HEWLETT hp PACKARD

HP ASSEMBLER

HP ASSEMBLER
Programmer's Reference Manual

HEWLETT PACKARD

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PREFACE

This publication is a reference manual for the programmer using the HP Assembler or Extended Assembler. It includes both the elements of the language and the information required to execute either Assembler on the computer.

Other computer publications provided by Hewlett-Packard include:

Basic Control System Programmer's Reference Manual (02116-9017)
Program Library Routines (02116-9032)
Assembler/Basic Control System Training Manual (02116-9073)
Magnetic Tape System Manual (02116-91752)
Prepare Tape System Manual (02116-91751)

NEW AND CHANGED INFORMATION

All known errors in this manual have been corrected. Changes in the text are marked by a horizontal line in the margin.

CONTENTS

INTRODUCTION

The Assembler and the Extended Assembler translate symbolic source language instructions into an object program for execution on the computer. The source language provides mnemonic machine operation codes, assembler directing pseudo codes, and symbolic addressing. The assembled program may be absolute or relocatable.

The source program may be assembled as a complete entity or it may be subdivided into several subprograms (or a main program and several subroutines), each of which may be assembled separately. The loader of the Basic Control System loads the program and links the subprograms as required. The Basic Binary Loader loads programs in absolute form.

Input for the Assembler is prepared on paper tape; the Assembler punches the binary program on paper tape in a format acceptable to the loader.

The minimum equipment configuration required to use the Assembler is as follows:

2116A or 2115A Computer with 4K memory
2752A Teleprinter

The minimum configuration for the Extended Assembler is:

2116A or 2115A Computer with 8K memory
2752A Teleprinter

GENERAL DESCRIPTION 1

1.1 ASSEMBLY PROCESSING

The Assembler is a two pass system, or, if both punch and list output are requested, a three pass system on a minimum configuration. A pass is defined as a processing cycle of the source program input.

In the first pass, the Assembler creates a symbol table from the names used in the source statements. It also checks for certain possible error conditions and generates diagnostic messages if necessary.

During pass two, the Assembler again examines each statement in the source program along with the symbol table and produces the binary program and aprogram listing. Additional diagnostic messages may also be produced.

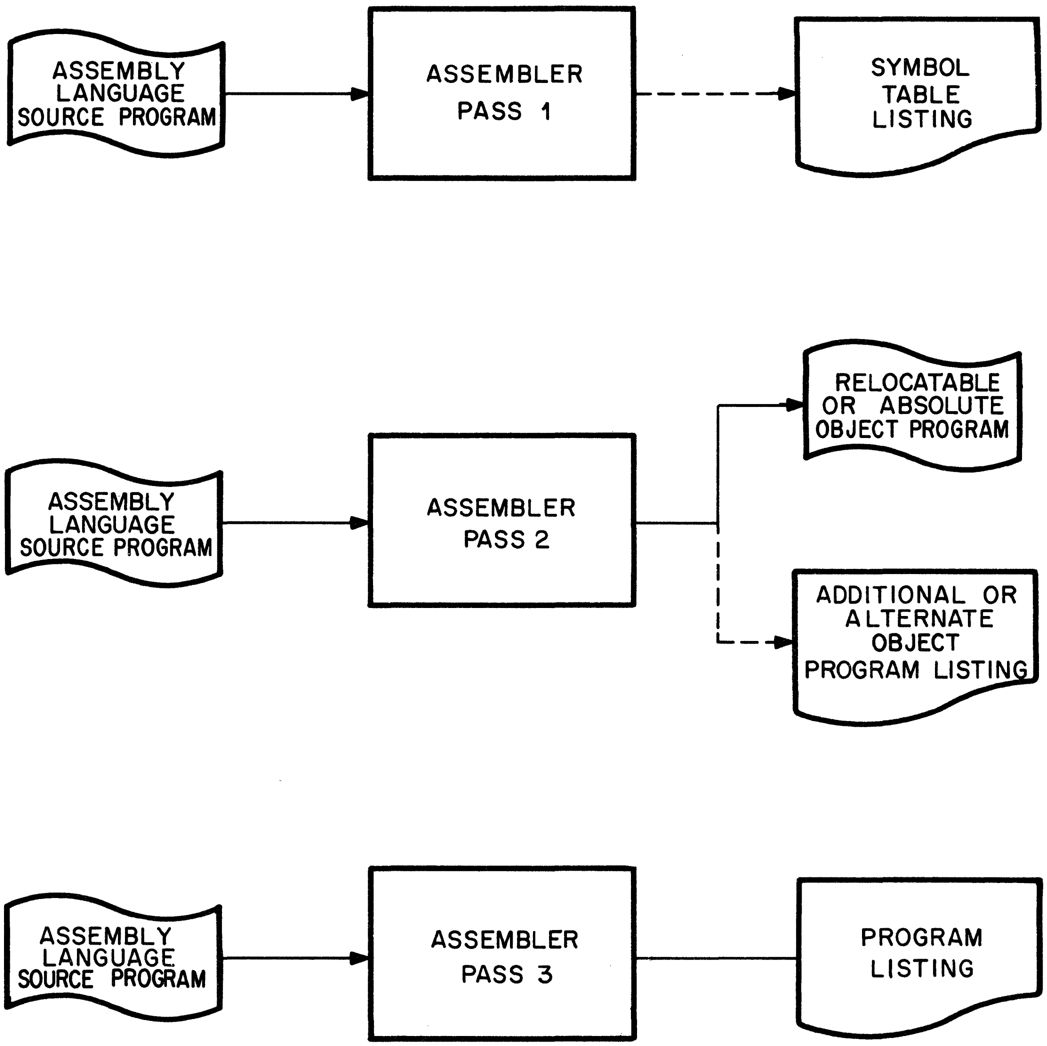
If only one output device is available and if both the binary output and the list output are requested, the listing function is deferred and performed as pass three.

When using the Assembler with a magnetic tape the source program is written on the tape during the first pass; the tape is backspaced and the second pass executed.

1.2 SYMBOLIC ADDRESSING

Symbols may be used for referring to machine instructions, data, constants, and certain other pseudo operations. A symbol represents the address for a computer word in memory. A symbol is defined when it is used as a label for a location in the program, a name of a common storage segment, the label of a data storage area or constant, the label of an absolute or relocatable value, or a location external to the program.

Through use of simple arithmetic operators, symbols may be combined with other symbols or numbers to form an expression which may identify a location other than that specifically named by a symbol. Symbols appearing in operand expres-


ASSEMBLY LANGUAGE SOURCE PROGRAM
ASSEMBLER PASS 1
SYMBOL TABLE LISTING
ASSEMBLY LANGUAGE SOURCE PROGRAM
ASSEMBLER PASS 2
RELOCATABLE OR ABSOLUTE OBJECT PROGRAM
ADDITIONAL OR ALTERNATE OBJECT PROGRAM LISTING
ASSEMBLY LANGUAGE SOURCE PROGRAM
ASSEMBLER PASS 3
PROGRAM LISTING

HP ASSEMBLER PROCESSING

sions, but not specifically defined, and symbols that are defined more than once are considered to be in error by the Assembler.

1.3 PROGRAM RELOCATION

Programs may be relocated in core by the Basic Control System loader; the location of the program origin and all subsequent instructions is determined at the time the program is loaded.

A relocatable program is assembled assuming a starting location of zero. All other instructions and data areas are assembled relative to this zero base. When the program is loaded, the relocatable operands are adjusted to correspond with the actual locations assigned by the loader.

The starting locations of the common storage area and the base page portion of the program are always established by the loader. References to the common area are common relocatable. References to the base page portion of the program are base page relocatable. If a program refers to the common area or makes use of the base page via the ORB pseudo instruction, the program must also be relocatable.

If a program is to be relocatable, all subprograms comprising the program must be relocatable; all memory reference operands must be relocatable expressions or literals, or have an absolute value of less than 100_8.

1.4 PROGRAM LOCATION COUNTERS

The Assembler maintains a counter, called the program location counter, that it uses to assign consecutive memory addresses to source statements.

The initial value of the program location counter is established according to the use of either the NAM or ORG pseudo operation at the start of the program. The NAM operation causes the program location counter to be set to zero for a relocatable program; the ORG operation specifies the absolute starting location for an absolute program.

Through use of the ORB pseudo operation a relocatable program may specify that certain operations or data areas be allocated to the base page. If so, a separate counter, called the base page location counter, is used in assigning these locations.

1.5 ASSEMBLY OPTIONS

Parameters specified with the first statement, the control statement, define the output to be produced by the Assembler:†

Absolute – The addresses generated by the Assembler are to be interpreted as absolute locations in memory. The program is a complete entity; external symbols, common storage references, and entry points are not permitted.

Relocatable – The program may be located anywhere in memory. All operands which refer to memory locations are adjusted as the program is loaded. Operands, other than those referring to the first 64 locations, must be relocatable expressions. Subprograms may contain external symbols and entry points, and may refer to common storage.

Binary output – An absolute or relocatable program is to be punched on paper tape.

List output – A program listing is produced either during pass two or pass three.

Table print – List the symbol table at the end of the first pass.

Selective assembly - Sections of the program may be included or excluded at assembly time depending on the option used.

† See Chapter 5 for complete details.

INSTRUCTION FORMAT 2

A source language statement consists of a label, an operation code, an operand, and comments. The label is used when needed as a reference by other statements. The operation code may be a mnemonic machine operation or an assembly directing pseudo code. An operand may be an expression consisting of an alphanumeric symbol, a number, a special character, or any of these combined by arithmetic operations. (For the Extended Assembler, an operand may also be a literal.) Indicators may be appended to the operand to specify certain functions such as indirect addressing. The comments portion of the statement is optional.

2.1 STATEMENT CHARACTERISTICS

The fields of the source statement appear in the following order:

Label

Opcode

Operand

Comments

Field Delimiters

One or more spaces separate the fields of a statement. An end-of-statement mark terminates the entire statement. On paper tape this mark is a return, CR, and line feed, LF .[†] A single space following the end-of-statement mark from the previous source statement is the null field indicator of the label field.

Character Set

The characters that may appear in a statement are as follows:

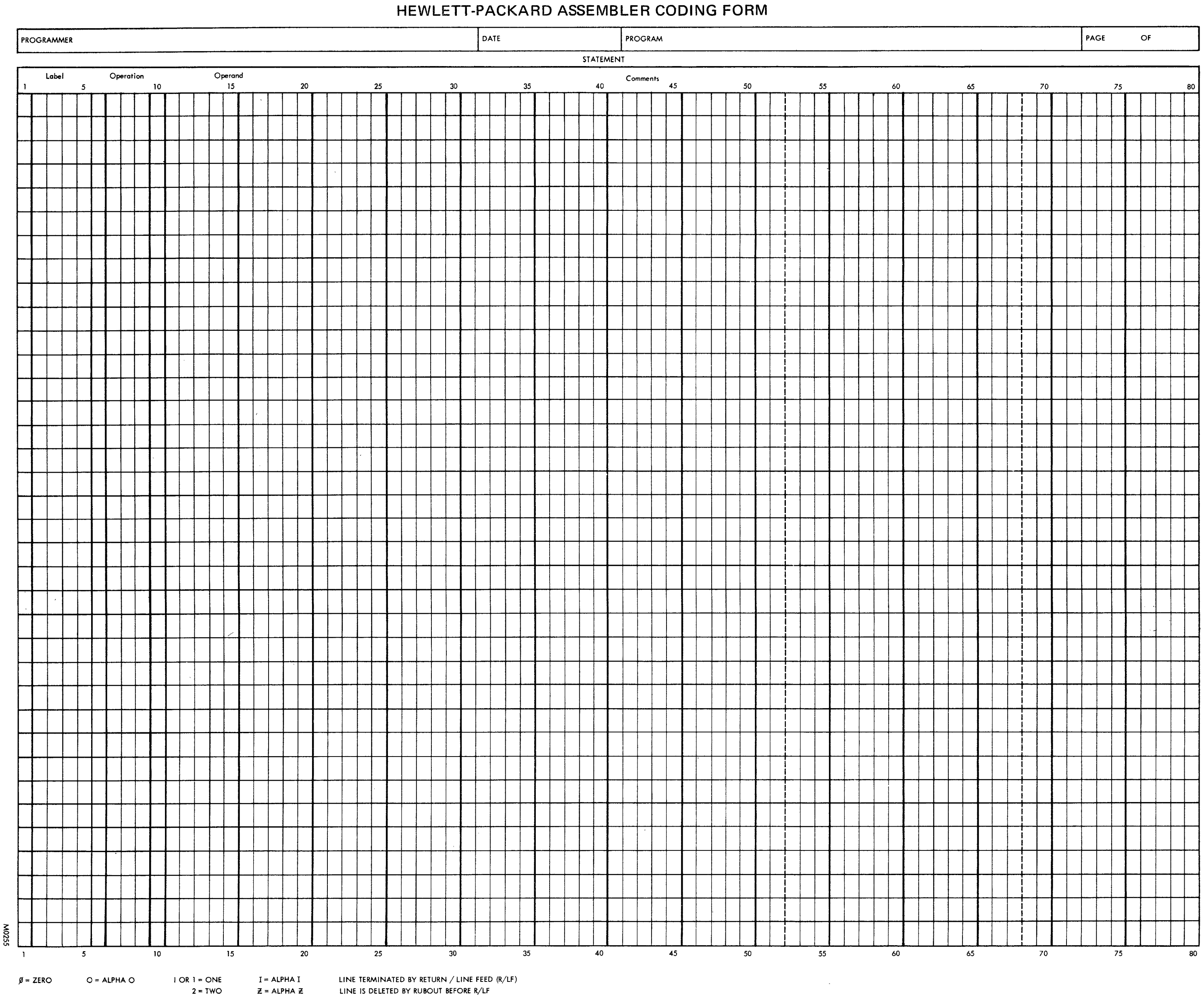
A through Z

0 through 9

. (period)

* (asterisk)

[†] A circled symbol (e.g., CR) represents an ASCII code or Teleprinter key.



HEWLETT-PACKARD ASSEMBLER CODING FORM

PROGRAMMER	DATE	PROGRAM	PAGE OF

STATEMENT

Label 1 5 Operation 10 Operand 15 20 25 30 35 40 Comments 45 50 55 60 65 70 75 80

1 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

M0255

Ø = ZERO O = ALPHA O I OR 1 = ONE 2 = TWO I = ALPHA I Z = ALPHA Z LINE TERMINATED BY RETURN / LINE FEED (R/LF) LINE IS DELETED BY RUBOUT BEFORE R/LF

SAMPLE CODING FORM
(Actual Size 11 × 13-1/2)

+	(plus)
-	(minus)
,	(comma)
=	(equals)
( )	(parentheses)
	(space)

Any other ASCII characters may appear in the Remarks field (See Appendix A).

The letters A through Z, the numbers 0 through 9, and the period may be used in an alphanumeric symbol. In the first position in the Label field, an asterisk indicates a comment; in the Operand field, it represents the value of the program location counter for the current instruction. The plus and minus are used as operators in arithmetic address expressions. The comma separates several operation codes, or an expression and an indicator in the Operand field. An equals sign indicates a literal value. The parentheses are used only in the COM pseudo instruction.

Spaces separate fields of a statement. They may also be used to establish the format of the output list. Within a field they may be used freely when following +, -, , , or (.

Statement Length

A statement may contain up to 80 characters including blanks, but excluding the end-of-statement mark. Fields beginning in characters 73 - 80 are not processed by the Assembler.

2.2 LABEL FIELD

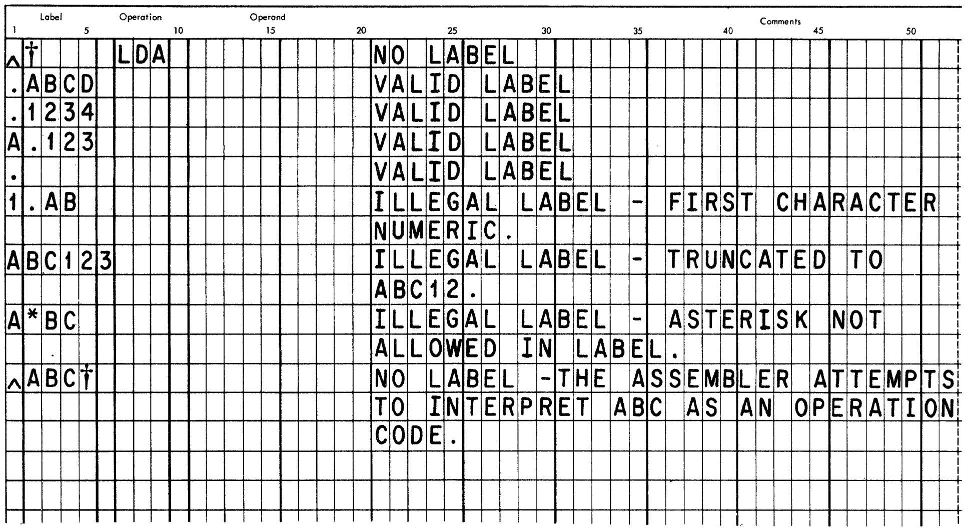
The Label field identifies the statement and may be used as a reference point by other statements in the program.

The field starts in position one of the statement; the first position following an end-of-statement mark for the preceding statement. It is terminated by a space. A space in position one is the null field indicator for the label field; the statement is unlabeled.

Label Symbol

A label must be symbolic. It may have one to five characters consisting of A through Z, 0 through 9, and the period. The first character must be alphabetic or a period. A label of more than five characters could be entered on the source language tape, but the Assembler flags this condition as an error and truncates the label from the right to five characters.

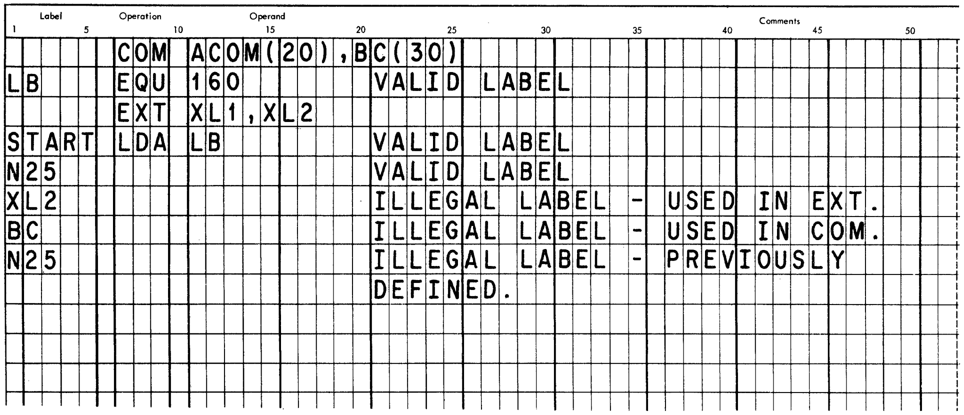
Examples:



```
 Label    Operation    Operand                               Comments
1   5     10   15   20   25   30   35   40   45   50
∧†    LDA           NO LABEL
.ABCD               VALID LABEL
.1234               VALID LABEL
A.123               VALID LABEL
.                   VALID LABEL
1.AB                ILLEGAL LABEL - FIRST CHARACTER
                    NUMERIC.
ABC123              ILLEGAL LABEL - TRUNCATED TO
                    ABC12.
A*BC                ILLEGAL LABEL - ASTERISK NOT
                    ALLOWED IN LABEL.
∧ABC†               NO LABEL -THE ASSEMBLER ATTEMPTS
                    TO INTERPRET ABC AS AN OPERATION
                    CODE.
```

Each label must be unique within the program; two or more statements may not have the same symbolic name. Names which appear in the Operand field of an EXT or COM pseudo instruction may not also be used as statement labels in the same subprogram.

Examples:



```
 Label    Operation    Operand                               Comments
1   5     10   15   20   25   30   35   40   45   50
      COM ACOM(20),BC(30)
LB    EQU 160       VALID LABEL
      EXT XL1,XL2
START LDA LB        VALID LABEL
N25                 VALID LABEL
XL2                 ILLEGAL LABEL - USED IN EXT.
BC                  ILLEGAL LABEL - USED IN COM.
N25                 ILLEGAL LABEL - PREVIOUSLY
                    DEFINED.
```

Asterisk

An asterisk in position one indicates that the entire statement is a comment. Positions 2 through 80 are available; however, positions 1 through 68 only are printed as part of the assembly listing on the 2752A Teleprinter. An asterisk within the Label field is illegal in any position other than one.

† The caret symbol, ∧, indicates the presence of a space.

2.3 OPCODE FIELD

The operation code defines an operation to be performed by the computer or the Assembler. The Opcode field follows the Label field and is separated from it by at least one space. If there is no label, the operation code may begin anywhere after position one. The Opcode field is terminated by a space immediately following an operation code. Operation codes are organized in the following categories:

- Machine operation codes
  - Memory Reference
  - Register Reference
  - Input/Output, Overflow, and Halt
  - Extended Arithmetic Unit
- Pseudo operation codes
  - Assembler control
  - Object program linkage
  - Address and symbol definition
  - Constant definition
  - Storage allocation
  - Arithmetic subroutine calls
  - Assembly Listing Control (Extended Assembler)

Operation codes are discussed in detail in Chapters 3 and 4.

2.4 OPERAND FIELD

The meaning and format of the Operand field depend on the type of operation code used in the source statement. The field follows the Opcode field and is separated from it by at least one space. It is terminated by a space except when the space follows , + - (or, if there are no comments, by an end-of-statement mark.

The Operand field may contain an expression consisting of one of the following:

- Single symbolic term
- Single numeric term
- Asterisk

Combination of symbolic terms, numeric terms, and the asterisk jointed by the arithmetic operators + and -.

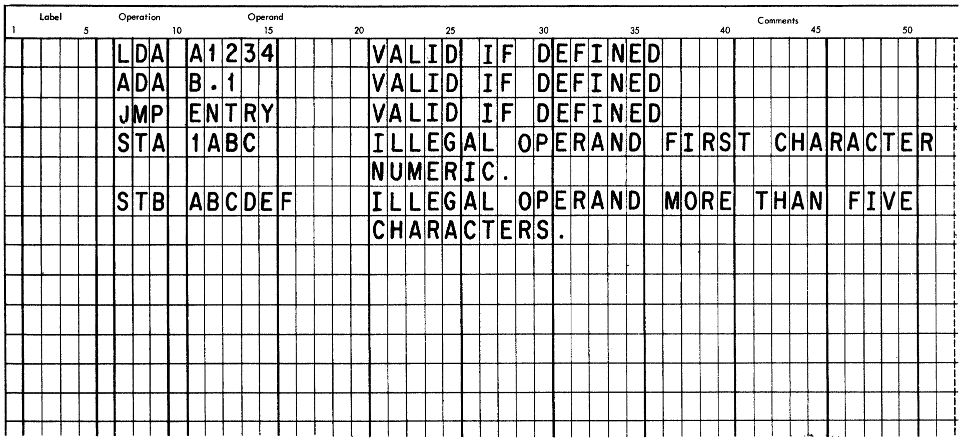
An expression may be followed by a comma and an indicator.

Programs being assembled by the Extended Assembler may also contain a literal value in the Operand field.

Symbolic Terms

A symbolic term may be one to five characters consisting of A through Z, 0 through 9, and the period. The first character must be alphabetic or a period.

Examples:


Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
      LDA A1234     VALID IF DEFINED
      ADA B.1       VALID IF DEFINED
      JMP ENTRY     VALID IF DEFINED
      STA 1ABC      ILLEGAL OPERAND FIRST CHARACTER
                    NUMERIC.
      STB ABCDEF    ILLEGAL OPERAND MORE THAN FIVE
                    CHARACTERS.
```

A symbol used in the Operand field must be a symbol that is defined elsewhere in the program in one of the following ways:

As a label in the Label field of a machine operation

As a label in the Label field of a BSS, ASC, DEC, DEX, OCT, DEF, ABS, EQU or REP pseudo operation

As a name in the Operand field of a COM or EXT pseudo operation

As a label in the Label field of an arithmetic subroutine pseudo operation

The value of a symbol is absolute or relocatable depending on the assembly option selected by the user. The Assembler assigns a value to a symbol as it appears in one of the above fields of a statement. If a program is to be loaded in absolute form, the values assigned by the assembler remain fixed. If the program is to be relocated, the actual value of a symbol is established on loading. A symbol may also be made absolute through use of the EQU pseudo instruction.

A symbolic term may be preceded by a plus or minus sign. If preceded by a plus or no sign, the symbol refers to its associated value. If preceded by a minus sign, the symbol refers to the two's complement of its associated value. A single negative symbolic operand may be used only with the ABS pseudo operation.

Numeric Terms

A numeric term may be decimal or octal. A decimal number is represented by one to five digits within the range 0 to 32767. An octal number is represented by one to six octal digits followed by the letter B; (0 to 177777B).

If a numeric term is preceded by a plus or no sign, the binary equivalent of the number is used in the object code. If preceded by a minus sign, the two's complement of the binary equivalent is used. A negative numeric operand may be used only with the DEX, DEC, OCT, and ABS pseudo operations.

In an absolute program, the maximum value of a numeric operand depends on the type of machine or pseudo instruction. In a relocatable program, the value of a numeric operand may not exceed 77B. Numeric operands are absolute. Their value is not altered by the assembler or the loader.

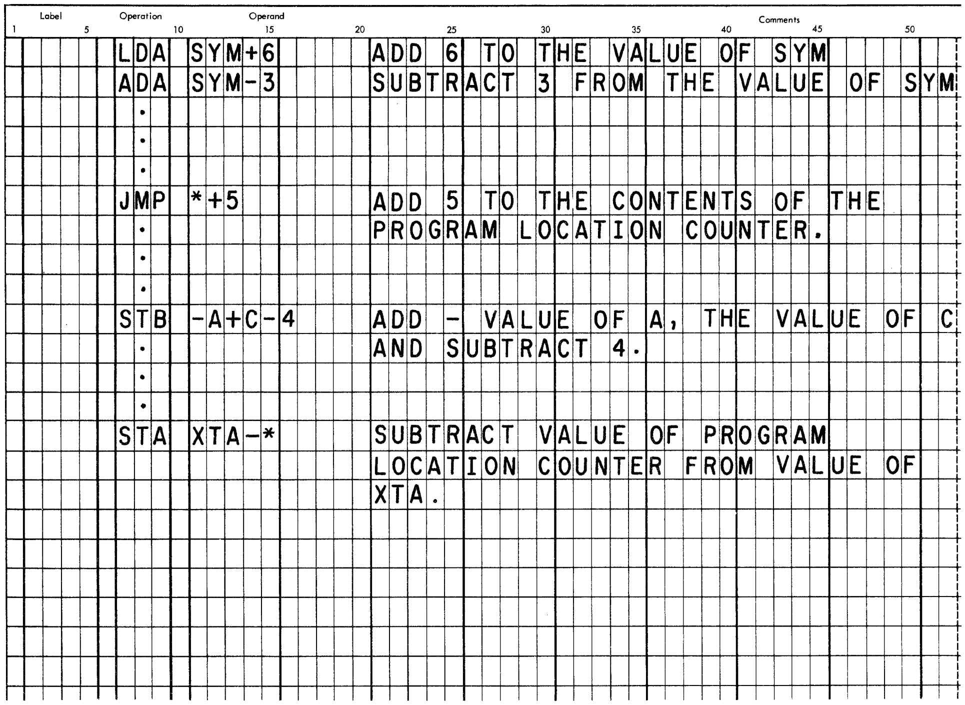
Asterisk

An asterisk in the Operand field refers to the value in the program location counter (or base page location counter) at the time the source program statement is encountered. The asterisk is considered a relocatable term in a relocatable program.

Expression Operators

The asterisk, symbols, and numbers may be joined by the arithmetic operators + and - to form arithmetic address expressions. The Assembler evaluates an expression and produces an absolute or relocatable value in the object code.

Examples:



Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
      LDA SYM+6     ADD 6 TO THE VALUE OF SYM
      ADA SYM-3     SUBTRACT 3 FROM THE VALUE OF SYM
       .
       .
       .
      JMP *+5       ADD 5 TO THE CONTENTS OF THE
       .            PROGRAM LOCATION COUNTER.
       .
       .
      STB -A+C-4    ADD - VALUE OF A, THE VALUE OF C
       .            AND SUBTRACT 4.
       .
       .
      STA XTA-*     SUBTRACT VALUE OF PROGRAM
                    LOCATION COUNTER FROM VALUE OF
                    XTA.
```

Evaluation of Expressions

An expression consisting of a single operand has the value of that operand. An expression consisting of more than one operand is reduced to a single value. In expressions containing more than one operator, evaluation of the expression proceeds from left to right. The algebraic expression A-(B-C+5) must be represented in the Operand field as A-B+C-5. Parentheses are not permitted in operand expressions for the grouping of operands.

