CONTROL DATA
CORPORATION

CONTROL DATA®
1700 COMPUTER SYSTEMS

1700 MSOS 4
MS FORTRAN VERSION 3A/B
REFERENCE MANUAL

REVISION RECORD

REVISION	DESCRIPTION
A	Original printing of Mass Storage FORTRAN Version 3.0 for MSOS Version 4.0.
5/72	
B	This printing includes double precision floating point package.
1/73	
C	Revision for MSOS 4
7/74	

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CONTENTS

FIGURES

TABLES

INTRODUCTION 1

This publication describes the features of the 1700 Mass Storage FORTRAN Version 3 language for the CONTROL DATA® 1704/1714/1774/1784 computers.

It is assumed that the reader has some knowledge of an existing FORTRAN language and the 1700 Mass Storage Operating System (MSOS) Version 4.

Mass Storage FORTRAN, with the use of a compile time option, is a subset of ANSI X3.9-1966 American National Standard FORTRAN. All FORTRAN source decks written according to the guidelines provided by this document will be compiled properly.

This manual contains the information necessary to produce 1700 Mass Storage FORTRAN programs.

CAUTION

Control Data Corporation intends the user of this product to exercise only those features, specifications, and parameters described in this document. Any use of adjunct code and/or undefined parameter values is done so at the user's risk.

1.1 RELATED DOCUMENTATION

Related manuals in which the FORTRAN user may find additional information are:

Control Data Manuals	Publication Number
1700 MSOS 4 Reference Manual	60361500
1700 MSOS 4 Macro Assembler Reference Manual	60361900
1700 MSOS 4 Computer System Codes	60163500
1700 MSOS 4 Macro Assembler General Information	39519800
1700 MSOS 4 Mass Storage FORTRAN General Information Manual	39519900
1700 MSOS 4 Small Computer Maintenance Monitor Reference Manual	39520200
1700 MSOS 4 Instant	39520500

Control Data Manuals	Publication Number
1700 MSOS 4 File Manager Version 1 Reference Manual	39520600
1700 MSOS 4 Installation Handbook	39520900
1700 MSOS 4 Small Computer Maintenance Monitor Instant	39521700
1700 MSOS 4 General Information Manual	39522400

1.2 PRODUCT ELEMENTS

The 1700 Mass Storage FORTRAN Version 3 product is composed of five basic elements:

- A Variant FORTRAN Compiler — This compiler version has a larger number of overlays; the largest overlay is approximately 8K. It requires more mass memory than the B variant and is slower in compilation speed.
- B Variant FORTRAN Compiler — This compiler has fewer overlays than the A variant; the largest overlay is approximately 16K. This variant is faster than the A variant. Both compilers process source statements identically and generate similar object codes.
- Re-entrant ENCODE/DECODE Run-time — This run-time library runs in the foreground and has the characteristics for multiprogramming described in Chapter 9.
- Non-Re-entrant ENCODE/DECODE Run-time — This run-time library runs in the background and has identical user interface as the re-entrant ENCODE/DECODE run-time library as described in Chapter 9. This run-time library is designed for use in debugging programs to run in the foreground.
- FORTRAN I/O Run-time — This run-time library runs in the background and has the capability described in this manual (except Chapter 9). In general, it has more extensive capability than the other two run-times.

1.3 PRODUCT CONFIGURATIONS

Several product configurations are possible using the five elements of the product.

Only one variant of the compiler may be present in a given MSOS system. With the selected compiler, the re-entrant ENCODE/DECODE run-time may be used (must be core-resident). Either the non-re-entrant ENCODE/DECODE or FORTRAN I/O run-times may be in the background. In addition, if the FORTRAN I/O run-time is in the background, the non-duplicative functions present in the non-re-entrant ENCODE/DECODE can also be in the background.

Specific details of the configurations can be found in the MSOS Customization Manual, CDC Publication No. 88860300.

1.4 PRODUCT HARDWARE REQUIREMENTS

The MSOS 4.1 Reference Manual, CDC Publication No. 60361500, should be consulted for the specific hardware options which are available.

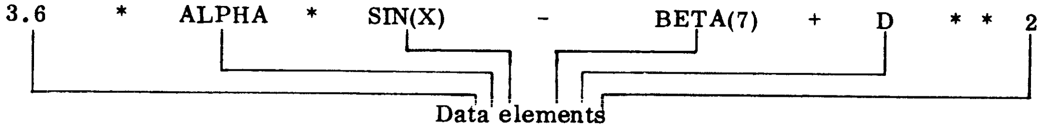
The minimum system memory requirements for MSOS do not include any of the elements of Mass Storage FORTRAN. If the A variant of the compiler is used, the minimum memory requirement is 24K. The B variant minimum is 32K. The foreground ENCODE/DECODE run-time requires an additional 4K of memory for single-precision floating-point or 8K for double-precision floating-point.

DATA FORMAT 2

2.1 DATA ELEMENTS

A data element is a single-valued unit of data which may be uniquely referenced. It may be any of the six types outlined in the following section. A data element may occupy part of a word (byte), a full word (integer or single), two full words (real), or three full words (double precision). The value of a data element may be altered during program execution.

The following expression contains six data elements.



2.2 DATA TYPES

1700 MS FORTRAN recognizes six types of data:

Integer

Single

Real

Double precision

Byte

Signed byte

Operations with data elements must take into account their type, since each has its own mathematical significance and word structure.

The type of a data element is indicated either by the first letter of its symbolic name or by a specification statement. Data types are shown in Figure 2-1.

Based on the six data elements in the preceding example, the data types are:

3.6	*	ALPHA	*	SIN(X)	-	BETA(7)	+	D	**	2
Real constant		Real variable		Function		Real array variable		Double precision variable		Integer constant

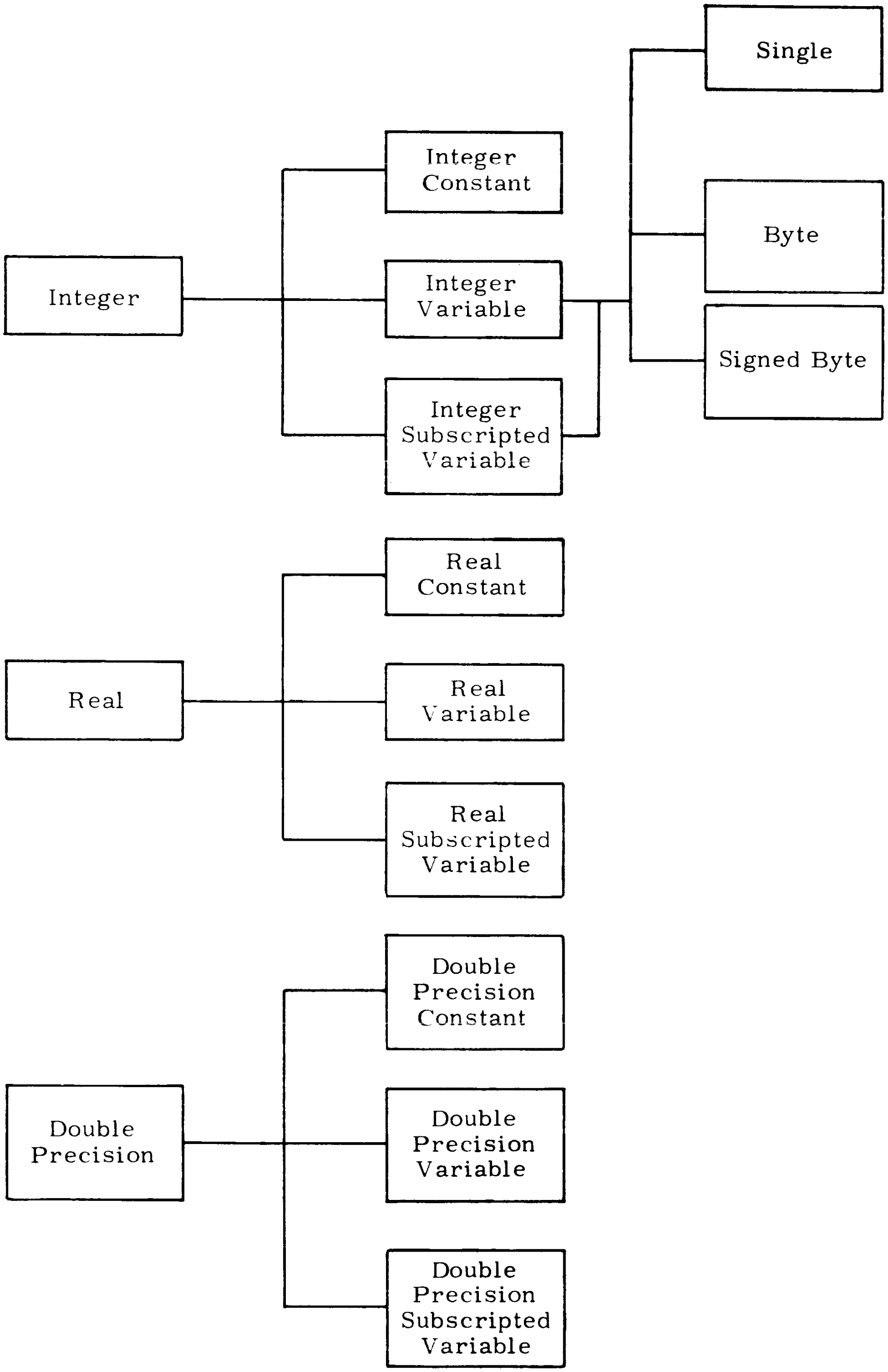
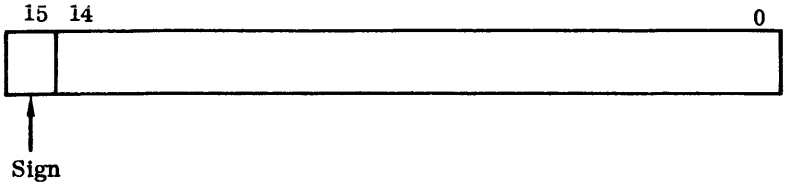

Integer
Integer Constant
Integer Variable
Integer Subscripted Variable
Single
Byte
Signed Byte
Real
Real Constant
Real Variable
Real Subscripted Variable
Double Precision
Double Precision Constant
Double Precision Variable
Double Precision Subscripted Variable

Figure 2-1. Data Types and Subdivisions

2.2.1 INTEGER TYPE DATA

An integer is a whole number expressed without a decimal point. It may be used as a subscript, an exponent, or in calculations that do not involve fractional parts. An integer occupies 16 bits of storage, or one 1700 computer word. The most significant bit is the sign bit.



The range of integer in magnitude is $0 \leq |n| \leq 2^{15}-1$.

There are three integer types:

- Constant — The value of an integer constant is stated explicitly in an expression. In 1700 MS FORTRAN, integer constants may be

  Decimal — Decimal integer constants consist of one to five decimal digits. If the range of $0 \leq |n| \leq 2^{15}-1$ is exceeded, a diagnostic is provided. Leading zeros are ignored.

  Hexadecimal — Hexadecimal integer constants are distinguished from decimal integer constants by a $ sign immediately preceding the string of digits. Hexadecimal integer constants consist of one to four hexadecimal digits. If this maximum is exceeded, the constant is treated as zero and a compiler diagnostic is provided. Leading zeros are ignored.

  Octal — An octal integer constant consists of one to five octal digits. Its use is restricted to PAUSEn and STOPn statements in which n is an octal constant.

  Equivalent decimal, hexadecimal, and octal integers are:

Decimal Integer	Hexadecimal Equivalent	Octal Equivalent
123	$7B	173
239	$EF	357
8405	$20D5	20325

- Variable — An integer identified by a symbolic name (Section 2.4) and capable of assuming a range of values during program execution is an integer variable. It may be designated a simple integer variable to distinguish it from an integer subscripted variable.

  SINGLE, BYTE, and SIGNED BYTE data types are subsets of the integer variable.

- Subscripted Variable

  This type of integer is a symbolic name with one, two, or three associated subscripts enclosed in parentheses. It is used to reference elements in an array (Appendix G) of successive memory locations. The name is typed integer by alphanumeric format (Section 2.4) or by declaration (Section 2.1.4). The subscripts must be integer constants, integer variables, or integer expressions. Permissible forms of subscripts are

Form	Example
(i)	(I)
(c)	(3)
(i±d)	(I+5)
(c*i)	(3*I)
(c*i±d)	(3*I+5)

i	Integer variable
c d	Integer constants
*	Arithmetic operator; multiplication
+	Arithmetic operator; addition or positive value
-	Arithmetic operator; subtraction or negative value

  Before an array can be used in a program, its name and dimensions must be declared in a DIMENSION, COMMON, or TYPE statement (Section 6.1.4). When so declared, .the subscripts are the actual dimensions of the array.

2.2.2 SINGLE TYPE DATA

This data type is the same as an integer variable. Dimension information may be given. When the ANSI option has been declared, appearance of a name in a SINGLE statement declares that each data element specified occupies a single storage unit.

2.2.3 BYTE TYPE DATA

A byte is an integer part (16 bits or less) of an integer variable. It is unsigned and may assume positive and zero values. To assume negative values the byte must be a full integer word (16 bits).

NOTE

When byte or signed byte integer parts of integer variables are used in subprogram parameter strings, the address of the integer variable is passed to the subprogram (not a redefined integer part address as defined by the BYTE or SIGNED BYTE declaration). The subprogram will then obtain the complete integer variable value when the byte parameter is referenced.

2.2.4 SIGNED BYTE TYPE DATA

A signed byte of an integer word may assume positive, negative, and zero values. In the special case where a signed byte is one bit, it has the value +0 or -0.

NOTE

When byte or signed byte integer parts of integer variables are used in subprogram parameter strings, the address of the integer variable is passed to the subprogram (not a redefined integer part address as defined by the BYTE or SIGNED BYTE declaration). The subprogram will then obtain the complete integer variable value when the byte parameter is referenced.

2.2.5 REAL TYPE DATA

A real data element can have a fractional part as well as an integer part and is always expressed with a decimal point. It is used in calculations that require decimal approximations.

A real number occupies 32 bits or two 1700 words.

	15	14 7	6 0
Word 1	S	EXPONENT	MSP
2	LEAST SIGNIFICANT PART OF COEFFICIENT		

Where: S is the sign bit

MSP is the most significant part of the coefficient

The approximate range of a real number is $10^{-39} < |n| < 10^{39}$. Precision is approximately seven decimal digits. (Refer to Appendix C.)

There are three real types:

- Constant

  The value of a real constant data element is expressed by an integer part, a decimal point, and a fractional part, in that order. It may be followed by the letter E and an optionally signed exponent representing a power of ten. In the following examples, n is the integer part, d the decimal (fractional) part, and s the exponent representing a power of 10. (Refer to the Constant description for double precision type, page 2-7.)

Form	Example
n.d	345.67
.d	.34567
n.	34567.
.dE±s	.34567E+5
n.E±s	34567.E-05
n.dE±s	345.67E-03

- Variable

  A real variable data element is identified by a symbolic name (Section 2.3). It is capable of assuming a range of values during program execution. A real variable is designated a simple real variable to distinguish it from a real subscripted variable.

- Subscripted Variable

  A real subscripted variable is a symbolic name with one, two, or three subscripts enclosed in parentheses. It is used to reference the elements in an array of memory locations. The name is typed real by alphanumeric format (Section 2.4) or by declaration (Section 6.1.4). The subscripts must be integer (constants, variables, or expressions). Permissible forms of subscripts are

Form	Example
(i)	(I)
(c)	(3)
(i±d)	(I+5)
(c*i)	(3*I)
(c*i±d)	(3*I+5)

i	Integer variable
c d	Integer constants
*	Arithmetic operator: multiplication
+	Arithmetic operator: addition or positive value
-	Arithmetic operator: subtraction or negative value

2.2.6 DOUBLE PRECISION TYPE DATA

A double precision data element can have a fractional part as well as an integer part and is always expressed with a decimal point. It is used in calculations that require decimal approximations of more accuracy than that obtainable with the use of a single precision data element.

A double precision number occupies 48 bits or three 1700 words.

<table>
<tr><th></th><th>15</th><th>14 … 7</th><th>6 … 0</th></tr>
<tr><td>Word 1</td><td>S</td><td>EXPONENT</td><td>MSP</td></tr>
<tr><td>2</td><td colspan="3">INTERMEDIATE PART OF COEFFICIENT</td></tr>
<tr><td>3</td><td colspan="3">LEAST SIGNIFICANT PART OF COEFFICIENT</td></tr>
</table>

Where: S is the sign bit

MSP is the most significant part of the coefficient

The approximate range of a double-precision number is $10^{-39} < |n| < 10^{39}$. Precision is approximately 11.5 decimal digits. (Refer to Appendix D.)

The double precision types are:

- Constant — The value of a double-precision constant data element is expressed by an integer part, a decimal point, and a fractional part followed by the letter D and an optionally signed exponent representing a power of ten. A constant with a decimal point, but without an exponent, is classed as a real constant. In the following examples, n is the integer part, d the decimal (fractional) part, and s the exponent representing a power of 10.

Form	Example	
n.dD±s	345.67D-03	
.dD±s	.34567D+5	
n.D±s	34567.D-05	
n.d	838.8607	(real)
n.d	838.8608	(real)
.d	.08388607	(real)
.d	.08388608	(real)
n.	-8388607.	(real)
n.	-8388607.0	(real)

- Variable — A double-precision variable data element is identified by a symbolic name (Section 2.3). It is capable of assuming a range of values during program execution. A double-precision variable is designated a simple double-precision variable to distinguish it from a double-precision subscripted variable.

- Subscripted Variable — A double-precision subscripted variable is a symbolic name with one, two, or three subscripts enclosed in parentheses. It is used to reference the elements in an array of memory locations. The name is typed by declaration (Section 6.1.4). The subscripts must be integer constants, variables, or expressions. See Section 2.2.4 for permissible forms of subscripts.

2.3 SYMBOLIC NAMES

Both type of symbolic names consist of one to six alphanumeric characters, the first of which must be alphabetic:

- Data names — Reference simple variables, arrays, the elements of an array, bytes, and data blocks
- Procedure names — Reference statement functions, intrinsic functions, external functions, subroutines, and certain external procedures

2.4 DATA NAMES

A data name identifies any of the variable data elements described in this section. It also references a data block. In the absence of an explicit declaration, type is implied by the first letter of the name: I, J, K, L, M, and N imply type integer[†]; any other letter implies type real.

Example:

Integer Variable	Real Variable
IOTA	A65302
MATRIX	BETA
J	C
K2S04	ALPHA (7)

[†] Byte and signed byte are always considered integer variable.

EXPRESSIONS 3

An expression is a set of data elements combined by operators and parentheses to produce, upon execution, a single-valued result. An expression can be a single data element, a constant, or a variable, or it can be a complex string of data elements and operators nested with parentheses.

There are three kinds of expressions: arithmetic, relational, and logical, and each has its own operators.

3.1 ARITHMETIC EXPRESSIONS

An arithmetic expression is a combination of arithmetic operators and data elements which, when evaluated by execution, produce a single numerical value. Both the expression and its data elements identify integer, real, or double-precision values. Byte and signed byte are synonymous with type integer.

Arithmetic operators	+	Addition or positive value
	-	Subtraction or negative value
	*	Multiplication
	/	Division
	**	Exponentiation
Arithmetic data elements	Constants	
	Simple or subscripted variables	
	Function references (refer to Chapter 7)	

3.1.1 RULES FOR FORMING ARITHMETIC EXPRESSIONS

Consecutive arithmetic operators are not allowed in an expression. If a minus sign is used to indicate a negative data element, the sign and the element must be enclosed in parentheses if preceded by an operator.

```
B*A/(-C)

A*(-C)
```

As in ordinary mathematical notation, parentheses may be used to indicate grouping, but they may not be used to indicate multiplication.

Any arithmetic data element or expression may be raised to a positive or negative integer element or expression.

```
M**N

(X+Y)**I

(A+B)**(-J)

IVAL**(K+2)
```

Only a positive real or double-precision data element or expression can be raised to a real or double-precision power.

```
ALPHA**3.2

(X+Y)**A

(A+B)**(C+3)
```

Because of truncation, integer expressions cannot be commuted. I*J/K may not yield the same result as J/K*I, as the following example shows.

```
4*3/2=6   but   3/2*4=4
```

A data element with a zero value may not be raised to a power valued as zero: thus, any expression that becomes 0**0 when evaluated is illegal.

All data elements in an arithmetic expression must have mathematically defined values before the expression can be evaluated.

3.1.2 ORDER OF EVALUATION

Evaluation begins with the innermost expression and proceeds outward in parenthetical expressions within parenthetical expressions.

Evaluation proceeds according to the following hierarchy of operators in an expression without parentheses or within a pair of parentheses.

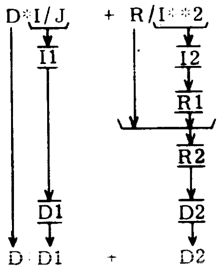
**	Exponentiation	Level 1
/	Division	Level 2
*	Multiplication	
+	Addition	Level 3
-	Subtraction	

3.1.3 MIXED MODE

Integer, real, and double-precision quantities may be used in the same arithmetic expression. In such a mixed mode expression, those parts involving purely integer (or real) operations are computed in the integer (or real) mode and the results are converted to real or double-precision. In those parts of the expression involving integer and real quantities, the integer is converted to real; in those parts of the expression involving integer, real, and double-precision quantities, the integer and real are converted to double-precision. Then the entire expression is computed in the real or double-precision mode.

Example:

D is double precision, R is real, I and J are integers.



I/J and I**2 involve only integer quantities. They are calculated in the integer mode to produce the intermediate integer results I1 and I2.

I2 is converted to real value R1.

R and R1 involve only real quantities. They are calculated in the real mode to produce the intermediate real result R2.

I1 and R2 are converted to double precision values D1 and D2.

The entire expression is computed in double-precision mode.

Example:

For the following statements

```
I  =  4*3/2
J  =  3 2*4
K  =  4.0D0*3/2
```

the results are:

I	J	K
6	4	4

3.2 RELATIONAL EXPRESSION

Two arithmetic expressions of the same data type may be combined with a relational operator to form a relational expression. The value of the expression will be true or false depending on the relation.

Relational Operators	Meaning
.EQ.	Equal to
.NE.	Not equal to
.GT.	Greater than
.GE.	Greater than or equal to
.LT.	Less than
.LE.	Less than or equal to

Examples:

```
(A+B).LE.(C+D)

I.EQ.J(K)

(3.*BETA+VALUE).NE.(ALPHA-44.8)

A.GT.16.
```

In 1700 MS FORTRAN, a relational expression is used only within the context of a logical IF statement (Section 5.2.3).

3.3 LOGICAL EXPRESSION

A logical expression is a combination of relational expressions and logical operators such that evaluation of the expression produces a result of true or false.

Logical Operators	Meaning
.NOT.	Logical negation
.AND.	Logical conjunction
.OR.	Logical disjunction

In 1700 MS FORTRAN, a logical expression is used only within the context of a logical IF statement (Section 5.2.3). Logical variables are not allowed in 1700 MS FORTRAN.

3.3.1 FORMATION OF LOGICAL EXPRESSION

If RE1 and RE2 are relational expressions, the logical operators can be defined as follows:

.NOT.RE1	False only if RE1 is true
RE1.AND.RE2	True only if RE1 and RE2 are both true
RE1.OR.RE2	False only if RE1 and RE2 are both false

.NOT. may appear only in the following combinations with .AND. or with .OR.:

```
RE1.AND..NOT.RE2

RE1.OR..NOT.RE2
```

Examples:

```
A.LE.B.AND.C.EQ.D
F.GT.16..OR.G.GE.3.14
ALPHA.LE.BETA.AND..NOT.GAMMA.EQ.BETA
.NOT.(A.NE.B) which is the same as A.EQ.B
```

3.3.2 ORDER OF EVALUATION

Within a logical expression, operators are evaluated in the following order:

```
.NOT.
.AND.
.OR.
```

STATEMENTS 4

4.1 CLASSIFICATION

Statements are the basic steps in a FORTRAN program. In general, statements are executable or nonexecutable.

4.1.1 EXECUTABLE STATEMENTS

Executable statements perform calculations, direct control of the program, and transfer data. Types of executable statements are

Assignment

Control

I/O

4.1.2 NONEXECUTABLE STATEMENTS

Nonexecutable statements provide the compiler with information regarding data structure and storage. Nonexecutable statements are

Specification

Data initialization

Format

Function defining

Subprogram

4.2 STATEMENT FORMAT

Statements are written in 72-column lines. A statement begins on the initial line and may be continued to additional lines. Up to five continuation lines are permitted per statement. The letter C in the first column identifies a comment line which does not affect the program; it is used as an editing convenience.

The use of the 72 columns is the same for punched card and paper tape input; however, for paper tape, column 72 indicates a carriage return which serves as a field separator marking the end of an input line.

Blanks may be used freely to improve the appearance of the program, subject to the restrictions on continuation lines.

In writing statements, the columns are used as follows:

Column	Description	Use
1 through 5	Statement label	If a statement is to be referenced in a program (such as in control transfer), it is given a number from 1 to 32,767 as a statement label. Otherwise, these columns are blank.
6	Continuation indicator	Where a statement extends beyond one line, additional lines are flagged as continuation lines by placing a character other than zero or blank in column 6. When column 6 is used, the line must contain some useful information or the compiler assumes the programmer made an error.
7 through 71	Statement field	The FORTRAN statement is written in columns 7 through 72 for punched card input and in columns 7 through 71 for paper tape input.
72	Carriage return	A carriage return symbol is placed in column 72 for every line of paper tape input to indicate the end of line.
73 through 80	User application	The programmer uses these columns to sequence source cards; the compiler ignores these columns.

EXECUTABLE STATEMENTS 5

An executable statement causes the program to perform an action such as the assignment of a value, the transfer of control, or the transfer of data. Executable statements are

Assignment

Control

I/O

5.1 ASSIGNMENT STATEMENTS

An assignment statement gives a variable numerical value. The value may be the result of calculation. or it may be assigned by the programmer. Assignment statements may be

Arithmetic assignment

Label assignment

5.1.1 ARITHMETIC ASSIGNMENT STATEMENT

An arithmetic assignment statement assigns a value of a constant, expression, or variable to another variable.

The format is

```
v = e
```

Where:

v	is the simple or subscripted variable
=	is the assignment symbol which directs the program to compute the value of the expression on the right and place that value in the storage location designated by the variable on the left
e	is the arithmetic expression

Examples:

```
I = I + 1

ALPHA = BETA*DELTA + SIN (X)

JOTA (K) = IVAL* *2 + IFOX (Y)
```

If the arithmetic assignment statement involves mixed mode, the data type of e may be converted according to the rules:

If v type is:	And e type is:	The assignment rule is:
Integer	Integer	Assign
Integer	Real	Fix and assign
Integer	Double precision	Dfix and assign
Real	Integer	Float and assign
Real	Real	Assign
Real	Double precision	Single and assign
Double precision	Integer	Dflt and assign
Double precision	Real	Double and assign
Double precision	Double precision	Assign

Definition of Rules

Assign	Transmit the value, without change, to v.
Fix/Dfix	Truncate any fractional part of the value and transform that result to the form of an integer.
Float	Transform the value to the form of a real number.
Dflt	Transform the value to the form of a double-precision number.
Single	Truncate the value to form a real number.
Double	Express the value in the form of a double-precision number.

5.1.2 LABEL ASSIGNMENT STATEMENT

A label assignment statement gives a variable the numerical label of another statement in the same program. Any subsequent statement with that variable automatically references the statement whose label is assigned. With READ and WRITE statements, this feature permits selection of several possible formats based on program execution.

The format is:

ASSIGN k TO i

Where: k is the statement label referencing a statement in the same program unit as the assign statement

i is an integer variable called the assign variable

Example:

```
25 ASSIGN 20 TO IOTA
      .
      .
      .
50 ASSIGN 30 TO IOTA
      .
      .
      .
      WRITE (3,IOTA) LIST
20 FORMAT (...)
30 FORMAT (...)
```

In the preceding example, if the program sequence includes statement 25 but skips 50, the WRITE is executed according to the FORMAT labeled 20; if the program sequence skips the statement labeled 25 but includes 50, the WRITE is executed according to the FORMAT labeled 30.

An assign variable is also used in conjunction with an assigned GO TO statement. After execution of an assignment statement, subsequent execution of an assigned GO TO statement transfers control to the statement identified by the assigned label, provided there was no intervening redefinition of that label. Used in this manner, the label must identify an executable statement.

An assign variable may be in common (Section 6.1.2) or it may be an actual argument in a procedure reference (Chapter 7). In these cases, it continues to function as an assign variable in the related program units. Thus, FORMAT statements and labels may be passed between program units.

Once it is defined in an ASSIGN statement, an integer variable may not be referenced in any statement other than an assigned GO TO statement or a formatted READ or WRITE statement until it is redefined.

5.2 CONTROL STATEMENTS

Program execution normally proceeds from statement to statement as they appear in a program. Control statements can be used to alter this sequence or cause a number of iterations of a program section. Control may only be transferred to an executable statement. A transfer to a nonexecutable statement results in a program error, which is usually recognized during compilation. With the DO statement, a predetermined sequence of instructions can be repeated any number of times by incrementing a simple integer variable after each iteration.

Statements to which control is transferred must have statement labels and they must reference executable statements within the same program as the control statement. This restriction does not apply to the assigned GO TO. The types of control statements are

GO TO	RETURN
Arithmetic IF	CONTINUE
Logical IF	Program Control
CALL	DO

5.2.1 GO TO STATEMENTS

GO TO statements transfer control unconditionally to a statement with a label whose reference is fixed or to a statement whose label is selected during execution of the program. GO TO statements may be

Unconditional GO TO

Assigned GO TO

Computed GO TO

UNCONDITIONAL GO TO STATEMENT

Execution of this statement causes the statement identified by the label to be executed next.

The format is:

```
GO TO k
```

Where: k is the statement label

Example:

```
    GO TO 10
  5 DIF  = DIF - SUM
 10 SUM = SUM + 1
```

In this program sequence, the GO TO statement causes control to skip statement 5 and execute statement 10 and those following in sequence until control is altered again. Statement 5 is not executed unless it is referenced by some other control statement in the program.

ASSIGNED GO TO STATEMENT

This statement acts as a many-branch GO TO.

The formats are:

GO TO i
GO TO i, $(k_1, \ldots, k_n)$

Where: i is an integer variable reference called an assign variable

k_i are optional statement labels which may be included for the programmer's convenience; they are not used by the compiler.

Before an assigned GO TO statement is executed, the current value of i must have been assigned by an ASSIGN statement. Control transfers to the statement identified by that statement label to be executed next. The i must be assigned in either the program unit of the GO TO or in another program unit where i was passed as an actual parameter or was in common.

The same integer variable reference used in the ASSIGN statement may be used in a subsequent arithmetic expression if it is re-equated to a value prior to its use in that expression.

Examples:

<u>Format 1</u>

```
       ASSIGN 15 TO K
       GO TO 60
  15   K = 9
       L = (I**2) + K
 100   ASSIGN 20 TO K
       GO TO 60
           .
           .
           .
  60   CONTINUE
           .
           .
           .
       GO TO K
  20   CONTINUE
```

When the program executes the ASSIGN statement, K has the statement label value 15.

Control moves to the next statement which causes a jump to statement 60, CONTINUE.

The program executes the statements following 60 in sequence until it reaches GO TO K. Since K previously has been assigned the value 15, control jumps to statement 15.

Statement 15 equates K to the value 9.

The following statement uses this value (9) of K in an arithmetic expression. (The variable reference is re-equated to a value and then used in an arithmetic expression.)

In the next statement, the program assigns 20 to K.

The next step causes a jump to 60, CONTINUE.

The program goes through the steps following 60 until it reaches GO TO K. As K has been assigned the statement label value 20, control jumps to statement 20, CONTINUE, and proceeds in sequence.

Format 2

```
ASSIGN 10 TO JUMP
          .
          .
          .
GO TO JUMP, (5,10,20)
          .
          .
          .
10 RESULT = RATE * AMOUNT
```

The program first assigns the value 10 to JUMP.

It proceeds in sequence until it encounters the GO TO JUMP statement. Since JUMP was assigned the value 10, control transfers to statement 10.

The list of labels (5, 10, 20) serves only as a check on JUMP, the variable reference. The second form operates in the same manner as the first; the list is optional.

COMPUTED GO TO STATEMENT

This form of the GO TO statement is an n-branch control transfer in which a sequence of statement labels is followed by an integer variable whose value at execution serves as an ordinal designation of the label which defines the transfer.

The format is:

GO TO $(k_1,k_2,k_3,\ldots,k_n),i$

Where: k is the statement label

i is an integer variable reference; for proper operation, i must not be specified by an ASSIGN statement

The statement identified by statement label k_i is executed next. Assume j is the value of i at the time of execution. If $j \leq 1$, statement label k_1 is executed next. If $j \geq n$, statement label k_n is executed next.

Example:

```
N=3
 .
 .
 .
GO TO (100, 101, 102, 103), N
```

N is 3 and the statement number 102 is the selected control transfer.

If N were less than 1, control would be transferred to 100. If N were greater than 4, control would be transferred to 103.

5.2.2 ARITHMETIC IF STATEMENT

An arithmetic IF statement is a three-branch transfer on an arithmetic expression.

The format is

IF (e)k_1, k_2, k_3

Where: e is an arithmetic expression

k is an executable statement label. If the evaluation of e is

-	Control is transferred to k_1
0	Control is transferred to k_2
+	Control is transferred to k_3

Example:

```
IF (IOTA-6) 3,6,9
```

If the evaluation of the expression IOTA-6 produces a negative result, control transfers to the statement labeled 3; if zero, to 6; if positive, to 9.

5.2.3 LOGICAL IF STATEMENT

A logical IF statement is a two-branch transfer on a logical expression.

The format is:

IF (e) s

Where: e is the logical or relational expression; upon execution of this statement, if

true	Statement s is executed
false	The sequence of statements following the logic IF is continued.

s is any executable statement except a DO statement or another logical IF statement

Examples:

```
IF (A.EQ. 10..AND. B .EQ. 5.) GO TO 3
IF (X.GT.Z) Y = SIN (X)/2
IF (I.EQ.J) IF (L + 2) 100, 200, 300
```

5.2.4 CALL AND RETURN STATEMENTS

The CALL and RETURN statements establish communication between a main program and subroutines. These statements are explained in Section 7.4.

5.2.5 CONTINUE STATEMENT

The CONTINUE statement is most frequently used as the last statement in a DO loop (Section 5.2.7) to avoid terminating on GO TO or IF statements, which are illegal termination statements in DO loops.

The format is:

```
CONTINUE
```

When CONTINUE is the terminating statement of a DO loop, it causes repetition of the loop. In any other position, it serves as a do-nothing statement passing control to the next statement.

5.2.6 PROGRAM CONTROL STATEMENTS

Program control statements are STOP, PAUSE, and END.

STOP STATEMENT

This statement terminates execution of the program. Normally it is used at the end of a program. It may be used to terminate execution when an abnormal condition occurs.

When this statement is executed, the word STOP and any octal digits following it appear on the output comment device, in five-digit form.

The formats are:

```
STOP
STOP n
```

Where: n is one to five octal digits

PAUSE STATEMENT

This statement temporarily halts the execution of a program to permit checking of intermediate results. The operator enters a carriage return to resume execution with the statement immediately following PAUSE.

When this statement is executed, the word PAUSE and any octal digits following it appear on the output comment device, in five-digit form.

The formats are:

```
PAUSE
PAUSE n
```

Where: n is one to five octal digits

END STATEMENT

This statement marks the physical end of a program or subprogram. It is executable in the sense that it affects return from a subprogram in the absence of a RETURN statement, but it may not have a label.

The format is:

```
END
```

5.2.7 DO STATEMENT

A DO statement makes it possible to repeat a group of statements a designated number of times using an integer variable whose value is progressively altered with each repetition. The range of repetition is called the DO loop. Minimally, the DO loop consists of the DO statement with its parameters and a final statement whose label is referenced by the DO statement.

The formats are:

DO n i = m_1, m_2
DO n i = m_1, m_2, m_3

Where: n is the label of the terminal statement of the loop.

i is a positive integer variable called the control variable. With each repetition, its value is altered progressively by the increment parameter m_3. Upon exiting from the range of a DO, the control variable remains defined as the last value acquired in execution of the DO. It does not matter if the exit results from satisfying the DO or by execution of a GO TO or IF.

m_1 is the initial parameter, the value of i at the beginning of the first loop.

m_2 is the terminal parameter; when the value of i surpasses the value of m_2, DO execution is terminated and control goes to the statement immediately following the terminal statement.

m_3 is the increment parameter; the amount i is increased with each repetition.

The parameters m_1 and m_2 must be unsigned integer constants, or unsigned non-subscripted integer variables. If m_3 has the value 1, it may be omitted (first form above). None of these parameters may be redefined during the execution of the DO.

5.2.7.1 DO LOOP STRUCTURE

The general form of a DO loop is:

```
          DO n i = m1,m2, m3
          Statement 1
          Statement 2
          Statement 3
              .
              .
              .
     n    Terminal statement
```

The range of the loop extends from the DO statement through the terminal statement, inclusively.

Statement 1, the first statement in the range of the DO, must be an executable statement.

Statements 1, 2, 3... may contain inner DO loops. This is called nesting and is explained below.

Table 5-1 shows how relationships among the DO statement parameters affect execution of a DO. The label n references the terminal statement of the DO loop, which must be an executable statement in the same program unit as the DO statement and must follow it.

