File No. S360-21
Form C28-6503-3

Systems Reference Library

# IBM System/360 Basic Programming Support

# Basic Assembler Language

This publication contains information required for writing programs in the Basic Assembler language, a symbolic programming language for the IBM System/360. The Basic Assembler language provides programmers with a convenient way to make full use of the operating capabilities of the IBM System/360. Source programs written in the Basic Assembler language are translated into object programs by a program called the Basic Assembler.

The Basic Assembler and its language are both described in this publication. The description of the language includes the rules for writing source programs, a list of the machine instructions that can be represented symbolically, and explanations of the instructions used to control the Basic Assembler. The description of the Basic Assembler consists primarily of discussions of those features that affect the planning and writing of source programs.

## PREFACE

This publication describes a symbolic programming language for the IBM System/360. All the information required for writing IBM System/360 programs is provided. This includes the rules for writing source statements, a description of the assembler "instructions," and a list of the machine instructions that can be represented in the language. There is also a section describing the Basic Assembler, the program that translates source programs into machine-language programs. The information in this section will be helpful in planning for the IBM System/360 and in writing programs to permit the most efficient operation of the Basic Assembler. This section describes the input to the Basic Assembler, the type of output that will be generated, and those operations of the Basic Assembler that have direct programming significance.

Completion of a basic course in computer systems and programming concepts, or the equivalent, is a prerequisite to using this publication. Readers should also be familiar with the IBM System/360 and have an understanding of the storage-addressing scheme, data formats, and machine instruction formats and functions. This information can be found in the publication _IBM System/360 Principles of Operation_, Form A22-6821.

Reference is made in this manual to the relocating loader and the absolute loader. A detailed description of these programs is contained in the publication _IBM System/360 Basic Programming Support Basic Utilities_, Form C28-6505.

MAJOR REVISION (February 1965)

This publication is a major revision of the previous edition, Form C28-6503-2, which is now obsolete. Significant changes have been made throughout this publication, and the present edition should be reviewed in its entirety.

This publication was prepared for production using an IBM computer to update the text and to control the page and line format. Page impressions for photo-offset printing were obtained from an IBM 1403 Printer using a special print chain.

Copies of this and other IBM publications can be obtained through IBM Branch Offices.

A form for readers' comments appears at the back of this publication. It may be mailed directly to IBM. Address any additional comments concerning this publication to the IBM Corporation, Programming Systems Publications, Department D58, PO Box 390, Poughkeepsie, N. Y. 12602

FIGURES

The Basic Assembler language is a symbolic programming language for use with the IBM System/360. This language provides programmers with a convenient means of writing machine instructions, designating registers and input/output devices, and specifying the format and addresses of storage areas, data, and constants. All the operational capabilities of the IBM System/360 can be expressed in Basic Assembler language programs.

The language features are designed to greatly simplify the writing of programs for the IBM System/360. By avoiding unnecessary complexity, the language features reduce program errors and, consequently, the time required to produce a program that is suitable for execution. They also make it easier to learn the language.

Source programs written in this language are translated into IBM System/360 machine language object programs by the Basic Assembler (that is, "the assembler"). In the process of translating programs, the assembler performs certain auxiliary functions. Some of these functions are automatically performed; others must be requested by special assembler instructions that the programmer writes in his source program.

The assembler is a two-phase program stored on cards. It has a special operating procedure for use with the IBM 1442 Card Read-Punch. When this procedure is used, the assembler punches information into the source-program deck during the first phase. Using this information in the second phase, the assembler produces an object program. For systems with tape or a 1402-2 Card Read-Punch, this intermediate information is stored in a tape or card file rather than in the source-program deck. The temporary file then serves as input for the second phase.

## FEATURES OF THE IBM SYSTEM/360 BASIC ASSEMBLER

The most significant features provided by the assembler and its language are summarized below. This summary does not include all the features nor does it contain complete explanations of the features listed. For more detailed descriptions, the reader is referred to subsequent sections.

Mnemonic Operation Codes: Mnemonic operation codes are provided for all machine instructions. These codes are used instead of the more cumbersome internal operation codes of the machine. For example, the Branch-on-Condition instruction can be represented by the mnemonic BC instead of the machine operation code, 01000111. The various machine mnemonic operation codes are presented under the topic "Machine Instruction Mnemonics."

Symbolic Referencing of Storage Addresses: Instructions, data area, register numbers, and other program elements can be referred to by symbolic names, instead of actual machine addresses and designations. See the topic "Symbols."

Automatic Storage Assignment: The assembler assigns consecutive addresses to program elements as it encounters them. After processing each element, the assembler increments a counter by the number of bytes assigned to that element. This counter indicates the storage location available to the next element. See the topic "Location Counter."

Convenient Data Representation: Constants can be specified as decimal digits, alphabetic characters, hexadecimal digits, and storage addresses. Conversion of the data into the appropriate machine format of the IBM System/360 is performed by the assembler. Data can be in a form suitable for use in fixed-point and floating-point arithmetic operations. See the topic "DC - Define Constant."

Renaming Symbols: A symbolic name can be equated to another symbol so that both refer to the same storage location, general register, etc. This makes it possible for the same program item to be referred to by different names in different parts of the program. See the topic "EQU - Equate Symbol."

Program Linking: Independently assembled programs that will be loaded and executed together may make symbolic references to instructions and data in one another. See the discussion of "Program Link Instructions."

Relocatable Programs: The assembler produces object programs in a relocatable format; that is, a format that enables programs to be loaded and executed at storage locations different from those assigned when the programs were assembled.

Assembler Instructions: A set of special instructions to the assembler is included in the language. Some of the features described in this section are implemented by these instructions. See the topic "Assembler Instructions."

Base Register and Displacement Assignment: The programmer can instruct the assembler to assign base registers and to compute displacements for symbolic machine addresses. See the discussion of "Base Register Instructions."

Program Listings: For every assembly, the assembler can provide a listing of both the source program and the resulting object program. A description of the listing format can be found under the topic "Program Listing."

Error Checking: Source programs are examined by the assembler for possible errors arising from incorrect usage of the language. Wherever an error is detected, a coded warning message (called a flag) will be printed in the program listing. For card systems without printers, limited error notification is provided. See the topic "Error Notification."

Program Reassembly: A special reassembly procedure is provided for programs assembled by the IBM 1442-2 Card Read-Punch card-operating procedure. This will permit partially or completely assembled source programs, that have been modified, to be reassembled in less time than required for a new assembly. See the topic "Reassembly Procedure."

## COMPATIBILITY WITH OTHER SYSTEM/360 ASSEMBLERS

Programs written in the Basic Assembler Language as described in this publication are acceptable to the other Basic Programming Support, Basic Operating System, and Operating System Assemblers, and the 7090/7094 Support Package Assembler. Similarly, source programs written in these other assembly languages are acceptable to the Basic Assembler if they do not embody any of the features of these assemblers which are unacceptable to the Basic Assembler. Appendix D contains a list of features supported by the System/360 Assemblers and may be used as a guide for the interchangeability of source programs.

The Basic Assembler will also accept programs written for the IBM System/360 Model 20 Basic Assembler, except where differences in machine design have made it necessary to include some instructions in the Model 20 Basic Assembler Language that are not contained in the Basic Assembler Language. These instructions are:

BAS BASR CIO HPR SPSW TIOB XIO
Y-type Expression Constants

Note also that the pseudo-registers zero through three on the Model 20 are handled differently from the corresponding actual registers on other models of the System/360.

## MACHINE REQUIREMENTS

The assembler will operate on an IBM System/360 with the following minimum configuration:

8,192 bytes of storage
Standard Instruction Set
One IBM 1442 Model 2 or 1402 Card Read-Punch

The above configuration is for the card-operating procedure for the assembler, hereinafter called the card option.

If, in addition to the equipment required for the card option, IBM 2400-Series Magnetic Tape Units are available, the tape-operating procedure may be used. This procedure will be henceforth termed the tape option.

If an IBM 1443 Model 2 or 1403 Printer, or an IBM 1052 Printer-Keyboard is provided, the assembler will provide a program listing, complete with error messages, for each assembly. An option is available to list only those statements containing errors. For information concerning this option, refer to the topic "Program Listing."

## CARD AND TAPE OPTIONS

The Basic Assembler is a two-phase program. The first phase produces data for use by the second phase. The intermediate data produced by phase 1 must be passed on to the second phase via some external storage medium. The storage mediums used are punched cards or magnetic tape. If punched cards are used for the intermediate data, the system is known as a "Card Option System." If tape is used, the system is termed a "Tape Option System." The machine configuration determines which option applies at a particular installation.

An assembler language source program consists of a sequence of source statements punched into cards, one statement per card. The card columns available for punching source statements vary with the machine configuration (that is, input device, card or tape option) and the programmer's discretion. See the following list.

| Input Unit | Option | Columns Available |
|---|---|---|
| 1402 | tape | 1-71 or 25-71 |
| 1402 | card | 1-47 (see note) or 25-71 |
| 1442 | tape | 1-71 or 25-71 |
| 1442 | card | 25-71 |

Note: Columns 1-71 may be used for the 1402 card option rather than only columns 1-47. The assembler scans all 71 columns of the statement field when obtaining the information required to generate the appropriate object code; however, only the contents of columns 1-47 are included in the program listing produced by the assembler.

In addition to a source statement, each card may contain an identification sequence number in columns 73-80.

In this section, the discussion of card formats assumes that all statements begin in column 1. When card column assignments differ because of statements beginning in column 25, the column numbers associated with the statements beginning in column 25 are placed in parentheses. Example: 1(25).

The statements may be written on the standard coding forms that IBM provides. Two forms are available: a "long" form, Form X28-6507 (Figure 1), and a "short" form, Form X28-6506, for IBM Card Read-Punch card-option assemblies (Figure 2).

Each line of the coding form is used to write a single statement and/or comments. The information on each line is punched into one card. If a card is completely blank, it will be ignored by the assembler. The position numbers shown in the forms correspond to the card columns.

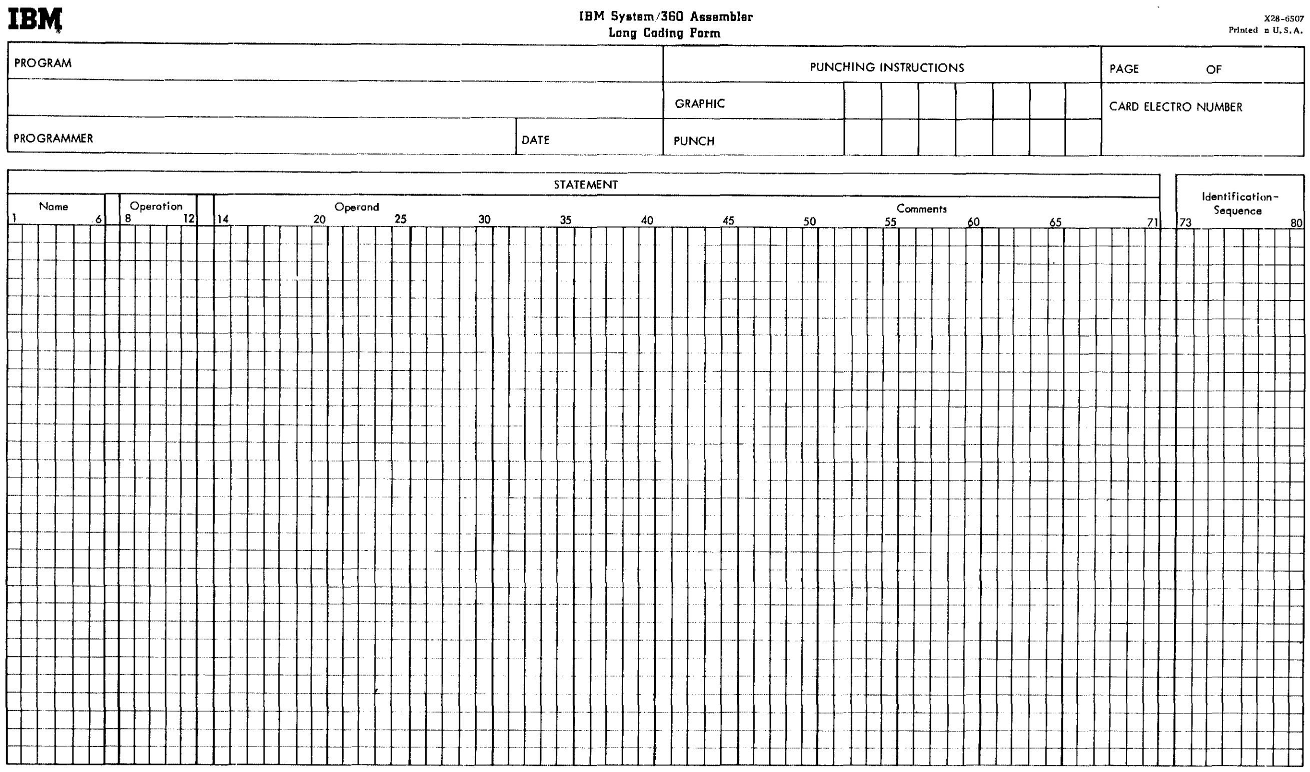
Space is provided at the top of both coding forms to identify the program and give instructions to the keypunch operator. None of this information is punched into the statement cards.

## STATEMENT FIELDS

An assembler statement is composed of one to four fields, from left to right: name field, operation field, operand field, and comments field. The identification-sequence field is not part of the statement. The statement fields can be written on the coding form in what basically is a free form. As a convenience, however, the name and operation fields are marked on the coding forms by heavy lines that indicate the maximum length of these fields. Programmers may wish to align the fields at these lines to create a neat and orderly appearance in the program listing.

Some general rules that must be observed when writing statements are:

1. The only required field in a statement is the operation field. The other fields are optional, depending on the operation and the programmer's wishes.
2. The fields in a statement must be in order and separated from one another by at least one blank.
3. The name, operation, and operand fields must not contain embedded blanks. A blank may, however, occur in the operand field as a character self-defining value or character constant.
4. Only one statement is allowed to a line; a statement cannot be continued on additional lines.
5. Column 72 must be blank.



IBM System/360 Assembler
Long Coding Form

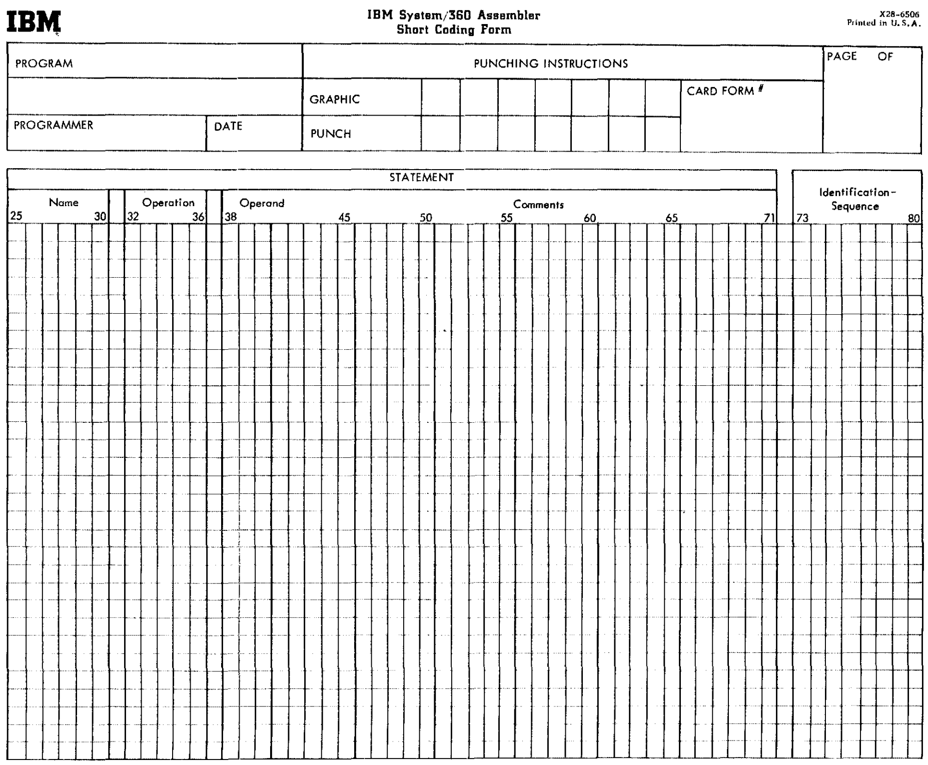
X28-6507
Printed in U.S.A.

| | | | |
|---|---|---|---|
| PROGRAM | | PUNCHING INSTRUCTIONS | PAGE OF |
| | | GRAPHIC | CARD ELECTRO NUMBER |
| PROGRAMMER | DATE | PUNCH | |

STATEMENT

Name 1 6 | Operation 8 12 | 14 Operand 20 25 30 35 40 45 50 Comments 55 60 65 71 | Identification-Sequence 73 80

Figure 1. IBM System/360 Long Coding Form



IBM System/360 Assembler
Short Coding Form

X28-6506
Printed in U.S.A.

| | | | | |
|---|---|---|---|---|
| PROGRAM | | PUNCHING INSTRUCTIONS | | PAGE OF |
| | | GRAPHIC | CARD FORM # | |
| PROGRAMMER | DATE | PUNCH | | |

STATEMENT

Name 25 30 | Operation 32 36 | Operand 38 45 50 Comments 55 60 65 71 | Identification-Sequence 73 80

Figure 2. IBM System/360 Short Coding Form

## Name Field

The name field is used to assign a symbolic name to a statement. A name enables other statements to refer to the statement by that name. If a name is given, it must begin in column 1 (25) and must not extend beyond column 6 (30). A name is always a symbol and must conform to the rules for symbols (see section, "Symbols"). Figure 3 shows the symbol FIELD2 used as a name.

If column 1 (25) is blank, the assembler will assume that the statement has no name. Column 1 (25) is also used to indicate that the card is a comments card (see discussion of the "Comments Field").

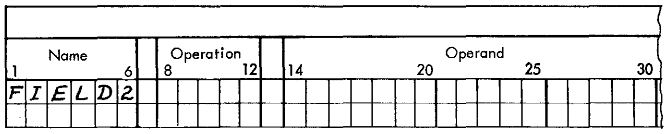


Figure 3. Example of the Name Field

## Operation Field

The operation field is used to specify the mnemonic operation code of a machine or assembler instruction. This field may begin in any column to the right of column 1 (25) if the name field is blank. If the name field is not blank, at least one blank must separate the name and operation fields. The operation field may contain any valid mnemonic operation code. The valid machine-instruction mnemonics are listed in the section "Machine Instruction Statements;" the valid assembler-instruction mnemonics are listed in the section "Assembler Instructions." A valid mnemonic will never exceed five characters. If an invalid mnemonic is specified, the assembler will treat the statement as a comments statement and flag an error.

Figure 4 shows the mnemonic for the compare instruction (RR format) used in a statement named TEST. Note that this mnemonic could have been placed in columns 6-7, since this would have satisfied the requirement that at least one blank space separate the fields.

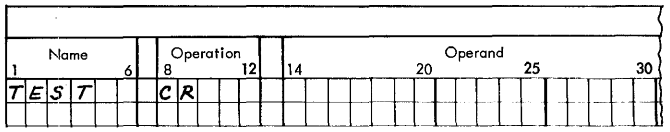


Figure 4. Example of the Operation Field

## Operand Field

The contents of the operand field provide the assembler with additional information about the instruction specified in the operation field. If a machine instruction has been specified, the operand field contains information required by the assembler to generate the machine instruction. That is, the operand field specifies registers, storage addresses, input/output devices, immediate data, masks, and storage-area lengths. For an assembler instruction, the operand field conveys whatever information the assembler requires for the particular instruction.

The operand field may begin in any column to the right of the operation field, provided at least one blank space separates it from the last character of the mnemonic.

Certain assembler instructions do not require the operand field to be specified. If there is no operand field but there is a comments field, the absence of the operand field must be indicated by a comma, preceded and followed by one or more blanks. Figure 5 illustrates this rule.

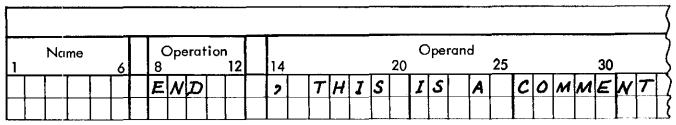
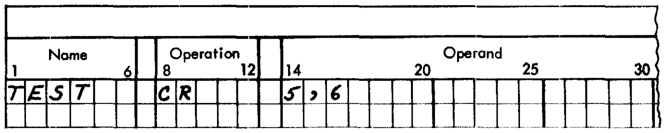


Figure 5. Example of No Operand Field with Comments

Depending on the instruction, the operand field may be composed of one or more subfields, called operands. Operands must be separated by commas. It must be remembered that a blank delimits the field; thus, a blank must not intervene between operands and commas. Figure 6 is an example of the same compare instruction shown in Figure 4, with its two operands specifying general registers 5 and 6. In Figure 6, as in Figure 4, the fields are separated by more than the minimum number of blank spaces.



```
 Name        Operation     Operand
1      6   8        12   14      20      25     30
TEST       CR            S,6
```

Figure 6. Example of the Operand Field

### Comments Field

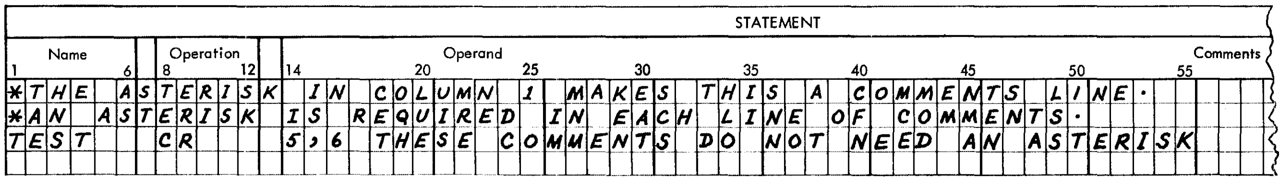
Comments are strictly for the convenience of the programmer. They permit lines or paragraphs of descriptive information about the program to be inserted into the program listing. Comments appear only in the program listing; they have no effect on the assembled object program. Any valid characters (including blanks) may be used as comments.

