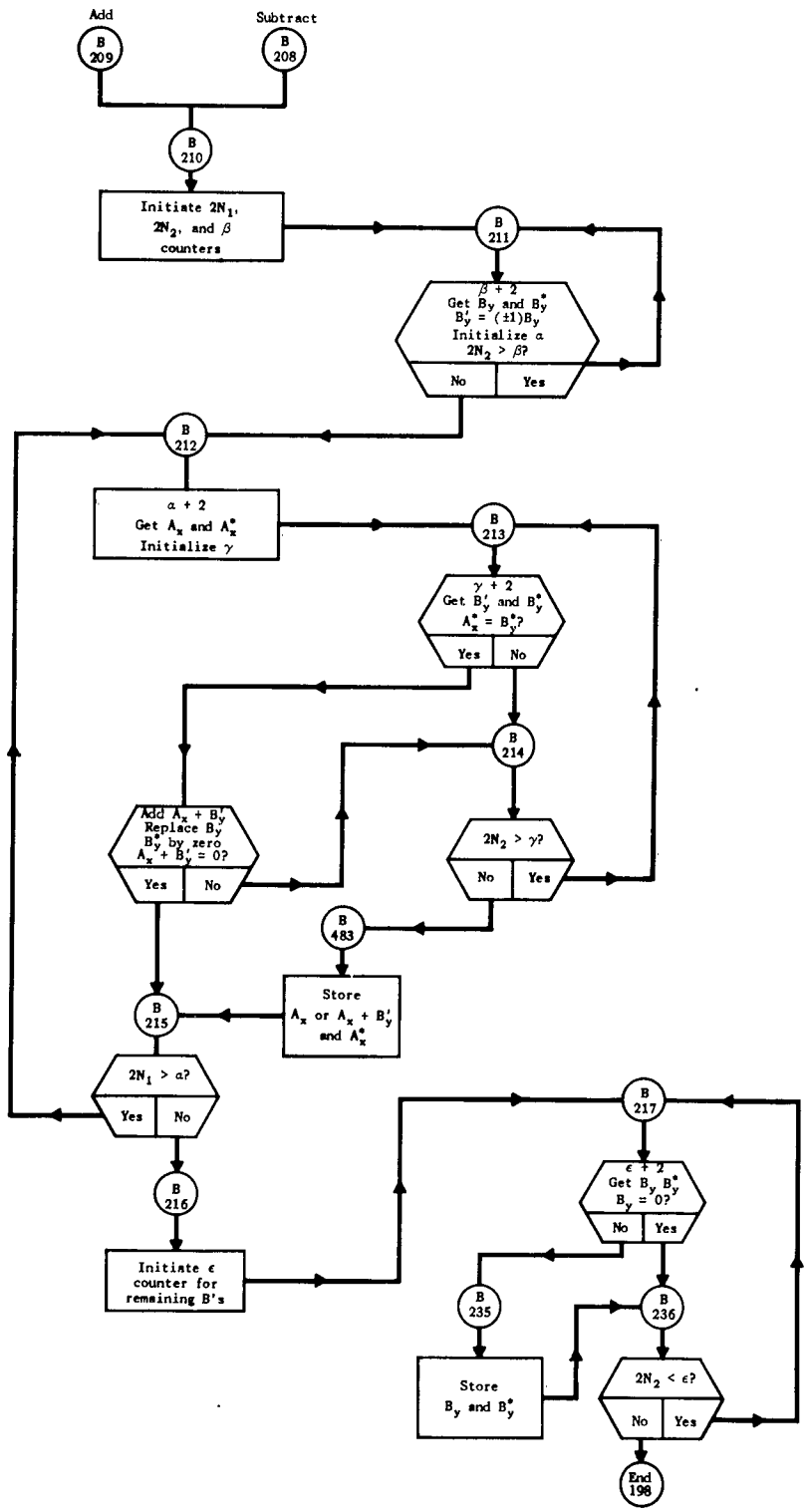


Flow Chart for Multiplication (Continued)

