Reference Manual

IBM 7030 Data Processing System

FORTRAN IV

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Contents

Part I. The Language of FORTRAN IV

Chapter 1. General Definitions

A FORTRAN source program consists of a sequence of FORTRAN statements.

Each statement is a string of characters grouped into records of 72 characters. If a statement is too long to fit into a single 72-character record, it may be continued on up to nine successive records. The first through fifth characters of a continuation record should not be used, and the sixth character of a continuation record must contain a non-blank, non-zero character. A record which is not a continuation record must have a zero or blank sixth character.

The order of the statements is governed solely by the order of records.

A number, less than six digits long, may be used to label any statement. This would appear among the first five characters of the first 72-character record.

If the first character is a "C" the record is treated as a comment and does not affect the object program in any way.

The seventh through 72nd characters of the record contain the statement proper.

Blanks are simply ignored by FORTRAN and may be used freely to improve the readability of the listings. (An exception is that blanks within an alphameric field are significant.)

Chapter 2. Constants, Variables, Subscripts, and Expressions

As required of any programming language, FORTRAN provides a means of expressing numerical constants and variable quantities. In addition, a subscript notation is provided for expressing one-, two-, or three-dimensional arrays of variables.

Constants

Three types of constants are permissible in the FORTRAN source program language: fixed point (restricted to integers), floating point (characterized by being written with a decimal point), and logical (one of the values, .TRUE. or .FALSE.).

FIXED POINT CONSTANTS

GENERAL FORM	EXAMPLES
1 to 11 decimal digits. A preceding + or − sign is optional. The magnitude or absolute value of the constant must be less than 2^{35}.	3 + 1 − 28987 +31415928535

Where a fixed point constant is used for the value of a subscript, it is treated modulo 2^{18}.

FLOATING POINT CONSTANT

GENERAL FORM	EXAMPLES
Less than 15 decimal digits, with a decimal point at the beginning, at the end, or between two digits. A preceding + or − sign is optional. The magnitude of the constant must be between 10^{-308} and 10^{+308}. A decimal exponent preceded by an E may follow a floating point constant. A + or − sign between E and the exponent is optional.	17. 5.0 .0003 5.0E3 (meaning 5.0×10^3) 5.0E+3 (meaning 5.0×10^3) 5.0E−7 (meaning 5.0×10^{-7})

LOGICAL CONSTANTS

GENERAL FORM	EXAMPLES
There are only two forms of logical constants: .TRUE. and .FALSE.	.TRUE. .FALSE.

Variables

Three types of variables are permissible: fixed point, floating point, and logical. References to variables are made in the FORTRAN source language by symbolic names consisting of alphabetic and numeric characters.

NAMES

GENERAL FORM	EXAMPLES
1 to 6 alphabetic or numeric characters, the first of which is alphabetic.	R M23A SOBNO

FIXED POINT VARIABLES

GENERAL FORM	EXAMPLES
A variable name starting with I, J, K, L, M, N if not declared otherwise, or any variable name declared INTEGER.	IIII4 M23A JOBNO

FLOATING POINT VARIABLES

GENERAL FORM	EXAMPLES
A variable name starting with any letter but I-N, if not declared otherwise by a type declaration, or any variable name declared REAL.	ABC B9 DELTA R

Logical Variables

GENERAL FORM	EXAMPLES
Any variable name declared LOGICAL by a type statement (Take on value of .TRUE. or .FALSE.)	TRUTH LIES

Subscripts

A variable can be made to represent any element of a one-, two-, or three-dimensional array of quantities by appending one, two, or three subscripts to it, respectively. The variable is then a subscripted variable. These subscripts are fixed-point quantities whose values determine the member of the array to which reference is made. The variable in a subscript must not itself be subscripted.

GENERAL FORM	EXAMPLES
Let v represent any fixed point variable and c (or c′) any unsigned fixed point constant. Then a subscript is an expression in one of the forms: v c v+c or v−c c*v c*v+c′ or c*v−c′ (The symbol * denotes multiplication.)	I 3 I+3 3*I 3*I+3 4*I−5

Subscripted Variables

GENERAL FORM	EXAMPLES

A variable followed by parentheses enclosing one, two or three subscripts which are separated by commas.	A(I)
	K(3)
	BETA(5*J−2,K+2,L)

Each variable which appears in subscripted form must have the size of its array (i.e., the maximum values which its subscripts can attain) specified in a DIMENSION or COMMON statement preceding the first appearance of the variable in the source program.

Expressions

A FORTRAN expression is any sequence of constants, variables (subscripted or not subscripted), and functions (see Chapter 6) separated by operation symbols, commas, and parentheses so as to form a meaningful mathematical or logical expression.

The arithmetic operation symbols are:

+	Addition
−	Subtraction
*	Multiplication
/	Division
**	Exponentiation

Rules for Constructing Normal Arithmetic Expressions

1. A normal arithmetic expression may be either fixed point or floating point, but must not be a mixed expression. This does not mean that a floating-point quantity cannot appear in a fixed-point expression, but rather that a quantity of one type can appear in an expression of another type only in certain ways.

   a. A floating-point quantity can appear in a fixed-point expression only as an argument of a function.

   b. A fixed point quantity can appear in a floating-point expression only as an argument of a function, or as a subscript, or as an exponent.

2. Constants, variables, and subscripted variables are also expressions of the same type as the constant or variable name. For example, the fixed point variable J53 is a fixed point expression.

3. Functions are expressions of the same type as the function name, provided that the arguments of the function are of the types assumed in the definition of the function. For example, if SOMEF (A,B) is a function with a floating point name, then SOMEF (C, D) is a floating point expression if C and D are of the same types as A and B, respectively.

4. Exponentiation of an expression does not affect the type of the expression; however, a fixed point expression may not be given a floating point exponent.

   NOTE: The expression A**B**C is interpreted as ((A**B)**C).

5. Preceding an expression by a + or − does not affect the type of the expression produced. For example, E, +E, and −E are all expressions of the same type.

6. Enclosing an expression in parentheses does not affect the type of the expression. For example, A, (A), ((A)), and (((A))) are all expressions of the same type.

7. Expressions may be connected by operators to form more complex expressions provided:

   a. No two operators appear in sequence. For example, A + −B is illegal but A+(−B) is legal.

   b. Items so connected are all of the same type.

Hierarchy of Operations

When the hierarchy of operations in an expression is not explicitly specified by the use of parentheses, it is understood by FORTRAN to be in the following order (from innermost operations to outermost):

**	Exponentiation
−	Unary minus
* and /	Multiplication and Division
+ and −	Addition and Subtraction

For example, the expression

G = −A+B/C+D**E*F

will be taken to mean

$G = (((-A)+(B/C))+D^{E}*F)$

Ordering Within a Hierarchy

Parentheses that have been omitted from a sequence of consecutive multiplications and divisions (or consecutive additions and subtractions) will be understood to be grouped from the left. Thus, if · represents either * or / (or either + or −), then

A • B • C • D • E

will be taken by FORTRAN to mean

((((A • B) • C) • D) • E)

Rules for Constructing Logical Expressions

1. Quantities which are not logical variables or constants may only appear in logical expressions in the following ways:
   a. As arguments to logical functions.
   b. As parts of relations.
2. A relation is a logical expression of the form:

E.GT.F
E.GE.F
E.LT.F
E.LE.F
E.EQ.F
E.NE.F

(where E, F are arithmetic expressions of the same type). The operations mean:

E.GT.F is true when $E > F$
E.GE.F is true when $E \geqslant F$
E.LT. F is true when $E < F$
E.LE.F is true when $E \leqslant F$
E.EQ.F is true when $E = F$
E.NE.F is true when $E \neq F$

3. A logical constant or variable is an expression.
4. A relation is an expression.
5. An expression enclosed in parentheses is an expression.
6. .NOT. any expression is an expression.
7. Any two expressions connected by .AND. create an expression.
8. Any two expressions connected by .OR. create an expression.

Hierarchy of Operations

Arithmetic expressions are calculated first, then values are found for relations. These, and variables, are then operated upon by .NOT.. Next, results are connected by .AND. and these results are connected by .OR.. Parentheses indicate any requisite recursions. Associated with this expression, then, is a value .TRUE. or .FALSE. but not both.

Chapter 3. Arithmetic Statements

Normal Arithmetic Statements

GENERAL FORM	EXAMPLES

"a=b" where a is a variable (subscripted or not subscripted) and b is an expression.	Q1=K
	A(I)=B(I)*SIN (C(I))
	(SIN and other functions are discussed in Chapter 6.)

The arithmetic formula defines a numerical or logical calculation. A FORTRAN arithmetic statement resembles very closely a conventional arithmetic formula. However, in a FORTRAN arithmetic statement the equal sign means "is to be replaced by," not "is equivalent to." Thus, the arithmetic statement

Y=N−LIMIT(J−2)

means that the value of N−LIMIT(J−2) is to replace the value of Y. The result is stored in fixed-point or in floating-point form if the variable to the left of the equal sign is a fixed-point or a floating-point variable, respectively.

If the variable on the left is fixed point and the expression on the right is floating point, the result will first be computed in floating point and then truncated and converted to a fixed-point integer. Thus, if the result is +3.872, the fixed-point number stored will be +3, not +4. If the variable on the left is floating point and the expression on the right fixed point, the latter will be computed in fixed point, and then converted to floating point.

The following examples illustrate types of arithmetic statements:

EXAMPLES	MEANING
A=B	Store the value of B in A.
I=B	Truncate B to an integer, convert to fixed point, and store in I.
A=I	Convert I to floating point, and store in A.
I=I+1	Add 1 to I and store in I. This example illustrates the fact that an arithmetic statement is not an equation, but is a command to replace a value.
A=3.0*B	Replace A with the product of B multiplied by 3.0.
A=I*B	Not permitted. The expression is mixed, i.e., contains both fixed-point and floating-point variables.
A=3*B	Not permitted. The expression is mixed.

Logical Statements

A logical variable is equated to a logical expression. The expression will be evaluated and the appropriate value .TRUE. or .FALSE. will be stored as the current value of the variable. Example:

T=Q.AND.(.NOT.R).AND.(V.GT.5.)

Chapter 4. Control Statements and END Statement

This class of FORTRAN statements is the set of control statements which enable the programmer to state the flow of his program.

Unconditional GO TO

GENERAL FORM	EXAMPLE
"GO TO n" where n is a statement number. This statement causes transfer of control to the statement with statement number n.	GO TO 3

Computed GO TO

GENERAL FORM	EXAMPLE
"GO TO (n_1, n_2, ..., n_m), i" where n_1, n_2, ..., n_m are statement numbers and i is a non-subscripted fixed point variable.	GO TO (30, 42, 50, 9), I

Control is transferred to the statement with statement number n_1, n_2, n_3, . . . , n_m, depending on the current value of i. Thus, in the example, if i is 3 at the time of execution, a transfer to the third statement of the list, (statement 50), will occur. This statement is used to obtain a computed many-way fork.

Assigned GO TO

GENERAL FORM	EXAMPLES
"GO TO i," where i is a non-subscripted fixed-point variable appearing in a previously executed ASSIGN statement.	GO TO K GO TO JOE, (10, 20, 30)

This statement causes transfer of control to the statement with statement number equal to that value of i which was last assigned by an ASSIGN. The assigned GO TO is used to obtain a pre-set many-way fork. An optional form of this statement is GO TO i, (n_1, n_2, . . . , n_m) where n_1, n_2, . . . , n_m are statement numbers.

ASSIGN

GENERAL FORM	EXAMPLE
"ASSIGN n TO i" where n is a statement number and i is a non-subscripted fixed point variable which appears in an assigned GO TO statement.	ASSIGN 12 to K

This statement causes a subsequent GO TO i to transfer control to the statement with the statement number n.

IF

GENERAL FORM	EXAMPLES

"IF(t)S" where t is a logical expression and S is any executable FORTRAN statement, except DO, or another IF statement.	IF(A.AND.B)F=SIN (R)
	IF(16.GT.L)GO TO 24
	IF(D.OR.X.NE.Y)GO TO
	(18,20),I

If t is .TRUE., statement S is executed; if t is .FALSE., control passes to the next statement.

DO

GENERAL FORM	EXAMPLES
"DO n i=m_1, m_2" or "DO n i=m_1, m_2, m_3" where n is a statement number, i is a non-subscripted fixed point variable, and m_1, m_2, m_3 are each either an unsigned fixed point constant or non-subscripted fixed point variable. If m_3 is not stated, it is taken to be 1.	DO 30 I=1, 10 DO 30 I=1, M, 3 DO 30 I=N, M DO 30 I=N, M, L

The DO statement is a command to execute repeatedly the statements which follow, up to and including the statement with statement number n.

The first time, the statements are executed with i = m_1. For each succeeding execution, i is increased by m_3. After they have been executed with i equal to the highest of this sequence of values *which does not exceed* m_2, control passes to the statement following the last statement in the range of the DO.

The *range* of a DO is that set of statements which will be executed repeatedly, i.e., it is the sequence of consecutive statements immediately following the DO, up to and including the statement numbered n.

The *index* of a DO is the fixed point variable i, which is controlled by the DO in such a way that its value begins at m_1 and is increased each time by m_2 until it is about to exceed m_3. Throughout the range it is available for computation, either as an ordinary fixed-point variable or as the variable of a subscript. After the last execution of the range, the DO is said to be *satisfied.*

Suppose, for example, that control has reached statement 10 of the program:

```
.
.
.
10 DO 11 I=1, 10
11 A(I)=I*N(I)
12
.
.
.
```

The range of the DO is statement 11, and the index is I. The DO sets I to 1 and control passes into the range. The value of 1*N(1) is computed, converted to floating point, and stored in location A(1). Since statement 11 is the last statement in the range of the DO and the DO is unsatisfied, I is increased to 2 and control returns to the beginning of the range, statement 11. The value of 2*N(2) is then computed and stored in location A(2). The process continues until statement 11 has been executed with I = 10. Since the DO is satisfied, control then passes to statement 12.