The terminal statement may <u>not</u> be any of the following:

GO TO

Arithmetic IF

RETURN

STOP

PAUSE

DO

Logical IF (if it contains any of the preceding forms)

ASSEM (if terminal statement label is imbedded within)

Table 5-1. DO Statement Parameters

M1	M2	M3	EXAMPLE	ACTION

Integer constant	Integer constant	Integer constant	I=1,9,2
			I=9,1,2
			I=9,1,-1
			I=5,6,-1
			I=5,5
				Control variable is initialized.
				DO loop is executed at least once.
				Control variable is incremented.
				Completion test is made to see if loop is to be executed again.

Integer constant	Integer constant	Integer variable	I=1,9,N
			I=9,1,N
			I=1,9,-N
			I=9,1,-N	

Integer constant	Integer variable	Integer constant	I=2,J,2
			I=5,J,-2
			I=5,J
				Control variable is initialized.
				Completion test is made to see if loop is to be executed.
				Loop is executed.
				Control variable is incremented.

Integer constant	Integer variable	Integer variable	I=4,J,K
			I=10,J,-K	

Integer variable	Integer variable	Integer constant	I=J,K,2
			I=K,J,-2
			I=K,J	

Integer variable	Integer variable	Integer variable	I=M1,M2,N
			I=M1,M2,-N	

Integer variable	Integer constant	Integer variable	I=J,10,K
			I=J,6,-K	

Integer variable	Integer constant	Integer constant	I=J,5,2
			I=J,3,-2
			I=J,10	

Example:

The following program calculates the sum of all odd numbers and the sum of all even numbers in the range of 1 to 100.

```
      IODD = 0

      IEVEN = 0

      DO 25 I = 1, 99, 2

      IODD = IODD + I

      J = I + 1

      IEVEN = IEVEN + J
 25   CONTINUE
```

The first two steps zero out the counters for the odd and the even numbers. The DO statement initiates a loop that begins at the index value of 1 and increments in steps of 2. This series provides the odd numbers. The J = I + 1 statement provides the series of even numbers by adding a 1 to each of these values. The operation of this DO loop is tabulated in the following chart.

Loop	I	IODD=IODD+I	(store)	J=I+1	(store)	IEVEN=IEVEN+J	(store)
1	1	1=0+1	(1)	2=1+1	(2)	2=0+2	(2)
2	3	4=1+3	(4)	4=3+1	(4)	6=2+4	(6)
3	5	9=4+5	(9)	6=5+1	(6)	12=6+6	(12)
4	7	16=9+7	(16)	8=7+1	(8)	20=12+8	(20)
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•

Successive values of control variable I which is the sequence of odd numbers

Progressive addition of odd numbers

Sequence of even numbers

Progressive addition of even numbers

5.27.2 DECREMENTED DO LOOP

When decrementation is desired in a DO loop, the following form applies:

DO $n_i = m_1, m_2 - m_3$

Where the value of the incremental parameter m_3 is established in a preceding statement and $m_1 > m_2$.

Example:

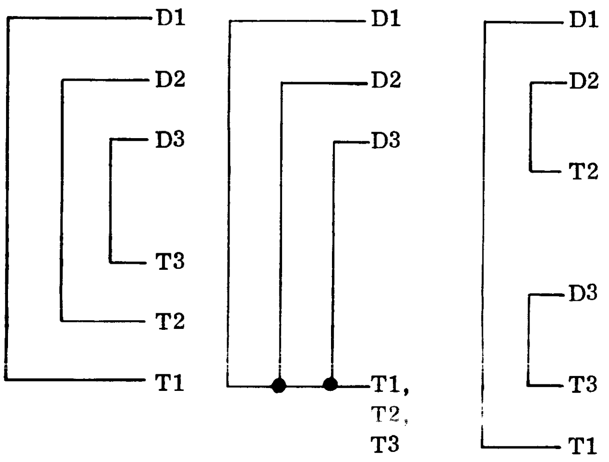
To find the value of N factorial (N!):

```
      READ(1,5) N
  5   FORMAT (I2)
      FACT = 1.0
      K = 1
      DO 10 I = N, 2, -K
 10   FACT = FACT*I
      WRITE (3,15) FACT
 15   FORMAT (F10.0)
```

5.2.7.3 NESTED DO LOOPS

DO loops may be included within DO loops as long as no inner range overlaps with any outer range. However, two or more DO loops may share the same terminal statement. DO loops may be nexted up to 10 deep.

If D1, D2, and D3 are DO statements and T1, T2, and T3 are the associated terminal statements, then the following nested structures of DO loops are permitted:



Example:

This example may be used to test Fermat's Last Theorem with combinations of integer values up to 1000. The theorem states that the equation

$$X^n + Y^n = Z^n$$

is not valid for positive integer values of X, Y, and Z when n is an integer greater than 2.

Letting I, J, K equal X, Y, Z to imply integer values, the test may be programmed as follows:

```
      PROGRAM FERMAT
      DO 13 N = 3, 1000
      DO 13 I  = 1, 1000
      DO 13 J  = 1, 1000
      DO 13 K = 1, 1000
      IF (I**N+J**N-K**N) 13, 7, 13
  7   WRITE (3, 100) I, J, K, N
100   FORMAT (6HEUREKA/4I5)
 13   CONTINUE
```

Example:

If a loan is repaid in N monthly payments with each payment equal to P and with an interest rate of R, the total repaid, S, is given by:

$$S = \frac{P}{R}\left(1 - \frac{1}{(1+R)^N}\right)$$

The following program calculates the sums repaid for monthly payments of 24, 30, and 36 months in amounts of $20, $30, $40, and $50 at interest rates 6%, 7%, 8%, 9%, and 10%.

```
      DIMENSION SUM (5)
      DO 30 N = 24, 36, 6
      DO 20 J = 20, 50, 10
      DO 10 I  = 6, 10
      R = I*0.01
 10   SUM (I-5) = J/R*(1. -1. /((1.+R)**N))
 20   WRITE (3,40) (SUM(K), K=1,5)
 40   FORMAT (5F10.2)
 30   CONTINUE
```

This would print out the sums, five to a line, according to the five interest rates.

The following tabulation shows how the cycling proceeds through the DO loops, with the innermost loop varying the most rapidly and the outermost loop varying the least rapidly.

Months	Amount	Rate	Months	Amount	Rate
24	20	.06	30	40	.06
		.07			.07
		.08			.08
		.09			.09
		.10			.10
	30	.06		50	.06
		.07			.07
		.08			.08
		.09			.09
		.10			.10
	40	.06	36	20	.06
		.07			.07
		.08			.08
		.09			.09
		.10			.10
	50	.06		30	.06
		.07			.07
		.08			.08
		.09			.09
		.10			.10
30	20	.06		40	.06
		.07			.07
		.08			.08
		.09			.09
		.10			.10
	30	.06		50	.06
		.07			.07
		.08			.08
		.09			.09
		.10			.10

5.2.7.4 DO LOOP TRANSFER

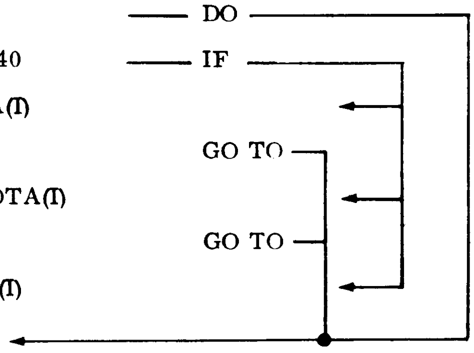
Control can be transferred within a DO loop by means of an IF or a GO TO statement, provided neither is used as a terminal statement.

The label of a terminal statement in a series of more than one DO statement may not be used in any GO TO or arithmetic IF statement that occurs anywhere but in the range of the most deeply contained DO that has that terminal statement.

Example:

This example may be used to test 100 values for sign and accumulate three sums: negative, zero, and positive values.

```
          PROGRAM TEST
          DIMENSION IOTA (100)
          READ (1,10) (IOTA(I), I=1,100)
    10    FORMAT(10I5)
          INEG = 0
          IZERO = 0
          IPOS = 0
          DO 50 I = 1,100
          IF (IOTA(I))20, 30, 40
    20    INEG = INEG + IOTA(I)
          GO TO 50
    30    IZERO = IZERO + IOTA(I)
          GO TO 50
    40    IPOS = IPOS + IOTA(I)
    50    CONTINUE
             .
             .
             .
```



5.2.7.5 EXTENDED RANGE OF A DO

If control can be transferred out of a DO loop and returned, the DO is said to have an extended range. More specifically, a DO has an extended range if it contains a GO TO or arithmetic IF that can pass control outside the range of the DO and there is a GO TO or arithmetic IF outside the range of the DO that can return control into the range of the DO.

Control can be transferred from an inner DO loop to the outer DO loop that contains it. Control cannot initially pass from an outer DO loop into an inner DO loop.

Example:

This example may be used to compare two arrays of numbers and print out all sets of equivalent values.

```
        DO 50 I = 1,20                  outer DO
        DO 30 J = 1,20                  inner DO
        IF(A(1).EQ.B(J))GO TO 40        transfer
  30    CONTINUE
        GO TO 50
  40    WRITE(3,10)A(I),B(J)
        GO TO 30
  10    FORMAT(F8.5,3H = ,F8.5)
  50    CONTINUE
```

Control can be transferred out of a DO loop or nest of DO loops and returned, provided the indexing parameters are not altered and control is transferred back to the range of the same DO loop from which the exit was made.

Example:

```
             DO 66 I=1,21,3
             ALPHA=SQRT(X)          library routine for
                                    square root of X
             DO 33 J=1,10
             BETA=DENOM(Y)          FUNCTION DENOM(A)
               .                        .
               .                        .
               .                    RETURN
       33    CONTINUE
             CALL GAMMA (Z)         SUBROUTINE GAMMA (W)
                                        .
                                        .
             next statement         RETURN
             GO TO 17
       66    CONTINUE
       17    WRITE (3,18)ALPHA, BETA,Z
       18    FORMAT (3F10.5)
             GO TO 66
```

5.3 I/O STATEMENTS

I/O statements are classified as data transfer statements and auxiliary I/O statements. The first type is the READ and WRITE statements which read records from an external unit into core and write records out of core onto an external unit. Under the second type, BACKSPACE, REWIND, and ENDFILE affect the position and check the status of external magnetic tape files; basic functions (Section 7.3.2) check the status of I/O devices. The following section applies only to the FORTRAN I/O run-time package. Consult Chapter 9 for the I/O statements that are used with other run-time packages.

The logical units defined for the various I/O operations are those defined for the MSOS system in which Mass Storage FORTRAN operates. Logical units for specific devices are likely to vary from system to system. Standard FORTRAN units should be used as much as possible:

Logical Unit Number	Description
1	Standard Input Device
2	Standard Binary Output Device
3	Standard Print Output Device
4	Standard Output Comment Device

5.3.1 I/O DEVICES

The Mass Storage FORTRAN product supports all I/O devices present in MSOS 4. The MSOS Reference Manual should be consulted for specific devices.

5.3.2 MASS STORAGE FILES

There are two distinct methods of using files in MSOS 4. The use of file manager files is discussed in Chapter 4 of the MSOS 4 Reference Manual. The material presented here applies only to FORTRAN files and must not be confused with files created via the File Manager.

Mass storage files are assigned to the scratch area of the mass storage device and are not retained after execution of a job. (Permanent files in the program library may not be defined or manipulated by FORTRAN I/O statements.) Files to be read in to or written out of mass storage must be preceded by an OPEN statement that defines the file.

5.3.3 OPEN STATEMENT

This statement provides for parameters to describe each mass storage file to be used by the program.

The formats are:

```
OPEN k,i,j,u,x
OPEN k,i,j,u
```

Where: k is the integer name of the mass storage file to be defined; integer constant or variable.

i is the number of sectors per record; minimum record length is one sector; integer constant or variable.

j is the maximum number of records in the file; integer constant or variable.

u is the logical unit number to which file k is assigned; integer constant or variable.

x is the starting section address[†] for file k on logical unit u; positive integer constant or variable. The sector address will be assigned relative to the start of mass memory scratch.

If any of the above variables are omitted, the starting sector address is to be assigned at execution time. Subsequent mass storage files are assigned sequentially.

NOTE

> If x is omitted for one mass storage file in a program, it must be omitted for all mass storage files in that program.
>
> If x is specified for one mass storage file in a program, it must be specified for all mass storage files in that program.

Attempting to read or write a file on mass storage without defining the file by an OPEN statement results in an execution-time diagnostic and program termination. The syntax legality of the values specified by OPEN is checked at compile time.

Examples:

```
    OPEN 35, 2, 50, 5, 1
```

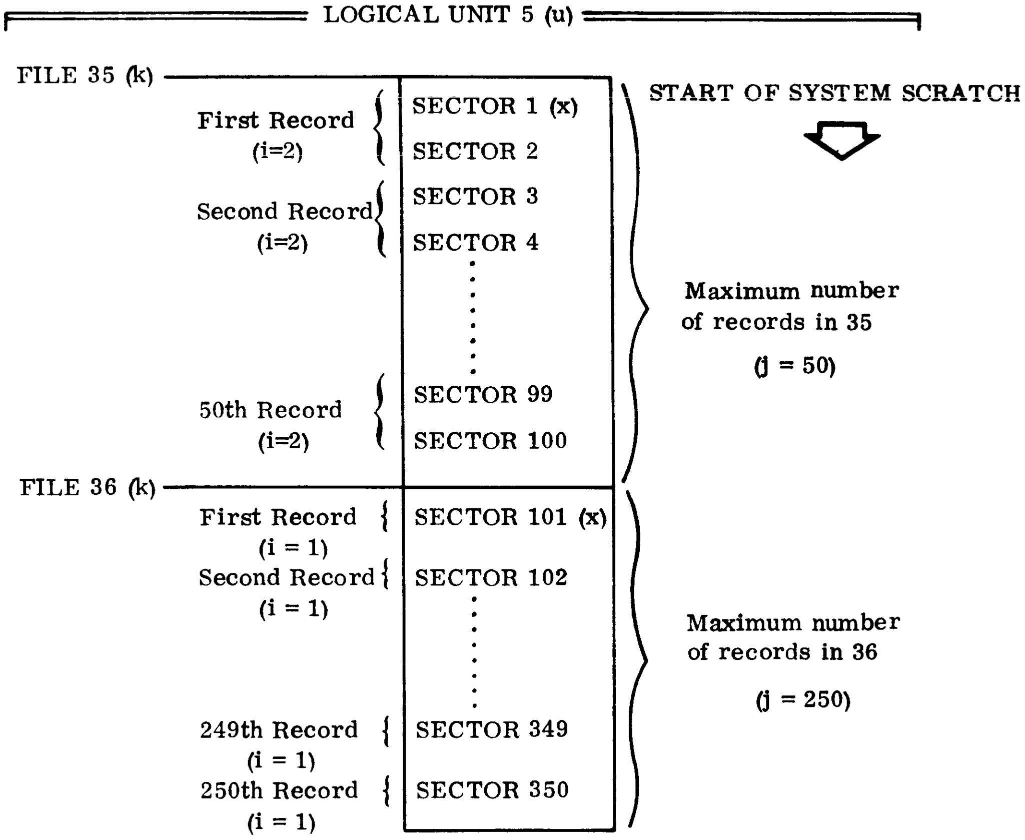
This statement defines a file referenced as 35. This file uses two sectors per record and consists of 50 records maximum (100 sectors). The file is assigned to logical unit 5 and starts at the location of the first sector relative to the start of the mass memory scratch area.

```
    OPEN 36, 1, 250, 5, 101
```

This statement defines a file referenced as 36. This file uses one sector per record and consists of 250 records maximum (250 sectors). The file is assigned to logical unit 5 and starts at the location of sector 101 (relative to the start of the mass memory scratch area), which means that file 36 immediately follows file 35.

[†] The maximum number of data words in a sector is 94, since two words of each sector are for addressing that sector.

The following diagram shows the arrangement and significance of the parameter values for examples.



5.3.4 READ AND WRITE STATEMENTS

The READ and WRITE statements transfer data lists between core and external devices. These lists may include the names of variables, arrays, and array elements. The named elements are assigned values on input, and their values are transferred on output. Arrays in a list may be transferred with an implied DO of the forms:

$i = m_1, m_2, m_3$
$i = m_1, m_2$

The parameters i, m_1, m_2, m_3 are defined exactly as they are for the DO statement (Section 5.2). An implied DO does not reference a terminal statement; the range is the array to which it is applied.

Example:

```
           READ (7, 10) (A (I), I = 1,4)
     10    FORMAT (F 10.6)
```

has the same effect as:

```
           DO 20 1=1,4
     20    READ (7,30) A (I)
     30    FORMAT (F 10.6)
```

Both of these examples read the first value of four records into array elements A(1), A(2), A(3), and A (4). If integer variables in an input list appear as subscripts elsewhere in the list, they must appear as input variables before they appear as subscripts unless they have been previously defined.

Example:

```
    READ (7) I,J, ALPHA (I,J)
```

Data records are written in binary or ASCII. Because binary records are coded within the computer, format cannot be selected. Such records are referred to as unformatted, and they are used with magnetic tape and mass storage devices. ASCII records are used for man/machine communication and format must be specified. Such records are called formatted and can be transferred by READ and WRITE statements only when controlled by FORMAT statements (Section 6.3). In the explanations that follow, two forms of each READ/WRITE statement are given; the first applies to non-mass storage files; the second applies to mass storage files. For the ANSI option, unformatted I/O will transmit two words per integer list element. If the integer list element was typed SINGLE, then only one word is transmitted per integer list element.

Formatted READ

The format of this statement has two variations.

The first causes the input of the next record from the unit identified by lu (logical unit).

The format is

```
    READ (lu,f) list
```

Where: lu is the integer constant or non-subscripted variable reference used to identify the logical unit. 1700 MS FORTRAN assigns logical unit numbers to reference standard MSOS logical units as follows:

1 = Standard input (contained in $F9)

2 = Standard binary output (contained in $FA)

3 = Standard list output (contained in $FB)

4 = Standard comment (contained in $FC)

Logical units 5 through 99 reference actual assigned MSOS logical units of like number.

NOTE

> MSOS logical units 1 through 4 cannot be referenced by FORTRAN programs unless they are also MSOS standard logical units. Actual logical unit assignments vary from system to system.

f is the format specification (Section 6.3).

label is the statement label of a FORMAT statement. The identified statement must appear in the same program unit as the I/O statement.

array is the array name which must conform to the specifications in Section 6.3.

assign is an assigned variable; the statement label assigned must be a format specification. The variable assigned may be a dummy argument or, if it is in common, it may come from another program unit.

list is a series of variables separated by commas.

The information is scanned and converted according to the format specification identified by f.

The resulting values are assigned to the elements specified by the list. If the list is not present, READ (lu,f), spaces over one record.

Example:

```
      READ (5,20) A,B,C
   20 FORMAT (3F10.6)
```

These statements read in three floating-point values from logical unit 5 according to the FORMAT labeled 20. This specifies field widths of 10 positions with 6 decimal places.

The second format causes input of the nth record from mass storage file k.

The format is

```
READ (k(n),f) list
```

Where: k is the mass storage file

n is the nth record from mass storage file k

f is the format specification (see Section 6.3).

label is the statement label of a FORMAT statement. The identified statement must appear in the same program unit as the I/O statement.

array is an array name which must conform to the specifications in Section 6.3.

assign is an assigned variable; the statement label assigned must be a format specification. The variable assigned may be a dummy argument or, if it is in common, it may come from another program unit.

list is a series of variables separated by commas.

The information is scanned and converted as specified by the format specification identified by f. The file must have been opened by a previous OPEN statement.

If the file is not on a mass storage device, the request is ignored. If f specifies H (Hollerith) conversion, the record is read into the storage locations of the FORMAT statement replacing the H part of f.

Example:

```
          OPEN 40,1,200,5
                  .
                  .
                  .
          READ (40(12),10) X
    10    FORMAT (50A1)
```

These statements read the twelfth record of mass storage file 40 from logical unit 5 into array X which has been previously dimensioned. The record contains 50 ASCII characters according to the FORMAT labeled 10.

Formatted WRITE

The format of this statement has two variations.

The first writes the next record on the unit identified by lu (logical unit).

The format is

```
    WRITE (lu,f) list
```

Where: lu is the integer constant or non-subscripted variable reference used to identify the logical unit. 1700 MS FORTRAN assigns logical unit numbers to reference standard MSOS logical units as follows:

1 = Standard input (contained in $F9)

2 = Standard binary output (contained in $FA)

3 = Standard list output (contained in $FB)

4 = Standard comment (contained in $FC)

Logical units 5 through 99 reference actual assigned MSOS logical units of like number.

NOTE

MSOS logical units 1 through 4 cannot be referenced by FORTRAN programs unless they are also MSOS standard logical units. Actual logical unit assignments vary from system to system.

f is the format specification (See Section 6.3).

label is the statement label of a FORMAT statement. The identified statement must appear in the same program unit as the I/O statement.

array is an array name which must conform to the specifications in Section 6.3.

assign is an assigned variable; the statement label assigned must be a format specification. The variable assigned may be a dummy argument or, if it is in common, it may come from another program unit.

list is a series of variables separated by commas. The list specifies a sequence of values which are converted and positioned according to the format specified by f. The list may be omitted if f specifies /, nX, or nH conversion. If f does not contain /, X, or H editing characters and the list is omitted, a line of blanks is assumed.

Example:

```
      WRITE (9,20) A,B,C
   20 FORMAT (3F10.6)
```

These statements write the floating-point numbers from locations A, B, and C on logical unit 9.

The second format writes record n on mass storage file k.

The format is

```
WRITE (k(n),f) list
```

Where: k is the mass storage file

n is the nth record from mass storage file k

f is the format specification (see Section 6.3).

label is the statement label of a FORMAT statement. The identified statement must appear in the same program unit as the I/O statement.

array is an array name which must conform to the specifications in Section 6.3.

assign is an assigned variable; the statement label assigned must be a format specification. The variable assigned may be a dummy argument or, if it is in common, it may come from another program unit.

list is a series of variables separated by commas. The list specifies a sequence of values which are converted and positioned according to the format specified by f. The list may be omitted if f specifies /, nX, or nH conversion. If f does not contain /, X, or H editing characters and the list is omitted, a line of blanks is assumed.

If k(n) is not large enough to accommodate the converted data, truncation occurs.

Example:

```
      WRITE (55(2),10)A
   10 FORMAT (F10.2)
```

These statements write the floating-point number from location A into the second record of mass storage file 55. The file must have been opened by a previous OPEN statement.

Unformatted READ

The format of this statement has two variations.

The first form of the statement causes the input of the next record from the unit identified by lu.

The format is

```
READ (lu) list
```

Where: lu is the integer constant or non-subscripted variable reference used to identify the logical unit. 1700 MS FORTRAN assigns logical unit numbers to reference standard MSOS logical units as follows:

1 = Standard input (contained in $F9)

2 = Standard binary output (contained in $FA)

3 = Standard list output (contained in $FB)

4 = Standard comment (contained in $FC)

Logical units 5 through 99 reference actual assigned MSOS logical units of like number.

NOTE

MSOS logical units 1 through 4 cannot be referenced by FORTRAN programs unless they are also a MSOS standard logical unit. Actual logical unit assignments vary from system to system.

list is a series of variables separated by commas. If list is specified, these values are assigned to the sequence of elements specified by the list. The sequence of values required by the list may not exceed the sequence of values from the unformatted record. If the file is on a mass storage device, the request is ignored.

Examples:

```
READ (1) (A(I), I=1,100)
```

This statement reads a record from unit 1 into the storage areas specified in the DO implied list.

```
READ (6)
```

This statement skips the next record on logical unit 6. Unit 6 cannot be a mass storage device.

The second form of the statement inputs the nth record from mass storage file k.

The format is

```
READ (k(n)) list
```

Where: k is the mass storage file

n is the nth record from mass storage

list is a series of variables separated by commas. If list is specified, these values are assigned to the sequence of elements specified by the list. The sequence of values required by the list may not exceed the sequence of values from the unformatted record.

Example:

```
READ (31 (9)) X
```

This statement reads the ninth record of the mass storage file 31 into storage location X.

Unformatted WRITE

The format of this statement has two variations.

The first form of the statement creates the next record on the unit identified by lu from the sequence of values specified by the list.

The format is

```
WRITE (lu) list
```

Where: lu is the integer constant or non-subscripted variable reference used to identify the logical unit. 1700 MS FORTRAN assigns logical unit numbers to reference standard MSOS logical units as follows:

1 = Standard input (contained in $F9)

2 = Standard binary output (contained in $FA)

3 = Standard list output (contained in $FB)

4 = Standard comment (contained in $FC)

Logical units 5 through 99 reference actual assigned MSOS logical units of like number.

NOTE

MSOS logical units 1 through 4 cannot be referenced by FORTRAN programs unless they are also MSOS standard logical units. Actual logical unit assignments vary from system to system.

list is a series of variables separated by commas. The list may not be empty.

Example:

```
DIMENSION A (80), B (4)
WRITE (2) A,B
```

These statements write one record of two blocks on logical unit 2.

The second form writes record n on mass storage file k.

The format is

```
WRITE (k(n)) list
```

Where: k is the mass storage file

n is the nth record from mass storage file k

list is a series of variables separated by commas. The list may not be empty. If the number of words in the list exceeds the record size specified for k, an execution time diagnostic is given and the program terminates.

Example:

```
     DIMENSION A(10)
     OPEN 22, 1, 500, 8
              .
              .
              .
     WRITE (22(100)) A
```

These statements write ten words from array A into the 100th record of mass storage file 22 on logical unit 8.

5.3.5 AUXILIARY I/O STATEMENTS

Auxiliary I/O statements are applicable only to files residing on magnetic tape.

REWIND Statement

This statement positions the unit identified by lu at its loadpoint.

The format is

```
     REWIND lu
```

Where: lu is the integer constant or non-subscripted variable reference used to identify the logical unit. 1700 MS FORTRAN assigns logical unit numbers to reference standard MSOS logical units as follows:

1 = Standard input (contained in $F9)

2 = Standard binary output (contained in $FA)

3 = Standard list output (contained in $FB)

4 = Standard comment (contained in $FC)

Logical units 5 through 99 reference actual assigned MSOS logical units of like number.

NOTE

MSOS logical units 1 through 4 cannot be referenced by FORTRAN programs unless they are also a MSOS standard logical unit. Actual logical unit assignments vary from system to system.

BACKSPACE Statement

This statement causes the unit identified by lu to go back to the beginning of the preceding block. If the unit identified by lu is positioned at its load point, an error diagnostic is printed and the program is terminated. If a record contains n blocks of data, then n BACKSPACEs must be specified to skip backwards over that record.

The format is

```
BACKSPACE lu
```

ENDFILE Statement

This statement causes an endfile record to be recorded on the unit identified by lu. The endfile record is a unique record signifying a demarcation of a sequential file. The EOF function (Table 7-4) is used to determine if an endfile record has been encountered during execution of a READ statement. After reading an ENDFILE and before reading again from that unit, a test must be made for the END FILE using the EOF function.

The format is

```
ENDFILE lu
```

Where: lu is the integer constant or non-subscripted variable reference used to identify the logical unit. 1700 MS FORTRAN assigns logical unit numbers to reference standard MSOS logical units as follows:

1 = Standard input (contained in $F9)

2 = Standard binary output (contained in $FA)

3 = Standard list output (contained in $FB)

4 = Standard comment (contained in $FC)

Logical units 5 through 99 reference actual assigned MSOS logical units of like number.

NOTE

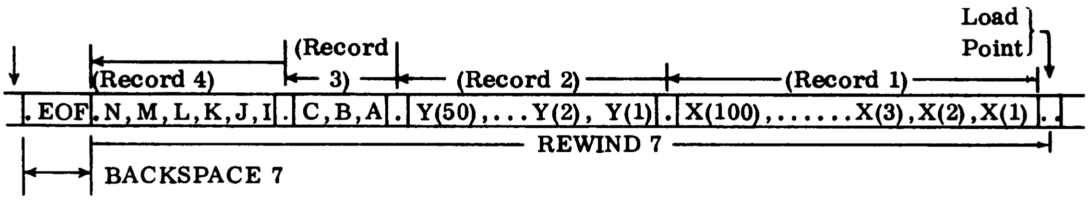
MSOS logical units 1 through 4 cannot be referenced by FORTRAN programs unless they are also a MSOS standard logical unit. Actual logical unit assignments vary from system to system.

Example:

```
WRITE(7) (X(I), I=1,100)          (record 1)
WRITE (7) (Y(I), I=1,50)          (record 2)
WRITE (7) A, B, C                 (record 3)
WRITE(7) I, J, K, L, M, N         (record 4)
ENDFILE 7
BACKSPACE 7
REWIND 7
```

This sequence of auxiliary I/O statements would write and move the tape of logical unit 7 as illustrated.

ENDFILE 7



5.3.6 TAPE RECORDS AND BLOCKS

Tape records and blocks may be binary or ASCII. Binary tape records (paper or magnetic tape) are composed of 85-word blocks. The first word of a binary block, the control word, is followed by 84 data words. Records may be one per block or extend over several blocks. A block may not contain more than one record.

The control word is zero for all blocks except the last, where it equals the number of blocks in the record.

ASCII tape records (paper or magnetic tape) are composed of blocks with a maximum of 68 words. Each block is one record. Output statements which write more than 68 words (136 characters) in a record are truncated to 68-word records. Input statements which read more than 68 words (136 characters) result in diagnostics and program termination.

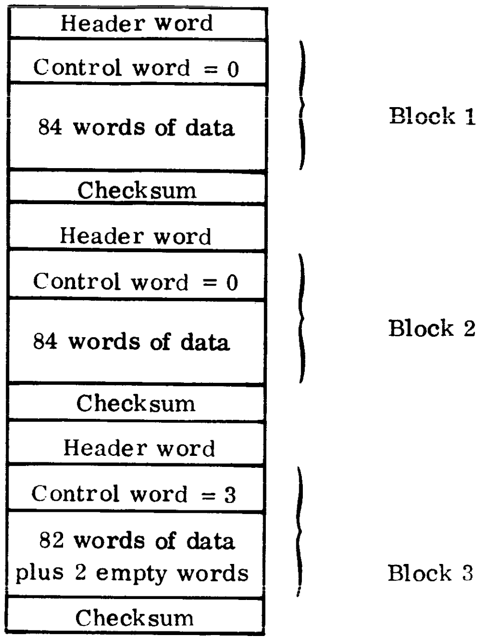
Paper Tape

A binary block is preceded by a header word which contains the block size in one's complement form. It is followed by a checksum word. The checksum added to the sum of the data words and the header word equals zero. Overflow is ignored when computing the checksum.

Example:

```
WRITE (2) (A(I), I = 1,250)
```

This request produces a record on paper tape with the following format.



An unformatted (binary) read transmits one record with the format produced by an unformatted (binary) write. The header word and checksum are not transmitted to the buffer.

Magnetic Tape

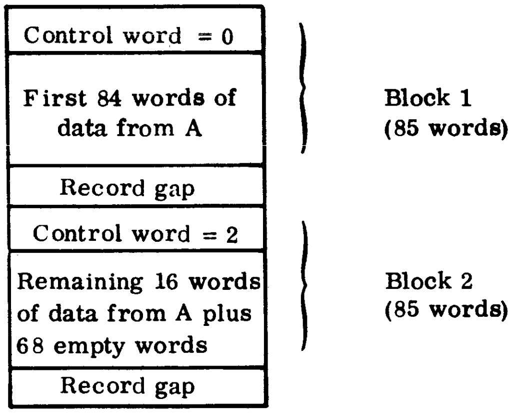
All binary blocks and ASCII blocks on magnetic tape are followed by a record gap.

ASCII is converted to extended BCD before output on magnetic tape and converted from extended BCD to ASCII when input from magnetic tape.

Example:

```
DIMENSION A(100)
WRITE (6) (A(I), I=1,100)
```

This request produces the following binary record on magnetic tape.



If no list is specified, the binary read request skips one block. Regardless of the length of the record, only the number of words specified in each list is transmitted; the remainder of the record is skipped.

5.3.7 MASS STORAGE RECORDS AND SECTORS

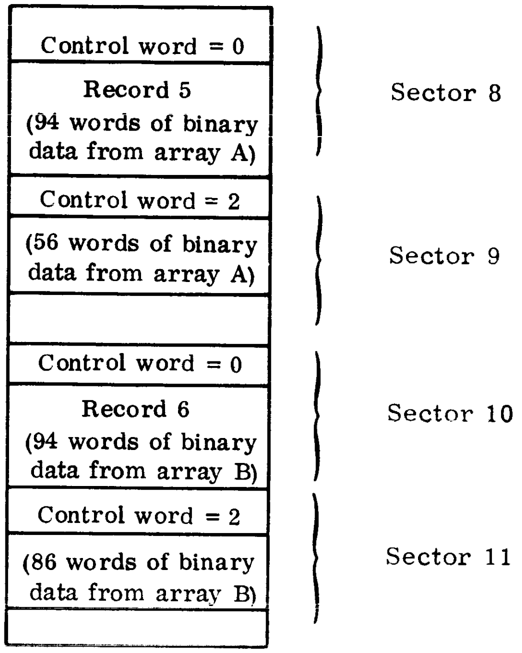
Mass storage records may be binary or ASCII. Binary records on disk or drum are composed of 96-word sectors. The control word (first two words of a sector) is followed by 94 data words. Records may be one per sector or may extend over several sectors. A sector may not contain more than one record.

Mass storage ASCII records are subject to the same restrictions as ASCII records on tape. Each record may contain a maximum of 68 words (136 characters). Statements which output more than 68 word records cause the record to be truncated to 68 words. Statements that input records exceeding 68 words result in a diagnostic and program termination.

Example:

```
DIMENSION A(150),B(180)

OPEN 2,2,25,5,1

WRITE (2(5))A

WRITE (2(6))B
```

These requests produce the following binary records on disk or drum.


Control word = 0
Record 5
(94 words of binary data from array A)
Sector 8
Control word = 2
(56 words of binary data from array A)
Sector 9
Control word = 0
Record 6
(94 words of binary data from array B)
Sector 10
Control word = 2
(86 words of binary data from array B)
Sector 11

A binary read transmits the number of words specified in the list; the list must not specify more words than the record contains. If no list is specified, the binary read request is ignored.

5.3.8 PRINTING OF FORMATTED RECORDS

The first character of a formatted record is not printed if the print unit is the FORTRAN line printer. The first character which can appear as a single Hollerith character (for example, 1H0), determines vertical spacing on I/O printer units as follows:

Character	Vertical Spacing Before Printing
0	Two lines
1	To first line of next page
+	No advance
Other	One line

Consult the MSOS Reference Manual for specific characteristics of each character output device driver.

5.4 ASSEM STATEMENT

The ASSEM statement provides communication with the operating system or the core-resident programs, or in-line coding (not possible with FORTRAN statements). With ASSEM, in-line code can be compiled in the form of absolute constants, relative address constants, and absolute address constants. Each parameter generates one word (16 bits) of code, except for statement labels and control indicators.

The format is

ASSEM $p_1, p_2, \ldots, p_n$

Where any p_i may be

1. Hexadecimal constant of the form

   $HH...H

   where each H is a hexadecimal digit (up to 4 digits).

2. Absolute address constant of the form

   +AA...A(c)

3. Self-relative address constant of the form

   AA...A(c)

4. $.n_1 \ldots n_j$

   where n_1 through n_j is the statement label, $j \le 5$ of the next p_i.

5. Control indicator for relative address constants which are to be other than self-relative of the form

   *

6. Relative address constant which is other than self-relative of the form

   *AA...A(c)

7. Relative indirect address constant which is other than self-relative of the form

   *(AA...A(c))

In 2, 3, 6, and 7, AA...A may be a variable, an array name, or a statement label. The c is an integer constant greater than zero designating an element within the array if AA...A is an array name. External names are permitted only in forms 2 and 3 and, if used, must be declared in an EXTERNAL statement (Section 7.4.3).

The ASSEM statement produces a string of successive constants in the program in the order specified. Hexadecimal constants can be used to specify data or instructions. When used to generate instructions, the operation code, indirect flags, relative flags, indices, and delta value are coded in hexadecimal. The self-relative address constant produces a value equal to the distance between the location of the variables in the program and the location to the address constant (the positive direction is from smaller to larger address).

Relative address constants, other than self-relative (forms 6 and 7), are special forms to create calling sequences to the operating system (refer to the 1700 MSOS Reference Manual). They are created as distance relative to the last occurrence of the control indicator (form 5). These address constants, along with associated control indicators, must appear on the same or consecutive ASSEM statements (no intervening FORTRAN statements are allowed). Forms 6 and 7 are illegal if no control indicator (form 5) has been encountered.

Example 1.

```
DIMENSION   K(3)
ASSEM       $C0C5,$6400,+K(1)
```

These statements produce the equivalent of the following code at the point of the ASSEM statement:

Operation Code	Address
LDA-	$C5
STA+	K

Example 2.

```
ASSEM       .12,$C800,K(2)
```

This statement produces the equivalent of the following code:

Statement Label	Operation Code	Address
12	LDA	K + 1

The address (K+1) in this example is relative to the current location counter. The statement label may be referenced from anywhere within the bounds of the program unit, except as a DO loop statement terminator.

Example 3.

This example shows how an operating system request can be generated with the ASSEM statement.