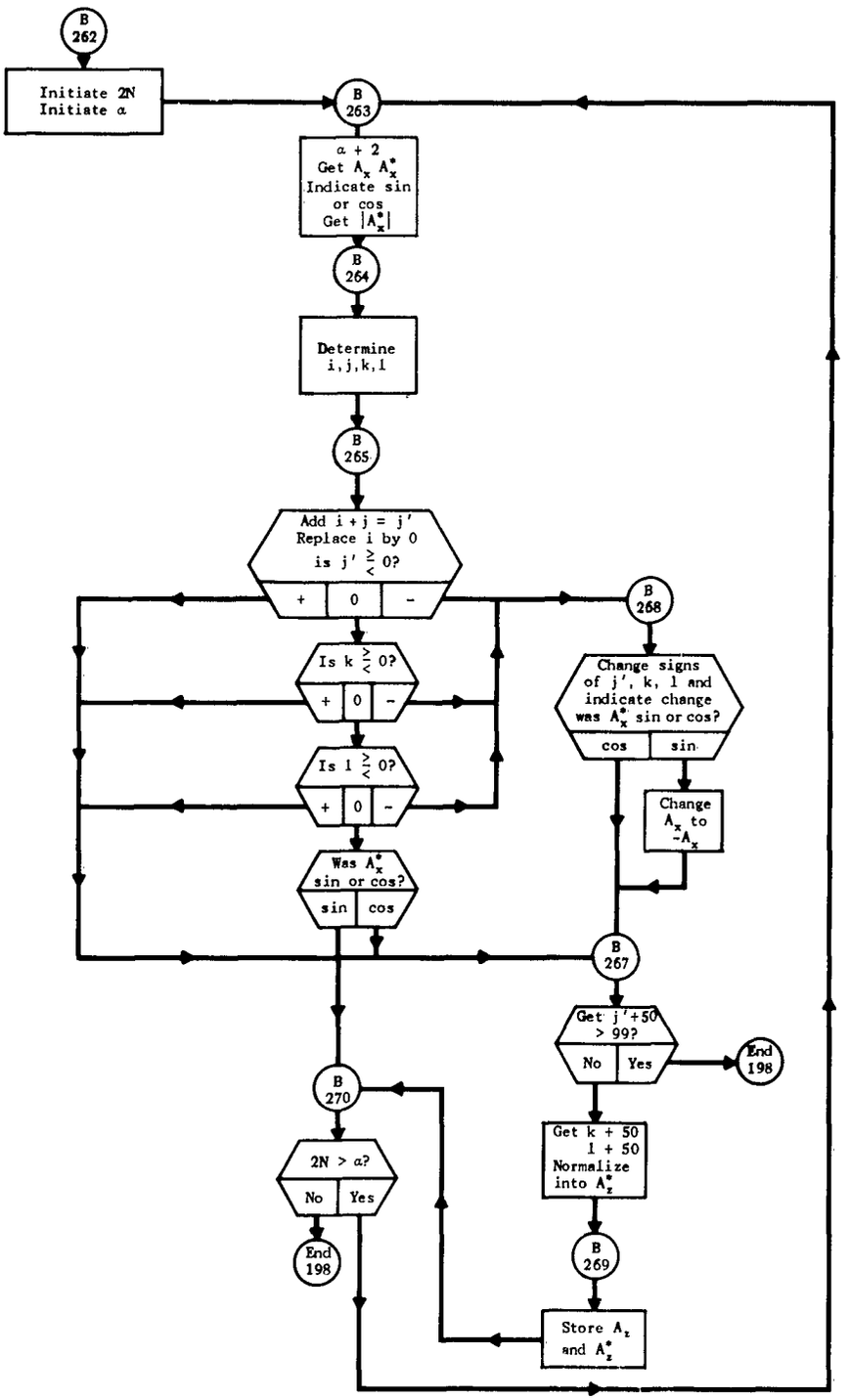
Arranger



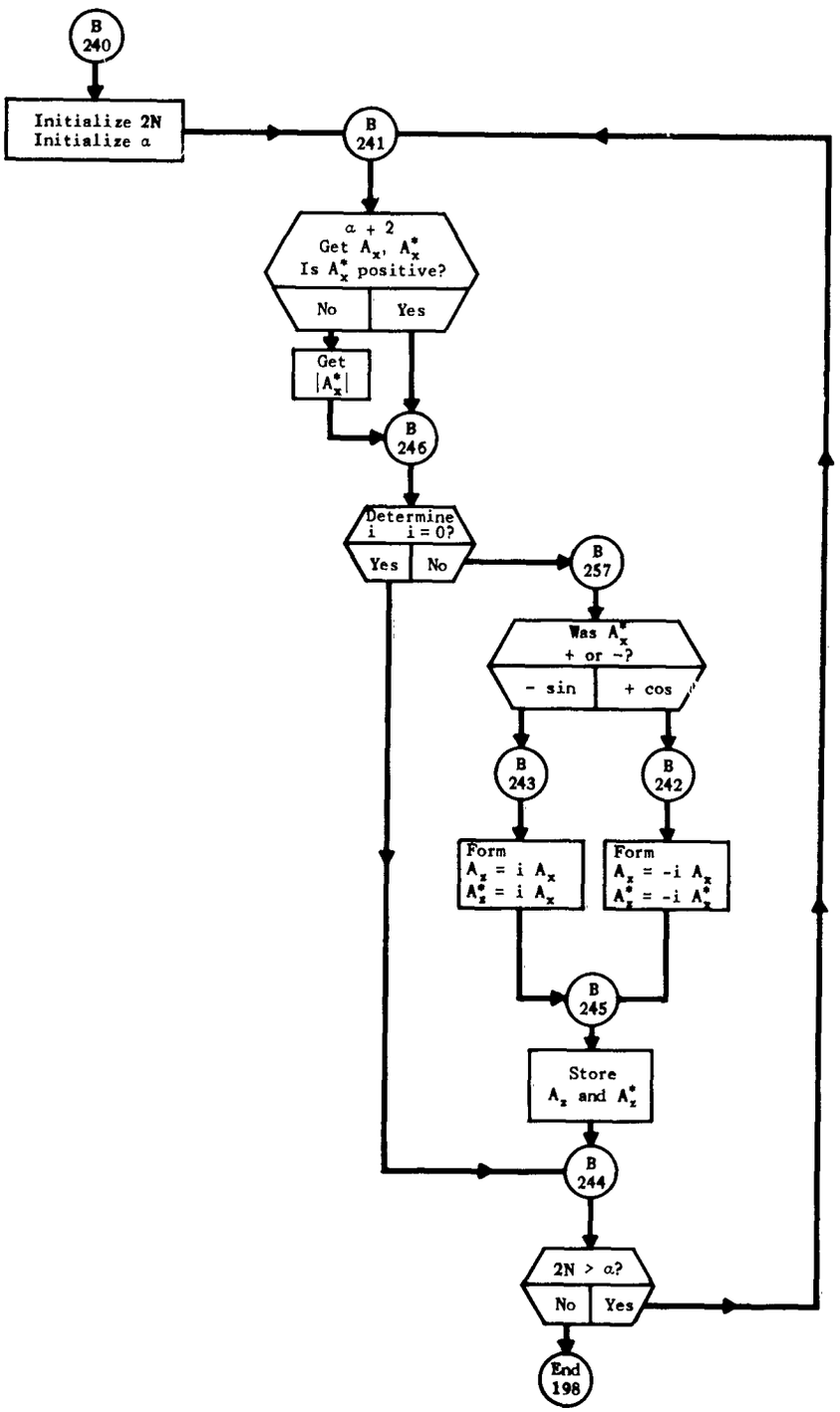
Flow Chart for Addition or Subtraction



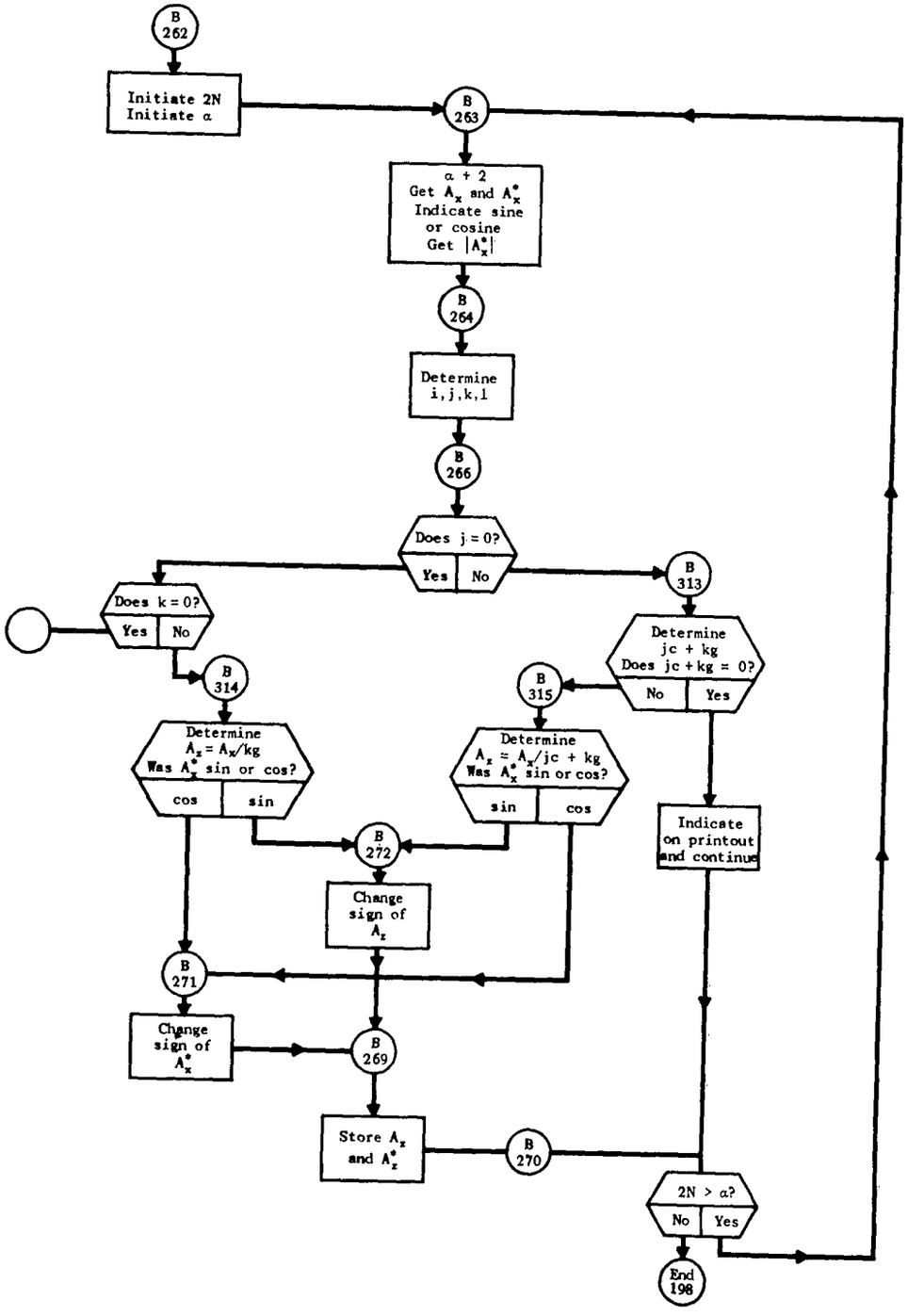
Flow Chart for Bar Operation



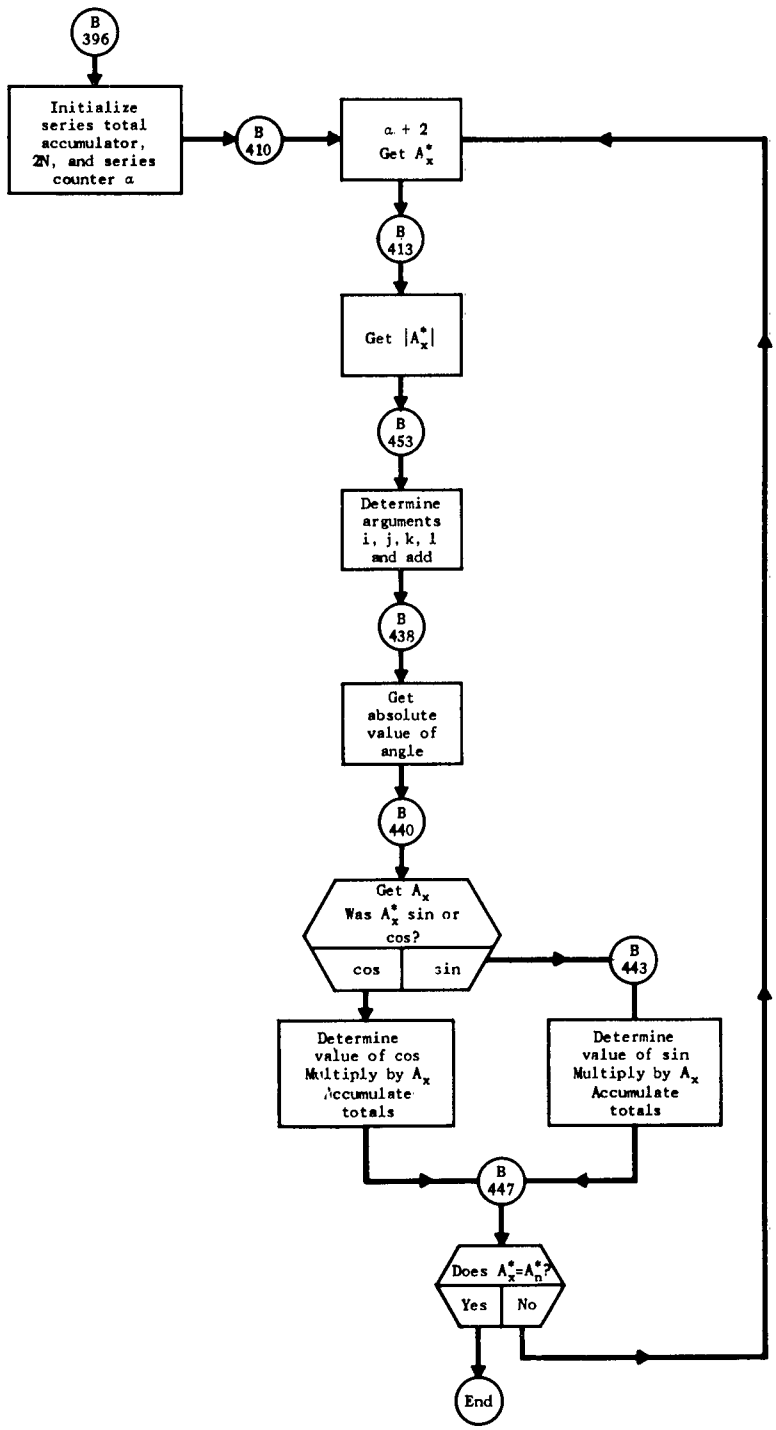
Flow Chart for Differentiation



Flow Chart for Integration



Flow Chart for Series Evaluation



Appendix C

Listing of Instructions

The following is a listing of instructions for multiplication (including the collapser and the arranger), addition or subtraction, differentiation, integration, bar operation, scalar multiplication, and coefficient extraction.

The square root instructions are for standard number representations and therefore have not been discussed in the report.

K= 00000

```
      HANSEN SATELLITE THEORY MLC
           ADAPTER PACKAGE
 @ 21750                                  ORIGIN CARD
 K 00000
 K 00050
*B 00001                                  SQUARE ROOT FUNCTION
 V 00005 +00000000+00
 V 00007  10000000 01
 V 00010  20000000-07
 G 00003 00001 00003
 C 00003 00005 00006
 H 00001 00004 00005
 E 00002
*B 00006
 A 00008 00007 00007
 R 00009 00007
 S 00011 00007 00010
 C 00007 00003 00012
 R 00009 00003
*B 00012
 D 00013 00003 00009
 A 00014 00009 00013
 D 00015 00014 00008
 D 00016 00015 00009
 R 00009 00015
 C 00011 00016 00012
 H 00001 00004 00009
 E 00002
 K 00000
 K 00070
*B 00001                                  SIN COSINE FUNCTION
 V 00009  17000000-04
 V 00010  10000000 01
 V 00011  67108864 08
 V 00012  15707963 01
 V 00013 -64596371 00
 V 00014  79689679-01
 V 00015 -46737660-02
 V 00016  15148400-03
 V 00018 +00000000+00
 V 00019 +62831853+01
 G 00003 00001 00003
```

```
 R 00020 00010                                                  043
 C 00003 00018 00021                                            044
 S 00020 00018 00020                                            045
 S 00003 00018 00003                                            046
*R 00021                                                        047
 D 00022 00003 00019                                            048
 A 00022 00022 00011                                            049
 S 00022 00022 00011                                            050
 M 00022 00022 00019                                            051
 S 00003 00003 00022                                            052
 M 00003 00003 00020                                            053
 S 00020 00018 00012                                            054
 R 00023 00010                                                  055
*B 00024                                                        056
 I 00025 +31415926+01                                           057
 C 00003 00012 00026                                            058
 S 00025 00018 00025                                            059
 C 00020 00003 00026                                            060
 D 00003 00003 00012                                            061
 M 00027 00003 00003                                            062
 M 00028 00016 00027                                            063
 A 00028 00028 00015                                            064
 M 00028 00028 00027                                            065
 A 00028 00028 00014                                            066
 M 00028 00028 00027                                            067
 A 00028 00028 00013                                            068
 M 00028 00028 00027                                            069
 A 00028 00028 00012                                            070
 M 00028 00028 00023                                            071
 M 00003 00028 00003                                            072
 H 00001 00004 00003                                            073
 F 00002                                                        074
*R 00026                                                        075
 S 00003 00003 00025                                            076
 S 00023 00018 00023                                            077
 F 00024                                                        078
*R 00005                                                        079
 G 00003 00005 00007                                            080
 S 00017 00012 00003                                            081
 F 00017 00001 00017                                            082
 H 00005 00008 00017                                            083
 F 00006                                                        084
```

K= 00070

```
 K 00000                                                                085
 K 00100                                                                086
*B 00001                        F0URIER SERIES M0VE                     087
 G 00005 00001 00003                                                    088
 A 00006 00005 00005                                                    089
 A 00006 00006 00003                                                    090
 H 00001 00004 00005                                                    091
*B 00007                                                                092
 A 00003 00003 00008                                                    093
 A 00004 00004 00008                                                    094
 G 00005 00001 00003                                                    095
 H 00001 00004 00005                                                    096