DO's Within DO's

Among the statements in the range of a DO may be other DO statements. When this is so, the following rule must be observed:

Rule 1: If the range of a DO includes another DO, then all of the statements in the range of the second must also be in the range of the first.

A set of DO's satisfying this rule is called a *nest of* DO's.

Transfer of Control

Transfers of control from and into the range of a DO are subject to the following rule:

Rule 2: No transfer is permitted into the range of any DO from outside its range. Thus, in the configuration (Figure 1), 1, 2, and 3 are permitted transfers, but 4, 5, and 6 are not.

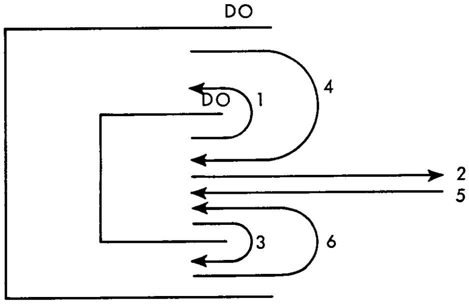


Figure 1

Preservation of Index

When control leaves the range of a DO in the ordinary way (i.e., when the DO becomes satisfied and control passes on to the next statement after the range) the exit is said to be a normal exit. After a normal exit from a DO occurs, the value of the index controlled by that DO is not defined, and the index cannot be used again until it is redefined.

If exit occurs by a *transfer* out of the range, however, the current value of the index remains available for any subsequent use. If exit occurs by a transfer which is in the ranges of several DO's the current values of all the indexes controlled by those DO's are preserved for any subsequent use.

Restrictions on Statements

Only one type of statement is not permitted in the range of a DO, namely, any statement which redefines the value of the index or of any of the indexing parameters. In other words, the indexing of a DO loop must be completely set before the range is entered and the initial, terminal, and incremental values of the index may not be altered.

Exits

When a CALL statement is executed in the range of a DO, care must be taken that the subprogram does not alter the DO index or indexing parameters. This applies as well when a closed function is invoked in the range of a DO. (See Chapter 6.)

CONTINUE

GENERAL FORM	EXAMPLE
"CONTINUE"	CONTINUE

CONTINUE is a dummy statement which gives rise to no instructions in the object program. It is most frequently used as the last statement in the range of a DO to provide a transfer address for IF and GO TO statements which are intended to begin another repetition of the DO range.

As an example of a program which requires a CONTINUE, consider the table search:

```
.
.
.
10  DO 12 I=1, 100
    IF (ARG.NE.VALUE(I)) GO TO 12
    GO TO 20
12  CONTINUE
.
.
.
```

The program will scan the 100-entry VALUE table an entry at a time until it finds the first entry which equals the value of the variable ARG, whereupon it exits to statement 20 with the value of I available for fixed point use; if no entry in the table equals the value of ARG, a normal exit to the statement following the CONTINUE will occur.

PAUSE

GENERAL FORM	EXAMPLE
"PAUSE"	PAUSE

A PAUSE statement causes a temporary halt in object program execution, providing the operator with the option of resuming or of abandoning the job. The contents of the instruction counter are displayed on the console numerical display.

STOP

GENERAL FORM	EXAMPLE
"STOP"	STOP

This statement causes an "Abnormal End-of-Job" return to MCP ("Normal End-of-Job" return to MCP is accomplished by the RETURN statement. See Chapter 6.)

END

GENERAL FORM	EXAMPLE
"END"	END

This statement differs from the previous statements discussed in this chapter in that it does not affect the flow of control in the object program being compiled.

The END statement marks the end of any given FORTRAN source program, separating it from the program that follows. Each FORTRAN source program must be terminated with an END statement.

Chapter 5. Input-Output Statements

Nine statements in IBM 7030 FORTRAN IV specify the transmission of information to or from magnetic tapes, disks, card readers, card punches, and printers. These statements may be grouped as follows:

1. System Input and System Output Statements: Three statements, READ, PUNCH and PRINT, cause the transmission of edited (decimal) information to or from the system input and system output devices.

2. General Read/Write Statements: Two statements, READ ( ) and WRITE ( ), cause the transmission of either edited (decimal) or non-edited (binary) data to or from magnetic tapes, disk or, under certain conditions, non-system readers, punches, and printers. The choice between edited and non-edited transmission is indicated by the presence or absence of a "format" specification within the parentheses of these so-called generalized Read/Write commands.

3. Manipulative Statements: Three statements, END FILE, BACKSPACE, and REWIND, affect magnetic tapes or the disk unit.

4. One statement, FORMAT, which is a non-executable statement, specifies the editing process required in transmission of information to or from the I-O device.

Array and List Specifications

SPECIFYING LISTS OF QUANTITIES

Some I-O statements call for the transmission of information and must, therefore, include a list of the quantities to be transmitted. This list is ordered, and its order must be the same as the order in which the words of information exist (for input), or will exist (for output) in the input-output medium.

The formation and meaning of a list is best described by an example:

```
A, B(3), (C(I), D(I,K), I=1, 10), ((E(I,J), I=1, 10, 2),
  F(J,3), J=1, K)
```

Suppose that this list is used with an output statement. Then the information will be written on the input-output medium in this order:

```
A,B(3),C(1),D(1,K),C(2),D(2,K),...,C(10),D(10,K),
E(1,1),E(3,1),...,E(9,1),F(1,3),
E(1,2),E(3,2),...,E(9,2),F(2,3),...,
E(1,K),E(3,K),...,E(9,K),F(K,3)
```

Similarly, if this list were used with an input statement, the successive words, as they were read from the external medium, would be placed into the sequence of storage locations just given.

Thus the list reads from left to right with repetition for variables enclosed within parentheses. Only variables, and not constants, may be listed. The execution is exactly that of a DO-loop, as though each opening parentheses (except subscripting parentheses) were a DO, with indexing given immediately before the matching closing parentheses, and with the DO range extending up to that indexing information. The order of the above list can thus be considered the equivalent of the "program":

```
  A
  B(3)
  DO 5 I=1, 10, 1
  C(I)
5 D(I,K)
  DO 9 J=1, K, 1
  DO 8 I=1, 10, 2
8 E(I,J)
9 F(J,3)
```

Note that indexing information, as in DO's, consists of three constants or fixed point variables, and that the last of these may be omitted, in which case it is taken to be 1.

For a list of the form K, (A(K)) or K, (A(I), I=1, K) where an index or indexing parameter itself appears earlier in the list of an input statement, the indexing will be carried out with the newly read-in value.

INPUT-OUTPUT IN ARRAY FORM

FORTRAN treats variables according to conventional matrix practice. Thus, the input-output statement,

```
READ 1 ((A(I,J),I=1,2),J=1,3)
```

causes the reading of I ×J (in this case 2 ×3) items of information. The data items will be read into storage in the same order as they are found on the input medium.

INPUT-OUTPUT OF ENTIRE ARRAYS

When input-output of an entire matrix is desired, an abbreviated notation may be used for the list of the input-output statement; only the name of the array need be given and the indexing information may be omitted.

Thus, if A has previously been listed in a DIMENSION statement, the statement,

```
READ 1, A
```

is sufficient to read in all of the elements of the array A.

Format Specifications

FORMAT

GENERAL FORM	EXAMPLES
"FORMAT (Specification)" where Specification is as described below.	FORMAT (I2/(E12.4,F10.4))

The system input/output and general READ/WRITE statements may contain, in addition to the list of quantities to be transmitted, the statement number of a FORMAT statement describing the information format to be used. Alternatively, the name of an array containing A-type data may be supplied. In this case, this data is to be interpreted (at object time) as a FORMAT specification. It also specifies the type of conversion to be performed between the internal machine-language and external notation. FORMAT statements are not executed; their function is merely to supply information to the object program. Therefore, they may be placed anywhere in the source program.

For the sake of clarity, the details of writing a FORMAT specification are given below for use with PRINT statements. The description is valid for any case, however, simply by generalizing the concept of "printed line" to that of unit record in the input-output medium.

A unit record may be:

1. A printed line with a maximum of 132 characters.
2. A punched card with a maximum of 72 characters.
3. A BCD tape record with a maximum of 132 characters.

Numeric Fields

Three basic types of decimal-to-binary or binary-to-decimal conversion are available:

INTERNAL	TYPE	EXTERNAL
Floating point variable	E	Floating point, decimal
Floating point variable	F	Fixed point, decimal
Fixed point variable	I	Decimal integer

The FORMAT specification describes the line to be printed by giving for each field in the line (from left to right, beginning with the first type wheel):

1. The type of conversion (E, F, or I) to be used.
2. The width (w) of the field.
3. For the E- and F-type conversion, the number of places (d) after the decimal point that are to be printed (d is treated modulo 14).

These basic field specifications are given in the forms

Iw, Ew.d, and Fw.d

with the specification for successive fields separated by commas. Thus, the statement FORMAT (I2, E12.4, F10.4) might give the line:

```
27    −0.9321E 03    −0.0076
```

As in this example, the field widths may be made greater than necessary so as to provide spacing blanks between numbers. In this case, there is one blank following the 27, one blank after the E (automatically supplied except in cases of a negative exponent, when a minus sign will appear), and three blanks after the 03. Within each field the printed output will always appear in the rightmost positions.

Alphameric Fields

There are two ways of reading or writing alphameric information; the specifications for this purpose are Aw and wH. Both result in storing the information internally in A8 form. The basic difference is that information handled with the A specification is given a variable or array name and hence can be referred to by means of this name for processing and/or modification. Information handled with the H specification is not given a name and cannot be referred to or manipulated in storage in any way.

The specification Aw causes w characters to be read into, or written from, a variable or array.

The specification wH is followed in the FORMAT statement by w alphameric characters. Example:

32HSHE WAS POOR, BUT SHE WAS HONEST

Note that blanks are considered alphameric characters, and must be included as part of the count w.

It is possible to read and write alphameric information only, by giving no list with the input-output statement and specifying no I, E, or F fields in the FORMAT statement.

Consider an alphameric field in a FORMAT statement at the time of execution of the object program. If the FORMAT statement is used with an input statement, the alphameric text listed in the FORMAT statement will be replaced by whatever text is read in from the corresponding field in the input-output medium. When that same FORMAT statement is used for output, whatever information is then in the FORMAT statement will appear in the output data. Thus, text can be originated in the source program, or as input to the object program.

Blank Fields

Blank characters may be provided in an output record and characters of an input record may be skipped by means of the specifications wX where $0<w\leq 132$ (w is the number of blanks provided or characters skipped). When the specification is used with an input record, w characters are considered to be blank regardless of what they actually are, and are skipped over. (The control character X need not be separated by a comma from the specification of the next field.)

Repetition of Fields

It may be desired to print n successive fields within one record, in the same fashion. This may be specified by giving n (an unsigned fixed point constant) before E, F, I or A. Thus, the statement:

```
FORMAT (I2, 3E12.4)
```

might give

```
27     -0.9321E 02     -0.7580E-02     0.5536E 00
```

Repetition of Groups

A limited parenthetical expression is permitted in order to permit repetition of data fields according to certain format specifications within a longer FORMAT statement specification. Thus, FORMAT (2(F10.6, E10.2), I4) is equivalent to FORMAT (F10.6, E10.2, F10.6, E10.2, I4).

Scale Factors

To permit more general use of F-type conversion, a scale factor followed by the letter P may precede the specification. The scale factor is defined such that:

Printed number = Internal number × $10^{\text{scale factor}}$. Thus, the statement FORMAT (I2, 1P3F1 1.3) used with the data of the preceding example would give:

```
27     -932.096     -0.076     5.536
```

whereas FORMAT (I2, -1P3F11.3) would give:

```
27     -9.321     -0.001     0.055
```

A positive scale factor may also be used with E-type conversion to increase the number and decrease the exponent. Thus, FORMAT (I2, 1P3E12.4) would produce with the same data:

```
27     -9.3210E 01     -7.5804E-03     5.5361E-01
```

The scale factor is assumed to be zero if no other value has been given. However, once a value has been given, it will hold for all E- and F-type conversions following the scale factor within the same FORMAT statement. (This applies to both single-record and multiple-record formats.) Once a scale factor has been given, a subsequent scale factor of zero in the same FORMAT statement must be specified by P. Scale factors have no effect on I-conversion.

Multiple-Record Formats

To deal with a block of more than one line of print, a FORMAT specification may have several different one-line formats, separated by a slash (/) to indicate the beginning of a new line. Thus, FORMAT (3F9.2, 2F10.4/8E14.5) would specify a multi-line block of print in which lines 1, 3, 5, . . . have format (3F9.2, 2F10.4), and lines 2, 4, 6, . . . have format 8E14.5.

If a multiple-line format is desired such that the first two lines will be printed according to a special format and all remaining lines according to another format, the last line-specification should be enclosed in a second pair of parentheses; e.g., FORMAT (I2, 3E12.4/2F10.3, 3F9.4/(10F12.4)). If data items remain to be transmitted after the format specification has been completely "used," the format repeats from the last open parenthesis.

As these examples show, both the slash and the closing parenthesis of the FORMAT statement indicate termination of a record.

Blank lines may be introduced into a multi-line FORMAT statement, by listing consecutive slashes. N + 1 consecutive slashes produce N blank lines.