For the macro instruction

```
FREAD    l,ca,sa,wc,m,cp,a,x,d
```

the macro assembler generates the following command sequence output:

<table>
<tr><th></th><th>15</th><th>14</th><th>13</th><th>12</th><th>11</th><th>10</th><th>9</th><th>8</th><th>7</th><th></th><th></th><th>4</th><th>3</th><th></th><th></th><th>0</th></tr>
<tr><td>Word 0</td><td colspan="16">RTJ — ($F4)</td></tr>
<tr><td>1</td><td>0</td><td>d</td><td colspan="5">rc</td><td>x</td><td colspan="4">rp</td><td colspan="4">cp</td></tr>
<tr><td>2</td><td colspan="16">ca</td></tr>
<tr><td>3</td><td colspan="16">thread</td></tr>
<tr><td>4</td><td colspan="3">ec</td><td>m</td><td colspan="2">a</td><td colspan="10">l</td></tr>
<tr><td>5</td><td colspan="16">wc or wca</td></tr>
<tr><td>6</td><td colspan="16">sa</td></tr>
</table>

If the following values are assigned

Parameter	Meaning	Value
d	Part 1 request indicator	0
rc	Request code	4
rp	Request priority	0
cp	Completion priority	1
ca	Completion address	Statement label 1000
thread		Value 0
ec	Error code upon completion of request	0
m	Mode	0
a, l	Pointer to unit	I,$F9 (unit is system input)
wc	Word count	ICOUNT
sa	Starting address	ISTART

And if x is 1, then

ca	Completion address	ca + address of WORD1
wca	Word count address	(wca) + address of WORD1
sa	Starting address	sa + address of WORD1

If sa is enclosed in parentheses, it produces an indirect address for the starting address.

(sa) location of starting address = (sa)+(address of WORD1).

The parameter list begins at the statement label 1001. An ASSEM statement simulates the macro instruction FREAD with the parameters previously described in either of two ways:

1. Using a relative address to reference the starting address:

   ```
   ASSEM $54F4,*,.1001,$0901,*1000,$0,$08F9,*(ICOUNT),*ISTART
   ```

2. Using a relative indirect address to reference the starting address:

   ```
   ASSEM $54F4,*,.1001,$0901,*1000,$0,$08F9,*(ICOUNT),*(ISTART)
   ```

NONEXECUTABLE STATEMENTS 6

Nonexecutable statements provide the compiler with information regarding data structure and storage; they perform no action in the execution of a program. Nonexecutable statements are as follows:

Specification

Data initialization

FORMAT

Function defining (refer to Chapter 7)

Subprogram (refer to Chapter 7)

6.1 SPECIFICATION STATEMENTS

Specification statements specify type, word structure, and storage for variables. These statements are as follows:

DIMENSION

COMMON

EQUIVALENCE

EXTERNAL (refer to Chapter 7)

RELATIVE (refer to Chapter 7)

Type

Byte

6.1.1 DIMENSION STATEMENT

Before an array can be used in a program, sequential storage locations must be reserved for all its elements, usually through the DIMENSION statement.

The format is:

DIMENSION $v_1(i_1)$, $v_2(i_2)$, . . . , $v_n(i_n)$

Where: v **is an array name**

i **is one, two, or three subscripts giving the maximum dimensions of the array (refer to Appendix G for a detailed treatment of arrays).**

Example:

For an array IOTA with three rows, four columns, and five planes, the statement would be

DIMENSION IOTA (3, 4, 5)

6.1.2 COMMON STATEMENT

Through the COMMON statement, variables in a subprogram (Section 7.4) reference the same storage locations as variables in the main program. In this way, the subprogram can make use of data blocks that are a part of the main program without the use of dummy arguments (Section 7.1).

The format is:

COMMON /x/$a_1, a_2, \ldots, a_n$

Where: x is a symbolic name identifying a block of storage. This block is called a labeled common block; only one such block may appear in a program. If x is missing, the block is referred to as a blank common block; the pair of slashes may be omitted. Only one blank common block may appear in a program.

a is a list of simple variables and arrays (subscripted and unsubscripted). These are stored sequentially in each block in the order of their appearance.

Although a program may only have one labeled common block and one blank common block, variables and arrays can be assigned to these blocks by any number of COMMON statements, both labeled and blank. In addition, a single COMMON statement may contain labeled and blank assignments in any order. In all cases, the lists are stored in appropriate blocks in the order of their appearance. A list a_i may not contain formal arguments. If a nonsubscripted array name appears, the dimensions must be defined by a DIMENSION statement in that program unit. Arrays may be dimensioned in the COMMON statement by a subscript string following the array identifier. If an array is dimensioned in both a COMMON statement and a DIMENSION statement, a compiler diagnostic results.

Items in labeled common may be preset with initial values in the BLOCK DATA subprogram (Section 7.4.7).

Consult the MSOS Reference Manual for system organization when blank and/or labeled common is used in a system.

The length of a common block is determined by the number and type of the list identifiers. The length of common block AB in Figure 6-1 is the sum of the length of the items in the labeled blocks. LIST is

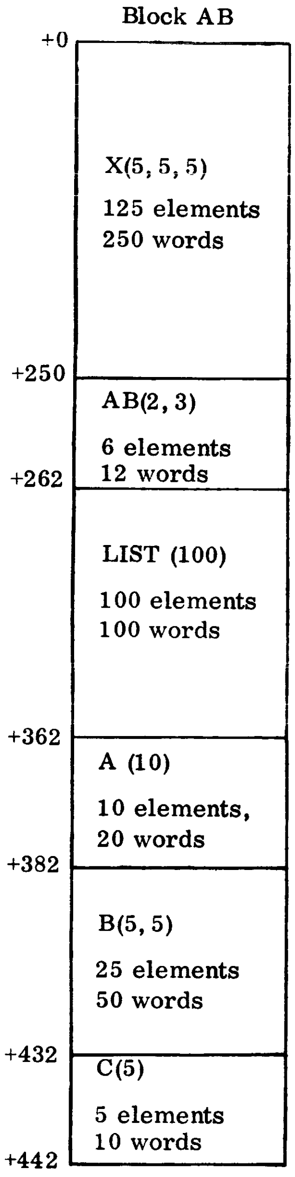


Figure 6-1. Common Block

the only integer array; and, assuming it is type SINGLE, each element requires only one word. The other arrays are real and require two computer words for each element. The total number of words in block AB is 442.

Another block of common is formed from the elements in blank or unlabeled common: A1, B1, C1, D, E, and F. The length of blank common depends on the dimensions of A1, B1, C1, and E which are are not specified in the COMMON statements. If no DIMENSION statement appears for any of these identifiers, they are assumed to be simple variables.

Example:

```
    COMMON/AB/X(5,5,5),AB(2,3),LIST(100)

    COMMON/AB/A(10)/AB/B(5,5),C(5)

    COMMON//A1,B1,C1,D(10,10)

    COMMON E, F(10,10,10)
```

The various program units executed together need not declare the same size common storage block, but the first program unit to be loaded must declare the largest block.

To meet ANSI standards, a real data element and an integer data element must occupy the same number of storage units to accommodate mixed-mode extensions of common through the EQUIVALENCE statement. To maintain ANSI compatibility, 1700 MS FORTRAN includes the ANSI option of allocating two words of storage for each integer data element. Only the first word is used in computation. If an integer is type SINGLE (Section 6.1.4), it always occupies one word of storage.

6.1.3 EQUIVALENCE STATEMENT

This statement makes it possible for different variables in a single program to reference the same storage location. The difference between COMMON and EQUIVALENCE is that COMMON assigns variables in different programs to the same storage locations, whereas EQUIVALENCE assigns variables in the same program to the same locations.

The format is:

EQUIVALENCE $(a_1, b_1, \ldots), (a_2, b_2, \ldots), \ldots, (a_n, b_n)$

Where: $(a_i, b_i, \ldots)$ is an equivalence group of two or more simple variables or subscripted array elements sharing a single location

A multisubscripted array element can be represented as a singly subscripted variable with the formula

```
    a + A*(b-1) + A*B*(c-1)
```

which gives the ordinal location on an element with subscript (a, b, c) in an array whose maximum dimensions are (A, B, C). The formula is explained in Appendix G.

Example:

If an array element of a three-dimensional array were to be referenced with a single-dimensional array element:

```
    DIMENSION I(3,4,5), K(60)
    EQUIVALENCE (I(1,1,1), K(1))
```

then element I (2,1,4) may be referenced as K(38) by using the array successor function.

```
2 + 3*(1-1) + 3*4*(4-1) = 38
```

The manner in which storage is allocated to equivalenced arrays depends on whether the storage area is a common block or not. The EQUIVALENCE statement does not rearrange common, but arrays may be defined as equivalent so that the length of the common block is extended.

However, the origin of a common block may not be changed by an EQUIVALENCE statement. When two variables or array elements share storage because of the effects of EQUIVALENCE statements, both their symbolic names may not appear in COMMON statements in the same program, because COMMON stores elements in serial order as they appear, making it impossible for any two elements to share the same storage.

Examples:

If two arrays, not in common, are equivalenced according to the following definitions:

```
INTEGER A, B, C
DIMENSION A(3), B(2), C(4)
EQUIVALENCE (A(3), C(2))
```

Then storage locations are assigned as follows:

L	A(1)	
L+1	A(2)	C(1)
L+2	A(3)	C(2)
L+3		C(3)
L+4		C(4)
.		
.		
.		
M	B(1)	
M+1	B(2)	

However, when one of the arrays in common is used in an EQUIVALENCE statement

```
COMMON A(3), B(2)
EQUIVALENCE (B(2), C(2))
```

storage locations are assigned as follows:

L	A(1)	
L+1	A(2)	
L+2	A(3)	
L+3	B(1)	C(1)
L+4	B(2)	C(2)
L+5		C(3)
L+6		C(4)

EQUIVALENCE statements may be written

$\text{EQUIVALENCE } (A_1, B_1)$
$\text{EQUIVALENCE } (A_2, B_2)$

where the variable names or the array element names are paired. Up to 51 EQUIVALENCE statements of this form are permissible. This limits the number of equivalenced names to 102. More variable or array element names can be used if multiple names are included in one EQUIVALENCE statement. The maximum number is 100 names in a statement of the form EQUIVALENCE $(A_1, A_2, A_3, \ldots, A_{98}, A_{99}, A_{100})$. The number of statements must be reduced if this form is used.

An optimum declaration is six statements of the paired form with one statement of the multiple name form, resulting in the equivalencing of 112 names.

Formal parameters specified in SUBROUTINE or FUNCTION statements may be referenced in EQUIVALENCE statements (Section 7.4).

6.1.4 TYPE STATEMENT

To override or confirm implicit typing of a symbolic name, a type statement is used. It may supply dimension information for arrays.

The format is

$t\ v_1, v_2, \ldots, v_n$

Where:	t	is INTEGER, REAL, DOUBLE PRECISION, or SINGLE
	v_i	is a variable name, function name, array name, or an array declarator

If a symbolic name appears in a SINGLE statement the associated data is typed as integer. Dimension information may be given. When the ANSI option has been declared, appearance of a name in a SINGLE statement declares that each data element specified occupies a single storage unit.

Examples:

INTEGER ALPHA	(Over-ride)
REAL BETA	(Confirming)
DOUBLE PRECISION DELTA	(Over-ride)
SINGLE IOTA (3, 6)	(Confirms the integer type and gives dimensions of the array named)

6.1.5 BYTE STATEMENTS

Byte statements make it possible to reference a segment of an integer variable.

The format is

$$t\ (a_1, b_1\ (c_1{=}d_1)), \ldots, (a_n, b_n(c_n{=}d_n)$$

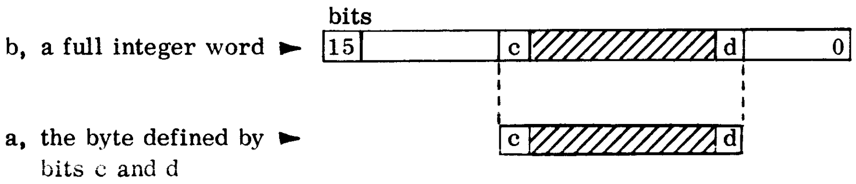
Where:

t is BYTE or SIGNED BYTE

a is the name of the byte (either an integer variable or an integer array)

b is the integer from which a is derived (integer variable, integer array, or an integer array element)

c/d are upper and lower bits of b that define a as illustrated:



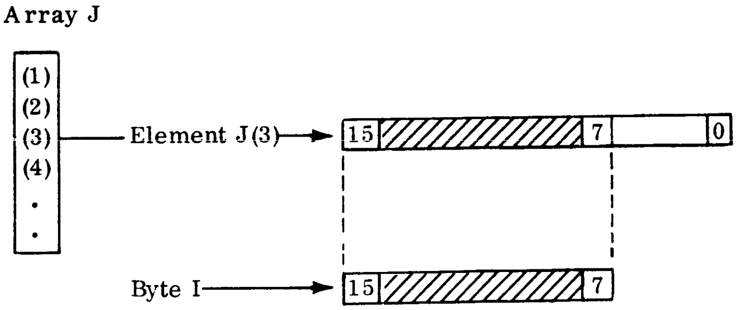
c and d are positive integer constants with the range $15 \geq c \geq d \geq 0$

All arrays must be previously dimensioned (Appendix G).

The simplest forms of the byte statements are the cases where a is an integer variable and b is an integer variable or an integer array element.

Example:

BYTE (I, J(3) (15=7))



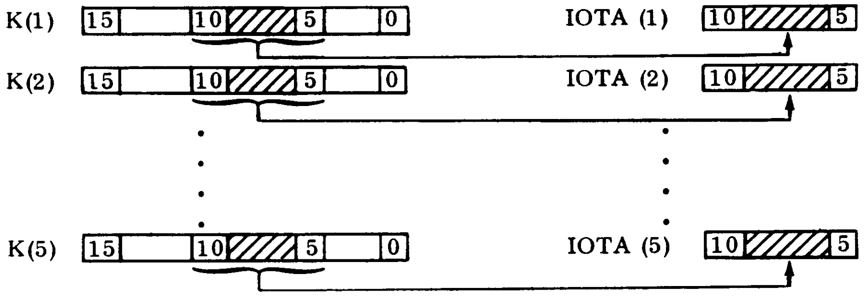
Byte I is defined as the segment from bit 15 to bit 7 of the third element of array J

When a is an integer array, b must be an integer array or an integer array element.

Examples:

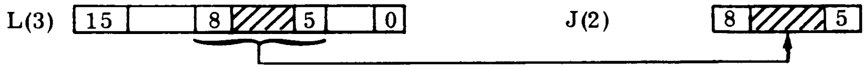
1. With b an array:

DIMENSION K(7), IOTA (5)
BYTE (IOTA(1), K(1) (10=5))



2. With b an array element:

DIMENSION J(3), L(5)
BYTE (J(2), L(3) (8=5))



If a_i is an array name, then each element of the array will be such a byte of the corresponding element of b_i. The statement acts as an EQUIVALENCE, extending the size of b_i as much as is necessary to accommodate a_i; the number of byte statements permissible follows the same rules as the EQUIVALENCE statements.

If t is BYTE, a_i will be treated as a positive integer. The exception is if $c_i = 15$ and $d_i = 0$. In this case, a_i is treated as signed.

If t is SIGNED BYTE, a_i is treated as a signed integer. A signed byte of a single bit will be treated as zero. The byte is stored in one's complement form. The high order bit is thus a sign bit. In both cases, a_i will be type integer.

A byte variable or array is treated as an integer variable or array in the list of an I/O statement, as an argument for an intrinsic function, or as a parameter in the subroutine or function statement calls.

Formal parameters specified in SUBROUTINE or FUNCTION statements may be referenced in BYTE statements (Section 7.4).

6.2 DATA STATEMENT

The DATA statement is used to assign constant values to variables or arrays at the time of compilation; therefore, it is not executable.

The format is

$$\text{DATA } k_1/d_1/, k_2/d_2/, \ldots, k_n/d_n/$$

Where: k is a list containing names of variables, arrays, array elements, and implied DO loops.

d is a list of optionally signed numeric constants or literal constants, any of which may be preceded by J*. When the form J* appears before a constant, it indicates that the constant is to be repeated J times. J must be an integer constant. There must be a one-to-one correspondence between the list-specified items and the constants.

If an array or elements of an array are to be assigned values by a DATA statement, the array must have been previously dimensioned and each element may be listed separately in the DATA statement.

The DATA statement may be used with labeled common (only in a BLOCK DATA subprogram, Section 7.4.7) but not with blank common. The list k may not include byte or dummy arguments (Section 7.1). Values assigned may be redefined during execution, but not by a DATA statement, since its action terminates at compile time.

Arrays may be assigned values with an implied DO of the form:

$(A(I), I=l_1 l_2)$ or $(A(I), I=l_1, l_1, l_2)$

$((A(I, J), I=l_1, l_2), J=l_1, l_2)$ or $((A(I,J), I=l_1, l_2, l_3,\ J=l_1, l_2, l_3)$

$(((A(I, J, K), I=l_1, l_2), J=l_1, l_2), K=l_1, l_2)$ or $(((A(I, J, K), I=l_1, l_2, l_3,\ J=l_1, l_2, l_3)\ K=l_1, l_2, l_3)$

For each k_n

A is the name of a previously defined array.

I, J, K are the names of integer variables. The order of the subscripts must be maintained. Constants are not allowed as subscripts.

I_1 is a non-zero positive integer constant for initial value; may not be greater than limit value.

I_2 is a non-zero positive integer constant for limit value; may not be greater than the array's previously defined dimension.

I_3 is an optional non-zero positive integer constant for increment value; equals 1 if not expressed.

Implied DO loop examples:

```
DATA (A(I),I=1,5) /1.0,2.0,3.0,4.0,5.0/

DATA ((A(I,J),I=1,3,2),J=1,5,2) /2*1.0,2*2.0,3.0,4.0/

DATA (A(I),I=1,10,2),(B(J),J=1,4) /9*'ABCD'/,K/8/
```

If the implicit type of a variable does not agree with its declared type, for example, (REAL I), then a DATA statement assigning a value to that variable must appear after the type is declared.

Examples:

```
Illegal     DATA I/3.5/
            REAL I

Legal       REAL I
            DATA I/3.5/
```

LITERALS IN DATA STATEMENT

Numeric constants are right-justified with leading zeros and literal constants are left-justified with trailing blanks.

The simple general form is:

```
DATA R,I/'AAAA','BB'/
```

This stores $4141 $4141 into R and $4242 into I.

The alternate equivalent form is:

```
DATA R/'AAAA'/,I/'BB'/
```

There must be a matching total set of data for the total elements specified.

```
Illegal     DATA R,I/'AAAA'/

Legal       DATA R,I/'AA','B'/
```

This stores $4141 $2020 into R and $4220 into I.

```
DATA I(1),I(2),I(3)/3*'AB'/
        or
DATA I/3*'AB'/
        or
DATA (I(K),K=1,3)/3*'AB'/
```

This stores $4142 $4142 $4142 into array I.

Blank within quotes, as well as other legal characters allowed by the compiler except another quote, will be stored in their corresponding ASCII hexadecimal value.

6.3 FORMAT STATEMENT

The following section applies to the FORTRAN I/O run-time package only.

Formatted READ and WRITE statements must be accompanied by a FORMAT statement which defines the field and data type of each element in the I/O list. The whole set enclosed in parentheses is the format specification.

The format is:

FORMAT $(q_1 t_1 z_1 t_2 z_2 \ldots t_n z_n q_n)$

Where: q is a set of one or more slashes or is empty

t is a field descriptor or a group of field descriptors

z is a field separator which is either a comma or a slash

Some representative combinations of the FORMAT statement form are the following:

(q_1	t_1	z_1	t_2	z_2	t_3	z_3	t_4	z_4	q_2)
(	3I5	,	E10.2	,	2F10.4				)
(//	5F10.5	,	3I1	/	10I10	,	E12.6		)
(	3A3	,	A1	,	3R3	,	R1		//)
(	1H0	,	5E12.6	,	3HEND				)

The FORMAT statement is nonexecutable. It must appear in the same program unit as the I/O statement and it must have a statement label. The label may be assigned in an ASSIGN statement. The assign variable and label can be from a different program unit. The type of field descriptor determines the type of specification. A conversion specification contains field descriptors for converting information; an editing specification contains field descriptors for editing information

6.3.1 FIELD DESCRIPTORS

The format field descriptors are of the following forms:

rFw.d	Single-precision floating-point without exponentiation	
rEw.d	Single-precision floating-point with exponentiation	
rDw.d	Double-precision floating-point with exponentiation	
rIw	Decimal integer conversion	
r$w or rZw	Hexadecimal conversion	
rAw	Alphanumeric conversion	
rRw	Alphanumeric conversion	
$nHh_1h_2,\ldots,h_n$	Heading and labeling	Editing specifications
nX	Spacing factor	
Asterisk	*String of ASCII characters*	
or		
Quote	'String of ASCII characters'	

1. The symbols F, E, D, I, $, Z, A, R, H, and X are the conversion codes; they indicate the manner of conversion and editing between the internal and external representation.

2. w and n are non-zero integer constants representing the width of the field in the external character string.

3. d is an integer constant representing the number of digits in the fractional part of the external character string.

4. r, the repeat count, is an optional non-zero integer constant indicating the number of times to repeat the succeeding basic field.

5. Each h_i is one of the characters in the FORTRAN character set.

For all descriptors other than Hollerith literals, the field width must be specified. For descriptors of the form w.d, the d must be specified, even if it is zero. Furthermore, w must be greater than or equal to d. The number of characters produced by an output conversion should not exceed the field width. If so, data is not transferred and the output field is filled with asterisks.

The phrase basic field descriptor will be used to signify the field descriptor unmodified by r.

6.3.2 FIELD SEPARATORS

The format field separators are the slash and the comma. A series of slashes is also a field separator. The field descriptors or groups of field descriptors are separated by a field separator.

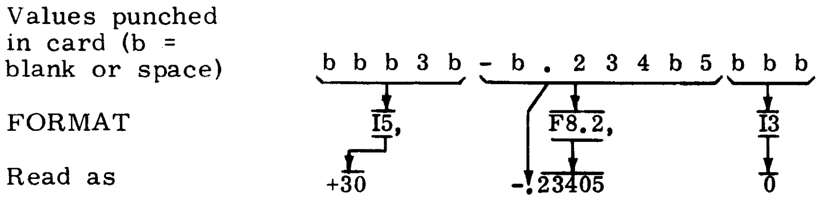
6.3.3 NUMERIC CONVERSION

The numeric field descriptors Iw, Fw.d, Ew.d, Dw.d, Zw and $w are used to specify the I/O of integer, real, and double-precision data. The following rules apply to all numeric conversions.

1. Leading blanks are not significant and other blanks are zeros. Plus signs may be omitted. A field of blanks is zero.

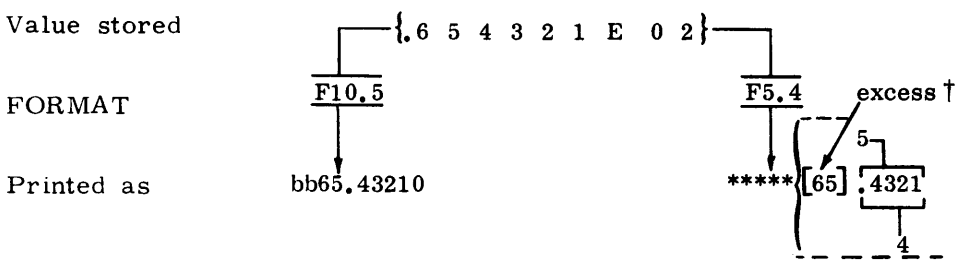
2. In input conversion of floating-point numbers, a decimal point in the input field overrides the decimal point specification in the FORMAT statement.

   Examples:


Values punched in card (b = blank or space)
b b b 3 b - b . 2 3 4 b 5 b b b
FORMAT
I5,
F8.2,
I3
Read as
+30
-.23405
0

3. In numeric output conversions, the output field is right-justified and blanks are inserted if the number of characters produced by the conversion is less than the specified field width.

   Examples:



4. If the conversion produces a negative value, the output field will be signed. A positive value will be unsigned, except for the exponent in an E or D conversion which will always be signed.

5. If the number of characters produced is greater than the field width, the data is not transferred and the output field is filled with asterisks.

6.3.3.1 INTEGER CONVERSION

The specifications for integer conversion are Iw for decimal and $w or Zw for hexadecimal.

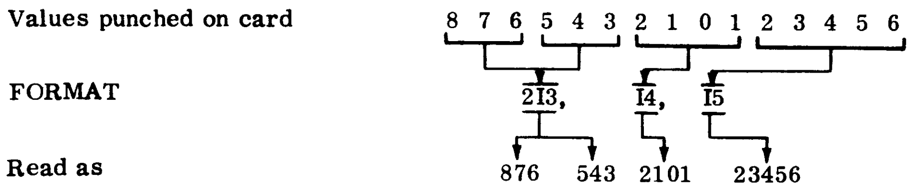
† Only asterisks are printed because the number is too large for the field.

Iw INPUT

Iw specification is used to input decimal integer values. The input field consists of an integer subfield and may contain only the characters +, -, 0 through 9, or blank. When a sign appears, it must precede the first digit justified in the specified variable.

Blanks are interpreted as zeros. The value is stored right-justified in the specified variable.

Example:



Iw OUTPUT

Iw specification is used to output decimal integer values; the corresponding list element must be a decimal integer quantity. The output quantity occupies w output record positions right-justified in the field w as

Δsd,. . . ,d

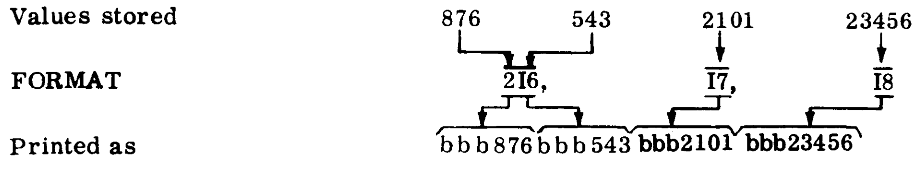
Where: Δ is a possible blank fill

s is the sign; minus if negative, blank or suppressed if positive.

d,. . . ,d are the most significant decimal digits of the integer (maximum absolute value is 32,767).

If the field w is larger than the number required, the output quantity is right-justified with blank fill on the left. If the field is too short, it is filled with asterisks.

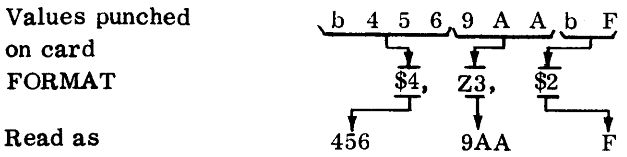
Example:



$w OR Zw INPUT

$w or Zw specification is used to input hexadecimal integer values. The input field w consists of a string of hexadecimal integer characters; blanks are interpreted as zero.

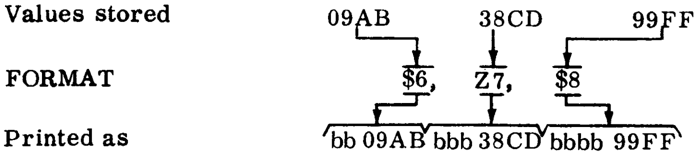
Example:



$w OR Zw OUTPUT

$w or Zw specification is used to output hexadecimal integer values. The output quantity occupies w output record positions right-justified in the field w. It is an unsigned hexadecimal integer value, with a maximum absolute value of FFFF.

Example:



6.3.3.2 REAL CONVERSION

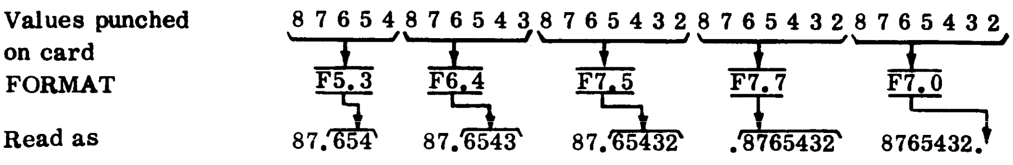
The specifications for real conversion are Fw.d and Ew.d.

Fw.d INPUT

The field descriptor Fw.d indicates that the external field occupies w positions, the fractional part of which consists of d digits. The field is scanned from left to right and embedded blanks are interpreted as zeros.

The basic input field consists of an optional sign followed by a string of digits which may contain a decimal point. If the decimal point is present, it will override the d specification of the field descriptor.

Example:



Fw.d OUTPUT

The basic output field occupies w positions. The corresponding list element must be a floating-point quantity which will appear as a decimal number, right-justified in field w with possible leading blanks, as

$\Delta s\ x_1, \ldots, x_n$

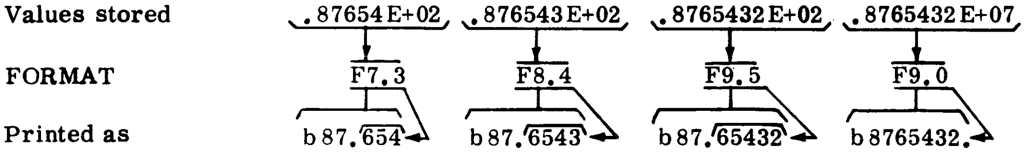
Where: Δ is a possible blank fill

s is the sign; minus if the number is negative, blank or omitted if the number is positive

$x_1, \ldots, x_n$ is a string of digits containing a decimal point. The number of digits to the right of the decimal point is specified by d in the Fw.d. If d is zero, the digits to the right of the decimal point do not appear. d may contain a maximum of 19 digits.

If the field is too short to accommodate the number, asterisks fill the output field. If the field w is longer than required, the number is right-justified with blank fill to the left.

Example:



Ew.d INPUT

The number in the input field w is converted to a floating-point number and stored. The total number of characters in the input field is specified by w. The field is scanned from left to right and embedded blanks are interpreted as zeros.

The basic input field consists of an optional sign followed by a string of digits which may contain a decimal point. The basic field may be followed by an exponent of one of the following forms:

- Signed integer constant
- E followed by an integer constant
- E followed by a signed integer constant

The value of the exponent must not exceed ±39 after normalization of the input field. The normalized number is the mantissa and the characteristic.

+1.327

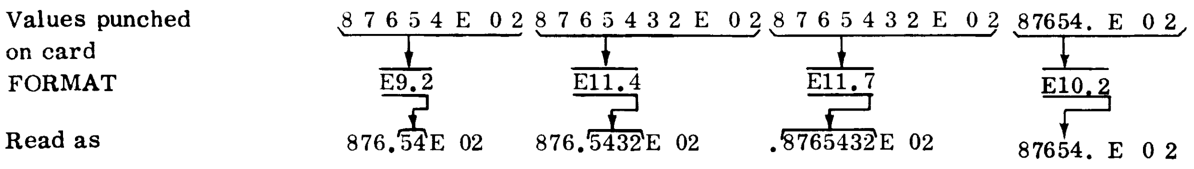
Permissible combinations:

+1.327E-04	Integer fraction exponent
-32.721	Integer fraction
+328E+5	Integer exponent
.629E-1	Fraction exponent
+136	Integer only
.0762	Fraction only

Normalized as	Mantissa	Characteristic
	.1327	E - 03
	-.32721	E + 02
	.328	E + 08
	.629	E - 01
	.136	E + 03
	.762	E - 01

A decimal point in the input number will always override d. The field length specified by w in Ew.d should always be the same as the length of the input field containing the input number. When it is not, incorrect numbers may be read, converted, and stored. The field w includes the significant digits, signs, decimal point, E, and exponent.

Example:



Ew.d OUTPUT

For output, floating-point numbers in storage are converted to the FORTRAN character form. The field occupies w positions in the output record; the corresponding floating-point number appears right-justified in the field as

$\Delta s0.x_1, \ldots, x_n E\pm ee \qquad 0 \leq ee < 39$

Where: Δ is a possible blank fill

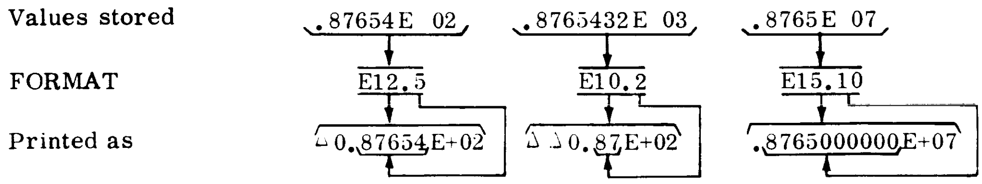
s is the optional sign: minus if negative, blank or suppressed if positive

$x_1, \ldots, x_n$ are the n most significant rounded digits of the value of the output data

ee are the digits of the exponent

Field w must be long enough to contain the specified number of digits, signs, decimal point, and exponent. For E conversion, w must be greater than or equal to d+7. The maximum number of digits in d is 19. If field w is too small to contain the output value, asterisks fill the field. If the field is longer than the output value, the number is right-justified with blank fill to the left.

Example:



6.3.3.3 DOUBLE-PRECISION CONVERSION

The specification for double-precision conversion is Dw.d.

Dw.d INPUT

The number in the input field w is converted to a double-precision floating-point number and stored. The total number of characters in the input field is specified by w. The field is scanned from left to right and embedded blanks are interpreted as zeros.

The basic input field consists of an optional sign followed by a string of digits which may contain a decimal point. The basic field may be followed by an exponent of one of the following forms:

- Signed integer constant
- D (or E) followed by an integer constant
- D (or E) followed by a signed integer constant

The value of the exponent must not exceed ±39 after normalization of the input field. The normalized number is the mantissa and the characteristic.

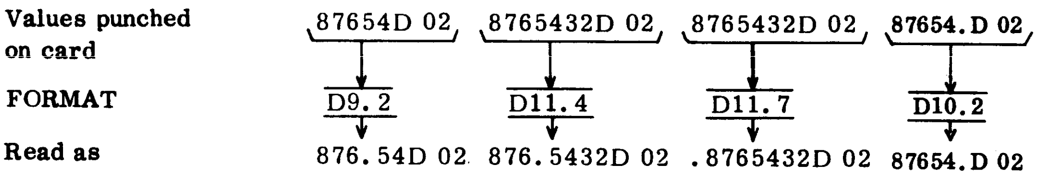
Permissible combinations:

+1.327D-04	Integer fraction exponent
-32.721	Integer fraction
+328D+5	Integer exponent
.629D-1	Fraction exponent
+136	Integer only
.0762	Fraction only

Normalized as	Mantissa	Characteristic
	.1327	D - 03
	-.32731	D + 02
	.328	D + 08
	.629	D - 01
	.136	D + 03
	.762	D - 01

A decimal point in the input number will always override d. The field length specified by w in Dw.d should always be the same as the length of the input field containing the input number. When it is not, incorrect numbers may be read, converted, and stored. The field w includes the significant digits, signs, decimal point, D, and exponent.

Example:



Values punched on card	87654D 02	8765432D 02	8765432D 02	87654.D 02
FORMAT	D9.2	D11.4	D11.7	D10.2
Read as	876.54D 02	876.5432D 02	.8765432D 02	87654.D 02

Dw.d OUTPUT

For output, double-precision floating-point numbers in storage are converted to the FORTRAN character form. The field occupies w positions in the output record; the corresponding double precision floating point number appears right-justified in the field as:

$\Delta s0.x_1,\ldots,x_n D\pm dd \qquad 0 \leq dd < 39$

Where: Δ is a possible blank fill

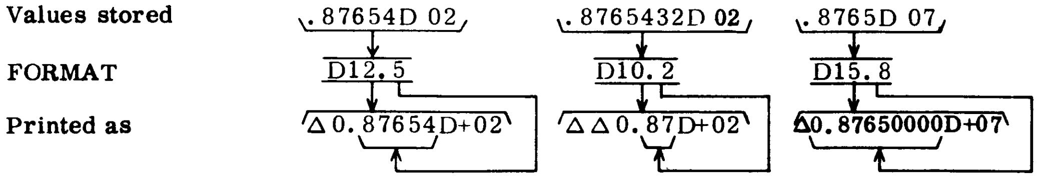
s is the sign; minus if negative, blank or suppressed if positive

$x_1,\ldots,x_n$ are the n most significant rounded digits of the value on the output data

dd are the digits of the exponent

Field w must be long enough to contain the specified number of digits, signs, decimal point, and exponent. For D conversion, w must be greater than or equal to d+7. The maximum number of digits in d is 10. If the field w is too small to contain the output value, asterisks fill the field. If the field is longer than the output value, the number is right-justified with blank fill to the left.

Example:



Values stored	.87654D 02	.8765432D 02	.8765D 07
FORMAT	D12.5	D10.2	D15.8
Printed as	Δ0.87654D+02	ΔΔ0.87D+02	Δ0.87650000D+07

6.3.4 ALPHANUMERIC CONVERSION

Aw and Rw specify I/O of alphanumeric data. The internal representation is ASCII. Refer to Appendix H for ASCII code.

Aw I/O

On input, the Aw specification accepts as list elements any two Hollerith characters. If the field width w is two or more, the rightmost two characters from the external input field are stored as the list element. If w equals one, the character from the external input field is left-justified in storage with a trailing blank.

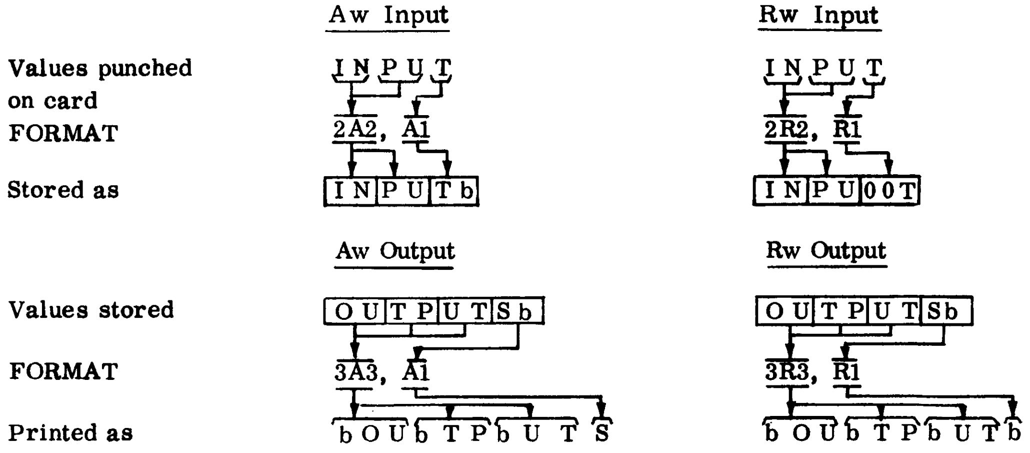
The A conversion outputs w Hollerith characters from a two-character list element. If w is two or more, the two characters from memory appear right-justified in the external output field preceded by blanks. If w equals one, the leftmost character from memory is stored in the output field.