The range of values that may result from an operand expression depends on the type of operation. The Assembler evaluates expressions as follows:†

Pseudo Operations	modulo 2^{15}-1
Memory Reference	modulo 2^{10}-1
Input/Output	2^6 - 1 (maximum value)

† The evaluation of expressions by the Assembler is compatable with the addressing capability of the hardware instructions (e.g., up to 32K words through Indirect Addressing). The user must take care not to create addresses which exceed the memory size of the particular configuration.

Expression Terms

The terms of an expression are the numbers and the symbols appearing in it. Decimal and octal integers, and symbols defined as being absolute in an EQU pseudo operation are absolute terms. The asterisk and all symbols that are defined in the program are relocatable or absolute depending on the type of assembly. Symbols that are defined as external may appear only as single term expressions.

Within a relocatable program, terms may be program relocatable, base page relocatable, or common relocatable. A symbol that names an area of common storage is a common relocatable term. A symbol that is allocated to the base page is a base page relocatable term. A symbol that is defined in any other statement is a program relocatable term. Within one expression all relocatable terms must be base page relocatable, program relocatable, or common relocatable; the three types may not be mixed.

Absolute and Relocatable Expressions

An expression is absolute if its value is unaffected by program relocation. An expression is relocatable if its value changes according to the location into which the program is loaded. In an absolute program, all expressions are absolute. In a relocatable program, an expression may be base page relocatable, program relocatable, common relocatable, or absolute (if less than 100_8) depending on the definition of the terms composing it.

Absolute Expressions

An absolute expression may be any arithmetic combination of absolute terms. It may also contain relocatable terms alone, or in combination with absolute terms. If relocatable terms do appear, there must be an even number of them; they must be of the same type; and they must be paired by sign (a negative term for each positive term). The paired terms do not have to be contiguous in the expression. The pairing of terms by type cancels the effect of relocation; the value represented by the pair remains constant.

An absolute expression reduces to a single absolute value. The value of an absolute multiterm expression may be negative only for ABS pseudo operations. A single numeric term also may be negative in an OCT, DEX, or DEC pseudo instruction. In a relocatable program the value of an absolute expression must be less than 100_8 for instructions that reference memory locations (Memory Reference, DEF, Arithmetic subroutine calls).

Examples:

If P_1 and P_2 are program relocatable terms; B_1 and B_2, base page relocatable; C_1 and C_2, common relocatable; and A, an absolute term; then the following are absolute terms:

$A-C_1+C_2$ $\quad$ $A-P_1+P_2$ $\quad$ C_1-C_2+A

$A+A$ $\quad$ P_1-P_2 $\quad$ B_1-B_2

$*-P_1$ $\quad$ B_1-B_2-A $\quad$ $-C_1+C_2+A$

B_1-* $\quad$ $-P_1+P_2$ $\quad$ $-A-P_1+P_2$

The asterisk is base page relocatable or program relocatable depending on the location of the instruction.

Relocatable Expressions

A relocatable expression is one whose value is changed by the loader. All relocatable expressions must have a positive value.

A relocatable expression may contain any odd number of relocatable terms, alone, or in combination with absolute terms. All relocatable terms must be of the same type. Terms must be paired by sign with the odd term being positive.

A relocatable expression reduces to a single positive relocatable term, adjusted by the values represented by the absolute terms and paired relocatable terms associated with it.

Examples:

If P_1, P_2, and P_3 are program relocatable terms; B_1, B_2, and B_3, base page relocatable; C_1, C_2 and C_3, common relocatable; and A, an absolute term; then the following are relocatable terms:

P_1-A $\quad$ C_1-A $\quad$ B_1+A

$P_1-P_2+P_3$ $\quad$ $C_1-C_2+C_3$ $\quad$ C_1+A

$*+A$ $\quad$ $*-P_1+P_2$ $\quad$ $*-A$

$A+B_1$ $\quad$ $A+C_1$ $\quad$ $-A-P_1+P_2+P_3$

$B_1-B_2+B_3-A$ $\quad$ $C_1-C_2+C_3-A$ $\quad$ $A+*$

$*+P_1-*$ $\quad$ P_1-P_2+* $\quad$ $-C_1+C_2+C_3$

Literals

Actual literal values may be specified as operands in relocatable programs to be assembled by the Extended Assembler. The Extended Assembler converts the literal to its binary value, assigns an address to it, and substitutes this address as the operand. Locations assigned to literals are those immediately following the last location used by the program.

A literal is specified by using an equal sign and a one-character identifier defining the type of literal. The actual literal value is specified immediately following this identifier; no spaces may intervene.

The identifiers are:

=D a decimal integer, in the range -32767 to 32767, including zero. †

=F a floating point number; any positive or negative real number in the range 10^{-38} to 10^{38}, including zero. †

=B an octal integer, one to six digits, $b_1b_2b_3b_4b_5b_6$, where b_1 may be 0 or 1, and b_2-b_7 may be 0 to 7. †

=A two ASCII characters. †

=L an expression which, when evaluated, will result in an absolute value. All symbols appearing in the expression must be previously defined.

If the same literal is used in more than one instruction, only one value is generated, and all instructions using this literal refer to the same location.

Literals may be specified only in the following memory reference instructions and pseudo instructions:

ADA	ADB	AND	MPY	may use =D, =B, =A, =L
LDA	LDB	XOR	DIV	
CPA	CPB	IOR		

DLD	FAD	may use =F
FMP	FSB	
FDV		

† See CONSTANT DEFINITION, Section 4.4.

Examples:

LDA =D798Ø A-Register is loaded with the binary equivalent of $798\emptyset_{1\emptyset}$.

IOR =B777 Inclusive or is performed with contents of A-Register and 777_8.

LDA =ANO A-Register is loaded with binary representation of ASCII characters NO.

LDB =LZETZ-ZOOM+68 B-Register is loaded with the value resulting from the absolute expression.

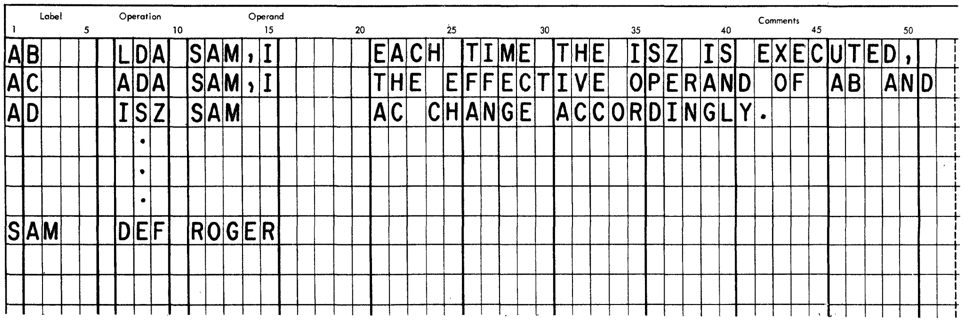
FMP =F39.75 Contents of A- and B-Registers multiplied by floating point constant 39.75.

Indirect Addressing

The HP computers provide an indirect addressing capability for Memory Reference instructions. The operand portion of an indirect instruction contains an address of another location rather than an actual operand. The secondary location may be the operand or it may be indirect also and give yet another location, and so forth. The chaining ceases when a location is encountered that does not contain an indirect address. Indirect addressing provides a simplified method of address modifications as well as allowing access to any location in core.

The Assembler allows specification of indirect addressing by appending a comma and the letter I to any Memory Reference operand other than one referring to an external symbol. The actual operand of the instruction may be given in a DEF pseudo operation; this pseudo operation may also be used to indicate further levels of indirect addressing.

Examples:


Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
AB    LDA SAM,I     EACH TIME THE ISZ IS EXECUTED,
AC    ADA SAM,I     THE EFFECTIVE OPERAND OF AB AND
AD    ISZ SAM       AC CHANGE ACCORDINGLY.
       .
       .
       .
SAM   DEF ROGER
```

A relocatable assembly language program, however, may be designed without concern for the pages in which it will be stored; indirect addressing is not required in the source language. When the program is being loaded, the Basic Control System (BCS) provides indirect addressing whenever it detects an operand which does not fall in the current page or the base page. The BCS loader substitutes a reference to the base page and then stores an indirect address in this referenced location. References to the same operand from other pages will be linked through the same location in the base page.

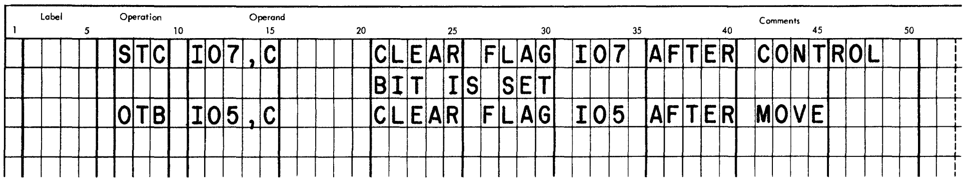
Base Page Addressing

The computer provides a capability which allows the Memory Reference instructions to address either the current page or the base page. The Assembler or the BCS loader adjusts all instructions in which the operands refer to the base page; specific notation defining an operand as a base page reference is not required in the source program.

Clear Flag Indicator

The majority of the input/output instructions can alter the status of the input/output interrupt flag after execution or after the particular test is performed. In source language, this function is selected by appending a comma and a letter C to the Operand field.

Examples:


Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
      STC I07,C          CLEAR FLAG I07 AFTER CONTROL
                         BIT IS SET
      OTB I05,C          CLEAR FLAG I05 AFTER MOVE
```

2.5 COMMENTS FIELD

The Comments field allows the user to transcribe notes on the program that will be listed with source language coding on the output produced by the Assembler. The field follows the Operand field and is separated from it by at least one space. The end-of-statement mark, (CR) (LF), or the 80th character in the entire statement terminates the field. If the listing to be produced on the 2752A Teleprinter, the total statement length, excluding the end-of-statement mark, should not exceed 52 characters, the width of the source language portion of the listing. Statements consisting solely of comments may contain up to 68 characters including the asterisk in the first position. On the list output, statements consisting entirely of comments begin in position 5 rather than 21 as with other source statements.

If there is no operand present the Comments field should be omitted in the NAM and END pseudo operations and in the input/output statements, SOC, SOS, and HLT. If a comment is used, the Assembler attempts to interpret it as an operand.

MACHINE INSTRUCTIONS 3

The HP Assembler language machine instruction codes take the form of three-letter mnemonics. Each source statement corresponds to a machine operation in the object program produced by the Assembler.

Notation used in representing source language instruction is as follows:

label	Optional statement label
m	Memory location -- an expression
I	Indirect addressing indicator
sc	Select code -- an expression
C	Clear interrupt flag indicator
comments	Optional comments
[ ]	Brackets defining a field or portion of a field that is optional
{ }	Brackets indicating that one of the set may be selected.
lit	literal

3.1 MEMORY REFERENCE

Memory Reference instructions perform arithmetic, logical and jump operations on the contents of the locations in core and the registers. An instruction may directly address the 2048 words of the current and base pages. If required, indirect addressing may be utilized to refer to all 32, 768 words of memory. Expressions in the operand field are evaluated modulo 2^{10} .

If the program is to be assembled in relocatable form, the operand field may contain relocatable expressions or absolute expressions which are less than 100_8 in value. If the program is to be absolute, the operands may be any expressions consistent with the location of the program. Literals may not be used in an absolute program. Absolute programs must be complete entities; they may not refer to external subroutines or common storage.

Jump and Increment-Skip

Jump and Increment-Skip instructions may alter the normal sequence of program execution.

label	JMP	m [, I]	comments

Jump to m. Jump indirect inhibits interrupt until the transfer of control is complete.

label	JSB	m [, I]	comments

Jump to subroutine. The address for label+1 is placed into the location represented by m and control transfers to m+1. On completion of the subroutine, control may be returned to the normal sequence by performing a JMP m, I.

label	ISZ	m [, I]	comments

Increment, then skip if zero. ISZ adds 1 to the contents of m. If m then equals zero, the next instruction in memory is bypassed.

Add, Load, and Store

Add, Load, and Store instructions transmit and alter the contents of memory and of the A- and B-Registers. A literal, indicated by ''lit'', may be either =D, =B, =A, or =I type.

label	ADA	$\begin{Bmatrix}\text{m [, I]}\\\text{lit}\end{Bmatrix}$	comments

Add the contents of m to A.

label	ADB	$\begin{Bmatrix}\text{m [, I]}\\\text{lit}\end{Bmatrix}$	comments

Add the contents of m to B.

label	LDA	$\begin{Bmatrix}\text{m [, I]}\\\text{lit}\end{Bmatrix}$	comments

Load A from m.

label	LDB	m [, I] lit	comments

Load B from m.

label	STA	m [, I]	comments

Store contents of A in m.

label	STB	m [, I]	comments

Store contents of B in m.

In each instruction, the contents of the sending location is unchanged after execution.

Logical Operations

The Logical instructions allow bit manipulation and the comparison of two computer words.

label	AND	m [, I] lit	comments

The logical product of the contents of m and the contents of A are placed in A.

label	XOR	m [, I] lit	comments

The modulo-two sum (exclusive "or") of the bits in m and the bits in A is placed in A.

label	IOR	m [, I] lit	comments

The logical sum (inclusive "or") of the bits in m and the bits in A is placed in A.

label	CPA	m [, I] lit	comments

Compare the contents of m with the contents of A. If they differ, skip the next instruction; otherwise, continue.

label	CPB	m [, I] lit	comments

Compare the contents of m with the contents of B. If they differ, skip the next instruction; otherwise, continue.

3.2 REGISTER REFERENCE

The Register Reference instructions include a Shift-Rotate group, an Alter-Skip group, and NOP (no-operation). With the exception of NOP, they have the capability of causing several actions to take place during one memory cycle. Multiple operations within a statement are separated by a comma.

Shift-Rotate Group

This group contains 19 basic instructions that can be combined to produce more than 500 different single cycle operations.

CLE	Clear E to zero
ALS	Shift A left one bit, zero to least significant bit. Sign unaltered
BLS	Shift B left one bit, zero to least significant bit. Sign unaltered
ARS	Shift A right one bit, extend sign;sign unaltered.
BRS	Shift B right one bit, extend sign;sign unaltered.
RAL	Rotate A left one bit
RBL	Rotate B left one bit
RAR	Rotate A right one bit
RBR	Rotate B right one bit
ALR	Shift A left one bit, clear sign, zero to least significant bit
BLR	Shift B left one bit, clear sign, zero to least significant bit
ERA	Rotate E and A right one bit
ERB	Rotate E and B right one bit
ELA	Rotate E and A left one bit
ELB	Rotate E and B left one bit
ALF	Rotate A left four bits
BLF	Rotate B left four bits
SLA	Skip next instruction if least significant bit in A is zero
SLB	Skip next instruction if least significant bit in B is zero

These instructions may be combined as follows:

$$\text{label} \quad \left[\begin{Bmatrix}\text{ALS}\\\text{ARS}\\\text{RAL}\\\text{RAR}\\\text{ALR}\\\text{ALF}\\\text{ERA}\\\text{ELA}\end{Bmatrix}\right] \; [\text{, CLE}] \quad [\text{, SLA}] \; \left[\text{,} \begin{Bmatrix}\text{ALS}\\\text{ARS}\\\text{RAL}\\\text{RAR}\\\text{ALR}\\\text{ALF}\\\text{ERA}\\\text{ELA}\end{Bmatrix}\right] \quad \text{comments}$$

$$\text{label} \quad \left[\begin{Bmatrix}\text{BLS}\\\text{BRS}\\\text{RBL}\\\text{RBR}\\\text{BLR}\\\text{BLF}\\\text{ERB}\\\text{ELB}\end{Bmatrix}\right] \; [\text{, CLE}] \quad [\text{, SLB}] \; \left[\text{,} \begin{Bmatrix}\text{BLS}\\\text{BRS}\\\text{RBL}\\\text{RBR}\\\text{BLR}\\\text{BLF}\\\text{ERB}\\\text{ELB}\end{Bmatrix}\right] \quad \text{comments}$$

CLE, SLA, or SLB appearing alone or in any valid combination with each other are assumed to be a Shift-Rotate machine instruction.

The Shift-Rotate instructions must be given in the order shown. At least one and up to four are included in one statement. Instructions referring to the A-register may not be combined in the same statement with those referring to the B-register.

No-Operation Instruction

When a no-operation is encountered in a program, no action takes place; the computer goes on to the next instruction. A full memory cycle is used in executing a no-operation instruction.

label	NOP	comments

A subroutine to be entered by a JSB instruction should have a

NOP as the first statement. The return address can be stored in the location occupied by the NOP during execution of the program. A NOP statement causes the Assembler to generate a word of zeros.

Alter-Skip Group

The Alter-Skip group contains 19 basic instructions that can be combined to produce more than 700 different single cycle operations.

CLA	Clear the A-Register
CLB	Clear the B-Register
CMA	Complement the A-Register
CMB	Complement the B-Register
CCA	Clear, then complement the A-Register (set to ones)
CCB	Clear, then complement the B-Register (set to ones)
CLE	Clear the E-Register
CME	Complement the E-Register
CCE	Clear, then complement the E-Register
SEZ	Skip next instruction if E is zero
SSA	Skip if sign of A is positive (0).
SSB	Skip if sign of B is positive (0).
INA	Increment A by one.
INB	Increment B by one.
SZA	Skip if contents of A equals zero
SZB	Skip if contents of B equals zero
SLA	Skip if least significant bit of A is zero
SLB	Skip if least significant bit of B is zero
RSS	Reverse the sense of the skip instructions. If no skip instructions precede in the statement, skip the next instruction.

These instructions may be combined as follows:

label	$\left[\begin{Bmatrix}\text{CLA}\\ \text{CMA}\\ \text{CCA}\end{Bmatrix}\right]$ [,SEZ] ,$\left[\begin{Bmatrix}\text{CLE}\\ \text{CME}\\ \text{CCE}\end{Bmatrix}\right]$ [,SSA] [,SLA] [,INA] [,SZA] [,RSS]	comments

label	$\left[\begin{Bmatrix}\text{CLB}\\ \text{CMB}\\ \text{CCB}\end{Bmatrix}\right]$ [,SEZ] ,$\left[\begin{Bmatrix}\text{CLE}\\ \text{CME}\\ \text{CCE}\end{Bmatrix}\right]$ [,SSB] [,SLB] [,INB] [,SZB] [,RSS]	comments

The Alter-Skip instructions must be given in the order shown. At least one and up to eight are included in one statement. Instructions referring to the A-register may not be combined in the same statement with those referring to the B-register. When two or more skip functions are combined in a single operation, a skip occurs if any one of the conditions exists. If a word with RSS also includes both SSA and SLA (or SSB and SLB) a skip occurs only when sign and least significant bit are both set (1).

3.3 INPUT/OUTPUT, OVERFLOW, AND HALT

The input/output instructions allow the user to transfer data to and from an external device via a buffer, to enable or disable external interrupt, or to check the status of I/O devices and operations. A subset of these instructions permits checking for an arithmetic overflow condition.

Input/Output instructions require the designation of a select code, sc, which indicates one of 64 input/output channels or functions. Each channel consists of a connect/disconnect control bit, a flag bit, and a buffer of up to 16 bits. The setting of the control bit indicates that a device associated with the channel is operable. The flag bit is set automatically when transmission between the device and the buffer is completed. Instructions are also available to test or clear the flag bit for the particular channel. If the interrupt system is enabled, setting of the flag causes program interrupt to occur; control transfers to the interrupt location related to the channel.

Expressions used to represent select codes (channel numbers) must have a value of less than 2^6. The value specifies the device or operation referenced. Instructions which transfer data between the A or B register and a buffer, access the Switch register when sc = 1. The character C appended to such an instruction clears the overflow bit after the transfer from the Switch register is complete.

Input/Output

Prior to any input/output data transmission, the control bit is set. The instruction which enables the device may also transfer data between the device and the buffer.

label	STC	sc [, C]	comments

Set I/O control bit for channel specified by sc. STC transfers or enables transfer of an element of data from an input device to the buffer or to an output device from the buffer. The exact function of the STC depends on the device; for the 2752A Teleprinter, an STC enables transfer of a series of bits. If sc = 1, this statement is treated as NOP. The C option clears the flag bit for the channel.

label	CLC	sc [, C]	comments

Clear I/O control bit for channel specified by sc. When the control bit is cleared, interrupt on the channel is disabled, although the flag may still be set by the device. If sc = 0, control bits for all channels are cleared to zero; all devices are disconnected. If sc = 1, this statement is treated as NOP.

label	LIA	sc [, C]	comments

Load into A the contents of the I/O buffer indicated by sc.

label	LIB	sc [, C]	comments

Load into B the contents of the I/O buffer indicated by sc.

label	MIA	sc [, C]	comments

Merge (inclusive "or") the contents of the I/O buffer indicated by sc into A.

label	MIB	sc [,C]	comments

Merge (inclusive "or") the contents of the I/O buffer indicated by sc into B.

label	OTA	sc [,C]	comments

Output the contents of A to the I/O buffer indicated by sc.

label	OTB	sc [,C]	comments

Output the contents of B to the I/O buffer indicated by sc.

label	STF	sc	comments

Sets the flag bit of the channel indicated by sc. If sc = 0, STF enables the interrupt system. A sc code of 1 causes the overflow bit to be set.

label	CLF	sc	comments

Clear the flag bit to zero for the channel indicated by sc. If sc = 0, CLF disables the interrupt system. If sc = 1, the overflow bit is cleared to zero.

label	SFC	sc	comments

Skip the next instruction if the flag bit for channel sc is clear. If sc = 1, the overflow bit is tested.

label	SFS	sc	comments

Skip the next instruction if the flag bit for channel sc is set. If sc = 1, the overflow is tested.

Overflow

In addition to the use of a select code of 1, the overflow bit may be accessed by the following instructions:

label	CLO	comments

Clear the overflow bit.

label	STO	comments

Set overflow bit.

label	SOC	[C]	comments

Skip the next instruction if the overflow bit is clear. The C option clears the bit after the test is performed.

label	SOS	[C]	comments

Skip the next instruction if the overflow bit is set. The C option clears the bit after the test is performed.

The C option is identified by the sequence ''space C space'' following either ''SOC'' or ''SOS''. Anything else is treated as a comment.

Halt

label	HLT	{[sc [,C]] [c]}	comments

Halt the computer. The machine instruction word is displayed in the T-Register. If the C option is used, the flag bit associated with channel sc is cleared.

If neither the select code nor the C option is used, the comments portion must be omitted.

3.4 EXTENDED ARITHMETIC UNIT

Ten instructions may be used with the EAU version of the Assembler or Extended Assembler to increase the Computer's overall efficiency. The Computer must include the Extended Arithmetic Unit option to obtain the resulting increase in available core storage and decrease in program run time.

label	MPY	m[,I] lit	comments

The MPY instruction multiplies the contents of the A-Register by the contents of m. The product is stored in registers B and A. B contains the sign of the product and the 15 most significant bits; A contains the least significant bits.

label	DIV	m[,I] lit	comments

The DIV instruction divides the contents of registers B and A by the contents of m. The quotient is stored in A and the remainder in B. Initially B contains the sign and the 15 most significant bits of the dividend; A contains the least significant bits.

label	DLD	m[,I] lit	comments

The DLD instruction loads the contents of locations m and m + 1 into registers A and B, respectively.

label	DST	m[,I]	comments

The DST instruction stores the contents of registers A and B in locations m and m + 1, respectively.

MPY, DIV, DLD, DST results in two machine words: a word for the instruction code and one for the operand.

The above four instructions are available without the Extended Arithmetic Unit option as software subroutines.† As a part of the Extended Arithmetic option, they require less core storage and can be executed in less time.

The following seven instructions can be used only on machines with the Extended Arithmetic Unit. These shift-rotate instructions provide the capability to shift or rotate the B- and A-Registers n number of bit positions, where 1 ≤ n ≤ 16.

label	ASR	n	comments

The ASR instruction arithmetically shifts the B- and A-Registers right n bits. The sign bit (bit 15 of B) is extended.

label	ASL	n	comments

The ASL instruction arithmetically shifts the B- and A-Register left n bits. Zeroes are placed in the least significant bits. The sign bit (bit 15 of B) is unaltered. The overflow bit is set if bit 14 differs from bit 15 before each shift, otherwise, exit with Overflow bit cleared.

label	RRR	n	comments

The RRR instruction rotates the B- and A-Registers right n bits.

label	RRL	n	comments

The RRL instruction rotates the B- and A-Registers left n bits.

label	LSR	n	comments

The LSR instruction logically shifts the B- and A-Registers right n bits. Zeroes are placed in the most significant bits.

label	LSL	n	comments

The LSL instruction logically shifts the B- and A-Registers left n bits. Place zeroes into the least significant bits.

† See ARITHMETIC SUBROUTINE CALLS, Section 4.7.

	SWP		

Exchange the contents of the A- and B-Registers. The contents of the A-Register are shifted into the B-Register and the contents of the B-Register are shifted into the A-Register.

PSEUDO INSTRUCTIONS 4

The pseudo instructions control the Assembler, establish program relocatablility, and define program linkage as well as specify various types of constants, blocks of memory, and labels used in the program. With the Extended Assembler, pseudo instructions also control listing output.

4.1 ASSEMBLER CONTROL

The Assembler control pseudo instructions establish and alter the contents of the base page and program location counters, and terminate assembly processing. Labels may be used but they are ignored by the Assembler. NAM records produced by the Assemblers are accepted by the Real-Time, DOS, and BCS Loaders.

```
          | NAM  | [name]  | comments
```

NAM defines the name of a relocatable program. A relocatable program must begin with a NAM statement.† A relocatable program is assembled assuming a starting location of zero (i. e., zero relative). The name may be a symbol of one to five alphanumeric characters the first of which must be alphabetic or a period. The program name is printed on the list output. The name is optional and if omitted, the comments must be omitted also.

```
          | ORG  | m       | comments
```

The ORG statement defines the origin of an absolute program, or the origin of subsequent sections of absolute or relocatable programs.

An absolute program must begin with an ORG statement. † The operand m, must be a decimal or octal integer specifying the initial setting of the program location counter.

