HP Assembler

Programmer's Reference Manual

HEWLETT hp PACKARD

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PREFACE

This publication is the reference manual for the Hewlett-Packard Assembly Language for the 2100 family of computers. Since Hewlett-Packard provides assemblers with all of its operating systems, this manual covers only the specifications of assembly language, not operating procedures for the assemblers. The user should refer to the appropriate system manual or operator's guide listed below:

SOFTWARE OPERATING PROCEDURES	
SIO SUBSYSTEMS module	(5951-1390)
DISC OPERATING SYSTEM	(02116-91748)
MOVING-HEAD DISC OPERATING SYSTEM	(02116-91779)
MAGNETIC TAPE SYSTEM	(02116-91752)

In addition, the Formatter and other relocatable subroutines that can be called by relocatable assembly language programs are described in full in the RELOCATABLE SUBROUTINES manual (02116-91780). Interaction between relocatable programs and operating systems is described in:

BASIC CONTROL SYSTEM	(02116-9017)
MOVING-HEAD DISC OPERATING SYSTEM	(02116-91779)
DISC OPERATING SYSTEM	(02116-91748)
MAGNETIC TAPE SYSTEM	(02116-91752)

Interaction between absolute programs and SIO drivers is described in an appendix to this book.

NEW AND CHANGED INFORMATION

All known errors in this manual have been corrected. In addition, the Assembler operating procedures (formally in Section V) are now contained in the *SOFTWARE OPERATING PROCEDURES, SIO SUBSYSTEMS* module (5951-1390).

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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 relocatable subprograms (or a main program and several subroutines), each of which may be assembled separately. The relocating loader loads the program and Links the subprograms as required. The Basic Binary Loader or Basic Binary Disc Loader loads absolute programs.

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

SECTION I
GENERAL DESCRIPTION

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 a program listing. Additional diagnostic messages may also be produced.

If only the 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 mass storage device the source program is written on the device during the first pass; the second pass of the source is read from the mass storage.

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.

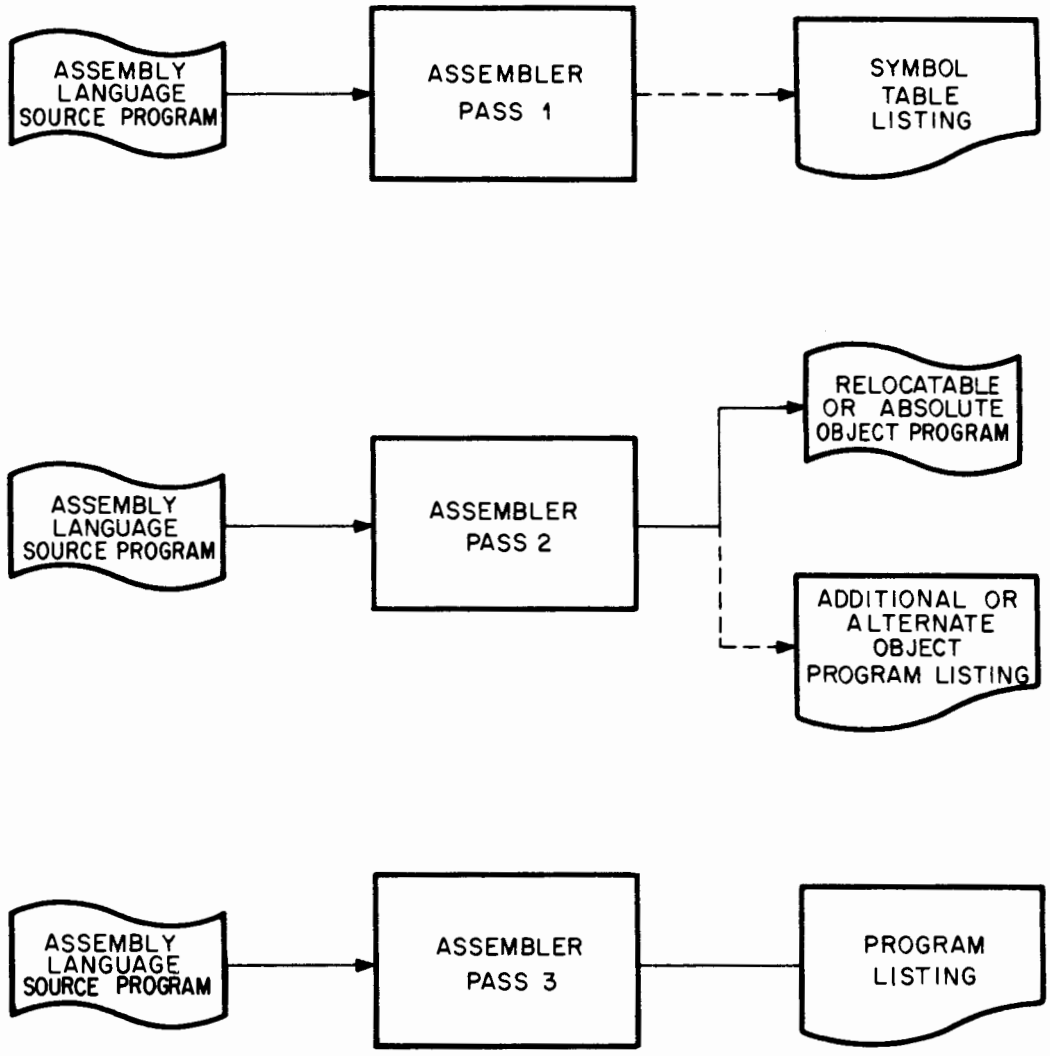


Figure 1-1. HP Assembler Processing

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

PROGRAM RELOCATION

Relocatable programs may be relocated in core by the relocating 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.

PROGRAM LOCATION COUNTERS

The Assembler maintains a counter, called the program location counter, that assigns 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.

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.

†See Section V for complete details.

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.

SECTION II
INSTRUCTION FORMAT

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.

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.