Rw I/O

This specification is the same as the Aw specification with the following exceptions.

- On input, if w equals one, the character taken from the external input field is right-justified in storage with a leading hexadecimal 00.
- On output, if w equals one, the rightmost character from memory is stored in the output field.

Examples:



6.3.5 EDITING SPECIFICATIONS

Editing specifications are used to provide alphanumeric headings and comments, define spacing between characters and lines, skip records, and begin new records.

nH INPUT

On input, the H specification is used to place Hollerith characters in a pre-existing format. The n is an unsigned integer specifying the number of characters to the right of H that are to be placed in the format.

Unlike the A and R specifications, the characters input by an H specification are not stored in memory to be referenced by a symbolic name; instead, they are placed in a FORMAT statement already established in the source program. A READ instruction referencing this FORMAT statement will obtain a set of characters from an input device, such as a punched card, and place them in the FORMAT specification, replacing characters previously established.

Example:

The source program contains the instruction

```
READ (1, 15)

15 FORMAT (22HREPLACE THIS STATEMENT)
```

When this instruction is executed with the following input card

```
DETERMINATION OF SIGMA
```

the heading DETERMINATION OF SIGMA is placed into FORMAT 15, replacing the character set REPLACE THIS STATEMENT.

Subsequently, the output statement

```
WRITE (3, 15)
```

would produce the printed line

```
DETERMINATION OF SIGMA.
```

The number of characters in the H input must exactly equal the number of characters pre-established in the FORMAT. If necessary, blanks can be used to balance out the input. It is immaterial what characters appear in the original source program FORMAT. In the preceding example, the instruction could be written

```
READ (1, 15)

15 FORMAT (22H^^^^ ^^^^^^^^^^^^^^^^^^)
```

The value of the H input specification lies in the flexibility it gives in varying a FORMAT specification at time of execution.

nH OUTPUT

This specification provides for the output of any set of Hollerith characters, including blanks, in the form of comments, titles, and headings. n is an unsigned integer specifying the number of characters to the right of H that will be transmitted to the output record. H denotes a Hollerith field.

Examples:

Source program

```
WRITE(3,20)
20 FORMAT(28H BLANKS COUNT IN AN H FIELD.)
```

produces output record

```
BLANKS COUNT IN AN H FIELD.
```

Source program

```
A = 1.5
WRITE(3,30)A
30 FORMAT(6H LMAX=,F5.2)
```

produces output record

```
LMAX= 1.50
```

LITERAL FREE-FIELD I/O

The literal free-field descriptor causes Hollerith information to be read into or written from the characters specified between two delimiters. The delimiters may be asterisks or single quotes. If the delimiters are asterisks, then embedded asterisks are not allowed. If the delimiters are single quotes, then embedded single quotes are not allowed.

Example:

```
          WRITE (3,20)
       20 FORMAT (* THIS IS A FREE FIELD FORMAT*)
or     20 FORMAT (' THIS IS A FREE FIELD FORMAT')
```

produces the output record

```
THIS IS A FREE FIELD FORMAT
```

6.3.6 NEW RECORD SPECIFICATIONS

A slash, signalling the end of an ASCII record, may appear anywhere in a FORMAT statement. It need not be separated by commas. A slash at the end of a FORMAT causes a record to be skipped, since the end of the list itself signals the end of a record. Likewise, a slash at the beginning of a FORMAT skips a record since the initiation of the list is itself a new record. Multiple slashes can be used to skip a number of records; however, the repeat specification does not apply to the slash. N slashes in the middle of a FORMAT skips N-1 records since the first slash merely signals a new record. N slashes at the beginning or end of a FORMAT list skips N records.

Examples:

These examples refer to the reading of records. They apply equally to output statements.

FORMAT(I2/F10.5)	Reads two records in succession
FORMAT(I2//F10.5)	Reads first record, skips second record, and reads the third record
FORMAT(I2////F10.5)	Reads one record, skips three, and reads the fifth
FORMAT(I2,F10.5/)	Reads one record and skips one record
FORMAT(I2/F10.5//)	Reads one record with I2, reads a second record with F10.5, and then skips two records
FORMAT(///F10.5)	Skips three records and reads a fourth with F10.5

6.3.7 BLANK FIELD SPECIFICATION

The general form of this specification is nX, where n is the number of blank spaces to be skipped on input or the number of blanks to be inserted in output.

Examples:

nX INPUT

The following values are to be read from a card:

X = 0.54321

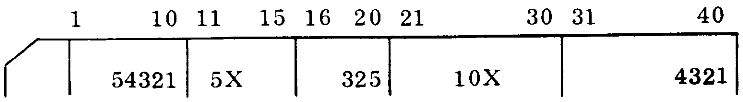
Y = 3.25

I = 4321

The input statements

```
    READ(1,20)X,Y,I
 20 FORMAT(F10.5, 5X, F5.2, 10X, I10)
```

will interpret the input card as follows:



nX OUTPUT

The following values are to be printed out.

IOTA	=	7
ALPHA	=	13.6
BETA	=	1462.37

The output statements

```
      WRITE(3,44)IOTA, ALPHA, BETA
   44 FORMAT(I2,6X,F6.2,7X,E12.5)
```

prints out

```
I2           F6.2    7X           E12.5
 7       13.60        0.14623E+04
```

6.3.8 REPEATED FORMAT SPECIFICATIONS

Any format specification may be repeated by using a positive integer repetition constant r as follows:

r (spec)

Where: spec is any conversion specification except nX or nH.

Example:

```
      WRITE (3,10) I,K,A,B,C
   10 FORMAT (I2,I2,F8.4,F8.4,F8.4)
```

could be written

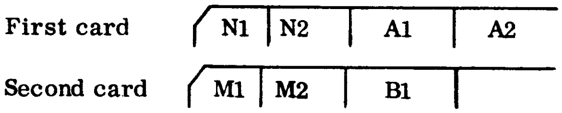
```
      WRITE (3,10) I,K,A,B,C
   10 FORMAT (2I2,3F8.4)
```

Only one level of group repeat is allowed; group repeats may not be nested.

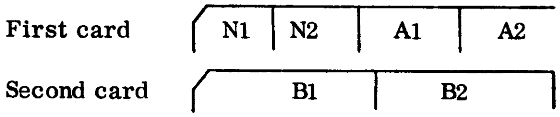
When the format control reaches the last outer right parenthesis of the specification, a test is made to determine if the I/O list is exhausted. If it is, control terminates. If another list element is specified, control returns to the group repeat specification terminated by the last preceding outer right parenthesis. If no repeat specification exists, control returns to the first left parenthesis of the specification.

Examples:

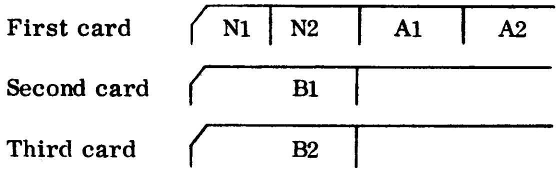
```
    READ(1,10)N1,N2,A1,A2,M1,M2,B1
 10 FORMAT (2I2,2F6.2)
```



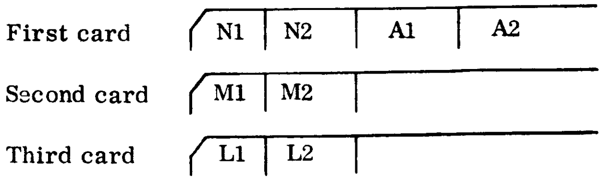
```
    READ(1,11)N1,N2,A1,A2,B1,B2
 11 FORMAT (2I2,(2F6.2))
```



```
    READ(1,12)N1,N2,A1,A2,B1,B2
 12 FORMAT(2I2,2(F6.2))
```



```
    READ(1,13)N1,N2,A1,A2,M1,M2,L1,L2
 13 FORMAT((2I2),2F6.2)
```



6.3.9 FORMAT SPECIFICATION IN ARRAYS

The formatted READ and WRITE statements may contain an array name in place of the reference to a FORMAT statement label. When an array is referenced in such a manner, the first part of the information contained in the array, taken in the natural order, must constitute a valid format specification. There are restrictions on the information contained in the array following the right parenthesis that ends the format specification. The format specification which is to be inserted in the array has the same form as that defined for a FORMAT statement; that is, it begins with a left parenthesis and ends with a right parenthesis. The format specification may be inserted in the array by use of a READ statement together with the A format or by use of a DATA statement. If the ANSI option is used, the integer array containing the format must be typed SINGLE.

Example:

```
      DIMENSION IFMT (40)
      READ (1,20) (IFMT (1), I=1,40)
   20 FORMAT (40A2)
      READ (1,IFMT) A
```

Source data

```
   (1H1,5X,  'OBJECT ^ TIME ^ FORMATTING'/6X,F6.2)
```

PROCEDURES AND SUBPROGRAMS 7

A FORTRAN program consists of a main program with or without auxiliary procedures and subprograms. Auxiliary sets of statements are used to evaluate frequently used mathematical functions, to perform repetitious calculations, and to supply data specifications and initial values to the main program. 1700 MS FORTRAN provides six procedures and subprograms:

- Statement function
- Intrinsic function
- Basic external function
- External function
- External subroutine
- Block data subprogram

The intrinsic function and the basic external function are furnished with the system. They are used to evaluate standard mathematical functions. The others are user-defined. The statement function and intrinsic function are compiled within the main program, the basic external function is furnished with the system, and the others are compiled separately. The first five are referred to as procedures, since each is an executable unit that performs its set of calculations when referenced. The first four are called functions; they return a single result to the point of reference. The last three are subprograms; they are user-defined and are compiled independently. The block data subprogram supplies specifications and initial values to labeled common. Table 7-1 outlines these categorical divisions.

Use of procedures and subprograms is determined by their individual capabilities. If the program requires the evaluation of a standard mathematical function, then an intrinsic function or a basic external function is used (Tables 7-3 and 7-4). If a single nonstandard computation is needed repeatedly, a statement function is inserted in the program. If a number of calculations are required to obtain a single result, a function subprogram is written; if a number of calculations are required to obtain an array of values, a subroutine is written. When the program requires initial values in labeled common, a BLOCK DATA subprogram is used.

Table 7-1. Subdivision of Procedures and Subprograms

<table>
<tr><th>STATEMENT FUNCTION</th><th>INTRINSIC FUNCTION</th><th>BASIC EXTERNAL FUNCTION</th><th>EXTERNAL FUNCTION</th><th>EXTERNAL SUBROUTINE</th><th>BLOCK DATA SUBPROGRAM</th></tr>
<tr><td>User-defined</td><td colspan="2">Compiler-defined</td><td colspan="3">User-defined</td></tr>
<tr><td colspan="2">Compiled within the referencing program</td><td>Not compiled
— LIBRARY —</td><td colspan="3">Compiled externally to the referencing program</td></tr>
<tr><td colspan="5">PROCEDURE: Any defined calculation that can be referenced and which will exchange values between reference and definition through a list of arguments.</td><td rowspan="4"></td></tr>
<tr><td colspan="2"></td><td colspan="3">EXTERNAL PROCEDURE: A procedure defined externally to the program unit that references it.</td></tr>
<tr><td colspan="4">FUNCTION: A procedure that supplies a single result to be used at the point of reference.</td><td rowspan="2"></td></tr>
<tr><td colspan="2"></td><td colspan="2">EXTERNAL FUNCTION: A function defined externally to the program unit that references it.</td></tr>
<tr><td colspan="3" rowspan="2"></td><td colspan="3">SUBPROGRAM: A user-defined set of statements compiled independently of the program unit which references it or to which it supplies specifications and initial values.</td></tr>
<tr><td colspan="2">PROCEDURE SUBPROGRAM: An external procedure that is defined by FORTRAN statements.</td><td>SPECIFICATION SUBPROGRAM: A subprogram without reference that supplies specifications and initial values to labeled common.</td></tr>
</table>

7.1 ARGUMENTS

7.1.1 ACTUAL

Procedures exchange values with referencing programs through argument lists. Arguments in the list of a referencing program are called actual arguments since they represent actual values relative to the referencing program.

7.1.2 DUMMY

Arguments listed in the procedure definition are called dummy arguments since they serve to exchange values between the reference list and the procedure calculations. Because of one-to-one correspondence, actual arguments and dummy arguments must agree in order, number, and type. A list of arguments that can be used with functions and subroutines is given in Table 7-2.

7.2 STATEMENT FUNCTION

A statement function is defined by a single statement in the program unit in which it is referenced. It must precede the first executable statement of the program unit and follow the specification statements, if any. During compilation, the statement function definition is compiled once at the beginning of the program; a transfer to this definition is generated whenever the statement function reference appears as an operand in an expression.

The format is:

$f(a_1, a_2, \ldots, a_n)=e$

Where: f is the symbolic name of the function

a is a dummy argument (at least one must be included)

e is a defining arithmetic expression

The statement function is referenced by the appearance of its symbolic name followed by a list of actual arguments in an arithmetical or logical expression. Execution of the statement function calculation returns a single value to the reference.

Example:

The following program calculates various parameters of a set of circles (one to ten). Input is an array of diameters (DIAM). The calculations include the determination of area, arc length, and circumference. These are given by statement functions at the beginning of the program which are referenced as needed.

Table 7-2. Permissible Arguments for Functions and Subprograms

	ACTUAL ARGUMENTS	FORMAL ARGUMENTS
STATEMENT FUNCTION	Constant Variable Array element Arithmetic expression	Variable
INTRINSIC FUNCTION	(Refer to Table 7-3)	
BASIC EXTERNAL FUNCTION	(Refer to Table 7-4)	
EXTERNAL FUNCTION	Constant Variable Array element Array name Any expression The name of an external procedure A BYTE or SIGNED BYTE variable if 1. It is passed as an integer (16 bit) variable or array, and 2. It is specified as BYTE or SIGNED BYTE in the FUNCTION or SUBROUTINE definition. For subroutine only: The name of the current procedure.	Variable Array name External procedure name (May not appear in COMMON or DATA statement)
EXTERNAL SUBROUTINE		

Note: Actual arguments and their corresponding formal arguments must agree in order, type, and number.

```
      PROGRAM CIRCLE
      DIMENSION DIAM (10)
      AREA (RADIUS) = 3.14159 * RADIUS * RADIUS
      ARC (D, THETA) = 0.5 * D * THETA
      CIRCUM (D) = 3.14159 * D
           .
           .
           .
      X = CIRCUM (DIAM(I))
           .
           .
           .
      Y = ARC(DIAM(I), ANGLE)
           .
           .
           .
      Z = AREA(A+I)
           .
           .
           .
      END
```

Explanation: The first reference is contained in the statement:

```
X=CIRCUM(DIAM(I))
```

in which the subscript I has been determined by calculations in the program. This reference places the actual argument DIAM(I) in the statement function:

```
CIRCUM(D)=3.14159*D
```

via the dummy argument D. The calculation is made and a single value for CIRCUM is returned to the referencing statement. The next reference supplies two actual arguments, DIAM(I) and ANGLE, to the statement function for ARC through the dummy arguments D and THETA. A single value for ARC is returned to the referencing statement.

The third reference uses an arithmetic expression, A+I, for an actual argument. This enters the statement function calculation for AREA through the dummy argument RADIUS. A single value for AREA is returned to the referencing statement.

7.3 SUPPLIED FUNCTIONS

To evaluate frequently used mathematical functions, 1700 MS FORTRAN supplies predefined calculations as well as references to library routines contained in the system. The predefined calculations are called intrinsic functions, and the references to the library routines are called basic external functions.

The intrinsic function inserts simple sets of calculations into the object program at compile time. The basic external function deals with more complex evaluations by inserting a reference to a library routine in the object program. The names of the supplied functions, their data types, and permissible arguments are predefined (Tables 7-3 and 7-4). References using these functions must adhere to the format defined in the tables. The type of a supplied function cannot be changed by a type statement.

Table 7-3. Intrinsic Functions

INTRINSIC FUNCTIONS	DEFINITION	NUMBER OF ARGUMENTS	SYMBOLIC NAME	TYPE OF ARGUMENT	TYPE OF FUNCTION
Absolute value	$\|a\|$	1	ABS IABS DABS	Real Integer Double	Real Integer Double
Float	Conversion from integer to floating point	1	FLOAT DFLT	Integer Integer	Real Double
Fix	Conversion from floating point to integer	1	IFIX DFIX	Real Double	Integer Integer
Transfer of sign	Sign of a_2 times $\|a_1\|$ The sign of 0 is +.	2	SIGN ISIGN DSIGN	Real Integer Double	Real Integer Double
Obtain most significant part of double-precision argument		1	SNGL	Double	Real
Express single-precision argument in double-precision form		1	DBLE	Real	Double
Logical sum	Form the bit by bit logical sum of a_1 and a_2.	2	OR	Integer	Integer
Exclusive OR	Complement those bits of a_1 which are one in a_2.	2	EOR	Integer	Integer
Logical product	Form the bit by bit logical product of a_1 and a_2.	2	AND	Integer	Integer
Complement	Complement a_1	1	NOT	Integer	Integer

7.3.1 INTRINSIC FUNCTION

An intrinsic function is a compiler-defined set of calculations that is inserted in the referencing program at compile time. If the set involves only a few machine instructions, it is inserted in the program every time the reference appears. This method is called in-line code. The intrinsic functions IABS, OR, EOR, AND, and NOT produce in-line code. If the set of instructions needed to evaluate the intrinsic function is lengthy, it is compiled once at the beginning of the program; then a transfer to this set of calculations is generated whenever the function is referenced.

The intrinsic function is referenced by the appearance of the function name with appropriate arguments in an arithmetic or logical statement. A list of intrinsic functions is given in Table 7-3. The name of an intrinsic function listed in this table must satisfy all of the following requirements:

1. The name must not appear in an EXTERNAL or a RELATIVE statement (Sections 7.4.3 and 7.4.4), an array name or an array element, or be the name of a statement function (Section 7.2).
2. The name must not appear in a type statement (Section 6.1.4) declaring it to be other than the type specified in the table.
3. Every appearance of the name must be followed by a list of arguments enclosed in parentheses, unless the name is in a type statement.

The use of an intrinsic function in one program unit precludes the use of its name as the name of a different entity in another program unit in that same program. If a user-defined subprogram has the same name as an intrinsic function, the name of the subprogram must be further defined by a type declaration (Section 6.1.4) or by an EXTERNAL statement (Section 7.4.3).

7.3.2 BASIC EXTERNAL FUNCTION

A basic external function is a call on one of the predefined library routines included with the system. These library routines are used to evaluate standard mathematical functions such as sine, cosine, square root, etc. When a reference to a basic external function appears in an expression, the compiler identifies it and generates the calling sequence in the object program. A basic external function is referenced by the appearance of the function name with appropriate arguments in an arithmetic or logical statement. A list of basic external functions is given in Table 7-4.

NOTE

> The compiler does not generate the calculations for a basic external function; it generates the call to the library routine for that particular function in the object program. At execution time, illegal values input to the basic external functions in Table 7-4 will give predetermined results (Table 7-5).

Table 7-4. Basic External Functions

BASIC EXTERNAL FUNCTION	DEFINITION	NUMBER OF ARGUMENTS	SYMBOLIC NAME	TYPE OF ARGUMENT	TYPE OF FUNCTION
Exponential	e^a	1	EXP DEXP	Real Double	Real Double
Natural logarithm	log (a)	1	ALOG DLOG	Real Double	Real Double
Trigonometric sine	sin (a)	1	SIN DSIN	Real Double	Real Double
Trigonometric cosine	cos (a)	1	COS DCOS	Real Double	Real Double
Hyperbolic tangent	tanh (a)	1	TANH	Real	Real
Square root	$(a)^{1/2}$	1	SQRT DSQRT	Real Double	Real Double
Arctangent	arctan (a)	1	ATAN DATAN	Real Double	Real Double
End of file check on unit a	EOF (a) Check previous read on unit a for end-of-file. 2 is returned if none. 1 is returned if EOF.	1	EOF	Integer	Integer
Floating-point fault	IFALT (a) If a is 0, overflow is tested. If a is 1, divide fault is tested. If a is 2, underflow is tested. A 2 is returned if the condition has not occurred, a 1 otherwise.	1	IFALT	Integer	Integer
Parity error check on unit	IOCK (a) Check previous read or write on unit a for parity error. 2 is returned if none. 1 is returned if parity error occurred.	1	IOCK	Integer	Integer

Table 7-5. Basic External Functions, Predetermined Results

BASIC EXTERNAL FUNCTION	ARGUMENT VALUE	RESULT
SIN or COS	$/Z/ > 2^{21}$	0
EXP	$/Z/ > 88.02968$	∞
ALOG	$Z \leq 0$	∞
SQRT	$Z < 0$	$-\sqrt{/Z/}$
DSIN or DCOS	$/Z/ > 2^{21}$	0
DEXP	$/Z/ > 88.02968$	∞
DLOG	$Z \leq 0$	∞
DSQRT	$Z < 0$	$-\sqrt{/Z/}$

7.4 SUBPROGRAMS

Subprograms are used to implement programming capability beyond the limitations of supplied functions and the statement function. Although written as a subset of another program, the subprogram is compiled separately; it has its own independent variables, and its use is not limited to communication with the program for which it was written. Procedure subprograms handle routine calculations unique to the user; specification subprograms are used to enter values into labeled COMMON and to supply such program information as is given by DIMENSION, DATA, EQUIVALENCE, and COMMON statements.

Procedure subprograms may be function or subroutine. In both cases, a series of FORTRAN statements is used to perform a calculation in conjunction with another program that calls it into operation. Subprograms are called either by the appearance of the name in an arithmetic or logical statement (function subprogram) or by a CALL statement (subroutine subprogram). Distinctive features of procedure subprograms include the ability to pass array names and external procedure names as arguments (Section 7.4.3). A BYTE or SIGNED BYTE may become an argument in a reference to a subprogram. The user is reminded that only the address of the BYTE or SIGNED BYTE is passed to the subprogram.

A subprogram returns control to a calling program through one or more RETURN statements or by an assigned GO TO statement, whose assign variable has been defined by an ASSIGN statement in the subprogram or in the calling program. If the ASSIGN statement is in the calling program, the assign variable must be passed as an actual argument or be in common.

Because they are independent programs, procedure subprograms must terminate with an END statement to signal to the compiler that the physical end of the source program has been reached. An END statement causes a return to the calling program and may replace a final RETURN statement.

Formal arguments specified in SUBROUTINE or FUNCTION statements may be referenced in EQUIVALENCE statements and BYTE statements.

Example:

```
      INTEGER FUNCTION TEST6 (A,B)
      INTEGER A(10), B(10)
      BYTE (IA2, A(2) (15=13))
      EQUIVALENCE (M, B(3))
      N = M + IA2
      TEST6 = N - IA2
      END
```

The fundamental differences between a function and subroutine subprogram are given in Table 7-6.

There is one type of specification subprogram, the block data subprogram.

Table 7-6. Differences Between Function and Subroutine Subprograms

FUNCTION	SUBROUTINE
Passes a value back to the calling statement	Does not pass a value back to the calling statement
Referenced by the name appearing in an arithmetic or logical statement	Referenced by a CALL statement
Must have one or more arguments	Need not have any arguments
Name is typed by first letter or by the type designation appearing before the word FUNCTION	No type associated with name

7.4.1 FUNCTION SUBPROGRAM

A function subprogram is a collection of FORTRAN statements headed by a FUNCTION statement and written as a separate program to perform a set of calculations when its name appears in an arithmetic or logical expression in the referencing program.

The format is

t FUNCTION f($a_1, a_2, \ldots, a_n$)

Where: t is the type designation: INTEGER, REAL, DOUBLE PRECISION, or empty

f is the symbolic name of the function to be defined

a_i are dummy arguments which may be variable names, array names, or external procedure names

The function subprogram accepts arguments from the referencing program through the argument list and through common. It returns a single value through the function name. The function name must be assigned a value by appearing at least once in the subprogram as a variable on the left side of an arithmetic statement or by appearing in the list of an input statement.

When a function reference is encountered in an expression, control transfers to the function subprogram indicated. When RETURN or END is encountered in the function subprogram, control returns to the statement containing the function reference, or an assigned GO TO statement transfers control to an indicated statement.

Example:

```
Referencing Program                Function Subprogram

PROGRAM IMPED                        FUNCTION VECTOR (X,Y)
          .                          Z=SQRT(X*X+Y*Y)
          .                          IF (Z)2,2,3
          .                        2 VECTOR=0.
RESULT=VECTOR (A,B)                  GO TO 5
          .                        3 VECTOR=Z
          .                        5 RETURN
          .                          END
END
```

The function subprogram is referenced by the appearance of the name and list in the statement

```
RESULT=VECTOR (A,B)
```

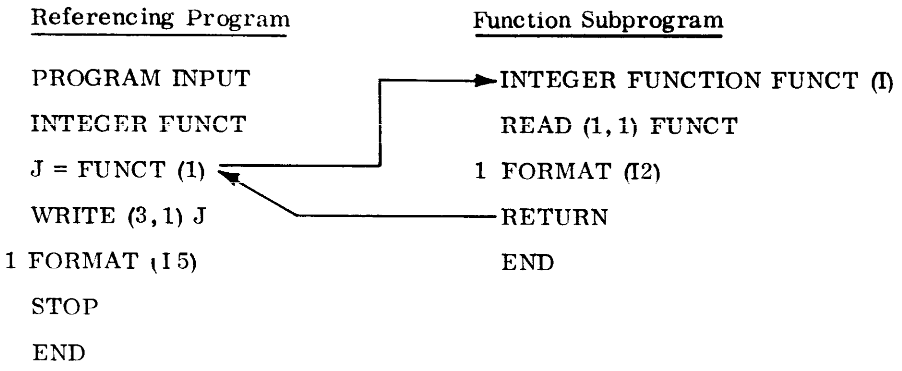
The values represented by the actual arguments A and B are communicated to the subprogram through the dummy arguments X and Y.

The function subprogram can also return results through its arguments and/or through common.

The first calculation in the subprogram involves the appearance of a secondary reference: SQRT. This reference passes the calculated value in the parentheses to the basic external function for obtaining a square root. The result is returned to the subprogram and placed in storage location Z. Z is then tested to see if it is positive. If not, function name VECTOR is equated to zero and that value is returned to the reference; if it is positive, function name VECTOR is equated to that positive value and returned to the reference.

The following example shows how a function subprogram can establish a value for the function name by using an input statement rather than an arithmetic statement.

Example:



```
  Referencing Program          Function Subprogram

  PROGRAM INPUT              ->INTEGER FUNCTION FUNCT (I)
  INTEGER FUNCT                READ (1,1) FUNCT
  J = FUNCT (1)              1 FORMAT (I2)
  WRITE (3,1) J                RETURN
1 FORMAT (I 5)                 END
  STOP
  END
```

Since the subprogram is intended to deal with integer values and its name is implicitly real, the name is typed integer in the referencing program and in the FUNCTION statement of the subprogram. The subprogram is referenced by the statement

```
J = FUNCT (1)
```

which arbitrarily passes the constant 1 as an actual argument. It enters the subprogram through dummy argument I in the FUNCTION statement but is never used. This step is performed solely to satisfy the requirements of a function subprogram. The subprogram reads in the value from a card and stores it in the location designated by the name of the function subprogram, where it is available to the referencing program which stores it in J and then prints it out.

7.4.2 SUBROUTINE SUBPROGRAM

A subroutine subprogram is a collection of FORTRAN statements headed by a SUBROUTINE statement and written as a separate program to perform a set of calculations when called by a referencing program.

The formats are:

SUBROUTINE s
SUBROUTINE s(a_1,a_2,...,a_n)

Where: s is the symbolic name of the subroutine to be defined

a is a dummy argument; it can be a variable name, array name, or external procedure name

A CALL statement transfers control from the calling program to the subroutine. A RETURN or END statement returns control to the next executable statement following the CALL statement in the referencing program, or an assigned GO TO statement transfers control to an indicated statement.

The subroutine subprogram accepts arguments from the calling program and/or through common. It can return one or more results through its arguments and/or through common.

Example:

```
Referencing Program              Subroutine Subprogram

PROGRAM TENSOR                ┌──► SUBROUTINE MATRIX
COMMON/BLK1/X(20,20),         │    COMMON/BLK1/A(20,20),
* Y(20,20),Z(20,20)           │   * B(20,20),C(20,20)
        .                     │
        .                     │
CALL MATRIX───────────────────┘    DO 10 I = 1,20
Next statement ◄──────────────┐    DO 10 J = 1,20
        .                     │    X = 0.0
        .                     │    DO 20 K = 1,20
STOP                          │ 20 X = X + A(I,K)*B(K,J)
END                           └─10 C(I,J) = X
                                   RETURN
                                   END
```

The referencing program reserves storage for three successive arrays in labeled common. It is assumed that two of these arrays, X and Y, have values stored in them before the CALL statement is reached. The CALL statement transfers control to the subroutine without passing any arguments. The subroutine performs the matrix multiplication of the first two arrays and stores the results in the third. Control is returned to the next statement after the CALL in the referencing program. The subroutine obtains the values for its calculations from the labeled common block and returns the results it derives to the same labeled common block.

7.4.3 EXTERNAL STATEMENT

The name of an external procedure (basic external function, function subprogram, or subroutine subprogram) can be passed as an argument to a procedure subprogram (function or subroutine) provided that name has been first declared in an EXTERNAL statement.

The format is:

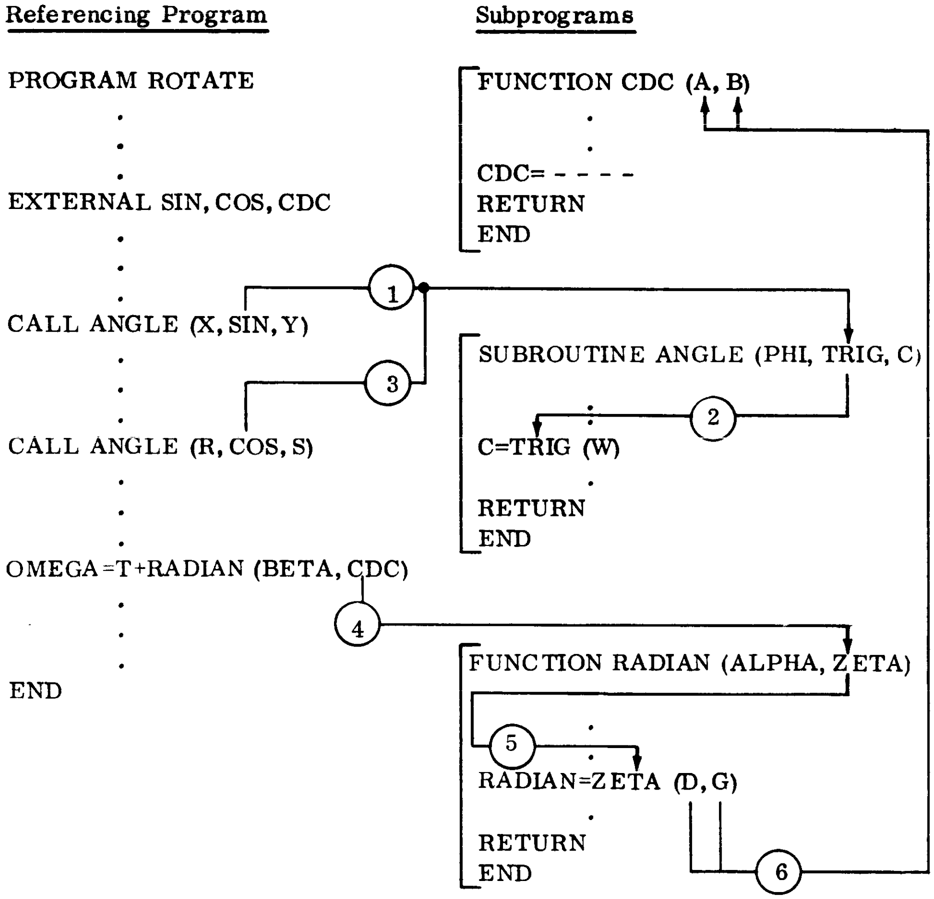
EXTERNAL $v_1, v_2, \ldots, v_n$

Where: v_i is an external procedure

Use of this statement enables the compiler to distinguish the address of an external procedure from that of an ordinary variable.

Once the name of the external procedure is passed through a dummy variable of the subprogram, it operates as a procedure in the subprogram just as it would in the calling program.

Examples:



Referencing Program

```
PROGRAM ROTATE
      .
      .
      .
EXTERNAL SIN,COS,CDC
      .
      .
      .
CALL ANGLE (X,SIN,Y)
      .
      .
      .
CALL ANGLE (R,COS,S)
      .
      .
      .
OMEGA=T+RADIAN (BETA,CDC)
      .
      .
      .
END
```

Subprograms

```
FUNCTION CDC (A, B)
      .
      .
CDC= - - - -
RETURN
END

SUBROUTINE ANGLE (PHI, TRIG, C)
      .
C=TRIG (W)
      .
RETURN
END

FUNCTION RADIAN (ALPHA, ZETA)
      .
      .
RADIAN=ZETA (D,G)
      .
RETURN
END
```

The referencing program declares three external procedures in the EXTERNAL statement. SIN and COS are basic external functions in the system library and CDC is a user-written function subprogram. This declaration makes it possible to pass these names as arguments to subprograms where they can operate as procedures and evaluate variables in the subprograms.

The first subprogram reference in PROGRAM ROTATE is

```
CALL ANGLE (X,SIN,Y)
```

The name SIN is passed to the dummy argument TRIG in SUBROUTINE ANGLE.

The appearance of the name TRIG in the statement

```
C = TRIG (W)
```

makes that statement the equivalent of

```
C - SIN (W)
```

and the basic external function SIN is called into operation using the argument W.

The next reference is a call to the same subroutine

```
CALL ANGLE (R.COS.S)
```

This time the name COS is passed through the dummy argument TRIG and the statement

```
C = TRIG (W)
```

becomes the equivalent of

```
C = COS (W)
```

which calls into operation the basic external function for COS using the argument W.

The final reference is the appearance of the external function name RADIAN in the statement

```
OMEGA = T - RADIAN (BETA.CDC)
```

The name CDC is passed through the dummy argument ZETA in the subprogram FUNCTION RADIAN.

The appearance of ZETA in the statement

```
RADIAN = ZETA (D,G)
```

makes it the equivalent of

```
RADIAN = CDC (D.G)
```

which references the user-written subprogram FUNCTION CDC.

The actual arguments D and G are passed through the dummy arguments A and B. This subprogram calculates a value for CDC and returns it to the radian subprogram. From here it is returned to the referencing program.

The following example illustrates a use of a function reference as an argument which does not require declaration in an EXTERNAL statement.

Example:

```
Referencing Program                   Subprogram

PROGRAM SIGMA                   evaluated
        .
        .                       SUBROUTINE GAMMA (A, B, C)
        .                                  .
        .                                  .
CALL GAMMA (X, SQRT (BETA), Y)  RETURN
        .                       END
END
```

In the CALL statement, SQRT is not itself an argument; the function SQRT (BETA) is evaluated first and the result is passed as an argument to the dummy variable B in the subroutine. Thus, SQRT need not be declared in an EXTERNAL statement.

7.4.4 RELATIVE STATEMENT

The RELATIVE statement declares a name to be an external procedure name.

The format is:

RELATIVE $v_1, v_2, v_3, \ldots, v_n$

Where: v_i is an external procedure name

Appearance of a name is a RELATIVE statement declares that name to be an external procedure name. When the run-anywhere option has been selected, appearance of a name in a RELATIVE statement will cause all references to this procedure to be made in a way which preserves the run-anywhere characteristic. An external procedure name which is to be passed as an actual argument to a procedure subprogram cannot appear in a RELATIVE statement. (It would appear in an EXTERNAL statement.)

7.4.5 CALL STATEMENT

Subroutines are referenced by the appearance of a CALL statement in the referencing program.

The formats are:

CALL s
CALL s $(a_1, a_2, \ldots, a_n)$

Where: s is the name of the subroutine being called

a is an actual argument

The name may not appear in any specification statement in the calling program except in an EXTERNAL or a RELATIVE statement.

The CALL statement transfers control to the subroutine named. When a RETURN or END statement is encountered in the subroutine, control returns to the next executable statement following the CALL in the referencing program. If the CALL statement is the last statement in a DO loop, looping continues until the DO is satisfied.

7.4.6 RETURN STATEMENT

This statement marks the logical end of a procedure subprogram; it returns control to the calling program.

7.4.7 BLOCK DATA SUBPROGRAM

Initial values can be entered into the elements of the labeled common block at compile time with the block data subprogram. This is a nonexecutable subprogram composed of specification statements, a DATA statement, and an END statement.

The first statement of this subprogram must be

BLOCK DATA

It is followed by the specification statements:

COMMON

EQUIVALENCE

DIMENSION

Type statements

These specification statements are followed by the DATA statement which enters initial values into one or more elements of labeled common. If an element in a common block is being given an initial value, specification statements for the entire block must be included. Elements in unlabeled common may not be given initial values by the block data subprogram.