FORMAT and Input-Output Statement Lists

The FORMAT statement indicates, among other things, the size of each record to be transmitted. In this connection, it must be remembered that the FORMAT statement is used in connection with the list of some particular input-output statement, except when a FORMAT statement consists entirely of alphameric fields. In all other cases, control in the object program switches back and forth between the list (which specifies whether data remains to be transmitted) and the FORMAT statement (which gives the specifications for transmission of that data).

Ending a FORMAT Statement

During input-output of data, the object program scans the FORMAT statement to which the relevant input-output statement refers. When a specification for a numeric field is found and list items remain to be transmitted, input-output takes place according to the specification and scanning of the FORMAT statement resumes. If no items remain, transmission ceases and execution of that particular input-output statement is terminated. Thus, a decimal input-output operation will be brought to an end when a specification for a numeric field or the end of the FORMAT statement is encountered, and there are no items remaining in the list.

Format Statements Read in at Object time

FORTRAN will accept a variable FORMAT address. This provides the facility of specifying a record format at object time. Examples:

```
       DIMENSION FMT(9), C(5)
    1  FORMAT (9A8)
    5  READ 1, (FMT(I), I=1,9)
   10  READ FMT, A,B,(C(I), I=1,5)
```

Thus, A, B, and the array C would be converted and stored, according to the FORMAT specification read into the array FMT, by statement 5.

The format read in at object time must take the same form as a source program FORMAT statement, except that the word FORMAT is omitted, i.e., the variable format begins with a left parenthesis.

Carriage Control

A WRITE statement that includes a FORMAT number prepares a BCD tape which can be used to obtain off-line printed output. Off-line printing will be done on a 1401 with a program which operates in one of three modes: single space, double space, and program control. Under program control, which gives the greatest flexibility, the first character of each BCD record controls spacing of the 1403 printer and that character is not printed. The control characters and their effects are:

blank	Single space before printing
0	Double space before printing
1	Restore paper before printing

Any other control character willl be passed to the output device unchanged. Thus, a FORMAT statement for this type of WRITE statement will usually begin with 1H followed by the appropriate control character, if the printing is to be done under program control.

Data Input to the Object Program

Decimal input data to be read when the object program is executed must be in essentially the same format as given in the previous examples. Thus, a card to be read according to FORMAT (I2, E12.4, F10.4) might be punched:

```
    27     -0.8321E 02     -0.0076
```

Within each field, all information must appear at the extreme right. Plus signs may be omitted or indicated by a blank or +. Minus signs may be punched with an 11-punch or an 8-4 punch. Blanks in numeric fields are regarded as zeros. Numbers for E- and F-type conversion may contain any number of digits, but only the high-order digits will be retained (no rounding will be performed). Numbers for I-type conversion will be treated modulo 2^{38}.

To permit economy in punching, certain relaxations in input data format are permitted:

1. Numbers of E-type conversion need not have 5 columns devoted to the exponent field. The start of the exponent field must be marked by an E, or if that is omitted, by a + or − (not a blank). Thus E2, E02, +2, +02, E−02, and E+02 are permissible exponent fields.

2. Numbers for E- or F-type conversion need not have their decimal point punched. If it is not punched, the FORMAT specification will supply it; for example, the number −09321+2 with the specification E12.4 will be treated as though the decimal point had been punched between the 0 and the 9. If the decimal point is punched in the card, its position overrides the indicated position in the FORMAT specification.

System Input and System Output Statements

(System) READ

GENERAL FORM	EXAMPLE
"READ f, list" where f is either the statement number of a FORMAT statement, or the name of an array containing A-type data to be used as a format specification.	READ 10,A,B(3), (C(I),I=1,5)

The READ statement is used to input decimal information from the System reader. Card after card is read until the complete list has been satisfied.

(System) PUNCH

GENERAL FORM	EXAMPLE
"PUNCH f, list" where f is either the statement number of a FORMAT statement, or the name of an array containing A-type data to be used as a format specification.	PUNCH 251, ((Z(I,J), I=1, 5), J=1, I)

The PUNCH statement causes cards to be punched by the systems punch. Cards are punched in accordance with the specified format until the entire list has been satisfied.

(System) PRINT

GENERAL FORM	EXAMPLES
"PRINT f, list" where f is either the statement number of a FORMAT statement, or the name of an array containing A-type data to be used as a format specification.	PRINT FMT,K,(A(J), J=M,K,2) PRINT 1012,A,B,C, D(3,I),F

The PRINT statement causes the object program to prepare a system output tape for subsequent off-line printing. Successive lines are written in accordance with the specified format until the complete list has been satisfied.

General Read/Write Statements

Two basic types of input/output activity are controlled by the general Read/Write statements: decimal (in a format) data transmission, and binary (not in a format)data transmission. The particular action required is specified by the presence or absence of a format specification in the statement concerned.

(Binary) READ

GENERAL FORM	EXAMPLES
"READ (unit) list" where unit is an unsigned fixed-point variable or constant, and list is as described elsewhere.	READ (5)A,B,C(3,1,9) READ (J) (M(N,N), N=1,NMAX)

This form of the general READ statement causes the input of binary data from either binary magnetic tapes, or from disk, depending upon the definition supplied for the value of "unit" at IOD compile time. (See Part II, Chapter 11.)

If the list calls for less data than is present in the logical record being brought in, then the remaining, unread, data is spaced over.

(Decimal) READ

GENERAL FORM	EXAMPLES
"READ (unit, f) list" where unit is an unsigned fixed-point variable or constant, and f is either the statement number of a FORMAT statement, or the name of an array containing A8 data to be used as a format specification.	READ (6,10)A READ (ITAPE, 707)K, (A(I), I=1, K)

This version of the general READ statement causes the input of information, in accordance with the specified format, from either BCD tape or under special conditions, as described in the next section, from the system reader.

The actual I-O device actuated by this statement depends upon the running time value of "unit," and the particular definition supplied at IOD compile time for this value.

If the list calls for less data than is present in the logical record being brought in, then the remaining, unread data is spaced over.

(Binary) WRITE

GENERAL FORM	EXAMPLES
"WRITE (unit) list" where unit is an unsigned fixed-point variable or constant, and list is as described elsewhere.	WRITE (JFILE)((A(I,J), J=1,10), I=6, ITCH WRITE (NO1)P,Q,R

This form of the general WRITE statement causes the output of binary data onto either binary magnetic tape or disk, depending upon the actual value of "unit" at run time, and the definitions supplied at IOD-compile time.

The output of a single WRITE statement is considered to be just one logical record.

(Decimal) WRITE

GENERAL FORM	EXAMPLES
"WRITE (unit, f) list" where unit is an unsigned fixed-point variable or constant, and f is either the statement number of a FORMAT statement, or the name of an array containing A8 data to be used as a format specification.	WRITE (LIST,FORMAT) D,A,T,U,M WRITE (99,10)(Q(3*I-2), I=1,200)

This form of the general write statement may be used to put out data according to the specified format, either onto BCD magnetic tape or, under special circumstances, onto system output tapes.

It may also be used to put information on the non-system printer. These various options are controlled by programmer action at IOD-compile time.

Manipulative Statements

END FILE

GENERAL FORM	EXAMPLES

"END FILE unit" where unit is an unsigned fixed-point variable or constant.	END FILE 10
	END FILE JTAPE

The END FILE statement causes the object program to write an end-of-file mark on the designated symbolic unit, provided the definition supplied via an IOD card is meaningful in this context.

BACKSPACE

GENERAL FORM	EXAMPLES
"BACKSPACE unit" where unit is an unsigned fixed-point variable or constant.	BACKSPACE 3 BACKSPACE M1

The BACKSPACE statement is used to backspace the symbolic file "unit" one logical record.

REWIND

GENERAL FORM	EXAMPLES
"REWIND unit," where unit is an unsigned fixed point constant or variable.	REWIND 3 REWIND K

The REWIND statement causes the object program to rewind the symbolic file identified by "unit." If "unit" is defined to be a disk file, then the meaning here is to locate the first arc of the file.

Chapter 6. Subprogram Statements, Functions and Subroutines

It is possible to construct, in the FORTRAN language, subprograms which are referred to by other programs. These subprograms may, in turn, refer to still other lower level subprograms, which *may* also be coded in FORTRAN language. It is therefore possible to code problems using several levels of subprograms. This configuration may be thought of as a total problem consisting of one main program and any number of subprograms.

Because of the interrelationship among several different programs, it is possible to include a block of hand-coded instructions in a sequence including instructions compiled from FORTRAN source programs. It is only necessary that hand-coded instructions conform to rules for subprogram formation, since they will comprise a distinct subprogram.

This section presents a discussion of the various types of subprograms possible, two of which are the FORTRAN-coded Function subprogram and the Subroutine subprogram.

Although Function subprograms and Subroutine subprograms are treated together and may be viewed as similar, it must be remembered that they differ in two fundamental respects.

1. The Function subprogram is always single-valued, whereas the Subroutine subprogram may be multi-valued.
2. The Function subprogram is called or referred to by the arithmetic expression containing its name; the Subroutine subprogram can only be referred to by a CALL statement.

Each of these two types of subprograms, when coded in FORTRAN language, must be regarded as independent FORTRAN programs. In all respects, they conform to rules for FORTRAN programming. They may be compiled with the main program of which they are parts, however, by means of multiple program compilation. In this way, the result of multiple program compilation will be a complete main program-subprogram sequence ready to be executed.

Subprograms may be referred to in two distinct ways. One of these is by the use of the name in an arithmetic expression. This applies to Functions. The other, which applies to Subroutine subprograms, is by means of a CALL statement.

Following are examples of arithmetic expressions including Function names:

```
    Y=A-SIN (B-C)
    C=AMIN0 (M, L)+ABC(B*FORTF(Z), E)
```

The appearance in the arithmetic expression serves to call the Function; the value of the Function is then computed, using the arguments which are supplied in the parentheses following the Function name. (A value is here defined to be a single quantity.)

Functions

Naming

The rules for naming Functions are the same as those for naming variables. The name may be one to six alphameric characters (except special characters), and the first must be alphabetic. The mode of the Function must be given either by a Type statement or, in the case of integer and real, by the proper first letter of the name as described in the rules for naming variables.

Definition

There are three different types of FORTRAN Functions:

1. Open (or built-in) Functions.
2. Arithmetic or Logical Statement Functions.
3. Closed Functions.

Open (or Built-in) Functions

These are Functions which are predefined, and exist in the processor. They generate instructions which are compiled in-line every time the function is referred to.

The IBM 7030 FORTRAN IV System will contain the 21 built-in Functions shown in Figure 2. It has the capacity for more Functions to be added.

Name	Definition	No. of Args	Argument Mode	Function Mode
ABS IABS	$\vert Arg \vert$	1	Floating Fixed	Floating Fixed
AINT INT	Sign of Arg times Largest integer$\leq \vert Arg \vert$	1	Floating Floating	Floating Fixed
AMOD MOD	Arg_1 (Mod Arg_2)	2	Floating Fixed	Floating Fixed
AMAX0 AMAX1 MAX0 MAX1	Max (Arg_1, Arg_2,...)	≥ 2	Fixed Floating Fixed Floating	Floating Floating Fixed Fixed
AMIN0 AMIN1 MIN0 MIN1	Min (Arg_1, Arg_2,...)	≥ 2	Fixed Floating Fixed Floating	Floating Floating Fixed Fixed
FLOAT	Fixed to floating	1	Fixed	Floating
IFIX	Floating to fixed	1	Floating	Fixed
SIGN ISIGN	(Sign of Arg_2) times $\vert Arg_1 \vert$	2	Floating Fixed	Floating Fixed
DIM IDIM	Arg_1 - min (Arg_1, Arg_2)	2	Floating Fixed	Floating Fixed
SQRT	$\sqrt{Arg_1}$	1	Floating	Floating

Note: The function AMOD (Arg_1, Arg_2) = Arg_1 - [Arg_1/Arg_2] Arg_2 where [ ] means "integer part of." Hence, this quantity is the remainder of Arg_1/Arg_2 when the quotient is expressed as an integer, and the sign of Arg_1 is given to the remainder.

Figure 2

Arithmetic or Logical Statement Functions

These are Functions which are defined by a single FORTRAN arithmetic or logical statement and apply only to the particular program or subprogram in which their definition appears.

GENERAL FORM	EXAMPLES
"a=b" where a is a name followed by parentheses enclosing its arguments (which must be distinct nonsubscripted variables) separated by commas, and b is an expression which does not involve subscripted variables. Any Functions appearing in b must be built-in, or available, or already defined by preceding arithmetic statement Functions.	FIRSTF(X)=A*X+B SECOND(X,B)=A*X+B THIRDF(D)=FIRST F(E)/D FOURTH(F,G)=SECOND (F, THIRDF(G)) FIFTH(I,A)=3.0*A**I SIXTH(J)=J+K SEVNF(A,B)=A.AND.B

The right-hand side of an arithmetic statement Function may be any expression, not involving subscripted variables, that meets the requirements specified for expressions. In particular, it may involve Functions freely, provided that any such Function, if it is not built-in or available, has been defined in a preceding arithmetic statement Function. As many as desired of the variables appearing in the expression on the right-hand side may be stated on the left-hand side to be the arguments of the Function. Since the arguments are only dummy variables, their names are unimportant (except as indicating fixed or floating point mode) and may even be the same as names appearing elsewhere in the program.

Those variables on the right-hand side which are not stated as arguments are treated as parameters. Thus, if FIRSTF is defined in an arithmetic statement Function as FIRSTF(X)=A*X+B then a later reference to FIRSTF(Y) will cause ay+b, based on the current values of a, b, and y, to be computed. The naming of parameters, therefore, must follow the normal rules of uniqueness.