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

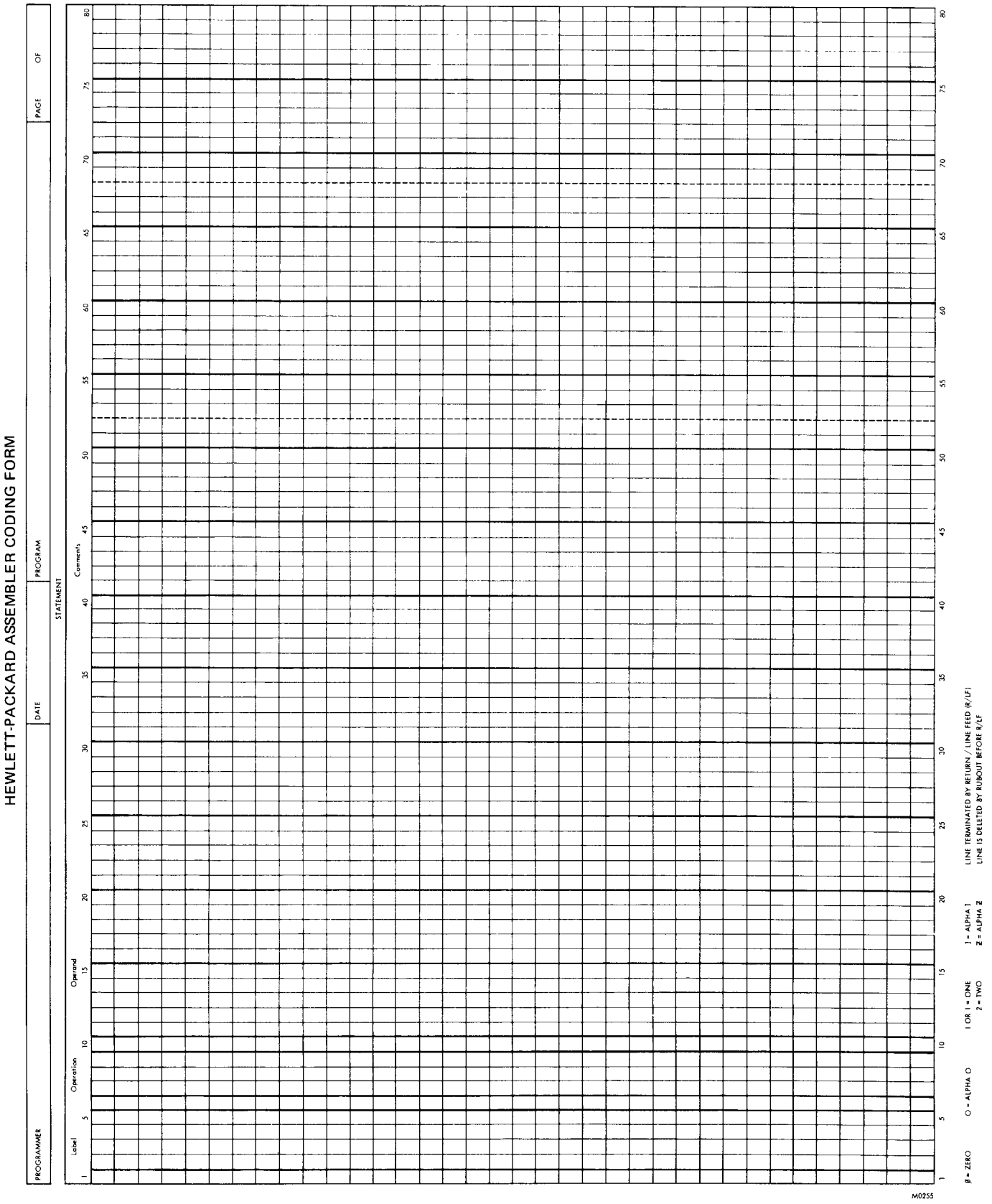


Figure 2-1. Sample Coding Form (Actual Size 11 x 13-1/2)

Character Set

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

A through Z
0 through 9
. (period)
* (asterisk)
+ (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.

LABEL FIELD

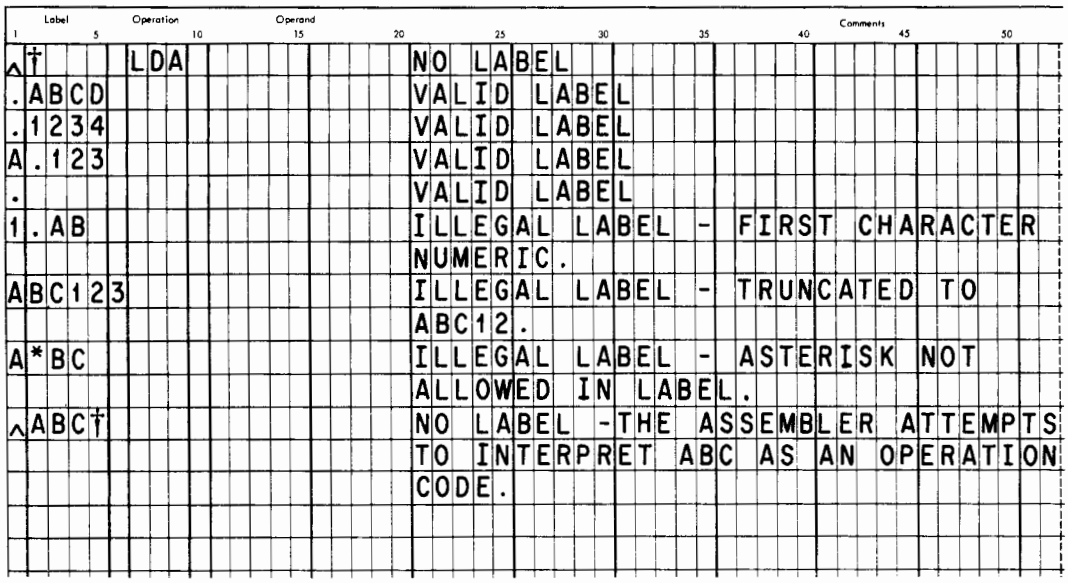
The Label field identifies the statement and may be used as a reference point by other statements in the program.

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:



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

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
                    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.

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 Sections III and IV.

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 -.

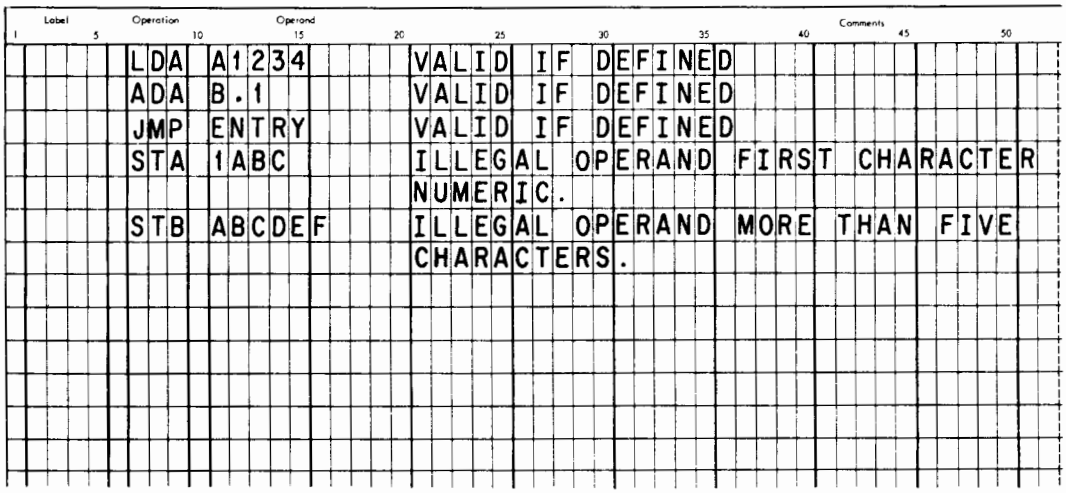
An expression may be followed by a comma and an indicator.

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:



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)

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

†The evaluation of expressions by the Assembler is compatible 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.

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:

$A-C_1 + C_2$	$A - P_1 + P_2$	$C_1 - C_2 + A$
$A + A$	$P_1 - P_2$	$B_1 - B_2$
$* - P_1$	$B_1 - B_2 - A$	$-C_1 + C_2 + A$
$B_1 - *$	$- P_1 + P_2$	$-A -P_1 +P_2$

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	C_1-A	B_1+A
P_1-P_2+P_3	C_1-C_2+C_3	C_1+A
*+A	*-P_1+P_2	*-A
A+B_1	A+C_1	-A-P_1+P_2+P_3
B_1-B_2+B_3-A	C_1-C_2+C_3-A	A+*
+P_1-	P_1-P_2+*	-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.

† See CONSTANT DEFINITION, Section 4.