The comments field must (1) appear to the right of the operand field and (2) be preceded by at least one blank. If there is no operand field but there is a comments field, the absence of the operand field must be indicated by a comma, preceded and followed by one or more blanks. The entire statement field can be used for comments by placing an asterisk in column 1 (25); the entire statement will be treated as comments. Column 72, however, must remain blank.

If it is necessary to continue full-card comments on additional lines, each such line must have an asterisk in column 1 (25), as illustrated in Figure 7.

### IDENTIFICATION-SEQUENCE FIELD

The identification-sequence field may be used for program identification and statement sequence numbers. This field can occupy columns 73-80 only. The information in this field normally is punched in every statement card. The assembler, however, will not check this field. It will merely reproduce the information in the field on the output listing of the program.



```
                                          STATEMENT
 Name        Operation     Operand                                                  Comments
1      6   8        12   14      20      25      30       35      40      45      50      55
*THE ASTERISK IN COLUMN 1 MAKES THIS A COMMENTS LINE.
*AN ASTERISK IS REQUIRED IN EACH LINE OF COMMENTS.
TEST       CR            S,6 THESE COMMENTS DO NOT NEED AN ASTERISK
```

Figure 7. Example of the Comments Field

Language statements will be accepted by the assembler only if they conform to the established grammatical rules and vocabulary restrictions that are presented in this section. The reader can expect that many of the points not fully explained when they are first mentioned in this section will be described in detail subsequently.

## CHARACTER SET

Basically, statements may be written using the following characters:

A through Z
0 through 9
* + - , ( ) ' . blank

The card column punch-combinations that the assembler will accept for these characters are listed below. This list also contains the punches assumed for additional printer graphics, which may be used in comments.

| Character | Punch Combination |
|---|---|
| A - I | 12 punch and a 1 - 9 punch, respectively |
| J - R | 11 punch and a 1 - 9 punch, respectively |
| S - Z | 0 (zero) punch and a 2 - 9 punch, respectively |
| 0 - 9 | 0 (zero) - 9, respectively |
| blank | No punches |
| & | 12 |
| / | 0-1 |
| - | 11 |
| . (period) | 12-3-8 |
| $ | 11-3-8 |
| , | 0-3-8 |
| # | 3-8 |
| < | 12-4-8 |
| * | 11-4-8 |
| % | 0-4-8 |
| @ | 4-8 |
| ( | 12-5-8 |
| ) | 11-5-8 |
| ' (single quotation) | 5-8 |
| + | 12-6-8 |
| = | 6-8 |

## SYMBOLS

Symbols are created by the programmer and used by him for symbolic referencing of storage areas, instructions, input/output units, and registers.

A symbol may contain from one to six characters; the characters may be any combination of alphabetic (A through Z) and numerical (0 through 9) characters. The first character must be alphabetic. Special characters and embedded blanks must not be used in symbols. Any violation of these rules will be noted with an error flag in the program listing and the symbol will not be used.

The following are valid symbols:

READER
A23456
LOOP2
N
S4

These symbols are invalid:

| | |
|---|---|
| 256B | First character is not alphabetic |
| AREATWO | More than six characters |
| RCD*34 | Contains a special character |

### Defining Symbols

Symbols are meaningful in statements when used as operands and names. When a symbol is used as an operand, the assembler will normally assign certain attributes to it. These "attributes" are assigned to the symbol by the assembler when the symbol is defined. In order for a symbol to be used as an operand, it must be defined somewhere in the program.

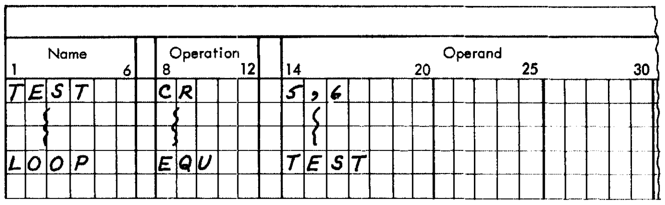
A symbol is defined when the programmer uses it as the name of a statement. When the assembler finds a symbol in the name field, it will assign an address-value attribute and a length attribute to the symbol. The address value is the storage address of the leftmost byte of the field allotted to the statement; the length is the number of bytes in the storage field named by the symbol. This length is called the implied length associated with the symbol. The convenience of having implied lengths will become apparent in the discussion of the symbolic format of machine instructions in the SS format.

A symbol defined in this manner is normally called a relocatable symbol. That is, the address value of the symbol will change if the program is loaded at a location other than its assembled location.

Symbols can be assigned arbitrary absolute values by use of the EQU assembler instruction. These values may designate registers, input/output units, immediate data, etc. They can also specify actual storage addresses such as permanently allocated interrupt locations. Symbols so defined are termed absolute symbols since their values are fixed and will not change because of program location.

### Previously Defined Symbols

Sometimes the programmer will desire to give an alternate name to a previously defined symbol. "Previously defined" means that the symbol has appeared as the name of some statement prior to being used in the operand field of another statement. Figure 8 shows how the symbol TEST, defined in the first statement, is given an alternate name.



| Name (1–6) | Operation (8–12) | Operand (14–30) |
|---|---|---|
| TEST | CR | 5,6 |
| LOOP | EQU | TEST |

Figure 8. Example of Coding with Previously Defined Symbols

### External and Entry-Point Symbols

Symbols are normally defined in the same program in which they are used as operands. It is possible, however, to define a symbol in one program, use it in another program assembled independently of the first, and then execute both programs together. Such a symbol is called an "external symbol" when it is used as an operand. The symbol is termed an "entry-point symbol" in the program in which it is defined. The address value of the entry-point symbol will be assigned to the external symbol when both programs are loaded by the relocating loader.

Before using an external symbol or defining an entry-point symbol, the programmer must indicate to the assembler which of the symbols are external and which are entry points. The ENTRY and EXTRN assembler instructions are provided for this purpose. Both instructions are described in the section "Assembler Instructions."

External symbols are always relocatable. They are subject to certain usage restrictions that are discussed at pertinent places elsewhere in this publication.

### General Restrictions on Symbols

The following restrictions are in addition to those imposed elsewhere in the discussion of symbols:

1. A symbol may appear only once in a program as the name of a statement. If a symbol is used as a name more than once, only the first usage will be recognized. Each subsequent usage of the symbol as a name will be ignored and noted with an error flag in the program listing.
2. The number of symbols that may be defined in a program is restricted, depending on the machine's storage size. These restrictions are explained in detail in the section "The Symbol Table."
3. A symbol must always be defined as having a positive value not exceeding 65,535. Any symbol whose definition is contrary to this rule will not be used and the statement in which it appears will be flagged as an error.

## THE LOCATION COUNTER

The assembler maintains a counter that it uses to assign consecutive storage addresses to program statements. This counter is called the Location Counter. It always points to the current address. After each machine instruction is processed, the Location Counter is incremented by the number of bytes assigned to that instruction. Certain assembler instructions also cause the Location Counter to be incremented, whereas others do not affect it.

The programmer can set and change the Location Counter by using the START and ORG assembler instructions described in the section "Assembler Instructions."

Location Counter Overflow: The maximum value of the Location Counter is 65,535, a 16-bit value. If a program being assembled causes the Location Counter to be incremented beyond 65,535, the assembler will retain only the rightmost 16 bits in the counter and continue the assembly, checking for any other source program errors. No object program will be produced. The assembler can, however, provide a listing of the entire source program. The statement causing the overflow will be flagged in the listing.

Program References: The programmer may refer to the current value of the Location Counter at any place in a program by using an asterisk as an operand. The asterisk represents the location of the first byte currently available. The use of an asterisk in a machine-instruction statement is the same as giving the statement a name and then using that name as an operand in the same statement. Note that the asterisk will have a different address value each time it is used. The asterisk will have the same length attribute that a symbol placed in the name field would have. An asterisk used as an operand is considered a relocatable symbol.

## SELF-DEFINING VALUES

The ability to represent an absolute value symbolically is an advantage in cases where the value will be referred to repeatedly. However, it is equally necessary to have a convenient means of specifying an actual machine value or a bit configuration without having to go through the procedure of equating it to a symbol and using the symbol. The assembler language provides this facility through the self-defining value, which can be a decimal, hexadecimal, or character representation.

Self-defining values may be used to specify such program elements as immediate data, masks, registers, addresses, and address increments. The type of representation selected (decimal, hexadecimal, or character) will depend on what is being specified. The use of a self-defining value is quite distinct from the use of data constants specified by the DC assembler instruction and by literal operands. When a self-defining value is used in a machine-instruction statement, its value is assembled into the instruction. When a data constant is specified in a machine instruction, its address is assembled into the instruction.

### Decimal

A decimal self-defining value is an unsigned number of from one to six decimal digits. A decimal self-defining value of more than six digits is not valid. The acceptable decimal digits are 0 through 9. Some examples are:

```
  7    4092     0007
147     128   199860
```

The assembler imposes additional restrictions on decimal self-defining values, depending on their use. For example, a decimal self-defining value designating a general register should be from 0 through 15; one designating a core storage address should not exceed the size of available storage.

### Hexadecimal

A hexadecimal self-defining value is an unsigned number of from one to six hexadecimal digits, enclosed in single quotation marks and preceded by the letter X. Hexadecimal self-defining values of more than six digits are not valid.

Each hexadecimal digit converts to a four-bit value. The hexadecimal digits, and their bit patterns are:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 0000 | 4 | 0100 | 8 | 1000 | C | 1100 |
| 1 | 0001 | 5 | 0101 | 9 | 1001 | D | 1101 |
| 2 | 0010 | 6 | 0110 | A | 1010 | E | 1110 |
| 3 | 0011 | 7 | 0111 | B | 1011 | F | 1111 |

The following are examples of hexadecimal self-defining values:

```
X'25'     X'B'      X'12FA1E'
X'F4F'    X'00CD'   X'00E0'
```

A table for converting decimal to hexadecimal is provided in Appendix B.

### Character

A character self-defining value is a single character, enclosed in single quotation marks and preceded by the letter C. A character self-defining value may be a blank or any combination of punches in a single card column that translates into the 8-bit IBM Extended BCD Interchange Code. There are 256 such combinations. Appendix A is a table of these combinations, their interchange codes, and, where applicable, their printer graphics. A single quotation mark used as a character self-defining value, or an ampersand, is represented as two single quotation marks, or two ampersands, enclosed in single quotation marks, thus: C'''' or C'&&'

Examples of character self-defining values are:

```
C'/'      C'#'      C'.'
C'B'      C'2'      C' ' (blank)
```

The same value can frequently be represented by any one of the three types of self-defining values. Thus, the decimal self-defining value 196 can be expressed in hexadecimal as X'C4' and as a character, C'D'. The selection of a particular type of value is left to the programmer. Decimal self-defining values, for example, might be used for actual addresses or register and input/output unit numbers; hexadecimal self-defining values for masks; and character self-defining values for immediate data.

## EXPRESSIONS

The term "expression" refers to symbols or self-defining values used as operands, either singly or in some arithmetic combination. Expressions are used to specify the various fields of machine instructions. They also are used as the operands of assembler instruction statements.

Expressions are classified as either simple or compound and either relocatable or absolute. Unless otherwise qualified, the term "expression" as used hereinafter implies any expression, simple or compound, absolute or relocatable.

A simple expression is a single unsigned symbol (including the asterisk used as the Location Counter value) or a single unsigned self-defining value used as an operand. The following are simple expressions:

```
FIELD2      2      C'R'
X'BF'       *      ALPHA
```

A compound expression is a combination of two or, at most, three simple expressions, connected to each other by arithmetic operators. The recognized operators are + (plus), - (minus), and * (asterisk), denoting, respectively, addition, subtraction, and multiplication. The following are compound expressions:

```
N+14*256        ENTRY-OVER
FIELD+X'2D'     *+GAMMA-200
```

Note that an asterisk is used above both for the Location Counter (*+GAMMA-200) and as an operator (N+14*256), but cannot be used in succession to denote the two in the same expression. The following example is invalid:

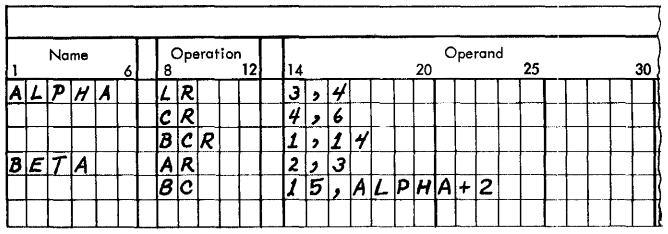
```
**5
```

A compound expression must not contain either two simple expressions or two operators in succession, nor may it begin with an operator. The following examples violate these rules and, therefore, are invalid:

```
AREAX'C'       -DELTA+256
FIELD+-10      +FIELD-10
```

### Relative Addressing

Using compound expressions, the programmer can address instructions and data areas relative to the Location Counter or to some symbolic storage location. This is called relative addressing. In the sequence of instructions shown in Figure 9, the location of the CR instruction can be expressed as ALPHA+2 or BETA-4. Note that relative addressing is always in bytes, never in words or instructions. All of the mnemonics in Figure 9 are for two-byte instructions in the RR format.



| Name 1–6 | Operation 8–12 | Operand 14–30 |
|---|---|---|
| ALPHA | LR | 3,4 |
|  | CR | 4,6 |
|  | BCR | 1,14 |
| BETA | AR | 2,3 |
|  | BC | 15,ALPHA+2 |

Figure 9. Example of Relative Addressing

### Attributes of Expressions

The assembler separately evaluates each expression in the operand field. An expression is considered terminated by a comma, a left or right parenthesis, or a blank, depending on what the expression specifies (see section "Machine Instruction Statements"). The evaluation procedure is as follows:

1. Each simple expression is given its numerical value.

2. Moving from left to right, the arithmetic operations are performed, multiplication before addition and subtraction. Thus, A+B*C is evaluated as A+(B*C) and not (A+B)*C.
3. The arithmetic result becomes the value attribute of the expression.

In addition to computing the value attribute of an expression, the assembler also determines its length attribute. For a compound expression, the length attribute is the same as the implied length attribute of its leftmost simple expression. If the leftmost simple expression in an expression is a self-defining value or an asterisk, the implied length attribute of that expression is one byte.

## Absolute and Relocatable Expressions

An expression is absolute if it (1) contains only absolute symbols or self-defining values, or (2) is of the following forms (where R is a relocatable symbol and A is an absolute symbol or self-defining value):

```
R-R      R-R+A    R-R-A    A+R-R
R-A-R    A-R+R    R+A-R
```

Although the address values of both relocatable symbols are subject to change when the program is loaded, the difference between their values will be constant; that is, absolute.

A relocatable expression is one whose value would change by N if the program was loaded N bytes away from its assembled location. Relocatable expressions must therefore conform to these rules:

1. A relocatable expression must contain either one or three relocatable symbols. If there are three relocatable symbols, one (and only one) must be preceded by the minus (-) operator. If only one relocatable symbol is present, it must not be preceded by the minus operator.
2. A relocatable symbol may not be multiplied. That is, it must not be preceded or followed by the asterisk (*) operator.

The following examples illustrate absolute and relocatable expressions. R represents relocatable symbols; A, absolute symbols.

Absolute Expressions:
```
R-R+5
A+14*C'H'
2048
A*A
```

Relocatable Expressions:
```
R+2
R-8*A
R-R+R
*-X'FB2'
R-A
```

The following expressions are invalid for the reasons listed:

| | |
|---|---|
| R+R<br>R+R-A | Contain two relocatable symbols. |
| R*A | Relocatable symbol is multiplied. |
| R+R+R | No minus operator. |
| A-R | Single relocatable symbol is preceded by a minus operator. |
| R-R-R | Two minus operators. |

## Restrictions

The following restrictions apply to all expressions. Additional limitations are imposed where pertinent in this publication.

1. An expression can have a negative value only when it is an absolute expression specifying an address constant using the DC assembler instruction.
2. An expression containing an external symbol may not contain any other relocatable symbols. For the purpose of evaluating such an expression, the value of the external symbol at assembly time will be zero; the symbol will be revalued when the program is loaded.
3. If an expression is used as the operand of a machine instruction statement, any self-defining values within it must not exceed 4,095. Instructions containing self-defining values exceeding 4,095 will be set to zero. The operation code will remain unchanged.
4. The maximum value of an expression is 65,535. If an expression exceeding this maximum is used in a machine instruction statement, the entire instruction except for the operation code will be set to zero; if used in

instruction except for the operation code will be set to zero; if used in an assembler instruction statement, the action taken depends on the instruction.

Note: The maximum value of each individual term in the operand field of USING, ORG, END, EQU, CCW (second operand), and DC (A) assembler instructions must not exceed 16,777,215. The maximum value of an entire expression in an operand field of a USING, ORG, END, or EQU instruction is, however, 65,535. The maximum value of an entire expression in the operand field of a DC (A) or CCW (second operand) instruction is 16,777,215.

The assembler language provides for the symbolic representation of all machine instructions. The symbolic format of these instructions varies with the machine format. There are five basic machine formats: RR, RX, RS, SI, and SS. Within each basic format, further variations are possible.

Machine instructions are automatically aligned by the assembler on half-word boundaries. Any byte skipped because of alignment will be set to zero. Such situations arise when data is inserted into the instruction string, as in a calling sequence.

Any machine instruction statement may be given a name, which other language statements can use. The value attribute of such a name is the address of the leftmost byte assigned to the assembled instruction. The length attribute of the name depends on the basic machine format:

| Basic Machine Format | Implied Length (in Bytes) |
|---|---|
| RR | 2 |
| RX | 4 |
| RS | 4 |
| SI | 4 |
| SS | 6 |

## INSTRUCTION FORMAT

Figure 10 shows each basic machine format, followed by its corresponding symbolic operand field formats and mnemonic operation codes. The numbers in the basic machine formats are the bit sizes of the field.

Figure 11 identifies the field codes used in Figure 10. Figure 11 also contains other pertinent information for specifying the fields in machine instruction statements. The following are additional points that must be considered:

1. If no indexing is used in an RX instruction and the base register (B2) is present, the X2 field must be written as a zero. If indexing is used, and if the base register is implied, the base register field may be omitted.
2. If the field or fields enclosed in parentheses are omitted, the parentheses (and the comma between them) may also be omitted.
3. If the value of an absolute expression exceeds the maximum (stated in Figure 11) for a field, the entire instruction will be set to zero except for the operation code; the statement will be flagged in the program listing. The preceding does not apply to the displacement field.
4. If the value of a displacement field exceeds 4,095, only the rightmost 12 bits will be used; the listing will be flagged.
5. If the programmer writes an absolute expression specifying a displacement and does not specify a base register, the assembler will place zero in the base-register field. The same applies to the index register.
6. If any invalidity in the operand field (other than those listed above) prevents correct evaluation of an expression, the entire instruction, except for the operation code, will be set to zero and the statement will be flagged. Such invalidities would include undefined symbols, use of relocatable expressions where absolute expressions are called for, etc.

## IMPLIED BASE REGISTERS AND DISPLACEMENTS

The assembler has the facility for assigning base registers and computing displacements for symbolic storage addresses. If this facility is used, the programmer simply specifies a symbolic address, by using a relocatable symbol, thus implying that the assembler is to select the base register and displacement. Before this can be done, however, the programmer must indicate to the assembler the contents and number of the general registers available for base registers. This information is conveyed with the USING and DROP instructions described in the section "Base Register Instructions."

| | Basic Machine Format | | | | | | | Assembler Operand Field Format | Applicable Instructions |
|---|---|---|---|---|---|---|---|---|---|
| Bits | 8 | 4 | 4 | 4 | 12 | 4 | 12 | | |
| RR | Op Code | R1 | R2 | N/A | N/A | N/A | N/A | R1,R2 | All RR instructions except BCR,SPM,SVC |
| | Op Code | M1 | R2 | N/A | N/A | N/A | N/A | M1,R2 | BCR |
| | Op Code | R1 | 0 | N/A | N/A | N/A | N/A | R1 | SPM |
| | Op Code | I | | N/A | N/A | N/A | N/A | I | SVC |
| RX | Op Code | R1 | X2 | B2 | D2 | N/A | N/A | R1,D2 (X2,B2) | All RX instructions except BC |
| | Op Code | M1 | X2 | B2 | D2 | N/A | N/A | M1,D2 (X2,B2) | BC |
| RS | Op Code | R1 | R3 | B2 | D2 | N/A | N/A | R1,R3,D2 (B2) | BXH,BXLE,LM,STM |
| | Op Code | R1 | R3 | B2 | D2 | N/A | N/A | R1,D2 (B2) | All shift instructions |
| SI | Op Code | I2 | | B1 | D1 | N/A | N/A | D1 (B1) ,I2 | All SI instructions except LPSW,SSM,HIO, SIO,TIO,TCH |
| | Op Code | 0 | 0 | B1 | D1 | N/A | N/A | D1 (B1) | LPSW,SSM,HIO, SIO,TIO,TCH,TS |
| SS | Op Code | L1 | L2 | B1 | D1 | B2 | D2 | D1 (L1,B1) ,D2 (L2,B2) | PACK,UNPK,MVO, AP,CP,DP,MP,SP, ZAP |
| | Op Code | L | | B1 | D1 | B2 | D2 | D1 (L,B1) ,D2 (B2) | NC,OC,XC,CLC, MVC,MVN,MVZ,TR, TRT,ED,EDMK |

Figure 10. Machine Instruction Statement Formats

Base registers and displacements can be implied for RX, RS, SI, and SS instructions. For example, the operands of an RS instruction can be specified as

R1, R3, S2

where S2 represents a symbolic address (i.e., a relocatable symbol) that the assembler will separate into a displacement (D2) and base register (B2).