Example:

```
  BLOCK DATA
  COMMON/ENTER/A,C,D,I,K
  DIMENSION A(4), B(4), C(5), D(2), I(3), J(3), K(2)
  EQUIVALENCE (A,B),(I,J)
  DATA A(1), A(2), A(3), A(4)/1.1,2.2,3.3,4.4/,C(1),C(2),C(3),C(4),C(5)/
*1.1,2.2,3.3,4.4,5.5/,D(1),D(2)/10.1,10.2/,I(1),I(2),I(3),K(1),K(2)/
*1,2,3,4,5/
```

Explanation:

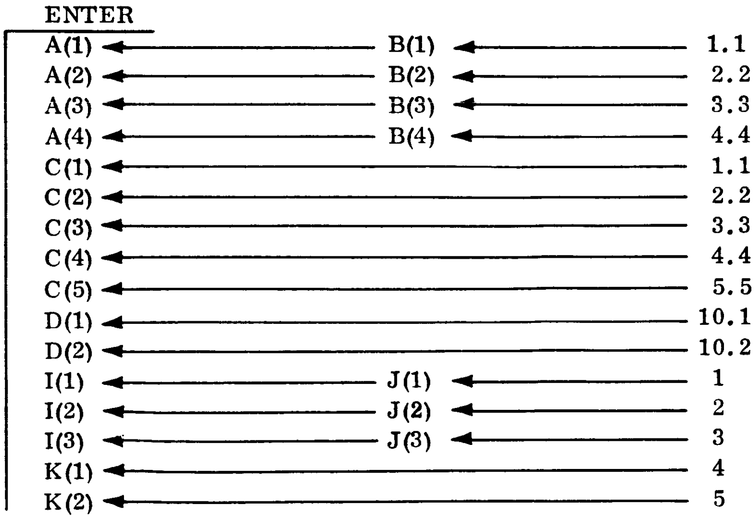
The DIMENSION statement reserves storage for the following arrays.

```
A(1)   B(1)   C(1)   D(1)   I(1)   J(1)   K(1)
A(2)   B(2)   C(2)   D(2)   I(2)   J(2)   K(2)
A(3)   B(3)   C(3)          I(3)   J(3)
A(4)   B(4)   C(4)
              C(5)
```

The COMMON statement enters arrays A,C,D,I,K, in that order in the common block labeled ENTER.

The EQUIVALENCE statement enters arrays B and J into the labeled common block to share storage with arrays A and I.

The DATA statement enters the following values into the designated locations of the labeled common block:



```
ENTER
A(1) ◄──────────── B(1) ◄──────── 1.1
A(2) ◄──────────── B(2) ◄──────── 2.2
A(3) ◄──────────── B(3) ◄──────── 3.3
A(4) ◄──────────── B(4) ◄──────── 4.4
C(1) ◄─────────────────────────── 1.1
C(2) ◄─────────────────────────── 2.2
C(3) ◄─────────────────────────── 3.3
C(4) ◄─────────────────────────── 4.4
C(5) ◄─────────────────────────── 5.5
D(1) ◄─────────────────────────── 10.1
D(2) ◄─────────────────────────── 10.2
I(1) ◄──────────── J(1) ◄──────── 1
I(2) ◄──────────── J(2) ◄──────── 2
I(3) ◄──────────── J(3) ◄──────── 3
K(1) ◄─────────────────────────── 4
K(2) ◄─────────────────────────── 5
```

COMPILATION AND EXECUTION 8

8.1 COMPILATION

The user provides the source programs. 1700 MS FORTRAN will continue compiling source programs until it encounters a statement of the following form:

ΔMON

MON must be in character positions 2, 3, and 4 immediately preceded by a blank (Δ) in character position 1. This statement must immediately follow the END statement which marks the physical end of a source program unit. The MON statement returns control to the operating system.

The OPT statement allows the user to select options from the standard input device. The selected options may exist in three ways:

1. L, X, P options assumed with omission of OPT card.
2. OPT card with desired options after column 5.
3. No options specified by OPT card. This permits options to be entered through the standard input comment device.

OPT must be in character positions 2, 3, and 4 immediately preceded by a blank in column 1. Options must be preceded by a blank in column 5. The options may begin any column after column 5.

The options are:

P Relocatable binary object program output on standard binary output device.

L Source program listing (contains the generated statement numbers) on the standard list device.

A Object code listing on the list device.

M Condensed object code listing on the list device. Listing contains generated statement numbers and first word of object code generated by each statement.

R Run-anywhere object code. This option allows a program to be executed anywhere in allocatable core.

CAUTION

Programs compiled with the R option will not execute properly in partitioned core or at addresses above $8000. In addition, programs compiled with the R option which call user-written subroutines must not declare formal parameters located in Part 1. For example:

```
PROGRAM
   .
   .
   .
EXTERNAL IPART1
   .
   .
   .
CALL SUB (PART1)
   .
   .
   .
END
```

will not execute properly if the R option is used and IPART1 is in Part 1 memory.

K   ANSI FORTRAN compatibility; integers occupy two 1700 computer words

X   Relocatable binary object program placed on the load-and-go file. Disk or drum is used for load-and-go.

Unrecognized parameters and blanks are ignored. Compiler diagnostics are provided on the list device regardless of the options selected. Compilation error diagnostics are in Appendix L. A fatal diagnostic prevents generation of any object code.

The following examples illustrate the output from the various options for a small test program.

OPTION L

Note that full compilation is not done. Only a statement syntax check is made.

```
 1                PROGRAM FTNOPT
           C
           C    EXAMPLE FOR FORTRAN COMPILER OPTIONS
           C
 2                DIMENSION A(5),I(5)
 3                DO 1 II=1,5
 4                I(II)=II*3/A(II)
 5              1 CONTINUE
 6                CALL SUBEXM(A,I)
 7                J=K+6*C
 8                IF(FUNEXM(4,9)) 10,20,10
 9             10 GO TO 20
10             20 CONTINUE
11                END
```

OPTIONS LA

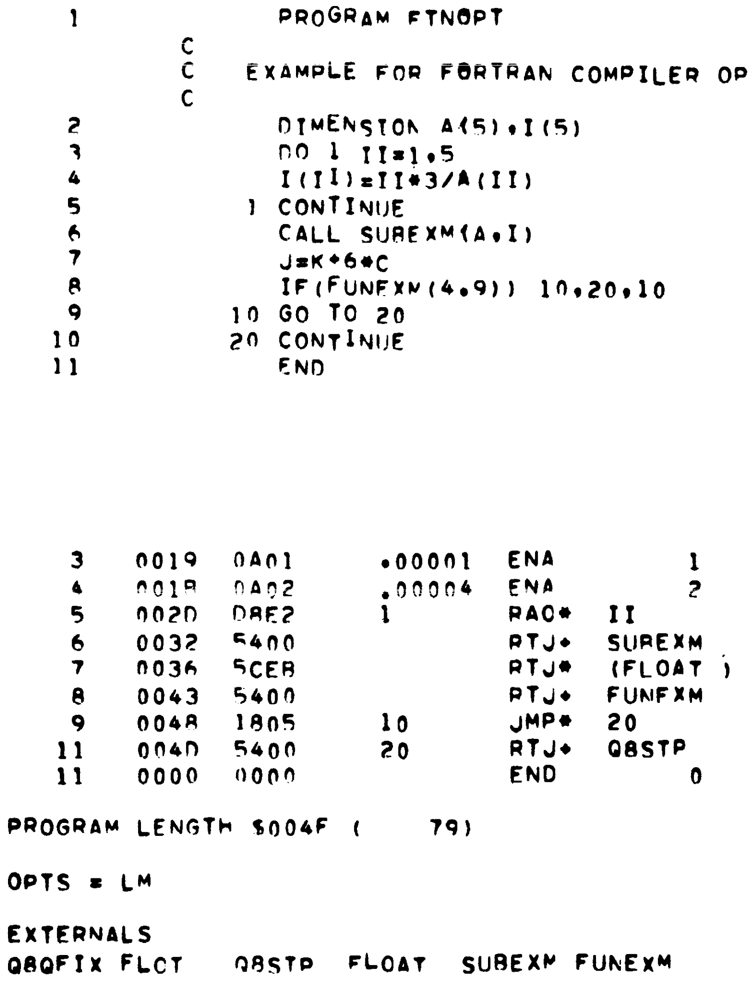
```
   1             PROGRAM FTNOPT
           C
           C    EXAMPLE FOR FORTRAN COMPILER OPTIONS
           C
   2             DIMENSION A(5),I(5)
   3             DO 1 II=1,5
   4             I(II)=II*3/A(II)
   5           1 CONTINUE
   6             CALL SUBEXM(A,I)
   7             J=K*6*C
   8             IF(FUNEXM(4.9)) 10,20,10
   9          10 GO TO 20
  10          20 CONTINUE
  11             END
```

```
         0000   0000                  NAM    FTNOPT
         0000   1819      FTNOPT      JMP*   .00001
         0001   000A      A           BSS        10
         000B   0005      I           BSS         5
         0010   0001      II          BSS         1
         0011   0003      0003$       CON         3
         0012   0001      J           BSS         1
         0013   0001      K           BSS         1
         0014   0006      0006$       CON         6
         0015   0002      C           BSS         2
         0017   41CE      41CE.       CON     16846
         0018   6666                  CON     26214
    3    0019   0A01      .00001      ENA         1
         001A   68F5                  STA*   II
    4    001B   0A02      .00004      ENA         2
         001C   28F3                  MUI*   II
         001D   682C                  STA*   .00005
         001E   C8F1                  LDA*   II
         001F   28F1                  MUI*   0003$
         0020   682A                  STA*   .00006
         0021   5400                  RTJ+   FLOAT
         0022   7FFF
         0023   004A P                ADC    .00006
         0024   5400                  RTJ+   FLOT
         0025   7FFF
         0026   FA40                  CON     -1471
         0027   0049 P                ADC    .00005
         0028   7FFE P                ADC    A              -2
         0029   5400                  RTJ+   Q8QFIX
         002A   7FFF
         002B   E8F4                  LDQ*   II
         002C   6A00                  STA*   I              -I,Q
```

```
     5    002D  08E2        1          RAO*   II
          002E  0A05                   ENA        5
          002F  98E0                   SUB*   II
          0030  0131                   SAM        1
          0031  18E9                   JMP*   .00004
     6    0032  5400                   RTJ+   SUBEXM
          0033  7FFF
          0034  0001 P                 ADC    A
          0035  000B P                 ADC    I
     7    0036  5CEB                   RTJ*   (FLOAT )
          0037  0014 P                 ADC    0006$
          0038  5CFC                   RTJ*   (FLOT  )
          0039  9D40                   CON    -25279
          003A  0015 P                 ADC    C
          003B  004B P                 ADC    .00007
          003C  5CE5                   RTJ*   (FLOAT )
          003D  0013 P                 ADC    K
          003E  5CE6                   RTJ*   (FLOT  )
          003F  E400                   CON     -7167
          0040  004B P                 ADC    .00007
          0041  5CEB                   RTJ*   (Q8QFIX)
          0042  68CF                   STA*   J
     8    0043  5400                   RTJ+   FUNEXM
          0044  7FFF
          0045  0017 P                 ADC    41CE.
          0046  C0C5                   CON    -16186
          0047  0105                   SAZ        5
     9    0048  1805        10         JMP*   20
          0049  0001        .00005     BSS        1
          004A  0001        .00006     BSS        1
          004B  0002        .00007     BSS        2
    11    004D  5400        20         RTJ+   Q8STP
          004E  7FFF
    11    0000  0000                   END        0

PROGRAM LENGTH $004F (      79)

OPTS = AL

EXTERNALS
Q8QFIX FLOT   Q8STP  FLOAT  SUBEXM FUNEXM
```

OPTIONS LM

Note condensed object code listing. This form is useful when the list device is a teletype.



```
    1              PROGRAM FTNOPT
             C
             C    EXAMPLE FOR FORTRAN COMPILER OPTIONS
             C
    2              DIMENSION A(5),I(5)
    3              DO 1 II=1,5
    4              I(II)=II*3/A(II)
    5            1 CONTINUE
    6              CALL SUBEXM(A,I)
    7              J=K+6*C
    8              IF(FUNFXM(4,9)) 10,20,10
    9           10 GO TO 20
   10           20 CONTINUE
   11              END
```

```
    3   0019  0A01     .00001  ENA          1
    4   001B  0A02     .00004  ENA          2
    5   0020  0BE2     1       RAO*    II
    6   0032  5400             RTJ+    SUBEXM
    7   0036  5CEB             RTJ*    (FLOAT )
    8   0043  5400             RTJ+    FUNFXM
    9   004B  1805     10      JMP*    20
   11   004D  5400     20      RTJ+    Q8STP
   11   0000  0000             END          0

PROGRAM LENGTH $004F (      79)

OPTS = LM

EXTERNALS
Q8QFIX FLCT    Q8STP  FLOAT  SUBEXM FUNEXM
```

OPTIONS LAR

Note that no program relocatable addresses are generated; hence, the program can run in allocatable core.

```
 1                 PROGRAM FTNOPT
         C
         C     EXAMPLE FOR FORTRAN COMPILER OPTIONS
         C
 2                 DIMENSION A(5),I(5)
 3                 DO 1 II=1,5
 4                 I(II)=II*3/A(II)
 5               1 CONTINUE
 6                 CALL SUBEXM(A,I)
 7                 J=K+6*C
 8                 IF(FUNFXN(4.9)) 10,20,10
 9              10 GO TO 20
10              20 CONTINUE
11                 END

      0000  0000              NAM   FTNOPT
                     .00001
      0000  1819     FTNOPT   JMP*  .00002
      0001  000A     A        BSS      10
      000B  0005     I        BSS       5
      0010  0001     II       BSS       1
      0011  0003     0003$    CON       3
      0012  0001     J        BSS       1
      0013  0001     K        BSS       1
      0014  0006     0006$    CON       6
      0015  0002     C        BSS       2
      0017  41CE     41CE.    CON   16846
      0018  6666              CON   26214
      0019  5802     .00002   RTJ*  .00005
      001A  FFE5              ADC   .00001
      001B  0001     .00005   BSS       1
      001C  C8FF              LDA*  .00005
      001D  88FC              ADD*  .00005      -1̄
      001E  68FC              STA*  .00005
3     001F  0A01              ENA       1
      0020  68EF              STA*  II
4     0021  0A02     .00006   ENA       2
      0022  28ED              MUI*  II
      0023  682C              STA*  .00007
      0024  C8EB              LDA*  II
      0025  28EB              MUI*  0003$
      0026  682A              STA*  .00008
      0027  5400              RTJ+  FLOAT
      0028  7FFF
      0029  8027              ADC   .00008
      002A  5400              RTJ+  FLOT
      002B  7FFF
      002C  5FA4              CON    24484
      002D  0022              ADC   .00007
      002E  7FD0              ADC   A           -2
      002F  5400              RTJ+  Q8QFIX
      0030  7FFF
      0031  E8DE              LDQ*  II
      0032  6AD7              STA*  I           -1̄,Q
```

```
    5   0033  D8DC      1       RAO*   II
        0034  0A05              ENA        5
        0035  98DA              SUB*   II
        0036  0131              SAM        1
        0037  18E9              JMP*   .00006
    6   0038  5400              RTJ+   SUBEXM
        0039  7FFF
        003A  FFC6              ADC    A
        003B  FFCF              ADC    I
    7   003C  5CEB              RTJ*   (FLOAT )
        003D  FFD6              ADC    0006$
        003E  5CEC              RTJ*   (FLOT  )
        003F  59D4              CON     22996
        0040  7FD4              ADC    C
        0041  0010              ADC    .00009
        0042  5CF5              RTJ*   (FLOAT )
        0043  FFCF              ADC    K
        0044  5CE6              RTJ*   (FLOT  )
        0045  5E40              CON     24128
        0046  000B              ADC    .00009
        0047  5CE8              RTJ*   (Q8QFIX)
        0048  68C9              STA*   J
    8   0049  5400              RTJ+   FUNEXM
        004A  7FFF
        004B  FFCB              ADC    41CE.
        004C  C0C5              CON    -16186
        004D  0105              SAZ        5
    9   004E  1805      10      JMP*   20
        004F  0001      .00007  BSS        1
        0050  0001      .00008  BSS        1
        0051  0002      .00009  BSS        2
   11   0053  5400      20      RTJ+   Q8STP
        0054  7FFF
   11   0000  0000              END        0

PROGRAM LENGTH $0055 (     85)

OPTS = RAL

EXTERNALS
Q8QFIX FLOT   Q8STP  FLOAT  SUBEXM FUNEXM
```

OPTIONS LAK

This form allocates two words of memory for each integer. The actual executable code only uses one of the two words.

```
  1               PROGRAM FTNOPT
          C
          C    EXAMPLE FOR FORTRAN COMPILER OPTIONS
          C
  2               DIMENSION A(5),I(5)
  3               DO 1 II=1,5
  4               I(II)=II*3/A(II)
  5             1 CONTINUE
  6               CALL SUBEXM(A,I)
  7               J=K+6*C
  8               IF(FUNEXM(4,9)) 10,20,10
  9            10 GO TO 20
 10            20 CONTINUE
 11               END
```

```
       0000  0000               NAM    FTNOPT
       0000  1821     FTNOPT    JMP*   .00001
       0001  000A     A         BSS        10
       000B  000A     I         BSS        10
       0015  0002     II        BSS         2
       0017  0003     0003$     CON         3
       0018  0002     J         BSS         2
       001A  0002     K         BSS         2
       001C  0006     0006$     CON         6
       001D  0002     C         BSS         2
       001F  41CE     41CE.     CON     16846
       0020  6666               CON     26214
  3    0021  0A01     .00001    ENA         1
       0022  68F2               STA*   II
  4    0023  0A02     .00004    ENA         2
       0024  28F0               MUI*   II
       0025  682F               STA*   .00005
       0026  0A02               ENA         2
       0027  28ED               MUI*   II
       0028  682D               STA*   .00006
       0029  C8EB               LDA*   II
       002A  28EC               MUI*   0003$
       002B  682B               STA*   .00007
       002C  5400               RTJ+   FLOAT
       002D  7FFF
       002E  0056 P             ADC    .00007
       002F  5400               RTJ+   FLOT
       0030  7FFF
       0031  FA40               CON     -1471
       0032  0055 P             ADC    .00006
       0033  7FFE P             ADC    A                -2
       0034  5400               RTJ+   Q8QFIX
       0035  7FFF
       0036  F81E               LDQ*   .00005
       0037  6AD1               STA*   I                -2,Q
```

```
 5   0038  D8DC      1         RAO*   II
     0039  0A05                ENA         5
     003A  98DA                SUB*   II
     003B  0131                SAM         1
     003C  18E6                JMP*   .00004
 6   003D  5400                RTJ+   SUREXM
     003E  7FFF
     003F  0001 P              ADC    A
     0040  000B P              ADC    I
 7   0041  5CEB                RTJ*   (FLOAT )
     0042  001C P              ADC    0006$
     0043  5CEC                RTJ*   (FLOT  )
     0044  9D40                CON    -25279
     0045  001D P              ADC    C
     0046  0057 P              ADC    .00008
     0047  5CE5                RTJ*   (FLOAT )
     0048  001A P              ADC    K
     0049  5CE6                RTJ*   (FLOT  )
     004A  E400                CON     -7167
     004B  0057 P              ADC    .00008
     004C  5CEB                RTJ*   (Q8QFIX)
     004D  68CA                STA*   J
 8   004E  5400                RTJ+   FUNEXM
     004F  7FFF
     0050  001F P              ADC    41CE.
     0051  C0C5                CON    -16186
     0052  0106                SAZ         6
 9   0053  1806      10        JMP*   20
     0054  0001      .00005    BSS         1
     0055  0001      .00006    BSS         1
     0056  0001      .00007    BSS         1
     0057  0002      .00008    BSS         2
11   0059  5400      20        RTJ+   Q8STP
     005A  7FFF
11   0000  0000                END         0

PROGRAM LENGTH $0058 (     91)

OPTS = KAL

EXTERNALS
Q8QFIX FLOT   Q8STP  FLOAT  SUREXM FUNEXM
```

OPTIONS LX

Note that the full compilation has taken place.

```
       1               PROGRAM FTNOPT
                 C
                 C   EXAMPLE FOR FORTRAN COMPILER OPTIONS
                 C
       2               DIMENSION A(5),I(5)
       3               DO 1 II=1,5
       4               I(II)=II*3/A(II)
       5             1 CONTINUE
       6               CALL SUBEXM(A,I)
       7               J=K*6*C
       8               IF(FUNEXM(4,9)) 10,20,10
       9            10 GO TO 20
      10            20 CONTINUE
      11               END

   PROGRAM LENGTH $004F (     79)

   OPTS = LX

   EXTERNALS
   Q8QFIX FLOT   Q8STP  FLOAT  SUBEXM FUNEXM
```

OPTIONS PX

Note that no listing output is generated, but full compilation has occurred with object and load and go output.

```
    OPTS = PX
```

8.2 EXECUTION

When option P is selected, a punched output is generated containing the binary object program. This output may be loaded by MSOS. This form may also be loaded by the system initializer. When option X is selected, the binary object program is output as a load-and-go file on disk or drum. It can be loaded and executed in the same run as the compilation.

Upon completion of the load, any unsatisfied external references in the object program are satisfied from the program library.

Execution time error messages are listed in Appendix M.

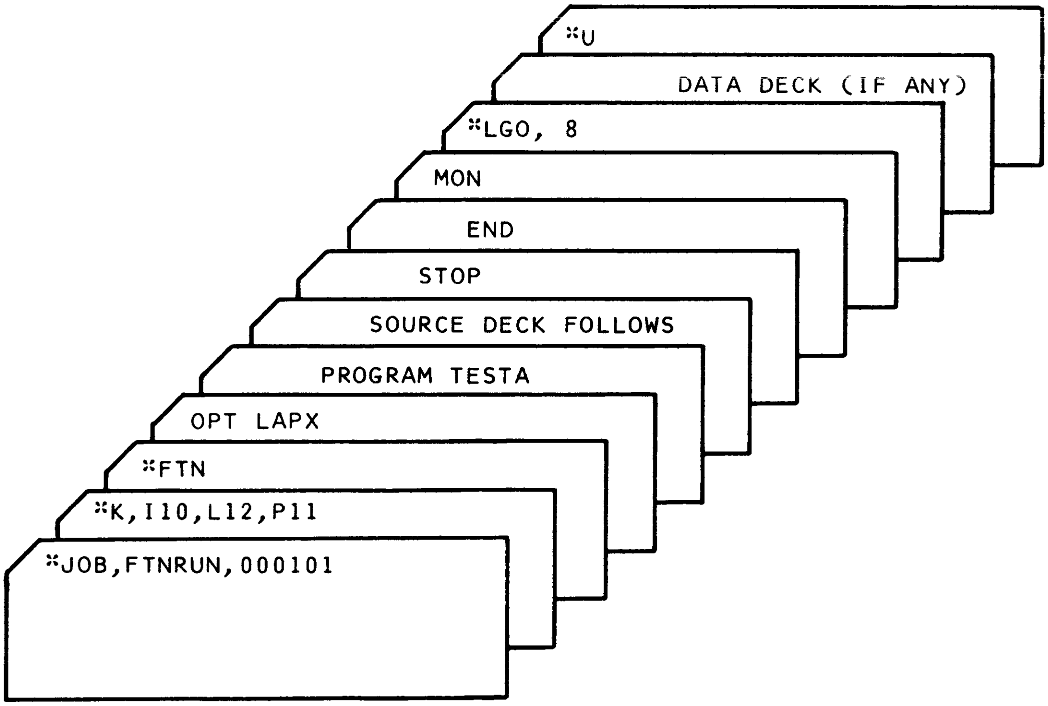
8.3 PROGRAM OPERATING PROCEDURES

This section outlines the method of compiling and executing a FORTRAN program under 1700 MSOS. To illustrate the step-by-step interaction between the operator and the system, typical values are selected for the parameters. It is assumed the system is without a timer.

The following logical unit designations are made.

Device	Unit No.
Card punch	11
Card reader	10
Mass storage device	8
Printer	12

The FORTRAN deck is placed in the card reader with the system control cards around it as shown in the following illustration:



```
*JOB,FTNRUN,000101
*K,I10,L12,P11
*FTN
OPT LAPX
PROGRAM TESTA
SOURCE DECK FOLLOWS
STOP
END
MON
*LGO, 8
DATA DECK (IF ANY)
*U
```

The JOB card is utilized in the job processor to begin a new background job. The next card assigns the I/O units. In this example, it specifies standard input from the card reader, list output to the printer, and binary output to the card punch. The *FTN card calls in the compiler to compile the source deck. The OPT card is read by the compiler, in this case list, list assembly code, punch relocatable binary, and put binary on the load and go file are the options selected. The compiler then reads in the source seck and compiles the program. The MON card after the source deck releases the compiler and returns control to the job processor. The *LGO card instructs the job processor to load the object code for the program, along with any object library routines necessary to execute the program. It is assumed in this example that the program reads in the data deck during execution. After execution, control is returned to the job processor which reads in the *U card and returns control to the teletype.

FORTRAN MULTIPROGRAMMING 9

This chapter discusses the use of the re-entrant ENCODE/DECODE and non-re-entrant ENCODE/DECODE run-time packages. These packages have, in general, reduced capability from the FORTRAN I/O run-time discussed in other chapters with an extension in the interface capability to MSOS monitor requests. The features throughout this section are to be used with one word integer-type variables wherever integer-type variables are used.

The re-entrant and non-re-entrant packages have an identical user interface. This duplication of capability allows inital program debugging in the background using the non-re-entrant version with a transfer to the re-entrant version for execution in the foreground.

The intrinsic functions defined in Table 7-3 and the basic external functions defined in Table 7-4 are also operable with the ENCODE/DECODE run-times.

9.1 RE-ENTRANT FORTRAN

Two characteristics of FORTRAN programs which execute in a multiprogramming environment are:

- Priority levels can be assigned to the different programs executing in the computer.
- The monitor and standard FORTRAN library are re-entrant.

9.1.1 PRIORITIES

Assigning different priorities to the programs in memory permits the monitor (the basic portion of 1700 MSOS which allocates the use of the computer on a priority basis) to determine the order in which programs execute. When a program asks the monitor to initiate an I/O request, control may be given to another program to execute, rather than waiting for completion of the I/O request. Upon completion of the request, if the completion priority is higher than the current executing program, control returns to the program which made the I/O request. The program currently executing is interrupted, and the monitor retains all pertinent information at the point of interruption. When control is eventually returned to this program of lower priority, all pertinent information saved upon interruption is restored. If the completion priority of the I/O request is not higher than the currently executing program, the completion of the I/O request is processed at a later time according to its priority. The process can be cascaded to the depth allowed by the monitor. In the standard release system levels 4, 5, and 6 are defined as re-entrant FORTRAN levels.

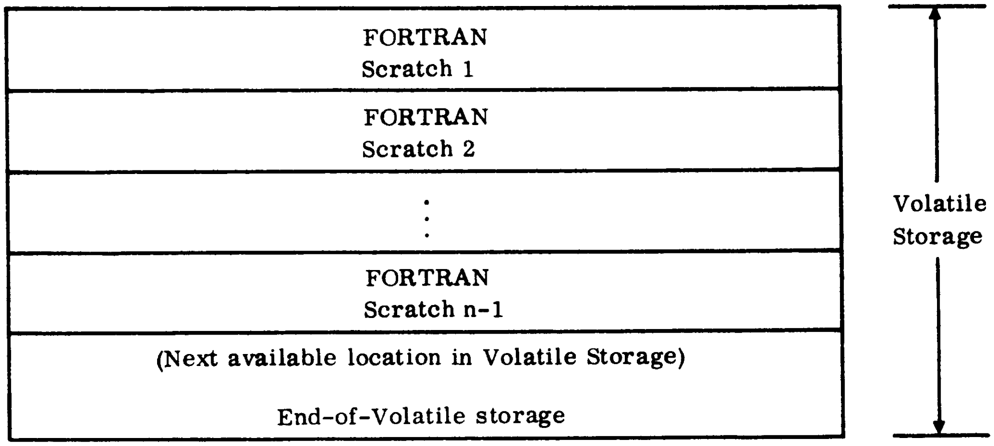
9.1.2 RE-ENTRANCY

A program which can be interrupted and re-entered by another program of high priority level is called re-entrant. Re-entrant programs require all pertinent information be saved upon interruption and restored when execution is resumed.

All programs or subprograms that may run at more than one level concurrently must be re-entrant. The FORTRAN library falls into the re-entrant category since it can be called from more than one priority level.

9.1.3 FORTRAN LIBRARY

All routines in the FORTRAN library use a scratch area in the communications region of the monitor (locations $C5 to $E5) for intermediate results. Interruption of a FORTRAN program by another FORTRAN program requires storing and restoring this scratch area into and from volatile storage in the monitor. Thus, n levels of interrupts by FORTRAN programs result in n-1 copies of the scratch area in volatile storage.



It is not desirable for n to assume large values since larger core requirements for the monitor restrict the amount of core available for user programs. Limiting the priority levels of FORTRAN programs to three or four levels restricts the number of interrupts FORTRAN programs can have. This holds the requirements on volatile storage to a reasonable size.

9.1.4 FORTRAN READ/WRITE STATEMENT PROCESSOR

In order to implement the FORTRAN READ/WRITE statement as part of a re-entrant statement processor, a deviation from the ANSI standard FORTRAN specifications was made for the following reasons:

- The size of the input/output buffer to be reserved in the statement processor is dependent upon the largest message for input/output by any FORTRAN program.
- Since the statement processor is re-entrant, either the buffer is stored in volatile storage on interruption (again requiring a large amount of volatile) or interrupts are inhibited until the complete buffer is input/output. Since several milliseconds are required to inhibit interrupts, this method would defeat the purpose of a multiprogramming system.

To resolve the preceding objections, the FORTRAN READ/WRITE statement processor places the responsibility of providing an input/output buffer upon the FORTRAN programmer. Also, since control is not returned to the FORTRAN program until a READ/WRITE statement has been completely processed, there is no chance of the user destroying the message by attempting to do more READ/WRITE processing into his buffer. This negates the necessity of storing and restoring his buffer.

Re-entrancy places a further restriction on the READ/WRITE statement. The FORMAT statement may designate only one input record (80 card columns) per READ statement.

9.1.5 FORTRAN/MONITOR RUN-TIME INTERFACE (FORTRA)

The monitor has provisions to request a mass storage READ/WRITE or an unformatted READ/WRITE, schedule the execution of a new program, schedule the execution of a new program after a time increment has elapsed, release core after execution of the current program is completed, etc. For the FORTRAN programmer, however, communication with the monitor is only possible through the FORTRAN/monitor run-time package. This package has entry points which generate specific requests to the monitor when called by a FORTRAN program. Thus, when a CALL READ is made with the logical unit equal to mass storage and the mass storage addresses are provided, the run-time package generates the necessary calling sequence to the monitor, then makes the input request and returns to the user's program.

CALL READ, CALL WRITE, CALL FREAD, and CALL FWRITE, which are entry points to the FORTRAN/monitor run-time package, are direct requests to the monitor. The READ/WRITE FORTRAN statements are used specifically for reads or writes with a FORTRAN FORMAT statement.

9.1.6 ENCODE/DECODE

If the FORTRAN/monitor run-time interface is used to transfer the record, ENCODE/DECODE provides the programmer with the capability to convert ASCII characters to hexadecimal data (DECODE) or to convert hexadecimal data to ASCII characters (ENCODE).

With the FORTRAN/monitor run-time interface, ENCODE/DECODE, and the READ/WRITE statement processor, the FORTRAN programmer has the full capabilities of data input/output and has sufficient control over the problem to achieve correct results in a multiprogramming real-time environment.

9.1.7 RUN-ANYWHERE PROGRAMS

So that FORTRAN programs can execute properly in allocatable core, a run-anywhere option was added to the FORTRAN compiler, removing all absolute address references from the compiled program.

CAUTION

> Users are warned that programs compiled with the run-anywhere (R) option will not execute properly in partitioned core or at addresses above $8000.

9.2 FORMAT SPECIFICATIONS

Data transmission between storage and an external unit requires a call to an I/O routine (READ, WRITE, etc.) and may require a FORMAT statement. The I/O call specifies the input/output device, the process, and a list of data to be transmitted. No FORMAT statement is required to transmit binary information, and a direct call to an I/O routine may be made. With ASCII information, a FORMAT statement specifies the type of conversion to be made on the data before or after transmission.

9.2.1 FORMAT STATEMENT

The FORMAT statement contains the specifications relating to the internal/external structure of the corresponding data elements.

$\text{FORMAT}(\text{spec}_1,\ldots,\text{k}(\text{spec}_m,\ldots),\text{spec}_n,\ldots)$

Where: spec is a format specification

k is an optional repetition factor which must be an unsigned integer constant

FORMAT statements are nonexecutable and may appear anywhere in the program.

9.2.2 FORMAT CONVERSION

The data elements in I/O lists are converted from external to internal or from internal to external representations according to conversion and editing specifications in the FORMAT statement. The FORMAT statement may contain both conversion and editing specifications. The format conversion specifications are:

Ew. d	Floating-point conversion with exponent	Limited to output specifications only
Dw. d	Double-precision floating-point with exponent	
Fw. d	Floating-point conversion without exponent	
Iw or Iw. d	Decimal integer conversion	
$w or Zw	Hexadecimal integer conversion	
Aw	Alphanumeric conversion	
Rw	Alphanumeric conversion	

The format editing specifications are:

wX	Intra-line spacing
xH	Heading and labeling
Asterisk or	*String of ASCII Characters*
Quote	'String of ASCII Characters'
/	Line-feed/new record

Both w and d are unsigned integers. w specifies the field width (the number of character positions in the record) and d specifies the number of digits to the right of the decimal within the field.

9.2.3 CONVERSION SPECIFICATIONS

Dw. d OUTPUT

This specification converts double-precision floating-point numbers in storage to ASCII characters, including an exponent for output. The field occupies w positions in the output record with d digits as the most significant part of the fraction. The corresponding floating-point number will appear right-justified in the field as:

±.xxxxxxD±ee

Where: 0≤ce≤39

Let: A contain -1276.45 or .001276450D0

And: FORMAT(D15.4)

Result: ∧∧∧∧∧-.1276D+04 or

∧∧∧∧∧∧.1276D-02

Ew.d OUTPUT

This specification converts floating-point numbers in storage to ASCII characters, including an exponent for output. The field occupies w positions (minimum 6) in the output record with d digits (≠0) as the most significant part of the fraction. The corresponding floating-point number appears right-justified in the field as:

±.XXXXXX±ee

Where: 0≤ee≤39

The fractional portion of the number contains a maximum of six digits. If the field width is too short to accommodate the number, an asterisk appears in the most significant position to indicate an error.

Let: A contain -67.32 or .06732

And: FORMAT(E10.3)

Result: ∧-.673E 02 or
∧∧.673E-01

Let: A contain -67.32 or .06732

And: FORMAT(E7.3)

Result: *.6E 02 or
*.6E-01

Fw.d OUTPUT

This specification converts floating-point numbers in storage to ASCII characters, excluding an exponent for output. The field occupies w positions in the output record with d digits to the right of the decimal. The corresponding floating-point number appears right-justified in the field as:

±X...X.X...X.

The range of the internal number represented must be from 10^{-5} to 10^{+5}-1. If this range is exceeded, the field is filled with asterisks and no error flag is returned as in Section 9.4.3. If the field width is too short to accommodate the number, an asterisk appears in the most significant character position to indicate the error.

Let:	A contain +32.694
And:	FORMAT(F7.3)
Result:	∧32.694

Let:	A contain -32767.0
And:	FORMAT(F7.3)
Result:	*2767.0

Fw.d INPUT

This specification converts ASCII characters in storage to a floating-point number and scales the string of integer digits by 10^{-d}. The field occupies w positions in the input record; a decimal point in the input record causes the d portion of the conversion specifications to be ignored. With d = 0, both fields must be specified to indicate no scaling. The range of the internal number represented must be from 10^{-5} to 10^{+5}-1.

Let:	INPUT = A(1) = ∧9. A(2) = 35 Where: A contains ASCII characters
And:	FORMAT(F4.2)
Result:	9.35

Let:	INPUT = A(1) = ∧- A(2) = 52 A(3) = .3
And:	FORMAT(F6.3)
Result:	-52.3

Let:	INPUT = A(1) = ∧9 A(2) = .5 A(3) = 20 A(4) = ∧- A(5) = 50 A(6) = 60
And:	FORMAT(2F6.2)
Result:	9.520 and -50.36

Iw, Iw.d OUTPUT

This specification converts integer values to ASCII characters with 10^{-d} scaling if d is specified. The magnitude of the integer number must be from 10^{-5} to 10^{+5}-1. If the field is wider than required, the output quantity is right-justified and blank-filled. If the field width is too short, an asterisk appears in the most significant character position to indicate the error.

Let:	N contain 301
And:	FORMAT(I5)
Result:	ʌʌ301

Let:	N contain -336
And:	FORMAT(I5. 3)
Result:	-. 336

Iw INPUT

This specification converts ASCII characters to an integer value. The magnitude of the number must be from $-(2^{+15}-1)$ to $2^{+15}-1$.

Let:	INPUT = 1905
And:	FORMAT(I4)
Result:	N = 1905

Let:	INPUT = 0, 9, 3, 8, 0, 2	
And:	FORMAT(6I1)	
Result:	N(1) = 00	N(4) = 08
	N(2) = 09	N(5) = 00
	N(3) = 03	N(6) = 02

$w or Zw OUTPUT

This specification converts a hexadecimal integer value in storage to ASCII characters for output. The field occupies w positions in the output record. If the field width is too short, an asterisk is inserted in the most significant character position. The magnitude of the internal number represented must be from $-(2^{+15}-1)$ to $2^{+15}-1$.

Let:	N contain $03A2_{16}$
And:	FORMAT($6) or FORMAT (Z6)
Result:	ʌʌ03A2

Let:	N contain $83A2_{16}$
And:	FORMAT($3) or FORMAT (Z3)
Result:	*A2

$w or Zw INPUT

This specification converts ASCII characters in storage to a hexadecimal integer value. The magnitude of the internal number represented must be from $-(2^{+15}-1)$ to $2^{+15}-1$.