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		

Examples:

LDA	=D798Ø	A-Register is loaded with the binary equivalent of $798Ø_{1Ø}$.
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
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 loader provides indirect addressing whenever it detects an operand which does not fall in the current page or the base page. The 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.

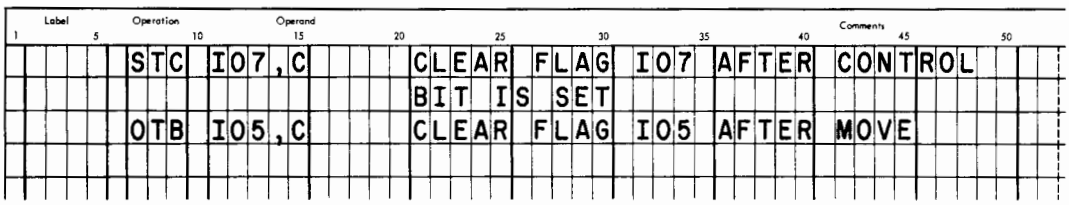
Base Page Addressing

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 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:



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 is 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.

SECTION III
MACHINE INSTRUCTIONS

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

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	{m [,I] / lit}	comments

Add the contents of m to A.

label	ADB	m [,I] {lit}	comments

Add the contents of m to B.

label	LDA	m [,I] {lit}	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.

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.

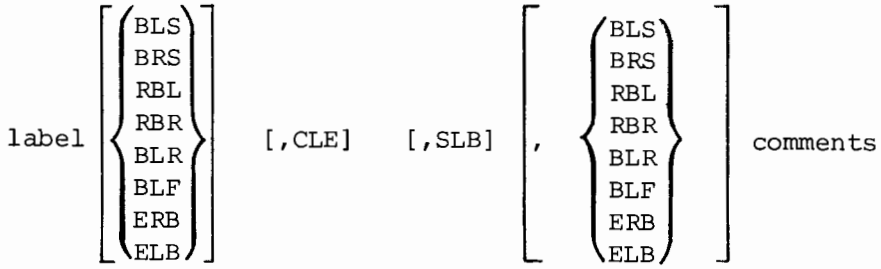
Shift-Rotate Group

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:

```
label [{ALS}] [,CLE] [,SLA] [,{ALS}] comments
      [{ARS}]                [{ARS}]
      [{RAL}]                [{RAL}]
      [{RAR}]                [{RAR}]
      [{ALR}]                [{ALR}]
      [{ALF}]                [{ALF}]
      [{ERA}]                [{ERA}]
      [{ELA}]                [{ELA}]
```



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	[{CLA / CMA / CCA}] [,SEZ]	[,{CLE / CME / CCE}] [,SSA] [,SLA] [,INA] [,SZA] [,RSS]		comments
label	[{CLB / CMB / CCB}] [,SEZ]	[,{CLE / CME / CCE}] [,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).

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 or 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.

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.

† See ARITHMETIC SUBROUTINE CALLS, Section 4.

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 $1 \leq n \leq 16$.

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.

```
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.

FLOATING-POINT INSTRUCTIONS

Floating-point instructions provide a means of performing calculations on floating-point values. Computers with the hardware floating-point option should use assemblers and libraries with floating-point capabilities. The floating-point assembler generates calls to the appropriate hardware function instead of the library subroutines. If the computer does not have the hardware floating-point option, then non-floating-point assemblers and libraries should be used.

FAD	m[I,] lit	comments

FAD performs an addition between a floating-point number stored in the A- and B-registers and a floating-point number stored in memory locations m and m + 1 The result is returned in the A- and B-registers.

FSB	m[I,] lit	comments

The FSB instruction subtracts a floating-point value in memory locations m + 1 from a floating-point value in the A- and B-registers. The result is returned in the A- and B-registers.

FMP	m[I,] lit	comments

The FMP instruction multiplies a floating-point value in memory locations m and m + 1 with a floating-point value in the A- and B-registers. The result is returned in the A- and B-registers.

FDV	m[I,] lit	comments

The FDV instruction divides the floating-point value in memory locations m and m + 1 into the value stored in the A- and B-registers. The result is returned in the A- and B-registers.

FIX		comments

The FIX instruction converts a floating-point number contained in the A- and B-registers to a fixed point number. The result is returned in the A-register. The contents of the B-register are meaningless.

FLT		comments

The FLT instruction converts a fixed-point value contained in the A-register to a floating-point value. The result is returned in the A- and B-registers.

SECTION IV
PSEUDO INSTRUCTIONS

The pseudo instructions control the Assembler, establish program relocatability, 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.

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 DOS, DOS-M 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.

---

† 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.

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.

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	COMMENT

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

Example:

```
Label Operation Operand          Comments
      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.
```

† 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.

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:

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```
Label     Operation  Operand     Comments
      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
      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.

†See CONTROL STATEMENT, Section 5.

```
        |          |
        |   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.

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.

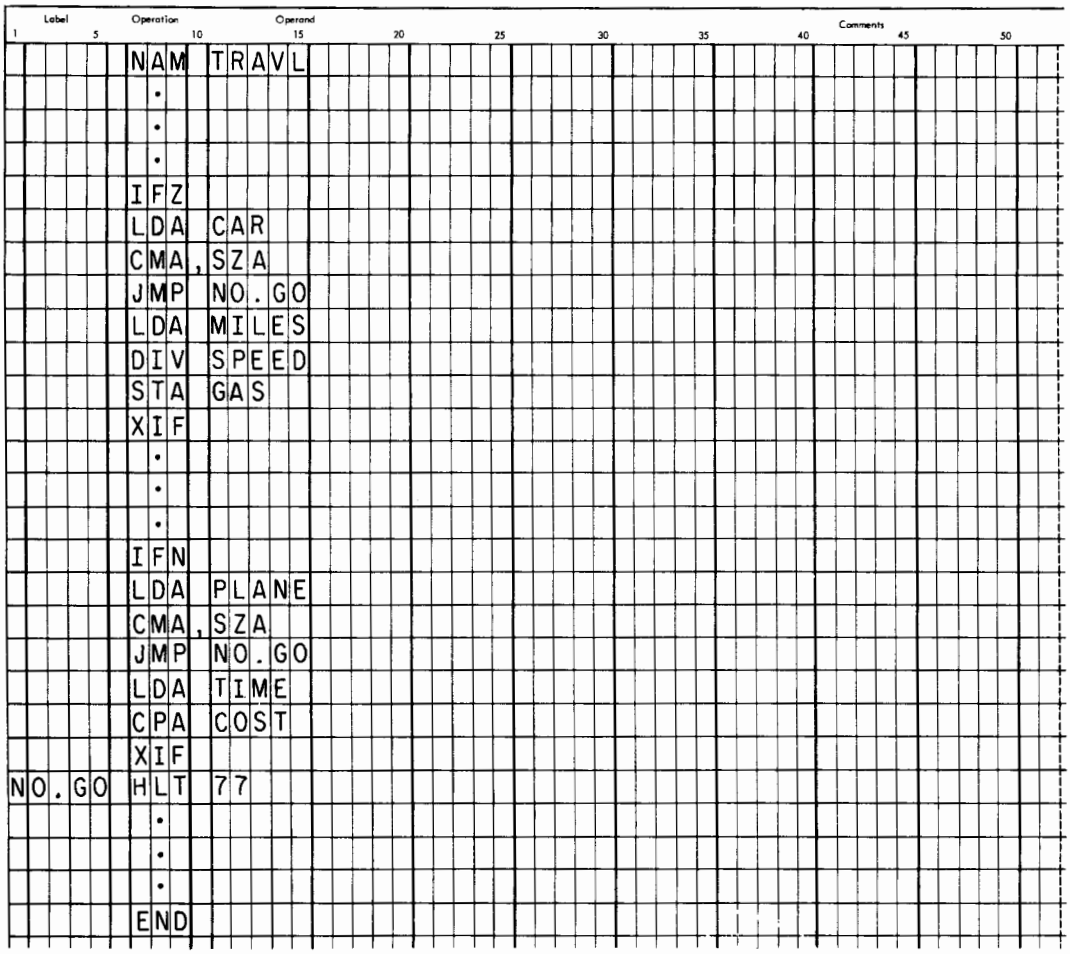
```
        |          |
        |   IFZ    |  comments
        |          |
          :
          :
          :
         XIF
```

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.