 C 00006 00003 00007                                                    097
 F 00002                                                                098
 V 00008 +10000000+01                                                   099
 K 00010                                                                100
*B 00001                        F0URIER ADDITI0N (11)                   101
 R 00080 00299                                                          102
 R 00072 00002                                                          103
 S 00073 00003 00005                                                    104
 S 00074 00004 00005                                                    105
 E 00071                                                                106
 V 00005 +70000000+02                                                   107
 K 00005                                                                108
*B 00001                        F0URIER SUBTRACTI0N (16)                109
 R 00075 00293                                                          110
 R 00067 00002                                                          111
 S 00068 00003 00005                                                    112
 S 00069 00004 00005                                                    113
 F 00066                                                                114
 V 00005 +65000000+02                                                   115
 K 00005                                                                116
*B 00001                        F0URIER MULTIPLICATI0N (21)             117
 R 00070 00111                                                          118
 R 00062 00002                                                          119
 S 00063 00003 00005                                                    120
 S 00064 00004 00005                                                    121
 F 00061                                                                122
 V 00005 +60000000+02                                                   123
 K 00005                                                                124
*B 00001                        F0URIER K-MULTIPLICATI0N (26)           125
 R 00057 0000                                                           126
```

K= 00125

```
 G 00414 00001 00003                                                    127
 S 00059 00004 00005                                                    128
 C 00414 00067 00405 00405                                              129
 H 00001 00004 00066                                                    130
 H 00002 00004 00067                                                    131
 H 00003 00004 00069                                                    132
 F 00002                                                                133
 V 00005 +55000000+02                                                   134
 K 00005                                                                135
*B 00001                          FOURIER TERM FXTRACTION (31)          136
 R 00052 00002                                                          137
 G 00419 00001 00003                                                    138
 S 00054 00004 00005                                                    139
 F 00415                                                                140
 V 00005 +50000000+02                                                   141
 K 00005                                                                142
*B 00001                          FOURIER DIFFERENTIATION (36)          143
 R 00055 00305                                                          144
 R 00047 00002                                                          145
 S 00048 00003 00005                                                    146
 S 00049 00004 00005                                                    147
 F 00046                                                                148
 V 00005 +45000000+02                                                   149
 K 00005                                                                150
*B 00001                          FOURIER INTEGRATION (41)              151
 R 00042 00002                                                          152
 R 00050 00321                                                          153
 S 00043 00003 00005                                                    154
 S 00044 00004 00005                                                    155
 F 00041                                                                156
 V 00005 +40000000+02                                                   157
 K 00005                                                                158
*B 00001                          FOURIER ARGUMENT REPLACEMENT (46)     159
 R 00037 00002                                                          160
 S 00038 00003 00005                                                    161
 S 00039 00004 00005                                                    162
 R 00045 00315                                                          163
 F 00036                                                                164
 V 00005 +35000000+02                                                   165
 K 00035                                                                166
*B 00001                          FOURIER PKG ADAPTER                   167
 A 00013 00015 00015                                                    168
```