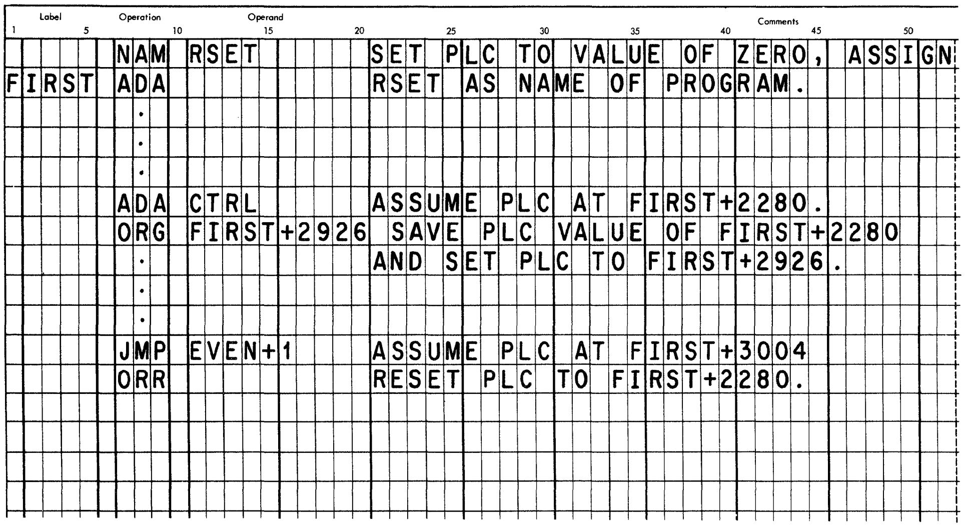
†The Control Statement, the HED instruction, and comments may appear prior to the NAM or ORG statements. If the Control Statement (ASMB,...) does not appear on tape preceding the program it must be entered from the Teleprinter.

ORG statements may be used elsewhere in the program to define starting addresses for portions of the object code. For absolute programs the Operand field, m, may be any expression. For relocatable programs, m, must be a program relocatable expression; it may not be base page or common relocatable or absolute. An expression is evaluated modulo 2^{15}. Symbols must be previously defined. All instructions following an ORG are assembled at consecutive addresses starting with the value of the operand.

	ORR	comments

ORR resets the program location counter to the value existing when an ORG or ORB instruction was encountered.

Example:

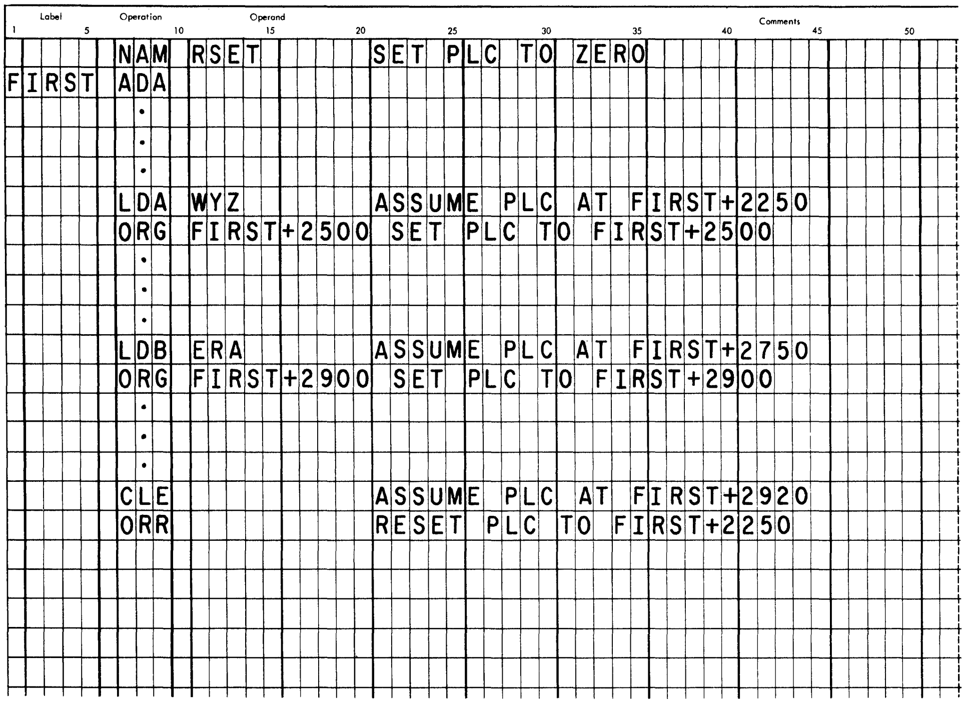


Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
       NAM RSET         SET PLC TO VALUE OF ZERO, ASSIGN
FIRST  ADA              RSET AS NAME OF PROGRAM.
        .
        .
        .
       ADA CTRL         ASSUME PLC AT FIRST+2280.
       ORG FIRST+2926    SAVE PLC VALUE OF FIRST+2280
        .               AND SET PLC TO FIRST+2926.
        .
        .
       JMP EVEN+1       ASSUME PLC AT FIRST+3004
       ORR              RESET PLC TO FIRST+2280.
```

More than one ORG or ORB statement may occur before an ORR is used. If so, when the ORR is encountered, the program location counter is reset to the value it contained when the first ORG or ORB of the string occurred.

Example:


Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
      NAM RSET      SET PLC TO ZERO
FIRST ADA
       .
       .
       .
      LDA WYZ       ASSUME PLC AT FIRST+2250
      ORG FIRST+2500 SET PLC TO FIRST+2500
       .
       .
       .
      LDB ERA       ASSUME PLC AT FIRST+2750
      ORG FIRST+2900 SET PLC TO FIRST+2900
       .
       .
       .
      CLE           ASSUME PLC AT FIRST+2920
      ORR           RESET PLC TO FIRST+2250
```

If a second ORR appears before an intervening ORG or ORB, the second ORR is ignored.

ORR cannot be used to reset the location counter for locations in the base page that are governed by the ORB statement.

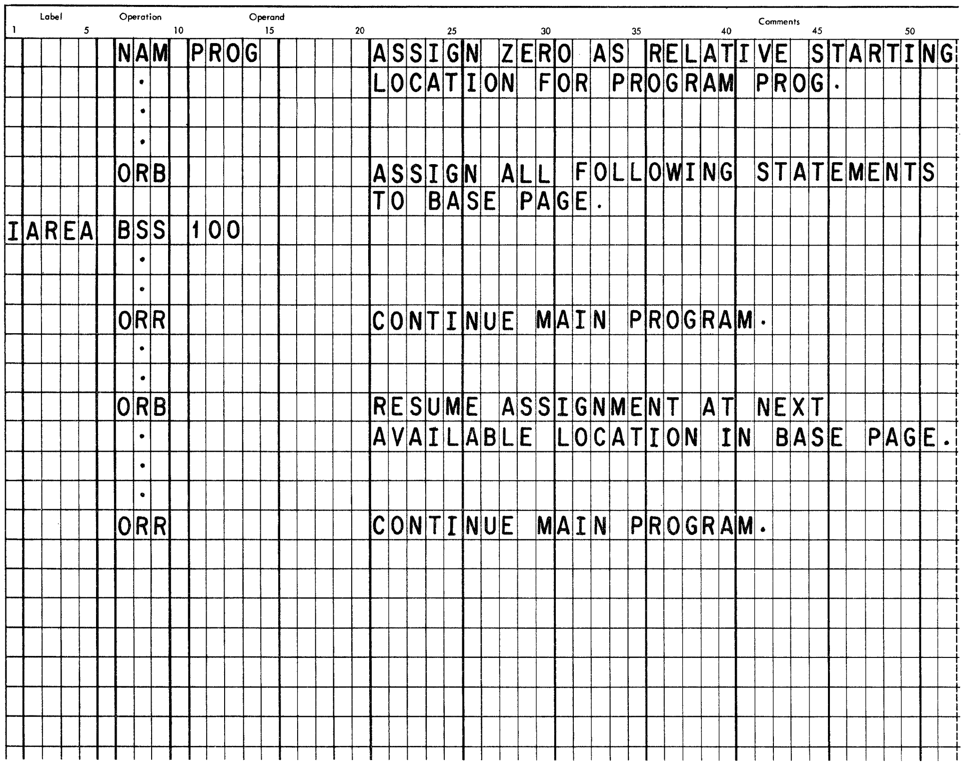
	ORB	comments

ORB defines the portion of a relocatable program that must be assigned to the base page by the Assembler. The Label field if given is ignored, and the statement requires no operand. All statements that follow the ORB statement are assigned contiguous locations in the base page. Assignment to the base page terminates when the Assembler detects an ORG, ORR, or END statement.

When more than one ORB is used in a program. Each ORB causes the Assembler to resume assigning base page locations at the address following the last assigned base page location.

An ORB statement in an absolute program has no significance and is flagged as an error.

Example:


Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
      NAM PROG      ASSIGN ZERO AS RELATIVE STARTING
       .            LOCATION FOR PROGRAM PROG.
       .
       .
      ORB           ASSIGN ALL FOLLOWING STATEMENTS
                    TO BASE PAGE.
IAREA BSS 100
       .
       .
      ORR           CONTINUE MAIN PROGRAM.
       .
       .
      ORB           RESUME ASSIGNMENT AT NEXT
       .            AVAILABLE LOCATION IN BASE PAGE.
       .
       .
      ORR           CONTINUE MAIN PROGRAM.
```

The IFN and IFZ pseudo instructions cause the inclusion of instructions in a program provided that either an "N" or "Z", respectively, is specified as a parameter for the ASMB control statement.† The IFN or IFZ instruction precedes the set of statements that are to be included. The pseudo instruction XIF serves as a terminator. If XIF is omitted, END acts as a terminator to both the set of statements and the assembly. IFN and IFZ may be used only when the source program is translated by the Extended Assembler which is provided for 8K or larger machines.

```
      IFN     comments
       .
       .
       .
      XIF
```

All source language statements appearing between the IFN and the XIF pseudo instructions are included in the program if the character "N" is specified on the ASMB control statement.

†See CONTROL STATEMENT, Section 5.1.

All source language statements appearing between the IFZ and the XIF pseudo instructions are included in the program if the character "Z" is specified on the ASMB control statement.

```
        | IFZ  |            comments
           .
           .
           .
          XIF
```

When the particular letter is not included on the control statement, the related set of statements appears on the Assembler output listing but is not assembled.

Any number of IFN-XIF and IFZ-XIF sets may appear in a program, however, they may not overlap. An IFZ or IFN intervening between an IFZ or IFN and the XIF terminator results in a diagnostic being issued during compilation; the second pseudo instruction is ignored.

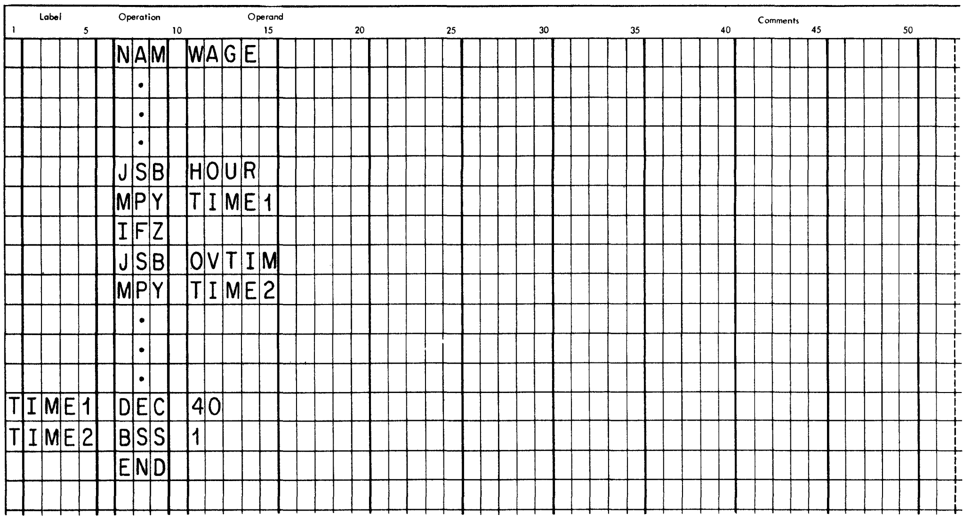
Both IFN-XIF and IFZ-XIF pseudo instructions may be used in the program; however, only one type will be selected in a single assembly. Therefore, if both characters "N" and "Z" appear in the control statement, the character which is listed last will determine the set of coding that is to be included in the program.

Example:

```
Label     Operation      Operand                                  Comments
1   5         10          15        20        25        30        35        40        45        50
      NAM TRAVL
       .
       .
       .
      IFZ
      LDA CAR
      CMA,SZA
      JMP NO.GO
      LDA MILES
      DIV SPEED
      STA GAS
      XIF
       .
       .
       .
      IFN
      LDA PLANE
      CMA,SZA
      JMP NO.GO
      LDA TIME
      CPA COST
      XIF
NO.GO HLT 77
       .
       .
       .
      END
```

Program TRAVL will perform computations involving either or neither CAR or PLANE considerations depending on the presence or absence of Z or N parameters in the Control Statement.

Example:



Label 1 5 Operation 10 Operand 15 20 25 30 35 40 Comments 45 50

```
      NAM WAGE
       .
       .
       .
      JSB HOUR
      MPY TIME1
      IFZ
      JSB OVTIM
      MPY TIME2
       .
       .
       .
TIME1 DEC 40
TIME2 BSS 1
      END
```

Program WAGES computes a weekly wage value. Overtime consideration will be included in the program if ''Z'' is included in the parameters of the Control Statement.

The REP pseudo instruction, available in the Extended Assembler only, causes the repetition of the statement immediately following it a specified number of times.

label	REP	n	comments

The statement following the REP in the source program is repeated n times. The n may be any absolute expression. Comment lines (indicated by an asterisk in character position 1) are not repeated by REP. If a comment follows a REP instruction, the comment is ignored and the instruction following the comment is repeated.

A label specified in the REP pseudo instruction is assigned to the first repetition of the statement. A label cannot be part of the instruction to be repeated; it would result in a doubly defined symbol error.

Example:

```
         CLA
TRIPL    REP        3
         ADA        DATA
```

The above source code would generate the following:

```
         CLA                   Clear the A-Register;
                               the content of DATA
TRIPL    ADA        DATA       is tripled and stored
         ADA        DATA       in the A-Register.
         ADA        DATA
```

Example:

```
FILL     REP        100B
         NOP
```

The example above loads 100_8 memory locations with the NOP instruction. The first location is labeled FILL.

Example:

```
        REP 2
        MPY DATA
```

The above source code would generate the following:

```
        MPY DATA
        MPY DATA
```

```
     |  END  |  [m]  |  comments
```

This statement terminates the program; it marks the physical end of the source language statements. The Operand field, m, may contain a name appearing as a statement label in the current program or it may be blank. If a name is entered, it identifies the location to which the BCS loader transfers control after a relocatable program is loaded. A NOP should be stored at that location; the loader transfers control via a JSB.

If the Operand field is blank, the Comments field must be blank also, otherwise, the Assembler attempts to interpret the first five characters of the comments as the transfer address symbol.

The Label field of the END statement is ignored.

4.2 OBJECT PROGRAM LINKAGE

Linking pseudo instructions provide a means for communication between a main program and its subroutines or among several subprograms that are to be run as a single program. These instructions maybe used only in a relocatable program.

The Label field of this class is ignored in all cases. The Operand field is usually divided into many subfields, separated by commas. The first space not preceded by a comma or a left parenthesis terminates the entire field.

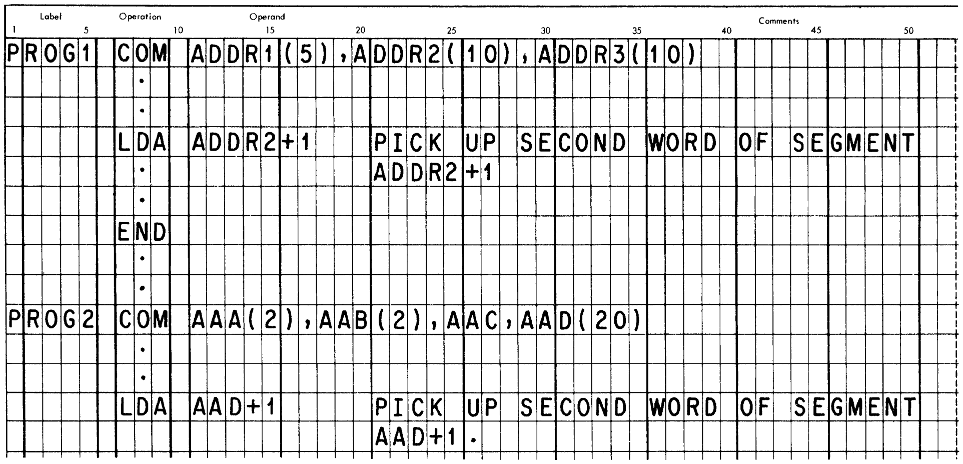
	COM	name_1 [(size_1)] [, name_2 [(size_2)], . . . , name_n[(size_n)]]	comments

COM reserves a block of storage locations that may be used in common by several subprograms. Each name identifies a segment of the block for the subprogram in which the COM statement appears. The sizes are the number of words allotted to the related segments. The size is specified as an octal or decimal integer. If the size is omitted, it is assumed to be one.

Any number of COM statements may appear in a subprogram. Storage locations are assigned contiguously; the length of the block is equal to the sum of the lengths of all segments named in all COM statements in the subprogram.

To refer to the common block, other subprograms must also include a COM statement. The segment names and sizes may be the same or they may differ. Regardless of the names and sizes specified in the separate subprograms, there is only one common block for the combined set. It has the same relative origin; the content of the nth word of common storage is the same for all subprograms.

Example:



Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
PROG1 COM ADDR1(5),ADDR2(10),ADDR3(10)
       .
       .
      LDA ADDR2+1  PICK UP SECOND WORD OF SEGMENT
       .           ADDR2+1
       .
      END
       .
       .
PROG2 COM AAA(2),AAB(2),AAC,AAD(20)
       .
       .
      LDA AAD+1    PICK UP SECOND WORD OF SEGMENT
                   AAD+1.
```

Organization of common block:

PROG1 name	PROG2 name	Common Block
ADDR1	AAA	(location 1)
		(location 2)
	AAB	(location 3)
		(location 4)
	AAC	(location 5)
ADDR2	AAD	(location 6)
		(location 7)
		(location 8)
		(location 9)
		(location 10)
		(location 11)
		(location 12)
		(location 13)
		(location 14)
		(location 15)
ADDR3		(location 16)
		(location 17)
		(location 18)
		(location 19)
		(location 20)
		(location 21)
		(location 22)
		(location 23)
		(location 24)
		(location 25)

The LDA instructions in the two subprograms each refer to the same location in common storage, location 7.

The segment names that appear in the COM statements can be used in the Operand fields of DEF, ABS, EQU, or any Memory Reference statement; they may not be used as labels elsewhere in the program.

The loader establishes the origin of the common block; the origin cannot be set by the ORG or ORB pseudo instruction. All references to the common area are relocatable.

Two or more subprograms may declare common blocks which differ in size. The subprogram that defines the largest block must be the first submitted for loading.

	ENT	$name_1$ [, $name_2$, . . . , $name_n$]	comments

ENT defines entry points to the program or subprogram. Each name is a symbol that is assigned as a label for some machine operation in the program. Entry points allow another subprogram to refer to this subprogram. All entry points must be defined in the program.

Symbols appearing in an ENT statement may not also appear in EXT or COM statements in the same subprogram.

The Label field of the ENT instruction is ignored.

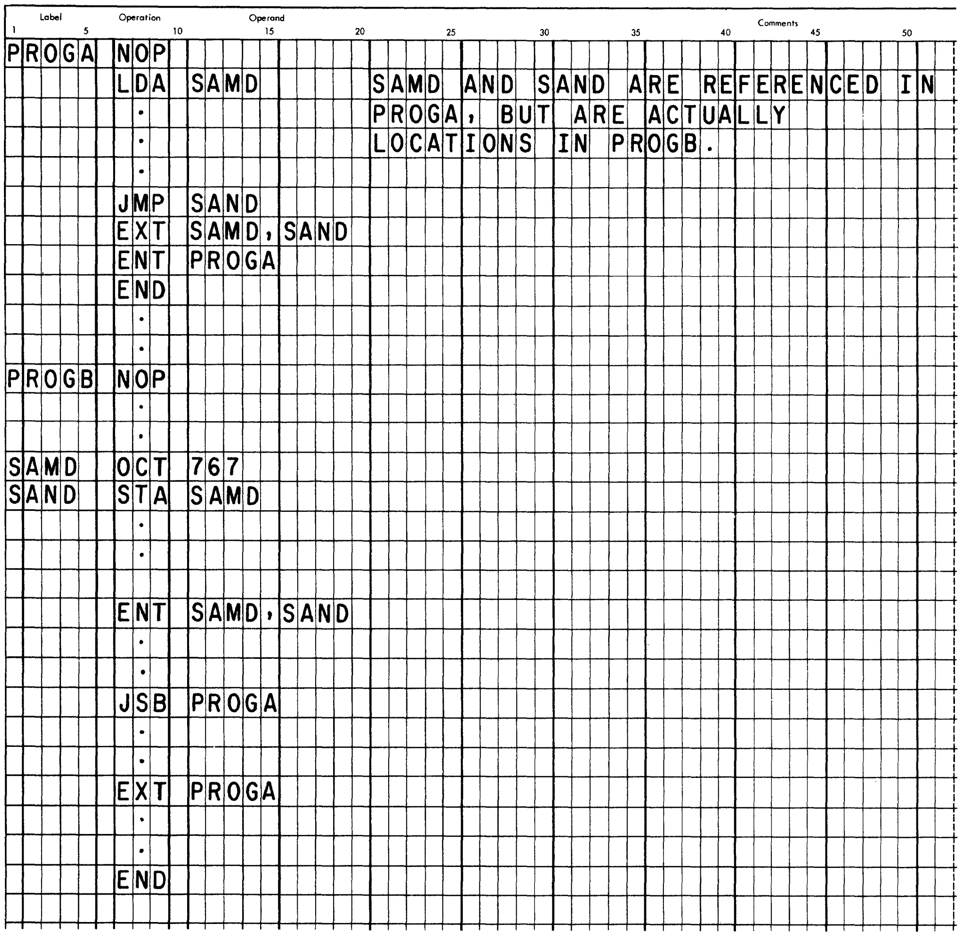
	EXT	$name_1$ [, $name_2$, . . . , $name_n$]	comments

This instruction designates labels in other subprograms which are referenced in this subprogram. The symbols must be defined as entry points by the other subprograms.

The symbols defined in the EXT statement may appear in Memory Reference statements, the EQU or DEF pseudo instructions. An external symbol must appear alone; it may not be in a multiple term expression or be specified as indirect. References to external locations are processed by the BCS loader as indirect addresses linked through the base page.

Symbols appearing in EXT statements may not also appear in ENT or COM statements in the same subprogram. The label field is ignored.

Example:



```
Label   Operation   Operand                 Comments
1    5          10       15        20        25        30        35        40        45        50
PROGA NOP
      LDA SAMD                SAMD AND SAND ARE REFERENCED IN
       .                      PROGA, BUT ARE ACTUALLY
       .                      LOCATIONS IN PROGB.
       .
      JMP SAND
      EXT SAMD,SAND
      ENT PROGA
      END
       .
       .
PROGB NOP
       .
       .
SAMD  OCT 767
SAND  STA SAMD
       .
       .

      ENT SAMD,SAND
       .
       .
      JSB PROGA
       .
       .
      EXT PROGA
       .
       .
      END
```

4.3 ADDRESS AND SYMBOL DEFINITION

The pseudo operations in this group assign a value or a word location to a symbol which is used as an operand elsewhere in the program.

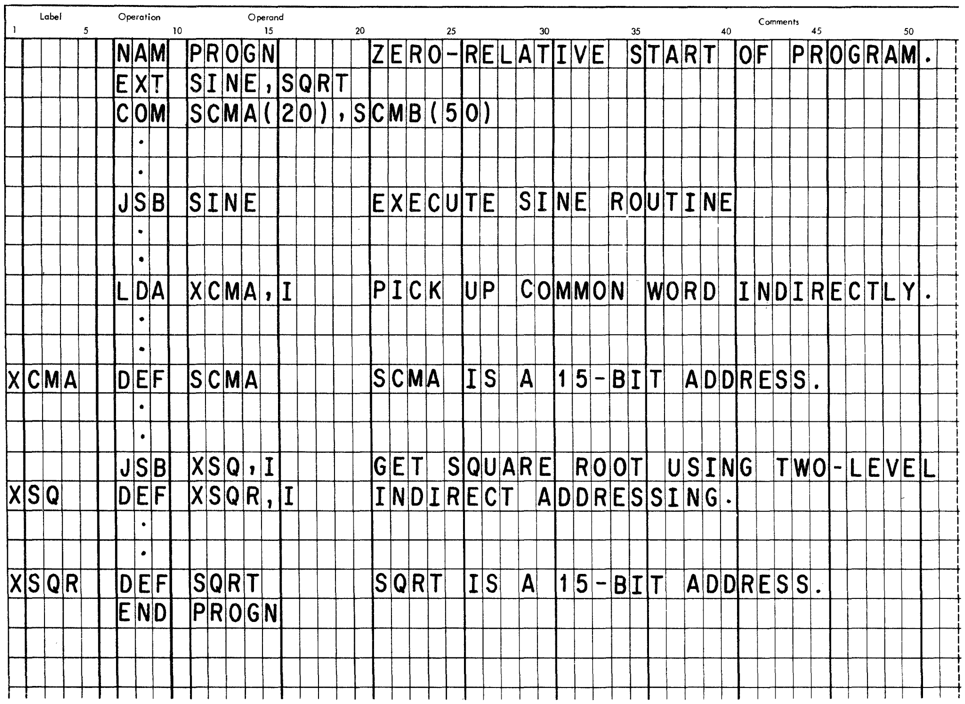
label	DEF	m [,I]	comments

The address definition statement generates one word of memory as a 15-bit address which may be used as the object of an indirect address found elsewhere in the source program. The symbol appearing in the label is that which is referenced; it appears in the Operand field of a Memory Reference instruction.

The operand field of the DEF statement may be any positive expression in an absolute program; in a relocatable program it may be a relocatable expression or an absolute expression with a value of less than 100_8. Symbols that do appear in the Operand field, may appear as operands of EXT or COM statements, in the same subprogram and as entry points in other subprograms.

The expression in the Operand field may itself be indirect and make reference to another DEF statement elsewhere in the source program.