A Function of this type may be used just as any other Function. In particular, its arguments may be expressions and may involve subscripted variables; thus, a reference to FIRSTF (Z+Y(I)), with the above definition of FIRSTF, will cause $a(z+y_i)+b$ to be computed on the basis of the current values of a, b, y, and z.

Functions defined by arithmetic or logical statements are always compiled as closed subroutines.

NOTE: All the Function definitions in a program must precede the first executable statement of the program.

CLOSED FUNCTIONS

These are Functions that are prewritten and/or precompiled and may exist on the library tape or in prepared card decks. These Functions are compiled as "closed" subroutines; instead of appearing in the object program for every reference that has been made to them in the source program, they appear only once regardless of the number of references.

Closed Functions may be conveniently defined by a conventional FORTRAN program. In this instance compiling a FORTRAN program produces a Function subroutine in exactly the form required for object program execution. Such a FORTRAN Program must be headed by a FUNCTION statement, whose definition follows:

FUNCTION

GENERAL FORM	EXAMPLES
"FUNCTION Name ($a_1,\ldots,a_j$)"	FUNCTION KRUM (P,Q,R)
"REAL FUNCTION Name ($a_1,\ldots,a_j$)"	REAL FUNCTION ARCSIN (RADIAN)
"INTEGER FUNCTION Name ($a_1,\ldots,a_j$)"	INTEGER FUNCTION INTRST (RATE, YEARS)
"LOGICAL FUNCTION Name ($a_1,\ldots,a_j$)" where Name is the symbolic name of the single-valued function, and the arguments $a_1,\ldots,a_j$ of which there must be at least one are non-subscripted variable names, or the names of closed Functions or Subroutines. The Function name consists of one to six alphameric characters the first of which must be alphabetic and is defined (by this statement) to be the same type as the first word of the function statement (unless the first form illustrated is used, in which case the initial letter shows the type). The Function name must not occur in a DIMENSION statement of the subprogram, or in a DIMENSION statement in any program which uses the Function.	

The FUNCTION statement must be the first statement of a FORTRAN Function subprogram and defines it to be such.

In a Function subprogram, the name of the Function must appear at least once as the variable on the left-hand side of an arithmetic or logical statement, or alternately in an input statement list, e.g.,

```
FUNCTION NAME (A, B)
.
.
.
NAME=Z+B
.
.
.
RETURN
```

By this means, the output value of the Function is returned to the calling program.

This type of program may either be compiled independently or multiple-compiled with others. A Function subprogram must never be inserted between two statements of any other single program.

The arguments following the name in the FUNCTION statement may be considered as "dummy" variable names. That is, during object program execution other actual arguments are substituted for them. Therefore, the arguments which follow the Function reference in the calling program must agree with those in the FUNCTION statement in the subprogram in number, order, and type. Furthermore, when a dummy argument is an array name, the corresponding actual argument must also be an array name. Each of these array names must appear in DIMENSION statements of their respective programs with the same dimensions, unless the dimensions are variable.

None of the dummy variables may appear in EQUIVALENCE or COMMON statements in the Function subprogram.

Hand-coded closed Functions may be added to the library. Among the closed functions distributed in the FORTRAN library are:

NAME	TYPE OF FUNCTION
ALOG	Natural Logarithm
SIN	Trigonometric Sine
COS	Trigonometric Cosine
EXP	Exponential
ATAN	Arctangent
TANH	Hyperbolic Tangent

Subroutines

SUBROUTINE

GENERAL FORM	EXAMPLES
"SUBROUTINE Name (a_1, a_2, ...,a_n)where Name is the symbolic name of a subprogram, and the arguments a_1, a_2,...,a_n, if any, are non-subscripted variable names, or the names of lower level subprograms. The name of the subprogram may consist of one to six alphameric characters, the first of which is alphabetic. Also, the name of the subprogram must not be listed in a DIMENSION statement of any program which calls the subprogram, or in a DIMENSION statement of the subprogram itself.	SUBROUTINE MATMPY (A,N,M,B,L,C) SUBROUTINE QDRTIC (B,A,C, ROOT1, ROOT2)

This statement is used as the first statement of a subroutine subprogram and defines it to be such. A subprogram introduced by the SUBROUTINE statement must be a FORTRAN program and may contain any FORTRAN statements except FUNCTION or another SUBROUTINE statement.

Unlike the Function-type subprogram which returns only a single numerical value, the Subroutine subprogram uses one or more of its arguments to return output. The arguments so used must, therefore, appear on the left side of an arithmetic statement within the program.

If an argument is an array name, it must appear in a DIMENSION statement in the subroutine.

None of the arguments may appear in EQUIVALENCE statements in the Subroutine subprogram. These subprograms may be compiled independently or multiple-compiled with others.

CALL

GENERAL FORM	EXAMPLES
"CALL Name (a_1, a_2,...,a_n)" where Name is the name of a Subroutine subprogram, and a_1, a_2,...,a_n are the arguments which take one of the forms described below.	CALL MATMPY (X,5,10,Y,7,Z) CALL QDRTIC (P*9.732,Q/4.536, R-S**2, X1, X2)

This statement is used to call Subroutine subprograms; the CALL transfers control to the subprograms and presents it with the parenthesized arguments. Each argument may be one of the following:

1. Fixed point constant, floating point constant, logical constant.

2. A variable, with or without subscripts, fixed, floating or logical types.

3. Arithmetic expression, or logical expression.

4. Alphameric characters. Such arguments must be preceded by nH where n is the count of characters included in the arguments, e.g., 9HEND POINT. Note that blank space and special characters are considered characters when used in alphameric fields.

5. The name of a Closed Function or another Subroutine subprogram (in which case an EXTERNAL statement is required).

The arguments presented by the CALL statement must agree in number, order, type and array size with the corresponding arguments in the SUBROUTINE statement of the called subprogram.

A subprogram may contain a DIMENSION statement for an array with variable dimensions. The actual dimensions of the array must be given in the calling program and passed along in the Subroutine CALL. (See Chapter 7.)

EXTERNAL

GENERAL FORM	EXAMPLES
"EXTERNAL name, name,..., name" where name is the name of a Function or Subroutine	EXTERNAL SIN, COS, TAN EXTERNAL BOB, JOE

Whenever a subroutine or function name appears in the argument list of:

1) a CALL

2) a function name in an expression

all such names must appear in an EXTERNAL statement. Example:

```
    EXTERNAL SIN, A
    CALL JOE (B, SIN)
    C=F(X, A)
      .
      .
      .
RETURN
```

GENERAL FORM	EXAMPLE
"RETURN"	RETURN

This statement terminates any subprogram, whether of the type headed by a SUBROUTINE or a FUNCTION statement, and returns control to the calling program. A RETURN statement must, therefore, be the last executed statement of the subprogram; it can be any point reached by a path of control and any number of RETURN statements may be used.

This statement should also be used to terminate normal execution of a main program. It causes a normal End-of-Job condition to be established within MCP (c.f. the STOP statement, which causes an "Abnormal End-of-Job" return).

Chapter 7. Declarative Statements

Another type of FORTRAN statement is the declarative statement. Statements in this category are non-executable.

DIMENSION

GENERAL FORM	EXAMPLES
"DIMENSION v, v, v, ... where each v is the name of a variable, subscripted with 1, 2, or 3 unsigned fixed point constants. Any number of v's may be given. In a SUBROUTINE or FUNCTION subprogram, the subscripts may be fixed point variables. (See Chapter 6.)	DIMENSION A(10), B (5,15), CVAL (3,4,5)

The DIMENSION statement provides the information necessary to allocate storage in the object program for arrays.

Each variable which appears in subscripted form in a program or subprogram must appear in a DIMENSION statement of that program or subprogram, or as a dimensioned COMMON entry. (See COMMON.) The DIMENSION or COMMON statement must precede the first appearance of that variable. The DIMENSION or COMMON statement lists the maximum dimensions of arrays; in the object program, references to these arrays must never exceed the specified dimensions.

The above example indicates that B is a two-dimensional array for which the subscripts never exceed 5 and 15. If B is a floating point variable, the DIMENSION statement causes 75 (i.e., 5 × 15) storage locations to be set aside for the array B. A single DIMENSION statement may specify the dimensions of any number of arrays. A program must not contain a DIMENSION statement which includes the name of the program itself, or any program which it calls.

Adjustable Dimensions

The name of an array, and the constants which are its dimensions, may be passed as arguments when calling a Function or Subroutine subprogram. By this means, a subprogram may perform calculations on one or more arrays whose size is not known within the subprogram until it is called.

The following illustrates how this effect is obtained within a subprogram:

```
SUBROUTINE MATMY (. . . R, L, M . . .)
               .
               .
               .
DIMENSION . . R(L, M) . . . .
               .
               .
               .
DO 100 I = 1, L
               .
               .
               .
```

Note that a special form of the DIMENSION statement is required. The dimensions listed within parentheses are symbolic; they are not constants. Variables may be used as dimensions of an array only in a FUNCTION or SUBROUTINE subprogram. For any such array, the array name and all variables used as its dimensions must appear as arguments in the FUNCTION or SUBROUTINE statement at the head of the program in which such a DIMENSION statement occurs.

A subprogram, handling arrays with adjustable dimensions, need not be recompiled for each set of dimension sizes.

EQUIVALENCE

GENERAL FORM	EXAMPLE
"EQUIVALENCE (a, b, c, . . .), (d, e, f, . . .), . . ." where a, b, c, d, e, f, . . . are variables optionally followed by a single unsigned fixed point constant in parentheses.	EQUIVALENCE (A, B(1), C(5)), (D(17), E(3))

The EQUIVALENCE statement provides the option of controlling the allocation of data storage in the object program. In particular, when the logic of the program permits it, the number of storage locations used can be reduced by causing locations to be shared by two or more variables.

An EQUIVALANCE statement may be placed anywhere in the source program. Each pair of parentheses of the statement list encloses the names of two or more quantities which are to be stored in the same locations during execution of the object program; any number of equivalences (i.e., sets of parentheses) may be given.

Quantities or arrays which are not mentioned in an EQUIVALENCE statement will be assigned unique locations. Locations can be shared only among variables, not among constants. EQUIVALANCE should not be used to establish mathematical equivalence.

COMMON

GENERAL FORM	EXAMPLES
"COMMON a, b, c . . . /r/d, e, f . . . /s/g, h, j . . ." where a, b . . . are dimensioned or non-dimensioned variable names of any type. /r/,/s/are symbols conforming to FORTRAN naming conventions.	COMMON A, B, C/X/Q, R /Y/M, P, O COMMON/Z/G, H, J / / D

The COMMON statement permits data storage area to be shared between programs in a way analogous to that by which EQUIVALENCE permits data storage sharing within a single program. Where the logic of the programs permits, this can result in a large saving of storage space.

The programmer has complete control over the locations assigned to the variables appearing in COMMON. The locations are assigned in the sequence in which the variables appear in the COMMON statements, beginning with the first COMMON statement of the problem.

Arguments in Common Storage

Because of the above, COMMON statements may be used to serve another important function: as a medium by which to transmit arguments from the calling program to the called Function or Subroutine subprogram. In this way, they are transmitted implicitly rather than explicitly by being listed in the parentheses following the subroutine name.

To obtain implicit arguments, it is necessary only to have the corresponding variables in the two programs occupy the same location.

This can be obtained by having them occupy corresponding positions in COMMON statements of the two programs.

All elements placed in COMMON may be placed in separate blocks of COMMON, each block of which is located separately at object time. The block name is carried symbolically at load time so that blocks with the same name from different programs may be given the same location. The block name must not be used in any other reference in the program.

Common Block

The symbolic name of a block is placed at the head of the variable names belonging to the block. It is always enclosed between slashes. There are two types of COMMON blocks: blank and labeled.

a. Blank COMMON is indicated as in FORTRAN II (no slashes), or by preceding the blank COMMON variables by two consecutive slashes ("//").

b. Labeled COMMON is indicated by preceding the labeled COMMON variables by the block name between two slashes.

Rules

1. The field of entries pertaining to a block name ends with a new block name or the end of the COMMON statement.

2. Block name entries are cumulative throughout a program. A block name may appear more than once with entries for previous appearances.

3. Blank COMMON may be of any length. Labeled COMMON must conform to this size requirement: all COMMON blocks of a given name should have the same length in programs which are to be operated together.

DIMENSION and COMMON

Dimension information may be included in the COMMON statement. In this case, it need not be included in a DIMENSION statement. Example:

```
COMMON A, B(10, 15), C.
```

EQUIVALENCE and COMMON

Equivalence will never re-order COMMON, but may lengthen COMMON.

Note 1: In order to force correspondence in storage locations between two variables which otherwise will occupy different relative positions in COMMON storage, it is valid to place dummy variable names in a COMMON statement. These dummy names, which may be dimensioned, will cause reservation of the space necessary to cause correspondence.

Note 2: While implicit arguments can take the place of all arguments in CALL-type subroutines, there must be at least one explicit argument in a FORTRAN function. Here, too, a dummy variable may be used for convenience. When a variable is made equivalent to a variable which appears in a COMMON statement, the first variable will also be located in COMMON storage.

Variables brought into a COMMON block through equivalence statements may increase the size of the block indicated by the COMMON statements as in the following example:

```
COMMON A, B, C
DIMENSION D(3)
EQUIVALENCE (B, D)
```

The layout of core storage indicated by this example is:

```
    A
    B, D(1)
    C, D(2)
       D(3)
```

However, a variable may not be made equivalent to an element of an array in such a way as to cause the array to extend below the beginning of the COMMON block. For example:

```
    COMMON A, B, C
    DIMENSION D(3)
    EQUIVALENCE (B, D(3))
```

This would cause the following impossible situation:

```
       D(1)
    A, D(2)
    B, D(3)
    C
```

Type Statements

There are three Type statements: LOGICAL, INTEGER, and REAL.