To specify addresses in this manner, the programmer must observe these rules:

1. The base register instructions (USING and DROP) must be used as described subsequently in this publication.
2. The symbolic address must be represented by a simple or compound _relocatable_ expression.

| Reference Summary for Operand Fields | | | | |
|---|---|---|---|---|
| Field Code | Code Represents | Field Bit Size | Expression | |
| | | | Allowable Types | Maximum Values |
| R1,R2,R3 | General or floating-point register | 4 | Simple absolute | 15 |
| M1 | Mask | 4 | Simple absolute | 15 |
| D1,D2 | Displace-ment | 12 | Simple or compound absolute | 4095 |
| B1,B2 | Base register | 4 | Simple absolute | 15 |
| X2 | Index register | 4 | Simple absolute | 15 |
| L1,L2 | Length | 4 | Simple absolute | 16* |
| L | Length | 8 | Simple absolute | 256* |
| I2,I | Immediate | 8 | Simple absolute | 255 |
| * These are maximum values for length fields allowed in assembler statements; the values assembled for the instruction length fields are one less than these values. | | | | |

Figure 11. Operand Field Summary

3. A base register must not be written. An explicit base register will cause the assembler to treat the storage address as a displacement and an error will result because a displacement must always be an absolute expression. An explicit index register may be used, however, in the usual manner.

In the following example, the relocatable expression FIELD, with an address value of 7400, is used in a machine instruction; assume that the assembler has been told that general register 12 contains 4096 and is available as a base register.

```
    ST    4,FIELD
```

The assembled machine instruction (in decimal) would be as follows, the value of D2 being the difference between 7400 and 4096.

| Operation Code | R1 | X2 | B2 | D2 |
|---|---|---|---|---|
| 50 | 4 | 0 | 12 | 3304 |

Had the instruction been ST 4,FIELD(2), the assembled machine instruction would differ from the previous example only in that the content of the X2 field would be 2 rather than zero.

## IMPLIED AND EXPLICIT LENGTHS

The length field in SS instructions can be implied or explicit. An implied length is the length attribute of either the absolute expression specifying the displacement or the relocatable expression specifying the symbolic address, whichever

| Reference Summary for Implied Operands | | | | |
|---|---|---|---|---|
| Basic Machine Format | Explicit Base Registers and Displacement | | Implied Base Registers and Displacement | |
| | Explicit Length (1) | Implied Length (2) | Explicit Length (3) | Implied Length (4) |
| RX | D2 (2,B2) | N/A | S2 (X2) | N/A |
| RS | D2 (B2) | N/A | S2 | N/A |
| SI | D1 (B1) | N/A | S1 | N/A |
| SS | D1 (L1,B1) | D1 (,B1) | S1 (L1) | S1 |
| SS | D2 (L2,B2) | D2 (,B2) | S2 (L2) | S2 |
| SS | D1 (L,B1) | D1 (,B1) | S1 (L) | S1 |
| SS | D2 (B2) | N/A | S2 | N/A |
| The S1 and S2 fields are relocatable expressions or absolute expressions representing values up to 4095; all other fields are absolute expressions. Where the S1 and S2 fields are absolute expressions, base register zero is implied. | | | | |

Figure 12. Implied Operand Field Summary

is written in the statement. The length attribute of a compound expression is the implied length of its leftmost simple expression.

An explicit length, by contrast, is written by the programmer in the statement as a simple absolute expression. If a length is explicit, it overrides the implied length associated with the displacement or symbolic address.

Regardless of how the length is specified (implied or explicit), if it exceeds the values indicated in Figure 11 for the L, L1, and L2 fields, the entire assembled instruction, except the operation code, will be set to zero.

Note that the length, whether implied or explicit, is always an effective length. That is, it is one more than the value inserted into the length field of the assembled machine instruction. In the case where an explicit length of zero is specified, the assembler assumes an effective length of one. Thus, a zero is inserted in the length field of the assembled instruction.

The reference summary in Figure 12 is for use with the figure showing the machine instruction formats (Figure 10). For each explicit operand format in column 1, any of the corresponding implied operand formats in columns 2, 3, or 4 can be substituted in order to specify an implied length or an implied base register and displacement, or both.

## MACHINE INSTRUCTION MNEMONICS

This section contains an alphabetical listing of the mnemonics of all the machine instructions and their operand field formats. The column headings in the list are:

1. Mnemonic Code: This column contains the mnemonic operation code for the machine instruction.
2. Instruction: This column contains the name of the instruction associated with the mnemonic.
3. Operation Code: This column contains the hexadecimal equivalent of the actual machine operation code.
4. Basic Machine Format: This column contains the basic machine format of the instruction:
   RR, RS, RX, SI, or SS.
5. Operand Field Format: This column shows the explicit symbolic format of the operand and field for the particular mnemonic.

Appendix E provides a table for easy conversion of hexadecimal operation codes to their associated mnemonic codes.

| Mnemonic Code | Instruction | Oper-ation Code | Basic Machine Format | Operand Field Format |
|---|---|---|---|---|
| A | Add | 5A | RX | R1,D2 (X2,B2) |
| AD | Add Normalized, Long | 6A | RX | R1,D2 (X2,B2) |
| ADR | Add Normalized, Long | 2A | RR | R1,R2 |
| AE | Add Normalized, Short | 7A | RX | R1,D2 (X2,B2) |
| AER | Add Normalized, Short | 3A | RR | R1,R2 |
| AH | Add Half-Word | 4A | RX | R1,D2 (X2,B2) |
| AL | Add Logical | 5E | RX | R1,D2 (X2,B2) |
| ALR | Add Logical | 1E | RR | R1,R2 |
| AP | Add Decimal | FA | SS | D1 (L1,B1) ,D2 (L2,B2) |
| AR | Add | 1A | RR | R1,R2 |
| AU | Add Unnormalized, Short | 7E | RX | R1,D2 (X2,B2) |
| AUR | Add Unnormalized, Short | 3E | RR | R1,R2 |
| AW | Add Unnormalized, Long | 6E | RX | R1,D2 (X2,B2) |
| AWR | Add Unnormalized, Long | 2E | RR | R1,R2 |
| | | | | |
| BAL | Branch and Link | 45 | RX | R1,D2 (X2,B2) |
| BALR | Branch and Link | 05 | RR | R1,R2 |
| BC | Branch on Condition | 47 | RX | M1,D2 (X2,B2) |
| BCR | Branch on Condition | 07 | RR | M1,R2 |
| BCT | Branch on Count | 46 | RX | R1,D2 (X2,B2) |
| BCTR | Branch on Count | 06 | RR | R1,R2 |
| BXH | Branch on Index High | 86 | RS | R1,R3,D2 (B2) |
| BXLE | Branch on Index Low or Equal | 87 | RS | R1,R3,D2 (B2) |
| | | | | |
| C | Compare Algebraic | 59 | RX | R1,D2 (X2,B2) |
| CD | Compare, Long | 69 | RX | R1,D2 (X2,B2) |
| CDR | Compare, Long | 29 | RR | R1,R2 |
| CE | Compare, Short | 79 | RX | R1,D2 (X2,B2) |
| CER | Compare, Short | 39 | RR | R1,R2 |
| CH | Compare Half-Word | 49 | RX | R1,D2 (X2,B2) |
| CL | Compare Logical | 55 | RX | R1,D2 (X2,B2) |
| CLC | Compare Logical | D5 | SS | D1 (L,B1) ,D2 (B2) |
| CLI | Compare Logical Immediate | 95 | SI | D1 (B1) ,I2 |
| CLR | Compare Logical | 15 | RR | R1,R2 |
| CP | Compare Decimal | F9 | SS | D1 (L1,B1) ,D2 (L2,B2) |
| CR | Compare Algebraic | 19 | RR | R1,R2 |
| CVB | Convert to Binary | 4F | RX | R1,D2 (X2,B2) |
| CVD | Convert to Decimal | 4E | RX | R1,D2 (X2,B2) |
| | | | | |
| D | Divide | 5D | RX | R1,D2 (X2,B2) |
| DD | Divide, Long | 6D | RX | R1,D2 (X2,B2) |
| DDR | Divide, Long | 2D | RR | R1,R2 |
| DE | Divide, Short | 7D | RX | R1,D2 (X2,B2) |
| DER | Divide, Short | 3D | RR | R1,R2 |
| DP | Divide Decimal | FD | SS | D1 (L1,B1) ,D2 (L2,B2) |
| DR | Divide | 1D | RR | R1,R2 |
| | | | | |
| ED | Edit | DE | SS | D1 (L,B1) ,D2 (B2) |
| EDMK | Edit and Mark | DF | SS | D1 (L,B1) ,D2 (B2) |
| EX | Execute | 44 | RX | R1,D2 (X2,B2) |
| | | | | |
| HDR | Halve, Long | 24 | RR | R1,R2 |
| HER | Halve, Short | 34 | RR | R1,R2 |
| HIO | Halt I/O | 9E | SI | D1 (B1) |

| Mnemonic Code | Instruction | Oper-ation Code | Basic Machine Format | Operand Field Format |
|---|---|---|---|---|
| IC | Insert Character | 43 | RX | R1,D2(X2,B2) |
| ISK | Insert Storage Key | 09 | RR | R1,R2 |
| L | Load | 58 | RX | R1,D2(X2,B2) |
| LA | Load Address | 41 | RX | R1,D2(X2,B2) |
| LCDR | Load Complement, Long | 23 | RR | R1,R2 |
| LCER | Load Complement, Short | 33 | RR | R1,R2 |
| LCR | Load Complement | 13 | RR | R1,R2 |
| LD | Load, Long | 68 | RX | R1,D2(X2,B2) |
| LDR | Load, Long | 28 | RR | R1,R2 |
| LE | Load, Short | 78 | RX | R1,D2(X2,B2) |
| LER | Load, Short | 38 | RR | R1,R2 |
| LH | Load Half-Word | 48 | RX | R1,D2(X2,B2) |
| LM | Load Multiple | 98 | RS | R1,R3,D2(B2) |
| LNDR | Load Negative, Long | 21 | RR | R1,R2 |
| LNER | Load Negative, Short | 31 | RR | R1,R2 |
| LNR | Load Negative | 11 | RR | R1,R2 |
| LPDR | Load Positive, Long | 20 | RR | R1,R2 |
| LPER | Load Positive, Short | 30 | RR | R1,R2 |
| LPR | Load Positive | 10 | RR | R1,R2 |
| LPSW | Load PSW | 82 | SI | D1(B1) |
| LR | Load | 18 | RR | R1,R2 |
| LTDR | Load and Test, Long | 22 | RR | R1,R2 |
| LTER | Load and Test, Short | 32 | RR | R1,R2 |
| LTR | Load and Test | 12 | RR | R1,R2 |
| M | Multiply | 5C | RX | R1,D2(X2,B2) |
| MD | Multiply, Long | 6C | RX | R1,D2(X2,B2) |
| MDR | Multiply, Long | 2C | RR | R1,R2 |
| ME | Multiply, Short | 7C | RX | R1,D2(X2,B2) |
| MER | Multiply, Short | 3C | RR | R1,R2 |
| MH | Multiply Half-Word | 4C | RX | R1,D2(X2,B2) |
| MP | Multiply Decimal | FC | SS | D1(L1,B1),D2(L2,B2) |
| MR | Multiply | 1C | RR | R1,R2 |
| MVC | Move Characters | D2 | SS | D1(L,B1),D2(B2) |
| MVI | Move Immediate | 92 | SI | D1(B1),I2 |
| MVN | Move Numerics | D1 | SS | D1(L,B1),D2(B2) |
| MVO | Move with Offset | F1 | SS | D1(L1,B1),D2(L2,B2) |
| MVZ | Move Zones | D3 | SS | D1(L,B1),D2(B2) |
| N | AND Logical | 54 | RX | R1,D2(X2,B2) |
| NC | AND Logical | D4 | SS | D1(L,B1),D2(B2) |
| NI | AND Logical Immediate | 94 | SI | D1(B1),I2 |
| NR | AND Logical | 14 | RR | R1,R2 |
| O | OR Logical | 56 | RX | R1,D2(X2,B2) |
| OC | OR Logical | D6 | SS | D1(L,B1),D2(B2) |
| OI | OR Logical Immediate | 96 | SI | D1(B1),I2 |
| OR | OR Logical | 16 | RR | R1,R2 |
| PACK | Pack | F2 | SS | D1(L1,B1),D2(L2,B2) |
| RDD | Read Direct | 85 | SI | D1(B1),I2 |

| Mnemonic Code | Instruction | Operation Code | Basic Machine Format | Operand Field Format |
|---|---|---|---|---|
| S | Subtract | 5B | RX | R1,D2 (X2,B2) |
| SD | Subtract Normalized, Long | 6B | RX | R1,D2 (X2,B2) |
| SDR | Subtract Normalized, Long | 2B | RR | R1,R2 |
| SE | Subtract Normalized, Short | 7B | RX | R1,D2 (X2,B2) |
| SER | Subtract Normalized, Short | 3B | RR | R1,R2 |
| SH | Subtract Half-Word | 4B | RX | R1,D2 (X2,B2) |
| SIO | Start I/O | 9C | SI | D1 (B1) |
| SL | Subtract Logical | 5F | RX | R1,D2 (X2,B2) |
| SLA | Shift Left Single Algebraic | 8B | RS | R1,D2 (B2) |
| SLDA | Shift Left Double Algebraic | 8F | RS | R1,D2 (B2) |
| SLDL | Shift Left Double Logical | 8D | RS | R1,D2 (B2) |
| SLL | Shift Left Single Logical | 89 | RS | R1,D2 (B2) |
| SLR | Subtract Logical | 1F | RR | R1,R2 |
| SP | Subtract Decimal | FB | SS | D1 (L1,B1) ,D2 (L2,B2) |
| SPM | Set Program Mask | 04 | RR | R1 |
| SR | Subtract | 1B | RR | R1,R2 |
| SRA | Shift Right Single Algebraic | 8A | RS | R1,D2 (B2) |
| SRDA | Shift Right Single Algebraic | 8E | RS | R1,D2 (B2) |
| SRDL | Shift Right Single Logical | 8C | RS | R1,D2 (B2) |
| SRL | Shift Right Single Logical | 88 | RS | R1,D2 (B2) |
| SSK | Set Storage Key | 08 | RR | R1,R2 |
| SSM | Set System Mask | 80 | SI | D1 (B1) |
| ST | Store | 50 | RX | R1,D2 (X2,B2) |
| STC | Store Character | 42 | RX | R1,D2 (X2,B2) |
| STD | Store Long | 60 | RX | R1,D2 (X2,B2) |
| STE | Store Short | 70 | RX | R1,D2 (X2,B2) |
| STH | Store Half-Word | 40 | RX | R1,D2 (X2,B2) |
| STM | Store Multiple | 90 | RS | R1,R3,D2 (B2) |
| SU | Subtract Unnormalized, Short | 7F | RX | R1,D2 (X2,B2) |
| SUR | Subtract Unnormalized, Short | 3F | RR | R1,R2 |
| SVC | Supervisor Call | 0A | RR | I |
| SW | Subtract Unnormalized, Long | 6F | RX | R1,D2 (X2,B2) |
| SWR | Subtract Unnormalized, Long | 2F | RR | R1,R2 |
| TCH | Test Channel | 9F | SI | D1 (B1) |
| TIO | Test I/O | 9D | SI | D1 (B1) |
| TM | Test Under Mask | 91 | SI | D1 (B1) ,I2 |
| TR | Translate | DC | SS | D1 (L,B1) ,D2 (B2) |
| TRT | Translate and Test | DD | SS | D1 (L,B1) ,D2 (B2) |
| TS | Test and Set | 93 | SI | D1 (B1) |
| UNPK | Unpack | F3 | SS | D1 (L1,B1) ,D2 (L2,B2) |
| WRD | Write Direct | 84 | SI | D1 (B1) ,I2 |
| X | Exclusive OR | 57 | RX | R1,D2 (X2,B2) |
| XC | Exclusive OR | D7 | SS | D1 (L,B1) ,D2 (B2) |
| XI | Exclusive OR, Immediate | 97 | SI | D1 (B1) ,I2 |
| XR | Exclusive Logical OR | 17 | RR | R1,R2 |
| ZAP | Zero and Add Decimal | F8 | SS | D1 (L1,B1) ,D2 (L2,B2) |

## MACHINE INSTRUCTION EXAMPLES

The examples that follow are grouped according to machine instruction format. They illustrate the various symbolic operand formats. All symbols employed in the examples must be assumed to be defined elsewhere in the same assembly. All symbols that specify register numbers and lengths must be assumed to be equated elsewhere to absolute values.

Implied addressing (shown in the following examples) requires the use of the USING assembler instruction described later in the publication.

RR Format

| Name | Operation | Operand |
|---|---|---|
| ALPHA1 | LR | 1,2 |
| ALPHA2 | LR | REG1,REG2 |
| BETA | SPM | 15 |
| GAMMA1 | SVC | 250 |
| GAMMA2 | SVC | TEN |

The operands of ALPHA1, BETA, and GAMMA1 are decimal self-defining values, which are categorized as absolute expressions. The operands of ALPHA2 and GAMMA2 are symbols that are equated elsewhere to absolute values.

RX Format

| Name | Operation | Operand |
|---|---|---|
| ALPHA1 | L | 1,39(4,10) |
| ALPHA2 | L | REG1,39(4,TEN) |
| BETA1 | L | 2,ZETA(4) |
| BETA2 | L | REG2,ZETA(REG4) |
| GAMMA1 | L | 2,ZETA |
| GAMMA2 | L | REG2,ZETA |

Both ALPHA instructions specify explicit addresses; REG1 and TEN are absolute symbols. Both BETA instructions specify implicit addresses, and both use index registers. Indexing is omitted from the GAMMA instructions. GAMMA1 and GAMMA2 specify implicit addresses.

RS Format

| Name | Operation | Operand |
|---|---|---|
| ALPHA1 | BXH | 1,2,20(14) |
| ALPHA2 | BXH | REG1,REG2,20(REGE) |
| ALPHA3 | BXH | REG1,REG2,ZETA |
| BETA1 | SLL | 1,20(9) |
| BETA2 | SLL | REG1,20(9) |
| BETA3 | SLL | REG1,ZETA |

Whereas ALPHA1 and ALPHA2 specify explicit addresses, ALPHA3 specifies an implicit address. Similarly, the BETA instructions illustrate both explicit and implicit addresses.

SI Format

| Name | Operation | Operand |
|---|---|---|
| ALPHA1 | CLI | 40(9),X'40' |
| ALPHA2 | CLI | 40(REG9),TEN |
| BETA1 | CLI | ZETA,TEN |
| BETA2 | CLI | ZETA,C'A' |
| GAMMA1 | SIO | 40(9) |
| GAMMA2 | SIO | 0(9) |
| GAMMA3 | SIO | 40(0) |
| GAMMA4 | SIO | ZETA |

The ALPHA instructions and GAMMA1 through GAMMA3 specify explicit addresses, whereas the BETA instructions and GAMMA4 specify implicit addresses. GAMMA2 specifies a displacement of zero. GAMMA3 does not specify a base register.

SS Format

| Name | Operation | Operand |
|---|---|---|
| ALPHA1 | AP | 40(9,8),30(6,7) |
| ALPHA2 | AP | 40(NINE,REG8),30(REG6,7) |
| ALPHA3 | AP | FIELD2,FIELD1 |
| ALPHA4 | AP | FIELD2(9),FIELD1(6) |
| BETA | AP | FIELD2(9),FIELD1 |
| GAMMA1 | MVC | 40(9,8),30(7) |
| GAMMA2 | MVC | 40(NINE,REG8),DEC(7) |
| GAMMA3 | MVC | FIELD2,FIELD1 |
| GAMMA4 | MVC | FIELD2(9),FIELD1 |

ALPHA1, ALPHA2, GAMMA1, and GAMMA2 specify explicit lengths and addresses. ALPHA3 and GAMMA3 specify both implied length and implied addresses. ALPHA4 and GAMMA4 specify explicit length and implied addresses. BETA specifies an explicit length for FIELD2 and an implicit length for FIELD1; both addresses are implied.