Example:

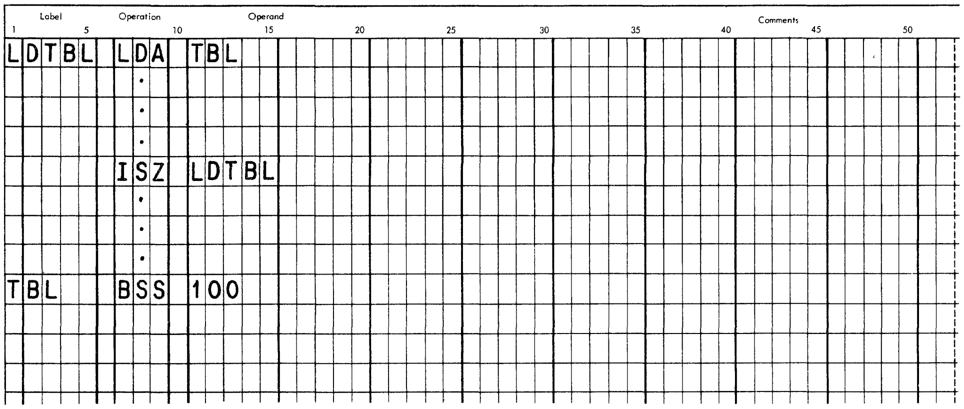

Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
      NAM PROGN     ZERO-RELATIVE START OF PROGRAM.
      EXT SINE,SQRT
      COM SCMA(20),SCMB(50)
       .
       .
      JSB SINE      EXECUTE SINE ROUTINE
       .
       .
      LDA XCMA,I    PICK UP COMMON WORD INDIRECTLY.
       .
       .
XCMA  DEF SCMA      SCMA IS A 15-BIT ADDRESS.
       .
       .
      JSB XSQ,I     GET SQUARE ROOT USING TWO-LEVEL
XSQ   DEF XSQR,I    INDIRECT ADDRESSING.
       .
       .
XSQR  DEF SQRT      SQRT IS A 15-BIT ADDRESS.
      END PROGN
```

The DEF statement provides the necessary flexibility to perform address arithmetic in programs which are to be assembled in relocatable form. Relocatable programs should not modify the operand of a memory reference instruction.

In the example below, if TBL and LDTBL are in different pages, the BCS Loader processes TBL as an indirect address linked through the base page. The ISZ erroneously increments the loader provided reference to the base page rather than the value of TBL.

Example:


Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
LDTBL LDA TBL
        .
        .
        .
      ISZ LDTBL
        .
        .
        .
TBL   BSS 100
```

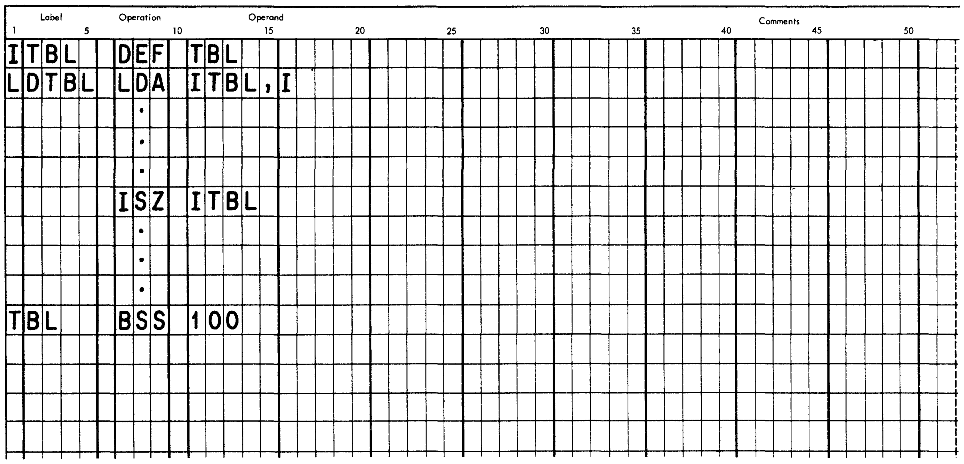
Assuming the loader might assign absolute locations comparable to the following octal values:

Page	Loc	Opcode	Reference
(0)	(700)	DEF	4000
		.	
		.	
		.	
(1)	(200)	LDA	(0) 700(I)
		.	
		.	
		.	
(1)	(300)	ISZ	(1) 200
		.	
		.	
		.	
(2)	(0)		(TBL)

It can be seen that the ISZ instruction would increment the quantity 700 rather than the address of the table (4000_8).

The following assures correct address modification during program execution.

Example:


Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
ITBL  DEF TBL
LDTBL LDA ITBL,I
       .
       .
       .
      ISZ ITBL
       .
       .
       .
TBL   BSS 100
```

This sequence might be stored by the loader as:

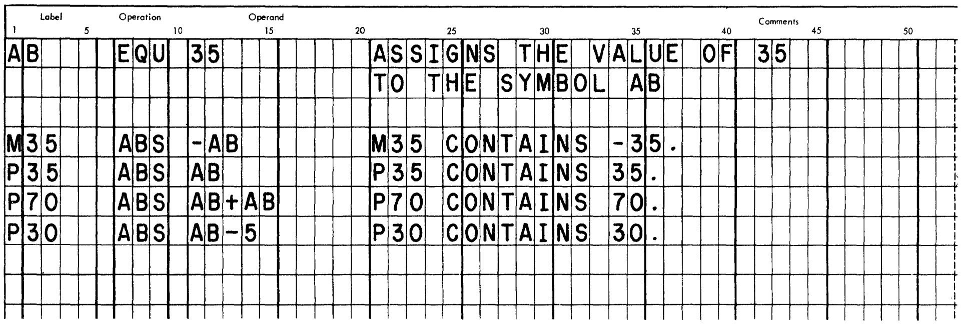
Page	Loc	Opcode	Reference
(1)	(200)	DEF	4000
(1)	(201)	LDA	200(I)
		.	
		.	
		.	
(1)	(300)	ISZ	(1) (200)
		.	
		.	
		.	
(2)	(0)		(TBL)

The value of 4000 is incremented; each execution of LDA will access successive locations in the table.

label	ABS	m	comments

ABS defines a 16-bit absolute value to be stored at the location represented by the label. The Operand field, m, may be any absolute expression; a single symbol must be defined as absolute elsewhere in the program.

Example:



```
AB    EQU 35        ASSIGNS THE VALUE OF 35
                    TO THE SYMBOL AB

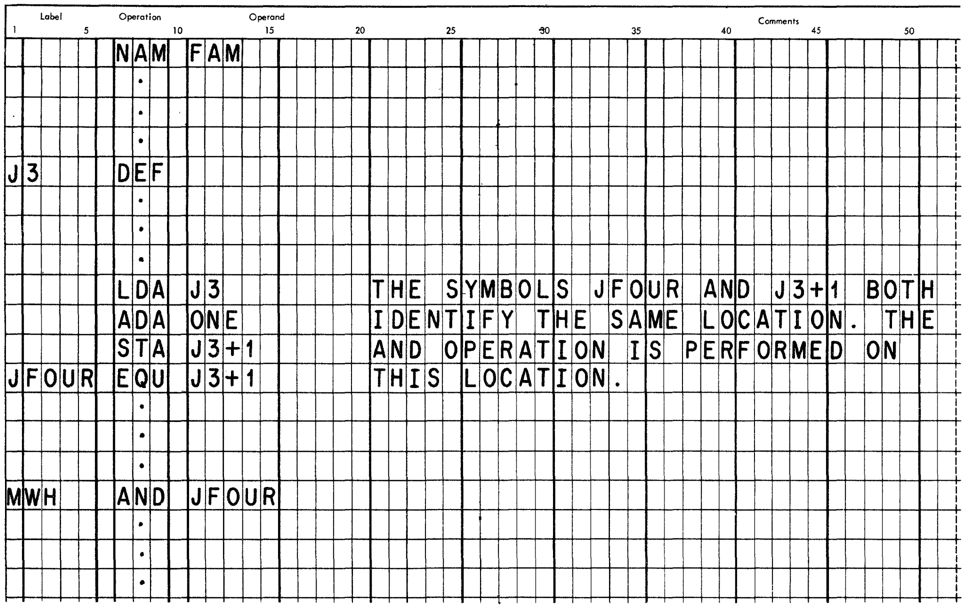
M35   ABS -AB       M35 CONTAINS -35.
P35   ABS AB        P35 CONTAINS 35.
P70   ABS AB+AB     P70 CONTAINS 70.
P30   ABS AB-5      P30 CONTAINS 30.
```

label	EQU	m	comments

The EQU pseudo operation assigns to a symbol a value other than the one normally assigned by the program location counter. The symbol in the Label field is assigned the value represented by the Operand field. The Operand field may contain any expression. The value of the operand may be common, base page or program relocatable as well as absolute, but it may not be negative. Symbols appearing in the operand must be previously defined in the source program.

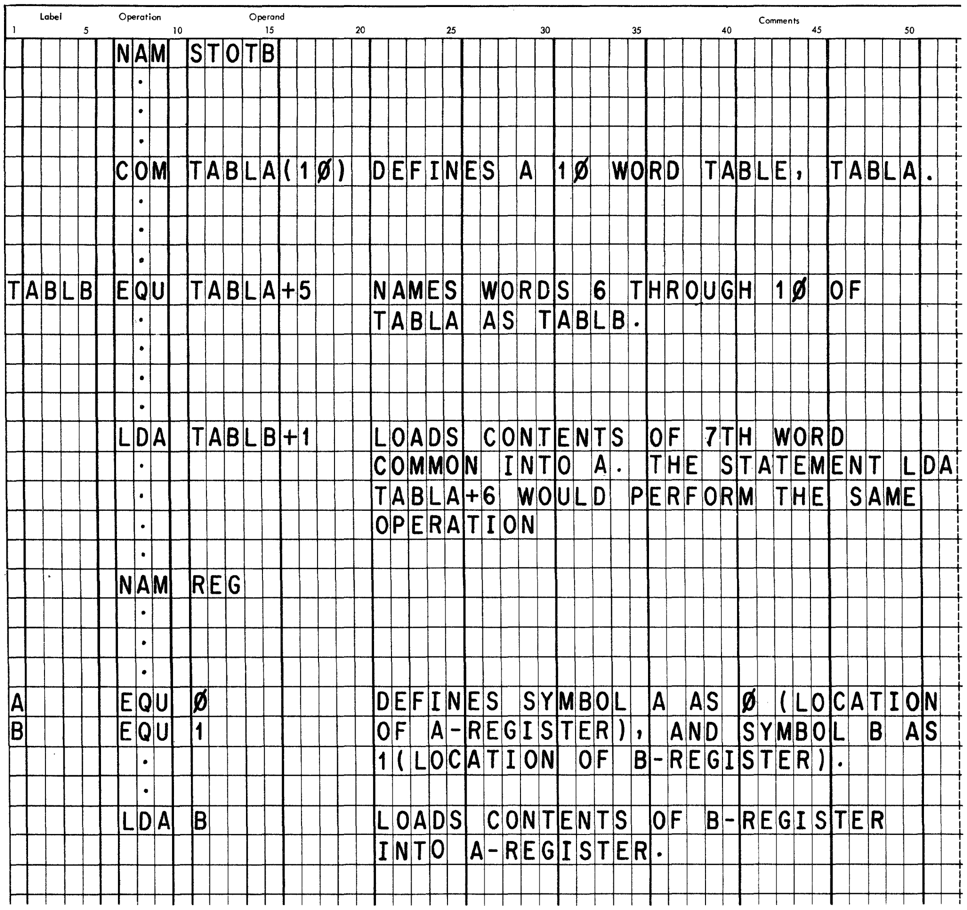
The EQU instruction may be used to symbolically equate two locations in memory; or it may be used to give a value to a symbol. The EQU statement does not result in a machine instruction.

Examples:


Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
      NAM FAM
       .
       .
       .
J3    DEF
       .
       .
       .
      LDA J3        THE SYMBOLS JFOUR AND J3+1 BOTH
      ADA ONE       IDENTIFY THE SAME LOCATION. THE
      STA J3+1      AND OPERATION IS PERFORMED ON
JFOUR EQU J3+1      THIS LOCATION.
       .
       .
       .
MWH   AND JFOUR
       .
       .
       .
```

Examples:


Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
      NAM STOTB
       .
       .
       .
      COM TABLA(1Ø) DEFINES A 1Ø WORD TABLE, TABLA.
       .
       .
       .
TABLB EQU TABLA+5   NAMES WORDS 6 THROUGH 1Ø OF
       .            TABLA AS TABLB.
       .
       .
       .
      LDA TABLB+1   LOADS CONTENTS OF 7TH WORD
       .            COMMON INTO A. THE STATEMENT LDA
       .            TABLA+6 WOULD PERFORM THE SAME
       .            OPERATION
       .
      NAM REG
       .
       .
       .
A     EQU Ø         DEFINES SYMBOL A AS Ø (LOCATION
B     EQU 1         OF A-REGISTER), AND SYMBOL B AS
       .            1(LOCATION OF B-REGISTER).
       .
      LDA B         LOADS CONTENTS OF B-REGISTER
                    INTO A-REGISTER.
```

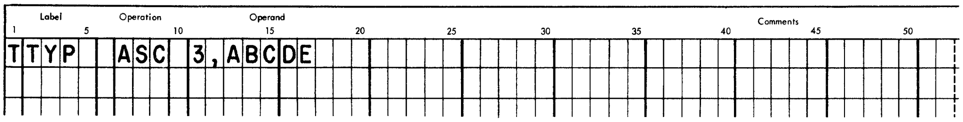
4.4 CONSTANT DEFINITION

The pseudo instructions in this class enter a string of one or more constant values into consecutive words of the object program. The statements may be named by labels so that other program statements can refer to the fields generated by them.

label	ASC	n, <2n characters>	comments

ASC generates a string of 2n alphanumeric characters in ASCII code into n consecutive words.† One character is right justified in each eight bits; the most significant bit is zero. n may be any expression resulting in an unsigned decimal value in the range 1 through 28. Symbols used in an expression must be previously defined. Anything in the Operand field following 2n characters is treated as comments. If less than 2n characters are detected before the end-of-statement mark, the remaining characters are assumed to be spaces, and are stored as such. The label represents the address of the first two characters.

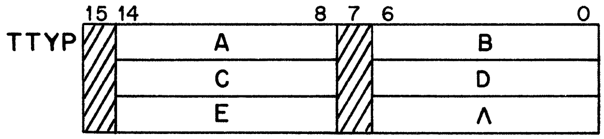
Example:


Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
TTYP ASC 3,ABCDE
```

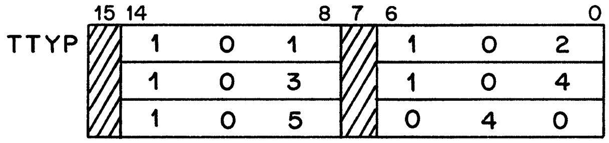
causes the following:

ALPHABETIC



TTYP	A	B
	C	D
	E	Λ

EQUIVALENT IN OCTAL NOTATION



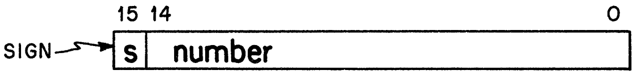
TTYP	1 0 1	1 0 2
	1 0 3	1 0 4
	1 0 5	0 4 0

† To enter the code for the ASCII symbols which perform some action (e.g., (CR) and (LF)), the OCT pseudo instruction must be used.

label	DEC	$d_1 [, d_2, \ldots, d_n]$	comments

DEC records a string of decimal constants into consecutive words. The constants may be either integer or real (floating point), and positive or negative. If no sign is specified, positive is assumed. The decimal number is converted to its binary equivalent by the Assembler. The label, if given, serves as the address of the first word occupied by the constant.

A decimal integer must be in the range of 0 to $2^{15}-1$; it may assume positive, negative, or zero values. It is converted into one binary word and appears as follows:



Examples:

```
Label     Operation   Operand                                    Comments
1     5          10    15    20    25    30    35    40    45    50
INT       DEC   50,+328,-300
```

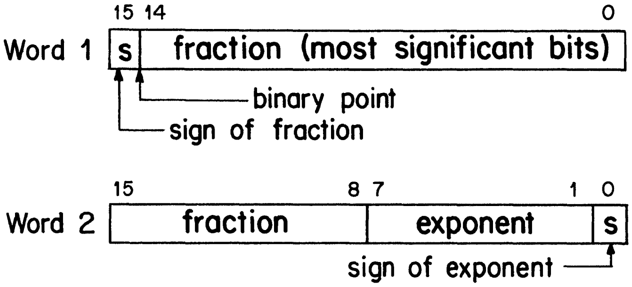
causes the following (octal representation)

	15	14				0
INT	0	0	0	0	6	2
	0	0	0	5	1	0
	1	7	7	3	2	4

A floating point number has two components, a fraction and an exponent. The exponent specifies the power of 10 by which the fraction is mutliplied. The fraction is a signed or unsigned number which may be written with or without a decimal point. The exponent is indicated by the letter E and follows a signed or unsigned decimal integer. The floating point number may have any of the following formats:

±n. n   ±n.   ±. n   ±n. nE±e   ±. nE±e   ±n. E±e   ±nE±e

The number is converted to binary, normalized (leading bits differ), and stored in two computer words. If either the fraction or the exponent is negative, that part is stored in two's complement form.



The floating point number is made up of a 7-bit exponent with sign and a 23-bit fraction with sign. The number must be in the approximate range of 10^{-38} through 10^{+38} and zero.

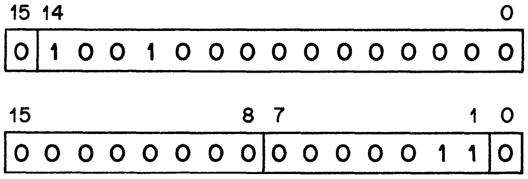
Examples:

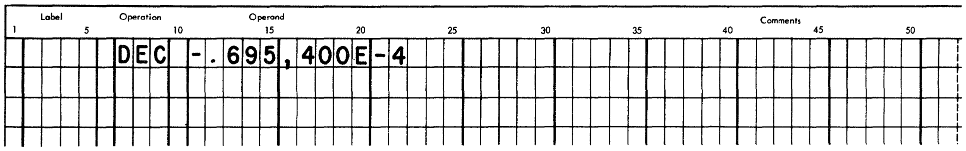
```
Label     Operation   Operand                                   Comments
          DEC   .45E1
          DEC   45.00E-1
          DEC   4500E-3
          DEC   4.5
```

are all equivalent to

$.45 \times 10^1$

and are stored in normalized form as:





```
Label     Operation      Operand                              Comments
1   5     10   15   20   25   30   35   40   45   50
      DEC -.695,400E-4
```

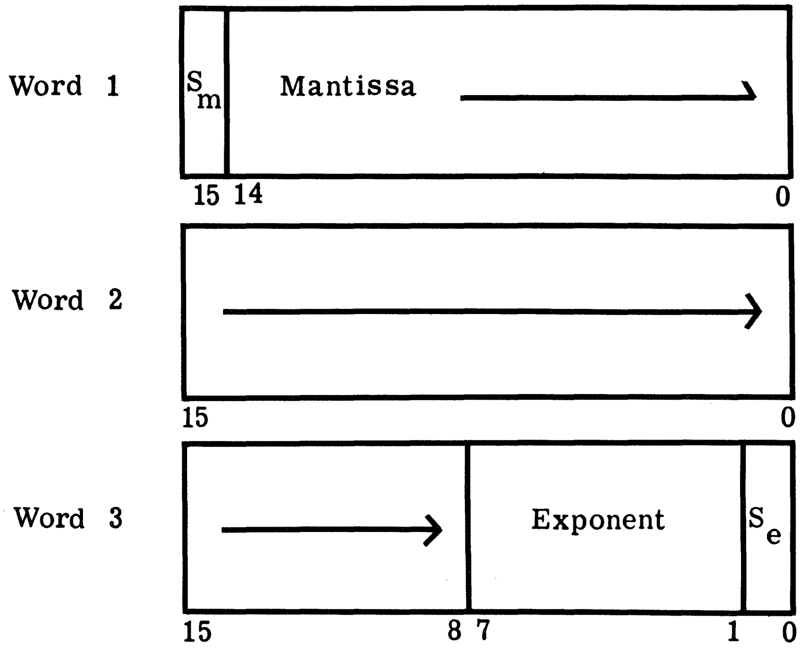
are stored as:

```
|1|0 1 0 0 1 1 1 0 0 0 0 1 0 1 0|
|0 0 1 1 1 0 1 1|0 0 0 0 0 0 0|0|


|0|1 0 1 0 0 0 1 1 1 1 0 1 0 1 1|
|1 0 0 0 0 1 0 1|1 1 1 1 1 0 0|1|
```

label	DEX	d_1[,d_2 ,... , d_n]	comments

DEX, for the Extended Assembler, records a string of extended precision decimal constants into consecutive words within a program. Each such extended precision constant occupies three words as shown below:



Legend: S_m = Sign of the mantissa (fraction)

S_e = Sign of the Exponent*

*NOTE: a value is entered only if normalizing of the Mantissa is needed.

An extended precision floating point number is made up of a 39-bit Mantissa (fraction) and sign and a 7-bit exponent and sign. The exponent and sign will be zero if the Mantissa does not have to be normalized.

This is the only form used for DEX. All values, whether they be floating point, integer, fraction, or integer and fraction, will be stored in three words as just described. This storage format is basically an extension of that used for DEC, as previously described:

Examples:

DEX 12,-.45

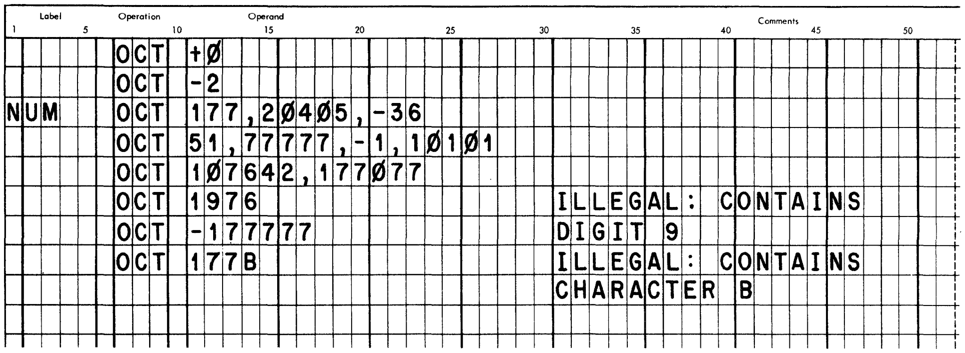
are stored as:

WORD 1	WORD 2	WORD 3
0110000000000000	0000000000000000	0000000000001000
WORD 1	WORD 2	WORD 3
1000110011001100	1100110011001100	100110111111111

label	OCT	o_1 [, o_2, . . . , o_n]	comments

OCT stores one or more octal constants in consecutive words of the object program. Each constant consists of one to six octal digits (0 to 177777). If no sign is given, the sign is assumed to be positive. If the sign is negative, the two's complement of the binary equivalent is stored. The constants are separated by commas; the last constant is terminated by a space. If less than six digits are indicated for a constant, the data is right justified in the word. A label, if used, acts as the address of the first constant in the string. The letter B must not be used after the constant in the Operand field; it is significant only when defining an octal term in an instruction other than OCT.

Examples:



```
Label  Operation  Operand                             Comments
       OCT +Ø
       OCT -2
NUM    OCT 177,2Ø4Ø5,-36
       OCT 51,77777,-1,1Ø1Ø1
       OCT 1Ø7642,177Ø77
       OCT 1976               ILLEGAL: CONTAINS
       OCT -177777            DIGIT 9
       OCT 177B               ILLEGAL: CONTAINS
                              CHARACTER B
```

The previous statements are stored as follows:

	15	14				0
	O	O	O	O	O	O
	1	7	7	7	7	6
NUM	O	O	O	1	7	7
	O	2	O	4	O	5
	1	7	7	7	4	2
	O	O	O	O	5	1
	O	7	7	7	7	7
	1	7	7	7	7	7
	O	1	O	1	O	1
	1	O	7	6	4	2
	1	7	7	O	7	7
	X	X	X	X	X	X
	O	O	O	O	O	1
	X	X	X	X	X	X

THE RESULT OF ATTEMPTING TO DEFINE AN ILLEGAL CONSTANT IS UNPREDICTABLE

4.5 STORAGE ALLOCATION

The storage allocation statement reserves a block of memory for data or for a work area.

label	BSS	m	comments

The BSS pseudo operation advances the program or base page location counter according to the value of the operand. The Operand field may contain any expression that results in a positive integer. Symbols, if used, must be previously defined in the program. The label, if given, is the name assigned to the storage area and represents the address of the first word. The initial content of the area set aside by the statement is unaltered by the loader.

4.6 ASSEMBLY LISTING CONTROL

Assembly listing control pseudo instructions allow the user to control the assembly listing output during pass 2 or 3 of the assembly process. These pseudo instructions may be used only when the source program is translated by the Extended Assembler provided for 8K or larger machines (8,192-word memory or larger).

	UNL	comments

Output is suppressed from the assembly listing, beginning with the UNL pseudo instruction and continuing for all instructions and comments until either an LST or END pseudo instruction is encountered. Diagnostic messages for errors encountered by the Assembler will be printed, however. The source statement sequence numbers (printed in columns 1-4 of the source program listing) are incremented for the instructions skipped.

	LST	comments

The LST pseudo instruction causes the source program listing, terminated by a UNL, to be resumed.

A UNL following a UNL, a LST following a LST, and a LST not preceded by a UNL are not considered errors by the Assembler.

	SUP	comments

The SUP pseudo instruction suppresses the output of additional code lines from the source program listing. Certain pseudo instructions, because they result in using subroutines, generate more than one line of coding. These additional code lines are suppressed by a SUP instruction until a UNS or the END pseudo instruction is encountered. SUP will suppress additional code lines in the following pseudo instructions:

ASC
OCT
DEC
DIV
DLD
DST
FAD
FDV
FMP
FSB
MPY

The SUP pseudo instruction may also be used to suppress the listing of literals at the end of the source program listing.

	UNS	comments

The UNS pseudo instruction causes the printing of additional coding lines, terminated by a SUP, to be resumed.

A SUP preceded by another SUP, UNS preceded by UNS, or UNS not preceded by a SUP are not considered errors by the Assembler.

	SKP	comments

The SKP pseudo instruction causes the source program listing to be skipped to the top of the next page. The SKP instruction is not listed, but the source statement sequence number is incremented for the SKP.

	SPC	n

The SPC pseudo instruction causes the source program listing to be skipped a specified number of lines. The list output is skipped n lines, or to the bottom of the page, whichever occurs first. The n may be any absolute expression. The SPC instruction is not listed but the source statement sequence number is incremented for the SPC.

	HED	m(heading)

The HED pseudo instruction allows the programmer to specify a heading to be printed at the top of each page of the source program listing.

The heading, m, a string of up to 56 ASCII characters, is printed at the top of each page of the source program listing following the occurrence of the HED pseudo instruction. If HED is encountered before the NAM or ORG at the beginning of a program, the heading will be used on the first page of the source program listing. A HED instruction placed elsewhere in the program causes a skip to the top of the next page.

The heading specified in the HED pseudo instruction will be used on every page until it is changed by a suceeding HED instruction.

The source statement containing the HED will not be listed, but source statement sequence number will be incremented.

4.7 ARITHMETIC SUBROUTINE CALLS

The members of this group of pseudo instructions request the Assember to generate calls to arithmetic subroutines* external to the source program. These pseudo instructions may be used in relocatable programs only. The Operand field may contain any relocatable expression or an absolute expression resulting in a value of less than 100_8.

label	MPY	{ m [,I] =Dn or =Bn }	comments

Multiply the contents of the A-register by the contents of m or the quantity defined by the literal and store the product in registers B and A. B contains the sign of the product and the 15 most significant bits; A contains the least significant bits.

label	DIV	{ m [,I] =Dn or =Bn }	comments

Divide the contents of registers B and A by the contents of m or the quantity defined by the literal. Store the quotient in A and the remainder in B. Initially B contains the sign and the 15 most significant bits of the dividend; A contains the least significant bits.

label	FMP	{ m [,I] =Fn }	comments

Multiply the two-word floating point quantity in registers A and B by the two-word floating point quantity in locations m and m+1 or the quantity defined by the literal. Store the two-word floating point product in registers A and B.

label	FDV	{ m [,I] =Fn }	comments

Divide the two-word floating point quantity in registers A and B by the two-word floating point quantity in locations m and m+1 or the quantity defined by the literal. Store the two-word floating point quotient in A and B.

*Not intended for use with DEX formatted numbers. For such numbers JSB's to Extended Precision Program Library routines must be used. See the Program Library Programmer's Reference Manual, Table of Contents.

label	FAD	m [,I] =Fn	comments

Add the two-word floating point quantity in registers A and B to the two-word floating point quantity in locations m and m+1 or the quantity defined by the literal. Store the two-word floating point sum in A and B.

label	FSB	m [,I] =Fn	comments

Subtract the two-word floating point quantity in m and m+1 or the quantity defined by the literal from the two-word floating point quantity in registers A and B and store the difference in A and B.

label	DLD	m [, I] =Fn	comments

Load the contents of locations m and m+1 or the quantity defined by the literal into registers A and B respectively.

label	DST	m [, I]	comments

Store the contents of registers A and B in locations m and m+1 respectively.

Each use of a statement from this group generates two words of instructions. Symbolically, they could be represented as follows:

```
JSB     <. arithmetic pseudo operation>
DEF     m [, I]
```

An EXT <. arithmetic pseudo operation> is implied preceding the JSB operation.

In the above operations, the Overflow bit is set when one of the following conditions occurs:

Integer overflow
Floating point overflow or underflow
Division by zero.