Let: INPUT = 00AB

And: FORMAT($2) or FORMAT (Z2)

Result: N contains AB as a hexadecimal integer value

Aw OUTPUT

This specification is used to output ASCII characters. w characters/word are picked up, starting with the leftmost character, and stored in the output buffer. If the field width is greater than two, an error return occurs.

Let: N(1) = C∧
N(2) = NX
N(3) = =∧
N(4) = Y∧
N(5) = 1∧

And: FORMAT(A1, A2, 3A1)

Result: CNX = Y1

Let: N(1) = CN
N(2) = 1=
N(3) = Y1

And: FORMAT(3A1)

Result: C1Y

Aw INPUT

This specification accepts as list elements any set of eight-bit characters including blanks. The internal representation is ASCII; the field width is w characters. If w exceeds two, an error return occurs. w characters are picked up as a left-justified ASCII word; the remaining spaces are blank filled.

Let: INPUT = CNXYYZ

And: FORMAT(6A1)

Result: N(1) = C∧ N(4) = Y∧
N(2) = N∧ N(5) = Y∧
N(3) = X∧ N(6) = Z∧

Let: INPUT = CNXYYZ

And: FORMAT(2A2, 2A1)

Result: N(1) = CN N(3) = Y∧
N(2) = XY N(4) = Z∧

Rw OUTPUT

This specification is the same as Aw specification except that the output quantity represents the rightmost quantity. If the field width is greater than one, an error return results.

Let:	N(1) = 0A and N(2) = 0B 0 = 8 bits of zeros
And:	FORMAT(2R1)
Result:	AB

Rw INPUT

With this specification the input quantity goes to the designated storage location as a right-justified zero-filled word. If w is greater than one, an error return results.

Let:	INPUT = AB
And:	FORMAT(2R1)
Result:	N(1) = 0A N(2) = 0B 0 = 8 bits of zeros

9.2.4 EDITING SPECIFICATIONS

wX OUTPUT/INPUT

This specification may be used to include w blanks in an output record or to skip w characters on input to permit spacing of input/output quantities.

Let:	A = -32.576
And:	FORMAT(3X, F7.3)
Result:	∧∧∧-32.576

wH OUTPUT/INPUT

This specification provides for the output of any set of eight-bit characters, including blanks in the form of comments, titles, and headings. w is an unsigned integer specifying the number of characters to the right of the H that are transmitted to the output record as ASCII characters. The H field may be used to read a new heading into an existing H field.

FORMAT(3X, 5HLABEL, 1X, 4HFOR∧, 6HOUTPUT)

Result: ∧∧∧LABEL∧FOR∧OUTPUT

FORMAT(H11, HHNEW∧HEADING)

Result: NEW∧HEADING

QUOTE OR ASTERISK I/O

The asterisk field descriptor causes Hollerith information (excluding asterisks) to be read into or written from the characters specified between two asterisk delimiters. The single quote field descriptor causes Hollerith information (excluding single quotes) to be read into or written from the characters specified between two single quote delimiters.

Examples:

```
          WRITE (3,20)
     20   FORMAT(*∧THIS IS A HOLLERITH STRING*)
     Result:   THIS IS A HOLLERITH STRING
          WRITE (3,30)
     30   FORMAT('∧THIS IS A HOLLERITH STRING')
     Result:   THIS IS A HOLLERITH STRING
```

NEW LINE

The slash, which signals the end of a line, may occur anywhere in the specification list. This generates a new line into the output record.

```
          FORMAT(1X, 6HLINE∧1, //7H∧LINE∧3)
     RESULT    ∧LINE∧1
               ∧LINE∧3
```

9.2.5 SPECIAL CHARACTER SPECIFICATIONS

If a special character appears as the first character in the output record, the following interpretation is made:

```
     1    Top-of-form
     0    Line feed
     FORMAT(1H1, 15X, 12HTOP-OF-FORM∧)
```

The run-time converts the first character of the output buffer: if it is an ASCII code for 0 ($ 30) to an ASCII code for a line feed ($0D), and if it is an ASCII code for 1 ($31) to an ASCII code for a top of form ($0C). This technique does not require the use of the FORTRAN line printer logical unit to interpret form control.

9.2.6 REPEATED FORMAT SPECIFICATIONS

Any FORMAT specifications may be repeated by using an unsigned integer constant repetition factor (k) as follows:

```
     k (spec)
```

Where: spec is any conversion specification. The level of repetitions is limited to one.

Thus, $(k_1(----k_2(----)))$ is an error.

But $(k_1----),----k_2(----),----k_3(----))$ does not result in an error return.

9.3 FORTRAN READ/WRITE STATEMENT PROCESSOR

Input/output FORTRAN control statements (READ/WRITE) transfer information between core storage and external peripheral devices connected to the computer.

9.3.1 WRITE STATEMENT

```
     WRITE(i,n) L
```

transfers information from storage locations given by identifiers in the list (L) to a specified peripheral device (i) according to the FORMAT statement (n).

```
          WRITE(10,20) A,B,C
     20   FORMAT(3F10.6)
          WRITE(10,30)
     30   FORMAT(33H THIS STATEMENT HAS NO DATA LIST.)
```

9.3.2 READ STATEMENT

```
     READ(i,n) L
```

transfers one record of information from a specified peripheral device (i) to storage locations named by the list (L) identifiers according to the FORMAT statement (n).

```
          READ(10,20)X,Y,Z
     20   FORMAT(3F10.6)
          READ(10,30)
     30   FORMAT(33H(message)) where 33 blank spaces must appear between the H and the
          terminating parenthesis.
          READ(10,40)(Z(K),K=1,8)
     40   FORMAT(F10.4)
```

9.3.3 STATEMENT PROCESSOR

The statement processor (Q8QIO) serves as an interface between the FORTRAN READ/WRITE statement, the format processor (ENCODE/DECODE), and the input/output processor (1700 Monitor READ/WRITE request processor). It allows the FORTRAN programmer to use the READ/WRITE statements as defined by FORTRAN with the following exceptions:

- The user must supply a buffer in which the format processing takes place.
- Eighteen temporary locations immediately preceding the buffer contain the calling sequence to the monitor for read/write processing and information for re-entrancy.
- Only one RECORD/READ statement on input may be executed; the FORMAT statement may specify only 80 columns of data for card input.
- The RECORD/WRITE statement on output may be as long as the space in the buffer allows with the following limitations: if the programmer has not specified a new line after 150 characters have been packed into the buffer, a carriage return is automatically inserted into the message and continues to be inserted every 150 characters until the FORMAT processing is complete.
- Noncompatible with ANSI FORTRAN option; no two-word integer values (K option).

9.3.4 CALL SETBFR

In order to communicate the starting location and the length of the user's buffer to Q8QIO, an entry point called SETBFR is provided. The call to transmit the information need only be made once and must precede any READ/WRITE statement. However, if the user's program makes a call to the dispatcher or a call to either ENCODE/DECODE, then a call to SETBFR must again be made prior to any READ/WRITE statement.

CALL SETBFR(buffer, length)

The first 18 words of the buffer contain the calling sequence for the I/O request and information for re-entrancy. The remainder contains the input/output message.

9.3.5 RESTRICTIONS

Length is the total length of the buffer which includes the 18 words needed by Q8QIO. This scratch area of 18 words has the following format:

Word	1	Last word address (LWA) of buffer
	2	Request code for READ/WRITE
	3	Completion address
	4	Thread
	5	Logical unit

Word 6 Message length

7 First word address (FWA) of message

8 Sector address MSB (unformatted READ/WRITE)

9 Sector address LSB (unformatted READ/WRITE)

10 Q register of user

11 Return address of user's program

12 I register of user

13 READ/WRITE flag (ICODE)

14 LIST address

15 Total number of variables in LIST

16 ENCODE/DECODE—READ/WRITE flag (DEFLAG)

17 FORTRAN FORMAT flag

18 I register for restoring volatile

19 User's I/O message begins here

The greatest restriction on implementing the READ/WRITE statement processor was placed on the input side. This restriction limits each READ statement to request one input record or 80 columns of data for card input.

```
      READ(10,20)(X(I,J),I=1,10),J=1,20)
20    FORMAT(10F8.4)
```

This example results in an error since the request specifies 20 cards of input. However, the following executes correctly:

```
      DO 30 J 1,20
      READ(10,20)(X(I,J),I=1,10)
20    FORMAT(10F8.4)
30    CONTINUE
```

Unformatted READ/WRITE may be performed by use of the re-entrant READ/WRITE statement processor.

READ(i)L transfers one record of information directly from the device (i) into the storage locations named by the list (L) identifiers.

WRITE(i)L transfers information from the storage locations named by the list (L) identifiers to the device (I).

If the device is mass storage, words 8 and 9 of the buffer specified by CALL SETBFR must contain the sector address.

Unformatted READ/WRITE is not implemented in the non-re-entrant READ/WRITE statement processor.

9.3.6 FORMAT ERRORS

To determine if a format error occurred during processing of a READ/WRITE statement, the programmer may follow the READ/WRITE statement with a call to the function subroutine IOERR. An error is indicated if the function value is -1.

```
      IF(IOERR(0).EQ.-1)GO TO 1000.

or    IERROR=IOERR(0).
      (and IERROR may be tested later)
```

9.3.7 I/O ERRORS

To determine if a hardware failure occurred during an I/O operation, the programmer may follow the READ/WRITE statement with a call to the function subroutine IRWERR:

```
      IF(IRWERR(0).LT0) GO TO 1000

or    JERROR = IRWERR(0)
      (and JERROR may be tested later)
```

The negative value of the function indicates that an I/O error occurred on the last READ/WRITE operation. This function is implemented only for the re-entrant ENCODE/DECODE run-time.

9.4 ENCODE/DECODE CALLS

The ENCODE/DECODE package gives the FORTRAN programmer the ability to transfer information under FORMAT specifications from one area of storage to another. For example, to transfer a floating-point number from a variable data list into an output buffer area with an F format specification, the programmer would use an ENCODE call to accomplish the conversion from floating-point representation to ASCII characters and pack the output buffer. ENCODE ′DECODE functions use the ENCODE/DECODE run-time routines. Therefore, the formatting capabilities are as described in this chapter.

The parameters to an ENCODE/DECODE call are as follows:

buffer   is an area to ENCODE into or DECODE from; always contains information in ASCII form.

iform   is an assigned variable when the statement label assigned is the statement number which represents the associated FORMAT statement.

n   equals the number of variables to ENCODE/DECODE.

list   equals the first word of the data list to input/output; always contains data in hexadecimal form.

9.4.1 ENCODE

ENCODE transmits n machine-language elements of the variable list according to FORMAT into locations starting with the first word in BUFFER. Up to 150 ASCII characters (one line) are stored in consecutive locations for output.

```
        ASSIGN 99 TO IFORM
        CALL ENCODE (IBUF,IFORM,3,LIST)
   99   FORMAT(I3)
```

Where: LIST(1) = $0023, LIST(2) = $FFFE, LIST(3) = $001A

Then: IBUF(1) = $2033, IBUF(2) = $3520, IBUF(3) = $2D31,
IBUF(4) = $2032, IBUF(5) = $3600

If IBUF is output on the teletypewriter, the following results:

```
∧35∧-1∧26
```

NOTE

In the preceding example the ASSIGN statement is used as the <u>only</u> way to set a variable (IFORM) equal to a statement number. The request also specifies that three variables are to be converted as three ASCII characters for a total of nine ASCII characters. Since each computer word contains two characters, IBUF must be dimensioned as a five-word data block. When the number of ASCII characters is odd, the last character on the teletypewriter results in no output.

```
        ASSIGN 99 TO IFORM
   99   FORMAT(5H LINE, I2, 3H X =,F5.2, 3H Y =,F5.2, 3H Z =,F5.2/)
        K=1
        DO 30 I=1,3
        LIST(I)=I
        DO 20 J=1,3
   20   FLIST(J) = DATA(I,J)
        CALL ENCODE (IBUF(K), IFORM, 4, LIST)
   30   K=K+16
```

The preceding example illustrates the mixing of floating-point with integer variables for ENCODE/ DECODE calls. By equivalencing the floating-point variable name to the second entry of the integer array, mixed values can be entered into the table. IBUF has been packed one line at a time (less than 150 characters per call) with a line feed indicated as the last character; however, the total number of characters packed in IBUF is 96. The following results when output:

```
LINE∧1∧X= 1.00∧Y= 1.00∧Z=∧1.00
LINE∧2∧X=0.52∧Y= 3.42∧Z=-1.50
LINE∧3∧X=24.50∧Y=-0.25∧Z=50.20
```

9.4.2 ENCODE MACRO

The ENCODE subroutine may be called in assembly language by calling the ENCODE macro as follows:

```
ENCODE A,B,C,D,E,     (absolute)
        or
ENCODE* A,B,C,D,E     (relative)
```

Parameters A, B, C, D correspond directly with the respective parameters in a FORTRAN call, as shown above. Parameter E is the address of an error routine to which control is given. If E is blank no test for error conditions is made. (See Section 9.4.5.)

9.4.3 DECODE

DECODE transmits n consecutive ASCII characters according to the FORMAT from locations starting with the first word in BUFFER to the variable list as n machine-language elements.

```
      ASSIGN 99 TO IFORM
      CALL DECODE (IBUF, IFORM, 10, LIST)
99    FORMAT(10I3)
```

In the preceding example, the ASSIGN statement is used as the only way to set a variable (IFORM) equal to a statement number. Also, the request specifies that ten integer values be stored in LIST as hexadecimal numbers. IBUF must contain 15 words of ASCII characters since a total of 30(10*I3) characters with two characters per word were requested.

```
      ASSIGN 99 TO IFORM
      CALL DECODE (IBUF, IFORM, 5, LIST)
99    FORMAT (3(2X, 2I5))
```

Where: Five integer values are stored in LIST as hexadecimal integers even though the FORMAT specifies six integer values; that is, skip two characters, pick up the next five characters twice, and repeat this format twice.

```
      ASSIGN 99 TO IFORM
      CALL DECODE (IBUF, IFORM, 20, LIST)
99    FORMAT(3(3I2, 1X, 2I3))
```

NOTE

Even though 15 integers were specified in the FORMAT statement, a repeat of the FORMAT starting with the first specification within the parenthesized expression is executed to complete the conversion of the LIST parameters.

```
      ASSIGN 99 TO IFORM
      CALL DECODE (IBUF, IFORM, 0, 0)
99    FORMAT(28H (message))
```

Where: 28 ASCII characters are transmitted from IBUF to IFORM.

NOTE

This is a way of editing FORMAT statements without recompiling.

```
      DIMENSION FLIST(10), LIST(20)
      EQUIVALENCE (FLIST, LIST)
            .
            .
            .
      ASSIGN 99 TO IFORM
      CALL DECODE (IBUF, IFORM, 10, LIST)
99    FORMAT(2I2, 8F10.3)
```

Where: The first two variables are integer values and the remaining eight are floating-point.

NOTE

Ten variables were specified even though the floating-point variables occupy two words per variable.

9.4.4 DECODE MACRO

The DECODE subroutine may be called from an assembly language program by calling the DECODE macro as follows:

```
DECODE  A,B,C,D,E     (absolute)
          or
DECODE* A,B,C,D,E     (relative)
```

Parameters A, B, C, and D correspond to the respective parameters in a FORTRAN call, as shown above. Parameter E is optional and may be left blank. If defined, E defines the address of an error routine to which control is given when errors are detected.

9.4.5 ENCODE/DECODE ERROR DETECTION

When calling the ENCODE/DECODE package as subroutines, the error flag returned in the A register is lost. However, when calling the ENCODE/DECODE package as function subroutines, the error flag (= -1) returned may be tested for FORMAT errors except Fw.d output. The A register equals +0 on correct formatting of results.

```
      CALL ENCODE (IBUF, IFORM, N, LIST)
```

In this example the ENCODE call is a subroutine call and the error flag (= -1) returned could not be tested.

```
      NFLAG = ENCODE (IBUF, IFORM, N, LIST)
      IF (NFLAG.EQ. -1) GO TO 1000
or    IF (ENCODE(IBUF,IFORM,N,LIST).EQ. -1) GO TO 1000
```

In this example, the ENCODE call is a function subroutine call and NFLAG is set to the value returned by ENCODE to be tested later in an IF statement, or the error flag returned in the A register can be directly tested in an IF statement. In the function subroutine call, ENCODE/DECODE should be declared in a type statement as INTEGER; otherwise, the compiler treats the results returning from ENCODE/DECODE as floating point.

CAUTION

When ENCODE or DECODE is used in an implied DO loop, termination will occur immediately upon format conversion errors. Subsequent conversions within the loop will not occur.

9.4.6 ADDITIONAL FORMATTING ROUTINES

Additional formatting routines have been added to enable the FORTRAN programmer to format one variable at a time to save execution time needed for interpretation of FORMAT. The features in this section are to be used with one word integer type variables whenever integer type variables are used.

HEXASC and HEXDEC

```
      CALL name(variable,buffer)
```

Where: name is HEXASC — Converts a hexadecimal integer to ASCII characters.

HEXDEC — Converts a hexadecimal integer to a decimal integer in ASCII characters.

variable is the location of the hexadecimal integer.

buffer is the location of a two-word buffer to contain the converted integer in hexadecimal form (HEXASC); or the location of a three-word buffer to contain the converted integer in decimal form (HEXDEC).

Example 1:

```
        DIMENSION LIST (10),IBUF(30)
              .
              .
              .
        J=1
        DO 10 I=1, 10
        CALL HEXDEC(LIST(I),IBUF(J))
   10   J=J+3
              .
              .
              .
```

This call is comparable to an Iw FORMAT specification for output except that the resulting field is zero-filled, not blank-filled, as I=1,2,3,...,10; J=1,4,7,...,28, and the subroutine HEXDEC fills IBUF with integer values from LIST.

```
        J=1
        DO 10 I=1, 10
        CALL HEXASC(LIST(I),IBUF(J))
   10   J=J+2
```

The subroutine HEXASC fills IBUF with ASCII values from LIST.

Example 2:

```
If IVAL = 258,

then  CALL HEXASC(IVAL,IBUF(1))

results in IBUF(1) = $3031
           IBUF(2) = $3032

and CALL HEXDEC(IVAL,IBUF(1))

results in IBUF(1) = $3030
           IBUF(2) = $3032
           IBUF(3) = $3538
```

HEXASC and HEXDEC Macros

The above subroutines may be called from assembly language programs by making these macro calls:

```
HEXASC  A,B    (absolute)
    or
HEXASC* A,B    (relative)
HEXDEC  A,B    (absolute)
    or
HEXDEC* A,B    (relative)
```

Where: A is the address of the variable.

B is the address of the buffer (two words HEXASC, three words HEXDEC).

ASCII and DECHEX

```
CALL name(buffer, variable)
```

Where: name is ASCII — Converts two words of ASCII characters in BUFFER to a hexadecimal integer.

DECHEX — Converts three words of a decimal integer in ASCII characters in BUFFER to a hexadecimal integer.

buffer is the starting location containing the ASCII representation of the integer.

variable is the location of the converted integer.

Example 1:

```
DIMENSION IBUF(25),LIST(10)
     .
     .
     .
J=1
```

```
          K=1
          DO 10 I=1,5
          CALL ASCII(IBUF(J),LIST(K))
          J=J+2
          K=K+1
          CALL DECHEX(IBUF(J),LIST(K))
          J=J+3
   10     K=K+1
```

This example assumes that words 1, 6, 11, 16, and 21 in IBUF are hexadecimal and words 3, 8, 13, 18, and 23 in IBUF are decimal. The calls are comparable to $w and Iw FORMAT specification (input), respectively.

Example 2:

```
If    IBUF(1) = $3030
      IBUF(2) = $3033
      IBUF(3) = $3035
```

then CALL ASCII(IBUF (2), IVALUE)

results in IVALUE = $305 = 773

and CALL DECHEX(IBUF(1), IVALUE)

results in IVALUE = 305

ASCII and DECHEX Macros

The above subroutines may be called in assembly language by calling the appropriate macro as follows:

```
ASCII  A,B    (absolute)
ASCII* A,B    (relative)

DECHEX  A,B   (absolute)
DECHEX* A,B   (relative)
```

Where: A is the buffer address (two words for ASCII and three words for DECHEX)

B is the variable address

AFORM and RFORM

CALL name(buffer, variable)

Where: name is AFORM — Converts a word containing two ASCII characters to two words each containing a character left-justified blank-filled

RFORM — Converts a word containing two ASCII characters to two words each containing a character right-justified zero-filled.

buffer is the location containing two ASCII characters

variable is two words containing the resultant of AFORM/RFORM

Example:

```
         DIMENSION LIST(2),IBUF(10)
                .
                .
                .
         DO 10 I=1,10
         CALL RFORM(IBUF(I),LIST)
         IF(LIST(1).EQ$2E) GO TO 20
         IF(LIST(2).EQ.$2E) GO TO 20
   10    CONTINUE
   20           .
                .
                .
```

In this example, LIST is being scanned for an ASCII period. AFORM/RFORM are comparable to Aw and Rw respectively, and are used on an input record.

FLOATG

CALL FLOATG (variable, buffer)

Where: variable is a two-word floating-point variable

buffer is a six-word output buffer containing the floating-point representation with its exponent in ASCII characters: ±.XXXXXXE±ee (this is equivalent to Ew.d FORMAT specification with d=6 and 0≤ee≤±39)

FLOATG Macro

The subroutine may also be called in assembly language by using a macro call as follows:

```
FLOATG  A,B     (absolute)
FLOATG* A,B     (relative)
```

Where: A is the address of a floating-point variable

B is the address of a buffer (six words)

9.5 FORTRAN/MONITOR RUN-TIME PACKAGE

The FORTRAN/monitor run-time package was written to give the FORTRAN programmer a means of communicating with the 1700 monitor. It is necessary for the programmer to make certain monitor requests, obtain monitor parameters, or execute I/O commands.

The monitor requests are:

READ

WRITE

FORMAT-READ

FORMAT-WRITE

SCHEDULER

TIMER

RELEASE Memory

The READ, WRITE, FORMAT-READ, and FORMAT-WRITE requests were provided as a supplement to the FORTRAN READ/WRITE statement processor (Q8QIO).

The 1700 monitor request for FORMAT-READ or FORMAT-WRITE has a different interpretation than the FORTRAN formatted records.

Consult the MSOS Reference Manual for device driver characteristics with READ, FREAD, WRITE, and FWRITE calls.

9.5.1 READ/WRITE CALLING SEQUENCE

CALL name(lu, buffer, length, completion, flag, temp)

Where: name is READ, WRITE, FREAD, or FWRITE

lu is the mode and logical unit

buffer is an area in memory where data is read into or written from

length is the number of words to be read or written. If this is a mass storage logical unit, then length is the name of a three-word table containing:

LENGTH(1)	Number of words
LENGTH(2)	Mass storage address (bits 30 through 15)
LENGTH(3)	Mass storage address (bits 14 through 0)

NOTE

Calls from background for READ or WRITE mass storage requests must ensure that LENGTH(3) does not access scratch sector 0. LENGTH(3) must be ≥ 96 words.

MODE AND LOGICAL UNIT

The logical unit of the device or a core location containing the logical unit number is in bits 9 through 0 of lu. If bit 11 equals 0, then bits 9 through 0 are the actual logical unit. If bit 11 equals 1, then bits 9 through 0 are a core location containing the logical unit. The mode indication is bit 12 (= 1 ASCII; = 0 unformatted or binary). The core locations containing the standard input/output logical units as defined in the monitor are detailed as follows:

Core Location$_{16}$	lu Format$_{16}$	Meaning	Mode
F9	18F9	Input medium	ASCII
	08F9	Input medium	Binary
FA	18FA	Output punch medium	ASCII
	08FA	Output punch medium	Binary
FB	18FB	Output list medium	ASCII
FC	18FC	Output comment	ASCII
FD	18FD	Input comment	ASCII
C2	08C2	Mass storage	Binary†

lu Format

15 13	12	11 10	9 0
	m	a	lu

Where: m is the mode (used only on devices capable of both modes).

1 ASCII mode

0 Binary mode

a is 0 Actual logical unit number

2 A core location containing the logical unit number

lu is the logical unit (as defined for the MSOS configuration).

COMPLETION LOCATION AND FLAG PRIORITY

When I/O has finished, control is returned to the completion location assigned at the time of the request.

The completion location may be a statement label in the same program (FLAG = 0). In FORTRAN, the only way to set a statement label as a completion location is with the ASSIGN statement.

†When writing ASCII information on mass storage the mode is ignored.

```
          ASSIGN 100 TO INCOMPL
          CALL  FWRITE(LU,IBUF,LENGTH,ICOMPL,FLAG,TEMP)
                  .
                  .
                  .
    100   CONTINUE
```

The completion location may be a program residing in the system library (FLAG = 1). An EXTERNAL statement is used to correctly define the name of the program in the system library and the loader inserts the index to the system directory as the completion location.

```
    EXTERNAL NAME1
    FLAG=$100
        .
        .
        .
    CALL  FWRITE(LU,IBUF,LENGTH,NAME1,FLAG,TEMP)
```

The completion location may be the name of another program in core (FLAG = 2). An EXTERNAL statement is used to define the name of the program correctly.

NOTE

The completion location may never be a subroutine.

```
    EXTERNAL NAME1
    FLAG=$200
        .
        .
        .
    CALL  FWRITE(LU,IBUF,LENGTH,NAME1,FLAG,TEMP)
```

The flag priority is a word containing a completion priority (level 0 through 15) in bits 3 through 0, a request priority (level 0 through 15) in bits 7 through 4, and a completion location flag in bits 11 through 8. If bit 15 is set, the actual buffer address can be found in the location specified in the calling sequence.

15	14 12	11 8	7 4	3 0
if		f	rp	cp

Where: if is the indirect flag (8 or 0).

f is the flag (0, 1, or 2).

rp is the request priority (level 0 through 15).

cp is the completion priority (level 0 through 15).

Example:

```
      ASSIGN 10 TO IBUF
      IBUF=IBUF+2
      IFLAG=$8012
      CALL FWRITE(LU,IBUF,LENGTH,ICOMPL,IFLAG,TEMP)
10    FORMAT(50H THIS IS AN EXAMPLE OF AN INDIRECT BUFFER ADDRESS )
```

NOTE

> In the preceding example the address IBUF was updated two words to remove "(50H" from the message. Also an even number of characters does not include the terminating).

Alternatively, the FORMAT statement may be written as

```
10    FORMAT ('^THIS IS AN EXAMPLE OF AN INDIRECT BUFFER ADDRESS^' )
```

NOTE

> The alternative form also requires that the address IBUF be updated by <u>two</u> words to skip over the compiler generated "(50H" in the buffer.

Example: (direct buffer address)

```
      DIMENSION IBUF(4), ITEMP(8)
      DATA IBUF /'^MESSAGE'/, LENGTH /4/
      IFLAG = $12
      CALL FWRITE (LU, IBUF, LENGTH, ICOMPL, IFLAG, ITEMP)
```

<u>Temporary Locations</u>

An eight-word area (TEMP) is needed for building the calling sequence to the monitor.

9.5.2 SCHEDULER AND TIMER

<u>REQUESTS</u>

In a given system, numerous requests for the execution of programs at specific priority levels may be generated. Specifically these requests are generated when:

- An I/O request has been completed
- A specified time interval has elapsed

- Core has been allocated/released
- A mass storage request has been executed

Requests may also be made directly by making a scheduler call. It is the function of the scheduler request processor to:

- Cause the immediate execution of a program if it is of a higher priority level than the current program
- Thread the request by priority and on a FIFO basis if its priority is lower than the current priority.

If the requested program is mass storage resident, the scheduler request processor causes allocation of core for this program and transfer of the program from mass storage. After the program has been transferred, a scheduler request is made, which results in one of the above.

Whenever a program terminates, the dispatcher selects the next program to be run, either from the top of the scheduler thread or the interrupt stack.

CALLING SEQUENCE

CALL SCHEDL(l, flag, parameter, temp)

Where: l is the requested program to be scheduled at the completion priority.

flag is a packed word with the completion priority in bits 3 through 0 and a flag in bits 11 through 8. The flag interpretation is:

15 12	11 8	7 4	3 0
0 ←——→ 0	f	0 ←——→ 0	cp

f is the flag

0 L is a statement label
1 L is an index to the directory
2 L is an external core-resident main program

cp is the completion priority (levels 0 through 15)

parameter is a positive integer may be passed to the scheduled program. The scheduled program obtains the parameter by calling the integer function LINK.

temp is a four-word area in which the scheduler call is generated. After the scheduler call is complete, this area is available for other use.

CALL TIMER(l, flag, time, temp)

Where: l is the program to give control at priority CP after the time interval has expired.

flag is a packed word containing the completion priority in bits 3 through 0, a unit of time code in bits 7 through 4, and a flag in bits 11 through 8.

15 12	11 8	7 4	3 0
0 ◄——► 0	f	d	cp

f is the flag

0 L is a statement label
1 L is an index to the directory
2 L is an external core-resident main program

d is the unit of time

0 Counts of system time base
1 0.1 second
2 1.0 second
3 1.0 minute

cp is the completion priority

time is the time interval to delay before scheduling the program, l, at level CP. At the end of the time interval, the core clock (contents of cell $E8) is passed to the requested program as a parameter. To obtain this parameter the integer function LINK must be called.

temp is a four-word area in which the timer call is generated. After the call has been executed, this area is free for other use.

9.5.3 MISCELLANEOUS CALLING SEQUENCES

LINK

N = LINK (0)

N is set to:

- The passed parameter from a scheduler call if LINK is called at the start of the scheduled program.
- The value of the core clock if LINK is called at the start of the program called by a TIMER request.
- The error flag at the completion of I/O if LINK is called at the completion location.

DISPATCHER

CALL DISPAT or CALL DISP

Control is given to the dispatcher in the monitor to start the next highest priority program.

CORE CLOCK

The integer function ICLOCK obtains the value of the clock: I=ICLOCK(0)

I contains the current value of the clock (memory location $E8).

RELEASE OF ALLOCATED CORE

All programs that have been allocated core (either allocatable or partition) must return memory to the core allocator when they are finished. This includes all mass-storage-resident programs.

CALL RELESE (main)

Main is the name of the main program and must be compiled as the last executed statement in the program. No further program statements will be executed following CALL RELESE.

OUTPUT COMMANDS VIA THE A/Q CHANNEL

CALL OUTINS (IOUTAQ)

Where: IOUTAQ is a three-word table

IOUTAQ(1) is loaded into the Q register. Should contain converter, equipment, and station codes or the channel addresses for a connect command.

IOUTAQ(2) is loaded into the A register. Contents vary depending upon the device selected.

IOUTAQ(3) is a flag word which contains the following information after the call

0 No reject
1 Internal reject
2 External reject

INPUT COMMANDS VIA THE A/Q CHANNEL

CALL INPINS(IINAQ)

Where: IINAQ is a three-word table

IINAQ(1) is loaded into the Q register. Should contain converter, equipment, and station codes or the channel addresses for a connect command.

IINAQ(2) is after the call, contains the data or status obtained on input.

IINAQ(3) is a flag word which contains the following information after the call

0 No reject
1 Internal reject
2 External reject

CONNECT THE 1750 DATA AND CONTROL TERMINAL AND INPUT

```
CALL ICONCT(IINAQ)
```

Refer to input commands via the A/Q channel for the calling sequence interpretation.

CONNECT THE 1750 DATA AND CONTROL TERMINAL AND OUTPUT

```
CALL OCONCT(IOUTAQ)
```

Refer to output commands via the A/Q channel for the calling sequence interpretation.

9.5.4 BUFFERED INPUT/OUTPUT

There are many ways of accomplishing asynchronous I/O operation (for example, reading/writing from one buffer while executing from another) with programming techniques. The following example demonstrates how this may be accomplished.

```
DIMENSION DATA(100,2),TEMP(4)
             .
             .
             .
ASSIGN 100 TO ISTART
     1.      IPRIOR=4
             CALL SCHEDL(ISTART,IPRIOR,0,TEMP)
             CALL DISPAT
         100 KX=1
             ASSIGN 200 to ICOMPL
     2.      CALL READ(LU,DATA(1,KX),100,ICOMPL,IPRIOR,TEMP)
     3.      CALL DISPAT
     4.  200 IF(LINK(0).NE.0) GO TO 300
             JX=KX
             KX=3-KX
     5.      CALL READ(LU,DATA(1,KX),100,ICOMPL,IPRIOR,TEMP)
                .
                .
     6.         .     COMPUTE WITH DATA(1,JX)
     7.      CALL DISPAT
                .
                .
                .
     8.  300 CONTINUE
             END
```

Following is an explanation of the preceding coding.

1. Make a scheduler call to set the priority level of the program.

2. Initialize a READ of n words ($\leq$ 100 words) into DATA(1,KX) where KX=1.

> NOTE
>
> The first word address is DATA(1) and the priority level for this READ is the same as the program.

3. Make a dispatcher call. Another program is given control until the I/O is complete.

4. The completion location (200) tests for errors in reading the input data.

5. Initialize a second READ of n words ($\leq$ 100 words) into DATA (1,KX) where KX=2.

> NOTE
>
> FWA is DATA(101) and the completion priority must be at the same level as the program priority level.

6. Execute the data in the filled buffer where JX indicates which buffer is filled.

7. When execution of DATA(1,JX) is complete, call the dispatcher.

8. If the filling buffer (KX) is complete, control goes to the completion address where the buffers are switched and the sequence of operations is restarted. However, if the filling buffer (KX) is incomplete, control remains with another lower priority program, while I/O is in progress, before returning to the completion address.

COMMUNICATION BETWEEN FORTRAN AND ASSEMBLY LANGUAGE PROGRAMS A

THE FORM OF THE CALLING SEQUENCE

Calling sequences written in assembly language which are intended to communicate with FORTRAN-generated subprograms must have the following form, where SUB has been previously declared as an external.

```
LOC           RTJ        SUB
LOC+1         (RTJ SUB is a two-word instruction)
LOC+2         Address of argument 1
LOC+3         Address of argument 2
LOC+4         Address of argument 3
  .
  .
  .
LOC+N+ 1      Address of argument N
LOC+N+ 2      Program resumes
```

When a function subprogram returns a floating-point value, the result is placed in locations $00C5 and $00C6 (and $00C7 for double-precision).

The result of an integer function is left in the A register.

Addresses of arguments occur in consecutive locations following the RTJ command, one cell per address, in the order that the arguments appear in the actual parameter list which should be the same subprogram definition. Subroutines need not necessarily have arguments.

FORTRAN calls to assembly language subroutines must recognize the argument passing sequence as previously described. The arguments must have the same order as their use and are assembled in the form as previously shown. When a call to a routine outside of a FORTRAN program is made and I/O is performed, a priority problem may be encountered. In such a case the priority of FORTRAN I/O and other devices used should be examined to determine if a higher priority device has interfered.

ABSOLUTE ADDRESSES

All arguments in common will be in the calling sequence as absolute addresses. In a non-run-anywhere program, all arguments are absolute.

RELATIVE ADDRESSES

Relative addressing is only used in programs compiled under the R option.

All arguments which do not fall into the category for absolute addresses are represented in the calling sequence as relative addresses. The self-relative address (which is what is meant by a relative address in a calling sequence) is computed by subtracting the location of the self-relative address in the calling sequence, say LOC+3, from the address of the corresponding argument, say argument 3, and setting bit 15 to 1.

Only the 15 low order bits of an argument (14 through 0) are necessary to designate the address absolute or relative. Thus, in calling sequences, bit 15 is used as a flag to distinguish between the two addressing modes.

Bit 15 is 0 if argument address is absolute.

Bit 15 is 1 if argument address is relative.

The address returned from a floating-point calling sequence is absolute.

FORTRAN assumes that all assembly language routines save and restore the Q and I registers.

TABLE CAPACITIES B

FORTRAN TABLE LIMITS

Up to 2,340 compiler-generated and user symbols are allowed.

Up to 10 nested DO loops are allowed.

The maximum number of declared subscripts is 150.

The maximum number of continuation cards allowed per statement is five.

No more than 30 parenthesis levels are allowed.

The number of unique dummy argument index constant pairs must not exceed 50.

The number of subroutine arguments may not exceed 50.

Literals in DATA statements are limited to 387 characters.

Up to 51 EQUIVALENCE relations are allowed.

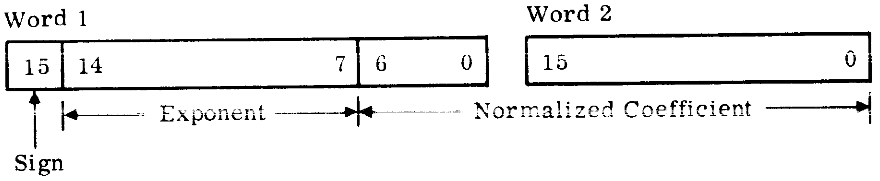
The number of compiler-generated words may not exceed 300 per source statement, or else a compiler table overflow error F,100 will be generated.

SINGLE-PRECISION FLOATING-POINT PACKAGE C

The single-precision floating-point package used by 1700 FORTRAN is described in this appendix. The package also can be used by an assembly-produced program.

Two similar floating-point packages are called by the same name (FLOT); one is re-entrant and the other is not. Both packages are usable by run-anywhere programs. The re-entrant package must operate in protected core; the other package may operate anywhere.

Each floating-point number requires two consecutive words of 1700 storage. The first word (most significant bits) is the one that is addressed. Normalized floating-point format is as follows:



A floating-point number x is in the range given in the following example and is significant to one part in eight million.

$$-2^{127}\ (1-2^{\frac{1}{23}}) \le x \le 2^{127}\ (1-2^{\frac{1}{23}})$$

If the most significant word is zero (16 bits of zero or one), a floating-point zero is assumed.