LOGICAL, INTEGER, AND REAL

GENERAL FORM	EXAMPLES
"LOGICAL a, b, c, . . ."	LOGICAL F, G, L
"INTEGER a, b, c . . ."	INTEGER Q, NAME
"REAL a, b, c, . . ." where a, b, c, . . . are variable and/or function names appearing within the program.	REAL J, S

A variable or function name, once declared as a certain type, will have that type throughout the program. Real and integer variables take arithmetic values; logical variables take the values ".TRUE." or ".FALSE.". A type declaration overrides the implicit declaration of any variable. For example, IOTA, which is normally an integer because it begins with I, can be declared a floating point variable by using the type declaration REAL IOTA.

If a variable does not appear in a Type statement, the variable will retain its implicit definition. That is, ALPHA is a floating point variable if it is not declared otherwise.

A declarative on a name must precede the first usage of that name in any executable statement.

Note that array specifications may not be given in these statements.

FREQUENCY

GENERAL FORM	EXAMPLES
"FREQUENCY n (i, j, . . .), m(k, l, . . .), . . ." where n, m, . . . are statement numbers and i, j, k, l, . . . are unsigned fixed point constants.	FREQUENCY 30(1, 2, 1), 40(11), 50(1, 7, 1, 1) 10(1, 7, 1, 1)

The FREQUENCY statement is accepted by the IBM 7030 FORTRAN IV, but it has absolutely no effect on compilation. The syntax of the statement is checked, but in all other respects, the statement is ignored.

Chapter 8. Specification Statements

DATA

By means of the DATA statement, information may be obtained in the data areas and/or COMMON block of the object program to be loaded with the program. The DATA statement specifies the information and the variables to which they belong.

GENERAL FORM	EXAMPLES
"DATA List (d_1, d_2/k/d_3, . . .), List (d_n, d_{n+1}). . .), . . . where k appears before d and means that the d field is to be repeated k times.	DATA A (3HEND), (B(I), I=1, 15) (/8/4, 23) DATA A(1.2), B(3.6), C(7.9)

RULES FOR CONSTRUCTING THE LIST

Variable names in the list follow the same rules as for constructing I-O lists with the following exceptions:

1. An array name may not appear unsubscripted.
2. Compiling of data into an array area must be under control of DO-implying parentheses and associated parameters. The DO-defining parameters must be constants.
3. If a variable appears with a subscript, not under control of DO-implying parentheses, the subscript must be a constant.

RULES FOR LITERALS

The d literals may take any of three forms:

1. Integers. These are listed in the standard FORTRAN manner.
2. Floating point numbers. These are listed in the standard FORTRAN manner.
3. Alphameric characters. (These may extend over more than one word.) nH precedes the alphameric characters which are treated in the standard 7030 FORTRAN manner (eight per word, left justified, filled out with blanks, etc.). A repeat field preceding an alphameric field covers the entire field.

With regard to the data list and its associated data: if the list is shorter than the data, the redundant data is ignored and, conversely, if the list is longer than the data the remaining items in the list are ignored.

Data may not be in blank COMMON. Data which is to be in a labelled COMMON block may be specified in a special separate program. This special program may contain only the DATA and COMMON statements, as well as any required EQUIVALENCE, DIMENSION and Type statements, and must be headed by the BLOCK DATA statement.

BLOCK DATA

GENERAL FORM	EXAMPLE
"BLOCK DATA"	BLOCK DATA

A program headed by this statement may contain only DIMENSION, COMMON, Type, EQUIVALENCE, and DATA statements, plus one END statement. Example:

```
BLOCK DATA
COMMON/D/A, B, C
DIMENSION B(2, 2)
INTEGER C
DATA ((B(I, J), I+1, 2), J=1, 2) (1.1, 1.2, 1.3, 1.4),
  C(16)
END
```

Part II. FORTRAN Programming for the IBM 7030

Chapter 9. First Principles

Subprograms

The existence in the FORTRAN language of the three statements CALL, SUBROUTINE and FUNCTION enables a programmer to construct programs in a hierarchical fashion; that is, to form sequences of FORTRAN statements, these sequences being given unique names by means of which they may be concisely referred to in the construction of yet higher level code sequences. For any given problem, the construction of these sequences — Subroutine, or Function subprograms — terminates with the construction of the highest level sequence of all, the main program.

Definition of a Job

It is possible to code these subprograms, not only in FORTRAN, but in lower level languages (e.g., STRAP) provided certain rules are followed. Hereafter, unless otherwise stated, the term "subprogram" will be taken to include main programs. Within the total collection of subprograms forming a machine procedure, some will have been proven error-free ("debugged"), some will be partially debugged, and some will be completely untested. Therefore, the total card deck submitted by a programmer to a machine operator most often consists of an arbitrary number of subprogram sub-decks, in a mixture of source languages. If the aim is not merely to compile the statement of the problem, but also to execute the resultant machine code, then the program deck may be followed by input data cards. The total collection of subprograms, plus data (if present), plus appropriate preceding control cards, comprises a job, in the sense described in the *IBM Reference Manual, 7030 Master Control Program* (Form C22-6678). If execution is not to be attempted at a particular time, then the compile-only job deck need not contain all the subprograms making up the total program, nor any data.

MCP Environment

The compilation process, and the ultimate execution of the generated machine code, are both under control of MCP.

Relocation, Linkages, and Common Storage

As each subprogram is independently processed by the compiler, the resultant object code is not precisely in the form it will assume at execution time. At that time, it will have been combined with the other subprograms of the job, each requiring a region of memory whose size cannot be known at the time of compilation of all the others. For this reason, every compiled subprogram is produced with a standard "origin" (initial cell occupied by the program) of 00000.0; it is the function of the loader to relocate each binary subprogram to its own unique region of memory, just prior to execution. As an aid to this function, the compiler produces a card containing certain descriptive information about each subprogram (length of program, its name or names, etc.). This card, known as a FORTRAN Program Card, precedes the cards containing the object code.

The Loader

The loader also:

1. Sets up the appropriate linkages between subprograms,
2. Sets aside the amount of common storage required (storage to which any or all subprograms may have access, to facilitate communication between routines),
3. Supplies requested subprograms from the System's binary library, and finally
4. Initiates execution by transferring control to the entry point of the main program.

Chapter 10. Program Environment

Program Termination

A FORTRAN job for the 7030 may, in general, be schematically represented as in Figure 3.

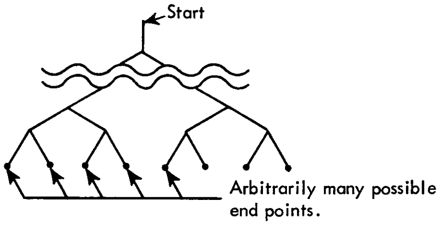


Figure 3

The procedure has a single starting point, and many possible finishing points, the particular one chosen for any given machine run depending upon the parameters characterizing that run. All possible end points may be categorized in two ways — "good stops" and "bad stops."

"Good Stops"

A successful termination is characterized by the emptying-out of any I-O buffers containing as yet unwritten information, the closing-out of any files on which the last activity was a WRITE, the writing of a tape mark on the system output tape, the release of all I-O equipment utilized by the job, and the issuance of appropriate messages to the operator. A successful termination may be achieved by any of the following:

1. The execution of a RETURN statement, *in a main program.*
2. An attempt to read data from the system input tape, when all data from that source has been exhausted.
3. Operator action following the execution of a PAUSE statement.

"Bad Stops"

An unsuccessful finish point is characterized by all the actions of the preceding section, but in addition, a memory dump is supplied on the system output tape. An unsuccessful finish is defined by any of the following:

1. The execution of a STOP statement, *in a subprogram at any level.*
2. An erroneous, illegal, or undefined I-O operation.
3. Operator action following the execution of a PAUSE statement.

Note that neither a (main program) RETURN, nor any STOP, actually causes the IBM 7030 to halt its activities; in both cases, control is returned to MCP. The only instruction capable of suspending machine activity indefinitely is the PAUSE operation.

FORTRAN Interrupt Handling

Like all programs operational under MCP control, a FORTRAN-compiled code runs with the 7030 "enabled." It will be recalled that prior to execution of a problem program, MCP has placed the required (MCP) interrupt table address in cell 2, and loaded the standard MCP mask (all maskable interrupts except IF off) into cell 12. Furthermore, the refill field of $X15 has been set to zero, thus indicating the absence of a Program Table of Exits. With respect to I-O interrupts, MCP expects the address of an I-O Table of Exits to be punched on each IOD card loaded, or, at worst, set up by a $CHEX pseudo-op before any activity on an I-O device.

I-O Interrupts

The implication of these facts, for FORTRAN programs, is as follows: All object program input-output is handled through the Input-Output Control Subroutine (actually a whole family of library subroutines linked in a fairly complex fashion). This subroutine will perform the necessary $CHEX operation for any given IOD-defined device, at the time that the first operation for that device is encountered in the running of the object program. The I-O Table of Exits, whose address is supplied to MCP in this fashion, is located *inside* the IOCS Subroutine, with the result that the various actions appropriate to the different possible returns can be taken, independent of the main-stream of the problem program.

Maskable Interrupts

Some further initialization of the *maskable* interrupt mechanism is required for FORTRAN object programs. The Stretch Compiling System inserts a call to an initializing routine as the first executable statement of each *main program* compiled. This results in the routine being fetched from the library at load time, and control being given to it before the true problem program gets under way. The routine replaces the contents of the Mask Register with the required FORTRAN mask, and places the address of a Program Table of Exits (if required) in the refill field of $X15. This table is itself contained in the initializing routine, as are any correction routines accessed through the table. It is possible for an installation to change this routine, if necessary.

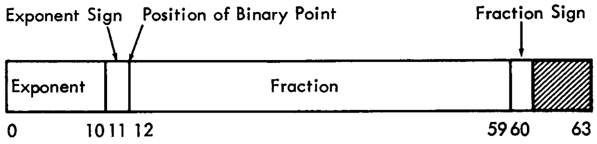
In summary, no interrupt indicator of any kind is accessible to the FORTRAN-language programmer. It is, however, entirely possible to STRAP-code routines that reference the indicators, and to CALL such routines in a FORTRAN-program.

Internal Representation

The IBM 7030 FORTRAN IV compiler handles three basic kinds of data, in two different ways. So-called real numbers and integers are operated on by the operations of addition, subtraction, multiplication and division, while "logical quantities" may be manipulated by the operations of "and-ing," "or-ing," and "negation."

Real Numbers

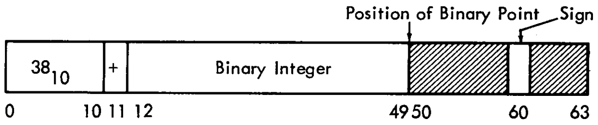
A real number is represented internally by a normalized floating-point binary number, that is, a fullword containing a 12-bit signed exponent, a 48-bit fraction, a fraction sign, and 3 (unused) flag bits. The conventional floating point instructions of the IBM 7030 are used to manipulate such data.



A FORTRAN real number

Integers

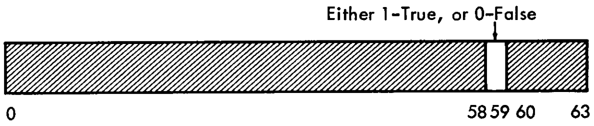
A FORTRAN integer is actually represented internally as an unnormalized floating point quantity, with a fixed exponent of 38_{10}. This enables the floating point instruction set to be used in manipulating these quantities, resulting in an appreciably shorter running time.



A FORTRAN integer

Logical Quantities

A logical quantity, as manipulated by a FORTRAN code, consists of a single bit, stored in bit 59 of a full word. Such quantities are operated on principally by CONNECT instructions.



A FORTRAN logical quantity

Zero

The FORTRAN programmer should be aware that in the manipulation of normalized floating point quantities (real numbers), a number having a zero fraction part and an arbitrary exponent may be generated as a result of add and/or subtract operations. It is necessary, therefore, that the generated code be such that two numbers with zero fractions and *different* exponents be found equal under comparison operations. In the case of the FORTRAN integers, however, the fixed exponent of $+38_{10}$ is always preserved, including the case of zero.

Precision

Note that even though FORTRAN arithmetic is single-precision in nature, the generated code contains some double precision operations. These are necessary for such cases as the multiplication of two FORTRAN integers; by reason of their internal format, a single precision multiplication operation would yield an incorrect result.

Chapter 11. IOD Card Preparation

All programs to be executed under MCP control are required to state their I-O requirements (other than the system I-O devices) in terms of IOD cards, placed at the front of a job input deck. This enables MCP to determine, prior to the execution of a program, the devices required by a job, so that these devices may be made ready, and any necessary messages in connection with tape reel mounting may be given to the operator.

For a FORTRAN job, two important preliminary statements may be made concerning IOD cards. First, unlike a STRAP program, IOD's need not be present for a "compile-only" job. This arises from the fact that in a FORTRAN program there are no direct references to the symbols punched in the IOD name field. For a compile-go job, or a go job, they are required. If the FORTRAN section of a job was processed in a compile-no-go operation, then the necessary IOD cards (prepared in the manner explained later in this chapter) must be passed through the compiling system by themselves, before they may be combined with the FORTRAN object deck and run into the machine as a go-job. (See Example 3, Chapter 4.)

Second, MCP requires *all* the IOD's of a job to be in one group, at the front of a job deck. Since a typical FORTRAN job consists arbitrarily of many subprograms, the I-O requirements must be considered for the job in toto, not merely for each individual subprogram.