Execution of any of the subroutines alters the contents of the E-Register.

ASSEMBLER INPUT AND OUTPUT 5

The Assembler accepts as input a paper tape containing a control statement and a source language program. A relocatable source language program may be divided into several subroutines; the designation of these elements is optional. The output produced by the Assembler may include a punched paper tape containing the object program, an object program listing, and diagnostic messages.

5.1 CONTROL STATEMENT

The control statement specifies the output to be produced:

ASMB, p_1, p_2, . . . , p_n

"ASMB," is entered in positions 1-5. Following the comma are one or more parameters, in any order, which define the output to be produced. The control statement must be terminated by an end-of-statement mark, (CR) (LF).

The parameters may be any legal combination of the following starting in position 6:

A Absolute: The addresses generated by the Assembler are to be interpreted as absolute locations in memory. The program is a complete entity. It may not include NAM, ORB, COM, ENT, EXT, arithmetic pseudo operation statements or literals. The binary output format is that specified for the Basic Binary loader.

R Relocatable: The program may be located anywhere in memory. Instruction operands are adjusted as necessary. The binary output format is that specified for the BCS Relocating loader.

B Binary output: A program is to be punched according to one of the above parameters.

L List output: A program listing is to be produced either during pass two or pass three (if binary output selected) according to one of the above parameters.

T Table print: List the symbol table at the end of the first pass. For the Extended Assembler: List the symbol table in alphabetic order in three sections: section 1 for one- character symbols, section 2 for two- and three- character symbols, and section 3 for four- and five- character symbols.

N Include sets of instructions following the IFN pseudo instruction.

Z Include sets of instructions following the IFZ pseudo instruction.

Either A or R must be specified in addition to any combination of B, L, or T.

If a programmer wishes to assemble Pass 1 of a source program to check for errors, he can specify only an A or R to be the sole parameter of the Assembler Control Statement, executing only Pass 1. (This produces Pass 1 error messages without listing the program or providing an object tape). Extended Assembler only.

The Assembler Control Statement must specifically request Pass 2 operations (list or punch) in order for Pass 2 to be executed. Lack of Pass 2 option information causes processing only of Pass 1 errors. If a C option is also provided, an automatic cross-reference symbol table is done after Pass 1 when operating in the MTS environment.

The control statement may be on the same tape as the source program, or on a separate tape; or it may be entered via the Teleprinter keyboard.

5.2 SOURCE PROGRAM

The first statement of the program (other than remarks or a HED statement) must be a NAM statement for a relocatable program or an ORG statement for indicating the origin of an absolute program. The last statement must be an END statement and may contain a transfer address for the start of a relocatable program. Each statement is followed by an end-of-statement mark.

5.3 BINARY OUTPUT

The punch output is defined by the ASMB control statement. The punch output includes the instructions translated from the source program. It does not include system subroutines referenced within the source program (arithmetic subroutine calls, .IOC., .DIO., .ENTR, etc.)

5.4 LIST OUTPUT

Fields of the object program are listed in the following print columns.

Columns	Content
1-4	Source statement sequence number generated by the Assembler
5-6	Blank
7-11	Location (octal)
12	Blank
13-18	Object code word in octal
19	Relocation or external symbol indicator
20	Blank
21-72	First 52 characters of source statement.

Lines consisting entirely of comments (i.e., * in column 1) are printed as follows:

Columns	Content
1-4	Source statement sequence number
5-72	Up to 68 characters of comments

A Symbol Table listing has the following format:

Columns	Content
1-5	Symbol
6	Blank
7	Relocation of external symbol indicator
8	Blank
9-14	Value of the symbol

The characters that designate an external symbol or type of relocation for the Operand field or the symbol are as follows:

Character	Relocation Base
Blank	Absolute
R	Program relocatable
B	Base page relocatable
C	Common relocatable
X	External symbol

At the end of each pass, the following is printed:

```
** NO ERRORS*
   or
** nnnn ERRORS*
```

The value nnnn, indicates the number of errors.

5.5 OPERATING INSTRUCTIONS

The exact operating procedures for an assembly depend on the available hardware configuration. The user should know the assignment of input/output equipment,† and memory size before initiating an assembly.

One possible allocation of equipment might be as follows:

Assembler Input/Output	Standard Unit Designation	Physical Unit Assignment
Binary Output	Teleprinter Output	2752A Teleprinter
Table Print List Output	List Output	2753A Tape Punch
Source Program	Input	2737A Punched Tape Reader

† As established when configuring the System Input/Output routines.

Assembly Options

If there are two output devices as shown above, there are only two passes; the Binary and List output are both produced in the second pass. If only one output device is available, the Binary output is produced in the second pass; and the List output, in the third pass.

The Assembler automatically provides a leader and trailer for binary output tapes. To suppress this leader and trailer, set Switch 0 to 1 (up) before the start of Pass 2.

In a three-pass assembly, the diagnostic messages and binary output are written on the same unit. To prevent these messages from being punched on the binary tape (they still appear on the printed output), perform the following steps:

1. Set Switch 15 to 1 (up) before start of Pass 2.
2. When the computer halts with the T-Register containing "102055", turn the punch unit off, and press Run.
3. When the computer again halts with the T-Register containing "102055", turn the punch unit on, and press Run.
4. At the end of Pass 2, set Switch 15 to 0 (down).

Steps 2 and 3 are repeated, each time a diagnostic message is produced.

Operating Procedures: Paper Tape System

The following procedures indicate the sequence of steps for assembly of a source program using the paper tape system.

A. Set Teleprinter to LINE and check that all equipment to be used is operable.

B. Load the Assembler using the Basic Binary Loader:†

1. Place Assembler binary tape in the device serving as the Standard Input unit (e. g., Punched Tape Reader).
2. Set Switch Register to starting address of Basic Binary Loader (e.g., 007700 for 4K memory, 017700 for 8K memory).
3. Press LOAD ADDRESS.
4. Set Loader switch to ENABLED.
5. Press PRESET.
6. Press RUN.
7. When the computer halts and indicates that the Assembler is loaded (T-Register contains 102077), set Loader switch to PROTECTED.

C. Set Switch Register to starting address of Assembler:

1. If control statement is on tape: 100_8
2. If control statement is to be entered via Teleprinter: 120_8

D. Press LOAD ADDRESS.

E. Place source language tape in unit serving as the Standard Input unit (e.g., Punched Tape Reader).

F. Press RUN.

G. If control statement is not on tape (i.e., starting address = 120_8), enter it via the Teleprinter, following it by (CR)(LF).

H. At end of Pass 1 (T-Register contains 102011), the Symbol Table, if requested, is on the Standard List Output unit. To execute Pass 2, replace the source language tape in the Standard Input unit, turn Teleprinter punch unit ON, and press RUN.

I. At the completion of each pass, repeat steps E and F. If a three-pass assembly is being executed, turn Teleprinter punch on at completion of Pass 1 and off at completion of Pass 2.

† The appropriate System Input/Output subroutines (drivers) are assumed to be included with the Assembler.

During the operation of the Assembler, the following halts may occur:

T-Register	Explanation	Action
102011	End of first pass.	Return to Step E.
	Write not enabled (MT)	Irrecoverable
102023	End of second of three passes. (only with ASR-33)	To perform Pass 3, return to Step E. To omit Pass 3 and assemble another program, remove output and return to Step C.
102040	EOT on MT	Press RUN. Assembler continues without MT; does not rewind
102054	Switch 1 selected during list to halt before printing a line. †	To continue,press RUN.
102055	Switch 15 option selected to prevent punching of printed messages on binary output tape. (Only halts with ASR-33).	See preceding instructions. (Assembly Options.)
102057	End of source tape section.	Place next section in unit serving as Standard Input unit and press Run.
102066	Control statement error. Press RUN to retry.	Correct control statement and return to Step E.
102077	End of assembly.	Remove output. To assemble another program, return to Step E.

† To halt Pass 2 at anytime, set Switch 1 up.

Several programs may be assembled consecutively without reloading the Assembler. If some of the object programs are to be relocatable and others are to be absolute, the programs that are to be assembled in relocatable form must be processed first. If relocatable program assemblies follow absolute program assemblies, an "R?" error will be diagnosed and the assembler must be reloaded.

5.6 Object Program Loading

If absolute binary output was specified, the Basic Binary Loader is used to load the object program tape.

If relocatable binary output was specified, the BCS Relocating Loader is used to load the object program tape. If the program refers to other Assembler FORTRAN or ALGOL generated object programs, these tapes are loaded by the Relocating Loader at the same time. If the program refers to .DIO. (the FORTRAN Formatter routine), or if it makes use of Arithmetic pseudo instructions, the Program Library tape must be submitted for loading also.

Listed below are summaries of procedures for normal loading of object programs:†

BASIC BINARY LOADER
OPERATING PROCEDURES SUMMARY

A. Place binary object tape in Standard Input unit.

B. Set Switch Register to starting address of Basic Binary Loader

C. Press LOAD ADDRESS.

D. Set Loader switch to ENABLED.

E. Press PRESET.

F. Press RUN.

G. When the computer halts with T-Register containing 102077, set Loader switch to PROTECTED.

H. Set Switch Register to starting address of object program.

I. Press LOAD ADDRESS.

J. Check that all I/O devices are ready and loaded for operation of the program.

K. Press RUN.

†For complete details, see Basic Control System Programmer's Reference Manual.

BASIC CONTROL SYSTEM LOADER
OPERATING PROCEDURES SUMMARY

A. Load the Basic Control System tape using the Basic Binary Loader.

B. Set Switch Register to 000002, press LOAD ADDRESS, and set Switch Register to 000000.

C. Place Assembler generated relocatable object tape in Standard Input unit.

D. Press RUN. The loader types "LOAD" if it expects another relocatable or library program.

E. If more than one relocatable object tape is to be loaded, repeat Steps C and D for each. Otherwise, set Switch Register to 000004 to load library routines.

F. Place Program Library tape in device serving as Program Library unit.

G. Press RUN. When the loading operation is complete, the Loader types "*LST". Press RUN. The Loader types "*RUN" indicating the program is ready for execution.

H. Press RUN to initiate execution.

5.7 ERROR MESSAGES

Errors detected in the source program are indicated by a 1- or 2-letter mnemonic followed by the sequence number and the first 62 characters of the statement in error. The messages are printed on the list output device during the passes indicated:

For Extended Assembler, error listings produced during Pass 1 are preceded by a number which identifies the source input file where the error was found. Pass 2 and 3 error messages are preceded by a reference to the previous page of the listing where an error message was written. The first error will refer to page "0".

Error Code	Pass	Description
CS	1	Control statement error: a) The control statement contained a parameter other than the legal set. b) Neither A nor R, or both A and R were specified. c) There was no output parameter (B, T or L.)
DD	1	Doubly defined symbol: A name defined in the symbol table appears more than once as: a) A label of a machine instruction. b) A label of one of the pseudo operations: BSS EQU ASC ABS DEC OCT DEF Arithmetic subroutine call DEX c) A name in the Operand field of a COM or EXT statement. d) A label in an instruction following a REP pseudo operation. e) Any combination of the above. An arithmetic subroutine call symbol appears in a program both as a pseudo instruction and as a label.

Error Code	Pass	Description
EN	1	The symbol specified in an ENT statement has already been defined in an EXT or COM statement.
EN ØØØØ <symbol>	start of 2 (top of page)	The entry point specified in an ENT statement does not appear in the label field of a machine or BSS instruction. The entry point has been defined in the Operand field of an EXT or COM statement, or has been equated to an absolute value.
IF	1	An IFZ or an IFN follows either an IFZ or an IFN without an intervening XIF. The second pseudo instruction is ignored.
IL	1	Illegal instruction: a) Instruction mnemonic cannot be used with type of assembly requested in control statement. The following are illegal in an absolute assembly: NAM EXT ENT COM ORB Arithmetic subroutine calls b) The ASMB statement has an R parameter, and NAM has been detected after the first valid Opcode.
IL	2 or 3	Illegal character: A numeric term used in the Operand field contains an illegal character(e.g. an octal constant contains other than + , -, or Ø - 7). Illegal instruction: ORB in an absolute assembly.

Error Code	Pass	Description
M	1, 2 or 3	Illegal operand: a) An operand is missing for an Opcode requiring one. b) Operands are optional and omitted but comments are included for: END HLT c) An absolute expression in one of the following instructions from a relocatable program is greater than 77_8. Memory Reference DEF Arithmetic subroutine calls d) A negative operand is used with an Opcode field other than ABS, DEX, DEC, and OCT. e) A character other than I follows a comma in one of the following statements: ISZ JMP JSB ADA ADB LDA LDB STA STB AND XOR IOR CPA CPB DEF Arithmetic Subroutine calls f) A character other than C follows a comma in one of the following statements: STC CLC LIA LIB MIA MIB OTA OTB HLT

Error Code	Pass	Description
		g) A relocatable expression in the operand field of one of the following: ABS ASR RRL REP ASL LSR SPC RRR LSL
		h) An illegal operator appears in an Operand field (e. g. + or - as the last character).
		i) An ORG statement appearing in a relocatable program includes an expression that is base page or common relocatable or absolute.
		j) A relocatable expression contains a mixture of program, base page, and common relocatable terms.
		k) An external symbol appears in an operand expression or is followed by a comma and the letter I.
		l) The literal or type of literal is illegal for the operation code used (e.g., STA =B7).
		m) An illegal literal code has been used (e.g., LDA =077).
		n) An integer expression in one of the following instructions does not meet the condition $1 \leq n \leq 16$. The integer is evaluated modulo 2^4. ASR RRR LSR ASL RRL LSL
		o) The value of an 'L' type literal is relocatable.

Error Code	Pass	Description
NO	1, 2, 3	No origin definition: The first statement in the assembly containing a valid opcode following the ASMB control statement (and remarks and/or HED, if present) is neither an ORG nor a NAM statement. If the A parameter was given on the ASMB statement, the program is assembled starting at 2000; if an R parameter was given, the program is assembled starting at zero.
OP	1, 2, 3	Illegal Opcode preceding first valid Opcode. The statement being processed does not contain an asterisk in position one. The statement is assumed to contain an illegal Opcode; it is treated as a remarks statement.
OP	1, 2, or 3	Illegal Opcode: A mnemonic appears in the Opcode field which is not valid for the hardware configuration or assembler being used. A word is generated in the object program.
OV	1, 2, or 3	Numeric operand overflow: The numeric value of a term or expression has overflowed its limit: $1 \geq N \geq 16$ EAU Shift-Rotate Set $2^6 - 1$ Input/Output, Overflow, Halt $2^{10} - 1$ Memory Reference (in absolute assembly) $2^{15} - 1$ DEF and ABS operands; data generated by DEC; or DEX; expressions concerned with program location counter. $2^{16} - 1$ OCT
R?	Before 1	An attempt is being made to assemble a relocatable program following the assembly of an absolute program.

Error Code	Pass	Description
SO	1	There are more symbols defined in the program than the symbol table can handle.
SY	1, 2, 3	Illegal Symbol: A Label field contains an illegal character or is greater than 5 characters. A label with illegal characters may result in an erroneous assembly if not corrected. A long label is truncated on the right to 5 characters.
SY	2 or 3	Illegal Symbol: A symbolic term in the Operand field is greater than five characters; the symbol is truncated on the right to 5 characters. Too many control statements: A control statement has been input both on the teleprinter and the source tape or the source tape contains more than one control statement. The Assembler assumes that the source tape control statement is a label, since it begins in column 1. Thus, the commas are considered as illegal characters and the "label" is too long. The binary object tape is not affected by this error, and the control statement entered via the teleprinter is the one used by the Assembler.
TP	1, 2, or 3	An error has occurred while reading magnetic tape.

Error Code	Pass	Description
UN	1, 2, or 3	Undefined Symbol: a) A symbolic term in an Operand field is not defined in the Label field of an instruction or is not defined in the Operand field of a COM or EXT statement. b) A symbol appearing in the Operand field of one of the following pseudo operations was not defined previously in the source program: BSS ASC EQU ORG END

HP CHARACTER SET

ASC II CHARACTER FORMAT

b_7				0	0	0	0	1	1	1	1
b_6				0	0	1	1	0	0	1	1
b_5				0	1	0	1	0	1	0	1
b_4	b_3	b_2	b_1								
0	0	0	0	NULL	DC$_0$	ƀ	0	@	P	UNASSIGNED	UNASSIGNED
0	0	0	1	SOM	DC$_1$	!	1	A	Q		
0	0	1	0	EOA	DC$_2$	"	2	B	R		
0	0	1	1	EOM	DC$_3$	#	3	C	S		
0	1	0	0	EOT	DC4 (STOP)	$	4	D	T		
0	1	0	1	WRU	ERR	%	5	E	U		
0	1	1	0	RU	SYNC	&	6	F	V		
0	1	1	1	BELL	LEM	' (APOS)	7	G	W		
1	0	0	0	FE$_0$	S$_0$	(	8	H	X		
1	0	0	1	HT / SK	S$_1$	)	9	I	Y		
1	0	1	0	LF	S$_2$	*	:	J	Z		
1	0	1	1	V$_{TAB}$	S$_3$	+	;	K	[		
1	1	0	0	FF	S$_4$	, (COMMA)	<	L	\		ACK
1	1	0	1	CR	S$_5$	−	=	M	]		①
1	1	1	0	SO	S$_6$		>	N	↑		ESC
1	1	1	1	SI	S$_7$	/	?	O	←		DEL

Standard 7-bit set code positional order and notation are shown below with b_7 the high-order and b_1 the low-order, bit position.

	b_7	b_6	b_5	b_4	b_3	b_2	b_1
EXAMPLE: The code for "R" is:	1	0	1	0	0	1	0

LEGEND

NULL	Null/Idle
SOM	Start of message
EOA	End of address
EOM	End of message
EOT	End of transmission
WRU	"Who are you?"
RU	"Are you . . . ?"
BELL	Audible signal
FE$_0$	Format effector
HT	Horizontal tabulation
SK	Skip (punched card)
LF	Line feed
V$_{TAB}$	Vertical tabulation
FF	Form feed
CR	Carriage return
SO	Shift out
SI	Shift in
DC$_0$	Device control reserved for data link escape

DC$_1$-DC$_3$	Device Control
DC$_4$(Stop)	Device control (stop)
ERR	Error
SYNC	Synchronous idle
LEM	Logical end of media
S$_0$-S$_7$	Separator (information)
ƀ	Word separator (space, normally non-printing)
<	Less than
>	Greater than
↑	Up arrow (Exponentiation)
←	Left arrow (Implies/Replaced by)
\	Reverse slant
ACK	Acknowledge
①	Unassigned control
ESC	Escape
DEL	Delete/Idle

BINARY CODED DECIMAL FORMAT

Kennedy 1406/1506 ASCII-BCD Conversion

Symbol	BCD (octal code)	ASCII Equivalent (octal code)	Symbol	BCD (octal code)	ASCII Equivalent (octal code)
(Space)	2Ø	Ø4Ø	A	61	1Ø1
!	52	Ø41	B	62	1Ø2
#	13	Ø43	C	63	1Ø3
$	53	Ø44	D	64	1Ø4
%	34	Ø45	E	65	1Ø5
&	6Ø	Ø46	F	66	1Ø6
'	14	Ø47	G	67	1Ø7
(	34	Ø50	H	7Ø	11Ø
)	74	Ø51	I	71	111
*	54	Ø52	J	41	112
+	6Ø	Ø53	K	42	113
,	33	Ø54	L	43	114
-	4Ø	Ø55	M	44	115
.	73	Ø56	N	45	116
/	21	Ø57	O	46	117
			P	47	12Ø
Ø	12	Ø6Ø	Q	50	121
1	Ø1	Ø61	R	51	122
2	Ø2	Ø62	S	22	123
3	Ø3	Ø63	T	23	124
4	Ø4	Ø64	U	24	125
5	Ø5	Ø65	V	25	126
6	Ø6	Ø66	W	26	127
7	Ø7	Ø67	X	27	13Ø
8	1Ø	Ø7Ø	Y	30	131
9	11	Ø71	Z	31	132
:	15	Ø72	[	75	133
;	56	Ø73	\	36	134
<	76	Ø74	]	55	135
=	13	Ø75			
>	16	Ø76			
?	72	Ø77			
@	14	1ØØ			

Other symbols which may be represented in ASCII are converted to spaces in BCD (20)

HP 2020A/B ASCII - BCD Conversion

Symbol	ASCII (Octal code)	BCD (Octal code)	Symbol	ASCII (Octal code)	BCD (Octal code)
(Space)	4Ø	2Ø	A	1Ø1	61
!	41	52	B	1Ø2	62
"	42	37	C	1Ø3	63
#	43	13	D	1Ø4	64
$	44	53	E	1Ø5	65
%	45	34	F	1Ø6	66
&	46	60 †	G	1Ø7	67
'	47	36	H	11Ø	70
(	5Ø	75	I	111	71
)	51	55	J	112	41
*	52	54	K	113	42
+	53	6Ø	L	114	43
,	54	33	M	115	44
-	55	4Ø	N	116	45
.	56	73	O	117	46
/	57	21	P	12Ø	47
			Q	121	50
Ø	6Ø	12	R	122	51
1	61	Ø1	S	123	22
2	62	Ø2	T	124	23
3	63	Ø3	U	125	24
4	64	Ø4	V	126	25
5	65	Ø5	W	127	26
6	66	Ø6	X	13Ø	27
7	67	Ø7	Y	131	30
8	7Ø	1Ø	Z	132	31
9	71	11			
			[	133	75 ‡
:	72	15	]	135	55 ‡
;	73	56	↑	136	77
<	74	76	←	137	32
=	75	35			
>	76	16			
?	77	72			
@	1ØØ	14			

† BCD code of 60 always converted to ASCII code 53 (+).

‡ BCD code of 75 always converted to ASCII code 50 (( ) and BCD code of 55 always converted to ASCII code 51 ( )).

ASSEMBLER INSTRUCTIONS B

Symbols	Meaning
label	Symbolic label, 1-5 alphanumeric characters and periods
m	Memory location represented by an expression
I	Indirect addressing indicator
C	Clear flag indicator
(m, m+1)	Two-word floating point value in m and m+1
comments	Optional comments
[ ]	Optional portion of field
{ }	One of set may be selected
P	Program Counter
( )	Contents of location
$\wedge$	Logical product
∀	Exclusive "or"
$\vee$	Inclusive "or"
A	A- register
B	B- register
E	E- register
A_n	Bit n of A-register
B_n	Bit n of B-register
b	Bit positions in B- and A-register
$\overline{(A/B)}$	Complement of contents of register A or B
(AB)	Two-word floating point value in register A and B
sc	Channel select code represented by an expression
d	Decimal constant
o	Octal constant
r	Repeat count
n	Integer constant
lit	Literal value

MACHINE INSTRUCTIONS

MEMORY REFERENCE

Jump and Increment-Skip

ISZ	m [,I]	(m) + 1 → m; then if (m) = 0, execute P + 2 otherwise execute P + 1
JMP	m [,I]	Jump to m; m → P
JSB	m [,I]	Jump subroutine to m: P + 1 → m; m + 1 → P

Add, Load and Store

ADA	$\left\{\begin{array}{c} m\ [,I] \\ \text{lit} \end{array}\right\}$	(m) + (A) → A
ADB	$\left\{\begin{array}{c} m\ [,I] \\ \text{lit} \end{array}\right\}$	(m) + (B) → B
LDA	$\left\{\begin{array}{c} m\ [,I] \\ \text{lit} \end{array}\right\}$	(m) → A
LDB	$\left\{\begin{array}{c} m\ [,I] \\ \text{lit} \end{array}\right\}$	(m) → B
STA	m [,I]	(A) → m
STB	m [,I]	(B) → m

Logical

AND	$\left\{\begin{array}{c} m\ [,I] \\ \text{lit} \end{array}\right\}$	(m) $\wedge$ (A) → A
XOR	$\left\{\begin{array}{c} m\ [,I] \\ \text{lit} \end{array}\right\}$	(m) $\forall$ (A) → A
IOR	$\left\{\begin{array}{c} m\ [,I] \\ \text{lit} \end{array}\right\}$	(m) $\vee$ (A) → A
CPA	$\left\{\begin{array}{c} m\ [,I] \\ \text{lit} \end{array}\right\}$	If (m) ≠ (A), execute P + 2, otherwise execute P + 1
CPB	$\left\{\begin{array}{c} m\ [,I] \\ \text{lit} \end{array}\right\}$	If (m) ≠ (B), execute P + 2, otherwise execute P + 1

REGISTER REFERENCE

Shift-Rotate

CLE	0 → E
ALS	Shift (A) left one bit, 0 → A_0, A_{15} unaltered
BLS	Shift (B) left one bit, 0 → B_0, B_{15} unaltered
ARS	Shift (A) right one bit, (A_{15}) → A_{14}
BRS	Shift (B) right one bit, (B_{15}) → B_{14}
RAL	Rotate (A) left one bit
RBL	Rotate (B) left one bit

Shift-Rotate (Continued)

RAR	Rotate (A) right one bit
RBR	Rotate (B) right one bit
ALR	Shift (A) left one bit, $0 \rightarrow A_{15}$
BLR	Shift (B) left one bit, $0 \rightarrow B_{15}$
ERA	Rotate E and A right one bit
ERB	Rotate E and B right one bit
ELA	Rotate E and A left one bit
ELB	Rotate E and B left one bit
ALF	Rotate A left four bits
BLF	Rotate B left four bits
SLA	If $(A_0) = 0$, execute P + 2, otherwise execute P + 1
SLB	If $(B_0) = 0$, execute P + 2, otherwise execute P + 1

Shift-Rotate instructions can be combined as follows:

$$\left[\left\{\begin{matrix}\text{ALS}\\ \text{ARS}\\ \text{RAL}\\ \text{RAR}\\ \text{ALR}\\ \text{ALF}\\ \text{ERA}\\ \text{ELA}\end{matrix}\right\}\right] \quad [,\text{CLE}] \quad [,\text{SLA}] \quad \left[,\left\{\begin{matrix}\text{ALS}\\ \text{ARS}\\ \text{RAL}\\ \text{RAR}\\ \text{ALR}\\ \text{ALF}\\ \text{ERA}\\ \text{ELA}\end{matrix}\right\}\right]$$

$$\left[\left\{\begin{matrix}\text{BLS}\\ \text{BRS}\\ \text{RBL}\\ \text{RBR}\\ \text{BLR}\\ \text{BLF}\\ \text{ERB}\\ \text{ELB}\end{matrix}\right\}\right] \quad [,\text{CLE}] \quad [,\text{SLB}] \quad \left[,\left\{\begin{matrix}\text{BLS}\\ \text{BRS}\\ \text{RBL}\\ \text{RBR}\\ \text{BLR}\\ \text{BLF}\\ \text{ERB}\\ \text{ELB}\end{matrix}\right\}\right]$$

No-operation

NOP	Execute P + 1

Alter-Skip

CLA	0's → A
CLB	0's → B
CMA	$\overline{(A)} \rightarrow A$
CMB	$\overline{(B)} \rightarrow B$
CCA	1's → A
CCB	1's → B
CLE	0 → E
CME	$\overline{(E)} \rightarrow E$

Alter-Skip (Continued)

CCE	1 → E
SEZ	If (E) = 0, execute P + 2, otherwise execute P + 1
SSA	If $(A_{15}) = 0$, execute P + 2, otherwise execute P + 1
SSB	If $(B_{15}) = 0$, execute P + 2, otherwise execute P + 1
INA	(A) + 1 → A
INB	(B) + 1 → B
SZA	If (A) = 0, execute P + 2, otherwise execute P + 1
SZB	If (B) = 0, execute P + 2, otherwise execute P + 1
SLA	If $(A_0) = 0$, execute P + 2, otherwise execute P + 1
SLB	If $(B_0) = 0$, execute P + 2, otherwise execute P + 1
RSS	Reverse sense of skip instructions. If no skip instructions precede, execute P + 2

Alter-Skip instructions can be combined as follows:

$$\left[\begin{Bmatrix}\text{CLA}\\\text{CMA}\\\text{CCA}\end{Bmatrix}\right]\quad[\text{,SEZ}]\quad\left[\begin{Bmatrix}\text{CLE}\\\text{CME}\\\text{CCE}\end{Bmatrix}\right]\quad[\text{,SSA}]\quad[\text{,SLA}]\quad[\text{,INA}]\quad[\text{,SZA}]\quad[\text{,RRS}]$$

$$\left[\begin{Bmatrix}\text{CLB}\\\text{CMB}\\\text{CCB}\end{Bmatrix}\right]\quad[\text{,SEZ}]\quad\left[\begin{Bmatrix}\text{CLE}\\\text{CME}\\\text{CCE}\end{Bmatrix}\right]\quad[\text{,SSB}]\quad[\text{,SLB}]\quad[\text{,INB}]\quad[\text{,SZB}]\quad[\text{,RSS}]$$

INPUT/OUTPUT, OVERFLOW, and HALT

Input/Output

STC	sc	[,C]	Set control bit$_{SC}$, enable transfer of one element of data between device$_{SC}$ and buffer$_{SC}$
CLC	sc	[,C]	Clear control bit$_{SC}$. If sc = 0 clear all control bits
LIA	sc	[,C]	(buffer$_{SC}$) → A
LIB	sc	[,C]	(buffer$_{SC}$) → B
MIA	sc	[,C]	(buffer$_{SC}$) $\vee$ (A) → A
MIB	sc	[,C]	(buffer$_{SC}$) $\vee$ (B) → B
OTA	sc	[,C]	(A) → buffer$_{SC}$
OTB	sc	[,C]	(B) → buffer$_{SC}$
STF	sc		Set flag bit$_{SC}$. If sc = 0, enable interrupt system. sc = 1 sets overflow bit.
CLF	sc		Clear flag bit$_{SC}$. If sc = 0, disable interrupt system. If sc =1, clear overflow bit.
SFC	sc		If (flag bit$_{SC}$) = 0, execute P + 2, otherwise execute P + 1. If sc = 1, test overflow bit.
SFS	sc		If (flag bit$_{SC}$) = 1, execute P + 2, otherwise execute P + 1. If sc = 1, test overflow bit.