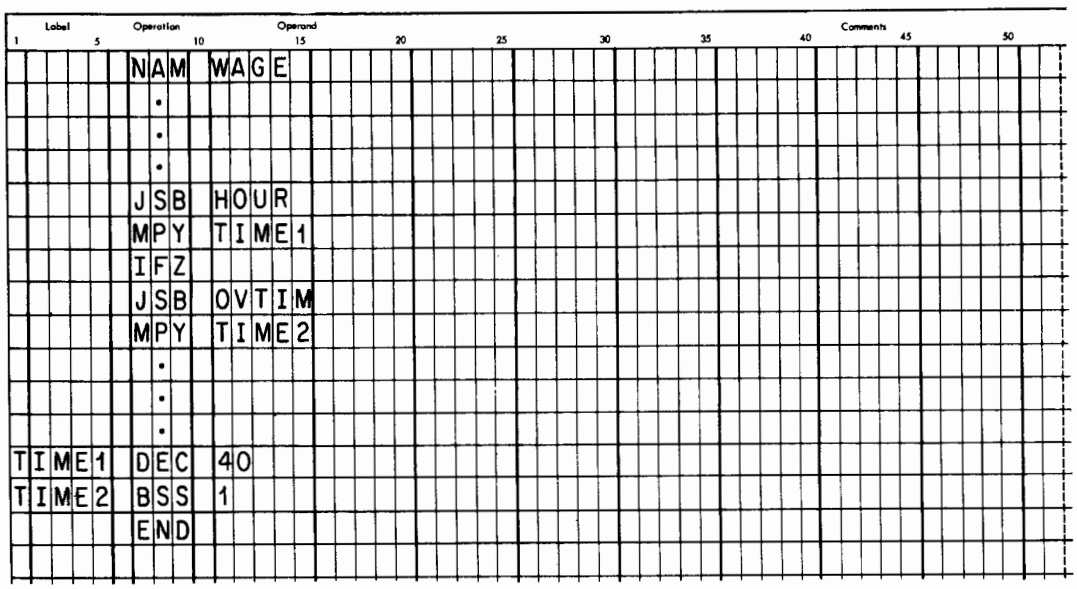
Example:



```
Label     Operation     Operand                    Comments
          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:



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 is
TRIPL     ADA     DATA      tripled and stored in the A-Register.
          ADA     DATA
          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 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.

OBJECT PROGRAM LINKAGE

Linking pseudo instructions provides 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 may be 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, [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 n^{th} word of common storage is the same for all subprograms.

```
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 that 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.

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

This instruction designates labels in other subprograms that 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
```

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.

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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.

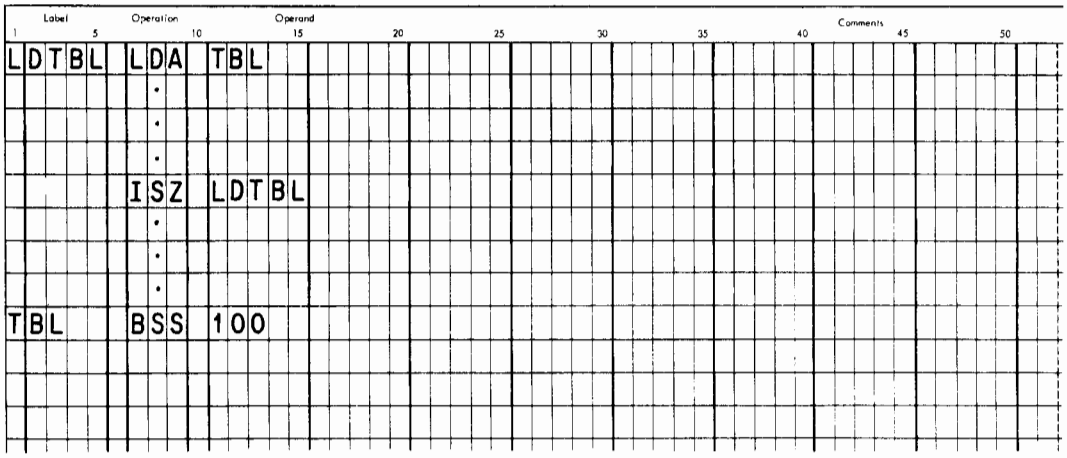
Example:

```
Label  Operation  Operand   Comments
      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 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:



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

Page	Loc	Opcode	Reference
(0)	(700)	DEF	400
		⋮	
(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 sucessive 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:

```
Label     Operation  Operand          Comments
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
        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
        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.
```

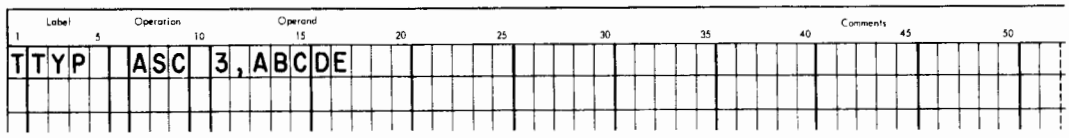
CONSTANT DEFINITION

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 sero. 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:



causes the following:

ALPHABETIC

	15 14			8	7	6			0
TTYP	A					B			
	C					D			
	E					Λ			

EQUIVALENT IN OCTAL NOTATION

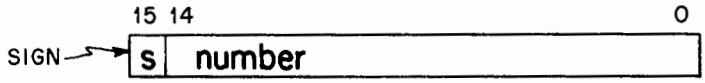
	15 14			8	7	6			0
TTYP	1	0	1			1	0	2	
	1	0	3			1	0	4	
	1	0	5			0	4	0	

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

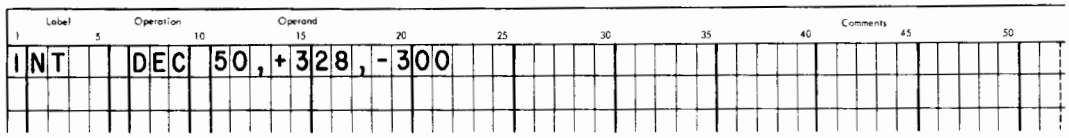
label	DEC	$d_1[.d_2,\ldots,d_n]$	comments

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:



Example:



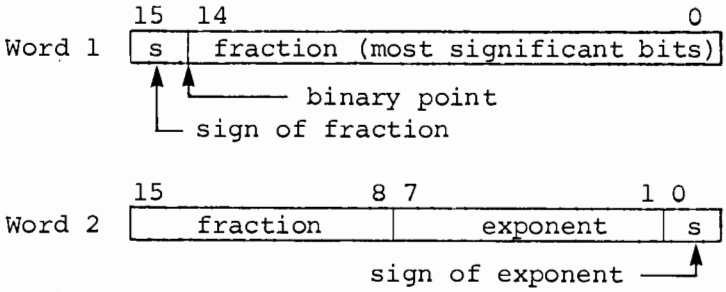
causes the following (octal representation)

	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 multiplied. 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:

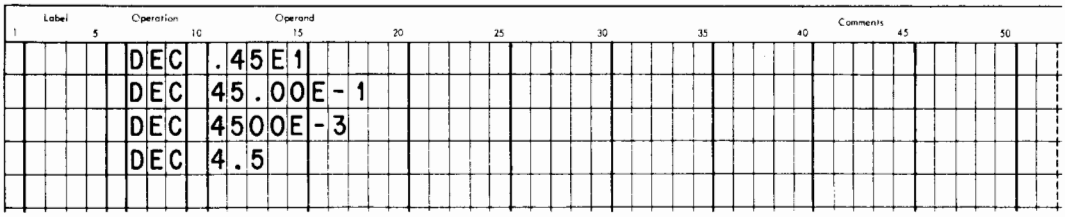
$\pm n.n \quad \pm n. \quad \pm n.nE\pm e \quad \pm .nE\pm e \quad \pm n.E\pm e \quad \pm nE\pm e$

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} and zero.

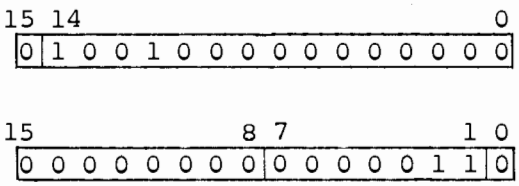
Examples:

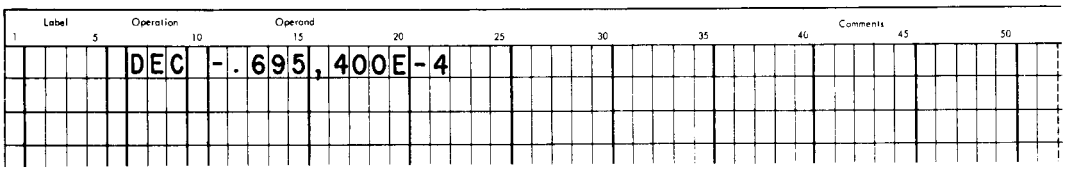


are all equivalent to

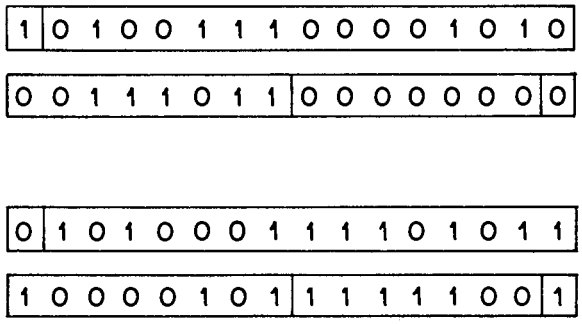
$$.45 \times 10^{1}$$

and are stored in normalized form as:





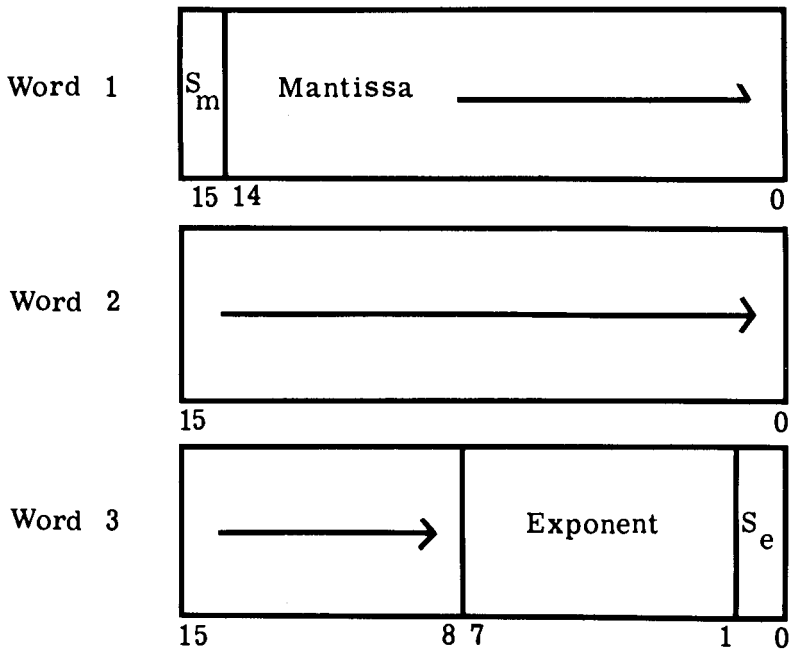
are stored as:



Computer Museum

label	DEX	$d_1[,d_2 ,\ldots , d_n]$	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	1001101111111111

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
	0	0	0	0	0	0
	1	7	7	7	7	6
NUM	0	0	0	1	7	7
	0	2	0	4	0	5
	1	7	7	7	4	2
	0	0	0	0	5	1
	0	7	7	7	7	7
	1	7	7	7	7	7
	0	1	0	1	0	1
	1	0	7	6	4	2
	1	7	7	0	7	7
	X	X	X	X	X	X
	0	0	0	0	0	1
	X	X	X	X	X	X

THE RESULT OF ATTEMPTING TO DEFINE AN ILLEGAL CONSTANT IS UNPREDICTABLE

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.

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	DIV	FAD	FSB
OCT	DLD	FDV	MPY
DEC	DST	FMP	

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.

ARITHMETIC SUBROUTINE CALLS

The members of this group of pseudo instructions request the Assembler to gener te 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 quanity 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

* Not intended for use with DEX formatted numbers. For such numbers JSB's to double precision subroutines must be used. See RELOCATABLE SUBROUTINES Manual.

Multiply the two-word floating point quanity 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.

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.

SECTION V
ASSEMBLER INPUT AND OUTPUT

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.

CONTROL STATEMENT

The control statement specifies the output to be produced:

$$\text{ASMB},p_1,p_2,\ldots,p_n$$

"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 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.

F Accepted by the Assembler to provide compatibility with DOS or DOS-M Assembler programs. F causes no action in any other assemblers.

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.

ASSEMBLER INPUT AND OUTPUT

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.

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.

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.)

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:

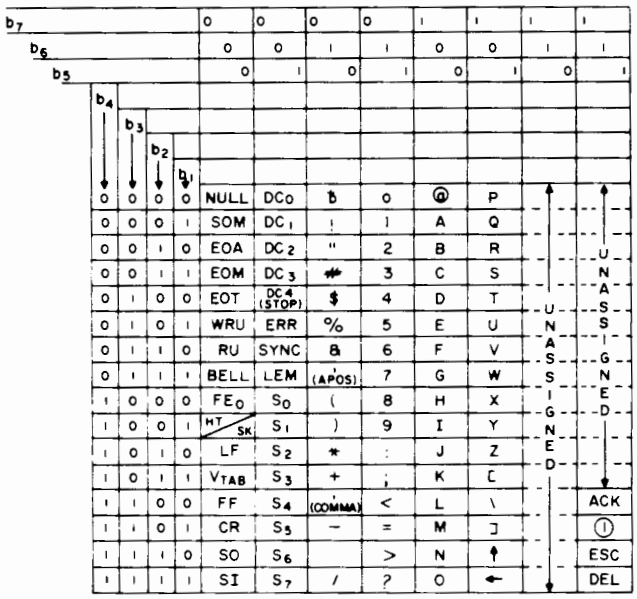
```
**NO ERRORS*
  or
**nnnn ERRORS*
```

The value nnnn indicates the number of errors.