K= 00180

```
 G 00005 00001 00003                                                169
 R 00720 00005                    PATS ADAPTER                      170
 A 00005 00005 00005                                                171
 A 00005 00005 00003                                                172
 R 00006 00012                                                      173
*B 00007                                                            174
 A 00006 00006 00011                                                175
 C 00006 00013 00016                                                176
 A 00003 00003 00011                                                177
 G 00008 00001 00003                                                178
 H 00720 00006 00008                PATS ADAPTER                    179
 C 00005 00003 00007                                                180
 A 00006 00013 00013                                                181
 I 00008 -10000000+01                                               182
*B 00018                                                            183
 A 00008 00008 00011                                                184
 H 00920 00008 00012                PATS ADAPTER                    185
 C 00006 00008 00018                                                186
 F 00010                                                            187
*B 00519                                                            188
 A 00005 00004 00920                                                189
 A 00005 00005 00920                                                190
 R 00006 00012                                                      191
 H 00001 00004 00920                                                192
 C 00920 00012 00009 00009          PATS ADAPTER                    193
 H 00001 00004 00011                                                194
 H 00002 00004 00012                                                195
 H 00003 00004 00014                                                196
 E 00002                                                            197
*B 00009                                                            198
 A 00004 00004 00011                                                199
 A 00006 00006 00011                                                200
 C 00006 00013 00017                                                201
 G 00008 00920 00006                PATS ADAPTER                    202
 H 00001 00004 00008                                                203
 C 00005 00004 00009                                                204
 F 00002                                                            205
 V 00011 +10000000+01                                               206
 V 00012 +00000000+00                                               207
 V 00014 +00505050+08                                               208
 V 00015 +98000000+02                                               209
*B 00016                                                            210
```

```
 R 00920 00015                    PATS ADAPTER                          211
 F 00010                                                                212
*B 00017                                                                213
 S 00004 00004 00006                                                    214
 H 00001 00004 00015                                                    215
 F 00002                                                                216
 K 00020                                                                217
 V 00006 +00000000+00                                                   218
 V 00007 +10000000+01                                                   219
 V 00008 -10000000+01                                                   220
 V 00009 +20000000+01                                                   221
 V 00010 -20000000+01                                                   222
 V 00011 +50000000+00                                                   223
 V 00012 +67108864+08                                                   224
 V 00013 +10000000+07                                                   225
 V 00014 +10000000+05                                                   226
 V 00015 +10000000+03                                                   227
 V 00016 +10000000-07                                                   228
 V 00016 +10000000-10          CRITERION FOR DROPPING TERMS              229
 V 00016 +10000000-12                                                   230
 V 00017 +50000000+02                                                   231
 V 00018 +40000000+01                                                   232
 V 00019 +19200000+03           (19.=     192                           233
*B 00031                                                                234
 I 00030 -20000000+01                                                   235
 A 00030 00030 00009                                                    236
 G 00049 00500 00030           N*1= NO OF TERMS IN A SERIES              237
 G 00050 00700 00030           N SUB 2                                  238
 G 00051 00501 00030           A*1                                      239
 G 00052 00701 00030           B SUB 1                                  240
 M 00053 00051 00052                                                    241
 M 00054 00053 00016                                                    242
 R 00054 00016                                                          243
 C 00006 00054 00032 00033                                              244
 F 00033                                                                245
*B 00032                                                                246
 S 00055 00006 00054                                                    247
*B 00033                                                                248
 R 00055 00054                                                          249
 I 00056 -20000000+01                                                   250
*B 00034                                                                251
 A 00056 00056 00009                                                    252
```

K= 00200

```
 I 00057 -20000000+01                                                  253
*B 00035                                                               254
 A 00057 00057 00009                                                   255
 G 00058 00501 00056                A*X                                256
 G 00059 00701 00057                B                                  257
 M 00060 00058 00059                                                   258
 C 00006 00060 00036 00037                                             259
*B 00036                                                               260
 S 00061 00006 00060                                                   261
 F 00038                                                               262
*B 00037                                                               263
 R 00061 00060                                                         264
*B 00038                                                               265
 C 00055 00061 00029 00039                                             266
*B 00029                                                               267
 C 00057 00006 00040 00198                                             268
 F 00198                                                               269
*B 00040                                                               270
 M 00047 00049 00009                                                   271
 S 00047 00047 00009                                                   272
 C 00047 00056 00034                                                   273
 F 00198                                                               274
 V 00140 +00000000+00                                                  275
 V 00141 -40000000+01                                                  276
*B 00039                                                               277
 A 00140 00140 00009                                                   278
 A 00141 00141 00018                                                   279
 G 00062 00502 00056                A*                                 280
 C 00062 00006 00041 00042                                             281
*B 00041                                                               282
 R 00063 00007                                                         283
 R 00064 00062                                                         284
 F 00043                                                               285
*B 00042                                                               286
 R 00063 00008                                                         287
 S 00064 00006 00062                                                   288
*B 00043                                                               289
 D 00065 00064 00013                                                   290
 A 00066 00065 00012                                                   291
 S 00067 00066 00012                                                   292
 M 00068 00067 00013                                                   293
 S 00069 00064 00068                                                   294
```

K= 00200

```
 D 00070 00069 00014                                                    295
 A 00071 00070 00012                                                    296
 S 00072 00071 00012                                                    297
 M 00073 00072 00014                                                    298
 S 00074 00069 00073                                                    299
 D 00075 00074 00015                                                    300
 A 00076 00075 00012                                                    301
 S 00077 00076 00012                                                    302
 M 00078 00077 00015                                                    303
 S 00079 00074 00078                                                    304
 A 00080 00079 00012                                                    305
 S 00081 00080 00012                                                    306
 G 00082 00702 00057                    B*                              307
 C 00082 00006 00044 00045                                              308
*B 00044                                                                309
 R 00083 00007                                                          310
 R 00084 00082                                                          311
 F 00046                                                                312
*B 00045                                                                313
 R 00083 00008                                                          314
 S 00084 00006 00082                                                    315
*B 00046                                                                316
 D 00085 00084 00013                                                    317
 A 00086 00085 00012                                                    318
 S 00087 00086 00012                                                    319
 M 00088 00087 00013                                                    320
 S 00089 00084 00088                                                    321
 D 00090 00089 00014                                                    322
 A 00091 00090 00012                                                    323
 S 00092 00091 00012                                                    324
 M 00093 00092 00014                                                    325
 S 00094 00089 00093                                                    326
 D 00095 00094 00015                                                    327
 A 00096 00095 00012                                                    328
 S 00097 00096 00012                                                    329
 M 00098 00097 00015                                                    330
 S 00099 00094 00098                                                    331
 A 00100 00099 00012                                                    332
 S 00101 00100 00012                                                    333
 S 00102 00072 00017                                                    334
 S 00103 00077 00017                                                    335
 S 00104 00061 00017                                                    336
```

K= 00200

```
 S 00105 00092 00017                                                337
 S 00106 00097 00017                                                338
 S 00107 00101 00017                                                339
 A 00108 00102 00105                                                340
 A 00109 00103 00106                                                341
 A 00110 00104 00107                                                342
 S 00111 00102 00105                                                343
 S 00112 00103 00106                                                344
 S 00113 00104 00107                                                345
 A 00114 00067 00087                                                346
 R 00160 00007                                                      347
 R 00200 00007                                                      348
 C 00114 00006 00154 00154                                          349
 C 00108 00006 00154 00153                                          350
 C 00109 00006 00154 00153                                          351
 C 00110 00006 00154 00153                                          352
 R 00200 00006                                                      353
 F 00154                                                            354
*B 00153                                                            355
 S 00108 00006 00108                                                356
 S 00109 00006 00109                                                357
 S 00110 00006 00110                                                358
 R 00160 00008                                                      359
*B 00154                                                            360
 S 00115 00067 00087                                                361
 R 00116 00007                                                      362
 R 00372 00007                                                      363
 C 00115 00006 00020 00021                                          364
 C 00111 00006 00020 00021                                          365
 C 00112 00006 00020 00021                                          366
 C 00113 00006 00020 00021                                          367
 R 00372 00006                                                      368
 F 00020                                                            369
*B 00021                                                            370
 S 00111 00006 00111                                                371
 S 00112 00006 00112                                                372
 S 00113 00006 00113                                                373
 S 00115 00006 00115                                                374
 R 00116 00008                                                      375
*B 00020                                                            376
 A 00117 00108 00017                                                377
 A 00118 00109 00017                                                378
```