It is now possible to examine the 11 I-O statements of the FORTRAN language individually, and to determine their implications in terms of required IOD cards. To this end, it is convenient to divide the statements into four groups.

Group 1: Statements Not Requiring IOD's

The three statements of Group 1 are unique in that their use does *not* require the manufacture of IOD cards. They are:

```
READ f, list
PRINT f, list
PUNCH f, list
```

where f is a format specification, and list is a list of the quantities to be transmitted. These three statements refer to the System reader, the System printer and the System punch, respectively.

Group 2: Binary I-O

The two statements in this group are:

```
READ (u) list
WRITE (u) list
```

where u is a fixed point integer or variable indicating the particular unit referenced. These statements are for the transmission of *binary* information to or from magnetic tape, or disk, the actual device required being determined by the related IOD cards.

The FORTRAN language is defined such that each distinct value of u implies a distinct I-O device, or, in the case of the disk, a distinct region (sometimes referred to as a symbolic file). Therefore, for each actual or possible value that u may assume at object time, it is necessary to prepare an IOD card. Before examining the two possible types of IOD (tape or disk), it may be stated that in both cases, the correspondence between the FORTRAN statement or statements, and the related IOD cards, is established by punching the appropriate decimal value of u in the IOD-name field. Thus, if a given job contains the following statements:

```
 2    READ (3) list
        .
        .
 4    WRITE (5) list
        .
        .
      DO 10 I=2, 10, 3
        .
        .
10    WRITE (I) list
      etc.
```

It will be necessary to prepare a total of four IOD cards, defining units 2, 3, 5 and 8. (If, however, the parameters characterizing a particular run are such that statement 4 in the example above will not be executed, then the IOD card defining unit 4 may be removed before loading the job deck, thus avoiding the scheduling of unnecessary equipment for this run.) This requirement, that the IOD-name field be numeric, is the only *required* difference between FORTRAN-oriented IOD's and STRAP-oriented IOD's.

General Rules for Constructing IOD Cards

1. A binary-type IOD (disk, or binary tape) should contain the decimal value of unit, followed by a B, punched in the name field.

2. A decimal-type IOD (printer, decimal tape, or system "pseudo-IOD's") should contain the decimal value of unit, followed by a D, punched in the name field.

3. If an IOD-name is seen, of which the *first* character is alphabetic, the compiler will assume that this IOD is for the benefit of a STRAP subprogram wishing to perform its own I-O operations. While the IOD will be passed through the system (and thus be assigned an I-O reference number equal to its relative placement in the IOD-deck excluding "pseudo-IOD's"), it will be ignored by the FORTRAN IOCS routines, except for the insertion of the letter "K" before the IOD-name.

It will be possible for the system to accept a DISK IOD, without the terminal B in the name field; similarly, a PRINTER, or "pseudo"-IOD can be handled without a terminal D.

If a TAPE IOD with a pure integer in the name field is encountered, it will be assumed to be binary and the appropriate control mechanisms set up. If, at object time, the *first* reference to this device is decimal in nature, then the appropriate corrections will be made in flight. However, if the first operation is non-decimal, binary usage will be confirmed, and a subsequent decimal operation will cause job rejection.

Binary Tape IOD's

The tape IOD card format is shown in Figure 4.

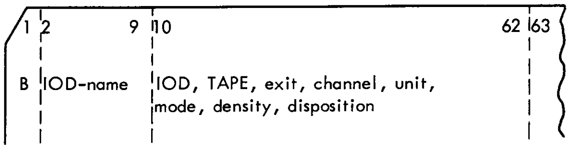


Figure 4

(See the MCP manual for a detailed description of each field indicated.) A right-to-left drop-out is permitted on the fields as shown. A TAPE IOD card prepared by a FORTRAN programmer *may* have every field shown above punched (although it will become apparent that punching in the exit field is meaningless). Anything acceptable to MCP is acceptable to the FORTRAN compiler.

1. *The exit field:* For STRAP programs, the contents of this field indicate to the assembler the address of the appropriate I-O Table of Exits for this symbolic unit. However, FORTRAN object programs communicate with MCP via the IOCS routine, and the necessary Table of Exits is embodied therein. It is impractical for the programmer to determine where this (relocated) table will be at execution time; therefore, IOCS is so constructed that it will dynamically perform a $CHEX pseudo-op, at object time, just before the first reference to the file. Even if there is punching in the exit field, the compiling system will delete the field, and by STRAP time, it will be void. Therefore, it is suggested that the FORTRAN programmer never fill in this field.

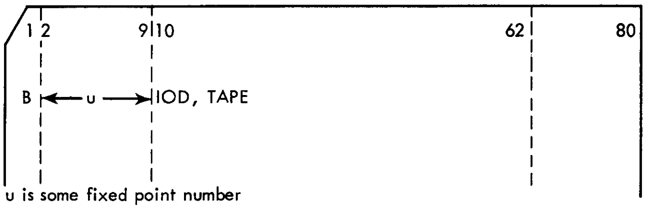
2. *The Channel and Unit Fields:* An attempt by a FORTRAN programmer to associate more than one IOD with a given physical tape unit is an error. Therefore, to simplify the preparation of tape IOD's for FORTRAN, MCP has been designed to assign distinct tape units to each tape IOD with both channel and unit void. Note that if it *is* desired to force two or more tape IOD's to reference a given tape unit, the standard MCP procedure of punching identical non-void symbols in these fields may be followed. However, this is *not* usual for FORTRAN; these fields will most often be blank.

3. *The Mode and Density Fields:* Binary tapes, which are automatically blocked in the FORTRAN system, must be written in *odd* parity. As this is the installation standard in the MCP system as distributed, it is not necessary for the programmer to specify this mode on the IOD card. Note, however, that as the compiling system is not aware of the use to which the

unit will be put, even parity specification will not be rejected. If a binary READ or WRITE references this IOD at execution time, the operation will be rejected and the job terminated. Similarly, the density field may be left void; this will result in a labeled tape being *read* in the density indicated by the label, while a labeled tape will be written, and an unlabeled tape written or read, in installation standard (high density).

4. *The Disposition Field:* If the assumption is made that the most frequent use of binary tapes is to provide temporary external storage to be used for the duration of a job, but not preserved thereafter, it may be said that usually this field may also be left void. A void disposition field implies that the tape is, under no circumstances, to be saved (removed from the machine). Once again, the programmer is at liberty to fill in this field in any of the ways specified in the MCP manual.

In summary, many binary tape usages can be satisfied by the simplest possible tape IOD (Figure 5).

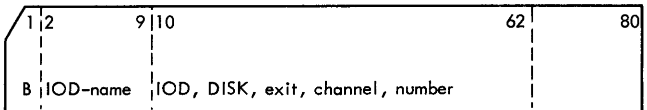


u is some fixed point number

Figure 5

Disk IOD's

A disk IOD, in the most general case, has the form shown in Figure 6.

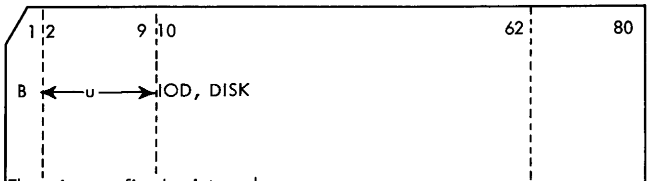


Number specifies the number of disk arcs to be reserved for this symbolic file.

Figure 6

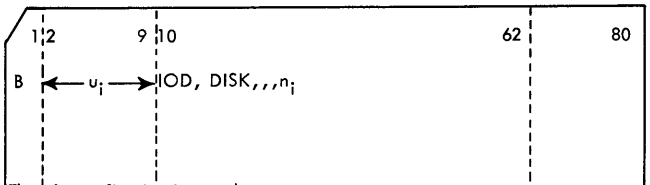
For identical reasons to those given for Tape IOD's, the exit and channel fields may be omitted. The number field may be omitted, if the job for which this IOD is prepared requires only one disk file. In this case all of disk is available to problem programs. Thus, the single disk IOD required is as shown in Figure 7.

For more than one disk file, each IOD has the form shown in Figure 8. Note that an attempt to read or write beyond the limits of the disk file will result in an abnormal termination of the object program.



The u is some fixed point number

Figure 7



The u's are fixed point numbers

Figure 8

Group 3: Decimal I-O Statements

The two statements of Group 3 are:

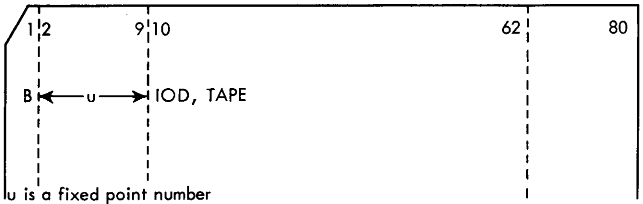
READ (u, f) list
WRITE (u, f) list

where u is a fixed point integer or variable denoting the unit, and f is a format specification. These statements are for the transmission of decimal information, to or from magnetic tape, *non-system* printer, or, under special circumstances, the system card-reader, card-punch, and printer. The specific device actuated depends upon the associated IOD cards.

Decimal Tapes

Magnetic tapes may be considered first. As in the case of binary tapes, for each possible object-time value of "u," a tape IOD card must be prepared, with the decimal value of u punched in the IOD name field. Again, the exit, channel and unit fields may be void. The mode and density field requirements, though, are slightly different. A decimal (BCD) tape written through the IOCS output routine is not blocked; each WRITE statement creates a series of records, from 1 to 17 words in length, which are not only logical, but also physical records on tape. No control information is generated, or written, by the IOCS routines. The use of a decimal READ or WRITE, as opposed to a binary READ or WRITE, actually implies two things to the IOCS routines: first, that a conversion process must be applied to the data transmitted, and second, that the tapes concerned are not to be blocked. There are no requirements on the mode or density of the tape to be written (or read). The mode and density, in fact, are determined by the use to which this tape is ultimately put. If it is to be used by subsequent FORTRAN codes, running on the IBM 7030, or by the off-line IBM 1401 list and/or punch routines, any mode and any density are permitted. Therefore, in this case, the FORTRAN programmer may very well leave both fields void. If the tape is to be taken outside the IBM 7030/1401 environment, however, it is probable that definite requirements exist for these variables. For example, if the tape is to be listed on the IBM 720 printer, then parity must be even, and density low.

In summary, the TAPE IOD associated with a decimal READ or WRITE may often be as simple as in Figure 9. No more complex form can cause job rejection, either at compile or object time.

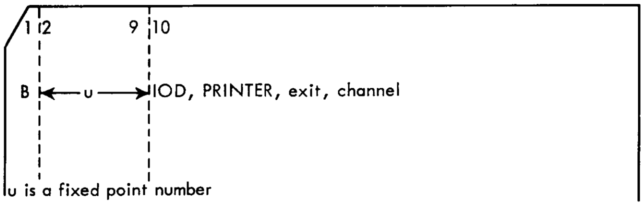


u is a fixed point number

Figure 9

Non-System Printer

The programmer may wish to force a generalized WRITE statement to output material on the on-line, non-system printer. In this case, an IOD must be prepared, with the chosen value of u in the IOD name field, in the format shown in Figure 10. For the usual reasons, the exit and channel fields may be omitted.



u is a fixed point number

Figure 10

System Devices

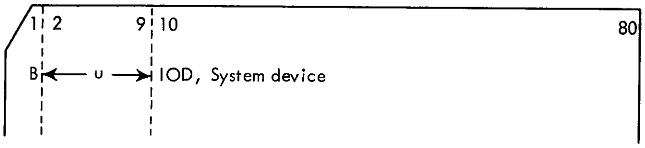
To reference the system reader, punch or printer, by the statements of this group, rather than by the three statements specifically designed for this purpose, READ, PUNCH, and PRINT, pseudo-IOD cards must be prepared. They must be linked to the READ or WRITE statement by means of the u-value in the name field. The format of the IOD's is shown in Figure 11.

An attempt to reference a value of u, defined by an IOD of this type, by a *binary* READ or WRITE will cause the job to be abnormally terminated.

Group 4: Manipulative Statements

The final group of statements in this area consists of the three so-called manipulative statements:

END FILE u
BACKSPACE u
REWIND u



The system device field is one of the following:
$ READER
$ PUNCH
$ PRINTER
u is a fixed point number

Figure 11

where u, as before, is a fixed point variable or literal. It is unlikely that a program will use any of these statements to reference a device *not* elsewhere referred to by at least one of the statements of Groups 2 or 3. Therefore, when these statements are considered in context of a given program, an IOD card defining u has probably already been prepared. If such is not the case, however, then an appropriate IOD must be created. Clearly, a value of u referenced in a REWIND statement, for example, should not be defined by an IOD PRINTER card; this gives trouble at object time. Note, though, that inasmuch as the disk is treated much like a binary tape, the operations of END FILE, BACKSPACE, and REWIND *are* defined for disk. They result in the writing of a pseudo-tape mark, the location of the start of the previous logical record, and the location of the first arc of the given disk file, respectively.

Summary

The programmer is required to consider the collective I-O requirements of *all* subprograms of his job, and prepare an appropriate set of IOD cards, belonging, in some sense, to the entire job. This set is liable to change if any part of any subprogram is changed.

Chapter 12. Control Cards, and Deck Preparation

A job, as presented to MCP and the Compiling System on the system input tape, is defined and delimited by certain control cards. This chapter describes the necessary control cards, and the construction of the input deck.

Control Cards for Entire Job

First, control cards govern the entire job. MCP requires that the very first card of each job be a JOB card (Figure 12).