Just as machine instructions are used to request the machine to perform a sequence of operations, so assembler instructions are requests to the assembler to perform certain operations. There are 15 such assembler instructions. Some already have been briefly mentioned in the preceding sections. All the assembler instructions are listed below by mnemonic operation code and name. They are fully described in the subsequent text. Figure 19 at the end of this section contains a summary description of all assembler instructions.

| Assembler Control Instructions | |
|---|---|
| ICTL | Input Control |
| START | Start Program |
| ORG | Reset Location Counter |
| CNOP | Conditional No Operation |
| END | End Program |
| EJECT | Start New Page |
| SPACE | Space Listing |

| Definition Instructions | |
|---|---|
| EQU | Equate Symbol |
| DS | Define Storage |
| CCW | Define Channel Command Word |
| DC | Define Constant |

| Base Register Instructions | |
|---|---|
| USING | Use Base Address Register |
| DROP | Drop Register |

| Program Linking Instructions | |
|---|---|
| ENTRY | Identify Entry-Point Symbol |
| EXTRN | Identify External Symbol |

Assembler instruction statements, in contrast to machine instruction statements, do not always cause actual machine instructions to be included in the object program. Some (for example, DS, DC) generate no instructions but cause storage areas to be set aside for constants and other data. Others (for example, EQU, SPACE) are effective only at assembly time; they generate nothing in the object program and have no effect on the Location Counter.

## ASSEMBLER CONTROL INSTRUCTIONS

The assembler control instructions are used to specify the beginning and end of an assembly, set the Location Counter to a value or word boundary, control the program listing, and indicate the statement format. Except for the CNOP instruction, none of these assembler instructions generate instructions or constants in the object program.

### ICTL - Input Control

The ICTL instruction tells the assembler in which card column the statement portion of the source-program cards begin. The mnemonic operation code of the ICTL statement <u>must</u> start in column 26 or higher. The format of the ICTL instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| Not used | ICTL | The decimal value 1 or 25 |

If the statements are to begin in column 25, the format is:

```
        ICTL      25
```

If the statements begin in column 1, the format is:

```
        ICTL      1
```

If (1) the ICTL statement is not used or (2) the operand field does not contain a 1 or 25, column 1 will be assumed for the tape option and column 25 will be assumed for the card option. When the ICTL statement is used, it must be the first statement in the source program. If it appears anywhere else, it will not be used. If a name is present, the name will not be used.

### START - Start Program

The START instruction may be used to indicate the beginning of an assembly, to give a name to the program, and to set the Location Counter to an initial value. The format of the START instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| A symbol (optional) | START | A self-defining value or blank |

The symbol in the name field becomes the name of the program. The symbol is assigned the address corresponding to the self-defining value in the operand field. This symbol can be specified as an external symbol (using the EXTRN instruction) in other programs, without using the ENTRY instruction to identify it as an entry point in this program. If there is no symbol in the name field, the assembler will assign a name consisting of six blanks.

A self-defining value that specifies the initial setting of the Location Counter is written in the operand field. If the value of the operand is not a multiple of eight, the Location Counter will be set at the next double-word boundary. The self-defining value must not exceed the maximum allowable setting of the Location Counter. If the operand field is invalid or blank, the Location Counter will be set to zero.

The initial setting of the Location Counter becomes the starting location of the program. This location is the initial loading location if the program is loaded by the absolute loader. It can also be used as the temporary starting location for loading the program while it is being tested. This enables the programmer to match the locations shown in the listing produced by the assembler with the locations in storage print listings. When the program has been checked out, it can then be relocated elsewhere by the relocating loader.

If both the START and ICTL instructions are used, the START instruction must immediately follow the ICTL instruction. If it appears anywhere else or if it is not used, the assembler will set the Location Counter to zero and give the program a name of six blanks. Any invalid occurrences of a START instruction will not be used. It should be noted that if the ICTL instruction is not used, the START instruction should be the first in the program.

Either of the START statements below could be used to assign the name PROG2 to the program and to set the Location Counter to a value of 2040:

```
PROG2    START   2040
PROG2    START   X'7F8'
```

## ORG - Reset Location Counter

The ORG instruction resets the Location Counter to a relative value. This instruction may be used anywhere in the program, as often as desired. The format of the ORG instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| Not used | ORG | A relocatable expression |

The Location Counter is reset to the value of the relocatable expression. An ORG instruction that resets the Location Counter below its initial value as specified in the START instruction will not be used; it will, however, be printed in the listing with an error flag. Any symbol(s) in the expression must be previously defined. If the operand field is blank or invalid, the ORG instruction will not be used. If a name is specified, the name will not be used.

The statement:

```
         ORG     *+500
```

increases the Location Counter by 500 above its current setting. Nothing is assembled for the 500 bytes skipped. That is, these bytes are not cleared by the assembler.

The ORG instruction provides an alternate way of reserving storage areas; the preferred way usually is with the DS (Define Storage) assembler instruction. However, where a storage area cannot be conveniently defined with the DS instruction, the ORG instruction can be used. For example, to reserve two storage areas of equal size, the following coding might be used:

```
TABLE1   DS      50F
         DS      100H
         .
         .
         .
TABLE2   EQU     *
         ORG     *+TABLE2-TABLE1
```

Note that the EQU assembler instruction permits TABLE2 to be used in the ORG statement as a previously defined symbol.

## CNOP - Conditional No Operation

The CNOP instruction allows the programmer to align an instruction at a specific word boundary without breaking the instruction flow should any bytes be skipped for alignment. This facility is useful in creating calling sequences consisting of a linkage to a subroutine followed by parameters such as Channel Command Words (CCW) which require proper word boundaries.

The CNOP instruction aligns the Location Counter setting to a half-word, word, or double-word boundary. If the Location Counter is already aligned, the CNOP instruction has no effect. If the alignment specified requires the Location Counter to be incremented, a no-operation instruction (an RR branch-on-condition instruction with a zero R1 and R2 field) will be generated for each pair of bytes (half-words) skipped. If an odd number of bytes are skipped, the first byte will be set to zero.

The format of the CNOP instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| Not used | CNOP | Two decimal values of the form: _b_, _w_ |

Operand _b_ specifies at which byte in a word or double-word the Location Counter is to be set; _b_ can be 0, 2, 4, or 6. Operand _w_ specifies whether the byte _b_ is in a word (4) or double-word (8).

The following pairs of _b_ and _w_ values are valid:

| _b_,_w_ | Explanation |
|---|---|
| 0,4 | Beginning of a word |
| 2,4 | Middle of a word |
| 0,8 | Beginning of a double-word |
| 2,8 | Second half-word of a double-word |
| 4,8 | Middle (third half-word) of a double-word |
| 6,8 | Fourth half-word of a double-word |

Figure 13 shows the position in a double-word that each of these pairs specifies. Note that 0,4 and 2,4 specify two locations in a double-word.

If the operand field is blank or invalid, the CNOP instruction will not be used. A name, if present, will not be used.

Assume that the Location Counter is currently aligned at a double-word boundary. Then the CNOP instruction in this sequence:

```
CNOP    0,8
BALR    2,14
```

will have no effect; it will be printed in the program listing. This sequence, however:

```
CNOP    6,8
BALR    2,14
```

will cause three branch-on-condition instructions (no operations) to be generated, thus aligning the BALR instruction at the last half-word in a double-word:

```
BCR     0,0
BCR     0,0
BCR     0,0
BALR    2,14
```

After the BALR instruction is generated, the Location Counter will be at a double-word boundary so that a Channel Command Word (CCW) can be correctly positioned.

## END - End Program

The END instruction terminates the assembly of a program. It may also supply a point in the program to which control is transferred after the program is loaded.

The END instruction must always be the last statement in the source program. When the assembler detects this statement, it produces a Load End card in the user's object program for use by the load program.

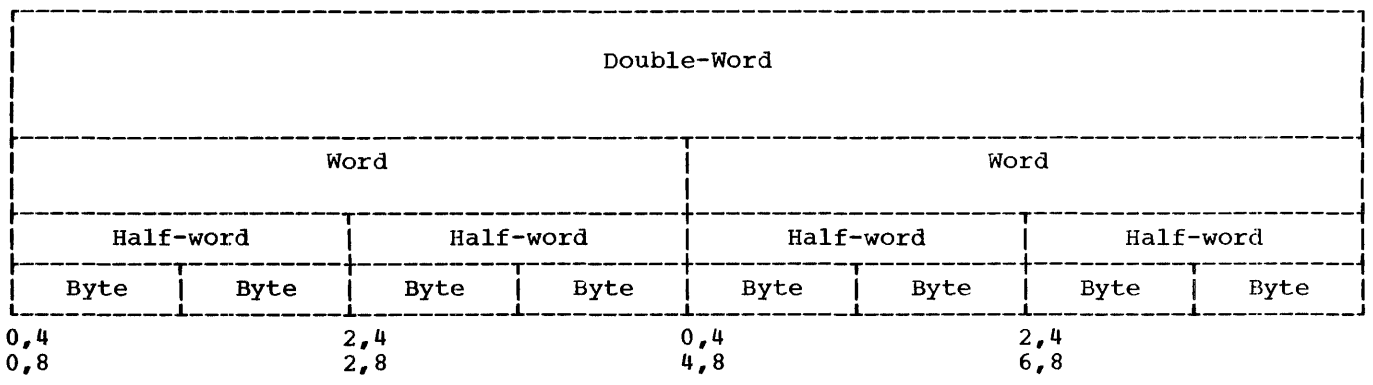


Figure 13. Boundary Alignment with a CNOP Instruction

The format of the END instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| Not used | END | A relocatable expression or blank |

The expression in the operand field specifies the point to which control is transferred when loading is complete. The value of the expression will be punched in the Load End card. If the operand field is blank or invalid, nothing will be punched in the Load End card. In this case, control will be passed to the first storage location (above decimal location 128) occupied by the user's program when the program is loaded. If the operand field is invalid, the statement will be flagged as a possible error. If a name is present, it will not be used.

The point to which control usually is transferred is the first machine instruction in the program, as shown in this sequence:

```
          START   2000
AREA      DS      50F
BEGIN     SR      3,3
          .
          .
          .
          END     BEGIN
```

EJECT - Start New Page

The EJECT instruction causes the next line of the listing to appear at the top of a new page. This instruction provides a convenient way to separate routines in the program listing. The format of the EJECT instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| Not used | EJECT | Not used |

Normally, the EJECT statement is not included in the program listing; however, anything appearing in the name or operand fields will result in including the statement in the listing. In this case, the EJECT statement is printed prior to skipping to the new page.

SPACE - Space Listing

The SPACE instruction is used to insert one or more blank lines in the listing. The format of the SPACE instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| Not used | SPACE | A decimal value |

A decimal value is used to specify the number of blank lines to be inserted in the program listing. If this value exceeds the number of lines remaining on the listing page, the statement will have the same effect as an EJECT statement. A blank operand field will cause one line to be skipped. Normally, the SPACE statement is not included in the program listing. There are, however, some exceptions. Anything in the name field of a SPACE statement results in including the statement in the listing. In this case, the statement is printed prior to spacing. If the operand field is invalid (that is, not a decimal value or one greater than 4095), the statement is flagged and listed. No space operation occurs.

## DEFINITION INSTRUCTIONS

The definition assembler instructions are used to define and enter constant data into a program, specify the contents of Channel Command Words, and reserve areas of core storage. The fields generated by these instructions can be referred to by symbolic names. The EQU instruction is included with the definition instructions because it is used for defining symbols.

### EQU - Equate Symbol

The EQU instruction is used to define a symbol by assigning to it the value and length attributes of an expression in the operand field. The format of the EQU instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| A symbol | EQU | An expression |

The symbol in the name field is given the same value attribute as the expression. The length attribute of the symbol will be that of the leftmost term of the expression. If the term is an asterisk (the Location Counter) or a self-defining value, the implied length of the symbol is one. The expression in the operand field can be relocatable or absolute, and the symbol will be similarly defined. Any symbols in the expression must be previously defined and have a positive value. Symbols not conforming to these rules will not be used. The associated EQU statements will be flagged.

If the expression in the operand field or the symbol in the name field, or both, are invalid or not present, the EQU statement will be flagged in the listing and will not be used.

The EQU instruction is the usual way of equating symbols to register numbers, input/output unit numbers, immediate data, actual addresses, and other arbitrary values. The examples below illustrate how this might be done:

```
REG2    EQU   2       General register
IO125   EQU   125     Input/output unit
TEST    EQU   X'3F'   Immediate data
TIMER   EQU   80      Actual address
```

To reduce programming time, the programmer can equate symbols to frequently used compound expressions and then use the symbols as operands in place of the expressions. Thus, in the statement

```
FIELD    EQU    ALPHA-BETA+GAMMA
```

FIELD will be defined as ALPHA-BETA+GAMMA and may be used in place of it. Note, however, that ALPHA, BETA, and GAMMA must all be previously defined.

### DS - Define Storage

The DS instruction is used to reserve storage areas and to assign names to the areas. This instruction is the preferred way of symbolically defining storage for work areas, input/output areas, etc. The format of the DS instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| A symbol (optional) | DS | An operand describing the area to be reserved, in the form shown below |

The single operand specifies the number, type, and, if desired, the length of the fields to be reserved. The general form of the operand is:

<u>dtLn</u>

Where:

<u>d</u>
is a decimal self-defining value that specifies the number of fields (from zero to 65,535) to be reserved. It is called the duplication factor. If it is omitted, one field will be reserved.

<u>t</u>
is the type code specifying the type of field to be reserved and can be one of the following letters:

| Code | Field Type | Implied Length (in Bytes) |
|---|---|---|
| C | Character (byte) | 1 |
| H | Half-word | 2 |
| F | Full-word | 4 |
| D | Double-word | 8 |

<u>Ln</u>

can be used only if the field code is C. <u>Ln</u> is the length code written as the letter L immediately followed by <u>n</u>, which is the length (in bytes) of each field. <u>n</u> can be a decimal value that is not zero or greater than 256.

Half-word, full-word, and double-word fields will be aligned to their proper boundaries. With a duplication factor (<u>d</u>) of zero, the DS instruction can be used to cause boundary alignment. Thus, the statement:

```
          DS        0D
```

will set the Location Counter at the next double-word boundary.

If there is a symbol in the name field, it will be assigned the current value of the Location Counter after any alignment. The length attribute of the symbol will be the implied length associated with the field code, unless a length code (<u>Ln</u>) is specified, in which case the length attribute will be the same as the length <u>n</u>.

For example, to define four 10-byte fields and one 100-byte field, the respective DS statements might be:

```
   FIELD    DS    4CL10
   AREA     DS    CL100
```

Then, to move the first 10 bytes at AREA into FIELD, the coding is as follows, assuming implied base registers and displacements:

```
   MVC      FIELD,AREA
```

Note that the length attribute of' FIELD, which is 10, is implied. Explicit length specification can be used to move the first 20 bytes at AREA into FIELD. The following instruction illustrates this:

```
   MVC      FIELD(20),AREA
```

Additional examples of DS statements are shown below. The implied length attribute of each symbol appears in parentheses before the symbol:

```
(80)  DONE    DS   CL80   One 80-byte field
(1)   DTWO    DS   80C    80 one-byte fields
(4)   DTHREE  DS   6F     Six full-words
(8)   DFOUR   DS   D      One double-word
(2)   DFIVE   DS   4H     Four half-words
```

If the operand is incorrectly specified, the statement will not be used. An error flag will appear in the listing.

A DS statement causes the reserved area to be skipped but not cleared. Therefore, the programmer should not assume that the area contains all zeros when the program is loaded. Whenever the assembler processes a DS statement, it will terminate the current output card (called a Text card) in the object deck and start the next card at the location following the reserved areas, thus skipping them. To minimize the number of Text cards punched, DS statements should be kept together as much as possible. Note, however, that Text cards are not terminated if no bytes are skipped by DS statements used only for boundary alignment.

## <u>CCW - Define Channel Command Word</u>

The CCW instruction provides a convenient way to define and generate an eight-byte Channel Command Word aligned at a double-word boundary. The internal machine format of a Channel Command Word is shown in Figure 14. The format of a CCW instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| A symbol (optional) | CCW | Four operands, separated by commas, specifying the contents of the Channel Command Word in the form described below |

The four operands, from left to right, are:

1. A <u>simple absolute</u> expression specifying the command code. The value of this expression will be right-justified in byte 1.
2. A <u>relocatable</u> expression specifying the data address. The value of this expression will be right-justified in bytes 2-4.
3. A <u>simple absolute</u> expression specifying the flags in bits 32-36 and zeros in bits 37-39. The value of

this expression is right-justified in byte 5. Byte 6 is set automatically to all zeros.

4. A simple absolute expression specifying the count. The value of this expression is right-justified in bytes 7-8.

The following is an example of a CCW statement:

```
CCW       X'OF',READIN,X'A8',80
```

Note that the form of the third operand sets bits 37-39 to zero, as required. The bit pattern of this operand is:

```
  32      36      40      44
   1010    1000    0000    0000
```

No operand field may be omitted. Operands not used must be written as zeros. An error in the operand field will cause eight bytes of zeros, aligned at a double-word boundary, to be assembled.

If there is a symbol in the name field, it will be assigned the value of the leftmost byte of the Channel Command Word after any boundary alignment. The length attribute of the symbol will be eight. Bytes skipped because of alignment will be assembled as zeros.

| Byte | Bits | Usage |
|---|---|---|
| 1 | 0-7 | Command code |
| 2-4 | 8-31 | Data address |
| 5 | 32-36 | Flags |
|  | 37-39 | Must be zero |
| 6 | 40-47 | Assembled automatically as all zeros |
| 7-8 | 48-63 | Count |

Figure 14. Channel Command Word

## DC - Define Constant

The DC instruction is for generating constant data in main storage. Data can be specified as characters, hexadecimal numbers, decimal numbers, and storage addresses. Decimal numbers may be in the form suitable for both fixed-point and floating-point arithmetic operations. The format of the DC instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| A symbol (optional) | DC | A single operand describing the constant, written in the form shown below |

The operand specifies the type of constant and the constant itself. It may also specify an explicit storage length for the constant and indicate how many times the constant is to be duplicated in storage. The format of this operand varies with the constant type. The basic format is either

dtLn'c' or ALn(c)

where:

d
is a decimal self-defining value (from 1 to 65,535) that specifies the number of identical constants to be generated. It is called the duplication factor. If it is omitted, one constant will be produced. A duplication factor cannot be specified for an expression (type A) constant.

Note: A print line is produced for each constant generated. Thus, assembler speed can be increased by keeping duplication factors small and length codes large.

t
is the type code, specifying the type of constant. It can be one of the following letters:

| Code | Constant Type | Machine Format |
|---|---|---|
| C | character | 8-bit BCD code. |
| X | hexadecimal | Fixed-point binary. |
| F | decimal | Full-word fixed-point binary. |
| E | decimal | Short-precision floating-point binary. |
| H | decimal | Half-word fixed-point binary. |
| D | decimal | Long-precision floating-point binary. |
| A | relocatable or absolute expression | Fixed-point binary. |

Ln

is the length code written as the letter L followed by n, a decimal value, which is the explicit length (in bytes) of the constant. A length code is not applicable with constant types H, E, and D. If a length code is not given, the implied lengths shown in Figure 15 will be used. An explicit length must not exceed those values shown in Figure 15.

'c'

is the constant itself enclosed in single quotation marks. Note that for constant type A, the expression specifying the constant is enclosed in parentheses (c).

If the operand is invalid, the statement will not be used and will be flagged in the listing.

All constant types except character (C) and hexadecimal (X) will be aligned at appropriate boundaries. Constants are not aligned if an explicit length is given. The boundaries for the various constant types are summarized in Figure 15. Any bytes skipped for alignment will be set to zero.

A symbol in the name field will be given the address value of the first byte assigned after any alignment. The length attribute of the symbol will be the implied (or explicit) length of the constant before the duplication factor is applied.

The implied or explicit length of a constant defined by a single DC statement must not exceed 16 bytes before the duplication factor is applied. If longer constants are required, successive DC statements should be used. The total storage alloted to a constant defined by one DC statement will be the duplication factor times the length of the constant.

The subsequent text, with examples, describes each of the constant types. This material is summarized in Figure 15. Note that the definition of character, hexadecimal, and decimal constants is not limited by the rules pertaining to self-defining values.

## Character Constants (C)

A character constant may comprise not more than 16 valid characters. A valid character is a blank or any combination of punches in a card column that translates into the 8-bit IBM Extended BCD Interchange Code. There are 256 such combinations; the table in Appendix A lists the combinations, their eight-bit codes, and, where applicable, their printer graphics.

Each character in the constant is translated into one byte. Boundary alignment is not performed. The number of bytes required for the constant becomes its implied length unless an explicit length is stated. In the following example, the length attribute of FIELD is 12:

```
FIELD     DC      C'TOTAL IS 10'
```

A single quotation mark used as a character is represented in the constant by two single quotation marks. The same rule applies to ampersands. Thus:

```
          DC      C'DON''T'
          DC      C'A,B&&C'
```

Five bytes will be used for each constant.