K= 00200

```
A 00119 00110 00017                                                    379
A 00120 00111 00017                                                    380
A 00121 00112 00017                                                    381
A 00122 00113 00017                                                    382
V 00495 +99000000+02
C 00114 00495 00198          I+I GREATER THAN 99 END
C 00117 00495 00198          J+J+50 GREATER THAN 99 END
C 00118 00495 00198          K+K+50 GREATER THAN 99 END
C 00119 00495 00198          L+L+50 GREATER THAN 99 END
C 00120 00495 00198          J-J+50 GREATER THAN 99 END
C 00121 00495 00198          K-K+50 GREATER THAN 99 END
C 00122 00495 00198          L-L+50 GREATER THAN 99 END
C 00007 00117 00198          J+J+50 LESS THAN 1 END
C 00007 00118 00198          K+K+50 LESS THAN 1 END
C 00007 00119 00198          L+L+50 LESS THAN 1 END
C 00007 00120 00198          J-J+50 LESS THAN 1 END
C 00007 00121 00198          K-K+50 LESS THAN 1 END
C 00007 00122 00198          L-L+50 LESS THAN 1 END
M 00123 00114 00013                                                    383
M 00124 00117 00014                                                    384
M 00125 00118 00015                                                    385
A 00126 00125 00119                                                    386
A 00127 00126 00124                                                    387
A 00128 00127 00123                                                    388
M 00129 00115 00013                                                    389
M 00130 00120 00014                                                    390
M 00131 00121 00015                                                    391
A 00132 00131 00122                                                    392
A 00133 00132 00130                                                    393
A 00134 00133 00129                                                    394
C 00063 00006 00022 00023                                              395
F 00198                                                                396
*B 00023                                                               397
C 00083 00006 00024 00025                                              398
F 00198                                                                399
*B 00025                                                               400
R 00135 00060                                                          401
M 00136 00135 00011                                                    402
R 00137 00128                                                          403
R 00138 00136                                                          404
R 00139 00134                                                          405
S 00136 00006 00136                                                    406
```

K= 00200


```
 F 00028                                                          407
*B 00024                                                          408
 R 00135 00060                                                    409
 M 00136 00135 00011                                              410
 S 00137 00006 00128                                              411
 R 00138 00136                                                    412
 S 00139 00006 00134                                              413
 M 00138 00138 00116                                              414
 M 00136 00136 00160                                              415
 M 00136 00136 00200                                              416
 M 00138 00138 00372                                              417
 F 00028                                                          418
*B 00022                                                          419
 C 00083 00006 00026 00027                                        420
 F 00198                                                          421
*B 00026                                                          422
 R 00135 00060                                                    423
 M 00136 00135 00011                                              424
 R 00137 00128                                                    425
 R 00138 00136                                                    426
 R 00139 00134                                                    427
 F 00028                                                          428
*B 00027                                                          429
 R 00135 00060                                                    430
 M 00136 00135 00011                                              431
 S 00137 00006 00128                                              432
 S 00138 00006 00136                                              433
 S 00139 00006 00134                                              434
 M 00138 00138 00116                                              435
 M 00136 00136 00160                                              436
 M 00136 00136 00200                                              437
 M 00138 00138 00372                                              438
*B 00028                                                          439
 R 00161 00136                                                    440
 R 00162 00137                                                    441
 F 00159                                                          442
*B 00156                                                          443
 R 00161 00138                                                    444
 R 00162 00139                                                    445
*B 00159                                                          446
 I 00164 +00000000+00                                             447
 I 00165 -10000000+01                                             448
```

```
 C 00161 00006 00155 00155                                          449
 F 00158                                                            450
*B 00155                                                            451
 A 00164 00164 00009                                                452
 G 00166 00900 00164            STORED A*                           453
 A 00165 00165 00007                                                454
 C 00162 00166 00157 00157                                          455
 G 00167 00899 00164            STORED A                            456
 A 00168 00167 00161                                                457
 C 00168 00006 00201 00201                                          458
 H 00899 00164 00006            REPLACE STORED A BY ZERO            459
 F 00158                                                            460
*B 00201                                                            461
 H 00899 00164 00168            STORE (AX+AS)                       462
 E 00158                                                            463
*B 00157                                                            464
 C 00900 00165 00155                                                465
 A 00900 00900 00007            UPDATE N                            466
 H 00899 00164 00161            STORE AX                            467
 H 00900 00164 00162            STORE A*X                           468
 V 00360 +19600000+03                                               469
 C 00900 00360 00198                                                470
*B 00158                                                            471
 R 00177 00156                                                      472
 R 00156 00178                                                      473
 R 00178 00177                                                      474
 F 00177                                                            475
*B 00178                                                            476
 M 00151 00050 00009                                                477
 S 00151 00151 00009                                                478
 C 00151 00057 00035                                                479
 M 00152 00049 00009                                                480
 S 00152 00152 00009                                                481
 C 00152 00056 00034                                                482
*B 00198                                                            483
 M 00179 00900 00009                                                484
 I 00197 +00000000+00                                               485
 S 00197 00179 00009                                                486
 I 00183 +00000000+00                                               487
*B 00180                                                            488
 A 00183 00183 00009                                                489
 S 00184 00183 00009                                                490
```

K= 00200

```
 G 00185 00899 00183                                                    491
 G 00186 00900 00183                                                    492
*B 00181                                                                493
 A 00184 00184 00009                                                    494
 G 00187 00901 00184                                                    495
 G 00188 00902 00184                                                    496
 C 00006 00185 00193                                                    497
 R 00191 00185                                                          498
*B 00194                                                                499
 C 00006 00187 00195                                                    500
 R 00192 00187                                                          501
*B 00196                                                                502
 C 00191 00192 00182 00190                                              503
 E 00182                                                                504
*B 00190                                                                505
 H 00901 00184 00185              INTERCHANGE A1+AX                     506
 H 00902 00184 00186              INTERCHANGE A*1+A*X                   507
 R 00185 00187                                                          508
 R 00186 00188                                                          509
*B 00182                                                                510
 C 00197 00184 00181                                                    511
 H 00899 00183 00185              STORE LARGEST A                       512
 H 00900 00183 00186              STORE LARGEST A*                      513
 C 00183 00019 00499                                                    514
 C 00197 00183 00180 00499        2N-2 GREATER THAN 183 -180            515
 F 00499                                                                516
 R 00900 00017                                                          517
 R 00361 00008                    (361)=-1 IND. OVERFLOW                518
 F 00499                                                                519
*B 00193                                                                520
 S 00191 00006 00185                                                    521
 F 00194                                                                522
*B 00195                                                                523
 S 00192 00006 00187                                                    524
 E 00196                                                                525
          FOURIER ADD + SUBTRACT                                        526
*B 00209                                                                527
 I 00207 +10000000+01                                                   528
 F 00210                                                                529
*B 00208                                                                530
 I 00207 -10000000+01                                                   531
*B 00210                                                                532
```

K= 00200

```
 M 00218 00500 00009              2N*1                                  533
 M 00219 00700 00009              2N SUB 2                              534
 I 00900 +00000000+00             N SUB 3 COUNTER                       535
 I 00223 +00000000+00             BTRNST COUNTER                        536
 I 00221 +00000000+00             STORAGE COUNTER                       537
*B 00211                                                                538
 A 00223 00223 00009                                                    539
 G 00224 00699 00223              B                                     540
 G 00225 00700 00223              B*                                    541
 M 00224 00224 00207              +B FOR ADD                            542
 H 00699 00223 00224              STORE B                               543
 H 00700 00223 00225              STORE B*                              544
 C 00219 00223 00211                                                    545
 I 00220 +00000000+00             (220)= A COUNTER                      546
*B 00212                                                                547
 A 00220 00220 00009                                                    548
 G 00226 00499 00220              A                                     549
 G 00227 00500 00220              A**                                   550
 I 00222 +00000000+00             B COUNTER = 0 ORIGINALY               551
*B 00213                                                                552
 A 00222 00222 00009              UPDATE B COUNTER BY 2                 553
 G 00228 00699 00222                    BX                              554
 G 00229 00700 00222              B*                                    555
 C 00227 00229 00214 00214        A*=B* GO TO 214                       556
 A 00226 00226 00228                                                    557
 H 00699 00222 00006                                                    558
 H 00700 00222 00006                                                    559
 C 00226 00006 00214 00214                                              560
 F 00215                                                                561
*B 00214                                                                562
 C 00219 00222 00213              2N                                    563
 C 00226 00006 00483 00483                                              564
 F 00215                                                                565
*B 00483                                                                566
 A 00221 00221 00009              UPDATE STOR. CTR. BY 2                567
 A 00900 00900 00007                                                    568
 H 00899 00221 00226              STORE A                               569
 H 00900 00221 00227              STORF A*                              570
*B 00215                                                                571
 C 00218 00220 00212              2N*1 GET A*X+1                        572
*B 00216                                                                573
 I 00230 +00000000+00             (230)= COUNTER FOR B SERIES STILL ST02 574
```