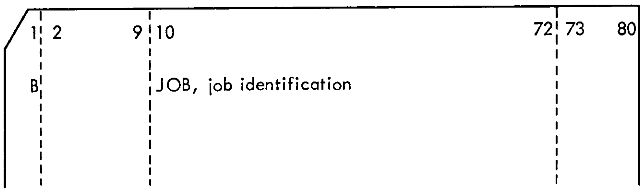


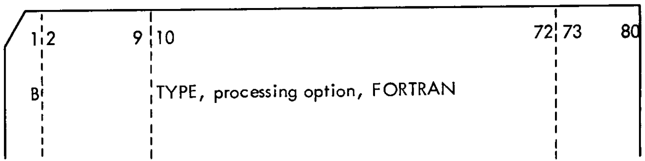
Figure 12

JOB Card

The JOB card serves to delimit this job from its predecessor. The contents of the job identification field are printed on the system output tape, for logging purposes.

TYPE Card

The second card of every FORTRAN job deck must be a TYPE card, punched as shown in Figure 13.



Processing option is one of the following:

COMPILE	(compilation, no execution)
COMPILGO	(compilation, finally execution)
GO	(execution only, no compilation)

If the field is void, or indecipherable, the entire job will be rejected.

Figure 13

Control Cards for Each Subprogram

As mentioned earlier, the typical FORTRAN job consists of many subprograms, in various levels of language (including binary, precompiled subprograms). Moreover, there will usually be a set of IOD cards relevant to the job as a whole, and sometimes a deck of punched data cards. For the purpose of describing subprogram control cards, it is convenient to treat both the IOD-deck and the data-deck (if present) as two more subprograms. Therefore, if *any* subprogram of a job requires compilation, then *every* subprogram of that job must be immediately preceded by a SUBTYPE card, whose general form is shown in Figure 14.

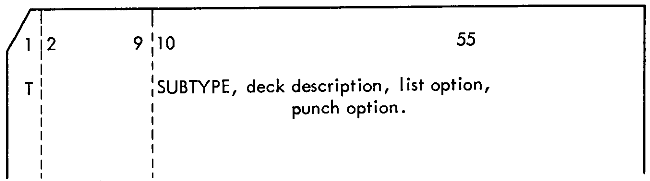


Figure 14

Deck Description

The deck description field indicates the language level of the following subprogram deck, and must be one of the following:

FORTRAN	– FORTRAN IV source language
A1	– SMAC source statements
STRAP	– STRAP II code
BIN	– Pre-assembled relocatable binary deck(s)
DATA	– Data deck
FIOD	– unprocessed FORTRAN-oriented IOD deck

An unrecognizable field or a null field will cause the processor to skip to the next SUBTYPE card, and to cancel any GO option selected by the TYPE card at the start of this job.

List Option

The list option field may be:

LSTRAP	– list-generated STRAP code
null	– list generated STRAP
NOLIST	– do not list generated STRAP

Clearly, LSTRAP in this field is meaningless if the deck description is BIN or DATA.

Punch Option

The punch option field may be either

PBIN	punch binary cards
NOPUN	do not punch binary cards
null	equivalent to PBIN

Again, it is clear that PBIN (and null) are meaningless on a SUBTYPE card whose deck description field contains BIN or DATA.

Exception for Consecutive Binary Decks

The rule stated above – that every subprogram deck in a COMPILE or COMPILGO job must be preceded by an appropriate SUBTYPE card – may be relaxed in the case of a job containing two or more pre-compiled binary decks placed contiguously in the input deck. The second and subsequent binary decks may have their SUBTYPE's omitted. Thus, after the SUBTYPE preceding the first binary deck, the next SUBTYPE seen (if any) is that preceding the next *non-binary* section of the deck.

IOD Subprogram First

It was mentioned above that the entire collection of IOD cards for a given job (plus any related REEL cards) must be collected together, and treated as a subprogram. This concept is pursued to the extent that it is necessary to follow the collection with an END statement, and to precede it with a SUBTYPE card (deck description FIOD). *This subprogram must be the first of a job; there is no exception to this rule.* The END must be punched beginning in column 10.

Subtype for Processed IOD Subprogram

After a job containing such a subprogram has been compiled, note (provided binary decks have been requested from the system) that IOD's are still present, even though all other decks now appear as column binary cards. These IOD's now have two extra fields punched; this has been done by STRAP, as described in the MCP manual. The cards are at the front of the binary deck, and they may not be removed from this position on any subsequent occasions in which the deck is presented to the IBM 7030. However, these *processed* IOD's are to be regarded as *binary* input – i.e., the preceding SUBTYPE card *must* have the deck-description field as BIN, if this binary deck is combined with some additional non-binary decks to form a (new) COMPILE, or, more probably, a COMPILGO job.

Data Subprogram

Any data to be input on the System input tape by the execution of a program *must follow all subprogram decks*. There is no exception to this rule. If the job is COMPILE, or COMPILGO, then the data deck must be preceded by a SUBTYPE card, with deck description data. If the job is a (FORTRAN) GO, then data must be separated from the last binary subprogram by a FORTRAN Branch card (see Appendix A).

Go Jobs

When a job requires no compilation whatsoever (i.e., all input consists of binary precompiled programs), then SUBTYPE cards are not needed. The presence of the TYPE, GO, FORTRAN cards will invoke the FORTRAN relocating loader. If input data is to follow, then the last subprogram must be followed by a FORTRAN Branch card.

Examples

A few sample input decks are illustrated below to indicate the various control cards required.

Example 1

A job consisting of two FORTRAN and one SMAC subprograms, to be compiled and executed, plus decimal data. No binary decks required, but STRAP listings requested.

```
B   JOB, RUN 35/A, BIRNHAM WOOD REFORESTATION
    PROJECT
B   TYPE, COMPILGO, FORTRAN
T   SUBTYPE, FIOD, LSTRAP, NOPUN
B   IOD, - - - - - -
B   IOD, - - - - - -            IOD subprogram
    - - - -
    END
T   SUBTYPE, FORTRAN, LSTRAP, NOPUN
    - - - -
    - - - -                     FORTRAN subprogram 1
    - - - -
    END
T   SUBTYPE, A1, LSTRAP, NOPUN
    - - - -
    - - - -                     SMAC subprogram
    - - - -
    END
T   SUBTYPE, FORTRAN, LSTRAP, NOPUN
    - - - -
    - - - -                     FORTRAN subprogram 2
    - - - -
    END
T   SUBTYPE, DATA
    - - - -
    - - - -                     Data Cards
    - - - -
```

Example 2

A job consisting of a FORTRAN subprogram: two binary decks, a STRAP deck, and a processed IOD deck. (This implies the FORTRAN and STRAP subprograms do not have any additional I-O requirements not known at the time the IOD deck was made up.) No STRAP listings are required, but binary decks are to be obtained. Execution is to be attempted.

```
B   JOB, RESEARCH PROB. 0001. CIRCLE,
      (SQUARING OF)
B   TYPE, COMPILGO, FORTRAN
T   SUBTYPE, BIN
B   IOD, - - - - -
B   IOD, - - - - -
    - - - -

     Binary deck
     produced by IOD
     compilation

T   SUBTYPE, BIN                (could be omitted)

     Binary
     Subprogram 1

T   SUBTYPE, BIN                (could be omitted)

     Binary
     Subprogram 2

T   SUBTYPE, STRAP
    - - - - -
    - - - - -                   STRAP subprogram
    - - - - -
    END
T   SUBTYPE, FORTRAN
    - - - - -
    - - - - -                   FORTRAN subprogram
    - - - - -
    END
```

Example 3

A job consisting of one binary subprogram, and an unprocessed IOD subprogram. No listings, but binary cards are required. Execution to be attempted with following data:

```
B   JOB, STATISTICAL EVALUATION OF SWINE-FEVER
      INCIDENCE IN AKRON.
B   TYPE, COMPILGO, FORTRAN
T   SUBTYPE, FIOD
B   IOD, - - - -
B   IOD, - - - -
    - - - -
    END
T   SUBTYPE, BIN
```

```
     Binary
     Subprogram
T    SUBTYPE, DATA
     Data
           deck
```

EXAMPLE 4

A straight GO job, with two previously compiled binary decks, and a processed IOD-deck.

```
B    JOB, ORBITAL CALCULATION 376. (VULCAN)
B    TYPE, GO, FORTRAN
B    IOD - - -
B    IOD - - -
     - - - -

     Binary deck pro-
     duced by IOD
     compilation

     Binary Subprogram
           1

     Binary Subprogram
           2

     FORTRAN Branch Card
         Data deck
```

Chapter 13. STRAP Subprograms and Binary Decks

Provided certain rules are followed, it is possible to write subprograms (either Function-type, or Subroutine-type) in STRAP, that may be continued with FORTRAN-coded routines to form a job. This chapter explains these rules after first reviewing the constitution of a typical binary subprogram deck.

Binary Deck

The usual binary deck consists of the following cards, in the order given:

1. A FORTRAN Program card.
2. One or more Common Definition cards.
3. An arbitrary number of Relocatable Instruction cards, and/or Relocatable Data cards.

PROGRAM CARD

The FORTRAN Program card provides certain descriptive information about the subprogram to the loader. After the routine has been loaded into memory and during execution, the Program card occupies no space. The information carried by this card is:

The number of full words of memory required by this routine.

(a) The number of full words of memory required by this routine.
(b) The number of full words of *blank* common required by this routine.
(c) The "name" of this routine.
(d) The entry point, relative to zero, associated with (c).

A STRAP subprogram, unlike a FORTRAN-coded routine, may have more than one entry point. For such routines, items (c) and (d) are repeated as many times as required.

COMMON DEFINITION CARD

A Common Definition card informs the loader of the names and sizes of the *named* common blocks utilized by this program, of which there may be arbitrarily many. For each such block, the information given is:

(a) Common block name.
(b) Total number of full words required for this block.

If a given subprogram references more common blocks than can be defined on one common definition card, then as many more additional cards of this type as are necessary may follow. There is no difference in formats between the first and any "continuation" common definition cards; however, it is vital that the original ordering of these cards (i.e., as produced by the Compiling System) be preserved.

RELOCATABLE INSTRUCTIONS AND DATA CARDS

Relocatable binary instruction and relocatable binary data cards contain the executable instructions of a subprogram and its associated data, respectively. The instruction card also contains a relative loading origin for the card, plus relocation bits, specifying how the individual instruction address references are to be relocated. The data card contains the data bits, a loading *base* (which specifies whether the data is to be loaded into the program region of memory, or into a named common block), and a relative loading *origin* (with respect to the loading base).

Compatibility Requirements

STRAP subprograms must observe certain rules in connection with the production of:

1. The FORTRAN Program Card.
2. Any necessary Common Definition cards.

Moreover, certain conventions must be followed in connection with the following additional points:

3. The calling of lower level routines (if any).
4. The acquisition of input arguments (if any).
5. Index register saving and restoring.
6. The production of output results (if any).
7. The returning of control to the calling routine.

PRODUCTION OF A PROGRAM CARD

A FORTRAN Program Card may be obtained by the following sequence of instructions:

	PUNFPC, S, C
Name$_1$	ENTER, address$_1$
Name$_2$	ENTER, address$_2$
	- - - - -
Name$_n$	ENTER, address$_n$

where:

S defines the number of full words occupied by this program (equal to the highest location relative to zero used, plus 1).

C defines the number of full words of blank common used by this program.

Name$_i$ is the *i*th entry point name to be placed on the program card.

Address$_i$ defines the actual entry point to be associated with name$_i$.

If more entry points are defined by means of the ENTER statements than can be punched on one card, then STRAP will automatically produce as many additional program cards as are required.

Production of Common Definition Cards

Any Common Definition cards that may be required can be produced by the following sequence of STRAP statements:

```
        PUNCDC
Name1   COMBLOCK, Q1
Name2   COMBLOCK, Q2
        - - - - - - - - - -
Namen   COMBLOCK, Qn
```

where:

Name$_i$ is the name of the ith common block defined for this program.

Q$_i$ is the number of full words to be reserved for this common block.

Calling Lower Level Routines; Transfer Vector

Any lower level routines to be referenced by a given subprogram, must be invoked in a standard fashion. The formal instructions passing control must be:

```
SIC, $X15
B, name
```

where name is the address of a word in the transfer vector, at the start of the program. This transfer vector is a consecutive series of full words, containing the A-8 coded names of the lower level routines to be called, beginning in cell 1 of the program (relative to zero). The first 18 bits of cell zero must contain an integer, specifying the length of this transfer vector. Thus, to call a lower level routine named GLOB, the following code should be used:

```
          PUNREL
          SLC, 0.0
          XW,, ENDTV-BEGINTV
BEGINTV   SYN, $
GLOB      (A*)DD(BU, 64,8), GLOB        *
          ------------------------------ other transfer
          ------------------------------ vector entries.
          ------------------------------
ENDTV     SYN, $
          ------------------------------ Executable
          ------------------------------ Code
          ------------------------------
          SIC, $X15                      Transfer of
          B, GLOB                        control to
          ------------------------------ routine GLOB
          ------------------------------
```

(Note that this example does *not* show the passing of arguments into GLOB.)

Argument Lists

The STRAP subprogrammer is concerned with argument lists in two connections. First, input arguments to a subprogram must be acquired by means of the argument list generated by the calling program; second, if a lower level routine is to be called, an appropriate argument list must be *constructed* in STRAP.

A subprogram list consists of a consecutive series of full words, one for each argument, immediately following the invoking "SIC;B" instructions. Each word is in the form:

```
VF, a1; VF, a2
```

where:

a$_1$ is the location of the argument value (in the calling program)

a$_2$ is either identical to a$_1$, if the argument is a single valued variable, or the first location of an array, a particular element of which is being specified by a$_1$.