If more than 16 characters are specified or a length code is given and the size of the constant exceeds the explicit length, the excess rightmost characters will be truncated before applying the duplication factor. The statement will be flagged. For example, the statement:

```
          DC      3CL4'ABCDE'
```

will generate:

```
          ABCDABCDABCD
```

If the number of characters is fewer than the explicit length, the constant will be padded by adding the necessary right-hand blanks. The statement:

```
          DC      4CL3'NO'
```

will generate in storage:

```
   NObNObNObNOb
```

| Reference Summary for DC Statements | | | | | |
|---|---|---|---|---|---|
| Constant-type Code | Boundary Alignment (If length is implied) | Length (in Bytes) | | Duplication Allowed | Truncation/ Padding Side |
| | | Implied | Maximum Explicit | | |
| C | none | variable* | 16 | yes | right |
| X | none | variable* | 16 | yes | left |
| F | word | 4 | 4 | yes | left |
| H | half-word | 2 | invalid | yes | left |
| E | word | 4 | invalid | yes | none |
| D | double-word | 8 | invalid | yes | none |
| A | word | 4 | 4 | no | left |
| * But not exceeding 16 bytes | | | | | |

Figure 15. DC Statement Summary

## Hexadecimal Constants (X)

A hexadecimal constant may comprise up to 32 hexadecimal digits. The valid hexadecimal digits are:

0 1 2 3 4 5 6 7 8 9 A B C D E F

A table for converting hexadecimal to decimal is included in Appendix B. The reader also is referred to the section "Self-Defining Values." Each hexadecimal digit represents four bits; hence, every pair of digits will be translated into one byte. Boundary alignment will not be performed. If an odd number of hexadecimal digits is present, the four leftmost bits of the leftmost byte will be set to zero. Unless an explicit length is specified, the number of bytes required for the constant will become its implied length.

An eight-digit hexadecimal constant provides a convenient way to set the bit pattern of a full binary word. The constant in the following example would set the first and third bytes of a word to ones. Note that the preceding DS statement is used to align the constant at a full-word boundary:

```
         DS      0F
TEST     DC      X'FF00FF00'
```

If (1) more than 32 hexadecimal digits are present or (2) a length code is specified and the byte size of the constant exceeds the explicit length, the excess leftmost digits will be truncated before the duplication factor is applied. The statement will be flagged in the listing. In the following statement, the A will be truncated and 6F4E will be used as the constant:

```
ALPHA    DC      3XL2'A6F4E'
```

The resulting constant will be generated three times:

```
6F4E6F4E6F4E
```

If the pairs of digits are fewer than the explicit length, the constant will be padded by adding zeros to the left before applying the duplication factor. Thus:

```
DC       2XL3'2DDA'
```

will generate two 3-byte constants:

```
002DDA002DDA
```

## Full-Word Constants (F)

The signed decimal constant in the operand is converted into a binary number. An unsigned number will be assumed to be positive. Negative numbers will be converted to two's complement notation.

If there is no explicit length, the binary number is placed in a full-word aligned at the proper boundary. An implied length of four is assigned. If a length code is present, alignment will not occur; the binary number will be right-justified in the specified number of bytes. An explicit length must not exceed four bytes.

Given the following statement:

```
CONWRD   DC      3F'+658474'
```

three full-word positive constants will be produced. The address value of CONWRD will correspond to the leftmost byte of the first word; the length attribute will be four. Thus, the expression CONWRD+4 can be used to address the second word symbolically.

The maximum permissible value of a full-word constant depends on the length, as follows:

| Length | Highest Value | Lowest Value |
|---|---|---|
| 4 | 2,147,483,647 | -2,147,483,648 |
| 3 | 8,388,607 | -8,388,608 |
| 2 | 32,767 | -32,768 |
| 1 | 127 | -128 |

Note: All lengths can be explicit. A length of 4, however, can also be implied.

If a value exceeds the limits associated with the length, a constant of zero will be generated before applying the duplication factor. The statement will be flagged in the listing. For example, the following statement would generate 12 bytes of zeros:

```
         DC        4FL3'-9500250'
```

## Half-Word Constants (H)

The signed decimal constant in the operand is converted into a binary number placed in a properly aligned half-word. A length code is not allowed. The implied length of the constant is two bytes.

If the number is unsigned, a positive value is assumed. Negative numbers will be converted to two's complement notation.

The largest number permitted is 32,767; the smallest is -32,768. If a number exceeds these limits, the constant will be set to zero before the duplication factor is applied. The statement will be flagged.

The following statement will generate two identical half-word positive constants, right-justified within two bytes:

```
         DC        2H'256'
```

## Short-Precision Floating-point Constants (E)

A short-precision floating-point constant is specified as a decimal fraction (mantissa) and an optional decimal exponent. The maximum allowable range for a floating-point constant is from approximately $(5.4)\times10^{-79}$ to $(7.2)\times10^{75}$. The constant will be aligned at a full-word boundary in the proper machine format for use in floating-point operations. A duplication factor may be applied to the constant. A length code, however, may not be used.

The format of the constant portion of the operand is described in the following text.

Fraction: The fraction is a signed decimal number (up to 8 digits) with or without a decimal point. The decimal point can appear before, within, or after the number. If the point is at the right-hand end of the number, it may be omitted. If the sign is omitted, a positive fraction is assumed. A negative fraction is carried in the machine in true form. The fraction, irrespective of its decimal point or sign, must not exceed 2 to the 24th power minus 1 (i.e., 16,777,215). The fraction part of a number converted to the short format will differ by no more than 1 from the exact value rounded to 24 places.

Exponent: The exponent is optional. It may be omitted if the decimal point appears in the fraction at the desired position. If the exponent is specified, it must immediately follow the fraction. It consists of the letter E followed by a signed decimal number denoting the exponent to the base ten. A positive exponent is assumed if the sign is omitted.

A negative exponent indicates that the true decimal point is to the left of the point written (or assumed) in the fraction. A positive exponent indicates that the true decimal point is to the right. The value of the exponent determines how many places to the left or right the true decimal point is located.

For example, to convert the number 46.415 to a floating-point format, any of the following statements could be used. They will all have the same effect:

```
         DC        E'46.415'
         DC        E'46415E-3'
         DC        E'+46415.E-3'
         DC        E'.46415E2'
         DC        E'4.6415E+1'
```

If either the fraction or the exponent is outside the permissible range, the full word (or words, if a duplication factor is specified) will be set to zero and a flag will appear in the listing. The statement:

```
         DC        4E'3.45E76'
```

would generate four full-words of zeros.

## Long-Precision Floating-Point Constants (D)

A long-precision floating-point constant is specified as a decimal fraction (mantissa) and an optional decimal exponent. The maximum allowable range for a floating-point constant is from approximately $(5.4)\times10^{-79}$ to $(7.2)\times10^{75}$. The constant will be aligned at a double-word boundary in the proper machine format for use in floating-point operations. A duplication factor may be applied to the constant. A length code, however, may not be used.

The format of the constant portion of the operand is described in the following text.

Fraction: The fraction is a signed decimal number (up to 17 digits) with or without a decimal point. The decimal point can appear before, within, or after the number. If the point is the right-hand end of the number, it may be omitted. If the sign is omitted, a positive fraction is assumed. A negative fraction is carried in the machine in true form. The fraction, irrespective of its decimal point or sign must not exceed 2 to the 56th power minus 1 (that is, 72,057,594,037,927,935). The fraction part of a number converted to the long format will differ by no more than 11 from the exact value rounded to 56 places.

Exponent: The exponent is optional. It may be omitted if the decimal point appears in the fraction at the desired position. If the exponent is specified, it must immediately follow the fraction. It consists of the letter E followed by a signed decimal number denoting the exponent to the base ten. A positive exponent is assumed if the sign is omitted.

A negative exponent indicates that the true decimal point is to the left of the point written (or assumed) in the fraction. A positive exponent indicates that the true decimal point is to the right. The value of the exponent determines how many places to the left or right the true point is located.

If either the fraction or exponent is outside the permissible range, the double word (or words, if a duplication factor is specified) will be set to zero. The statement will be flagged.

The following statements illustrate different ways of converting the same number to a long-precision floating-point number:

```
DC      D'-72957'
DC      D'-729.57E+2'
DC      D'-729.57E2'
DC      D'-.72957E5'
DC      D'-7295700.E-2'
```

## Expression Constants (A)

An expression constant consists of a relocatable or absolute expression enclosed in parentheses instead of single quotation marks. The value of the expression is generated as a 32-bit value constant. Since the expression frequently represents a storage address, the constant generated from it is commonly called an address constant. Hence, the letter A is used as the type code. Note that if the program is relocated, all address constants generated from relocatable expressions will be changed by the relocating program loader.

An explicit length not exceeding four bytes may be specified for expression constants. However, a duplication factor is not allowed.

Unless a length code is present, the 32-bit constant will be aligned at a full-word boundary and given an implied length of four. Thus, in the following statement, the value of AREA+2, as a 32-bit value, will be placed in the next available full word. ADCON1 will be given a length attribute of four:

```
ADCON1    DC      A(AREA+2)
```

If a length code is given, the constant will not be aligned. The constant will be right-justified in the specified number of bytes. Any excess bits to the left will be truncated. For example, in the statement:

```
ADCON2    DC      AL2(FIELD-256)
```

the rightmost 16 bits of the value of FIELD-256 will be right-justified in the next two bytes. The length attribute of ADCON2 will be two. In this case, FIELD must be equivalent to an absolute symbol. (see below.)

The following considerations govern type A constants:

1. A relocatable expression may be used only if the length is implied (that is, it is four) or if the explicit length is three or four.
2. An expression may have a negative value only if it is an absolute expression. A negative value will be stored in two's complement notation.
3. An expression may not begin with an arithmetic operator.

## BASE REGISTER INSTRUCTIONS

The USING and DROP base register assembler instructions enable programmers to use expressions representing core storage locations as operands of machine instruction statements, leaving the assignment of base registers and the calculation of displacements to the assembler.

This feature of the assembler, besides simplifying programming, also will eliminate a likely source of programming errors, thus reducing the time required to check out programs. To take advantage of this feature, the programmer must use the USING and DROP instructions described in this section.

### USING - Use Base Address Register

The USING instruction indicates that the general register specified in the operand is available for use as a base register. This instruction also states the base-address value that the assembler must assume is in the register at object time. Note that a USING instruction does not load the register specified. It is the programmer's responsibility to see that the specified base-address value is placed into the register. Suggested loading methods are described in the section "Programming with the USING and DROP Instructions." The format of the USING instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| Not used | USING | A relocatable expression and a simple absolute expression, separated by a comma |

The relocatable expression specifies a value that the assembler can use as a base address. The second operand is a simple absolute expression specifying the general register that can be assumed to contain the base address represented by the first operand. The value of the second operand must be from 1 to 15. For example, the statement:

```
USING    *,12
```

tells the assembler it may assume that the current value of the Location Counter will be in general register 12 at object time.

If the programmer changes the value in a base register currently being used, the assembler must be told the new value by means of another USING statement. In the following sequence, ALPHA is a relocatable expression:

```
USING    ALPHA,9
         .
         .
         .
USING    ALPHA+1000,9
```

The assembler will first assume that the value of ALPHA is in register 9. The second statement causes the assembler to assume ALPHA+1000 as the value in register 9.

If the value of the second operand is zero, implying no base addressing, the first operand should also have a value of zero. If it does not, zero will be used instead of the actual value and the statement will be flagged in the listing. The implications of using register zero as a base register are discussed later in "Base Register Zero."

A USING statement will not be used if either of its operands are incorrect. A flag will appear in the listing. Any symbol in the name field will not be used.

### DROP - Drop Register

The DROP instruction specifies a previously available register that may no longer be used as a base register.

| Name | Operation | Operand |
|---|---|---|
| Not used | DROP | A simple absolute expression |

The expression indicates a general register that previously had been named in a USING statement and now is unavailable for base addressing. The following statement, for example, removes register 11 from the list of available registers:

```
DROP     11
```

The DROP statement is ignored if the register it designates had never appeared in a USING statement. If the value of the expression exceeds 15, the statement will not be used and will be flagged in the listing. Any symbol in the name field will not be used.

It is not necessary to use a DROP statement when the base address in a register changes as a result of a USING statement; nor are DROP statements needed at the end of the source program.

A register made unavailable by a DROP instruction can be restored to the list of available registers by a subsequent USING instruction.

## Programming with the USING and DROP Instructions

The USING and DROP instructions may be used anywhere in a program, as often as needed. They provide the assembler with the information it needs to construct a "register table." Entries in the table are added, deleted, and changed by the assembler as each USING and DROP instruction is processed.

Whenever an effective address is specified in a machine instruction statement, the assembler consults this table to determine whether there is an available register containing a suitable base address. If more than one register will produce a valid displacement (that is, a displacement not exceeding 4095), the register whose contents produce the smallest displacement will be used. If two or more registers will produce the same displacement, the highest numbered register will be used. If there is no register that will produce a valid displacement, the corresponding base register and displacement fields will be set to zero; the statement will be flagged.

The sequence of instructions in Figure 16 illustrates the assignment of base registers. Instructions that load the registers are not shown.

```
0000   PGMNME   START    0
                USING    *,11
                USING    *+4096,12
                USING    *+8192,13
                USING    *+4500,14
                  .
                  .
                  .
2000   ALPHA    MR       1,2
                  .
                  .
                  .
5500   BETA     SR       1,2
                  .
                  .
                  .
       B1       BC       15,ALPHA
       B2       BC       15,BETA
       B3       BC       15,GAMMA
                  .
                  .
                  .
9750   GAMMA    AR       1,2
                DROP     11
```

B1--Although the effective address represented by ALPHA can be wholly contained in the displacement field without a base address, base register 11 is nonetheless assigned since to use base register 0 would make the program nonrelocatable (see below). Because the value in register 11 is zero, the displacement will be 2000.

B2--Either register 12 or 14 would produce valid displacements; register 14 is used, however, because it produces the smaller displacement, which is 1000.

B3--Only register 13 can be used as the base register; the calculated displacement is 1558.

Figure 16. Example of Coding with USING and DROP Instructions

## LOADING REGISTERS

Several methods exist for loading general registers that will be used for base addressing. However, for a program to be relocated when it is loaded, at least one of the base registers must be loaded with a relocatable address, using either of the instructions described below. The exact method of using these instructions can differ from the examples shown.

### Branch and Link (BALR or BAL) Instruction

In the sequence below, the BALR instruction loads into register 5 the address of the first storage location after the BALR instruction. The USING instruction indicates to the assembler that register 5 contains this location:

```
                BALR    5,0
        USING   *,5
```

When using this method, the USING instruction must immediately follow the BALR instruction.

Load Full-Word (L) Instruction

In the following coding, the value of RGLOAD is generated as a constant. RGLOAD is some symbol defined elsewhere in the program. This value, which is also specified in the USING instruction, is inserted into register 6 with the Load (L) instruction.

```
CNSTNT   DC       A(RGLOAD)
         .
         .
         .
         L        6,CNSTNT
         .
         .
         USING    RGLOAD,6
```

Note that if the symbol RGLOAD was used in the load instruction, register 6 would contain the full-word located at RGLOAD rather than the value of RGLOAD itself.

The Load instruction should precede the USING instruction to insure that the assumed contents of the register are, in fact, in the register when the program is executed. Otherwise, the assembler would use the specified register as a base register in machine instructions before the load instruction was encountered. This could lead to undesirable results when the program is executed. Observe, however, that the USING instruction need not immediately follow the load instruction, although it is recommended that the two instructions be consecutive.

If one register has been initialized by the Branch-and-Link or Load instruction, other registers may be loaded from it by other instructions. Thus, in the following example, the Load Address (LA) instruction causes 4,080 to be added to the contents of register 4 and the resulting total to be placed in register 3:

```
         BALR     4,0
         USING    HERE,4
HERE     LA       3,4080(0,4)
         .
         .
         .
         USING    HERE+4080,3
```

Note that the LA instruction could have been written alternately as LA 3,4080(4).

Base Register Zero

The specification of general register 0 as a base register indicates that a quantity of zero is to be used as the base address, regardless of the contents of general register 0. Therefore, if general register 0 is made available by a USING instruction for base addressing, the program will not be relocatable when there is no other general register available for referencing locations below location 4096. Figure 17 illustrates a program that would not be relocatable; any reference to AREA1 will require the use of register 0, since register 2 cannot produce a valid displacement. References to AREA2, however, will make use of register 2.

This restriction does not prevent a relocatable program from referring to actual storage locations by means of absolute expressions. For example, to reference a permanently allocated interrupt location at storage address 24, the following statement is perfectly correct:

```
LPSW     24
```

```
0000                START    0
                    USING    *,0
                    USING    *+2048,2
                      .
                      .
                      .
2000      AREA1     DS       20H
                      .
                      .
                      .
4000      AREA2     DS       10F
```

Figure 17. Example of Coding Using Base Register Zero

PROGRAM LINKING INSTRUCTIONS

The program linking assembler instructions allow the programmer to symbolically link independently assembled programs that will be loaded and executed together. Symbolic linkages between programs are created by means of symbols that are defined in one program and used as operands in another program. Such symbols are termed linkage symbols. A linkage symbol is called an "entry-point symbol" in the program in which it is defined; it is an "external symbol" in the program in which it is used as an operand. External and entry-point symbols are also described in the section "Symbols."

Every linkage symbol must be properly identified as such in the source program. A linkage symbol used as an external symbol is identified in each using program by the EXTRN instruction. A linkage symbol used as an entry point must be identified in the defining program by the ENTRY instruction.

A program name (defined in the name field of a START statement) is also considered an entry point. A program name, however, does not have to be identified as an entry point by the ENTRY instruction.

## ENTRY - Identify Entry-Point Symbol

The ENTRY instruction identifies an entry-point symbol to the program. Each such entry-point symbol (except a program name) must be identified by a separate ENTRY instruction. The format of the ENTRY instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| Not used | ENTRY | A relocatable symbol |

The relocatable symbol in the operand field is a symbol defined elsewhere in the program, which may be used as an entry point by other programs. A symbol that is not defined in the program will be flagged in the listing as an undefined symbol. Any symbol in the name field will not be used.

An ENTRY statement must be immediately preceded by either the START statement, an EXTRN statement, or another ENTRY statement. It cannot appear in a program unless the START statement has been used.

If an ENTRY statement is incorrectly placed or if the operand is invalid, the statement will not be used. An error flag will appear in the listing.

In the following sequence, SQRT is identified as an entry-point symbol. Note that the ENTRY statement appears immediately after the START statement:

```
SUBRO    START   0
         ENTRY   SQRT
         .
         .
         .
SQRT     STM     1,10,SAVE
```

## EXTRN - Identify External Symbol

The EXTRN instruction identifies a linkage symbol as an external symbol that will be referred to in this program. Each such external symbol must be identified by a separate EXTRN instruction. The format of the EXTRN instruction statement is:

| Name | Operation | Operand |
|---|---|---|
| Not used | EXTRN | A relocatable symbol |

The relocatable symbol in the operand field must be defined in another program, and identified in that program as an entry-point symbol by either the START or ENTRY instruction. Any symbol in the name field will not be used.

An EXTRN statement must be immediately preceded by either the START statement, an ENTRY statement, or another EXTRN statement. An EXTRN statement cannot appear in a program unless the START statement has been used. Not more than 14 EXTRN statements may appear in a program. If there are more than 14 statements, the symbol in each excess statement will be flagged as undefined.

If an EXTRN statement is incorrectly placed or if the operand is invalid, the statement will not be used. An error flag will appear in the listing.

As an example, if MTPLY is an entry-point symbol in another program, the using program identifies it as an external symbol, thus:

```
         EXTRN   MTPLY
```

The correct use of an external symbol elsewhere in a program is described below.

## LINKING CONVENTIONS

The only way that an external symbol may be referenced is to (1) identify it with the EXTRN instruction, (2) create an address constant from the external symbol, (3) load the constant into a general register, and (4) branch to the address via the register or use the register for base addressing.

For example, to link to a program named SINE, the following coding might be used:

```
PROGA    START    1000
         EXTRN    SINE
           .
           .
           .
         L        4,ADSINE
         BALR     15,4
           .
           .
           .
ADSINE   DC       A(SINE)
```

In this example, SINE would be given a value of zero at assembly time; four bytes of zeros would be reserved at the symbolic location ADSINE. When the programs are loaded, the relocating loader will add to the four bytes of zeros the effective address assigned to SINE.

If the programmer wished to link, say, to a location 12 bytes past SINE, the constant could be created as follows:

```
ADSINE   DC       A(SINE+12)
```

The relocating program loader will add 12 to the effective address of SINE and place the sum in the four bytes at ADSINE. The expression in which the external symbol is used must be a relocatable expression.

Another method of linking to SINE+12 is:

```
         START    1000
         EXTRN    SINE
           .
           .
           .
         USING    SINE,4
         L        4,ADSINE
           .
           .
           .
       { BAL      15,SINE+12 }
       { BAL      15,12(0,4) }
       { BAL      15,12(4)   }
           .
           .
ADSINE   DC       A(SINE)
```

In the above sequence, either BAL instruction can be used; if BAL 15,12(0,4) or BAL 15,12(4) is used, the USING statement may be omitted, since implicit base addressing is not involved.

A return branch from the program named SINE may be made via the registers without making any reference to a linkage symbol. Thus, if the branch to SINE was:

```
         BALR     10,4
```

the return branch may be:

```
         BCR      15,10
```

## Limitations on Program Linking

The order in which independently assembled programs are loaded generally determines the extent to which they can link to one another. The program(s) containing the entry point(s) must be loaded before the program(s) that will reference these points as external symbols. Note, however, that program names are not affected by this restriction. A program loaded first may refer to programs loaded after it by their names, using the facilities of the relocating loader. In addition, the use of relocating loader control cards can remove all restrictions on linking.