Overflow

CLO		0 → overflow bit
STO		1 → overflow bit
SOC	[C]	If (overflow bit) = 0, execute P + 2, otherwise execute P + 1
SOS	[C]	If (overflow bit) = 0, execute P + 2, otherwise execute P + 1

Halt

HLT	[sc [,C]]	Halt computer

EXTENDED ARITHMETIC UNIT (requires EAU version of Assembler or Extender Assembler)

MPY	$\left\{\begin{matrix}m[,I]\\ lit\end{matrix}\right\}$	(A) x (m) → ($B_{\pm msb}$ and A_{lsb})
DIV	$\left\{\begin{matrix}m[,I]\\ lit\end{matrix}\right\}$	($B_{\pm msb}$ and A_{lsb})/(m) → A, remainder → B
DLD	$\left\{\begin{matrix}m[,I]\\ lit\end{matrix}\right\}$	(m) and (m + 1) → A and B
DST	$\left\{\begin{matrix}m[,I]\\ \end{matrix}\right\}$	(A) and (B) → m and m + 1
ASR	b	Arithmetically shift (BA) right b bits, B_{15} extended
ASL	b	Arithmetically shift (BA) left b bits, B_{15} unaltered, 0's to A_{lsb}
RRR	b	Rotate (BA) right b bits
RRL	b	Rotate (BA) left b bits
LSR	b	Logically shift (BA) right b bits, 0's to B_{msb}
LSL	b	Logically shift (BA) left b bits, 0's to A_{lsb}

PSEUDO INSTRUCTIONS

ASSEMBLER CONTROL

NAM	[name]	Specifies relocatable program and its name.
ORG	m	Gives absolute program origin or origin for a segment of relocatable or absolute program.
ORR		Reset main program location counter at value existing when first ORG or ORB of a string was encountered.
ORB		Defines base page portion of relocatable program.
END	[m]	Terminates source language program. Produces transfer to program starting location, m, if given.
REP < statement>	r	Repeat immediately following statement r times.
IFN < statements> XIF		Include statements in program if control statement contains N.
IFZ < statements> XIF		Include statements in program if control statement contains Z.

OBJECT PROGRAM LINKAGE

COM	$\text{name}_1[(\text{size}_1)][,\text{name}_2[(\text{size}_2)], \ldots ,\text{name}_n[(\text{size}_n)]]$	Reserves a block of common storage locations. name_i identifies segments of block, each of length size.
ENT	$\text{name}_1[,\text{name}_2, \ldots ,\text{name}_n]$	Defines entry points, name_i, that may be referred to by other programs
EXT	$\text{name}_1[,\text{name}_2, \ldots ,\text{name}_n]$	Defines external locations, name_i, which are labels of other programs, referenced by this program.

ADDRESS AND SYMBOL DEFINITION

label	DEF	m[,I]	Generates a 15-bit address which may be referenced indirectly through the label.
label	ABS	m	Defines a 16-bit absolute value to be referenced by the label.
label	EQU	m	Equates the value, m, to the label.

CONSTANT DEFINITION

ASC n, <2n characters>	Generates a string of 2n ASCII characters.
DEC d_1 [$,d_2, \ldots ,d_n$]	Records a string of decimal constants of the form: Integer: ±n Floating point: ±n. n, ±n. , ±. n, ±nE±e, ±n. nE±e, ±n. E±e, ±. nE±e
DEX d_1 [$,d_2, \ldots , d_n$]	Records a string of extended precision decimals constants of the form Floating point: ±n, ±n.n, ±n., ±.n, ±nE+e, ±n.nE±e, ±n.E+e, ±.nE±e
OCT o_1 [$,o_2, \ldots ,o_n$]	Records a string of octal constants of the form: ±oooooo

STORAGE ALLOCATION

BSS	m	Reserves a storage area of length, **m.**

ARITHMETIC SUBROUTINE CALLS REQUESTS*

MPY†	$\begin{Bmatrix} m[,I] \\ lit \end{Bmatrix}$	(A) x (m) → ($B_{\pm msb}$ and A_{lsb})
DIV†	$\begin{Bmatrix} m[,I] \\ lit \end{Bmatrix}$	($B_{\pm msb}$ and A_{lsb})/(m) → A, remainder → B
FMP	$\begin{Bmatrix} m[,I] \\ lit \end{Bmatrix}$	(AB) x (m, m + 1) → AB
FDV	$\begin{Bmatrix} m[,I] \\ lit \end{Bmatrix}$	(AB)/(m, m + 1) → AB
FAD	$\begin{Bmatrix} m[,I] \\ lit \end{Bmatrix}$	(m, m + 1) + (AB) → AB
FSB	$\begin{Bmatrix} m[,I] \\ lit \end{Bmatrix}$	(AB) - (m, m + 1) → AB
DLD†	$\begin{Bmatrix} m[,I] \\ lit \end{Bmatrix}$	(m) and (m + 1) → A and B
DST†	m[,I]	(A) and (B) → m and m + 1

† For configurations including Extended Arithmetic Unit, these mnemonic generate hardware instructions when the EAU version of the Assembler or Extended Assembler is used.

*Not intended for use with DEX formatted numbers. For such numbers, JSB Machine Instructions must be used.

ASSEMBLY LISTING CONTROL

UNL		Suppress assembly listing output.
LST		Resume assembly listing output.
SKP		Skip listing to top of next page.
SPC	n	Skip n lines on listing
SUP		Suppress listing of extended code lines (e. g. , as produced by subroutine calls).
UNS		Resume listing of extended code lines.
HED	<heading>	Print <heading> at top of each page, where <heading> is up to 56 ASCII characters.

ALPHABETIC LIST OF INSTRUCTIONS

ABS	Define absolute value
ADA	Add to A
ADB	Add to B
ALF	Rotate A left 4
ALR	Shift A left 1, clear sign
ALS	Shift A left 1
AND	"And" to A
ARS	Shift A right 1, sign carry
ASC	Generate ASCII characters
ASL	Arithmetic long shift left
ASR	Arithmetic long shift right
BLF	Rotate B left 4
BLR	Shift B left 1, clear sign
BLS	Shift B left 1
BRS	Shift B right 1, carry sign
BSS	Reserve block of storage starting at symbol
CCA	Clear and complement A (1's)
CCB	Clear and complement B (1's)
CCE	Clear and complement E (set E = 1)
CLA	Clear A
CLB	Clear B
CLC	Clear I/O control bit
CLE	Clear E
CLF	Clear I/O flag
CLO	Clear overflow bit
CMA	Complement A
CMB	Complement B

CME	Complement E
COM	Reserve block of common storage
CPA	Compare to A, skip if unequal
CPB	Compare to B, skip if unequal
DEC	Defines decimal constants
DEF	Defines address
DEX	Defines extended precision constants
DIV	Divide
DLD	Double load
DST	Double store
ELA	Rotate E and A left 1
ELB	Rotate E and B left 1
END	Terminate program
ENT	Entry point
ERA	Rotate E and A right 1
ERB	Rotate E and B right 1
EQU	Equate symbol
EXT	External reference
FAD	Floating add
FDV	Floating divide
FMP	Floating multiply
FSB	Floating subtract
HED	Print heading at top of each page
HLT	Halt
IFN	When N appears in Control Statement, assemble ensuing instructions
IFZ	When Z appears in Control Statement, assemble ensuing instructions
INA	Increment A by 1
INB	Increment B by 1
IOR	Inclusive "or" to A
ISZ	Increment, then skip if zero
JMP	Jump

JSB	Jump to subroutine
LDA	Load into A
LDB	Load into B
LIA	Load into A from I/O channel
LIB	Load into B from I/O channel
LSL	Logical long shift left
LSR	Logical long shift right
LST	Resume list output (follows a UNL)
MIA	Merge (or) into A from I/O channel
MIB	Merge (or) into B from I/O channel
MPY	Multiply
NAM	Names relocatable program
NOP	No operation
OCT	Defines octal constant
ORB	Establish origin in base page
ORG	Establish program origin
ORR	Reset program location counter
OTA	Output from A to I/O channel
OTB	Output from B to I/O channel
RAL	Rotate A left 1
RAR	Rotate A right 1
RBL	Rotate B left 1
RBR	Rotate B right 1
REP	Repeat next statement
RRL	Rotate A and B left
RRR	Rotate A and B right
RSS	Reverse skip sense
SEZ	Skip if E = 0
SFC	Skip if I/O flag = 0 (clear)
SFS	Skip if I/O flag = 1 (set)
SKP	Skip to top of next page

SLA	Skip if LSB of A = 0
SLB	Skip if LSB of B = 0
SOC	Skip if overflow bit = 0 (clear)
SOS	Skip if overflow bit = 1 (set)
SPC	Space n lines
SSA	Skip if sign A = 0
SSB	Skip if sign B = 0
STA	Store A
STB	Store B
STC	Set I/O control bit
STF	Set I/O flag
STO	Set overflow bit
SUP	Suppress list output of additional code lines
SWP	Switch the (A) and (B)
SZA	Skip if A = 0
SZB	Skip if B = 0
UNL	Suppress list output
UNS	Resume list output of additional code lines
XIF	Terminate an IFN or IFZ group of instructions
XOR	Exclusive "or" to A

SAMPLE PROGRAMS D

Following are two sample problems, the second of which implements several options of the Extended Assembler.

A.

PARTS FILE UPDATE

A master file of parts is updated by a parts usage list to produce a new master parts file. A report, consisting of the parts used and their cost, is also produced.

The master file and the parts usage file contain four word records. Each record of the cost report is eleven words long.

The organization of the files is as follows:

Parts Master Files (PRTSM)

Identification	Quantity	Cost/ Item

Identification field of the Parts Master Files exists in ASCII although the entire record is read and written in binary.

Parts Usage File (PRTSU)

Identification	Quantity

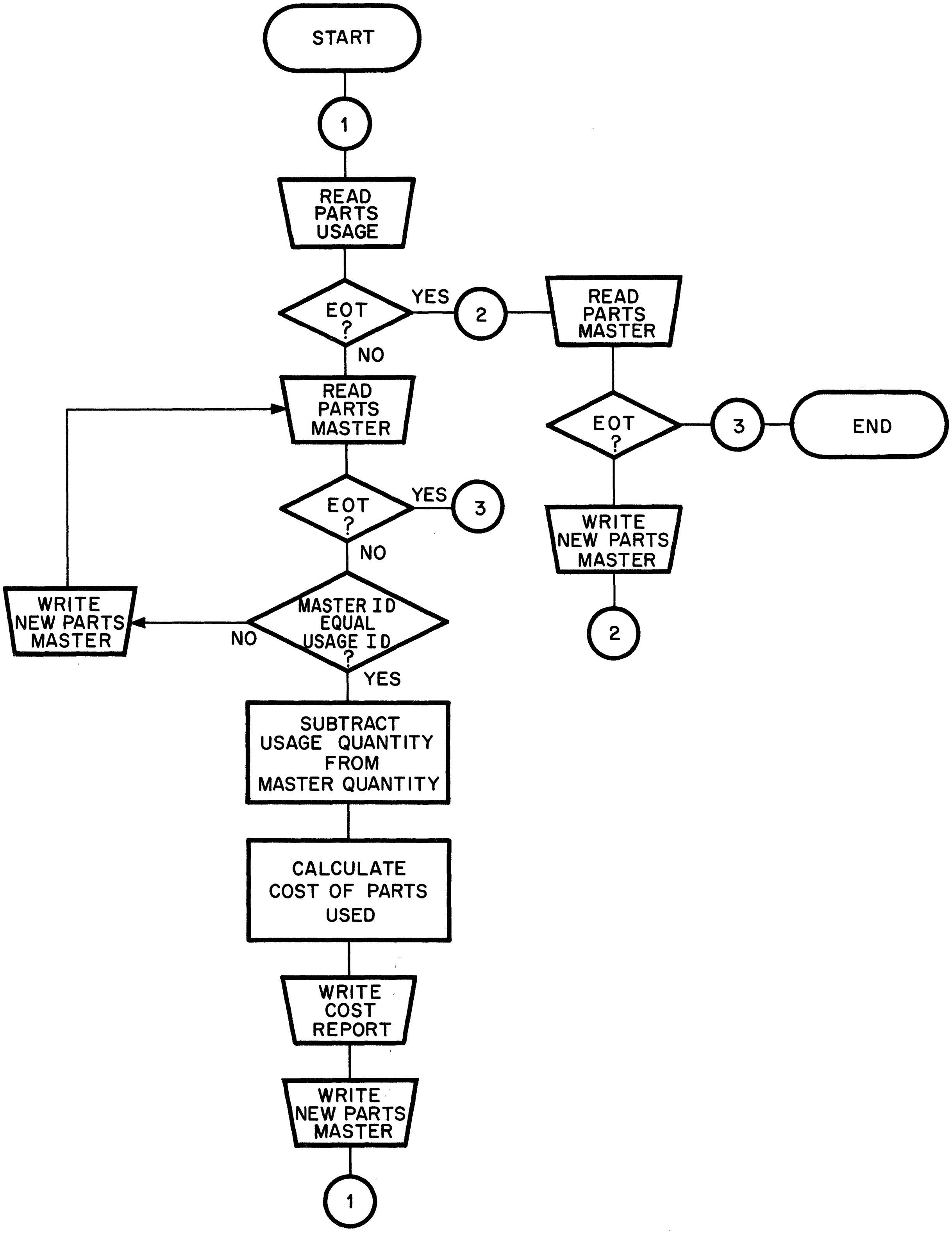
The parts usage file has been recorded in ASCII.

Parts Cost Report (PRTSC)

Identification	▨	Quantity used	▨	$	Cost for Quantity

The Parts Cost Report is recorded in ASCII with spacing and editing for printing.

The sample program reads and writes the files, adjusts the new stock levels, and calculates the cost. External subprograms perform the binary-to-decimal and decimal-to-binary conversions and handle unrecoverable input/output errors, invalid data conditions, and normal program termination. Input/output operations are performed using the Basic Control System input/output subroutine, .IOC.



SAMPLE PROGRAM
GENERAL FLOW CHART

SAMPLE ASSEMBLER SYMBOL TABLE OUTPUT

```
 PAGE 0001



           0001      ASMB,R,B,L,T
START R 000000
PRTSM B 000000
PRTSU B 000004
PRTSC B 000010
EOTS1 B 000023
EOTS2 B 000024
MTEMP B 000025
UTEMP B 000026
SWTMP B 000027
SPACS B 000031
DLRSG B 000033
A       000000
B       000001
.IOC. X 000001
BCONV X 000002
DCONV X 000003
ABORT X 000004
HALT  X 000005
DTOBI C 000000
DTOBO C 000002
BTODI C 000003
BTODO C 000005
OPEN  R 000002
SPCFL R 000003
DLD   X 000006
DST   X 000007
READU R 000013
CKSTU R 000020
RJCTU R 000035
EOTU  R 000040
MSGU  R 000051
READM R 000063
CKSTM R 000070
RJCTM R 000105
EOTM  R 000110
MSGM  R 000117
HLTSW R 000137
COMPR R 000140
PROCM R 000157
PROCC R 000165
MPY   X 000010
CONVM R 000213
CONU1 R 000224
CONU2 R 000235
CONVC R 000246
WRITC R 000261
CKSTC R 000266
RJCTC R 000276
WRITN R 000301
CKSTN R 000306
RJCTN R 000316
**  NO ERRORS*
```

SAMPLE ASSEMBLER LIST OUTPUT

```
 PAGE 0002



0001  00000              NAM UPDTE
0002  00000 000000 START NOP
0003  00001 026002R      JMP OPEN
0004  00000              ORB           ASSIGN STORAGE & CONSTANTS TO BP
0005  00000 000000 PRTSM BSS 4         MASTER PARTS FILE - BINARY.
0006  00004 000000 PRTSU BSS 4         PARTS USAGE LIST - ASCII.
0007  00010 000000 PRTSC BSS 11        PARTS COST REPORT - ASCII.
0008  00023 026063R EOTS1 JMP READM
0009  00024 026301R EOTS2 JMP WRITN
0010  00025 000000 MTEMP BSS 1
0011  00026 000000 UTEMP BSS 1
0012  00027 000000 SWTMP BSS 2
0013  00031 020040 SPACS ASC 2,
      00032 020040
0014  00033 020044 DLRSG ASC 1, $
0015  00000        A     EQU 0
0016  00001        B     EQU 1
0017                     EXT .IOC.     PERFORM I/O OPERATIONS USING BCS
0018*                                  I/O CONTROL ROUTINE.
0019                     EXT BCONV     ENTRY POINT FOR DECIMAL(ASCII)
0020*                                  TO BINARY CONVERSION SUBPROGRAM.
0021                     EXT DCONV     ENTRY POINT FOR BINARY TO
0022*                                  DECIMAL(ASCII) CONVERSION SUB-
0023*                                  PROGRAM.
0024                     EXT ABORT     ENTRY POINT FOR SUBPROGRAM WHICH
0025*                                  HANDLES UNRECOVERABLE I/O ERRORS
0026*                                  OR INVALID DATA.
0027                     EXT HALT      END OF PROGRAM SUBROUTINE.
0028                     COM DTOBI(2),DTOBO,BTODI(2),BTODO(2)
0029*                                  COMMON STORAGE LOCATIONS USED TO
0030*                                  PASS DATA BETWEEN MAIN PROGRAM
0031*                                  AND CONVERSION SUBPROGRAMS.
0032  00002              ORR           RESETS PLC AFTER USE OF ORB AT
0033*                                  BEGINNING OF PROGRAM.
0034  00002 000000 OPEN  NOP
0035  00003 016006X SPCFL DLD SPACS    STORES EDITING CHARACTERS IN
      00004 000031B
0036  00005 016007X      DST PRTSC+2   OUTPUT AREA FOR PARTS COST
      00006 000012B
0037  00007 016007X      DST PRTSC+6   REPORT.
      00010 000016B
0038  00011 060033B      LDA DLRSG
0039  00012 070020B      STA PRTSC+8
0040  00013 016001X READU JSB .IOC.    READ ONE RECORD FROM USAGE LIST
0041  00014 010001       OCT 10001     LOCATED ON STANDARD UNIT 1
0042  00015 026035R      JMP RJCTU     (TELEPRINTER INPUT). PRTSU IS
0043  00016 000004B      DEF PRTSU     ADDRESS OF STORAGE AREA; AREA IS
0044  00017 000004       DEC 4         4 WORDS LONG.
0045  00020 016001X CKSTU JSB .IOC.    CHECK STATUS OF UNIT 1.
0046  00021 040001       OCT 40001
0047  00022 002020       SSA
0048  00023 026020R      JMP CKSTU     IF BUSY, LOOP UNTIL FREE.
0049  00024 001200       RAL
0050  00025 002020       SSA
0051  00026 026030R      JMP *+2
0052  00027 026063R      JMP READM     IF COMPLETE, TRANSFER TO SECTION
0053*                                  WHICH READS MASTER FILE RECORD.
```

```
0054  00030 001727        ALF,ALF       TEST END OF TAPE STATUS BIT
0055  00031 001200        RAL           (ORIGINAL BIT 05).
0056  00032 002020        SSA
0057  00033 026040R       JMP EOTU      IF SET, GO TO EOT PROCEDURE.
0058  00034 026004X       JMP ABORT     IF NOT SET, SOME ERROR CONDITION
0059*                                   (UNRECOVERABLE) EXISTS.
0060  00035 006020  RJCTU SSB           CHECK CAUSE OF REJECT. IF UNIT
0061  00036 026013R       JMP READU     BUSY LOOP UNTIL FREE. ANY OTHER
0062  00037 026004X       JMP ABORT     CAUSE IS UNRECOVERABLE ERROR.
0063  00040 060023B EOTU  LDA EOTS1     IF END OF USAGE FILE, ALTER
0064  00041 072002R       STA OPEN      PROGRAM SEQUENCE TO BYPASS
0065  00042 060024B       LDA EOTS2     SECTIONS THAT READ AND PROCESS
0066  00043 072140R       STA COMPR     USAGE FILE. PRINT MESSAGE ON
0067  00044 016001X       JSB .IOC.     TELEPRINTER INDICATING EOT.
0068  00045 020002        OCT 20002
0069  00046 026044R       JMP EOTU+4
0070  00047 000051R       DEF MSGU
0071  00050 000011        DEC 9
0072  00051 042516  MSGU  ASC 9,END OF USAGE FILE
      00052 042040
      00053 047506
      00054 020125
      00055 051501
      00056 043505
      00057 020106
      00060 044514
      00061 042440
0073  00062 026063R       JMP READM
0074  00063 016001X READM JSB .IOC.     READ A RECORD FROM MASTER PARTS
0075  00064 010105        OCT 10105     FILE ON STANDARD UNIT 05(PUNCHED
0076  00065 026105R       JMP RJCTM     TAPE READER). PRTSM  IS ADDRESS
0077  00066 000000B       DEF PRTSM     OF STORAGE AREA; AREA IS 4 WORDS
0078  00067 000004        DEC 4         LONG. RECORD IS IN BINARY FORMAT
0079  00070 016001X CKSTM JSB .IOC.     CHECK STATUS OF UNIT 5.
0080  00071 040005        OCT 40005
0081  00072 002020        SSA
0082  00073 026070R       JMP CKSTM     IF BUSY, LOOP UNTIL FREE.
0083  00074 001200        RAL
0084  00075 002020        SSA
0085  00076 026100R       JMP *+2
0086  00077 026140R       JMP COMPR     IF COMPLETE, TRANSFER TO EITHER
0087  00100 001727        ALF,ALF       PROCESSING OR WRITE OUTPUT
0088  00101 001200        RAL           DEPENDING ON SETTING OF COMPR.
0089  00102 002020        SSA           TEST FOR END OF TAPE.
0090  00103 026110R       JMP EOTM      IF END, GO TO EOT PROCEDURE.
0091  00104 026004X       JMP ABORT     IF NOT, AN UNRECOVERABLE ERROR
0092*                                   EXISTS.
0093  00105 006020  RJCTM SSB           CHECK CONTENTS OF B FOR CAUSE OF
0094  00106 026063R       JMP READM     REJECT. IF UNIT BUSY, LOOP UNTIL
0095  00107 026004X       JMP ABORT     FREE, OTHERWISE I/O ERROR EXISTS
0096  00110 062137R EOTM  LDA HLTSW     ALTER PROGRAM SEQUENCE TO HALT
0097  00111 072315R       STA CKSTN+7   EXECUTION AFTER LAST RECORD IS
0098  00112 016001X       JSB .IOC.     WRITTEN  PRINT MESSAGE
0099  00113 020002        OCT 20002     INDICATING END OF MASTER INPUT.
0100  00114 026112R       JMP EOTM+2
0101  00115 000117R       DEF MSGM
0102  00116 000017        DEC 15
0103  00117 042516  MSGM  ASC 15,END OF MASTER PARTS FILE INPUT
```

```
PAGE 0004

      00120 042040
      00121 047506
      00122 020115
      00123 040523
      00124 052105
      00125 051040
      00126 050101
      00127 051124
      00130 051440
      00131 043111
      00132 046105
      00133 020111
      00134 047120
      00135 052524
0104  00136 026140R       JMP COMPR
0105  00137 026005X HLTSW JMP HALT       END OF PROGRAM SUBROUTINE.
0106  00140 000000  COMPR NOP
0107  00141 016224R       JSB CONU1      CONVERT ID NUMBER FIELDS OF
0108  00142 016213R       JSB CONVM      MASTER AND USAGE FILES TO BIN.
0109  00143 060026B       LDA UTEMP      LOAD THESE FIELDS FROM TEMPORARY
0110  00144 064025B       LDB MTEMP      STORAGE.
0111  00145 050001        CPA B          COMPARE
0112  00146 026157R       JMP PROCM      IF EQUAL, JUMP TO PROCESSING
0113  00147 007004        CMB,INB        IF ID NUMBER OF MASTER GREATER
0114  00150 040001        ADA B          THAN ID NUMBER OF USAGE, DATA IN
0115  00151 002020        SSA            USAGE FILE ERRONEOUS. TERMINATE
0116  00152 026004X       JMP ABORT      RUN.
0117  00153 062156R       LDA *+3        IF ID MASTER LESS THAN ID USAGE,
0118  00154 072315R       STA CKSTN+7    ALTER SEQUENCE: READ NEXT MASTER
0119  00155 026301R       JMP WRITN      RECORD IMMEDIATELY AFTER WRITING
0120  00156 026063R       JMP READM      CURRENT MASTER RECORD.
0121  00157 016235R PROCM JSB CONU2      CONVERT QUANTITY FIELD OF USAGE
0122  00160 060002B       LDA PRTSM+2    FILE TO BINARY AND SUBTRACT FROM
0123  00161 064027B       LDB UTEMP+1    QUANTITY FIELD OF MASTER AND
0124  00162 007004        CMB,INB        STORE RESULT.
0125  00163 040001        ADA B
0126  00164 070002B       STA PRTSM+2
0127  00165 016006X PROCC DLD PRTSU      STORE ID OF PARTS USED IN REPORT
      00166 000004B
0128  00167 016007X       DST PRTSC      FILE STORAGE AREA.
      00170 000010B
0129  00171 016006X       DLD PRTSU+2    STORE QUANTITY OF PARTS USED IN
      00172 000006B
0130  00173 016007X       DST PRTSC+4    REPORT FILE STORAGE AREA.
      00174 000014B
0131  00175 060003B       LDA PRTSM+3    COMPUTE COST OF PARTS USED.
0132  00176 016010X       MPY UTEMP+1
      00177 000027B
0133  00200 070030B       STA SWTMP+1
0134  00201 074027B       STB SWTMP
0135  00202 016246R       JSB CONVC      CONVERT RESULT TO DECIMAL
0136  00203 016006X       DLD SWTMP
      00204 000027B
0137  00205 016007X       DST PRTSC+9    STORE IN REPORT FILE AREA.
      00206 000021B
0138  00207 062212R       LDA *+3        ALTER SEQUENCE: READ NEXT USAGE
0139  00210 072315R       STA CKSTN+7    RECORD AFTER WRITING CURRENT
0140  00211 026261R       JMP WRITC      MASTER RECORD.
```