COEFFICIENT

The coefficient consists of a 23-bit number n, $1-2^{-23}$, $>|n| > 0$. The high-order bit position of the first word is the coefficient sign bit. A zero denotes a positive coefficient and a one denotes a negative coefficient. When the coefficient is negative, the entire floating-point number, exclusive of the sign bit, is stored in complement form.

EXPONENT

The floating-point exponent is an eight-bit quantity ranging from 00 to FF_{16}. Through biasing by 80_{16}, this range expresses both positive and negative exponents. The biasing is accomplished according to the following rules:

1. If the floating-point number is negative, complement the entire floating-point word and remember that the number is negative. The exponent is now in a true biased form.

2. If the biased exponent is equal to or greater than 80_{16}, subtract 80_{16} to obtain the true exponent. If less than 80_{16}, subtract $7F_{16}$ to obtain the true exponent. (Observe the algebraic rules for subtraction.)

3. Separate the coefficient and exponent. If the true exponent is negative, move the binary point left the number of bit positions indicated by the true exponent. If the exponent is positive move the binary point right the required number of places.

4. The coefficient has now been converted to fixed binary. The sign of the coefficient will be negative if the original floating-point number was complemented in step 1. The sign bit must be extended if the quantity is to be placed in a register.

5. Convert the quantity to decimal representation by using the Powers method.

Example 1:

Floating point number BFBF FFFF
IN BINARY 1011 1111 1011 1111 (FFFF)
NEG ∴ COMPLEMENT: 0100 0000 0100 0000 (0000)
EXTRACT EXPONENT: 100 0000 0

CONVERT TO HEX: 80_{16}

UNBIAS:

$$\begin{array}{r} 80 \\ \underline{-80} \\ 0_{16} \end{array}$$

NORMALIZED COEFFICIENT EQUALS

$.100 \quad 0000_2$ (0000)

NO BINARY POINT MOVEMENT NEEDED USING POWERS RULES

$.1x2^{-1}+0x2^{-2}+0x2^{-3}+.....+Ax2^{-n}$

DOING ARITHMETIC

$.1/2+0+0+......+0$

ANSWER = $-.5_{10}$

Example 2:

Floating point number 3BCO 0000

BINARY = 0011 1101 1100 0000 (0000)

011 1101 1

EXPONENT = $7B_{16}$

$$\begin{array}{r} 7B \\ -7F \\ \hline -\ 4 \end{array}$$

MOVE BINARY POINT LEFT 4 PLACES

.100 0000 (0000)

.0000100 0000

$= .\,0x2^{-1}+0x2^{-2}+0x2^{-3}+0x2^{-4}+1x2^{-5}+\ldots\ldots$

$= .\,2^{-5}$

ANSWER $= \frac{1}{32} = .03125_{10}$

Example 3:

Floating point number 44CO 0000

BINARY 0100 0100 1100 0000 (0000)

Exponent 100 0100 1

$8 \quad 9_{16}$

$$\begin{array}{r} 89 \\ -80 \\ \hline +\ 9 \end{array}$$

MOVE BINARY POINT RIGHT 9 PLACES

.100 0000 (0000)

100 0000 00.

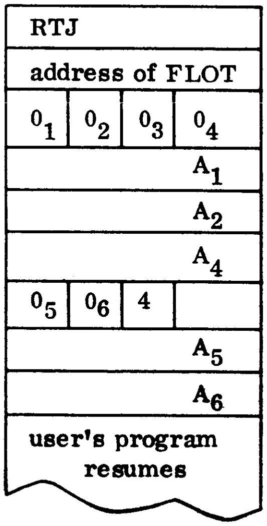
$1x2^{8}+0x2^{7}+\ldots\ldots\ldots+0x2^{0} \quad .0x2^{-1}+\ldots\ldots\ldots+Ax2^{-n}$

ANSWER $= 2^{8} = 256_{10}$

CALLING SEQUENCE

FLOT uses an interpretive calling sequence. Neither calling sequence saves Q or I, nor uses the communication cells. In the re-entrant cases, the communication cells must be saved upon entrance to a program unit and restored upon exit (it is the user's responsibility to save these communication cells). The interpretation is on a string of four-bit bytes, where the leftmost four-bit byte represents the first operation. The respective operands, if they exist, are in the same order as the bytes, with one operand per byte. As many operations as desired may exist, but the last one must be the terminator of a four. The pseudo accumulator is retained between calls to FLOT.

Example:



RTJ			
address of FLOT			
O_1	O_2	O_3	O_4
			A_1
			A_2
			A_4
O_5	O_6	4	
			A_5
			A_6
user's program resumes			

The calling sequence was designed to minimize core requirements, including core used to set up the calling sequence.

OPERATIONS

The following operations are used by the floating-point package.

Operation	4-Bit Code	Meaning
FEND	4	End of calling sequence. This operation terminates the calling sequence. No operand needed.
CHMD	5	Change mode of operation. All operand addresses following this operation code in the calling sequence are made relative if the preceding addresses were absolute, or absolute if the preceding addresses were relative. Addresses are initially absolute. No operand is needed.

Operation	4-Bit Code	Meaning
NIDX	6	No index. The succeeding operands do not have indexing increments. NIDX supersedes any preceding INDX and is superseded by any following INDX. NIDX is assumed initially. No operand is needed.
FCOM	7	Floating complement. The pseudo accumulator is complemented. No operand is needed.
FSUB	8	Floating subtract. The contents of the effective operand address is subtracted from the pseudo accumulator and the result is left in the pseudo accumulator.
FMPY	9	Floating multiply. The pseudo accumulator is multiplied by the contents of the effective operand address and the result is left in the pseudo accumulator.
FDIV	A_{16}	Floating divide. The pseudo accumulator is divided by the contents of the effective operand address and the result is left in the pseudo accumulator.
FLDD	B_{16}	Floating load. The floating-point number in the corresponding effective operand address is transferred to the pseudo accumulator.
FLST	D_{16}	Floating store. The floating-point number is transferred from the pseudo accumulator to the corresponding effective operand address.
FADD	E_{16}	Floating add. The contents of the effective operand address is added to the pseudo accumulator and the sum is left in the pseudo accumulator.
INDX	F_{16}	Index. The operand corresponding to INDX is used to increment the operand of the following operations: FLDD, FLST, FADD, FSUB, FMPY, and FDIV. Each succeeding INDX supersedes the last. No index is initially assumed.

Operation codes 0, 1, 2, 3, and C_{16} are not used.

ABSOLUTE ADDRESSING

If unprotected core is in the lower bank, the operand address may be a direct or indirect absolute address. As in the 1700, all indirect addressing will be executed before indexing. However, only one level of indirect addressing is allowed. If unprotected core is in the upper bank, indirect addressing is illegal.

RELATIVE ADDRESSING

The operand address, bits 14 through 0, is relative to self. If bit 15 is set, the addressing is relative-indirect to one level of indirectness if unprotected core is in part 0. The relative address is computed by subtracting the calling sequence operand address from the actual operand address, bit 15=0.

Example:

X = -((A(I) + B(I) * C(I)) + (D(J) * E (J))

Assume TEMP, X, J, D, and E are absolutely addressed and the other operands relatively addressed. The call to FLOT would look like the following.

RTJ			FLOT
F_{16}	B_{16}	9	6
absolute address J			
absolute address D			
absolute address E			
D_{16}	5	F_{16}	B_{16}
absolute address TEMP			
relative address I			
relative address A			
E_{16}	9	7	6
relative address B			
relative address C			
5	E_{16}	D_{16}	4
absolute address TEMP			
absolute address X			

FAULT CONDITIONS

At any time during execution, fault conditions are flagged by a communications cell. If a fault condition has been encountered, bit 15 will be set for exponent overflow, bit 14 for a divide fault, and bit 13 for exponent underflow. The device fault bit is set for division by zero. An exponent overflow/ underflow bit is set whenever the exponent of an arithmetic operation is not within range.

FLOATING-POINT ARITHMETIC WITH 23-BIT NUMBERS

A classic and straightforward technique is presented which is not limited to the size or type of the number representation used.

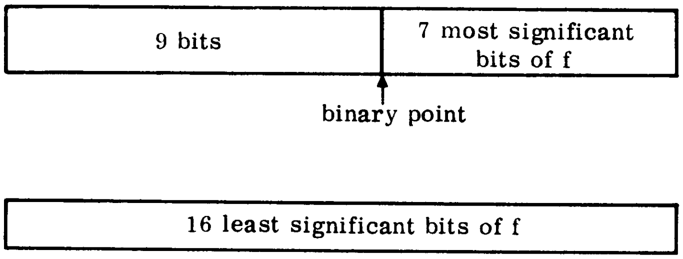
Consider the double-precision floating point number:

$$F = f \times \beta \tag{1}$$

where $|f|$ lies in the range

$$1/2 \leq |f| \leq 1 - 2^{-23} \tag{2}$$

Assume that we have a machine with a word length of 16 bits and that the 32 bits in the double-length word are divided in the following standard way:



The leftmost block of nine bits is divided into three parts:

- The first (leftmost) bit represents the sign of f.
- The second bit represents the sign of β.
- The next seven bits represent the magnitude of β.

This allows 23 bits for the representation of f. Assume that the binary point lies at the left of the 23 bits representing f so that the seven most significant bits of f are stored in the first word of the pair and the 16 least significant bits of f are stored in the second word of the pair.

If

$$|f| = c + d \times 2^{-7} \tag{3}$$

where c lies in the range

$$1/2 \leq c \leq 1 - 2^{-7} \tag{4}$$

and where d lies in the range

$$1/2 \leq d \leq 1 - 2^{-16} \tag{5}$$

then c represents the seven most significant bits of f and d represents the 16 least significant bits of f.

FOUR ARITHMETIC OPERATIONS

We wish to consider the four basic arithmetic operations using double-precision floating-point numbers of the form discussed. Consequently, in order to have notation for two operands, consider a second double-precision floating-point number

$$G = g \times 2^{\delta} \quad (6)$$

where $|g|$ lies in the range

$$1/2 \leq |g| \leq 1 - 2^{-23} \quad (7)$$

If

$$|g| = a + b \times 2^{-7} \quad (8)$$

where a lies in the range

$$1/2 \leq a \leq 1 - 2^{-7} \quad (9)$$

where b lies in the range

$$1/2 \leq b \leq 1 - 2^{-16} \quad (10)$$

then a represents the seven most significant bits of $|g|$ and b represents the 16 least significant bits of $|g|$.

Assume that the machine represents negative numbers using a one's complement system. Assume that the procedure for changing the sign of a double-precision floating-point number is to perform a bit-by-bit complement of the entire 32 bits (including the nine bits representing the sign and exponent).

Multiplication

$$\begin{aligned} F \times G &= (f \times 2^{\beta})\ (g \times 2^{\delta}) \\ &= (\text{sign } F \times G)\ |f| \times |g| \times 2^{\beta+\delta} \quad (11) \end{aligned}$$

The computational procedure is primarily concerned with the formation of $|f| \times |g| \times 2^{\beta+\delta}$ since (sign F × G) can be recorded in advance and used later to apply the correct sign to the product. In addition to recording (sign F × G), we record the exponents β and δ after the product $|f| \times |g|$ is formed. The following algorithm is proposed for multiplying F by G:

1. Determine and record (sign F × G).
2. Form $|F|$ and $|G|$.
3. Record the leftmost nine bits of $|F|$ and $|G|$. This, in effect, records β and δ.

4. Shift the 23 bits of |f| and |g| left until each has the bit pattern

+	15 most significant bits		C
0	8 least significant bits	7 zeros	D

If this procedure is followed, |f| is no longer represented by (3) during the computation in step 5 below, but has the form

$$|f| = C + D \times 2^{-15} \qquad (12)$$

where C lies in the range

$$1/2 \leq C \leq 1 - 2^{15} \qquad (13)$$

and D lies in the range

$$0 \leq D \leq 1 - 2^{-8} \qquad (14)$$

Likewise g has the form

$$|g| = A + B \times 2^{-15} \qquad (15)$$

where A lies in the range

$$1/2 \leq A \leq 1 - 2^{-15} \qquad (16)$$

and where B lies in the range

$$0 \leq B \leq 1 - 2^{-8} \qquad (17)$$

5. Use fixed-point operations in forming the product.

$$|f| \times |g| = (C + D \times 2^{-15})\,(A + B \times 2^{-15})$$

$$= CA + (CB + DA) \times 2^{-15} + DB \times 2^{-30} = DB \times 2^{-30}$$

$$= CA + (CB + DA) \times 2^{-15} \qquad (18)$$

Notice that the term $DB \times 2^{-30}$ may be ignored, because once the product is placed back in standard form, only 23 bits are retained. Notice also that (18) is written in such a way that it exhibits the efficiency of the following choice of computational steps:

a. Form CA giving a double-length product.

b. Form CB and retain the most significant half of the double-length product.

c. Form DA.

d. Add the most significant half of DA to the most significant half of CB.

e. Add the least significant half of CA to the sum obtained in (d). This result is the second half of the double-length product. The first half of the double-length product is the most significant half of CA which was formed in a.

6. Next, round and normalize the product obtained using (18) in step 5. Any adjustment in the exponent $\beta + \delta$ which is necessary because of the normalization of $|f| \times |g|$ must be performed.

7. Finally, pack the 23 bits of the normalized product and the nine bits representing the sign and the adjusted exponent into two 16-bit words (in the standard way). If (sign F × G) is negative, the two words must then be complemented to give the correct sign to the product.

Division

$$\frac{G}{F} = \frac{g \times 2^{\delta}}{f \times 2^{\beta}} \tag{19}$$

$$= (\text{sign } G \times F) \; \left|\frac{g}{f}\right| \times 2^{\delta \times \beta}$$

And since the following is wanted:

$$\left|\frac{g}{f}\right| < 1 \tag{20}$$

scale the numerator and write:

$$\frac{G}{F} = (\text{sign } G \times F) \frac{\left|\frac{g}{2}\right|}{|f|} \times 2^{\delta - \beta + 1} \tag{21}$$

Thus, propose the following algorithm for dividing G by F:

1. Determine and record (sign F × G).
2. Form |F| and |G|.
3. Record the leftmost nine bits of |F| and |G|. This, in effect, records β and δ.
4. Arrange the 23 bits of |f| to give the bit pattern

+	15 most significant bits of |f|		C
0	8 least significant bits	7 zeros	D

and the 23 bits of |g| to give the bit pattern

+	0	14 most significant bits of |g|	A
0	9 least significant bits	6 zeros	B

Thus, f is represented by (12), (13), and (14) as in the case of multiplication. However, in this case

$$\left|\frac{g}{2}\right| = A + B \times 2^{-15} \tag{22}$$

where A lies in the range

$$1/4 \leq A \leq 1/2 - 2^{-15} \tag{23}$$

and where B lies in the range

$$0 \leq B \leq 1 - 2^{-9} \tag{24}$$

5. Use fixed-point operations in forming the quotient:

$$\begin{aligned}
\left|\frac{\frac{g}{2}}{f}\right| &= \frac{A + B \times 2^{-15}}{C + D \times 2^{-15}} \\
&= \left[\frac{A + B \times 2^{-15}}{C}\right] \times \left[\frac{1}{1 + \frac{D}{C} \times 2^{-15}}\right] \\
&= \left[\frac{A}{C} + \frac{B}{C} \times 2^{-15}\right] \times \left[1 - \frac{D}{C} \times 2^{-15} + \frac{D^2}{C^2} \times 2^{-30} + \ldots.\right] \\
&= \frac{A}{C} + \frac{B}{C} \times 2^{-15} - \frac{AD}{C^2} \times 2^{-15} - \frac{BD}{C^2} \times 2^{-30} + \frac{AD^2}{C^3} \times 2^{-30} + \ldots \\
&= \frac{A}{C} + \left[\frac{B}{C} - \frac{AD}{C^2}\right] \times 2^{-15} + \left[\frac{AD^2}{C^3} - \frac{BD}{C^2}\right] \times 2^{-30} + \ldots \\
&= \frac{A + \left[B - \frac{AD}{C}\right] \times 2^{-15}}{C}
\end{aligned} \tag{25}$$

Notice that the terms beginning with

$$\left[\frac{AD^2}{C^3} - \frac{BD}{C^2}\right] \times 2^{-30}$$

may be ignored because only 23 bits of the quotient are retained. Notice also that (25) is written in such a way that it exhibits the efficiency of the following choice of computational steps.

a. Form -AD giving a double length product.

b. Divide -AD (as a double length dividend) by C.

c. Form $B - \frac{AD}{C}$ (rounded to a single length).

d. Form the double-length dividend:

$$A + \left[B - \frac{AD}{C}\right] \times 2^{-15}$$

(The sign of the second term requires special attention.)

e. Divide this double length dividend by C.

f. To obtain the second half of the double-length quotient, the remainder resulting from the division in the previous step must now be divided by C. This procedure is efficient only on those machines which feature fixed-point multiplication that a double-length product which can be used as a double-length dividend for fixed-point division.

6. Next, round and normalize the quotient obtained using (25) and the procedure of step 5. Any adjustment in the exponent which is necessary because of the normalization of

$$\left|\frac{\frac{g}{2}}{F}\right|$$

must be performed.

7. Finally, pack the 23 bits of the normalized quotient and the nine bits representing the sign and the adjusted exponent into two 16-bit words (in the standard way). If (sign F × G) is negative, the two words must then be complemented to give the correct sign to the quotient.

Addition

$$F + G = f \times 2^{\beta} + g \times 2^{\delta} \qquad (26)$$

The basic problem in floating-point addition is to adjust the exponent of F (or G) so that the binary points are aligned before the addition takes place.

Let L represent a pair of cells which contain the larger of the two numbers F and G, and S represent a pair of cells which contain the smaller of the two numbers. Assume that F is larger than G if

$$\beta \geq \delta \qquad (27)$$

and F is smaller than G if

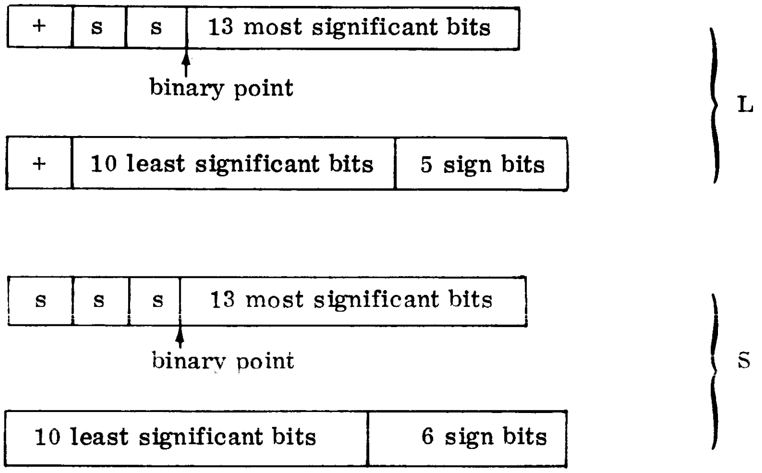
$$\beta < \delta \qquad (28)$$

Relative magnitudes of f and g, in case the exponents are equal, are of no concern. Using this convention, process the following algorithm for forming F + G.

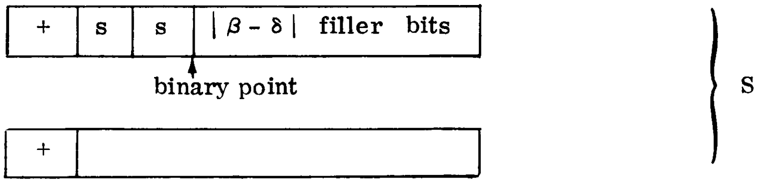
1. Record the leftmost nine bits of F and G. This, in effect, records β and δ.

2. Determine the sign of $(\beta-\delta)$ and thus determine whether F is smaller or larger than G according to (27) and (28).

3. Place f and g in L and S. If F is larger than G, then f goes into L; otherwise f goes into S and g goes into L. The following bit patterns should be formed (here s means sign bit).

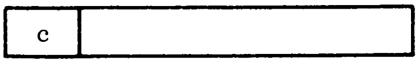


4. Shift S right $|\beta-\delta|$ places and put a + bit at the beginning of each of the two words. If $|\beta-\delta| = 23$, then there is no need to continue since all significant bits in S will be lost.



Notice that the $|\beta-\delta|$ filler bits between the binary point in S and the most significant bit of the fraction are sign bits. This is mathematically correct in a one's complement representation of negative numbers.

5. Add the second halves of L and S.



The first bit of this sum is c. If it is a one, there is actually a carry. However, it usually is easier to add c (refer to step 6) than to test to see whether or not it needs to be added as a carry bit in forming the sum of the first halves of L and S.

6. Add the first halves of L and S and add the carry bit obtained from step 5.

e	s	v	

If e = 1 then an end-around carry must be performed. This means that a one is added at the right end of the word produced in step 5. Since this might also produce a carry bit, the c in the diagram (refer to step 5) must be cleared to zero before the end-around carry. If a carry bit is again produced, then a one must be added at the right end of the word produced in step 5. It can be shown that this last operation can never produce another e = 1.

If v = s then v is a sign bit. If v ≠ s then there has been overflow during the addition and v is the most significant bit of the sum. In the latter case, an adjustment of the exponent will be necessary to give the correct answer.

7. Shift the second half of the sum left one place to clear out carry bit c. Then shift the double length sum left (a) one place if v ≠ s; (b) two places if v = s.

This leaves the sum in the following form:

s	15 most significant bits of the sum

at least 8 bits of the sum	sign bits

8. If the double-length sum was shifted one place left in step 7 (v ≠ s) then the exponent must be adjusted to take care of the overflow. This means adding one to the exponent β or δ, whichever is larger. (This will be the exponent of the sum.) If the double-length sum was shifted two places left in step 7, no adjustment of exponent is necessary.

9. The form of the sum given by step 7 must be checked for normalization since it is possible that several of the leading bits of the sum may be zero. (Cancellation occurs when two numbers of opposite sign but nearly equal magnitude are added.) If the sum is not normalized at this point appropriate adjustments in the exponents should be made.

If 23 left shifts are not sufficient for normalization then the sum should be made zero.

10. At this point the normalized sum may be rounded, although the extra coding involved may not be worth the gain. If rounding is desired, then there are two cases to be considered depending on the sign of the sum. These cases require that care be taken in handling any carry bit produced by the rounding operations.

11. Now pack the 23 most significant bits of the sum, along with nine bits representing the sign and exponent, into two 16-bit words (in the standard way). If the sign of the sum is negative, then the first nine bits must be complemented before the packing takes place.

Subtraction

No special subroutine is necessary since

$$F - G = F + (-G)$$

and one merely complements G before entering the addition subroutine.

FAULT CONDITIONS

If exponent underflow is encountered, a floating-point zero results. If exponent overflow is encountered, the largest word of the appropriate sign results. A divide check is treated as overflow.

REFERENCES

Robert T. Gregory and James L. Raney, "Floating Point Arithmetic with 84-Bit Numbers", Communications of the ACM, Volume 1, Number 1, January 1964.

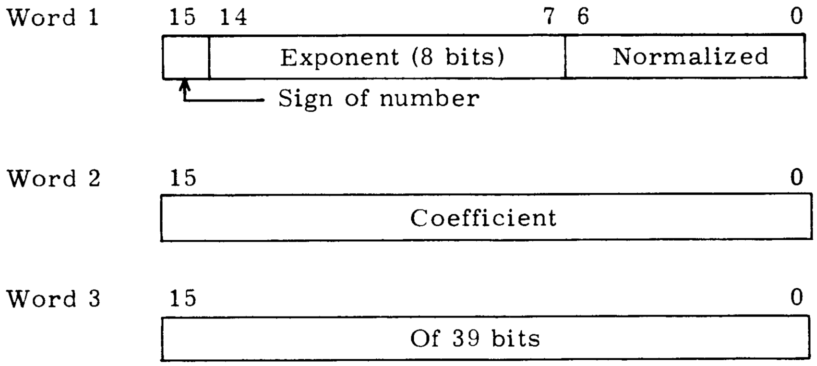
DOUBLE-PRECISION FLOATING-POINT PACKAGE D

The double-precision floating-point package used by 1700 FORTRAN is described in this appendix. The package can also be used by an assembly-produced program. For efficiency the package is not run-anywhere.

There are two similar floating-point packages. They are called by the same name (DFLOT), but one is re-entrant and the other non-re-entrant. Both packages are usable by run-anywhere programs. The re-entrant package must operate in protected core. The non-re-entrant package may operate anywhere.

The non-re-entrant version of DFLOT utilizes temporary storage to perform its computations. The re-entrant version utilizes volatile storage for temporary storage.

Each double-precision floating-point number requires three consecutive words of 1700 storage. The first word, containing the most significant bits, is the one that is addressed. Normalized floating-point format is as follows:



Thus the numbers, X, expressible are of the range $-2^{127}(1-2^{-39}) \leq X \leq 2^{127}(1-2^{-39})$ and are significant to one part in 549 billion. If the most significant word is zero (16 bits of zero or 1) a floating-point zero is assumed.

COEFFICIENT

The coefficient consists of a 39-bit number n, $1-2^{-39} \geq n \geq 1/2$. The high-order bit position of the first word is the coefficient sign bit. A 0 denotes a positive coefficient and 1 denotes a negative coefficient. When the coefficient is negative, the entire floating-point number, exclusive of the sign bit, is stored in complement form.

EXPONENT

The floating-point exponent is an eight-bit quantity with value ranging from 00 to FF_{16}. Through biasing by 80_{16}, this range expresses both positive and negative exponents.

CALLING SEQUENCE

DFLOT uses an interpretive calling sequence. Both the re-entrant and non-re-entrant calling sequences save the Q, A, and I registers in temporary storage. The interpretation is on a string of four-bit bytes, where the leftmost four-bit byte represents the first operation. Their respective operands, if they exist, follow in the bytes' respective order, one word per byte.

As many bytes may exist as desired, but the last one must be 4. The double-precision pseudo accumulator is not retained between calls to DFLOT.

Example:

15	11	07	03 00
RTJ			
address of DFLOT			
0_1	0_2	0_3	0_4
			A_1
			A_2
			A_4
0_5	0_6	4	
			A_5
			A_6

User's program resumes

The calling sequence was designed to minimize the amount of core needed, including core used to set up the calling sequence.

OPERATIONS

A description of the following operations and their four-bit byte codes follows. Bytes 0, 1, 2, and 3 are considered 4 (FEND).

Operation	4-Bit Code	Meaning
FEND	4	End of calling sequence. This operation terminates the calling sequence. No operand needed.

Operation	4-Bit Code	Meaning
CHMD	5	Change mode of operation. All operand addresses following this operation code in the calling sequence are made relative if the preceding addresses were absolute, or absolute if the preceding addresses were relative. Relative references are assumed relative to self. Addresses are initially absolute per call to DFLOT. No operand is needed.
NIDX	6	No index. The succeeding operands do not have indexing increments. NIDX supersedes any preceding INDX and is superseded by any following INDX. NIDX is assumed upon entry. No operand is needed.
DFCOM	7	Double floating complement. The pseudo accumulator is complemented. No operand is needed.
DFSUB	8	Double floating subtract. The contents of the effective operand address is subtracted from the pseudo accumulator and the result is left in the pseudo accumulator.
DFMPY	9	Double floating multiply. The pseudo accumulator is multiplied by the contents of the effective operand address and the result is left in the pseudo accumulator.
DFDIV	A_{16}	Double floating divide. The pseudo accumulator is divided by the contents of the effective operand address and the result is left in the pseudo accumulator.
DFLDD	B_{16}	Double floating load. The floating-point number will be loaded from core and transferred to the pseudo accumulator located in temporary storage.
DFLST	D_{16}	Double floating store. The double-precision floating-point number is transferred from the pseudo accumulator and stored in core.
DFADD	E_{16}	Double floating add. The contents of the effective operand address is added to the pseudo accumulator and the sum is left in the pseudo accumulator.
INDX	F_{16}	Index. The contents of the effective operand address is used to increment the operand of the following operations: DFLDD, DFLST, DFADD, DFSUB, DFMPY, and DFDIV. Each succeeding INDX supersedes the last. No index is initially assumed.

Operation codes 0, 1, 2, 3, and C_{16} are not used.

ABSOLUTE ADDRESSING

The operand address may be a direct or indirect absolute address. As in the 1700, all indirect addressing will be executed before indexing. Unlike the 1700, only one level of indirect addressing is allowed.

RELATIVE ADDRESSING

The operand address, bits 14 through 0, is relative to self. If bit 15 is set, the addressing is relative-indirect to one level of indirectness. The relative address is computed by subtracting the calling sequence operand address from the actual operand address, bit 15-0.

Example:

X = - (A(I)+B(I))*C(I)+D(J)*E(J)

Assume TEMP, X, J, D, and E are absolutely addressed, the other operands relatively addressed. The call to DFLOT would look like the following:

RTJ DFLOT			
F_{16}	B_{16}	9	6
Absolute address of J			
Absolute address of D			
Absolute address of E			
D_{16}	5	F_{16}	B_{16}
Absolute address of temporary cell TEMP			
Relative address of I			
Relative address of A			
E_{16}	9	7	6
Relative address of B			
Relative address of C			
5	E_{16}	D_{16}	4
Absolute address of temporary cell TEMP			
Absolute address of X			

FAULT CONDITIONS

At any time during execution, fault conditions are flagged by a communications cell (cell $C8_{16}$). If a fault condition has been encountered, bit 15 will be set for exponent overflow, bit 14 for a divide fault, and bit 13 for exponent underflow. The divide fault bit is set for division by zero. An exponent overflow/underflow bit is set whenever the exponent of an arithmetic operation is not within range.

FLOATING-POINT ARITHMETIC WITH 39-BIT NUMBERS

A classic and straightforward technique is presented which is not limited to the size or type of the number representation used.

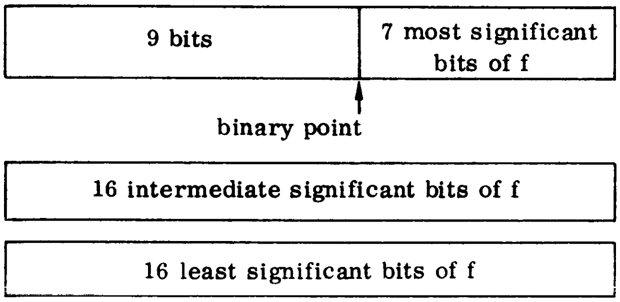
Consider the double-precision floating-point number:

$$F = f \times 2^{\beta} \qquad (1)$$

where $|f|$ lies in the range

$$1/2 \leq |f| \leq 1 - 2^{-39} \qquad (2)$$

Assume that we have a machine with a word length of 16 bits and that the 48 bits in the triple-length word are divided in the following standard way:


9 bits
7 most significant bits of f
binary point
16 intermediate significant bits of f
16 least significant bits of f

The leftmost block of nine bits is divided into three parts·

- The first (leftmost) bit represents the sign of f.
- The second bit represents the sign of β.
- The next seven bits represent the magnitude of β.

This allows 39 bits for the representation of f. We shall assume that the binary point lies at the left of the 39 bits representing f so that the seven most significant bits of f are stored in the first word of the three, and the 16 least significant bits of f are stored in the third word.

If we write

$$|f| = c + ci \times 2^{-7} + d \times 2^{-23} \qquad (3)$$

where c lies in the range

$$1/2 \leq c \leq 1 - 2^{-7} \qquad (4)$$

ci lies in the range

$$0 \leq ci \leq 1 - 2^{-16} \qquad (5)$$

and where d lies in the range

$$0 \leq d \leq 1 - 2^{-16} \qquad (6)$$

then c represents the seven most significant bits of f, ci represents the 16 intermediate bits of f, and d represents the 16 least significant bits of f.

FOUR ARITHMETIC OPERATIONS

We wish to consider the four basic arithmetic operations using double-precision floating-point numbers of the form discussed. Consequently, in order to have notation for two operands, let us consider a second double-precision floating-point number.

$$G = |g| \times 2^{\delta} \qquad (7)$$

where $|g|$ lies in the range

$$1/2 \leq |g| \leq 1 - 2^{-39} \qquad (8)$$

If

$$|g| = a + ai \times 2^{-7} + b \times 2^{-23} \qquad (9)$$

where a lies in the range

$$1/2 \leq a \leq 1 - 2^{-7} \qquad (10)$$

ai lies in the range

$$0 \leq ai \leq 1 - 2^{-16} \qquad (11)$$

and b lies in the range

$$0 \leq b \leq 1 - 2^{-16} \qquad (12)$$

then a represents the seven most significant bits of $|g|$, ai represents the 16 intermediate significant bits of $|g|$, and b represents the 16 least significant bits of $|g|$.

Assume that the machine represents negative numbers using a one's complement system. Assume that the procedure for changing the sign of a double-precision floating-point number is to perform a bit-by-bit complement of the entire 48 bits (including the nine bits representing the sign and exponent).

Addition

$$F + G = f \times 2^{\beta} + g \times 2^{\delta} \qquad (13)$$

The basic problem in floating-point addition is to adjust the exponent of F (or G) so that the binary points are aligned before the addition takes place.

Let L represent three cells which contain the larger of the two numbers F and G, and S represent three cells which contain the smaller of the two numbers. Assume that F is larger than G if

$$\beta \geq \delta \qquad (14)$$

and F is smaller than G if

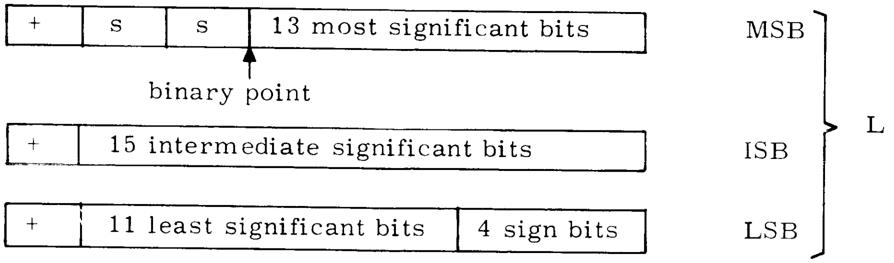
$$\beta < \delta \qquad (15)$$

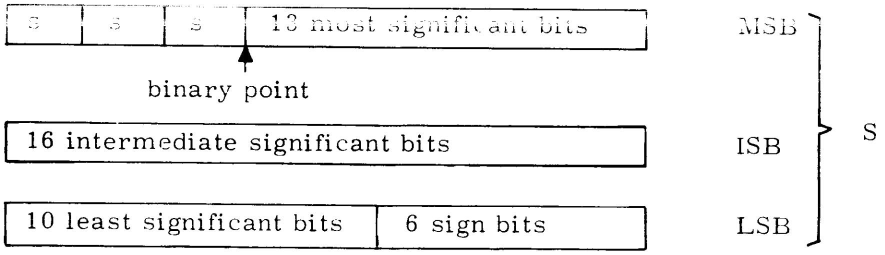
The relative magnitudes of f and g, in case the exponents are equal, are of no concern. Using this convention, process the following algorithm for forming F + G:

1. Record the leftmost nine bits of F and G. This, in effect, records β and δ.

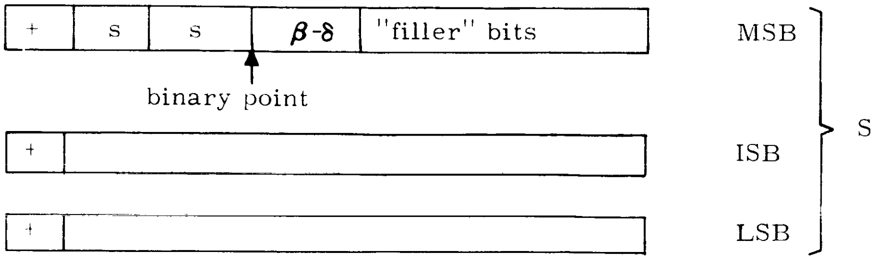
2. Determine the sign of $(\beta-\delta)$ and thus determine whether F is smaller or larger than G according to (14) and (15).

3. Place f and g in L and S. If F is larger than G, then f goes into L; otherwise, f goes into S and g goes into L. The following bit patterns should be formed (here s means sign bit):





4. Shift S right $|\beta-\delta|$ places and put a + bit at the beginning of each of the three words. If $|\beta-\delta| = 39$, then there is no need to continue since all significant bits in S will be lost.



Notice that the $|\beta-\delta|$ filler bits between the binary point in S and the most significant bit of the function are sign bits. This is mathematically correct in a one's complement representation of negative numbers.

5. Add the LSB portions of L and S.

c	

The first bit of this sum is c. If it is a one, there is actually a carry. However, it usually is easier to add c (see step 6) than to test to see whether or not it needs to be added as a carry bit in forming the sum of the ISB portions of L and S.

6. Add the ISB portions of L and S and the carry bit from step 5.

c1	

If C1 is set to one, we have a carry and we will add c1 to step 7 in forming the sum of the most significant bits of L and S.

7. Add the MSB portions of L and S and add the carry bit obtained from step 6.

e	s	v	

If e = 1 then an end-around carry must be performed. This means that a one is added at the right end of the word produced in step 5. Since this might also produce a carry bit, the c in the diagram (see step 5) must be cleared to zero before the end-around carry. If a carry bit is again produced, then a one must be added at the right end of the word produced in step 6. Since this might also produce a carry bit, the c1 in the diagram (see step 6) must be cleared to zero before the end-around carry. If a carry bit is again produced, then a one must be added at the right end of the word above. It can be shown that this last operation can never produce another e = 1.

If v = s then v is a sign bit. If v ≠ s then there has been overflow during the addition and v is the most significant bit of the sum. In the latter case, an adjustment of the exponent will be necessary to give the correct answer.