In the following situation, two independently assembled programs, Program A and Program B, are to be executed together. Each program contains the coding shown in Figure 18.

If Program A is loaded first, it can refer to Program B only by its name, PROGB. Program B however, can refer to Program A by its name, PROGA, and its entry points, LOOP and LINK. If the loading order is reversed, then Program B can refer to Program A only by its name, whereas Program A can refer to Program B by its name and by its entry points, SINE and COSINE.

Thus, if a common data area is to be used by two independently assembled programs, the data area should be assembled separately and then loaded first to enable both programs to refer freely to it.

## Program Relocation and Linking

Programs that will be linked together at object time must be relocatable. To be relocatable, a program must:

1. Contain all the information required by the relocating loader.
2. Not use absolute expressions to refer to any area that can be relocated.

```
               Program A                 |                Program B
-----------------------------------------+-----------------------------------------
      PROGA      START      0            |      PROGB      START      0
                 ENTRY      LOOP         |                 ENTRY      SINE
                 ENTRY      LINK         |                 ENTRY      COSINE
                 EXTRN      SINE         |                 EXTRN      LOOP
                 EXTRN      COSINE       |                 EXTRN      LINK
                 EXTRN      PROGB        |                 EXTRN      PROGA
                   .                     |                   .
                   .                     |                   .
                   .                     |                   .
      LOOP       ---        ---          |      SINE       ---        ---
                   .                     |                   .
                   .                     |                   .
                   .                     |                   .
      LINK       ---        ---          |      COSINE     ---        ---
                   .                     |                   .
                   .                     |                   .
                   .                     |                   .
      ADSINE     DC         A (SINE)     |      ADLOOP     DC         A (LOOP)
      ADCOSN     DC         A (COSINE)   |      ADLINK     DC         A (LINK)
      ADPRGB     DC         A (PROGB)    |      ADPRGA     DC         A (PROGA)
```

Figure 18. Example of Program Linking

3. Identify all entry-point and external symbols that will be used by the ENTRY and EXTRN instructions, respectively.
4. Specify all address constants (type A constants) that represent relocatable expressions with a length of three or four.
5. Not use general register zero as a base register.

## ASSEMBLER INSTRUCTION SUMMARY

Figure 19 contains all of the assembler instructions and the contents of their name and the operand fields.

| Reference Summary for Assembler Instructions | | |
|---|---|---|
| Name Field | Mnemonic | Operand Field |
| Not used | ICTL | The decimal value 1 or 25 |
| An optional symbol | START | A self-defining value, a comma, or blank |
| Not used | ENTRY | A relocatable symbol |
| Not used | EXTRN | A relocatable symbol |
| Not used | CNOP | Two decimal values separated by a comma |
| An optional symbol | CCW | Four operands separated by commas |
| An optional symbol | DC | A single operand describing the constant |
| Not used | DROP | A simple absolute expression |
| An optional symbol | DS | A single operand describing the area to be reserved |
| Not used | EJECT | Not used |
| A required symbol | EQU | An expression |
| Not used | ORG | A relocatable expression |
| Not used | SPACE | A decimal value not exceeding 63 |
| Not used | USING | A relocatable expression and a simple absolute expression, separated by a comma |
| Not used | END | A relocatable expression, a comma, or blank |

Figure 19. Assembler Instruction Summary

This section describes those operations of the assembler program that have a direct bearing on preparing programs for assembly. Note that the use of the Basic Assembler is described in detail in the publication IBM System/360 Basic Programming Support Operating Guide, Form C28-6557.

## ASSEMBLER PROCESSING

The assembler is a two-phase program. It is provided as two decks of cards, one for each phase.

### Phase 1

During the first phase, the assembler produces a symbol table (subsequently described) and intermediate text for use in the second phase. When the tape option is used, the intermediate text (but not the symbol table) is placed on tape. When the IBM 1442-2 Card Read-Punch is used in a card option system, this intermediate text is punched into the first 24 columns of each source program card. Because the intermediate text punched into the source card is still symbolic and pertains to the statement portion of the particular card only, the source program can be reassembled without being repunched. When the IBM 1402 Card Read-Punch is used in a card option system, this intermediate text is punched into the first 24 columns of a new card along with the first 47 columns of the source statement, column 72, and the Identification-Sequence Field (columns 73-80). If Phase 1 is successful, a 12 punch will appear in the first column of every card containing intermediate text.

The input to the first phase consists of the Phase 1 deck of the assembler followed by the source program. If the card option is used, blank cards must be available in the punch unit, for the symbol table.

One card will be punched for every six symbols defined in the program. The maximum number of symbols that can be defined is determined by main storage size, as explained in the section "Symbol Table." If the assembler is operating on a machine with 8,192 storage bytes, approximately 50 blank cards will be sufficient to handle the maximum number of symbols allowed; for 16,384 bytes, 230 blank cards; for 32,768 bytes, 570 cards; and for 65,536 bytes, 690 cards.

### Phase 2

The assembler produces the program listing and object program during the second phase. The format of Phase 2 input varies with the option used.

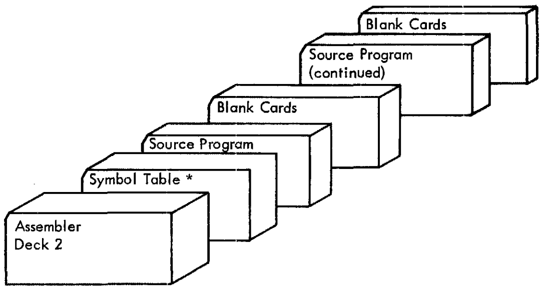
For the tape option, input is on cards and tape. The card input consists of the Phase 2 deck of the assembler. The tape input is the tape created in Phase 1. If the object program is to be produced on cards, blank cards should be provided at the approximate ratio of 10 blank cards for every 100 original source program cards. If the object program is to be placed on tape, blank cards are not required.

For card option, the second deck of the assembler is loaded followed by the repunched source program when the IBM 1442-2 Card Read-Punch is used, and by the newly punched intermediate deck when the IBM 1402 Card Read-Punch is used. If the second phase does not immediately follow the first phase, the symbol table will not be in storage. Consequently, it will be necessary to load the symbol table deck produced by Phase 1. It is placed between the assembler and source program decks. (See Figure 20.)

When the IBM 1442-2 Card Read-Punch is used, the assembler will accumulate the assembled object program in storage. When the storage area is full, and the next input card is not blank, the operator will be notified to insert blank cards in the 1442-2 Card Read-Punch for punching the object program. As each blank card is punched, it will be directed to the stacker reserved for the object deck. If a blank card is encountered when none is needed, the card will be directed to the other stacker, which is for the input cards. The remaining source cards will then be read, and the cycle repeated.

Operator intervention may be avoided, in a 1442 card system, by interleaving blank cards with the source program before starting Phase 2 (see Figure 20) at approximately the following ratios:

| Main Storage Size | Approximate Ratio of Blank Cards to Source Program Cards |
|---|---|
| 8,192 | 15 blanks every 150 source cards |
| 16,384 | 80 blanks every 800 source cards |
| 32,384 | 200 blanks every 2000 source cards |
| 65,536 | 450 blanks every 4500 source cards |



*Only required when Phase 2 does not immediately follow Phase 1.

Figure 20. Phase 2 Input for Use with IBM 1442-2 Card Read-Punch

If these ratios are observed, it should not be necessary for the operator to intervene and the time required to assemble the program will be reduced.

Blank cards may also be interleaved for Phase 1; their presence will not affect this phase of the assembly, except for time required to read the blank cards.

When the IBM 1402 Card Read-Punch is used, the assembler will punch an object program card as soon as one is assembled in storage.

## PROGRAM LISTING

A program listing (if requested) will be produced for every assembly, provided an IBM 1443 Model 2 Printer, IBM 1403 Printer, or an IBM 1052 Printer-Keyboard is available. Each statement in the source program will appear on a separate line of the listing unless the suppress option is used. If the suppress option is used, only those statements containing errors will be listed. The programmer avails himself of the suppress option by indicating to the machine operator that he does not wish a listing. More detailed information on the suppress option is contained in the description of "Configuration Cards" in the publication IBM System/360 Basic Programming Support Operating Guide for Basic Assembler and Utilities, Form C28-6557.

The program listing will consist of five fields, arranged from left to right, as follows.

Flags: This field (print positions 1-10) will contain, left-justified, a flag(s) to signal possible errors in the statement. Each flag will be represented by a single alphabetic character. See the topic "Error Notification."

Location Counter: This field (print positions 12-17) will contain the Location Counter value (in hexadecimal) assigned to the statement.

Assembled Output: This field (print positions 20-39) will contain the hexadecimal representation of the binary digits generated from the statement.

Source Statement: This field (print positions 40-111) will contain a column-for-column reproduction of the contents of the source statement. For the 1402 card-option, where statements begin in column 1, only columns 1-47 will be reproduced.

Identification-Sequence Field: This field (print positions 113-119) will be a reproduction of columns 73-80 of the source card.

## ERROR NOTIFICATION

The flags produced on the program listing for various source program errors are shown in the following list. Any error that causes the assembler to either a) ignore the instruction or b) assemble zeros in the operand field of the instruction will halt further evaluation of the instruction for other errors. Therefore, when correcting such an error, the user is advised to check for any other errors in the instruction.

| Flag | Cause |
|---|---|
| * A | Expression not simply relocatable. |
| * B | START, EXTRN, ENTRY or ICTL out of order. |
| * C | Location counter overflow. |
| * E | More than 14 EXTRNs. |
| * F | Operand field format error or self-defining value in operand field too large. |
| * G | DC, D, or E range error. |
| I | Expression can not be mapped into base and displacement. |
| * J | Symbol table full. |
| K | Relocation list dictionary buffer table full. |
| * L | Name field error. |
| * M | Multiple defined symbol. |

| | |
|---|---|
| * N | Statement not used. This flag is normally accompanied by other flags which define the reason the statement was not used. If it appears alone, it indicates that the statement was completely extraneous. If the flag (N) appears by itself when using a 1442 card option system, it indicates that the source statement has been modified since a previous assembly but the intermediate text field (columns 1-24) has not been left blank. See section "Reassembly Procedure." |
| * O | Invalid OP code. |
| R | Expression not absolute. |
| * S | Specification error. |
| * T | Value too large. |
| U | Undefined symbol. |
| * V | ORG or EQU symbol not previously defined. |
| W | Unused mask bits (37-39) in CCW not zero. |
| X | Duplicate entry statement. |
| * Y | Negative expression. |
| * Z | Column 72 not blank. |

Note: The * indicates those flags which may be punched in the intermediate text cards produced by Phase 1 in card-option systems. For systems without the ability to produce program listings, these flags provide a limited form of error notification. It should be noted that the intermediate text cards produced by Phase 1 contain an A, B, or C in column 1 if they are error free. Cards in error have a J, K, L, or M in column 1. Error flags are located in columns 23-24 on cards with a J or K in column 1. The error flags appear in columns 21-24 on cards beginning with L or M.

## OBJECT PROGRAM OUTPUT

The object program is generated by the assembler as a deck of cards or card images on tape acceptable as input to the loaders. It is the programmer's responsibility, to inform the operator about the medium (cards or tape) on which the object deck is to be placed. Detailed information on this option can be found in the publication IBM System/360 Basic Programming Support Operating Guide, Form C28-6557. Four types of cards constitute the object program deck. It should be noted that detailed descriptions of each of the four types of cards may be found in the publication IBM System/360 Basic Programming Support Basic Utilities, Form C28-6505. General descriptions of each follow.

### External Symbol Dictionary (ESD) Card

An ESD card is generated for each START, ENTRY, and EXTRN statement. The ESD card contains coded information that is used by the relocating loader.

### Text (TXT) Card

The Text cards contain the output assembled from the source program. Up to 56 contiguous bytes of output are punched into each Text card. Each Text card also contains the storage address at which the first byte in the card is to be loaded.

### Relocation List Dictionary (RLD) Card

The purpose of RLD cards is to indicate to the relocating loader those address constants that will have to be changed if the program is loaded at a location different from its assembled location. Address constants of this type are defined in the source program by (1) relocatable expressions in type A DC statements and (2) relocatable expressions specifying data addresses in CCW statements; that is, the second operands of CCW statements. Up to 13 address constants are punched into each RLD card.

The maximum number of address constants (that is, the type described above) that can be defined in a program is determined by the size of main storage thus:

| Main Storage Size (in Bytes) | Maximum Number of Address Constants |
|---|---|
| 8,192 | 30 |
| 16,384 | 60 |
| 32,768 | 120 |
| 65,536 | 240 |

### Load End Card

This card is produced when the assembler encounters the END statement. The Load End card also contains the address to which control is to be transferred when the program has been loaded, if one was specified in the END statement.

## PATCHING OBJECT PROGRAMS

The programmer may modify his object program at execution time through the use of a Replace card. This card is completely described in the publication IBM System/360 Basic Programming Support Basic Utilities, Form C28-6505.

## REASSEMBLY PROCEDURE

A special reassembly procedure is provided for assemblies using the IBM 1442-2 Card Read-Punch without tape. This procedure will enable a partially or completely assembled program to be reassembled in less time than a new assembly would require.

The program that is to use the reassembly procedure may be changed in any manner. New symbols can be added and existing ones redefined, provided that the symbol table is not full. New statements also can be included in the program.

The reassembly procedure is faster than the new assembly procedure because the assembler does not have to repunch the first 24 columns of those source program cards whose statements have not been changed. Hence, the fewer the changes, the faster the assembly.

The input to the first phase of a reassembly consists of the first deck of the assembler, followed in order by the previously punched symbol table decks, the source program with any changes, and the necessary number of blank cards into which a new symbol table will be punched. Note that any changed source program cards must be repunched, leaving columns 1-24 blank. This also applies to source program cards that did not have a 12-punch in column 1 as the result of the previous assembly.

The Phase 2 input and output of a reassembly is identical with the second phase of a new assembly (see topic "Phase 2").

## SYMBOL TABLE

For every program assembled, a table is created of the symbols in that program. This is the symbol table; each entry in the table records the attributes and other pertinent information about a particular symbol.

The maximum size of the symbol table and, hence, the maximum number of symbols that can be defined in a program is determined by the size of main storage, thus:

| Approximate Main Storage Size (in Bytes) | Approximate Number of Symbols in Table |
|---|---|
| 8,192 | 275 |
| 16,384 | 1299 |
| 32,768 | 3347 |
| 65,536 | 4094 |

All symbols defined in a program (including the program name and external symbols) are entered in the symbol table providing the following conditions are met:

1. The symbol table is not full.
2. The symbol conforms to the rules governing symbol specifications (see the topic "Symbols").
3. The symbol does not appear in the name field of an assembler instruction that does not allow the specification of a name. See Figure 19 for a list of these instructions.
4. The symbol is not already contained in the symbol table. For multiple defined symbols, only the first definition of the symbol results in an entry in the symbol table. Additional definitions of the same symbol are simply flagged.

Any reference in the operand field to a symbol not in the symbol table will be considered undefined; the statement will be flagged. An undefined symbol in a machine instruction statement will cause the entire instruction (except the operation code) to be set to zero.

### Symbol Table Overflow

If there are undefined symbols because the symbol table is full, three corrective procedures are available:

1. The assembled object deck produced by the assembler can be corrected with Replace (REP) cards before loading the program. Replace cards, a feature of the loaders, are used to alter an object deck on a byte-for-byte basis.
2. Reduce the number of symbols and then reassemble or run a new assembly.
3. Divide the program into segments and assemble each program segment separately.

Relative addressing may be used to reduce the number of symbols defined in a program. For example, the following sequence:

```
BEGIN    LA     3,10
         LA     1,0
LOOP     L      2,AUGEND(1)
         A      2,ADDEND(1)
         ST     2,SUM(1)
         LA     1,4(1)
         BCT    3,LOOP
         BC     15,OUT
AUGEND   DS     10F
ADDEND   DS     10F
SUM      DS     10F
OUT      LR     3,1
         .
         .
         .
```

could also be written:

```
BEGIN    LA     3,10
         LA     1,0
         L      2,AUGEND(1)
         A      2,AUGEND+40(1)
         ST     2,AUGEND+80(1)
         LA     1,4(1)
         BCT    3,*-16
         BC     15,OUT
AUGEND   DS     30F
OUT      LR     3,1
         .
         .
         .
```

thus eliminating four symbols. Note that the branch address of the BC instruction is given relative to AUGEND rather than the Location Counter, since any boundary alignment caused by the DS statement would change the number of bytes between the BC and LR instruction.

Note: Using the IBM 1442-2 Card Read-Punch reassembly procedure, the programmer must eliminate all undefined symbols from those cards that refer to such symbols in the operand field. The cards in which the undefined symbols appear in the name field can be left as they are. Since the symbol table is full, no new symbols may be defined for the reassembly.

If, in addition to reducing the number of symbols, the programmer wants to replace defined symbols (that is, symbols in the symbol table) with new symbols, the entire source program deck, with changes, must (for the IBM 1442-2 Card Read-Punch card option) be reproduced with columns 1-24 blank prior to assembling the program. For the tape option or the IBM 1402 Card Read-Punch card option, the source deck with the desired changes can be used as is.

## APPENDIX A. CHARACTER CODES

| 8-Bit BCD Code | Character Set Punch Combination | Decimal | Hexa-Decimal | Printer Graphics |
|---|---|---|---|---|
| 00000000 | 12,0,9,8,1 | 0 | 00 | |
| 00000001 | 12,9,1 | 1 | 01 | |
| 00000010 | 12,9,2 | 2 | 02 | |
| 00000011 | 12,9,3 | 3 | 03 | |
| 00000100 | 12,9,4 | 4 | 04 | |
| 00000101 | 12,9,5 | 5 | 05 | |
| 00000110 | 12,9,6 | 6 | 06 | |
| 00000111 | 12,9,7 | 7 | 07 | |
| 00001000 | 12,9,8 | 8 | 08 | |
| 00001001 | 12,9,8,1 | 9 | 09 | |
| 00001010 | 12,9,8,2 | 10 | 0A | |
| 00001011 | 12,9,8,3 | 11 | 0B | |
| 00001100 | 12,9,8,4 | 12 | 0C | |
| 00001101 | 12,9,8,5 | 13 | 0D | |
| 00001110 | 12,9,8,6 | 14 | 0E | |
| 00001111 | 12,9,8,7 | 15 | 0F | |
| 00010000 | 12,11,9,8,1 | 16 | 10 | |
| 00010001 | 11,9,1 | 17 | 11 | |
| 00010010 | 11,9,2 | 18 | 12 | |
| 00010011 | 11,9,3 | 19 | 13 | |
| 00010100 | 11,9,4 | 20 | 14 | |
| 00010101 | 11,9,5 | 21 | 15 | |
| 00010110 | 11,9,6 | 22 | 16 | |
| 00010111 | 11,9,7 | 23 | 17 | |
| 00011000 | 11,9,8 | 24 | 18 | |
| 00011001 | 11,9,8,1 | 25 | 19 | |
| 00011010 | 11,9,8,2 | 26 | 1A | |
| 00011011 | 11,9,8,3 | 27 | 1B | |
| 00011100 | 11,9,8,4 | 28 | 1C | |
| 00011101 | 11,9,8,5 | 29 | 1D | |
| 00011110 | 11,9,8,6 | 30 | 1E | |
| 00011111 | 11,9,8,7 | 31 | 1F | |
| 00100000 | 11,0,9,8,1 | 32 | 20 | |
| 00100001 | 0,9,1 | 33 | 21 | |
| 00100010 | 0,9,2 | 34 | 22 | |
| 00100011 | 0,9,3 | 35 | 23 | |
| 00100100 | 0,9,4 | 36 | 24 | |
| 00100101 | 0,9,5 | 37 | 25 | |
| 00100110 | 0,9,6 | 38 | 26 | |
| 00100111 | 0,9,7 | 39 | 27 | |
| 00101000 | 0,9,8 | 40 | 28 | |
| 00101001 | 0,9,8,1 | 41 | 29 | |
| 00101010 | 0,9,8,2 | 42 | 2A | |
| 00101011 | 0,9,8,3 | 43 | 2B | |
| 00101100 | 0,9,8,4 | 44 | 2C | |
| 00101101 | 0,9,8,5 | 45 | 2D | |
| 00101110 | 0,9,8,6 | 46 | 2E | |
| 00101111 | 0,9,8,7 | 47 | 2F | |
| 00110000 | 12,11,0,9,8,1 | 48 | 30 | |
| 00110001 | 9,1 | 49 | 31 | |
| 00110010 | 9,2 | 50 | 32 | |