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PAGE 0005

0141  00212 026013R       JMP READU
0142  00213 000000  CONVM NOP
0143  00214 016006X       DLD PRTSM     STORE ID FIELDS IN COMMON
      00215 000000B
0144  00216 016007X       DST DTOBI     LOCATIONS TO BE PROCESSED BY
      00217 000000C
0145  00220 016002X       JSB BCONV     CONVERSION SUBPROGRAM. ON
0146  00221 062002C       LDA DTOBO     COMPLETION, STORE RESULTS IN
0147  00222 070025B       STA MTEMP     LOCATIONS USED BY PROCESSING
0148  00223 126213R       JMP CONVM,I   SECTIONS. CONVM APPLIES TO ID OF
0149  00224 000000  CONU1 NOP           MASTER PARTS FILE; CONU1, TO ID
0150  00225 016006X       DLD PRTSU     OF USAGE; CONU2, TO QUANTITY OF
      00226 000004B
0151  00227 016007X       DST DTOBI     USAGE; AND CONVC, TO COST OF
      00230 000000C
0152  00231 016002X       JSB BCONV     PARTS(THIS IS A BINARY TO
0153  00232 062002C       LDA DTOBO     DECIMAL CONVERSION).
0154  00233 070026B       STA UTEMP
0155  00234 126224R       JMP CONU1,I
0156  00235 000000  CONU2 NOP
0157  00236 016006X       DLD PRTSU+2
      00237 000006B
0158  00240 016007X       DST DTOBI
      00241 000000C
0159  00242 016002X       JSB BCONV
0160  00243 062002C       LDA DTOBO
0161  00244 070027B       STA UTEMP+1
0162  00245 126235R       JMP CONU2,I
0163  00246 000000  CONVC NOP
0164  00247 016006X       DLD SWTMP
      00250 000027B
0165  00251 016007X       DST BTODI
      00252 000003C
0166  00253 016003X       JSB DCONV
0167  00254 016006X       DLD BTODO
      00255 000005C
0168  00256 016007X       DST SWTMP
      00257 000027B
0169  00260 126246R       JMP CONVC,I
0170  00261 016001X WRITC JSB .IOC.     WRITE ONE RECORD OF PARTS COST
0171  00262 020102        OCT 20102     REPORT ON STANDARD UNIT 2
0172  00263 026276R       JMP RJCTC     (TELEPRINTER OUTPUT). PRTSC IS
0173  00264 000010B       DEF PRTSC     ADDRESS IN STORAGE AREA; AREA IS
0174  00265 000013        DEC 11        11 WORDS LONG. RECORD IS IN ASCI
0175  00266 016001X CKSTC JSB .IOC.     CHECK STATUS OF UNIT 2.
0176  00267 040002        OCT 40002
0177  00270 002020        SSA
0178  00271 026266R       JMP CKSTC     IF BUSY, LOOP UNTIL FREE.
0179  00272 001200        RAL
0180  00273 002020        SSA
0181  00274 026004X       JMP ABORT     TERMINATE IF ANY I/O ERROR.
0182  00275 026301R       JMP WRITN     IF COMPLETE, TRANSFER TO WRITN.
0183  00276 006020  RJCTC SSB           IF BUSY, LOOP UNTIL FREE.
0184  00277 026261R       JMP WRITC     TERMINATE ON ANY OTHER REJECT
0185  00300 026004X       JMP ABORT     CONDITION.
0186  00301 016001X WRITN JSB .IOC.     WRITE ONE RECORD (BINARY) OF
0187  00302 020104        OCT 20104     NEW MASTER PARTS LIST ON UNIT 4
0188  00303 026316R       JMP RJCTN     (TAPE PUNCH). PRTSM (INPUT AREA)
```

```
PAGE 0006

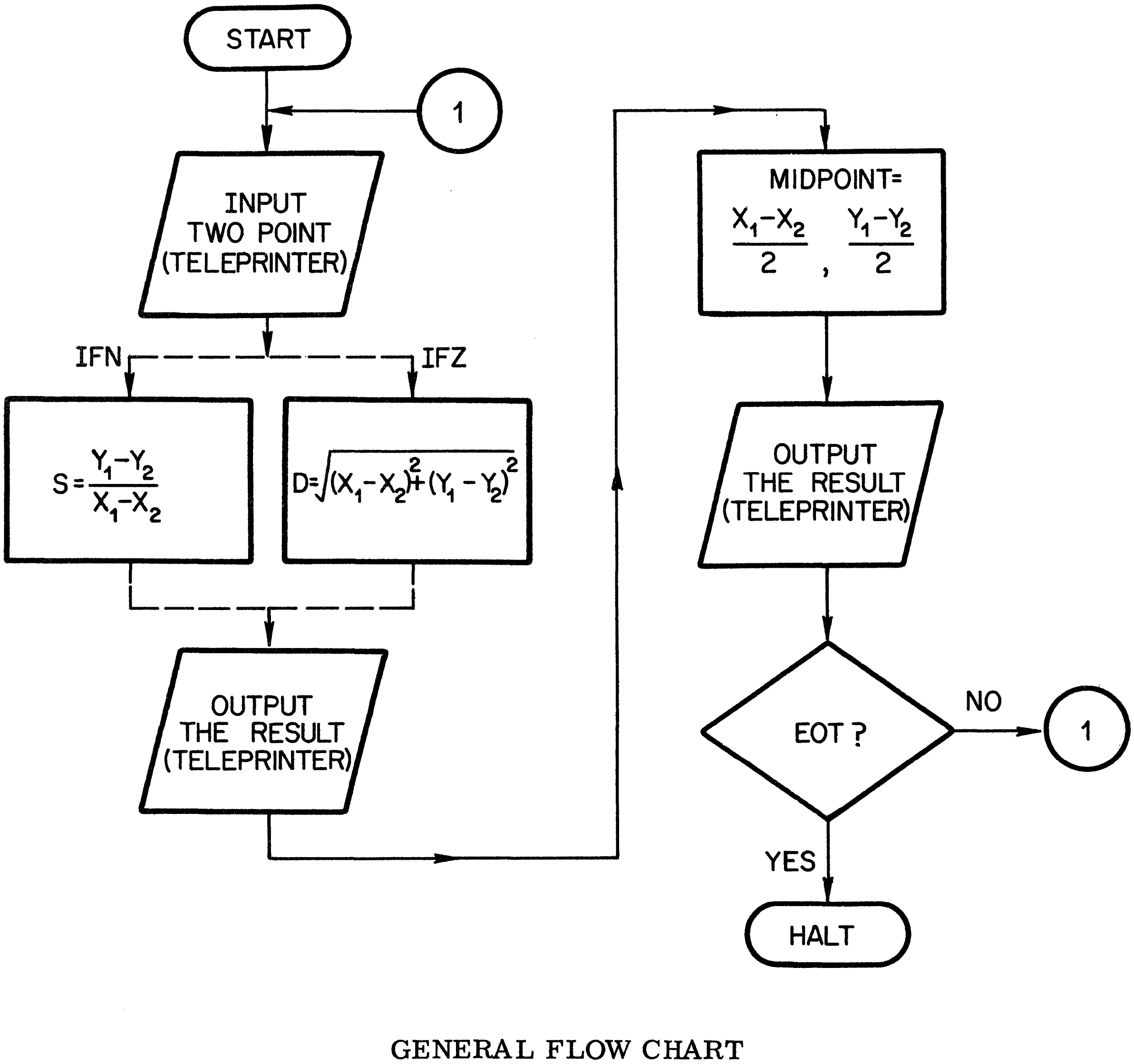

0189   00304 000000B         DEF PRTSM      IS ALSO USED AS OUTPUT AREA.
0190   00305 000004          DEC 4
0191   00306 016001X CKSTN   JSB .IOC.      CHECK STATUS OF UNIT 4.
0192   00307 040004          OCT 40004
0193   00310 002020          SSA
0194   00311 026306R         JMP CKSTN      IF BUSY, LOOP UNTIL FREE.
0195   00312 001200          RAL
0196   00313 002020          SSA
0197   00314 026004X         JMP ABORT
0198   00315 026013R         JMP READU
0199   00316 006020  RJCTN   SSB            IF BUSY, LOOP UNTIL FREE, OTHER-
0200   00317 026301R         JMP WRITN      WISE TERMINATE.
0201   00320 026004X         JMP ABORT
0202                         END START
**  NO ERRORS*
```

B.

Program "Line" will either calculate the distance between two points or find the slope of the line connecting the points; then the point equidistant from each point (the mid-point) is calculated.

Data is input using the formatter library routine four n-digit real numbers at a time. The first quantity is the X coordinate of the first point; the second quantity is the Y coordinate of the first point; the third and fourth quantities are the X and Y coordinates of the second point.

The result is output to the teleprinter by the formatter library routine; each quantity cannot be more than an eight digit real number.


START
1
INPUT TWO POINT (TELEPRINTER)
IFN
IFZ
$S = \frac{Y_1 - Y_2}{X_1 - X_2}$
$D = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2}$
OUTPUT THE RESULT (TELEPRINTER)
MIDPOINT= $\frac{X_1 - X_2}{2}, \frac{Y_1 - Y_2}{2}$
OUTPUT THE RESULT (TELEPRINTER)
EOT ?
NO
1
YES
HALT

GENERAL FLOW CHART

Below is the source program as it is typed up on the teleprinter. After it are the assembler listings. The first listing results from including the Z option in the control statement. In the second listing the N option has been included in the control statement.

> NOTE: When the complete data tape has been read and the tape reader encounters 10 blank feed frames, an EQT message is typed on the teleprinter and the computer halts. Thus no halt instruction is needed in the program.)

```
       HED LINE FORMULI:  DISTANCE, SLOPE, MID-POINT
*  PROGRAM LINE WILL EITHER CALCULATE THE DISTANCE BETWEEN
*  TWO POINTS OR FIND THE SLOPE OF THE LINE CONNECTING
*  THE POINTS; THEN THE POINT EQUIDISTANT FROM EACH
*  POINT (THE MID-POINT) IS CALCULATED.
*     DATA IS INPUT USING THE FORMATTER LIBRARY ROUTINE
*  FOUR N-DIGIT REAL NUMBERS AT A TIME.  THE FIRST
*  QUANTITY IS THE X COORDINATE OF THE FIRST POINT;THE
*  SECOND QUANTITY IS THE Y COORDINATE OF THE FIRST POINT;
*  THE THIRD AND FOURTH QUANTITIES ARE THE X AND Y COORDINATES
*  OF THE SECOND POINT.
*     THE RESULT IS OUTPUT TO THE TELEPRINTER BY THE
*  FORMATTER LIBRARY ROUTINE; EACH QUANTITY CANNOT BE MORE
*  THAN AN EIGHT DIGIT REAL NUMBER.
       NAM LINE
START  NOP
       JMP INPUT
       EXT .IOC.,FLOAT,IFIX,SQRT
       EXT .DIO.,.IOI.,.DTA.,.RAR.
       EXT .IOR.,.IAR.
.DATA  DEF DATA
.PRIN  DEF PRINT
DATA   BSS 4
FMT    ASC 3,(F8.3)
FMT2   ASC 8,(F8.3,",",F8.3/)
FMT3   ASC 3,(4I2)
       SKP
*  INPUT THE FIRST TWO POINTS; FOUR DATA WORDS
INPUT  NOP
       LDA =B5
       CLB,INB
       JSB .DIO.
       DEF FMT3
       DEF *+4
       LDA =B4
       LDB .DATA
       JSB .IAR.
       SPC 3
*  THE DISTANCE BETWEEN THE TWO POINTS:
       IFZ
       LDA DATA+2
       CMA,INA
       ADA DATA
       SPC 1
       JMP *+5
PRINT  REP 4
       NOP
       SPC 1
       STA PRINT
       SUP
```

```
      MPY PRINT
      STA PRINT
      SPC 1
      LDA DATA+3
      CMA,INA
      ADA DATA+1
      STA PRINT+1
      MPY PRINT+1
      ADA PRINT
      SPC 1
      JSB FLOAT
      JSB SQRT
      DST PRINT
      XIF
      SPC 3
*  FIND THE SLOPE OF THE LINE
      IFN
      LDA DATA+2
      CMA,INA
      ADA DATA
      JMP *+5
PRINT REP 4
      NOP
      STA PRINT
      SPC 1
      LDA DATA+3
      CMA,INA
      ADA DATA+1
      CLB
      DIV PRINT
      DST PRINT
      XIF
      SPC 3
*  OUTPUT THE RESULT
      LDA =B2
      CLB
      JSB .DIO.
      DEF FMT
      DEF *+4
      DLD PRINT
      JSB .IOR.
      JSB .DTA.
      SPC 3
*  FIND THE MID-POINT OF THE LINE SEGMENT:
      LDA DATA
      ADA DATA+2
      CLB
      JSB FLOAT
      FMP =F.5
      DST PRINT
      SPC 1
      LDA DATA+1
      ADA DATA+3
      CLB
      JSB FLOAT
      FMP =F.5
      DST PRINT+2
      SPC 1
      UNL
```

```
LDA =B2
CLB
JSB .DIO.
DEF FMT2
DEF *+5
LDA =B2
LDB .PRIN
JSB .RAR.
JSB .DTA.
LST
SPC 3
UNS
JMP INPUT
END START
```

```
 PAGE ØØØ1

ØØØ1                ASMB,R,L,T,Z
START R ØØØØØØ
.IOC. X ØØØØØ1
FLOAT X ØØØØØ2
IFIX  X ØØØØØ3
SQRT  X ØØØØØ4
.DIO. X ØØØØØ5
.IOI. X ØØØØØ6
.DTA. X ØØØØØ7
.RAR. X ØØØØ1Ø
.IOR. X ØØØØ11
.IAR. X ØØØØ12
.DATA R ØØØØØ2
.PRIN R ØØØØØ3
DATA  R ØØØØØ4
FMT   R ØØØØ1Ø
FMT2  R ØØØØ13
FMT3  R ØØØØ23
INPUT R ØØØØ26
PRINT R ØØØØ43
.MPY  X ØØØØ13
.DST  X ØØØØ14
.DLD  X ØØØØ15
.FMP  X ØØØØ16
**  NO ERRORS*
```

```
 PAGE 0002 #01  LINE FORMULI:  DISTANCE, SLOPE, MID-POINT


0002*  PROGRAM LINE WILL EITHER CALCULATE THE DISTANCE BETWEEN
0003*  TWO POINTS OR FIND THE SLOPE OF THE LINE CONNECTING
0004*  THE POINTS; THEN THE POINT EQUIDISTANT FROM EACH
0005*  POINT (THE MID-POINT) IS CALCULATED.
0006*     DATA IS INPUT USING THE FORMATTER LIBRARY ROUTINE
0007*  FOUR N-DIGIT REAL NUMBERS AT A TIME.  THE FIRST
0008*  QUANTITY IS THE X COORDINATE OF THE FIRST POINT;THE
0009*  SECOND QUANTITY IS THE Y COORDINATE OF THE FIRST POINT;
0010*  THE THIRD AND FOURTH QUANTITIES ARE THE X AND Y COORDINATES
0011*  OF THE SECOND POINT.
0012*     THE RESULT IS OUTPUT TO THE TELEPRINTER BY THE
0013*  FORMATTER LIBRARY ROUTINE; EACH QUANTITY CANNOT BE MORE
0014*  THAN AN EIGHT DIGIT REAL NUMBER.
0015  00000              NAM LINE
0016  00000 000000  START NOP
0017  00001 026026R       JMP INPUT
0018                      EXT .IOC.,FLOAT,IFIX,SQRT
0019                      EXT .DIO.,.IOI.,.DTA.,.RAR.
0020                      EXT .IOR.,.IAR.
0021  00002 000004R .DATA DEF DATA
0022  00003 000043R .PRIN DEF PRINT
0023  00004 000000  DATA  BSS 4
0024  00010 024106  FMT   ASC 3,(F8.3)
      00011 034056
      00012 031451
0025  00013 024106  FMT2  ASC 8,(F8.3,",",F8.3/)
      00014 034056
      00015 031454
      00016 021054
      00017 021054
      00020 043070
      00021 027063
      00022 027451
0026  00023 024064  FMT3  ASC 3,(4I2)
      00024 044462
      00025 024440
```

```
PAGE 0003 #01  LINE FORMULI:  DISTANCE, SLOPE, MID-POINT

0028*  INPUT THE FIRST TWO POINTS; FOUR DATA WORDS
0029  00026 000000  INPUT NOP
0030  00027 062131R        LDA =B5
0031  00030 006404         CLB,INB
0032  00031 016005X        JSB .DIO.
0033  00032 000023R        DEF FMT3
0034  00033 000037R        DEF *+4
0035  00034 062132R        LDA =B4
0036  00035 066002R        LDB .DATA
0037  00036 016012X        JSB .IAR.


0039*  THE DISTANCE BETWEEN THE TWO POINTS:
0040                       IFZ
0041  00037 062006R        LDA DATA+2
0042  00040 003004         CMA,INA
0043  00041 042004R        ADA DATA

0045  00042 026047R        JMP *+5
0046               PRINT REP 4
0047  00043 000000         NOP
0047  00044 000000         NOP
0047  00045 000000         NOP
0047  00046 000000         NOP

0049  00047 072043R        STA PRINT
0050                       SUP
0051  00050 016013X        MPY PRINT
0052  00052 072043R        STA PRINT

0054  00053 062007R        LDA DATA+3
0055  00054 003004         CMA,INA
0056  00055 042005R        ADA DATA+1
0057  00056 072044R        STA PRINT+1
0058  00057 016013X        MPY PRINT+1
0059  00061 042043R        ADA PRINT

0061  00062 016002X        JSB FLOAT
0062  00063 016004X        JSB SQRT
0063  00064 016014X        DST PRINT
0064                       XIF


0066*  FIND THE SLOPE OF THE LINE
0067                       IFN
0068                       LDA DATA+2
0069                       CMA,INA
0070                       ADA DATA
0071                       JMP *+5
0072               PRINT REP 4
0073                       NOP
0074                       STA PRINT
0075                       SPC 1
0076                       LDA DATA+3
0077                       CMA,INA
0078                       ADA DATA+1
```

```
 PAGE 0004 #01  LINE FORMULI:  DISTANCE, SLOPE, MID-POINT


0079                        CLB
0080                        DIV PRINT
0081                        DST PRINT
0082                        XIF



0084*  OUTPUT THE RESULT
0085  00066 062133R         LDA =B2
0086  00067 006400          CLB
0087  00070 016005X         JSB .DIO.
0088  00071 000010R         DEF FMT
0089  00072 000076R         DEF *+4
0090  00073 016015X         DLD PRINT
0091  00075 016011X         JSB .IOR.
0092  00076 016007X         JSB .DTA.



0094*  FIND THE MID-POINT OF THE LINE SEGMENT:
0095  00077 062004R         LDA DATA
0096  00100 042006R         ADA DATA+2
0097  00101 006400          CLB
0098  00102 016002X         JSB FLOAT
0099  00103 016016X         FMP =F.5
0100  00105 016014X         DST PRINT

0102  00107 062005R         LDA DATA+1
0103  00110 042007R         ADA DATA+3
0104  00111 006400          CLB
0105  00112 016002X         JSB FLOAT
0106  00113 016016X         FMP =F.5
0107  00115 016014X         DST PRINT+2

0119                        LST



0121                        UNS
0122  00130 026026R         JMP INPUT
      00131 000005
      00132 000004
      00133 000002
      00134 040000
      00135 000000
0123                        END START
**  NO ERRORS*
```

```
 PAGE 0001

0001                    ASMB,R,L,T,N
START R 000000
.IOC. X 000001
FLOAT X 000002
IFIX  X 000003
SQRT  X 000004
.DIO. X 000005
.IOI. X 000006
.DTA. X 000007
.RAR. X 000010
.IOR. X 000011
.IAR. X 000012
.DATA R 000002
.PRIN R 000003
DATA  R 000004
FMT   R 000010
FMT2  R 000013
FMT3  R 000023
INPUT R 000026
PRINT R 000043
.DIV  X 000013
.DST  X 000014
.DLD  X 000015
.FMP  X 000016
**  NO ERRORS*
```

```
PAGE 0002 #01  LINE FORMULI:  DISTANCE, SLOPE, MID-POINT


0002*  PROGRAM LINE WILL EITHER CALCULATE THE DISTANCE BETWEEN
0003*  TWO POINTS OR FIND THE SLOPE OF THE LINE CONNECTING
0004*  THE POINTS; THEN THE POINT EQUIDISTANT FROM EACH
0005*  POINT (THE MID-POINT) IS CALCULATED.
0006*     DATA IS INPUT USING THE FORMATTER LIBRARY ROUTINE
0007*  FOUR N-DIGIT REAL NUMBERS AT A TIME.  THE FIRST
0008*  QUANTITY IS THE X COORDINATE OF THE FIRST POINT;THE
0009*  SECOND QUANTITY IS THE Y COORDINATE OF THE FIRST POINT;
0010*  THE THIRD AND FOURTH QUANTITIES ARE THE X AND Y COORDINATES
0011*  OF THE SECOND POINT.
0012*     THE RESULT IS OUTPUT TO THE TELEPRINTER BY THE
0013*  FORMATTER LIBRARY ROUTINE; EACH QUANTITY CANNOT BE MORE
0014*  THAN AN EIGHT DIGIT REAL NUMBER.
0015  00000              NAM LINE
0016  00000 000000  START NOP
0017  00001 026026R       JMP INPUT
0018                     EXT .IOC.,FLOAT,IFIX,SQRT
0019                     EXT .DIO.,.IOI.,.DTA.,.RAR.
0020                     EXT .IOR.,.IAR.
0021  00002 000004R .DATA DEF DATA
0022  00003 000043R .PRIN DEF PRINT
0023  00004 000000  DATA  BSS 4
0024  00010 024106  FMT   ASC 3,(F8.3)
      00011 034056
      00012 031451
0025  00013 024106  FMT2  ASC 8,(F8.3,",",F8.3/)
      00014 034056
      00015 031454
      00016 021054
      00017 021054
      00020 043070
      00021 027063
      00022 027451
0026  00023 024064  FMT3  ASC 3,(4I2)
      00024 044462
      00025 024440
```

```
0028*  INPUT THE FIRST TWO POINTS; FOUR DATA WORDS
0029  00026 000000  INPUT NOP
0030  00027 062123R       LDA =B5
0031  00030 006404        CLB,INB
0032  00031 016005X       JSB .DIO.
0033  00032 000023R       DEF FMT3
0034  00033 000037R       DEF *+4
0035  00034 062124R       LDA =B4
0036  00035 066002R       LDB .DATA
0037  00036 016012X       JSB .IAR.


0039*  THE DISTANCE BETWEEN THE TWO POINTS:
0040                      IFZ
0041                      LDA DATA+2
0042                      CMA,INA
0043                      ADA DATA
0044                      SPC 1
0045                      JMP *+5
0046                PRINT REP 4
0047                      NOP
0048                      SPC 1
0049                      STA PRINT
0050                      SUP
0051                      MPY PRINT
0052                      STA PRINT
0053                      SPC 1
0054                      LDA DATA+3
0055                      CMA,INA
0056                      ADA DATA+1
0057                      STA PRINT+1
0058                      MPY PRINT+1
0059                      ADA PRINT
0060                      SPC 1
0061                      JSB FLOAT
0062                      JSB SQRT
0063                      DST PRINT
0064                      XIF


0066*  FIND THE SLOPE OF THE LINE
0067                      IFN
0068  00037 062006R       LDA DATA+2
0069  00040 003004        CMA,INA
0070  00041 042004R       ADA DATA
0071  00042 026047R       JMP *+5
0072                PRINT REP 4
0073  00043 000000        NOP
0073  00044 000000        NOP
0073  00045 000000        NOP
0073  00046 000000        NOP
0074  00047 072043R       STA PRINT

0076  00050 062007R       LDA DATA+3
0077  00051 003004        CMA,INA
0078  00052 042005R       ADA DATA+1
```

```
 PAGE 0004 #01  LINE FORMULI:  DISTANCE, SLOPE, MID-POINT


0079  00053 006400          CLB
0080  00054 016013X         DIV PRINT
      00055 000043R
0081  00056 016014X         DST PRINT
      00057 000043R
0082                        XIF



0084*  OUTPUT THE RESULT
0085  00060 062125R         LDA =B2
0086  00061 006400          CLB
0087  00062 016005X         JSB .DIO.
0088  00063 000010R         DEF FMT
0089  00064 000070R         DEF *+4
0090  00065 016015X         DLD PRINT
      00066 000043R
0091  00067 016011X         JSB .IOR.
0092  00070 016007X         JSB .DTA.