8. Shift the LSB portion of the sum left one place to clear out carry bit c. Then shift the ISB portion of the sum left one place to clear out the carry bit c1. Then shift the LSB portion of the sum one place and put the bit shifted off into the rightmost bit of the ISB portion of the sum. Then shift the triple length sum left (a) one place if v ≠ s; (b) two places if v = s.

This leaves the sum in the following form:

s	15 most significant bits of the sum

16 intermediate significant bits of the sum

at least 8 bits of the sum	sign bits

9. If the triple-length sum was shifted one place left in step 8 ($v \neq s$) then the exponent must be adjusted to take care of the overflow. This means adding one to the exponent β or δ, whichever is larger. (This will be the exponent of the sum.) If the double length sum was shifted two places left in step 8, no adjustment of exponent is necessary.

10. The form of the sum given by step eight must be checked for normalization since it is possible that several of the leading bits of the sum may be zero. (Cancellation occurs when two numbers of opposite sign but nearly equal magnitude are added.) If the sum is not normalized at this point, appropriate adjustments in the exponents should be made.

    If 39 left shifts are not sufficient for normalization, then the sum should be made zero.

11. At this point the normalized sum may be rounded, although the extra coding involved may not be worth the gain. If rounding is desired, then there are two cases to be considered depending on the sign of the sum. These cases require that care be taken in handling any carry bit produced by the rounding operations.

12. Now pack the 39 most significant bits of the sum, along with nine bits representing the sign and exponent, into three 16-bit words (in the standard way). If the sign of the sum is negative, then the first nine bits must be complemented before the packing takes place.

<u>Subtraction</u>

No special subroutine is necessary since

$$F - G = F + (-G)$$

and one merely complements G before entering the addition subroutine.

<u>Multiplication</u>

$$F \times G = (f \times 2^{\beta})\ (g \times 2^{\delta}) \qquad (16)$$

$$= (\text{sign } F \times G)\ |f| \times |g| \times 2^{\beta+\delta}$$

The computational procedure is primarily concerned with the formation of $|f| \times |g| \times 2^{\beta+\delta}$ since (sign F × G) can be recorded in advance and used later to apply the correct sign to the product. In addition to recording (sign F × G), we record the exponents β and δ after the product $|f| \times |g|$ is formed. The following algorithm is proposed for multiplying F by G:

1. Determine and record (sign F × G)
2. Form $|F|$ and $|G|$.
3. Record the leftmost nine bits of $|F|$ and $|G|$. This, in effect, records β and δ.

4. Shift the 39 bits of $|f|$ and $|g|$ left until each has the bit pattern

+	15 most significant bits		C and A
0	15 intermediate significant bits		Ci and Ai
0	9 least significant bits	6 zeros	D and B

If this procedure is followed, $|f|$ is no longer represented by (3) during the computation in step 5 below, but has the form:

$$f = C + Ci \times 2^{-15} + D \times 2^{-30} \tag{17}$$

where C, Ci, and D lie in the following ranges:

$$2^{-1} \leq C \leq 1 - 2^{-15} \tag{18}$$

$$0 \leq Ci \leq 1 - 2^{-15} \tag{19}$$

$$0 \leq D \leq 1 - 2^{-9} \tag{20}$$

Likewise $|g|$ has the form

$$|g| = A + Ai \times 2^{-15} + B \times 2^{-30} \tag{21}$$

where A, Ai, and B lie in the following ranges:

$$2^{-1} \leq A \leq 1 - 2^{-15} \tag{22}$$

$$0 \leq Ai \leq 1 - 2^{-15} \tag{23}$$

$$0 \leq B \leq 1 - 2^{-9} \tag{24}$$

5. Use fixed-point operations in forming the product.

$$\begin{aligned} |f| \times |g| &= (C + Ci \times 2^{-15} + D \times 2^{-30})\,(A + Ai \times 2^{-15} + B \times 2^{-30}) \\ &= CA + (CAi + CiA) \times 2^{-15} + (DA + CiAi + CB) \times 2^{-30} \\ &\quad + (DAi + CiB) \times 2^{-45} + DB \times 2^{-60} \\ &= CA + (CAi + CiA) \times 2^{-15} + (DA + CiAi + CB) \times 2^{-30} \end{aligned} \tag{25}$$

Notice that the terms (DAi + CiB) $\times 2^{-45}$ and DB $\times 2^{-60}$ may be ignored, because once the product is placed back in standard form, only 39 bits are retained. The following computational steps are performed:

a. Form CA giving a double-length product.

b. Form DA and retain the most significant half of the double-length product.

c. Form CiAi and retain the most significant half of the double-length product.

d. Form CiA giving a double-length product.

e. Add the most significant half of DA to the most significant half of CiAi.

f. Form CB and retain the most significant half of the double-length product.

g. Add the most significant half of DB to the sum obtained in (e).

h. Add the least significant half of CiA to the sum obtained in (g).

i. Form CAi giving a double-length product.

j. Add the least significant half of CAi to the sum obtained in (h). This result is the least significant portion of the triple-length product.

k. Add the most significant half of CiA to CAi.

l. Add the least significant half of CA to the sum obtained in (k). This result is the intermediate significant portion of the triple-length product. The first half of the double-length product is the most significant half of CA which was formed above in (a).

6. Next, round and normalize the product obtained using (25) in step 5. Any adjustment in the exponent $\beta+\delta$ which is necessary because of the normalization of $|f| \times |g|$ must be performed.

7. Finally, pack the 39 bits of the normalized product and the nine bits representing the sign and the adjusted exponent into three 16-bit words (in the standard way). If the (sign F $\times$ G) is negative, the two words must then be complemented to give the correct sign to the product.

Division

$$\frac{G}{F} = G \times \frac{1}{F} = (g \times 2^{\delta}) \times \left(\frac{1}{f \times 2^{\beta}}\right)$$

$$= (\text{sign } G \times F) \times g \times \frac{1}{f} \times 2^{\delta-\beta} \qquad (26)$$

As a matter of fact, since we want:

$$\left|\frac{g}{f}\right| < 1, \qquad (27)$$

scale the numerator and write:

$$\frac{G}{F} = (\text{sign } G \times F) \times |g| \times \left|\frac{\frac{1}{2}}{f}\right| \times 2^{\delta-\beta+1} \qquad (28)$$

Thus, propose the following algorithm for dividing G by F:

1. Determine and record (sign F × G).
2. Form |F| and |G|.
3. Record the leftmost eight bits of |F| and |G|. This, in effect, records β and δ.
4. Arrange the 39 bits of |f| to give the bit pattern:

+	15 most significant bits of |f|	A

0	15 intermediate significant bits of |f|	Ai

0	9 least significant bits	6 zeros	B

   and the 39 bits which represent the number 1.0 to give the bit pattern:

+	0	14 most significant bits of 1/2	\$2000	α

0	15 intermediate significant bits of 1/2	\$0000	γ

0	10 least significant bits of 1/2	5 zeros	\$0000	ϵ

5. Use fixed-point operations in forming the quotient.

$$\frac{1}{A + Ai \times 2^{-15} + B \times 2^{-30}} = \frac{\alpha + \gamma \times 2^{-15} + \epsilon \times 2^{-30}}{A + Ai \times 2^{-15} + B \times 2^{-30}}$$

where: $\alpha = \$2000$
$\gamma = \$0000$
$\epsilon = \$0000$

$$= \frac{\alpha}{A} + \frac{1}{A}\left(\gamma - \frac{\alpha Ai}{A}\right) \times 2^{-15} + \frac{1}{A}\left(\epsilon - \frac{\alpha B}{A}\right) \times 2^{-30}$$

$$- \frac{Ai}{A^2}\left(\gamma - \frac{\alpha Ai}{A}\right) \times 2^{-30}$$

$$= \frac{1}{A}\left[\alpha - \frac{\alpha}{A}\left[Ai \times 2^{-15} + (B - \frac{Ai^2}{A}) \times 2^{-30}\right]\right] \qquad (29)$$

Any terms beginning with 2^{-45} are ignored because only 39 bits of the quotient are retained. The following computational steps are performed:

a. Form $-Ai^2$ giving a double-length product.

b. Divide $-Ai^2$ (as a double-length dividend) by A.

c. Form $B-\frac{Ai^2}{A}$ (rounded to a single length).

d. Form the double length-dividend:

$$Ai \times 2^{-15} + \left[(B - \frac{Ai^2}{A}) \times 2^{-30}\right]$$

(The sign of the second term requires special attention.)

e. Divide the double-length dividend by A and multiply the result by α. The multiply is accomplished by shifting the result of the divide.

f. To obtain the second half of the double-length quotient, the remainder resulting from the division in the previous step must now be divided by A.

g. Form α (the most significant bits of 1/2) and the result obtained from step e as a double-length dividend.

h. Divide the double-length dividend by A. The result is the most significant bits of the quotient.

i. Form the remainder of step h and the result of step f as a double-length dividend.

j. Divide the double-length dividend by A. The result is the intermediate significant bits of the quotient.

k. Divide the remainder obtained in step j by A. The result is the least significant bits of the quotient.

l. Next, round and normalize the three-word quotient using (29) and the procedure of step 5. Any adjustment in the exponent which is necessary because of normalization of

$$\frac{\frac{1}{2}}{f}$$

must be performed.

m. The three-word quotient is then multiplied by $|g|$.

n. Next, round and normalize the product. Any adjustment in the exponent $\beta+\delta$ which is necessary due to the normalization must be performed.

o. Finally, pack the 39 bits of the normalized quotient and the nine bits representing the sign and the exponent into three 16-bit words (in the standard way). If (sign $F \times G$) is negative, the three words must then be complemented to give the correct sign to the quotient.

FAULT CONDITIONS

If exponent underflow is encountered, a floating point zero results. If exponent overflow is encountered, the largest word of the appropriate sign results. A divide check is treated like an overflow.

REFERENCES

Robert T. Gregory and James L. Raney, "Floating Point Arithmetic with 84-Bit Numbers", Communications of the ACM, Volume 1, Number 1, January 1964.

CODING HINTS E

The constants in an arithmetic expression should be collected. For example,

```
X = Y + 3.1 * 4.2
```

should be written

```
X = Y + 13.02
```

Subexpressions, including a byte variable as constant in a DO loop, should be pulled out of the loop. For example, the program

```
        SUBROUTINE SUM
        COMMON A(10), IC(10)
        DATA B/3.4/
        DO 1 I = 1, 10
        A (I) = 0.0
        DO 1 J = 1, 10
1       A(I) = (SIN(B) + FLOAT(I)) * FLOAT (IC(J)) + A(I)
        RETURN
        END
```

should be written

```
        SUBROUTINE SUM
        COMMON A(10), IC(10)
        DATA B/3.4/
        TEMP1 = SIN(B)
        DO 2 I = 1, 10
        C = 0.0
        TEMP2 - FLOAT(I) + TEMP1
        DO 1 J = 1, 10
1       C = TEMP2 FLOAT(IC(J)) + C
2       A(I) = C
        RETURN
        END
```

Only one dimensional array should be used. If two or three dimensions are desired, the programmer should use the subscript functions given in Appendix G. For example, the program

```
      SUBROUTINE TRANSF
      COMMON A(10, 10), B(10, 10)
      DO 1 J = 1, 10
      DO 1 I = 1, 10
1     A(I,J) = B(I,J) + 1.0
      RETURN
      END
```

should be written

```
      SUBROUTINE TRANSF
      COMMON A(100), B(100)
      DO 1 I = 1, 100
      1 A(I) = B(I) + 1.0
      DO 1 J = 1, 10
      ITEMP1 = 10 * (J-1)
      DO 1 I = 1, 10
      ITEMP2 = I + ITEMP1
1     A(ITEMP2) = B(ITEMP2) + 1.0
      RETURN
      END
```

Common subexpressions between two or more arithmetic expressions should be collected. For example,

```
Y(I) = A+B + FUNC1(IBYTE)
Z(I) = A+FUNC1(IBYTE) + FUNC2(IBYTE)
```

where IBYTE is a byte variable, should be written

```
ITEMP1 = IBYTE
TEMP1 = A + FUNC1(ITEMP1)
Y(I) = B + TEMP1
Z(I) = TEMP1 + FUNC2(ITEMP1)
```

When a program references a multi-dimensional array, the FORTRAN compiler on occasion generates a relocatable base address for an indexed variable which is intended to fall in front of data, common, or the program. Since this relocatable address is expressed in 15 bits, the loader on a 16-bit load has no way of knowing that this is not a forward relocation. To accommodate this, the loader assumes that any relocatable address in the range 7F80 to 7FFF is intended as backward relocation. This range can be changed by reassembly of the MSOS loader module RBDBZ1.

The user who has the double precision capability may write programs which require only single precision. To avoid linkage to the double precision library, the external references to DOUT, Q8DXP1, and Q8DXP9 must be satisfied. The user may write his own dummy routine with these references as entry points or use the routine DBLDMY (deck ID K19) contained in the MS FORTRAN product set, and load it with his programs. Refer to Section 2.2.6, Double Precision Type Data, and note the evaluation for double precision constants to avoid an external reference to DFLOT.

HARDWARE REQUIREMENTS F

1. The minimum hardware configuration is:

FORTRAN 3.2A	FORTRAN 3.2B
Mass Memory Device (.5 million words or more)	Mass Memory Device (.5 million words or more)
Card Reader	Card Reader
Teletypewriter	Teletypewriter
CDC 1700-Class CPU	CDC 1700-Class CPU
Core Storage Increments*	Core Storage Increments*
Compiler core requirement is less than 8,192 words.	Compiler core requirement is less than 16,200 words.
Minimum MSOS 4 Operating System core requirement is 9.2K	Minimum MSOS 4 Operating System core requirement is 9.2K.

2. The typical configuration is:

FORTRAN 3.2A	FORTRAN 3.2B
Mass Memory Device (1.0 million words or more)	Mass Memory Device (1.0 million words or more)
Teletypewriter	Teletypewriter
Card Reader/Punch	Card Reader/Punch
Magnetic Tape Devices	Magnetic Tape Devices
CDC 1700-Class CPU	CDC 1700-Class CPU
Core Storage Increments*	Core Storage Increments*
Compiler core requirement is less than 8,192 words.	Compiler core requirement is less than 16,200 words.
Typical MSOS 4 Operating System core requirement 19K**.	Typical MSOS 4 Operating System core requirement 12.5K**.

*Core requirements are based on the size of the Compiler used and the size of the MSOS operating system configured.

**Typical operating system core requirements for 3.2A versus 3.2B are different because certain nice-to-have MSOS features are usually not included in the 3.2B system to allow 32K configuration.

ARRAYS G

An array is a block of sequential memory locations referenced by a single name. The name types the elements of the array as integer or real (Section 2.4). Arrays are dimensioned in the mathematical sense of having rows, columns, and planes. The magnitude of these dimensions is defined by the array declarator, which is the array name followed by a set of numerical subscripts giving the maximum dimensions.

Examples:

IOTA (50)	One-dimensional array with 50 integer elements
BETA (4,6)	Two-dimensional array with 24 real elements
ALPHA (4,3,5)	Three-dimensional array with 60 real elements

Elements of arrays are stored by columns in ascending order of location. The ordering of elements in an array follows the rule that the first subscript varies most rapidly and the last subscript varies least rapidly. In the array declared as A(3,3,3)

A_{111}	A_{121}	A_{131}
A_{211}	A_{221}	A_{231}
A_{311}	A_{321}	A_{331}

A_{112}	A_{122}	A_{132}
A_{212}	A_{222}	A_{232}
A_{312}	A_{322}	A_{332}

A_{113}	A_{123}	A_{133}
A_{213}	A_{223}	A_{233}
A_{313}	A_{323}	A_{333}

The planes are stored in order, starting with the first, as follows.

$A_{111} \rightarrow L$ $\quad A_{121} \rightarrow L+3 \ldots A_{133} \rightarrow L+24$

$A_{211} \rightarrow L+1$ $\quad A_{221} \rightarrow L+4 \ldots A_{233} \rightarrow L+25$

$A_{311} \rightarrow L+2$ $\quad A_{321} \rightarrow L+5 \ldots A_{333} \rightarrow L+26$

For a given dimensionality, subscript declarator, and subscript, the value of a subscript pointing to an array element and the maximum value a subscript may attain is indicated in Table G-1. A subscript expression must be greater than zero.

The value of the array element successor function is obtained by adding one to the the entry in the subscript value column. Any array element whose subscript has this value is the successor to the original element. The last element of the array is the one whose subscript value is the maximum subscript value and which has no successor element.

The sequential location of a particular element of a stored array is determined according to the following:

Given the array defined by the declarator

AZ(A,B,C)

The ordinal location of element AZ(a,b,c) will be given by the formula

a + A * (b-1) + A * B * (c-1)

Derivation of the formula is illustrated in Figure G-1.

Example:

To find the ordinal location of element B(2,3,4) in the array B(5,6,7)

2 + 5 * (3-1) + 5 * 6 * (4-1) = 102

A subscript never may be less than 1 or greater than the maximum dimension declared for it. The elements of one-dimension array BETA (I) may not be referred to as BETA (I,J) or BETA (I,J,K). A diagnostic will be given if this is attempted.

The array name without subscripts references the entire array when it is used in an I/O list, as an argument of a function or subroutine (Sections 7.4.1 and 7.4.2), or in a specification statement other than DIMENSION (Section 6.1.1) or DATA (Section 6.2).

Table G-1. Value of a Subscript

DIMENSIONALITY	SUBSCRIPT DECLARATOR	SUBSCRIPT REFERENCE	SUBSCRIPT VALUE	MAXIMUM SUBSCRIPT VALUE
1	(A)	(a)	a	A
2	(A,B)	(a,b)	a+A*(b-1)	A*B
3	(A,B,C)	(a,b,c)	a+A*(b-1) +A*B*(c-1)	A*B*C
Notes: (1) a, b, and c are subscript expressions. (2) A, B, and C are dimensions.				

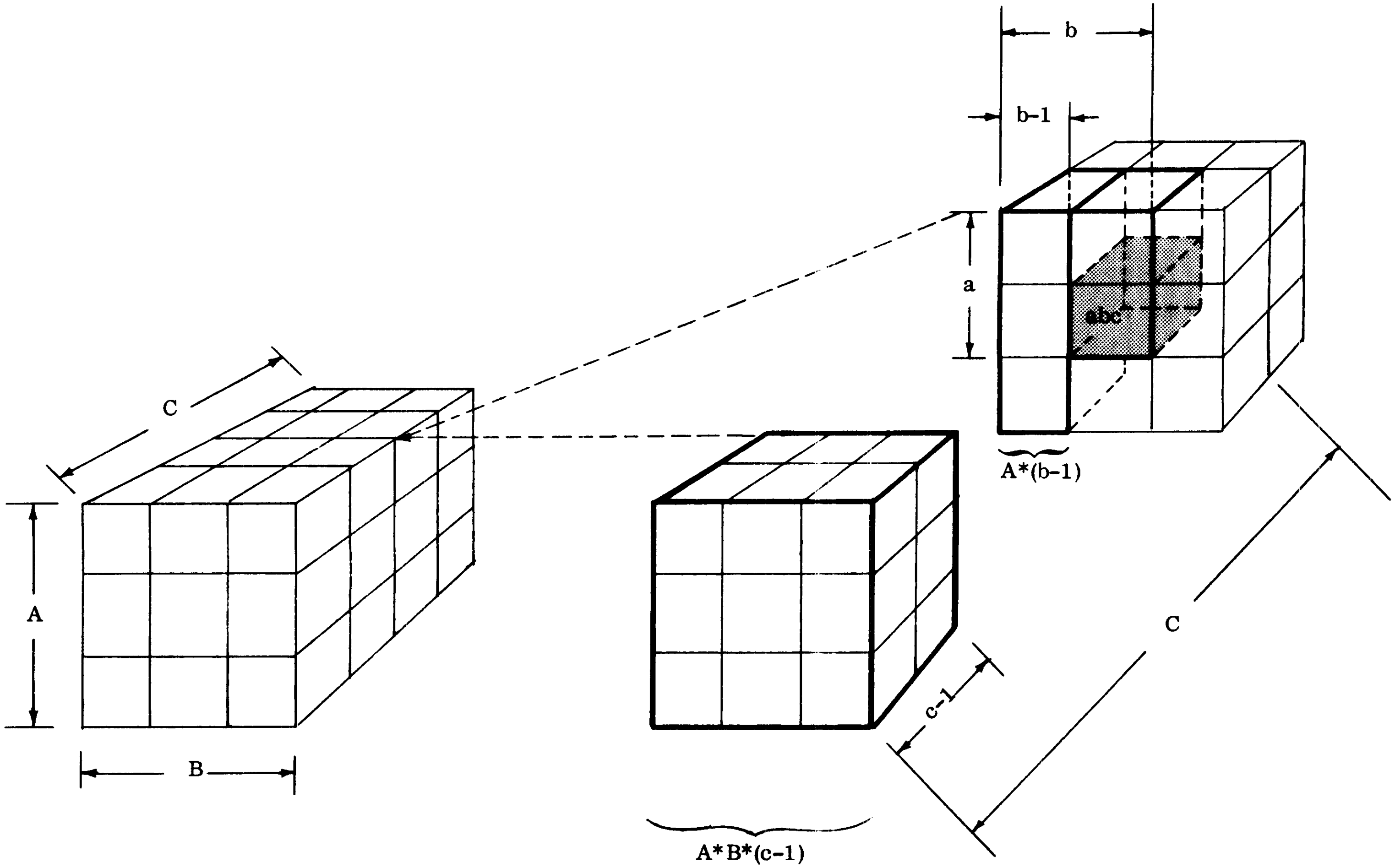


Figure G-1. Array Successor Function a + A * (b-1) + A * B * (c-1)

Before an array can be used in a program, its name and dimensionality must be declared in a DIMENSION, COMMON, or type statement (Sections 6.1.1, 6.1.2, and 6.1.4).

Example:

Given the array ALPHA(3,4,4)

It will be declared for program use by any of the following:

```
DIMENSION ALPHA (3,4,4)
COMMON // ALPHA (3,4,4)
INTEGER ALPHA (3,4,4)
```

ASCII CODES

The 1968 American Standard Code for Information Interchange (ASCII) is used by 1700 MSOS for communication between the 1700 and external I/O devices. In addition to the code for the FORTRAN character set, it includes code for control of the paper tape punch and the teletypewriter.

ASCII code uses eight bits, the first of which is always 0; it is omitted in the following table. Bits 1 through 4 contain the low-order four bits of code for the character in that row. Bits 5, 6, and 7 contain the high-order three bits of the code for the character in that column.

BITS				b7 → b6 → b5 →	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
b4 ↓	b3 ↓	b2 ↓	b1 ↓	COLUMN ROW	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	´	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FS	,	<	L	\	l	¦
1	1	0	1	13	CR	GS	-	=	M	]	m	}
1	1	1	0	14	SO	RS	.	>	N	^	n	~
1	1	1	1	15	SI	US	/	?	O	_	o	DEL

FORTRAN Character Set

LOAD MAP COMMENT FEATURE I

The user may insert comments in the binary name block by using the name card comment feature. This comment will appear on the load map to the right of the program name and load address.

The name card feature reserves columns 27 through 72 for comments by inserting a slash in column 26. An alternate method of using this feature is to make a continuation card for the program name card with the slash in column 7 and the comment immediately following the slash.

The comment field may follow any of the following statements: PROGRAM, SUBROUTINE, FUNCTION, DOUBLE PRECISION FUNCTION, REAL FUNCTION, INTEGER FUNCTION, or BLOCK DATA.

If the slash is used, the 46 characters following the slash appear on the NAM block of the binary output.

If neither the slash nor the comment appears on the source card, the binary NAM card is blank.

If there is no slash, but comments appear on the card, a diagnostic is issued and the binary NAM card contains blanks.

Examples:

```
7         15        26              40

PROGRAM   NAME      /99999999       SAMPLE NAME WITH ID        (With comments)

7           18
SUBROUTINE  NAME(A,B,C,D,E,F)                                  (Without comments)

6
1/A CONTINUATION CARD MAY ALSO BE USED
```

OPTIMIZATIONS J

1700 MS FORTRAN optimizations are listed as follows:

1. Index registers are optimally assigned.
2. Relative addressing is used where possible.
3. Storage is allocated to maximize relative addressing. For example, some arrays are put into the middle of code and constants may be duplicated.
4. All simple FORTRAN-provided functions are inserted in-line (for example, IABS or AND).
5. A comprehensive analysis of IF statements is made. Code generated takes cognizance of a transfer from the IF to the label of the next statement; and also if the statement is a GO TO. In a logical IF, the computations are structured to produce the least amount of computation for a determination of the expression's truth value.
6. Arithmetic expressions are analyzed and computed in an order which minimizes both the amount of code generated and its execution time.
7. The compiler may reference the values in A, Q, and I (FF_{16}) and make use of them. It may even reference each of these values by two different names. For example, if I = 0, the compiler can reference both I and 0 as representing a value in the accumulator.

FORTRAN CHARACTER SET K

FORTRAN uses alphanumeric and special characters.

Alphanumeric characters are the letters A through Z and digits 0 through 9.

The decimal system is used unless indicated otherwise; however, octal and hexadecimal numbers may be used in certain instances.

Following is a list of characters.

ASCII Character	ASCII Code	Hollerith Punch (026)	Description			
0	30	0	Digit	Octal	Decimal	Hexadecimal
1	31	1	Digit			
2	32	2	Digit			
3	33	3	Digit			
4	34	4	Digit			
5	35	5	Digit			
6	36	6	Digit			
7	37	7	Digit			
8	38	8	Digit			
9	39	9	Digit			
A	41	12-1	Letter			
B	42	12-2	Letter			
C	43	12-3	Letter			
D	44	12-4	Letter			
E	45	12-5	Letter			
F	46	12-6	Letter			
G	47	12-7	Letter			
H	48	12-8	Letter			
I	49	12-9	Letter			
J	4A	11-1	Letter			
K	4B	11-2	Letter			
L	4C	11-3	Letter			
M	4D	11-4	Letter			
N	4E	11-5	Letter			
O	4F	11-6	Letter			
P	50	11-7	Letter			
Q	51	11-8	Letter			
R	52	11-9	Letter			
S	53	0-2	Letter			

ASCII Character	ASCII Code	Hollerith Punch (026)	Description
T	54	0-3	Letter
U	55	0-4	Letter
V	56	0-5	Letter
W	57	0-6	Letter
X	58	0-7	Letter
Y	59	0-8	Letter
Z	5A	0-9	Letter
(space)	20	No punch	Blank
!	21	11-8-2	Exclamation point
"	22	8-7	Quotes
#	23	12-8-7	Number
$	24	11-8-3	Dollar
%	25	0-8-5	Percent
&	26	8-2	Ampersand
'	27	8-4	Apostrophe
(	28	0-8-4	Left parenthesis
)	29	12-8-4	Right parenthesis
*	2A	11-8-4	Asterisk
+	2B	12	Plus
,	2C	0-8-3	Comma
-	2D	11	Minus
.	2E	12-8-3	Period
/	2F	0-1	Slash
:	3A	8-5	Colon
;	3B	11-8-6	Semicolon
<	3C	12-8-6	Less than
=	3D	8-3	Equal
>	3E	8-6	Greater than
?	3F	12-8-2	Question
@	40	0-8-7	At
[	5B	12-8-5	Left bracket
\	5C	0-8-2	Reverse slash
]	5D	11-8-5	Right bracket
^	5E	11-8-7	Circumflex
_	5F	0-8-6	Underline

FORTRAN COMPILATION ERRORS L

Message	Significance
*$\left\{\begin{matrix}N\\F\end{matrix}\right\}$, code, no., part	A compilation free of diagnostics will be syntactically correct. The compilation will also be free of common semantic errors, such as undefined variables in context requiring definition. If the detected error prevents code from being generated in a reasonably accurate manner, the error is considered fatal and compilation terminates. When an assumption is made as to the intended meaning of a statement, the diagnostic indicates the assumption. When possible, errors which may not be fatal (e.g., an A in column 3) are flagged. A reference to such a label (or the intended nonexistent label) would cause the fatal error. N Trivial error; only flagged. Example: not separating array declarators in a dimension statement F Fatal error code Diagnostic number; see the following message for listing of codes no. Number of statements in error; appears only when applicable part Part of statement in error; appears only when applicable
variable *$\left\{\begin{matrix}N\\F\end{matrix}\right\}$, code	Compilation error. When errors cannot be detected until all the specification statements have been read and initially processed, the error appears in this format. As the specification statements are processed further, a few diagnostics can be printed. In these cases, the variable causing the difficulty is printed. The diagnostic is printed on the next line without a statement number reference since it is no longer available. N Trivial error; only flagged. Example: not separating array declarators in a dimension statement F Fatal error code Number of statements in error; appears only when applicable

Message	Significance
1	Field is not recognizable (illegal characters in field, such as 8 in octal field).
2	Minimum range limit of a constant is exceeded.
3	More than six characters in a name
4	Maximum range limit of a constant is exceeded.
5	Exponent is missing in a constant.
6	Subscripted variable was not previously dimensioned.
7	Expression in an IF statement does not have initial parenthesis .
8	Incorrect FORMAT statement
9	Illegal use of the .NOT. operator
10	Illegal operator or operand
11	Subprogram reference is illegal.
12	Labeled END card is illegal.
13	Number of arguments differs in references to the same subprogram.
14	Implied DO in DATA statement either contains wrong number of subscripts or subscript is out of range.
15	Expression has an illegal termination.
16	Unmatched parentheses in an expression
17	Relational operator is missing.
18	Relational operator used illegally.
19	Asterisk is assumed.
20	Only one ** is allowed per parentheses level.
21	A variable and a subprogram name are interchanged.
22	Subprogram name does not appear in an EXTERNAL statement.
23	One or more DO loops terminate on an undefined statement label.
24	Illegal subscript
25	Statement is syntactically correct.
26	This array was previously dimensioned in DIMENSION, COMMON, or TYPE statement or previously defined in an EXTERNAL statement. The previous dimensioning or defining is retained and the new ignored.
27	The field must be a variable or array name if processing a COMMON, DATA, EQUIVALENCE, BYTE, or SIGNED BYTE statement; an array name if processing a DIMENSION statement; or an array, variable, or FUNCTION name if processing a type statement.

Message	Significance
28	Logical IF statement contains another logical IF, DO, DATA, or FORMAT statement.
29	Name must be the name of an array.
30	Must be first statement of program unit.
32	A missing comma in this statement is assumed.
34	Illegal character in this statement is changed to a blank.
35	This line, which begins a statement, has other than zero or blank in column 6; blank is assumed.
36	Too many labeled common blocks declared, continuation of the last declared block is assumed.
37	The name in this COMMON statement is either a formal argument or defined in a previous COMMON statement. The name is ignored.
38	Name specified as two different types. This specification is ignored.
39	This byte typed as other than an integer, or it is a formal argument. The byte specification is ignored.
40	This byte previously specified as a different byte. The previous specification is retained and this specification is ignored.
41	The bit specified is not within bounds of the 1700 word size.
42	Least significant bit in this specification is greater than the most significant bit.
43	Name must be an external function or subroutine name.
44	Field must be a nonzero positive integer constant.
45	Array has more than three dimensions.
46	DATA statement contains too many constants for the space provided.
47	Statement has more than five continuation cards; excess cards are ignored.
48	An insufficient number of constants is provided in this data statement.
50	Constant is not same type as corresponding data cell.
51	Statement redefines DO loop parameter.
52	Statement type is unrecognizable; or it follows an executable statement.
53	Not defined
54	Statement label is meaningless; label is ignored.
55	Statement label previously defined; current label is ignored.

Message	Significance
56	Program name expected in this field.
57	Too many dimensions caused table overflow.
58	Symbol table overflowed; compilation terminates.
59	Statement label may not be zero.
60	No apparent exit from this program
61	Unclosed DO-implied list
62	Unformatted WRITE must have a list.
63	Name must be an integer variable or integer constant.
64	Name not implicitly an integer variable
65	A RETURN statement may appear only in a subroutine or function definition. A STOP statement is assumed.
66	Superflous information in this statement is ignored.
67	This field on STOP card must have an octal number not greater than 77777. STOP is assumed.
68	Field must be a positive integer.
69	Field must be an integer variable.
70	Field must be a statement label.
71	This form of ASSEM argument cannot reference elements in COMMON, EXTERNAL names, or subprogram arguments.
72	This type of statement may not terminate a DO loop.
73	This statement terminates a DO loop which is not the last DO encountered.
74	This GO TO jumps to itself.
75	A program consisting of only an END card is illegal.
78	Label in a DO statement must reference a statement following it.
79	Maximum allowable number of nested DOs exceeded. The DO loop may be implied in a DO list.
80	Subroutine argument table overflow; caused by large number of declared parameters and unique references to these parameters.
81	This formal argument was previously specified as another formal argument or the subprogram name.
82	Too many formal arguments caused a compiler table overflow.
83	The above name is not a variable or an array element.

Message	Significance
84	Two elements of the same array or common block are assigned to the same storage unit.
85	Blank common and formal arguments may not be initialized with DATA statements.
87	An array element in a BYTE, SIGNED BYTE, DATA, or EQUIVALENCE statement either has wrong number of subscripts or subscript is out of range.
88	Too many EQUIVALENCE names caused a compiler table overflow.
89	At least two elements must appear in an EQUIVALENCE statement.
91	DATA statement field is not an integer, real, double precision, or literal constant.
92	Missing terminating asterisk or quote in a literal string as appropriate
100	Catastrophic table overflow; compilation is abandoned. If the offending statement is arithmetic or a logical IF, the statement should be broken into two or more statements and the program recompiled.
101	Two PROGRAM, FUNCTION, SUBROUTINE, or BLOCK DATA statements in one program unit; the second is ignored.
103	Relative address argument in ASSEM statement requires an asterisk at the end of the preceding instruction.
152	Arithmetic table overflow

FORTRAN EXECUTION ERRORS M

The following error messages apply to the FORTRAN I/O run-time only.

Message	Significance	Action/Result
1 I/O RQST statement no. ffff	Error in a format statement; illegal character in format statement ffff The current decimal value of the format statement pointer	Program terminates
2 I/O RQST statement no. ffff gggg	Illegal character in the input field. ffff Current decimal value of format statement pointer gggg Current decimal value of input field pointer	Program terminates
3 I/O RQST statement no. ffff gggg	Input data exceeds limits of 1700 word: Exponent $>\|39_{10}\|$ ffff Current decimal value of format statement pointer gggg Current decimal value of the input field pointer	Program terminates
4 I/O RQST statement no. xx	Attempt to read on a write unit or write on a read unit xx Decimal unit number of a device used improperly	Program terminates
5 I/O RQST statement no. xx	Read or write request after an end-of-file has been read without first doing an EOF check xx Decimal unit number of a device used improperly	Program terminates

Message	Significance	Action/Result
7 I/O RQST statement no. xx	Write attempted on magnetic tape with no write enable xx The decimal unit number of a device used improperly	To continue press RETURN
8 I/O RQST statement no. xx	Attempt to use logical unit number greater than 99 xx The decimal unit number of a device used improperly	Program terminates
9 I/O RQST statement no. xx	Backspace at loadpoint xx The decimal unit number of a device used improperly	Program terminates
10 I/O RQST statement no. xx	End of magnetic tape sensed xx The decimal unit number of a device used improperly	To continue, press RETURN
12 I/O RQST statement no. ffff	Illegal formatted input; more elements are given than are contained in an input record ffff Current decimal value of format statement pointer	Program terminates
13 I/O RQST statement no. ffff	Illegal list; a list is given but there are no conversion codes in the format statement ffff Current decimal value of format statement pointer	Program terminates
14 I/O RQST statement no. xx	File defined twice; more than one OPEN request given for the same file xx Decimal file number for a mass storage device	Program terminates
15 I/O RQST statement no. xx	Parameter negative or zero; one of the parameters in an OPEN statement is negative or zero xx Decimal file number for a mass storage device	Program terminates

Message	Significance	Action/Result
16 I/O RQST statement no. xx	Sector address too large; the starting sector address or ending address exceeds $2^{15}-1$ xx Decimal file number for a mass storage device	Program terminates
17 I/O RQST statement no. xx	File not defined; a READ or WRITE request was given for a file which was not defined by an OPEN statement xx Decimal file number for a mass storage device	Program terminates
18 I/O RQST statement no. xx	Logical unit not a mass storage device xx Decimal file number for a mass storage device	Program terminates
19 I/O RQST statement no. xx	Record number in READ or WRITE request incorrect. Resulting sector address is out of the range of the file or it is zero xx Decimal file number for a mass storage device	Program terminates

FORTRAN MISCELLANEOUS ERRORS N

Message	Significance
CORE OVFL	More than 32,767 cells of object code have been produced
*UD	Undefined symbol in address field
UNDEFINED SYMS name name name	Undefined statement labels and variable names
*SO	Scratch mass memory overflow
INPUT ERROR	Request from comment device for input has returned on error. FORTRAN will exit the job.

MS FORTRAN RESERVED WORD LIST O

The following symbols may not be redefined in user programs.

DABS
DATAN
DBLE
DCOS
DEXP
DFIX
DFLOT
DFLT
DLOG
DSIGN
DSIN
DSQRT
DSTOR1
DSTOR2

FLOAT
FLOT

Q8DFLT
Q8DFNF
Q8PKUP
Q8PREP
Q8PSE
Q8PSEN
Q8QBCK
Q8QD2D
Q8QD2F
Q8QD2I
Q8QEND
Q8QF2I
Q8QF2I
Q8QFLE
Q8QFIX
Q8QFLT
Q8QI2F
Q8QINI
Q8QWND
Q8QX
Q8QX1
Q8QX2
Q8QX3
Q8QY
Q8QZ
Q8STP
Q8STPN
RSTOR1

INDEX

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