Note: For complete operating instructions for the HP Assembler or Extended Assembler, consult *SOFTWARE OPERATING PROCEDURES, SIO SUBSYSTEMS* module, (5951-1390).

APPENDIX A
HP CHARACTER SET

ASCII 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	b	0	@	P	
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	DC_4 (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	\	
1	1	0	1	CR	S_5	-	=	M	]	
1	1	1	0	SO	S_6	.	>	N	↑	
1	1	1	1	SI	S_7	/	?	O	←	

UNASSIGNED

UNASSIGNED

ACK

①

ESC

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.

Example: The code for "R" is:

b_7	b_6	b_5	b_4	b_3	b_2	b_1
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	Crrriage 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
b	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	Ø5Ø	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	5Ø	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	3Ø	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	7Ø
(	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	5Ø
			R	122	51
Ø	6Ø	12	S	123	22
1	61	Ø1	T	124	23
2	62	Ø2	U	125	24
3	63	Ø3	V	126	25
4	64	Ø4	W	127	26
5	65	Ø5	X	13Ø	27
6	66	Ø6	Y	131	3Ø
7	67	Ø7	Z	132	31
8	7Ø	1Ø			
9	71	11	[	133	75 ‡
			]	135	55 ‡
			↑	136	77
:	72	15	←	137	32
;	73	56			
<	74	76			
=	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 ()).

APPENDIX B
ASSEMBLER INSTRUCTIONS

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
$\not\vee$	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	{m [,I] / lit}	(m) + (A) → A
ADB	{m [,I] / lit}	(m) + (B) → B
LDA	{m [,I] / lit}	(m) → A
LDB	{m [,I] / lit}	(m) → B
STA	m [,I]	(A) → m
STB	m [,I]	(B) → m

Logical

AND	{m [,I] / lit}	(m) AND (A) → A
XOR	{m [,I] / lit}	(m) XOR (A) → A
IOR	{m [,I] / lit}	(m) IOR (A) → A
CPA	{m [,I] / lit}	If (m) ≠ (A), execute P + 2, otherwise execute P + 1.
CPB	{m [,I] / lit}	If (m) ≠ (B), execute P + 2, otherwise execute P + 1.

MACHINE INSTRUCTIONS (cont.)

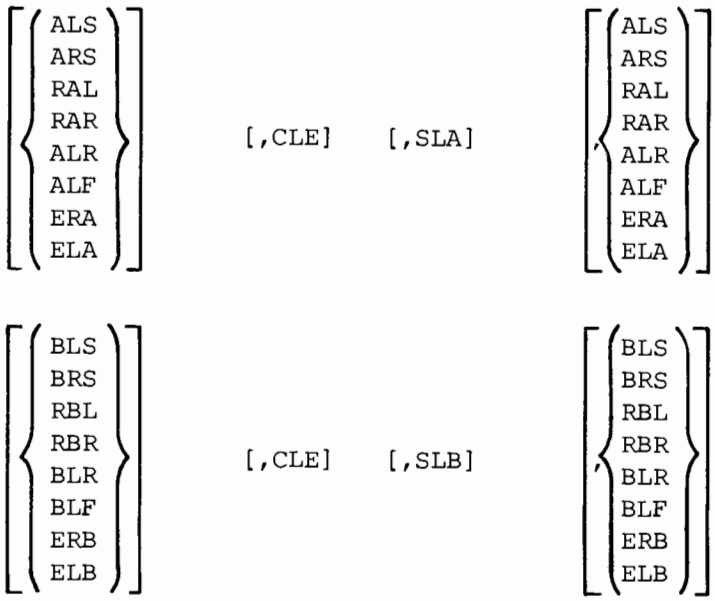
REGISTER REFERENCE

Shift-Rotate

CLE	$0 \rightarrow E$
ALS	Shift (A) left one bit, $0 \rightarrow A_0$, A_{15} unaltered
BLS	Shift (B) left one bit, $0 \rightarrow B_0$, B_{15} unaltered
ARS	Shift (A) right one bit, $(A_{15}) \rightarrow A_{14}$
BRS	Shift (B) right one bit, $(B_{15}) \rightarrow B_{14}$
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, $0 \rightarrow A_{15}$
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

MACHINE INSTRUCTIONS (cont)

Shift-Rotate instructions can be combined as follows:



No-operation

NOP	Execute P + 1

Alter-Skip

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

MACHINE INSTRUCTIONS (cont)

(Alter-Skip (cont)

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:

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

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

INPUT/OUTPUT, OVERFLOW, and HALT

Input/Output

STC	sc	[,C]	Set control bit_{sc}, enable transfer of one element of $data_{sc}$ 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]	$(buffer_{sc})$ (A) → A
MIB	sc	[,C]	$(buffer_{sc})$ (B) → B
OTA	sc	[,C]	(A) → $buffer_{sc}$
OTB	sc	[,C]	(B) → $buffer_{sc}$

MACHINE INSTRUCTIONS (cont)

Input/Output (cont)

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	m[,I] lit	(A) x (m) → ($B_{\pm msb}$ and $A_{\mid sb}$)
DIV	m[,I] lit	($B_{\pm msb}$ and $A_{\mid sb}$)/(m) → A, remainder → B
DLD	m[,I] lit	(m) and (m + 1) → A and B
DST	m[,I] lit	(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 $A_{\mid sb}$

MACHINE INSTRUCTIONS (cont)

EXTENDED ARITHMETIC UNIT (cont)

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, o'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.

PSEUDO INSTRUCTIONS (cont)

OBJECT PROGRAM LINKAGE

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

Reserves a block of common storage locations. $name_1$ identifies segments of block, each of length size.

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

Defines entry points, $name_1$, that may be referred to by other programs.

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

Defines external locations, $name_1$, 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.

PSEUDO INSTRUCTIONS (cont)

CONSTANT DEFINITION

ASC n, <2n characters>	Generates a string of 2n ASCII characters.
DEC d_1 [,d_2,...,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,...,d_n]	Records a string of extended precision decimals constants of the form Floating point: ±n, ±n.m, ±n., ±.n, ±nE±e, ±n.nE±e, ±n.E±e, ±.nE±e
OCT o_1 [,o_2,...,o_n]	Records a string of octal constants of the form: ±000000

STORAGE ALLOCATION

BSS m	Reserves a storage area of length, m.

PSEUDO INSTRUCTIONS (cont)

ARITHMETIC SUBROUTINE CALLS REQUESTS*

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

†For configurations including Extended Arithmetic Unit, these mnemonics 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.

PSEUDO INSTRUCTIONS (cont)

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.

APPENDIX C
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

ALPHABETIC LIST OF INSTRUCTIONS (cont)

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

ALPHABETIC LIST OF INSTRUCTIONS (cont)

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
RRL	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)

ALPHABETIC LIST OF INSTRUCTIONS (cont)

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

APPENDIX D
SAMPLE PROGRAM

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

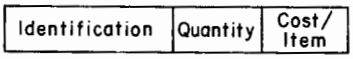
PARTS FILE UPDATE

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.