Thus, a$_1$ is the address to be used in the acquisition of arguments by the called program. If the argument specified in the calling program is the name of an array, without any appended subscript, then a$_1$ and a$_2$ are identical, the address given being that of the first cell of the array, or ARRAY (1, 1, 1). If the argument is alphameric data, then both addresses given are equivalent, and specify the *first* location occupied by that data.

Example of Argument List

```
FORTRAN code
    DIMENSION A(2, 3, 4), B(10, 10)
    CALL JOE (6.7, Q, 3HEND, B, A (1, 2, 2))
Generated STRAP code (for CALL statement)
    SIC, $X15
    B, TVLOC
    VF, L(6.7); VF, L(6.7)
    VF, Q; VF, Q
    VF, HOLARG; VF, HOLARG
    VF, B; VF, B
    VF, A+8.0; VF, A
    - - - - - - -                     return point
    - - - - - - -
    - - - - - - -
    HOLARG     (A*)DD(BU, , 8), END          *
```

Index Register Saving and Storing

A FORTRAN-coded subprogram always saves all 16 index registers upon initial entry to that routine. At each possible exit point, arrangements are made to restore these registers. While it is not strictly necessary for the STRAP subprogrammer to save and restore all 16 index registers, it is imperative that any registers liable to be changed should be preserved. It may be convenient for this to be done in a similar fashion to that in which FORTRAN-coded routines perform this action; here, 16 memory words are set aside, following the transfer vector (if any) for the preservation of the index register contents.

Results

A Function subprogram must always place its (single) result in the left part of the accumulator ($L). A Subroutine subprogram must place each of its results in a memory location. (Note that it is not required that a Subroutine produce *any* results.) A result represented by the nth argument of a CALL statement is to be stored in the location specified by the first 18 bits of location (n-1).0($X15).

Return of Control

Control may be returned to the calling routine by:

1. Restoring any altered index register.
2. Branching to the location immediately following the last word in the argument list (if present).

The appropriate instruction for a routine with n arguments is:

```
B, n.0($X15)
```

Array Storage

Note that data is stored in a *forward* direction in programs compiled by the IBM 7030 FORTRAN. Given an array A(2, 3, 4) the memory cells allocated are:

ADDRESS	CONTENTS
X	A(1, 1, 1)
X+1	A(2, 1, 1)
X+2	A(1, 2, 1)
X+3	A(2, 2, 1)
X+23	A(2, 3, 4)

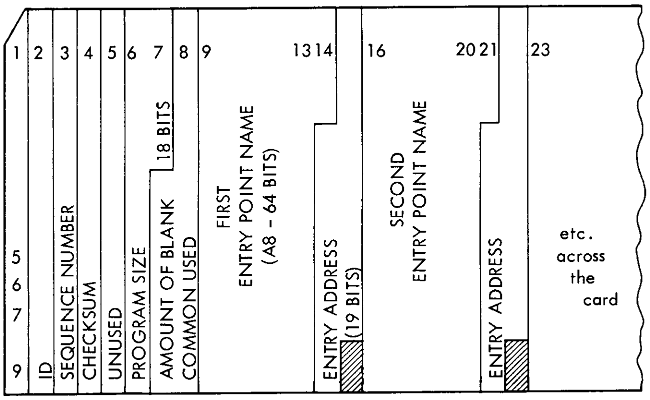
An array is stored forward by columns. Furthermore, the various items in a common block (including blank common) are also stored in a forward direction. That is, given the statement

```
COMMON A, B, C, D
```

A occupies a *lower* memory address than B, C, or D.

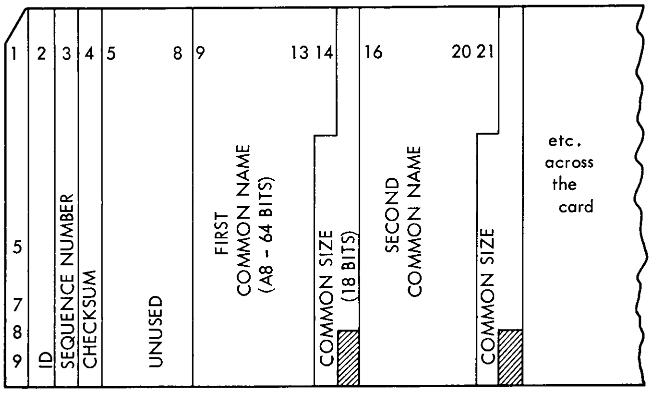
Appendix A. Binary Card Formats

FORTRAN Program Card



Columns 6, 7 and 8 are blank on any subsequent continuation program cards.

Common Definition Card

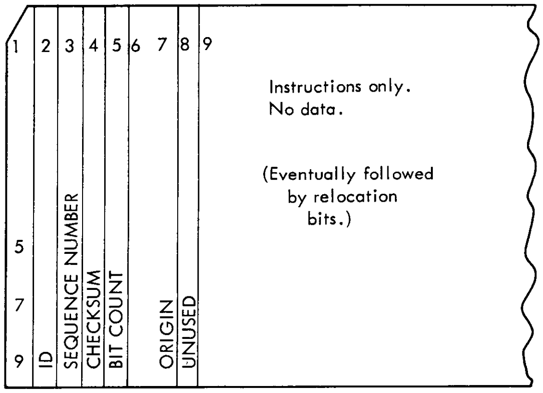


If the number of named commons is greater than that which will fit on a single card, additional cards will be punched in the same format.

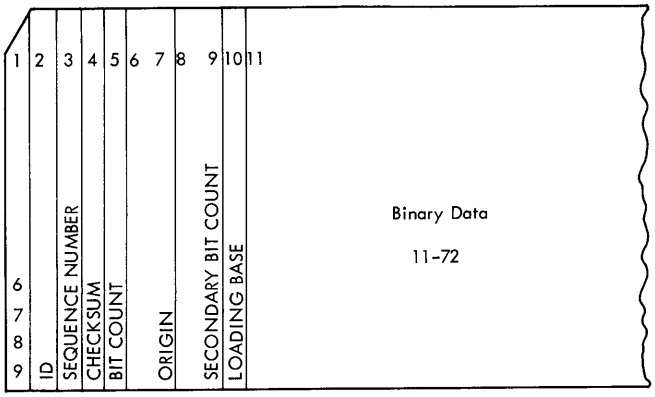
Relocatable Binary Instruction Card

Relocation Bits (describing a half-word field)

0	No relocation
1 0. . . .	Relocation
1 0 0 . .	First 18 bits (address)
1 0 1 . .	Last 18 bits (refill)
1 0 . . 0	As lower address
1 0 . . 1 . .	As upper address
1 0 . . 1 0	With respect to blank common
1 0 . . 1 1 i	with respect to named common number i (length of i sub-field is determined by number of named commons)



Relocatable Binary Data Card



No relocation bits on this card.

Loading Base (column 10)

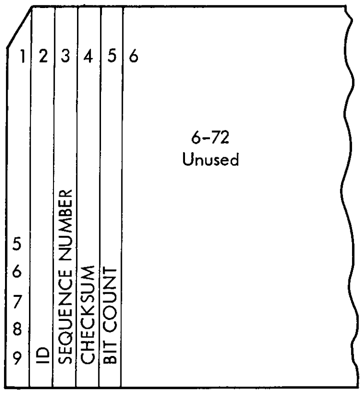
0 – Program Data
1 – 1st Named Common
2 – 2nd Named Common, etc.

Secondary Bit Count (columns 9-10)

Bits to be zeroed/skipped before/after loading as determined from 5.0, 5.1:

5.0	0-skip	1-zero
5.1	0-before	1-after

FORTRAN Branch Card



Appendix B: Principal Differences Between the IBM 709/90 FORTRAN II and the IBM 7030 FORTRAN IV

The differences between FORTRAN II and FORTRAN IV may be considered under two headings: changes to existing facilities, and addition of new features.

Changes

1. The IF statement has been redefined, to reflect a logical decision making process, rather than an arithmetic sign test, although the IBM 7030 FORTRAN IV compiler will accept the arithmetic-IF without flow analysis.
2. The I-O tape-oriented statements have been changed, to make them more general.
3. The machine dependent statements referencing sense lights, sense switches, and machine triggers have been dropped.
4. The EQUIVALENCE statement is no longer permitted to re-order COMMON storage.
5. Function naming rules have been changed, to unify the various conventions applicable to the different kinds of functions.
6. The B and F modal punch conventions have been dropped.
7. Implicit multiplication is not accepted.

Additions

1. Three type declarations have been added to the language to enable the nature of variable and function names to be (optionally) declared rather than established by declension.
2. Logical and relational operators have been added, to facilitate decision making processes.
3. A special statement, EXTERNAL, has been provided to permit the passing of subprogram names as arguments.
4. The concept of "named" common storage has been introduced, together with the ability to specify dimension information in COMMON statements.
5. The ability to write subprograms operating upon arrays of varying size specified by means of a variable DIMENSION statement, has been added.
6. A new statement, DATA, has been added, to permit initialization of data objects at compile time.

Appendix C: A STRAP Coded Subprogram

Suppose the programmer wishes to code a STRAP subprogram analogous to the following FORTRAN program:

```
  SUBROUTINE STRAP
  COMMON ANAME1(10)
  COMMON/BLOCK1/ANAME2,/BLOCK2/ANAME3(10)
  ANAME2 = SIN(0.0)
  DO 1 I = 1, 10
  ANAME3(I) = I
  ANAME1(I) = COS (ANAME3(I))
1 CONTINUE
  RETURN
  END
```

then the STRAP program should be similar to the following:

```
            PUNREL
            SEM, 92, 114, 116
            PUNFPC, LAST, COMMON
STRAP       ENTER, ENTER
            PUNCDC
BLOCK1      COMBLOCK, BLOCK1ND
BLOCK2      COMBLOCK, BLOCK2ND
            XW, , 2
COS         (A*)DD(BU), COS        *
SIN         (A*)DD(BU), SIN        *
ENTER       SX, $0, SAVE
            SX, $1, SAVE+1.0
            SX, $15, SAVE+2.0
            CNOP
            LVI, $15, $+1.0
            B, SIN
            VF, ZERO
            VF, ZERO
            ST(U), ANAME2
            LVI, $1, 0.0
            L(U), ONE
            ST(U), I
            LCI, $0, 10
BEGIN1      L(U), I
            ST(U), ANAME3($1)
            LV, $0, $L+0.32
            V+, $0, ARG1+0.32
            SV, $0, ARG1
            CNOP
            LVI, $15, $+1.0
            B, COS
ARG1        VF, ANAME3
            VF, ANAME3
            ST(U), ANAME1($1)
            V+I, $1, 1.0
            L(U), ONE
            M+(U), I
            CB, $0, BEGIN1
            LX, $0, SAVE
            LX, $1, SAVE+1.0
            LX, $15, SAVE+2.0
```

```
              B, 0.0($15)
              B, $MCP
              , $ABEOJ
              CNOP
ZERO          DD(N), 0.
ONE           (F10)DD(U), 1.0 × 38
I             DR(N), 1
SAVE          DR(N), 3
              SLCRCOM,
ANAME1        DR(N), 10
COMMON        SYN, $
              SLCRCOM, BLOCK1
ANAME2        DR(N), 1
BLOCK1ND      SYN, $
              SLCRCOM, BLOCK2
ANAME3        DR(N), 10
BLOCK2ND      SYN, $
              SLC, SAVE+3.0
LAST          SYN, $
              END
```

Appendix D: Segmentation on the IBM 7030

Segmentation is a method of overlay designed to handle the situation in which the entire problem program is too large to be held in internal storage at one time. As a part of the FORTRAN chain, the 7030 segmentation is implemented through the BSS-MCP loader. Internally, the segmentation portion of BSS will set up in the relocation tables the information required by the MCP loader to load the segmented program in the desired fashion. A special link program operates during execution of the problem program to determine when a new portion of the problem program is to be loaded and to transfer control to the MCP loader at that time.

Segmentation is used in the following manner: a segment is defined by placing in front of the binary deck for a group of subprograms a node control card, of the card format given below. No node card is needed for a program consisting of a single segment.

All of the subprograms defined as a segment by a node card will be loaded into storage whenever any part of that segment has to be loaded. Since a certain amount of time will be required during execution to bring in the various segments, the most efficient deck arrangement for segmentation will be that which requires the smallest number of transfers between segments.

Storage for a segmented program will be allocated in the following way: One segment, called the primary segment, will remain in storage at all times. This segment must contain the main subprogram, to which control will be initially transferred. All library subprograms which are called, as well as the link subprogram, will be assigned by BSS to the primary segment. The user must assign the IOD subprogram to the primary segment. Commons will be allocated space higher in storage than the program, but commons will be properly associated with the segments which reference them. Block data will be associated with the segment which contains that block data subprogram.

Node Card Format

The node control card, which indicates to BSS whether segmentation is to be used and how the segments are divided, has the following format:

```
col  1       T
col  10-19   NODE, XX, YY
```

XX is the two-digit segment number for the group of subprograms preceding the next node card. YY is a two-digit segment number of the segment to which the current segment, XX, is to be attached. The value of YY should be 00 on the node card for the primary segment.

Notes

1. The number of segments cannot exceed 99.
2. Care must be taken in setting up the segmentation deck. A call from one segment to another will be illegal if the call causes the originating segment to be overlaid.
3. Neither named common nor block data will be preserved when a segment associated with it is overlaid.
4. An error will be indicated if any group of segments which are to be in storage at the same time will exceed the amount of storage available.
5. The number of segments which are to be in storage at the same time cannot exceed eight.
6. FORTRAN subprograms must be compiled before node cards are inserted in the program deck.

5/63:2.5M-HP-40

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