0094*  FIND THE MID-POINT OF THE LINE SEGMENT:
0095  00071 062004R         LDA DATA
0096  00072 042006R         ADA DATA+2
0097  00073 006400          CLB
0098  00074 016002X         JSB FLOAT
0099  00075 016016X         FMP =F.5
      00076 000126R
0100  00077 016014X         DST PRINT
      00100 000043R

0102  00101 062005R         LDA DATA+1
0103  00102 042007R         ADA DATA+3
0104  00103 006400          CLB
0105  00104 016002X         JSB FLOAT
0106  00105 016016X         FMP =F.5
      00106 000126R
0107  00107 016014X         DST PRINT+2
      00110 000045R

0119                        LST



0121                        UNS
0122  00122 026026R         JMP INPUT
      00123 000005
      00124 000004
      00125 000002
      00126 040000
      00127 000000
0123                        END START
**  NO ERRORS*
```

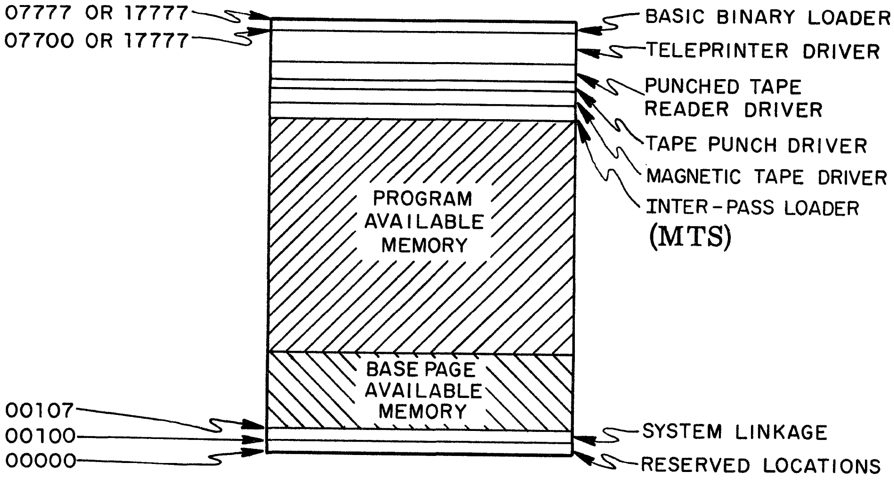
SYSTEM INPUT/OUTPUT SUBROUTINES

The System Input/Output (SIO) subroutines may be used to perform basic input/output operations for programs in absolute form.[†]

MEMORY ALLOCATION

These drivers are stored in high memory immediately preceding the Basic Binary Loader. The Teleprinter driver must be loaded first; it is stored in the highest portion of this area. The drivers for the Punched Tape Reader (or Marked Card Reader), the Tape Punch, and the Magnetic Tape Unit may then be loaded. The sequence of loading must fall within this order, depending on your equipment configuration: Line Printer Driver, Punched Tape Reader Driver (or Marked Card Reader), Tape Punch Driver, Magnetic Tape Driver, and if needed, the MTS Boot.

The drivers are accessed through 15-bit absolute addresses which are stored in the System Linkage area starting at location 101_8. The allocation of memory is as follows:



[†] The SIO subroutines are designed for use with FORTRAN, Assembler, Symbolic Editor, etc.; however, they may be used with any absolute object program.

OPERATION AND CALLING SEQUENCE: PAPER TAPE DEVICES

All data transmission is accomplished without interrupt control, and therefore, operations are not buffered by the drivers. Control is not returned to the calling program until an operation is completed. Data is transferred to and from buffer storage areas specified in the user program.

The general form of the paper tape input/output calling sequence is:

```
LDA <buffer length> (words or characters)
LDB <buffer address>
JSB 10fB,I     (f is Input/Output function)
<normal return>
```

Register Contents

When the JSB is performed, the A-Register must contain the length of the buffer storage area and the B-Register, the address of the buffer. Control returns to the location following the JSB. After an input request is completed, the A-Register contains a positive integer indicating the number of characters or words transmitted, or zeros, if an end-of-tape condition occurred.

The digit supplied for f in the JSB instruction determines the paper tape input/output function to be performed. The value of the operand address is the location in the System Linkage that contains the absolute address of the driver entry point. The following are available:

101	Input
102	List Output
103	Punch Output
104	Keyboard Input–ASCII data is read from Teleprinter and printed as it is received.

If the Teleprinter driver alone is loaded, these locations point to entry points of this driver. If Punched Tape Reader and Tape Punch drivers are in memory, location 101 points to the Punched Tape Reader driver and location 103, to the Tape Punch driver. If the latter are to be used, they must be loaded after the Teleprinter driver.

OPERATION AND CALLING SEQUENCE: MAGNETIC TAPE DRIVER

As with the Paper Tape SIO drivers, all data transmission is accomplished without interrupt control. Control is not returned to the calling program until an operation is completed. (Rewind and rewind standby are the only exceptions to this. In these cases return is made as soon as the command is accepted.)

The general form of the calling sequence is:

```
LDA  <buffer length>  or  <file count>
LDB  <buffer address>  or  <record count>
JSB   107B,I
OCT  <command code>
<EOF/EOT/SOT return>
<error return>
<normal return>
```

NOTE: Location 107_8 must contain the address of the magnetic tape driver.

Register Contents

Before initiating read or write operations, the A-Register must contain the buffer length. This will be a positive integer if length is defined in characters and a negative integer if length is defined in words. The B-Register must contain the buffer address.

Before initiating tape positioning operations, the A-Register must contain the number of files that are to be spaced. A positive integer indicates forward spacing; a negative integer indicates backward spacing. The B-Register contains the number of records that are to be spaced. A positive integer indicates forward spacing; a negative integer indicates backward spacing. The positioning may be defined in terms of any combination of forward or backward spacing of files and records (e.g., space forward two files then backspace three records). If files only or records only are to be spaced, the contents of the other register should be zeros.

The registers are not used when entering the subroutine to perform one of the following operations:

Write end-of-file
Write file gap
Rewind
Rewind/Standby
Status

Linkage Address

107B is the System Linkage word that contains the absolute address of the entry point for the Magnetic Tape driver.

On return from a read operation, the A-Register contains a positive value indicating the number of words or characters transmitted.

On return from all operations except Rewind and Rewind/ Standby the B-Register contains status of the operation (See Status).

MAGNETIC TAPE OPERATIONS

The magnetic tape driver will perform the following operations. The pertinent operation is specified by the command code which appears after the OCT in the calling sequence.

Operation	Command Code
Read	0
Write	1
Write End-of-File	2
Rewind (Auto mode)	3
Position	4
Rewind/Standby (Local mode)	5
Gap	6
Status	7

Read

One tape record is read into the buffer. The number of characters or words read is stored in the A-Register. The value will be equal to the buffer length except when the data on tape is less than the length of the buffer. One tape record is read to transfer the number of characters specified into the buffer. The number of characters in that record (not the number transferred) will be stored in the A-Register. If the tape record exceeds the buffer length, the data will be read into the buffer until the buffer is filled, the remainder of the record will be skipped. If the length of an input buffer is an odd number of characters, a read operation will result in the overlaying of the character following the last character of the buffer; the subroutine actually transmits full words only.

Three attempts are made to read the record before returning control to the parity error address.

If an EOT condition exists at the time of entry, the command will be ignored and control will be returned to the EOT/EOF address.

If the buffer length specified is 0 control will return to the normal address without any tape movement.

The input buffer storage area can be as large or as small as needed. The number of characters in the tape record will be stored in the A-Register.

Write

The contents of the buffer is written on tape preceded by the record length. Since a minimum of 7 tape characters (12 on 3030) may be written, short records are padded by the subroutine.

If the end-of-tape is detected during the write operation, the normal return is used. The next write operation, however, results in a return of control of the EOF/EOT location; no data is written. If an EOT condition exists at the time of entry, the command will be ignored and control willbe returned to the EOT/EOF address.

If the write request length specified is 0 control will return to the normal address without any tape movement.

If an error is detected during the write operation, the tape will be back-spaced over the bad record, 3 inches of tape will be erased, and another attempt will be made. These attempts will continue until either a good record is made or until the EOT is detected at which time the control will return to the error address.

Write End-of-File

A standard EOF character (17_8 for 2020, 23_8 for 3030) is written on tape. Control return to the normal location with the EOF status on the B-Register. No gap is written.

If the end of tape was reached on a previous write command, control returns to the EOF/EOT location; the character is written.

Rewind

This command initiates a rewind operation and then immediately returns control to the normal location.

The calling sequence for a Rewind operation consists of:

```
JSB      107B,I
OCT      3
<normal return>
```

The user need not test status on the rewind operation before issuing the next call.

Position

This is the general command to move the tape. Both file and record operations may be defined in the same operation. Either may be specified for forward or backward spacing. At the completion of the operation the tape will be positioned ready for reading or writing.

An attempt to space beyond the End-of-Tape or Start-of-Tape will terminate the positioning operation and return control to the EOF/EOT/SOT location.

Rewind / Standby

This causes the tape to be positioned at load point and switches the device to local status. Control returns to the normal location immediately after the operation is initiated.

The calling sequence for a Rewind / Standby operation consists of:

```
    JSB      107B,I
    OCT       5
    <normal return>
```

An attempt to issue another call on this device results in a halt (102044). The device must be switched to AUTO before the program can continue.

Gap

This command causes a 3-inch gap to be written on the tape.

If the End-of-Tape was reached on a previous write command, control returns to the EOF/EOT location; the gap is not written.

Status

This command returns certain status bits in the B-Register. The driver performs a clear command whenever it is entered and as a result the only bits that are valid indicators are:

Start-of-Tape
End-of-Tape
Write Not Enabled

All other commands (except Rewind and Rewind/Standby) provide valid status replies on return to the program.

The status reply consists only of bits 8-0 and has the following significance:

Bits 8-0	Condition
1xxxxxxxx	Local - The device is in local status
x1xxxxxxx	EOF- An End-of-File character (17_8 for 7 track, 23_8 for 9) has been detected while reading, forward spacing, or backspacing.
xx1xxxxxx	SOT - The Start-of-Tape marker is under the photo sense head.
xxx1xxxxx	EOT - The End-of-Tape reflective marker is sensed while the tape is moving forward. The bit remains set until a rewind command is given.
xxxx1xxxx	Timing - A character was lost.
xxxxx1xxx	Reject - a) Tape motion is required and the unit is busy. b) Backward tape motion is required and the tape is at load point. c) A write command is given and the tape reel does not have a write enable ring.
xxxxxx1xx	Write not enabled - Tape reel does not have write enable ring or tape unit is rewinding.
xxxxxxx1x	Parity error - A vertical or longitudinal parity error occurred during reading or writing. (Parity is not checked during forward or backward spacing operations.)
xxxxxxxx1	Busy - The tape is in motion or the device is in local status.

Following is a table summarizing the tape commands:

Operation	Command Code	Call		Return	
		A	B	A	B
Read	Ø	Buffer Length	Buffer Address	Buffer or Record Length	Status
Write	1	Buffer Length	Buffer Address	Buffer Length	Status
Write EOF	2	-	-	-	Status
Rewind (Auto mode)	3	-	-	-	-
Position	4	Number of Files, Direction	Number of Records, Direction	-	Status
Rewind/ Standby (Local mode)	5	-	-	-	-
Gap	6	-	-	-	Status
Status	7	-	-		Status

Error Messages

Tape Unit in Local Status: The subroutine halts with 102044 in the T-Register. Switch tape unit to AUTO mode and press RUN to continue.

Write Not Enabled: The subroutine halts with 102011 in the T-Register. The error is irrecoverable.

Additional Linkage Addresses

Other locations in the System Linkage area contain the following:

100_8 Used by the standard software system to store a JMP to the transfer address.

105_8 First word address of available memory.

106_8 Last word address of available memory.

The latter two locations may be accessed by an absolute program. The user may store the first word of available memory in 105 by performing the following:

```
ORG  105B
ABS  < last location of user program +1 >
```

The last word of available memory is established by the drivers; it is the location immediately preceding the first location used by the last driver loaded.

BUFFER STORAGE AREA

The Buffer Address is the location of the first word of data to be written on an output device or the first word of a block reserved for storage of data read from an input device. The length of the buffer area is specified in the A-Register in terms of ASCII input or output characters or binary output words. For binary input, the length of the buffer is the length of the record which is specified in the first character of the record. ASCII and binary input record lengths are given as positive integers. The length of a binary output record is specified as the two's complement of the number of words in the record.

In addition to describing the buffer area in the calling sequence, (or first word of binary input record), the area must also be specifically defined in the program, for example with a BSS instruction.

Record Formats

ASCII Records (Paper Tape)

An ASCII record is a group of characters terminated by an end-of-record mark which consists of a carriage return, CR, and a line feed, LF.

For an input operation, the length of the record transmitted to the buffer is the number of characters designated in the A-Register, or less if an end-of-record mark is encountered before the character count is exhausted. The codes for (CR) and (LF) are not transmitted to the buffer. An end-of-record mark preceding the first data character is ignored.

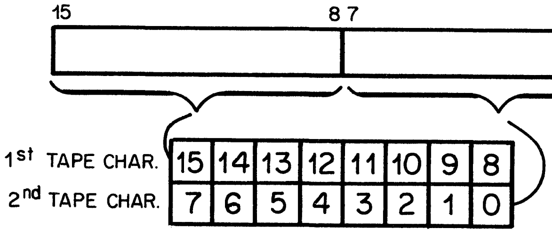
For an output operation, the length of the record is determined by the number of characters designated in the request. An end-of-record mark is supplied at the end of each output operation by the driver.

If a (RUB OUT) code followed by a (CR)(LF) is encountered on input from the Teleprinter or Punched Tape Reader, the current record is ignored (deleted) and the next record transmitted. †

If less than ten feed frames (all zeros) are encountered before the first data character from the Punched Tape Reader, they are ignored. Ten feed frames are interpreted as an end-of-tape condition.

Binary Records (Paper Tape)

A binary record is transmitted exactly as it appears in memory or on 8-level paper tape. Each computer word is translated into two tape "characters" (and vice versa) as follows:



1st TAPE CHAR.	15	14	13	12	11	10	9	8
2nd TAPE CHAR.	7	6	5	4	3	2	1	0

For an output operation, the record length is the number of words designated by the value in the A-Register (the value is the two's complement of the number of words). For input operations, the first word of the record contains a positive integer in bits 15-8 specifying the length (in words) of the record including the first word.

† (RUB OUT) which appears on the Teleprinter keyboard is synonymous with the ASCII symbol (DEL)

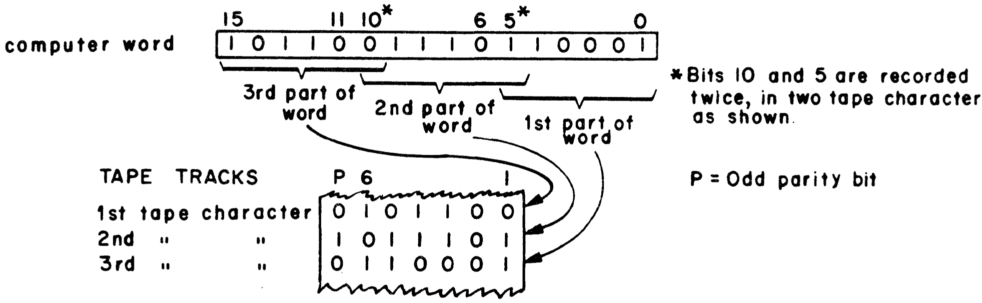
On input operations if less than ten feed frames precede the first data character, they are ignored; ten feedframes are interpreted as an end-of-tape condition. On output, the driver writes four feed frames to serve as a physical record separator.

Binary Records (Magnetic Tape)

The Magnetic Tape subroutine reads and writes binary (odd parity) records only. A record count is supplied by the driver as the first word of the record. This allows automatic padding of short records to the minimum record length with automatic removal of the padded portion of the record on read.

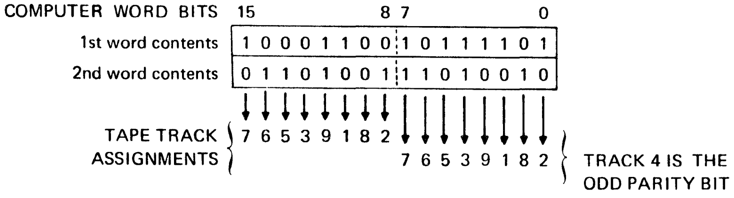
2020 7-LEVEL TAPE

Each Computer word is translated into three tape "characters" (and vice versa) as follows:



3030 9-LEVEL TAPE

Each Computer Word is translated into Two tape "characters" by repositioning the bits in the following scheme:



TAPE TRACKS	9					4			1
1st tape character	1	0	1	0	0	0	0	0	1
2nd tape character	1	0	1	0	1	1	1	1	1
3rd tape character	1	0	0	1	1	1	0	1	0
4th tape character	0	1	1	1	0	1	1	0	0

OPERATION AND CALLING SEQUENCE: MARK SENSE CARD READER

The SIO Mark Sense Card Reader Driver overlays the Punched Tape Reader Driver exactly, therefore, only one or the other of these two Drivers may be used in any one SIO System configuration. Further, the Driver has no binary read capability; if this ability is needed, the BCS Mark Sense Card Reader Driver will have to be used.

All data transmission is accomplished without interrupt control. Execution control is not returned to the calling program until either a complete card has been read.

The general form of the calling sequence is:

```
 LDA <character count > (positive)
 LDB <buffer address>
 JSB <101B,I>
< normal return >
```

Register Contents

Before the JSB is executed, the A-Register must contain the character count (the buffer length) and the B-Register must contain the buffer address. Control returns to the location following the JSB; then the A-Register will contain the number of characters transmitted not including trailing blanks, or, if a transmission error was detected, it will contain all zeroes.

FORMATTER F

CALLING SEQUENCES

The Formatter is a library subroutine used by FORTRAN and ALGOL to input or output data. An assembler program may access the Formatter routine with a 5 to 9 line calling sequence depending on the form of the call.

I. Format Definition

	INPUT		OUTPUT	
	LDA	(unit)	LDA	(unit)
Formatted	CLB, INB		CLB	
	JSB	.DIO.	JSB	.DIO.
	DEF	(fmt) or ABS 0	DEF	(fmt)
	DEF	(end of list)	DEF	(end of list)
	LDA	(unit)	LDA	(unit)
Binary	CLB, INB		CLB	
	JSB	.BIO.	JSB	.BIO.

where

unit — refers to the unit reference number of the device to be called

fmt — is the label of an ASC pseudo instruction which defines the format specification

end of list — is the location immediately following the last parameter of the calling sequence; it is to this location that the Formatter returns control.

ABS 0 — is an option for free field input

formatted input/output — is in ASCII code

binary input/output — is in binary code

II. Element Definition

```
                  INPUT                  OUTPUT

Real Variable     JSB    .IOR.           DLD    x
                  DST    x               JSB    .IOR.

Integer Variable  JSB    .IOI            LDA    i
                  STA    i               JSB    .IOI.

Array             LDA    array length
                  LDB    array address
                  JSB    .RAR. (real)  or  .IAR. (integer)
```

where

x or i — are addresses, real or integer, of the data

array length — is the number of elements (not the number of memory locations) in the block of data. (Maximum length is equivalent to 60 computer words.)

III. Terminator

```
                  INPUT              OUTPUT

                  (none)             JSB    .DTA.
```

Symbols such as .DIO., .IOR., etc., are entry points to the Formatter; all entry points used in the calling sequence must be declared external with an EXT pseudo code.

Data stored in memory may be converted internally from one format to another with the following initial call.

```
        LDA     =BO
        JSB     .DIO.
        DEF     buffer
        DEF     (fmt)
        DEF     (end of list)
         .
         .
        Element Definition
         .
        Terminator
```

where buffer is the address of the data to be converted.

FORMAT SPECIFICATIONS

Below are listed the format conversion and editing specifications.

rAw	Alphanumeric character
rEw.d	Real number with exponent
rFw.d	Real number without exponent
rIw	Decimal integer
r@w rKw	Octal integer
nX	Blank field descriptor
nHh$_1$. . . h$_n$ r"h$_1$. . . h$_n$"	Heading and labeling descriptors
r/	Begin new resord

where

r is the number of times the entire format is repeated

w is the number of digits in the format

d is the number of digits to the right of the decimal point (w-d should be greater than or equal to 4)

n is the number of characters or spaces

h's represents the ASCII characters

Aw translates alphanumeric data to or from memory. If w is greater than 2 only the last two characters are processed; if w is 1, the single character is read into or written from the right-half of the computer word.

Ew converts data to a real number. On output, data may consist of integer, fraction, and exponent subfields.

$$\overset{+}{\underset{N}{-}} n \ldots n.n \ldots n \overset{+}{\underset{E}{-}} ee$$

On output, data appears in floating point form.

$$\overset{\triangle}{-}.\ x_1 \ldots x_d\ E \pm ee$$

Fw

For output operations real numbers in memory are converted to character form which will appear right justified in decimal form. Input is identical to the E specification input.

$\underline{\wedge}\, x \ldots x . x \ldots x$

Iw

translates decimal integers to or from memory

$\underline{\wedge}\, x_1 \ldots x_d$

@w and Kw

translates octal integers to or from memory.

$\underline{\wedge}\, x_1 \ldots x_d$

$nHh_1 . . . h_n$

provides for the transfer of any combination of 8-bit ASCII characters, including blanks.

r“$h_1 . . . h_n$”

also transfers ASCII characters; field length is not specified, quotation marks are not transferred.

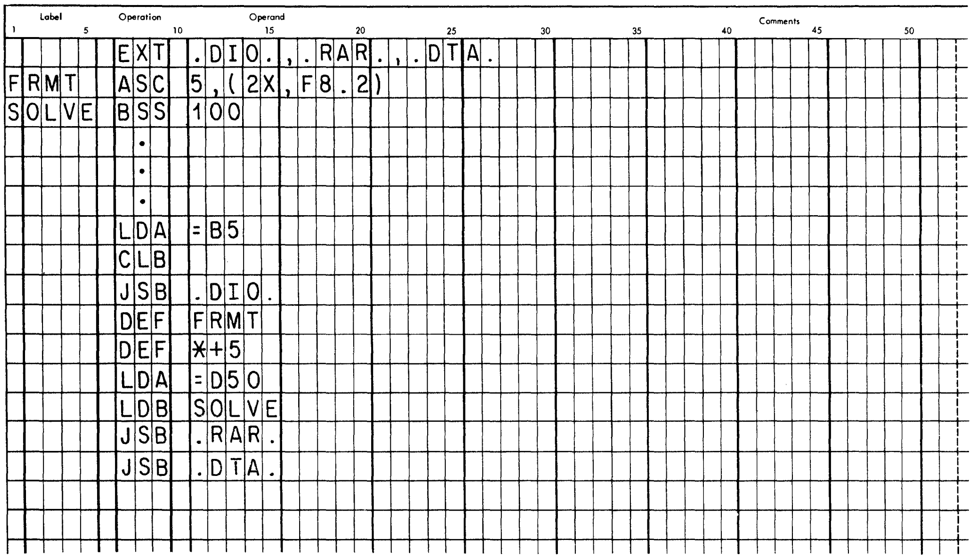
(For a more detailed description of the Format specifications see the FORTRAN Programmer's Reference Manual, Section 7.)

EXAMPLE

Below is an example of a calling sequence to the Formatter that will output the contents of a block data, SOLVE, such that each number is printed on the teleprinter in the following manner:

xxxxxx. xx

SOLVE occupies 100_{10} memory locations; the data stored there is in floating point form.



Label
Operation
Operand
Comments
1
5
10
15
20
25
30
35
40
45
50

```
       EXT .DIO.,.RAR.,.DTA.
FRMT   ASC 5,(2X,F8.2)
SOLVE  BSS 100
        .
        .
        .
       LDA =B5
       CLB
       JSB .DIO.
       DEF FRMT
       DEF *+5
       LDA =D50
       LDB SOLVE
       JSB .RAR.
       JSB .DTA.
```

CROSS REFERENCE TABLE GENERATOR G

The Cross Reference Symbol Table Generator routine processes an Assembly Language source program and prints a cross reference list of all symbols appearing in the program. The list contains the symbols in alphabetic order. Each is followed by the 4-digit sequence number of the statement in which the symbol was defined and the sequence numbers of all statements referring to the symbol. If the source program is contained on more than one tape, the tape number follows the statement sequence number. The tape number is determined by the order in which the tapes are submitted to the generator routine; it is not printed for the first tape. The general format of the list is as follows:

```
sssss dddd/tt rrrr/tt rrrr/tt rrrr/tt rrrr/tt rrrr/tt rrrr/tt
```

sssss = symbol
dddd = defining statement number (modulo 2048)
tt = tape number (modulo 31)
rrrr = reference statement numbers (modulo 2048)

Example:

The program;

```
(0001)           NAM TESTT
(0002)    BEGIN  DLD A
(0003)           FMP  A
(0004)           DST A
(0005)    TEST   ISZ I
(0006)           JMP BEGIN
(0007)           HLT 3
(0008)           COM A (2),I
(0009)           END
```

yields the cross reference table:

```
A       0008   0002   0003   0004
BEGIN   0002   0006
I       0008   0005
TEST    0005
```

If the Assembly Language program uses the IFN or IFZ psuedo-operations, doubly defined symbols may appear in the cross-reference listing. For literals, the statement number is always 0000 00 because the literal definition is not assigned a statement number. Only the first five characters of the literal, including the =, will become the symbol that is cross-referenced. As a result, different literals may be listed under the same entry in the listing (i.e., =D3156 and =D3157 would be listed under =D315). Negative literals are all listed under the symbol =D.

The Cross-Reference Symbol Table Generator can operate with or without a magnetic tape unit. The Generator checks location 107_8 to check whether a magnetic tape driver is present in core; if one is, the Generator assumes that the source program is already present on the magnetic tape (as it would be if it were written by a previous assembly or edit).

In addition, the Generator can be run stand-alone or as a part of the Magnetic Tape System. For operating procedures in the Magnetic Tape System, consult the MAGNETIC TAPE SYSTEM manual (02116-91752).

OPERATING PROCEDURES

A. Set Teleprinter to LINE and check that all equipment to be used is operable.

B. Load Cross Reference Symbol Table Generator using the Basic Binary Loader. †

1. Place Cross Reference Symbol Table Generator in the unit serving as the Standard Input unit (e.g., Punched Tape Reader).

2. Set Switch Register to starting address of Basic Binary Loader.

† The appropriate System Input/Output subroutines (drivers) are assumed to be included with the Cross Reference Table Generator program.

3. Press LOAD ADDRESS.

4. Set Loader switch to ENABLE.

5. Press PRESET.

6. Press RUN.

7. When the computer halts and indicates that the Cross Reference Symbol Table Generator is loaded (T-Register contains 102077), set Loader Switch to PROTECTED.

C. Set Switch Register to starting address of Cross Reference Table Generator.

000100

D. Press LOAD ADDRESS.

E. Place source language tape in unit serving as the Standard Input unit (e.g., Punched Tape Reader). If magnetic tape driver is present, source must be on third file of magnetic tape. If the number of symbols in the program is large enough to cause a table overflow, set switch register bit 15 up (on) to break the cross-reference into several passes based on character ranges. The Generator prints:

```
** ENTER CHARACTER RANGE:
```

The operator responds with two ASCII characters followed by a carriage-return and line feed. This causes the Generator to cross-reference only the symbols beginning with the characters between the two characters specified. Consult Appendix A for a full list of the characters. For three passes, the recommended ranges are:

```
(space) 9
:L
M ←
```

F. Press RUN.

G. At the end of each tape other than the last, the computer halts (102057). Repeat E and F.

H. At the end of the last tape (the tape containing the END statement), the table is printed on the Standard List Output device (e.g. , Teleprinter). When the table is printed, the computer halts. The B-register contains the number of symbols cross-referenced.

During the operation of the routine, the following may be printed:

Teleprinter Message	Explanation	Action
DD symbol	A doubly defined symbol has been encountered. The computer does not halt.	Correct source program after completion of routine.
TABLE OVERFLOW	The combined number of symbols and references to them exceeds the capacity of the routine.	Irrecoverable error. If the Table is necessary, the source program must be revised.

CONSOLIDATED CODING SHEET

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D/I	AND		001	0	Z/C	← Memory Address →									
D/I	XOR		010	0	Z/C										
D/I	IOR		011	0	Z/C										
D/I	JSB		001	1	Z/C										
D/I	JMP		010	1	Z/C										
D/I	ISZ		011	1	Z/C										
D/I	AD*		100	A/B	Z/C										
D/I	CP*		101	A/B	Z/C										
D/I	LD*		110	A/B	Z/C										
D/I	ST*		111	A/B	Z/C										

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	SRG		000	A/B	0	D/E	*LS		000	CLE	D/E	SL*	*LS		000
							*RS		001				*RS		001
							R*L		010				R*L		010
							R*R		011				R*R		011
							*LR		100				*LR		100
							ER*		101				ER*		101
							EL*		110				EL*		110
							*LF		111				*LF		111
				NOP	000				000		000				000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	ASG		000	A/B	1	CL*	01	CLE	01	SEZ	SS*	SL*	IN*	SZ*	RSS
						CM*	10	CME	10						
						CC*	11	CCE	11						

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	IOG		000	A/B	1	H/C	HLT		000	← Select Code →					
					1	0	STF		001						
					1	1	CLF		001						
					1	0	SFC		010						
					1	0	SFS		011						
					1	H/C	MI*		100						
					1	H/C	LI*		101						
					1	H/C	OT*		110						
				0	1	H/C	STC		111						
				1	1	H/C	CLC		111						
					1	0	STO		001		000			001	
					1	1	CLO		001		000			001	
					1	H/C	SOC		010		000			001	
					1	H/C	SOS		011		000			001	

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	EAU		000	MPY**		000		010			000			000	
				DIV**		000		100			000			000	
				DLD**		100		010			000			000	
				DST**		100		100			000			000	
				ASR		001		000		0	1		← number of bits →		
				ASL		000		000		0	1				
				LSR		001		000		1	0				
				LSL		000		000		1	0				
				RRR		001		001		0	0				
				RRL		000		001		0	0				

Notes: * = A or B.
D/I, A/B, Z/C, D/E, H/C coded: 0/1.
**Second word is Memory Address.

INDEX

CUT ALONG LINE

HEWLETT PACKARD

READER COMMENT SHEET

HP ASSEMBLER

HP 02116-9014 April, 1970

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