K= 00200

```
*R 00217                                                          575
 A 00230 00230 00009              (230)+2                         576
 G 00231 00699 00230              B                               577
 G 00232 00700 00230              B*                              578
 C 00231 00006 00235 00235        B=0 G0 T0 35                    579
 F 00236                                                          580
*B 00235                                                          581
 A 00221 00221 00009              UPDATE TFR + ST. CTN.           582
 A 00900 00900 00007              UPDATE N SUB 3 C0UNTER          583
 H 00899 00221 00231              ST0RF B                         584
 H 00900 00221 00232              ST0RE B*                        585
*B 00236                                                          586
 C 00219 00230 00217              2N*2) 230 G0 T0 217             587
 E 00198                                                          588
          F0URIER  DIFFERENTIAL                                   589
*B 00240                                                          590
 I 00247 +00000000+00                                            591
 I 00248 +00000000+00                                            592
 I 00900 +00000000+00             N                               593
 M 00255 00700 00009              2N                              594
*B 00241                                                          595
 A 00247 00247 00009                                             596
 R 00256 00007                                                   597
 G 00249 00699 00247              A                               598
 G 00250 00700 00247              A*                              599
 C 00250 00006 00246                                             600
 S 00250 0000( 00250                                             601
 R 00256 00008                                                   602
*B 00246                                                          603
 D 00251 00250 00013                                             604
 A 00251 00251 00012                                             605
 S 00251 00251 00012                                             606
 C 00251 00006 00257                                             607
 F 00244                                                         608
*B 00257                                                          609
 C 00256 00006 00242 00243                                       610
*B 00243                                                          611
 M 00252 00249 00251                                             612
 R 00253 00250                                                   613
 F 00245                                                         614
*R 00242                                                          615
 M 00252 00249 00251              -IA                             616
```

```
 M 00252 00252 00008                                                    617
 M 00253 00250 00008                                                    618
*B 00245                                                                619
 A 00248 00248 00009              B+2                                   620
 A 00900 00900 00007              UPDATE N COUNTER                      621
 H 00899 00248 00252              ST0RE A                               622
 H 00900 00248 00253              ST0RE A*                              623
*B 00244                                                                624
 C 00255 00247 00241                                                    625
 E 00198                                                                626
          F0URIER BAR, INT. SCALAR MULTIPLY BY A C0NSTANT AND EXTRACT    627
*B 00260                                                                628
 R 00276 00007                    (276)=1 BAR 0PERATI0N                 629
 E 00262                                                                630
*B 00261                                                                631
 R 00276 00006                    (276)=0 INTEGRATE                     632
*B 00262                                                                633
 M 00277 00700 00009                 2N                                 634
 I 00900 +00000000+00                                                   635
 I 00278 +00000000+00             278 = SERIES C0UNTER                  636
 I 00279 +00000000+00             279 = ST0RAGE C0UNTER                 637
*B 00263                                                                638
 R 00258 00007                    (258) = SIN C0S IND                   639
 A 00278 00278 00009              UPDATE (278)                          640
 G 00280 00699 00278              A                                     641
 G 00281 00700 00278              A*                                    642
 C 00281 00006 00264              A* + G0 T0 264                        643
 S 00281 00006 00281              -A* T0 +A*                            644
 R 00258 00008                    (258)=-1 SIN INDICAT0R                645
*B 00264                                                                646
 D 00282 00283 00013              A*/10 6                               647
 A 00283 00282 00012                                                    648
 S 00283 00283 00012              +1I1                                  649
 M 00284 00283 00013              1XX1001001001                         650
 S 00285 00281 00284              XX1XX1XX1                             651
 D 00286 00285 00014              XX.XXXX                               652
 A 00287 00286 00012                                                    653
 S 00287 00287 00012               J + 0R - 50                          654
 M 00288 00287 00014                XX0000                              655
 S 00289 00285 00288                XXXX                                656
 D 00290 00289 00015                  XX.XX                             657
 A 00291 00290 00012                                                    658
```

K= 00200

```
 S 00291 00291 00012                + ⊙R -K +50                                    659
 M 00292 00291 00015                                                               660
 S 00293 00289 00292                                                               661
 A 00294 00293 00012                                                               662
 S 00294 00294 00012                + ⊙R -L +50                                    663
 S 00296 00287 00017               J                                              664
 S 00297 00291 00017               K                                              665
 S 00298 00294 00017               L                                              666
 C 00276 00006 00265               BAR 265, INT 266                               667
 F 00266                                                                          668
*B 00265                                                                          669
 A 00300 00283 00296               I+J=J*                                         670
 C 00300 00006 00267 00268         J=0                                            671
 C 00297 00006 00267 00268         K=0                                            672
 C 00298 00006 00267 00268         L=0                                            673
 M 00282 00282 00258               J=0,K=0,L=0, SIN ⊙R C⊙S                        674
 R 00312 00007                     (312)=+1 SIGN CHANGE INDICAT⊙R                 675
 C 00282 00006 00267 00270         C⊙S(0,0,0,0) 267, SIN(0,0,0,0) ⊙MIT TERM       676
*B 00268                                                                          677
 S 00300 00006 00300               J 1 (-1)                                       678
 S 00297 00006 00297               K (-1)                                         679
 S 00298 00006 00298               L (-1)                                         680
 R 00312 00008                     (312)=-1 SIGN CHANGE INDICAT⊙R                 681
 C 00258 00006 00267                                                              682
 M 00280 00280 00312               SIN TERM CHANGE T⊙ -A                          683
*B 00267                                                                          684
 A 00301 00300 00017               J 1+50                                         685
 C 00301 00495 00198               1+J+50 GREATER THAN 99 END
 A 00302 00297 00017               K+50                                           686
 A 00303 00298 00017               L+50                                           687
 M 00304 00302 00015               10 2K                                          688
 M 00305 00301 00014               10 4 J 1                                       689
 A 00306 00304 00303                                                              690
 A 00307 00306 00305               A* ARS, VALUF                                  691
 M 00307 00307 00258               (A* ⊙R -A* IF SIN ⊙R C⊙S                       692
*B 00269                                                                          693
 A 00900 00900 00007               UPDATE N C⊙UNTER                               694
 A 00279 00279 00009               UPDATE ST⊙RAGE C⊙UNTER                         695
 H 00899 00279 00280               A                                              696
 H 00900 00279 00307               A*                                             697
*B 00270                                                                          698
 C 00277 00278 00263               2N GREATER 278 L⊙⊙P GET N+1 (A)(A*)             699
```

K= 00200

```
 F 00198                                                                  700
 V 00321 +20000000+00                                                     701
 V 00322 +20000000+00                                                     702
*B 00266                          INTEGRATE                              703
 C 00296 00006 00313 00313        J=0 T0 313                             704
 C 00297 00006 00314 00314        J=0 IS K=0                             705
 R 00368 00008                    368=-1                                 706
 R 00369 00280                    A                                      707
 M 00370 00281 00258              1 A*                                   708
 E 00270                                                                  709
*B 00314                          J=0,K=0                                710
 M 00308 00297 00322              KG                                     711
 D 00309 00280 00308              A/KG                                   712
 C 00258 00006 00271 00272        SIN 0R C0S                             713
*B 00313                                                                 714
 M 00305 00296 00321              JC                                     715
 M 00306 00297 00322              KG                                     716
 A 00308 00306 00305              JC+KG                                  717
 C 00308 00006 00315 00315        JC+KG=0                                718
 E 00270                          IND. 0N PRINT 0UT BUT C0NTINUE         719
*B 00315                                                                 720
 D 00309 00280 00308              A/JC+KG                                721
 C 00258 00006 00271 00272        SIN OR C0S                             722
*B 00271                                                                 723
 R 00280 00309                    A/JC+KG OR A/KG                        724
 M 00307 00281 00008              -A*                                    725
 F 00269                                                                 726
*B 00272                                                                 727
 M 00280 00309 00008              -A/JC+KG 0R -A/KG                      728
 R 00307 00281                    A*                                     729
 E 00269                                                                 730
 V 00339 +20000000+00             (339)= C0NSTANT                        731
*B 00330                          C0NSTANT MULTIPLY                      732
 I 00331 +00000000+00             (331)= ST0RAGE C0UNTER                 733
 R 00900 00500                                                           734
 A 00333 00500 00500                                                     735
*B 00334                                                                 736
 A 00331 00331 00009              (331)+2                                737
 G 00335 00499 00331                                                     738
 G 00336 00500 00331                                                     739
 M 00337 00335 00339              CA                                     740
 H 00899 00331 00337              ST0RE A                                741
```

K= 00200


```
 H 00900 00331 00336              ST@RE A*                                742
 C 00333 00331 00334              2N GREATER THAN (631)                   743
 F 00499                                                                  744
*B 00345                                                                  745
 V 00349 +00505050+08             ARGUMENT @F TERM F@R EXTRACTI@N         746
 M 00350 00500 00009              2N                                      747
 I 00351 +00000000+00             (351)=0 INITIAL                         748
*B 00346                                                                  749
 A 00351 00351 00009              (351)+2                                 750
 G 00352 00500 00351                                                      751
 C 00352 00349 00347 00347        2N=(351)                                752
 G 00353 00499 00351                                                      753
 R 00901 00353                                                            754
 R 00902 00352                                                            755
 R 00900 00007                                                            756
 F 00499                                                                  757
*B 00347                                                                  758
 C 00350 00351 00346                 2N=(351)                             759
 R 00900 00006                                                            760
 F 00499                                                                  761
```

0777 CARDS

Appendix D

Mystic Code

The Fourier Operating Package described in this report was written for the IBM 709 in Mystic Code. The following is an explanation of the Mystic Code.