| 8-Bit BCD Code | Character Set Punch Combination | Decimal | Hexa-Decimal | Printer Graphics |
|---|---|---|---|---|
| 00110011 | 9,3 | 51 | 33 | |
| 00110100 | 9,4 | 52 | 34 | |
| 00110101 | 9,5 | 53 | 35 | |
| 00110110 | 9,6 | 54 | 36 | |
| 00110111 | 9,7 | 55 | 37 | |
| 00111000 | 9,8 | 56 | 38 | |
| 00111001 | 9,8,1 | 57 | 39 | |
| 00111010 | 9,8,2 | 58 | 3A | |
| 00111011 | 9,8,3 | 59 | 3B | |
| 00111100 | 9,8,4 | 60 | 3C | |
| 00111101 | 9,8,5 | 61 | 3D | |
| 00111110 | 9,8,6 | 62 | 3E | |
| 00111111 | 9,8,7 | 63 | 3F | |
| 01000000 | | 64 | 40 | blank |
| 01000001 | 12,0,9,1 | 65 | 41 | |
| 01000010 | 12,0,9,2 | 66 | 42 | |
| 01000011 | 12,0,9,3 | 67 | 43 | |
| 01000100 | 12,0,9,4 | 68 | 44 | |
| 01000101 | 12,0,9,5 | 69 | 45 | |
| 01000110 | 12,0,9,6 | 70 | 46 | |
| 01000111 | 12,0,9,7 | 71 | 47 | |
| 01001000 | 12,0,9,8 | 72 | 48 | |
| 01001001 | 12,8,1 | 73 | 49 | |
| 01001010 | 12,8,2 | 74 | 4A | |
| 01001011 | 12,8,3 | 75 | 4B | . (period) |
| 01001100 | 12,8,4 | 76 | 4C | < |
| 01001101 | 12,8,5 | 77 | 4D | ( |
| 01001110 | 12,8,6 | 78 | 4E | + |
| 01001111 | 12,8,7 | 79 | 4F | |
| 01010000 | 12 | 80 | 50 | & |
| 01010001 | 12,11,9,1 | 81 | 51 | |
| 01010010 | 12,11,9,2 | 82 | 52 | |
| 01010011 | 12,11,9,3 | 83 | 53 | |
| 01010100 | 12,11,9,4 | 84 | 54 | |
| 01010101 | 12,11,9,5 | 85 | 55 | |
| 01010110 | 12,11,9,6 | 86 | 56 | |
| 01010111 | 12,11,9,7 | 87 | 57 | |
| 01011000 | 12,11,9,8 | 88 | 58 | |
| 01011001 | 11,8,1 | 89 | 59 | |
| 01011010 | 11,8,2 | 90 | 5A | |
| 01011011 | 11,8,3 | 91 | 5B | $ |
| 01011100 | 11,8,4 | 92 | 5C | * |
| 01011101 | 11,8,5 | 93 | 5D | ) |
| 01011110 | 11,8,6 | 94 | 5E | |
| 01011111 | 11,8,7 | 95 | 5F | |
| 01100000 | 11 | 96 | 60 | - |
| 01100001 | 0,1 | 97 | 61 | / |
| 01100010 | 11,0,9,2 | 98 | 62 | |
| 01100011 | 11,0,9,3 | 99 | 63 | |
| 01100100 | 11,0,9,4 | 100 | 64 | |
| 01100101 | 11,0,9,5 | 101 | 65 | |
| 01100110 | 11,0,9,6 | 102 | 66 | |
| 01100111 | 11,0,9,7 | 103 | 67 | |
| 01101000 | 11,0,9,8 | 104 | 68 | |
| 01101001 | 0,8,1 | 105 | 69 | |
| 01101010 | 12,11 | 106 | 6A | |
| 01101011 | 0,8,3 | 107 | 6B | , (comma) |

| 8-Bit BCD Code | Character Set Punch Combination | Decimal | Hexa-Decimal | Printer Graphics |
|---|---|---|---|---|
| 01101100 | 0,8,4 | 108 | 6C | % |
| 01101101 | 0,8,5 | 109 | 6D | |
| 01101110 | 0,8,6 | 110 | 6E | |
| 01101111 | 0,8,7 | 111 | 6F | |
| 01110000 | 12,11,0 | 112 | 70 | |
| 01110001 | 12,11,0,9,1 | 113 | 71 | |
| 01110010 | 12,11,0,9,2 | 114 | 72 | |
| 01110011 | 12,11,0,9,3 | 115 | 73 | |
| 01110100 | 12,11,0,9,4 | 116 | 74 | |
| 01110101 | 12,11,0,9,5 | 117 | 75 | |
| 01110110 | 12,11,0,9,6 | 118 | 76 | |
| 01110111 | 12,11,0,9,7 | 119 | 77 | |
| 01111000 | 12,11,0,9,8 | 120 | 78 | |
| 01111001 | 8,1 | 121 | 79 | |
| 01111010 | 8,2 | 122 | 7A | |
| 01111011 | 8,3 | 123 | 7B | # |
| 01111100 | 8,4 | 124 | 7C | @ |
| 01111101 | 8,5 | 125 | 7D | ' (quote) |
| 01111110 | 8,6 | 126 | 7E | = |
| 01111111 | 8,7 | 127 | 7F | |
| 10000000 | 12,0,8,1 | 128 | 80 | |
| 10000001 | 12,0,1 | 129 | 81 | |
| 10000010 | 12,0,2 | 130 | 82 | |
| 10000011 | 12,0,3 | 131 | 83 | |
| 10000100 | 12,0,4 | 132 | 84 | |
| 10000101 | 12,0,5 | 133 | 85 | |
| 10000110 | 12,0,6 | 134 | 86 | |
| 10000111 | 12,0,7 | 135 | 87 | |
| 10001000 | 12,0,8 | 136 | 88 | |
| 10001001 | 12,0,9 | 137 | 89 | |
| 10001010 | 12,0,8,2 | 138 | 8A | |
| 10001011 | 12,0,8,3 | 139 | 8B | |
| 10001100 | 12,0,8,4 | 140 | 8C | |
| 10001101 | 12,0,8,5 | 141 | 8D | |
| 10001110 | 12,0,8,6 | 142 | 8E | |
| 10001111 | 12,0,8,7 | 143 | 8F | |
| 10010000 | 12,11,8,1 | 144 | 90 | |
| 10010001 | 12,11,1 | 145 | 91 | |
| 10010010 | 12,11,2 | 146 | 92 | |
| 10010011 | 12,11,3 | 147 | 93 | |
| 10010100 | 12,11,4 | 148 | 94 | |
| 10010101 | 12,11,5 | 149 | 95 | |
| 10010110 | 12,11,6 | 150 | 96 | |
| 10010111 | 12,11,7 | 151 | 97 | |
| 10011000 | 12,11,8 | 152 | 98 | |
| 10011001 | 12,11,9 | 153 | 99 | |
| 10011010 | 12,11,8,2 | 154 | 9A | |
| 10011011 | 12,11,8,3 | 155 | 9B | |
| 10011100 | 12,11,8,4 | 156 | 9C | |
| 10011101 | 12,11,8,5 | 157 | 9D | |
| 10011110 | 12,11,8,6 | 158 | 9E | |
| 10011111 | 12,11,8,7 | 159 | 9F | |
| 10100000 | 11,0,8,1 | 160 | A0 | |
| 10100001 | 11,0,1 | 161 | A1 | |
| 10100010 | 11,0,2 | 162 | A2 | |
| 10100011 | 11,0,3 | 163 | A3 | |
| 10100100 | 11,0,4 | 164 | A4 | |

| 8-Bit BCD Code | Character Set Punch Combination | Decimal | Hexa-Decimal | Printer Graphics |
|---|---|---|---|---|
| 10100101 | 11,0,5 | 165 | A5 | |
| 10100110 | 11,0,6 | 166 | A6 | |
| 10100111 | 11,0,7 | 167 | A7 | |
| 10101000 | 11,0,8 | 168 | A8 | |
| 10101001 | 11,0,9 | 169 | A9 | |
| 10101010 | 11,0,8,2 | 170 | AA | |
| 10101011 | 11,0,8,3 | 171 | AB | |
| 10101100 | 11,0,8,4 | 172 | AC | |
| 10101101 | 11,0,8,5 | 173 | AD | |
| 10101110 | 11,0,8,6 | 174 | AE | |
| 10101111 | 11,0,8,7 | 175 | AF | |
| 10110000 | 12,11,0,8,1 | 176 | B0 | |
| 10110001 | 12,11,0,1 | 177 | B1 | |
| 10110010 | 12,11,0,2 | 178 | B2 | |
| 10110011 | 12,11,0,3 | 179 | B3 | |
| 10110100 | 12,11,0,4 | 180 | B4 | |
| 10110101 | 12,11,0,5 | 181 | B5 | |
| 10110110 | 12,11,0,6 | 182 | B6 | |
| 10110111 | 12,11,0,7 | 183 | B7 | |
| 10111000 | 12,11,0,8 | 184 | B8 | |
| 10111001 | 12,11,0,9 | 185 | B9 | |
| 10111010 | 12,11,0,8,2 | 186 | BA | |
| 10111011 | 12,11,0,8,3 | 187 | BB | |
| 10111100 | 12,11,0,8,4 | 188 | BC | |
| 10111101 | 12,11,0,8,5 | 189 | BD | |
| 10111110 | 12,11,0,8,6 | 190 | BE | |
| 10111111 | 12,11,0,8,7 | 191 | BF | |
| 11000000 | 12,0 | 192 | C0 | |
| 11000001 | 12,1 | 193 | C1 | A |
| 11000010 | 12,2 | 194 | C2 | B |
| 11000011 | 12,3 | 195 | C3 | C |
| 11000100 | 12,4 | 196 | C4 | D |
| 11000101 | 12,5 | 197 | C5 | E |
| 11000110 | 12,6 | 198 | C6 | F |
| 11000111 | 12,7 | 199 | C7 | G |
| 11001000 | 12,8 | 200 | C8 | H |
| 11001001 | 12,9 | 201 | C9 | I |
| 11001010 | 12,0,9,8,2 | 202 | CA | |
| 11001011 | 12,0,9,8,3 | 203 | CB | |
| 11001100 | 12,0,9,8,4 | 204 | CC | |
| 11001101 | 12,0,9,8,5 | 205 | CD | |
| 11001110 | 12,0,9,8,6 | 206 | CE | |
| 11001111 | 12,0,9,8,7 | 207 | CF | |
| 11010000 | 11,0 | 208 | D0 | |
| 11010001 | 11,1 | 209 | D1 | J |
| 11010010 | 11,2 | 210 | D2 | K |
| 11010011 | 11,3 | 211 | D3 | L |
| 11010100 | 11,4 | 212 | D4 | M |
| 11010101 | 11,5 | 213 | D5 | N |
| 11010110 | 11,6 | 214 | D6 | O |
| 11010111 | 11,7 | 215 | D7 | P |
| 11011000 | 11,8 | 216 | D8 | Q |
| 11011001 | 11,9 | 217 | D9 | R |
| 11011010 | 12,11,9,8,2 | 218 | DA | |
| 11011011 | 12,11,9,8,3 | 219 | DB | |
| 11011100 | 12,11,9,8,4 | 220 | DC | |
| 11011101 | 12,11,9,8,5 | 221 | DD | |

| 8-Bit BCD Code | Character Set Punch Combination | Decimal | Hexa-Decimal | Printer Graphics |
|---|---|---|---|---|
| 11011110 | 12,11,9,8,6 | 222 | DE | |
| 11011111 | 12,11,9,8,7 | 223 | DF | |
| 11100000 | 0,8,2 | 224 | E0 | |
| 11100001 | 11,0,9,1 | 225 | E1 | |
| 11100010 | 0,2 | 226 | E2 | S |
| 11100011 | 0,3 | 227 | E3 | T |
| 11100100 | 0,4 | 228 | E4 | U |
| 11100101 | 0,5 | 229 | E5 | V |
| 11100110 | 0,6 | 230 | E6 | W |
| 11100111 | 0,7 | 231 | E7 | X |
| 11101000 | 0,8 | 232 | E8 | Y |
| 11101001 | 0,9 | 233 | E9 | Z |
| 11101010 | 11,0,9,8,2 | 234 | EA | |
| 11101011 | 11,0,9,8,3 | 235 | EB | |
| 11101100 | 11,0,9,8,4 | 236 | EC | |
| 11101101 | 11,0,9,8,5 | 237 | ED | |
| 11101110 | 11,0,9,8,6 | 238 | EE | |
| 11101111 | 11,0,9,8,7 | 239 | EF | |
| 11110000 | 0 | 240 | F0 | 0 |
| 11110001 | 1 | 241 | F1 | 1 |
| 11110010 | 2 | 242 | F2 | 2 |
| 11110011 | 3 | 243 | F3 | 3 |
| 11110100 | 4 | 244 | F4 | 4 |
| 11110101 | 5 | 245 | F5 | 5 |
| 11110110 | 6 | 246 | F6 | 6 |
| 11110111 | 7 | 247 | F7 | 7 |
| 11111000 | 8 | 248 | F8 | 8 |
| 11111001 | 9 | 249 | F9 | 9 |
| 11111010 | 12,11,0,9,8,2 | 250 | FA | |
| 11111011 | 12,11,0,9,8,3 | 251 | FB | |
| 11111100 | 12,11,0,9,8,4 | 252 | FC | |
| 11111101 | 12,11,0,9,8,5 | 253 | FD | |
| 11111110 | 12,11,0,9,8,6 | 254 | FE | |
| 11111111 | 12,11,0,9,8,7 | 255 | FF | |

The table in this appendix provides for direct conversion of decimal and hexadecimal numbers in these ranges:

| Hexadecimal | Decimal |
|---|---|
| 000 to FFF | 0000 to 4095 |

For numbers outside the range of the table, add the following values to the table figures:

| Hexadecimal | Decimal |
|---|---|
| 1000 | 4096 |
| 2000 | 8192 |
| 3000 | 12288 |
| 4000 | 16384 |
| 5000 | 20480 |
| 6000 | 24576 |
| 7000 | 28672 |
| 8000 | 32768 |
| 9000 | 36864 |
| A000 | 40960 |
| B000 | 45056 |
| C000 | 49152 |
| D000 | 53248 |
| E000 | 57344 |
| F000 | 61440 |

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 000 | 0000 | 0001 | 0002 | 0003 | 0004 | 0005 | 0006 | 0007 | 0008 | 0009 | 0010 | 0011 | 0012 | 0013 | 0014 | 0015 |
| 010 | 0016 | 0017 | 0018 | 0019 | 0020 | 0021 | 0022 | 0023 | 0024 | 0025 | 0026 | 0027 | 0028 | 0029 | 0030 | 0031 |
| 020 | 0032 | 0033 | 0034 | 0035 | 0036 | 0037 | 0038 | 0039 | 0040 | 0041 | 0042 | 0043 | 0044 | 0045 | 0046 | 0047 |
| 030 | 0048 | 0049 | 0050 | 0051 | 0052 | 0053 | 0054 | 0055 | 0056 | 0057 | 0058 | 0059 | 0060 | 0061 | 0062 | 0063 |
| 040 | 0064 | 0065 | 0066 | 0067 | 0068 | 0069 | 0070 | 0071 | 0072 | 0073 | 0074 | 0075 | 0076 | 0077 | 0078 | 0079 |
| 050 | 0080 | 0081 | 0082 | 0083 | 0084 | 0085 | 0086 | 0087 | 0088 | 0089 | 0090 | 0091 | 0092 | 0093 | 0094 | 0095 |
| 060 | 0096 | 0097 | 0098 | 0099 | 0100 | 0101 | 0102 | 0103 | 0104 | 0105 | 0106 | 0107 | 0108 | 0109 | 0110 | 0111 |
| 070 | 0112 | 0113 | 0114 | 0115 | 0116 | 0117 | 0118 | 0119 | 0120 | 0121 | 0122 | 0123 | 0124 | 0125 | 0126 | 0127 |
| 080 | 0128 | 0129 | 0130 | 0131 | 0132 | 0133 | 0134 | 0135 | 0136 | 0137 | 0138 | 0139 | 0140 | 0141 | 0142 | 0143 |
| 090 | 0144 | 0145 | 0146 | 0147 | 0148 | 0149 | 0150 | 0151 | 0152 | 0153 | 0154 | 0155 | 0156 | 0157 | 0158 | 0159 |
| 0A0 | 0160 | 0161 | 0162 | 0163 | 0164 | 0165 | 0166 | 0167 | 0168 | 0169 | 0170 | 0171 | 0172 | 0173 | 0174 | 0175 |
| 0B0 | 0176 | 0177 | 0178 | 0179 | 0180 | 0181 | 0182 | 0183 | 0184 | 0185 | 0186 | 0187 | 0188 | 0189 | 0190 | 0191 |
| 0C0 | 0192 | 0193 | 0194 | 0195 | 0196 | 0197 | 0198 | 0199 | 0200 | 0201 | 0202 | 0203 | 0204 | 0205 | 0206 | 0207 |
| 0D0 | 0208 | 0209 | 0210 | 0211 | 0212 | 0213 | 0214 | 0215 | 0216 | 0217 | 0218 | 0219 | 0220 | 0221 | 0222 | 0223 |
| 0E0 | 0224 | 0225 | 0226 | 0227 | 0228 | 0229 | 0230 | 0231 | 0232 | 0233 | 0234 | 0235 | 0236 | 0237 | 0238 | 0239 |
| 0F0 | 0240 | 0241 | 0242 | 0243 | 0244 | 0245 | 0246 | 0247 | 0248 | 0249 | 0250 | 0251 | 0252 | 0253 | 0254 | 0255 |
| 100 | 0256 | 0257 | 0258 | 0259 | 0260 | 0261 | 0262 | 0263 | 0264 | 0265 | 0266 | 0267 | 0268 | 0269 | 0270 | 0271 |
| 110 | 0272 | 0273 | 0274 | 0275 | 0276 | 0277 | 0278 | 0279 | 0280 | 0281 | 0282 | 0283 | 0284 | 0285 | 0286 | 0287 |
| 120 | 0288 | 0289 | 0290 | 0291 | 0292 | 0293 | 0294 | 0295 | 0296 | 0297 | 0298 | 0299 | 0300 | 0301 | 0302 | 0303 |
| 130 | 0304 | 0305 | 0306 | 0307 | 0308 | 0309 | 0310 | 0311 | 0312 | 0313 | 0314 | 0315 | 0316 | 0317 | 0318 | 0319 |
| 140 | 0320 | 0321 | 0322 | 0323 | 0324 | 0325 | 0326 | 0327 | 0328 | 0329 | 0330 | 0331 | 0332 | 0333 | 0334 | 0335 |
| 150 | 0336 | 0337 | 0338 | 0339 | 0340 | 0341 | 0342 | 0343 | 0344 | 0345 | 0346 | 0347 | 0348 | 0349 | 0350 | 0351 |
| 160 | 0352 | 0353 | 0354 | 0355 | 0356 | 0357 | 0358 | 0359 | 0360 | 0361 | 0362 | 0363 | 0364 | 0365 | 0366 | 0367 |
| 170 | 0368 | 0369 | 0370 | 0371 | 0372 | 0373 | 0374 | 0375 | 0376 | 0377 | 0378 | 0379 | 0380 | 0381 | 0382 | 0383 |
| 180 | 0384 | 0385 | 0386 | 0387 | 0388 | 0389 | 0390 | 0391 | 0392 | 0393 | 0394 | 0395 | 0396 | 0397 | 0398 | 0399 |
| 190 | 0400 | 0401 | 0402 | 0403 | 0404 | 0405 | 0406 | 0407 | 0408 | 0409 | 0410 | 0411 | 0412 | 0413 | 0414 | 0415 |
| 1A0 | 0416 | 0417 | 0418 | 0419 | 0420 | 0421 | 0422 | 0423 | 0424 | 0425 | 0426 | 0427 | 0428 | 0429 | 0430 | 0431 |
| 1B0 | 0432 | 0433 | 0434 | 0435 | 0436 | 0437 | 0438 | 0439 | 0440 | 0441 | 0442 | 0443 | 0444 | 0445 | 0446 | 0447 |
| 1C0 | 0448 | 0449 | 0450 | 0451 | 0452 | 0453 | 0454 | 0455 | 0456 | 0457 | 0458 | 0459 | 0460 | 0461 | 0462 | 0463 |
| 1D0 | 0464 | 0465 | 0466 | 0467 | 0468 | 0469 | 0470 | 0471 | 0472 | 0473 | 0474 | 0475 | 0476 | 0477 | 0478 | 0479 |
| 1E0 | 0480 | 0481 | 0482 | 0483 | 0484 | 0485 | 0486 | 0487 | 0488 | 0489 | 0490 | 0491 | 0492 | 0493 | 0494 | 0495 |
| 1F0 | 0496 | 0497 | 0498 | 0499 | 0500 | 0501 | 0502 | 0503 | 0504 | 0505 | 0506 | 0507 | 0508 | 0509 | 0510 | 0511 |