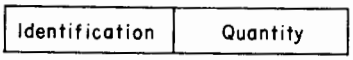
The organization of the files is as follows:

Parts Master Files (PRTSM)



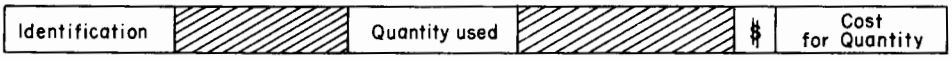
Identification field of the Parts Master Files exists in ASCII although the entire record is read and written in binary.

Parts Usage File (PRTSU)



The parts usage file has been recorded in ASCII.

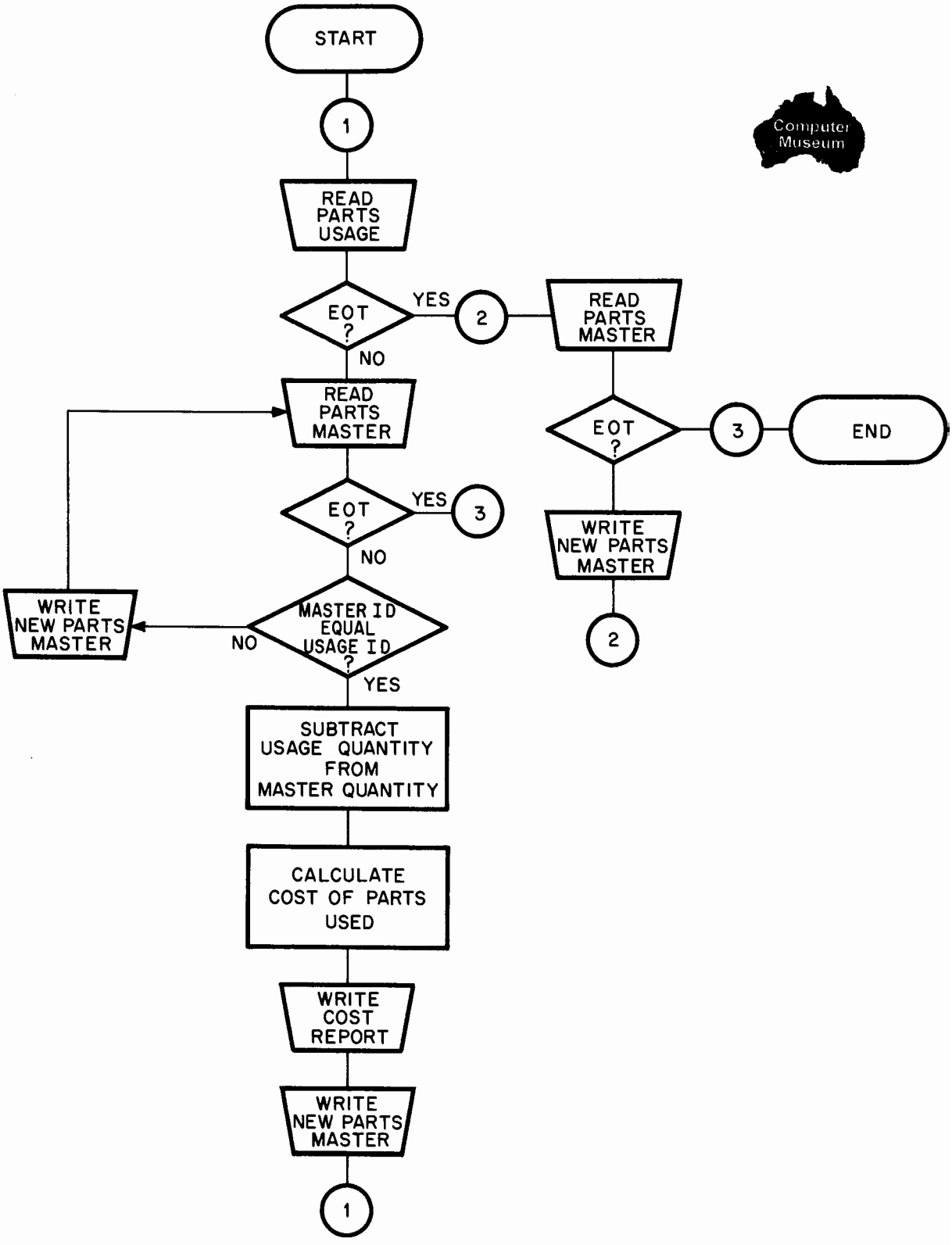
Parts Cost Report (PRTSC)



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

SAMPLE PROGRAMS (cont)

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*
```

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.
```

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```
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
```

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```
      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.
```

```
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)
```

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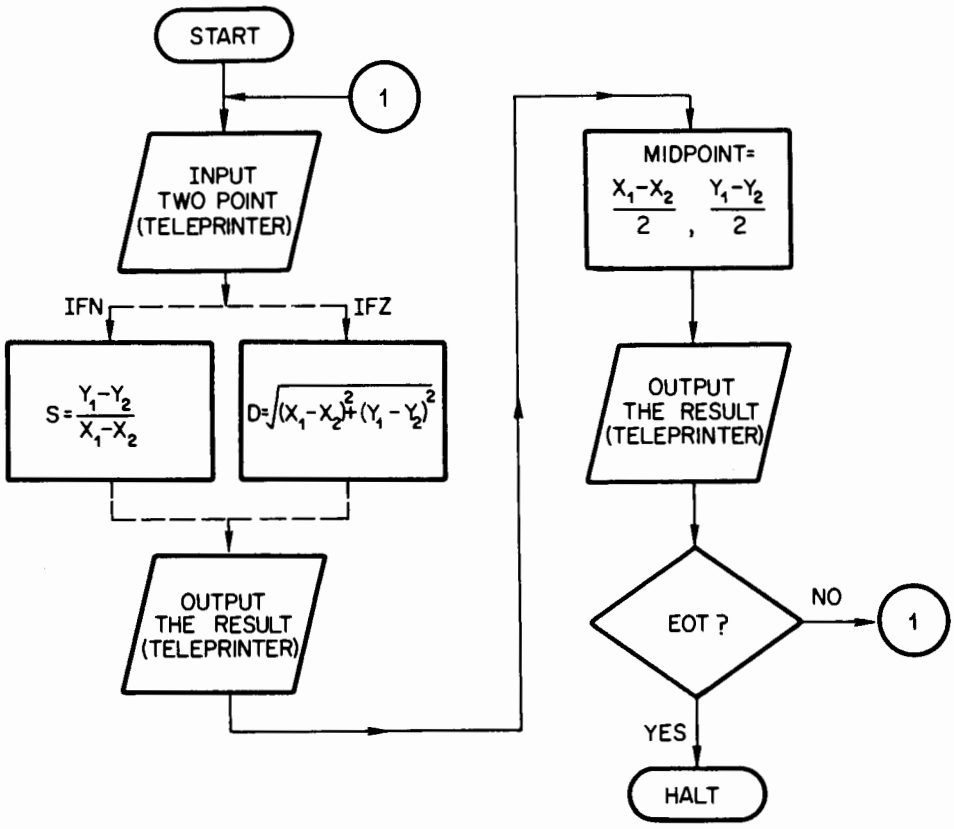
```
0189   00304 000000B        DEF PRTSM      IS ALSO USED AS OUTPUT AREA.
0190   00305 000004         DEC 4
0191   00306 016001X CKSTN  JSB .IOC.      CHECK STATUS OF UNIT 4.
0192   00307 040004         OCT 40004
0193   00310 002020         SSA
0194   00311 026306R        JMP CKSTN      IF BUSY, LOOP 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*
```

CALCULATING DISTANCE

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.