MYSTIC C0DE PAGE001

K= 00000

C 0DF	REMARKS 06/20/61
A X Y Z	ADD COMMAND (Y) + (Z) G0 INT0 L0CATI0N X. THAT IS, ADD (Y) T0 (Z) AND ST0RE THE RESULT IN X.
*B X	BEGIN P0INT PSEUD0 C0MMAND. THE SEQUENCE 0F INSTRUCTI0NS WHICH F0LL0W A BFGIN X IS ENTFRED FR0M AT LEAST TW0 PARTS 0F THE C0DING. ENTRANCE T0 A BEGIN INSTRUCTI0N CAN BE FR0M THE INSTRUCTI0N PRECEDING IT (I.E.,A SEQUENTIAL ENTRANCE), FR0M A C0MPARE C0MMAND 0R FR0M AN END C0MMAND. THIS INSTRUCTI0N MAY BE TH0UGHT 0F AS STATING THAT THE F0LL0WING INSTRUCTI0NS MAY BE ENTERED BY A TRANSFER T0 L0CATI0N X.
C X Y Z	C0MPARE (X) WITH (Y). IF (X) IS GREATER THAN (Y),G0 T0 L0CATI0N Z AND EXECUTE THE INSTRUCTI0NS WHICH F0LL0W THE B Z 0R N Z. IF (X) EQUALS 0R IS LESS THAN (Y), EXECUTE THE NEXT INSTRUCTI0N IN SEQUENCE.
C X Y Z Z*	C0MPARE (X) WITH (Y). IF (X) IS GREATER THAN (Y), G0 T0 L0CATI0N Z AND EXECUTE THE INSTRUCTI0NS WHICH F0LL0W THE B Z 0R N Z. IF (X) IS LESS THAN (Y),G0 T0 L0CATI0N Z* AND EXECUTE THE INSTRUCTI0NS WHICH F0LL0W THE B Z* 0R N Z*. IF (X) EQUALS (Y), EXECUTE THE NEXT INSTRUCTI0N IN SEQUENCE.
D X Y Z	DIVIDE C0MMAND. (Y)/(Z) G0 INT0 L0CATI0N X. THAT IS, DIVIDE (Y) BY (Z) AND ST0RE THE RESULT IN X.
E X	EXIT C0MMAND. UNC0NDITI0NAL TRANSFER T0 THE SET 0F INSTRUCTI0NS WHICH F0LL0W B X 0R N X.
F X Y Z	FUNCTI0N C0MMAND. THIS INSTRUCTI0N ENABLES 0NE T0 TRANSFER T0 A FUNCTI0N AND AFTER ITS EXECUTI0N, C0NTINUE T0 THE NEXT INSTRUCTI0N IN SEQUENCE F0LL0WING THE FUNCTI0N STATEMENT. Y IS THE L0CATI0N 0F THE FIRST BEGIN INSTRUCTI0N (B 1) IN A FUNCTI0N. N0RMALLY Z IS THE L0CATI0N 0F THE INPUT T0 THE

FUNCTION,WHILE X IS THE LOCATION OF THE OUTPUT. HOWEVER, THE REQUIREMENTS OF FUNCTIONS DIFFER FROM FUNCTION TO FUNCTION AND EACH ONE USED MUST HAVE ITS REQUIREMENTS MET BEFORE TRANSFERRING TO IT. (NOTE. FUNCTIONS ARE SOMETIMES REFERRED TO AS SUB-ROUTINES.)

G X Y Z — GET COMMAND. THE CONTENTS OF A LOCATION EQUAL TO (Z) + Y GO IN TO LOCATION X. THAT IS, REPLACE THE CONTENTS OF LOCATION X BY THE CONTENTS OF Y + (Z).

H X Y Z — HOLD COMMAND. THE CONTENTS OF LOCATION Z GO INTO A LOCATION = X + (Y) . THAT IS, REPLACE THE CONTENTS OF X + (Y) BY THE CONTENTS OF Z.

I X SY YYYYYYYSEE — INITIALIZE COMMAND. SET THE CONTENTS OF X = S.YYYYYYYY TIMES 10 EXP SEE. S= BLANK OR + MEANS POSITIVE VALUE, S= - MEANS NEGATIVE VALUE IN THE MANTISSA. S IN THE EXPONENT USES THE SAME SIGN NOTATION.

K X — KEY ADDRESS PSEUDO COMMAND. X=0 , SET THE K COUNTER TO ZERO. WHEN X DOES NOT EQUAL ZERO, THE KEY ADDRESS IS INCREASED BY X. THAT IS, THE K COUNTER + X GOES INTO THE K COUNTER. THE K COUNTER IS USED TO RELOCATE FUNCTIONS. THE K COUNTER IS ADDED TO THE ADDRESS OF EACH INSTRUCTION DURING COMPILATION, UNLESS THE ADDRESS IS IN THE LEFT HAND ADDRESS OF A Q COMMAND. THE K COMMAND CLEARS THE Q TABLE DURING COMPILATION.

L X Y Z F1 ,F2,. ...F18,T1,T2,...T18.
Z= CA ,LOAD F1 COLUMNS OF DATA INTO LOCATION X,THEN LOAD F2 COLUMNS OF DATA INTO LOCATION X+1, ETC. TO MAXIMUM OF 18 FIELDS OR 72 COLUMNS. T1,T2,..T18 DESCRIBE THE WAY THE DATA IS STORED IN X,X+1,ETC. THE TYPE OF DATA STORED IS NUMERIC OR ALPHABETIC. IF IT IS NUMERIC, THE CORRESPONDING TYPE CODE IS N. IF IT IS ALPHABETIC, THE CORRESPONDING TYPE CODE IS

K= 07000

A. TYPE 0F DATA C0DE ALS0 INCLUDES S F0R SKIP. WHEN THE SKIP TYPE IS USED, THIS D0ES N0T INV0LVE DATA ST0RED IN A W0RD. THUS, IF T1 IS TYPE S, T2 IS TYPE N, THE L C0MMAND READS THE DATA FR0M THE F2 C0LUMN INT0 W0RD X. THE C0LUMNS ARE READ STARTING FR0M THE LEFT ALWAYS. SKIP FIELDS T0 THE RIGHT 0F ALL 0THER DATA NEED N0T BE DEFINED IN THE L C0MMAND. THE FIRST BLANK FIELD MEANS THE REST 0F THE CARD IS SKIPPED. THE NUMBER 0F C0LUMNS 0F TYPE A MUST N0T EXCEED 4 PER FIELD. THE NUMBER 0F C0LUMNS 0F TYPE N MUST N0T EXCEED 9 PER FIELD INCLUDING THE SIGN. THE NUMBER 0F C0LUMNS 0F TYPE S MUST N0T EXCEED 15 PER FIELD. IF 1 CARD IS T0 BE L0ADED ACC0RDING T0 THE GIVEN F0RMAT, (Y) = 1. IF I CARDS ARE T0 BE L0ADED ACC0RDING T0 THE GIVEN F0RMAT, (Y)= I,THE NUMBER 0F CARDS. THE DATA F0R EACH CARD IS C0NSECUTIVELY ST0RED IN THE SAME WAY AS THAT F0R THE FIRST. THE DATA F0R THE FIRST W0RD 0F INPUT FR0M CARD J+1 F0LL0WS C0NSECUTIVELY THE LAST W0RD 0F INPUT FR0M CARD J. (Y) MUST BE AN INTEGER THAT IS AT LEAST 1.

Z= TA ,L0AD TAPE B1 BCD. SAME F0RMAT DESCRIPTI0N
Z= TB ,L0AD TAPE B2 BCD. AS AB0VE IN Z= CA,
Z= TC ,L0AD TAPE B3 BCD. REPLACING CARD BY BCD
Z= TD ,L0AD TAPE B4 BCD. REC0RD AND L0AD BY
Z= TE ,L0AD TAPE B5 BCD. THE APPR0PIATE READ
Z= TF ,L0AD TAPE B6 BCD. TAPE DESIGNATI0N.
Z= TG ,L0AD TAPE B7 BCD.
Z= TA ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TB ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TC ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TD ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TE ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TF ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TG ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.

IF I = 0, THE C0MMAND IS T0 BACKSPACE A FILE.
IF I = -N THE C0MMAND IS T0 BACKSPACE N REC0RDS.

L X Y Z Z= CAB, L0AD INT0 X,X+1,ETC. BINARY CARDS HAVING THE NUMBER 0F W0RDS SPECIFIED

K= 07000

IN THE CONTENTS OF Y.

Z= TAB, LOAD TAPE B1 BINARY. LOAD INTO X,X+1,ETC.
Z= TBB, LOAD TAPE B2 BINARY. A BINARY RECORD
Z= TCB, LOAD TAPE B3 BINARY. HAVING THE NUMBER
Z= TDB, LOAD TAPE B4 BINARY. OF WORDS SPECIFIED
Z= TEB, LOAD TAPE B5 BINARY. IN THE CONTENTS OF
Z= TFB, LOAD TAPE B6 BINARY. Y.
Z= TGB, LOAD TAPE B7 BINARY.

M X Y Z MULTIPLY COMMAND. (Y) TIMES (Z) GOES INTO X.
THAT IS, THE PRODUCT (Y)(Z) REPLACES THE
CONTENTS OF X.

N X NOTE COMMAND. NOTE THAT THE FOLLOWING COMMAND
SEQUENCE BEGINS WITH X. N X IS NORMALLY USED
TO BEGIN SEVERAL COMMAND SEQUENCES. THE N X
EXECUTED LATEST IS THE COMMAND SEQUENCE TO
BE FOLLOWED WHEN AN UNCONDITIONAL TRANSFER
OR A CONDITIONAL TRANSFER TO X IS MADE. THE N X
IS A VARIABLE CONNFCTOR.

O X ORIGIN COMMAND. THE COMPILATION WILL GENERATE
MACHINE LANGUAGE CODE FROM LOCATION X TO A
MAXIMUM OF 30,000.

P X Y Z F1 ,F2,. .. F18,T1,T2,...T18.
Z= CA ,PUNCH F1 COLUMNS OF DATA FROM LOCATION X,THEN
PUNCH F2 COLUMNS OF DATA FROM LOCATION X+1,
ETC. TO MAXIMUM OF 18 FIELDS OR 72 COLUMNS.
T1, T2,..T18 DESCRIBE THE WAY THE DATA IS
STORED IN X,X+1,ETC. THE TYPE OF DATA STORED
IS NUMERIC OR ALPHABETIC. IF IT IS NUMERIC,
THE CORRESPONDING TYPE CODE IS N. IF IT IS
ALPHABETIC, THE CORRESPONDIND TYPE CODE IS
A. TYPE OF DATA CODE ALSO INCLUDES S FOR
SKIP. WHEN THE SKIP TYPE IS USED, THIS
DOES NOT INVOLVE DATA STORED IN A WORD.
THUS, IF T1 IS TYPE S, T2 IS TYPE N, THE
P COMMAND GETS THE DATA FOR THE F2 COLUMNS
FROM WORD X. THE COLUMNS ARE BUILT UP STARTING
FROM THE LEFT ALWAYS. SKIP FILEDS TO THE RIGHT
OF ALL OTHER DATA NEED NOT BE DEFINED IN THE

K= 07000

P C0MMAND. THE FIRST BLANK FIELD MEANS THE REST
0F THE CARD IS SKIPPED. THE NUMBER 0F C0LUMNS
0F TYPE A MUST N0T EXCEED 4 PER FIELD. THE
NUMBER 0F C0LUMNS 0F TYPE N MUST EXCEED 9
PER FIELD INCLUDING THE SIGN. THE NUMBER 0F
C0LUMNS 0F TYPE S MUST N0T EXCEED 15 PER FIELD.
IF 1 CARD IS T0 BE PUNCHED ACC0RDING T0 THE
GIVEN F0RMAT, (Y) = 1. IF I CARDS ARE T0 BE
PUNCHED ACC0RDING T0 THE GIVEN F0RMAT,
(Y)= I,THE NUMBER 0F CARDS. THE DATA F0R EACH
CARD MUST BE C0NSECUTIVELY ST0RED IN THE SAME
WAY AS THAT F0R THE FIRST. THE DATA F0R THE
FIRST W0RD 0F 0UTPUT F0R CARD J+1 MUST F0LL0W
C0NSECUTIVELY THE LAST W0RD 0F 0UTPUT F0R
CARD J. (Y) MUST BE AN INTEGER THAT IS AT LEAST

Z= PA ,PRINT. INSERT PRINT F0R PUNCH IN THE DESCRIP-
TI0N AB0VE T0 INTERPRET AN INSTRUCTI0N T0 PRINT
0N THE 0N-LINE PRINTER. LINE REPLACES CARD IN
THE EXPLANATI0N AB0VE.

Z= TA ,WRITE TAPE B1 BCD. SAME F0RMAT DESCRIPTI0N
Z= TB ,WRITE TAPE B2 BCD. AS AB0VE IN Z= CA,
Z= TC ,WRITE TAPE B3 BCD. REPLACING CARD BY BCD
Z= TD ,WRITE TAPE B4 BCD. RECORD AND PUNCH BY
Z= TE ,WRITE TAPE B5 BCD. THE APPR0PIATE WRITE
Z= TF ,WRITE TAPE B6 BCD. TAPE DESIGNATI0N.
Z= TG ,WRITE TAPE B7 BCD.

Z= TA ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TB ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TC ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TD ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TE ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TF ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.
Z= TG ,(Y) =I , BLANK F1 THR0UGH F18 AND T1 T0 T18.

IF I = 0, THE C0MMAND IS T0 WRITE AN END 0F FILE MARK
0N THE APPR0PIATE TAPE.

IF I = -1, THE C0MMAND IS T0 REWIND THE APPR0PIATE TAPE.

P X Y Z

Z= CAB, PUNCH FR0M X,X+1,ETC. UP T0 THE NUMBER 0F
W0RDS SPECIFIED IN (Y) T0 CARDS IN BINARY
F0RM.

Z= TAB, WRITE TAPE B1 BINARY. WRITE FR0M X,X+1,
Z= TBB, WRITE TAPE B2 BINARY. ETC. UP T0 THE

K= 07000

Z= TCB, WRITE TAPE B3 BINARY.
Z= TDB, WRITE TAPE B4 BINARY.
Z= TEB, WRITE TAPE B5 BINARY.
Z= TFB, WRITE TAPE B6 BINARY.
Z= TGB, WRITE TAPE B7 BINARY.

NUMBER OF WORDS SPECIFIED IN THE CONTENTS OF Y.

Q X Y

THE Q COMMAND ENABLES ONE TO FIX ADDRESSES. THE K COUNTER MODIFIES EVERY ADDRESS EXCEPT EACH ONE EQUAL TO AN X IN A Q COMMAND. EACH SUCH ADDRESS IS THEN CHANGED DURING COMPILATION TO THE ADDRESS GIVEN IN THE Y ADDRESS OF THE Q COMMAND. THE Q TABLE IS CLEARED BY A K COMMAND DURING COMPILATION. THIS ENABLES ONE TO HAVE A SEPARATE Q TABLE FOR EACH FUNCTION. THE Q COMMAND MUST PRECEDE THE INSTRUCTIONS IT IS TO CONTROL. IT IS GOOD PRACTICE TO HAVE THE Q COMMANDS PRECEDE ANY OTHER INSTRUCTIONS WHICH FOLLOW A K COMMAND.

R X Y

REPLACE COMMAND.
REPLACE THE CONTENTS OF X BY THE CONTENTS OF Y.

S X Y Z

SUBTRACT COMMAND. REPLACE THE CONTENTS OF X BY (Y) - (Z).

T XX...X

TITLE COMMAND. THE CHARACTERS IN A TITLE COMMAND MAY GO FROM COL.2 TO COL.71. THEY CONTROL COL. 1 TO COL.70 OF AN OUTPUT CARD, PRINTER LINE, OR BCD LISTED LINE. A TITLE COMMAND NEED NOT PRECEDE EACH P COMMAND. THE LATEST T EXECUTED IS THE ONE IN POWER. IF NO TITLE INFORMATION IS DESIRED FOR THE OUTPUT, THE T COMMAND SHOULD HAVE COL. 2 TO 71 BLANK. IF TITLE INFORMATION IS DESIRED, IF SHOULD BE ARRANGED SO THAT IT WILL CONTROL ONLY BLANK COLUMNS OF THE P COMMAND.

V X SY YYYYYYYSEE

VALUE PSEUDO COMMAND. THE VALUE REPRESENTED AS A NORMALIZED FLOATING POINT NUMBER IS STORED IN X DURING COMPILATION. THE VALUE COMMAND IS EXECUTED ONLY DURING COMPILING. SEE INITIALIZE COMMAND FOR FORMAT OF VALUE.

W X YY YY

WORD PSEUDO COMMAND. THE WORD YYYY IS STORED IN ALPHABETIC

K= 07000

CODE IN LOCATION X. YYYY MAY BE NUMERIC OR ALPHABETIC CHARACTERS.

0255 CARDS

NASA-Langley, 1961 D-1078

NASA TN D-1078
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This report presents a computer program for multiplying, adding, differentiating, integrating, "barring" and scalarly multiplying "literal" Fourier series as such, and for extracting the coefficients of specified terms.

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II. NASA TN D-1078

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