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 0001


0001                          ASMB,R,L,T,Z
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
.MPY   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
```

Computer Museum

```
 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
```

```
 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 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*
```

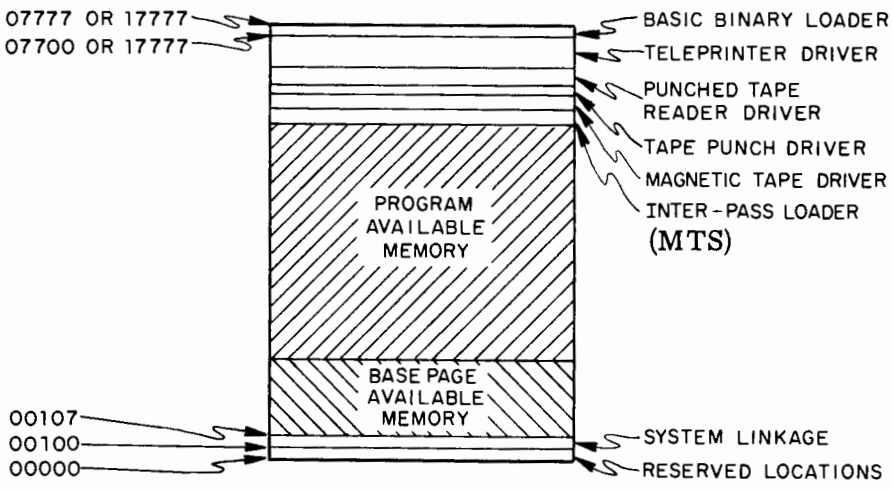
APPENDIX E
SYSTEM INPUT/OUTPUT SUBROUTINES

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 unitl an operation is completed. Date 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 forword 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	Rewind/Standby
Write file gap	Status
Rewind	

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.

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 will be returned to the EOT/EOF 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 three-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
lxxxxxxxx	Local - The device is in local status
xlxxxxxxx	EOF - An End-of-File character (17_8 for 7 track, 23_8 for 9) has been detected while reading, forward spacing, or backspacing.
xxlxxxxxx	SOT - The Start-of-Tape marker is under the photo sense head.
xxxlxxxxx	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.
xxxxlxxxx	Timing - A character was lost.
xxxxxlxxx	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.
xxxxxxlxx	Write not enabled - Tape reel does not have write enable ring or tape unit is rewinding.
xxxxxxxlx	Parity error - A vertical or logitudinal parity error occurred during reading or writing. (Parity is not checked during forward or backward spacing operations.)
xxxxxxxxl	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, Direc- tion	Number of Records, Direction	-	Status
Rewind/ Standby (Local mode)	5	-	-	-	-
Gap	6	-	-	-	Status
Status	7	-	-	-	Status

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 (for 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.

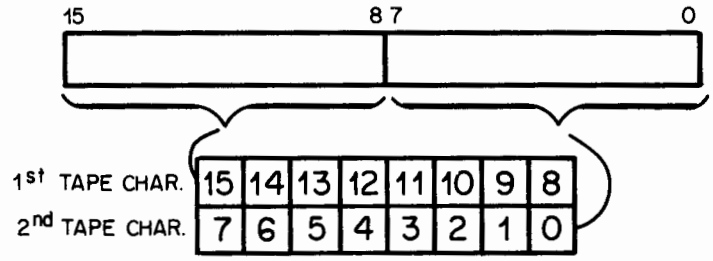
For an output operation, the length of the record is determined by the number of characters designated in the request. An end-of-record mark is supplied at the end of each output operation by the driver.

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:



† RUB OUT which appears on the teleprinter keyboard is synonymous with the ASCII symbol DEL .

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.

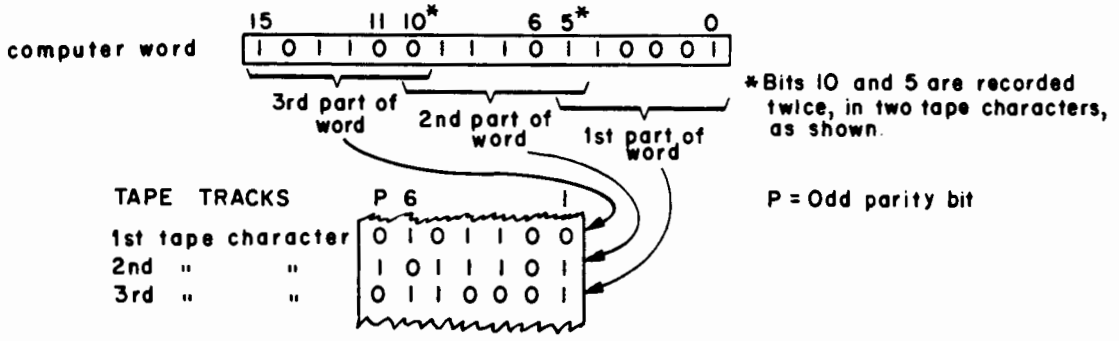
On input operations if less than ten feed frames precede the first data character, they are ignored; ten feedframes are interpreted as an end-of-tape condition. On output, the driver writes four feed frames to serve as a physical record separator.

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.

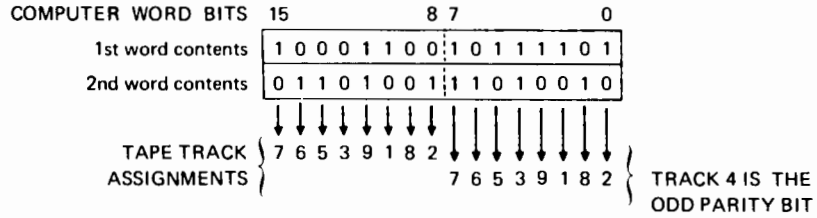
2020 7-LEVEL TAPE

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	1
2nd tape character	1	0	1	0	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 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.

APPENDIX F
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.

APPENDIX G

ASSEMBLER 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 "O".

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.

Error Code	Pass	Description
		e) Any combination of the above. An arithmetic subroutine call symbol appears in a program both as a pseudo instruction and as a label.
EN	1	The symbol specified in an ENT statement has already been defined in an EXT or COM statement.
ENØØØ <symbol>	2	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.
M	1, 2 or 3	Illegal operand: a) Operand is missing for an Opcode requiring one. b) Operands are optional and omitted but comments are included for: END HLT

Error Code	Pass	Description
M	1, 2 or 3	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 ADA AND DEF JMP ADB XOR Arithmetic JSB LDA IOR subroutine LDB CPA calls STA CPB STB
		f) A character other than C follows a comma in one of the following statements: STC MIB CLC OTA LIA OTB LIB HLT MIA
		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.

Error Code	Pass	Description
		k) An external symbol appears in an operand expression or is followed by a common 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.
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:

Error Code	Pass	Description
		$1 \geq N \geq 16$ 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 made to assemble a relocatable program following the assembly of an absolute program.
SO		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.
UN	1,2, or 3	Undefined Symbol:

Error Code	Pass	Description
		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

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