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 200 | 0512 | 0513 | 0514 | 0515 | 0516 | 0517 | 0518 | 0519 | 0520 | 0521 | 0522 | 0523 | 0524 | 0525 | 0526 | 0527 |
| 210 | 0528 | 0529 | 0530 | 0531 | 0532 | 0533 | 0534 | 0535 | 0536 | 0537 | 0538 | 0539 | 0540 | 0541 | 0542 | 0543 |
| 220 | 0544 | 0545 | 0546 | 0547 | 0548 | 0549 | 0550 | 0551 | 0552 | 0553 | 0554 | 0555 | 0556 | 0557 | 0558 | 0559 |
| 230 | 0560 | 0561 | 0562 | 0563 | 0564 | 0565 | 0566 | 0567 | 0568 | 0569 | 0570 | 0571 | 0572 | 0573 | 0574 | 0575 |
| 240 | 0576 | 0577 | 0578 | 0579 | 0580 | 0581 | 0582 | 0583 | 0584 | 0585 | 0586 | 0587 | 0588 | 0589 | 0590 | 0591 |
| 250 | 0592 | 0593 | 0594 | 0595 | 0596 | 0597 | 0598 | 0599 | 0600 | 0601 | 0602 | 0603 | 0604 | 0605 | 0606 | 0607 |
| 260 | 0608 | 0609 | 0610 | 0611 | 0612 | 0613 | 0614 | 0615 | 0616 | 0617 | 0618 | 0619 | 0620 | 0621 | 0622 | 0623 |
| 270 | 0624 | 0625 | 0626 | 0627 | 0628 | 0629 | 0630 | 0631 | 0632 | 0633 | 0634 | 0635 | 0636 | 0637 | 0638 | 0639 |
| 280 | 0640 | 0641 | 0642 | 0643 | 0644 | 0645 | 0646 | 0647 | 0648 | 0649 | 0650 | 0651 | 0652 | 0653 | 0654 | 0655 |
| 290 | 0656 | 0657 | 0658 | 0659 | 0660 | 0661 | 0662 | 0663 | 0664 | 0665 | 0666 | 0667 | 0668 | 0669 | 0670 | 0671 |
| 2A0 | 0672 | 0673 | 0674 | 0675 | 0676 | 0677 | 0678 | 0679 | 0680 | 0681 | 0682 | 0683 | 0684 | 0685 | 0686 | 0687 |
| 2B0 | 0688 | 0689 | 0690 | 0691 | 0692 | 0693 | 0694 | 0695 | 0696 | 0697 | 0698 | 0699 | 0700 | 0701 | 0702 | 0703 |
| 2C0 | 0704 | 0705 | 0706 | 0707 | 0708 | 0709 | 0710 | 0711 | 0712 | 0713 | 0714 | 0715 | 0716 | 0717 | 0718 | 0719 |
| 2D0 | 0720 | 0721 | 0722 | 0723 | 0724 | 0725 | 0726 | 0727 | 0728 | 0729 | 0730 | 0731 | 0732 | 0733 | 0734 | 0735 |
| 2E0 | 0736 | 0737 | 0738 | 0739 | 0740 | 0741 | 0742 | 0743 | 0744 | 0745 | 0746 | 0747 | 0748 | 0749 | 0750 | 0751 |
| 2F0 | 0752 | 0753 | 0754 | 0755 | 0756 | 0757 | 0758 | 0759 | 0760 | 0761 | 0762 | 0763 | 0764 | 0765 | 0766 | 0767 |
| 300 | 0768 | 0769 | 0770 | 0771 | 0772 | 0773 | 0774 | 0775 | 0776 | 0777 | 0778 | 0779 | 0780 | 0781 | 0782 | 0783 |
| 310 | 0784 | 0785 | 0786 | 0787 | 0788 | 0789 | 0790 | 0791 | 0792 | 0793 | 0794 | 0795 | 0796 | 0797 | 0798 | 0799 |
| 320 | 0800 | 0801 | 0802 | 0803 | 0804 | 0805 | 0806 | 0807 | 0808 | 0809 | 0810 | 0811 | 0812 | 0813 | 0814 | 0815 |
| 330 | 0816 | 0817 | 0818 | 0819 | 0820 | 0821 | 0822 | 0823 | 0824 | 0825 | 0826 | 0827 | 0828 | 0829 | 0830 | 0831 |
| 340 | 0832 | 0833 | 0834 | 0835 | 0836 | 0837 | 0838 | 0839 | 0840 | 0841 | 0842 | 0843 | 0844 | 0845 | 0846 | 0847 |
| 350 | 0848 | 0849 | 0850 | 0851 | 0852 | 0853 | 0854 | 0855 | 0856 | 0857 | 0858 | 0859 | 0860 | 0861 | 0862 | 0863 |
| 360 | 0864 | 0865 | 0866 | 0867 | 0868 | 0869 | 0870 | 0871 | 0872 | 0873 | 0874 | 0875 | 0876 | 0877 | 0878 | 0879 |
| 370 | 0880 | 0881 | 0882 | 0883 | 0884 | 0885 | 0886 | 0887 | 0888 | 0889 | 0890 | 0891 | 0892 | 0893 | 0894 | 0895 |
| 380 | 0896 | 0897 | 0898 | 0899 | 0900 | 0901 | 0902 | 0903 | 0904 | 0905 | 0906 | 0907 | 0908 | 0909 | 0910 | 0911 |
| 390 | 0912 | 0913 | 0914 | 0915 | 0916 | 0917 | 0918 | 0919 | 0920 | 0921 | 0922 | 0923 | 0924 | 0925 | 0926 | 0927 |
| 3A0 | 0928 | 0929 | 0930 | 0931 | 0932 | 0933 | 0934 | 0935 | 0936 | 0937 | 0938 | 0939 | 0940 | 0941 | 0942 | 0943 |
| 3B0 | 0944 | 0945 | 0946 | 0947 | 0948 | 0949 | 0950 | 0951 | 0952 | 0953 | 0954 | 0955 | 0956 | 0957 | 0958 | 0959 |
| 3C0 | 0960 | 0961 | 0962 | 0963 | 0964 | 0965 | 0966 | 0967 | 0968 | 0969 | 0970 | 0971 | 0972 | 0973 | 0974 | 0975 |
| 3D0 | 0976 | 0977 | 0978 | 0979 | 0980 | 0981 | 0982 | 0983 | 0984 | 0985 | 0986 | 0987 | 0988 | 0989 | 0990 | 0991 |
| 3E0 | 0992 | 0993 | 0994 | 0995 | 0996 | 0997 | 0998 | 0999 | 1000 | 1001 | 1002 | 1003 | 1004 | 1005 | 1006 | 1007 |
| 3F0 | 1008 | 1009 | 1010 | 1011 | 1012 | 1013 | 1014 | 1015 | 1016 | 1017 | 1018 | 1019 | 1020 | 1021 | 1022 | 1023 |

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 400 | 1024 | 1025 | 1026 | 1027 | 1028 | 1029 | 1030 | 1031 | 1032 | 1033 | 1034 | 1035 | 1036 | 1037 | 1038 | 1039 |
| 410 | 1040 | 1041 | 1042 | 1043 | 1044 | 1045 | 1046 | 1047 | 1048 | 1049 | 1050 | 1051 | 1052 | 1053 | 1054 | 1055 |
| 420 | 1056 | 1057 | 1058 | 1059 | 1060 | 1061 | 1062 | 1063 | 1064 | 1065 | 1066 | 1067 | 1068 | 1069 | 1070 | 1071 |
| 430 | 1072 | 1073 | 1074 | 1075 | 1076 | 1077 | 1078 | 1079 | 1080 | 1081 | 1082 | 1083 | 1084 | 1085 | 1086 | 1087 |
| 440 | 1088 | 1089 | 1090 | 1091 | 1092 | 1093 | 1094 | 1095 | 1096 | 1097 | 1098 | 1099 | 1100 | 1101 | 1102 | 1103 |
| 450 | 1104 | 1105 | 1106 | 1107 | 1108 | 1109 | 1110 | 1111 | 1112 | 1113 | 1114 | 1115 | 1116 | 1117 | 1118 | 1119 |
| 460 | 1120 | 1121 | 1122 | 1123 | 1124 | 1125 | 1126 | 1127 | 1128 | 1129 | 1130 | 1131 | 1132 | 1133 | 1134 | 1135 |
| 470 | 1136 | 1137 | 1138 | 1139 | 1140 | 1141 | 1142 | 1143 | 1144 | 1145 | 1146 | 1147 | 1148 | 1149 | 1150 | 1151 |
| 480 | 1152 | 1153 | 1154 | 1155 | 1156 | 1157 | 1158 | 1159 | 1160 | 1161 | 1162 | 1163 | 1164 | 1165 | 1166 | 1167 |
| 490 | 1168 | 1169 | 1170 | 1171 | 1172 | 1173 | 1174 | 1175 | 1176 | 1177 | 1178 | 1179 | 1180 | 1181 | 1182 | 1183 |
| 4A0 | 1184 | 1185 | 1186 | 1187 | 1188 | 1189 | 1190 | 1191 | 1192 | 1193 | 1194 | 1195 | 1196 | 1197 | 1198 | 1199 |
| 4B0 | 1200 | 1201 | 1202 | 1203 | 1204 | 1205 | 1206 | 1207 | 1208 | 1209 | 1210 | 1211 | 1212 | 1213 | 1214 | 1215 |
| 4C0 | 1216 | 1217 | 1218 | 1219 | 1220 | 1221 | 1222 | 1223 | 1224 | 1225 | 1226 | 1227 | 1228 | 1229 | 1230 | 1231 |
| 4D0 | 1232 | 1233 | 1234 | 1235 | 1236 | 1237 | 1238 | 1239 | 1240 | 1241 | 1242 | 1243 | 1244 | 1245 | 1246 | 1247 |
| 4E0 | 1248 | 1249 | 1250 | 1251 | 1252 | 1253 | 1254 | 1255 | 1256 | 1257 | 1258 | 1259 | 1260 | 1261 | 1262 | 1263 |
| 4F0 | 1264 | 1265 | 1266 | 1267 | 1268 | 1269 | 1270 | 1271 | 1272 | 1273 | 1274 | 1275 | 1276 | 1277 | 1278 | 1279 |
| 500 | 1280 | 1281 | 1282 | 1283 | 1284 | 1285 | 1286 | 1287 | 1288 | 1289 | 1290 | 1291 | 1292 | 1293 | 1294 | 1295 |
| 510 | 1296 | 1297 | 1298 | 1299 | 1300 | 1301 | 1302 | 1303 | 1304 | 1305 | 1306 | 1307 | 1308 | 1309 | 1310 | 1311 |
| 520 | 1312 | 1313 | 1314 | 1315 | 1316 | 1317 | 1318 | 1319 | 1320 | 1321 | 1322 | 1323 | 1324 | 1325 | 1326 | 1327 |
| 530 | 1328 | 1329 | 1330 | 1331 | 1332 | 1333 | 1334 | 1335 | 1336 | 1337 | 1338 | 1339 | 1340 | 1341 | 1342 | 1343 |
| 540 | 1344 | 1345 | 1346 | 1347 | 1348 | 1349 | 1350 | 1351 | 1352 | 1353 | 1354 | 1355 | 1356 | 1357 | 1358 | 1359 |
| 550 | 1360 | 1361 | 1362 | 1363 | 1364 | 1365 | 1366 | 1367 | 1368 | 1369 | 1370 | 1371 | 1372 | 1373 | 1374 | 1375 |
| 560 | 1376 | 1377 | 1378 | 1379 | 1380 | 1381 | 1382 | 1383 | 1384 | 1385 | 1386 | 1387 | 1388 | 1389 | 1390 | 1391 |
| 570 | 1392 | 1393 | 1394 | 1395 | 1396 | 1397 | 1398 | 1399 | 1400 | 1401 | 1402 | 1403 | 1404 | 1405 | 1406 | 1407 |
| 580 | 1408 | 1409 | 1410 | 1411 | 1412 | 1413 | 1414 | 1415 | 1416 | 1417 | 1418 | 1419 | 1420 | 1421 | 1422 | 1423 |
| 590 | 1424 | 1425 | 1426 | 1427 | 1428 | 1429 | 1430 | 1431 | 1432 | 1433 | 1434 | 1435 | 1436 | 1437 | 1438 | 1439 |
| 5A0 | 1440 | 1441 | 1442 | 1443 | 1444 | 1445 | 1446 | 1447 | 1448 | 1449 | 1450 | 1451 | 1452 | 1453 | 1454 | 1455 |
| 5B0 | 1456 | 1457 | 1458 | 1459 | 1460 | 1461 | 1462 | 1463 | 1464 | 1465 | 1466 | 1467 | 1468 | 1469 | 1470 | 1471 |
| 5C0 | 1472 | 1473 | 1474 | 1475 | 1476 | 1477 | 1478 | 1479 | 1480 | 1481 | 1482 | 1483 | 1484 | 1485 | 1486 | 1487 |
| 5D0 | 1488 | 1489 | 1490 | 1491 | 1492 | 1493 | 1494 | 1495 | 1496 | 1497 | 1498 | 1499 | 1500 | 1501 | 1502 | 1503 |
| 5E0 | 1504 | 1505 | 1506 | 1507 | 1508 | 1509 | 1510 | 1511 | 1512 | 1513 | 1514 | 1515 | 1516 | 1517 | 1518 | 1519 |
| 5F0 | 1520 | 1521 | 1522 | 1523 | 1524 | 1525 | 1526 | 1527 | 1528 | 1529 | 1530 | 1531 | 1532 | 1533 | 1534 | 1535 |

|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 600 | 1536 | 1537 | 1538 | 1539 | 1540 | 1541 | 1542 | 1543 | 1544 | 1545 | 1546 | 1547 | 1548 | 1549 | 1550 | 1551 |
| 610 | 1552 | 1553 | 1554 | 1555 | 1556 | 1557 | 1558 | 1559 | 1560 | 1561 | 1562 | 1563 | 1564 | 1565 | 1566 | 1567 |
| 620 | 1568 | 1569 | 1570 | 1571 | 1572 | 1573 | 1574 | 1575 | 1576 | 1577 | 1578 | 1579 | 1580 | 1581 | 1582 | 1583 |
| 630 | 1584 | 1585 | 1586 | 1587 | 1588 | 1589 | 1590 | 1591 | 1592 | 1593 | 1594 | 1595 | 1596 | 1597 | 1598 | 1599 |
| 640 | 1600 | 1601 | 1602 | 1603 | 1604 | 1605 | 1606 | 1607 | 1608 | 1609 | 1610 | 1611 | 1612 | 1613 | 1614 | 1615 |
| 650 | 1616 | 1617 | 1618 | 1619 | 1620 | 1621 | 1622 | 1623 | 1624 | 1625 | 1626 | 1627 | 1628 | 1629 | 1630 | 1631 |
| 660 | 1632 | 1633 | 1634 | 1635 | 1636 | 1637 | 1638 | 1639 | 1640 | 1641 | 1642 | 1643 | 1644 | 1645 | 1646 | 1647 |
| 670 | 1648 | 1649 | 1650 | 1651 | 1652 | 1653 | 1654 | 1655 | 1656 | 1657 | 1658 | 1659 | 1660 | 1661 | 1662 | 1663 |
| 680 | 1664 | 1665 | 1666 | 1667 | 1668 | 1669 | 1670 | 1671 | 1672 | 1673 | 1674 | 1675 | 1676 | 1677 | 1678 | 1679 |
| 690 | 1680 | 1681 | 1682 | 1683 | 1684 | 1685 | 1686 | 1687 | 1688 | 1689 | 1690 | 1691 | 1692 | 1693 | 1694 | 1695 |
| 6A0 | 1696 | 1697 | 1698 | 1699 | 1700 | 1701 | 1702 | 1703 | 1704 | 1705 | 1706 | 1707 | 1708 | 1709 | 1710 | 1711 |
| 6B0 | 1712 | 1713 | 1714 | 1715 | 1716 | 1717 | 1718 | 1719 | 1720 | 1721 | 1722 | 1723 | 1724 | 1725 | 1726 | 1727 |
| 6C0 | 1728 | 1729 | 1730 | 1731 | 1732 | 1733 | 1734 | 1735 | 1736 | 1737 | 1738 | 1739 | 1740 | 1741 | 1742 | 1743 |
| 6D0 | 1744 | 1745 | 1746 | 1747 | 1748 | 1749 | 1750 | 1751 | 1752 | 1753 | 1754 | 1755 | 1756 | 1757 | 1758 | 1759 |
| 6E0 | 1760 | 1761 | 1762 | 1763 | 1764 | 1765 | 1766 | 1767 | 1768 | 1769 | 1770 | 1771 | 1772 | 1773 | 1774 | 1775 |
| 6F0 | 1776 | 1777 | 1778 | 1779 | 1780 | 1781 | 1782 | 1783 | 1784 | 1785 | 1786 | 1787 | 1788 | 1789 | 1790 | 1791 |
| 700 | 1792 | 1793 | 1794 | 1795 | 1796 | 1797 | 1798 | 1799 | 1800 | 1801 | 1802 | 1803 | 1804 | 1805 | 1806 | 1807 |
| 710 | 1808 | 1809 | 1810 | 1811 | 1812 | 1813 | 1814 | 1815 | 1816 | 1817 | 1818 | 1819 | 1820 | 1821 | 1822 | 1823 |
| 720 | 1824 | 1825 | 1826 | 1827 | 1828 | 1829 | 1830 | 1831 | 1832 | 1833 | 1834 | 1835 | 1836 | 1837 | 1838 | 1839 |
| 730 | 1840 | 1841 | 1842 | 1843 | 1844 | 1845 | 1846 | 1847 | 1848 | 1849 | 1850 | 1851 | 1852 | 1853 | 1854 | 1855 |
| 740 | 1856 | 1857 | 1858 | 1859 | 1860 | 1861 | 1862 | 1863 | 1864 | 1865 | 1866 | 1867 | 1868 | 1869 | 1870 | 1871 |
| 750 | 1872 | 1873 | 1874 | 1875 | 1876 | 1877 | 1878 | 1879 | 1880 | 1881 | 1882 | 1883 | 1884 | 1885 | 1886 | 1887 |
| 760 | 1888 | 1889 | 1890 | 1891 | 1892 | 1893 | 1894 | 1895 | 1896 | 1897 | 1898 | 1899 | 1900 | 1901 | 1902 | 1903 |
| 770 | 1904 | 1905 | 1906 | 1907 | 1908 | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1918 | 1919 |
| 780 | 1920 | 1921 | 1922 | 1923 | 1924 | 1925 | 1926 | 1927 | 1928 | 1929 | 1930 | 1931 | 1932 | 1933 | 1934 | 1935 |
| 790 | 1936 | 1937 | 1938 | 1939 | 1940 | 1941 | 1942 | 1943 | 1944 | 1945 | 1946 | 1947 | 1948 | 1949 | 1950 | 1951 |
| 7A0 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 |
| 7B0 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
| 7C0 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
| 7D0 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| 7E0 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
| 7F0 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 | 2046 | 2047 |

|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 800 | 2048 | 2049 | 2050 | 2051 | 2052 | 2053 | 2054 | 2055 | 2056 | 2057 | 2058 | 2059 | 2060 | 2061 | 2062 | 2063 |
| 810 | 2064 | 2065 | 2066 | 2067 | 2068 | 2069 | 2070 | 2071 | 2072 | 2073 | 2074 | 2075 | 2076 | 2077 | 2078 | 2079 |
| 820 | 2080 | 2081 | 2082 | 2083 | 2084 | 2085 | 2086 | 2087 | 2088 | 2089 | 2090 | 2091 | 2092 | 2093 | 2094 | 2095 |
| 830 | 2096 | 2097 | 2098 | 2099 | 2100 | 2101 | 2102 | 2103 | 2104 | 2105 | 2106 | 2107 | 2108 | 2109 | 2110 | 2111 |
| 840 | 2112 | 2113 | 2114 | 2115 | 2116 | 2117 | 2118 | 2119 | 2120 | 2121 | 2122 | 2123 | 2124 | 2125 | 2126 | 2127 |
| 850 | 2128 | 2129 | 2130 | 2131 | 2132 | 2133 | 2134 | 2135 | 2136 | 2137 | 2138 | 2139 | 2140 | 2141 | 2142 | 2143 |
| 860 | 2144 | 2145 | 2146 | 2147 | 2148 | 2149 | 2150 | 2151 | 2152 | 2153 | 2154 | 2155 | 2156 | 2157 | 2158 | 2159 |
| 870 | 2160 | 2161 | 2162 | 2163 | 2164 | 2165 | 2166 | 2167 | 2168 | 2169 | 2170 | 2171 | 2172 | 2173 | 2174 | 2175 |
| 880 | 2176 | 2177 | 2178 | 2179 | 2180 | 2181 | 2182 | 2183 | 2184 | 2185 | 2186 | 2187 | 2188 | 2189 | 2190 | 2191 |
| 890 | 2192 | 2193 | 2194 | 2195 | 2196 | 2197 | 2198 | 2199 | 2200 | 2201 | 2202 | 2203 | 2204 | 2205 | 2206 | 2207 |
| 8A0 | 2208 | 2209 | 2210 | 2211 | 2212 | 2213 | 2214 | 2215 | 2216 | 2217 | 2218 | 2219 | 2220 | 2221 | 2222 | 2223 |
| 8B0 | 2224 | 2225 | 2226 | 2227 | 2228 | 2229 | 2230 | 2231 | 2232 | 2233 | 2234 | 2235 | 2236 | 2237 | 2238 | 2239 |
| 8C0 | 2240 | 2241 | 2242 | 2243 | 2244 | 2245 | 2246 | 2247 | 2248 | 2249 | 2250 | 2251 | 2252 | 2253 | 2254 | 2255 |
| 8D0 | 2256 | 2257 | 2258 | 2259 | 2260 | 2261 | 2262 | 2263 | 2264 | 2265 | 2266 | 2267 | 2268 | 2269 | 2270 | 2271 |
| 8E0 | 2272 | 2273 | 2274 | 2275 | 2276 | 2277 | 2278 | 2279 | 2280 | 2281 | 2282 | 2283 | 2284 | 2285 | 2286 | 2287 |
| 8F0 | 2288 | 2289 | 2290 | 2291 | 2292 | 2293 | 2294 | 2295 | 2296 | 2297 | 2298 | 2299 | 2300 | 2301 | 2302 | 2303 |
| 900 | 2304 | 2305 | 2306 | 2307 | 2308 | 2309 | 2310 | 2311 | 2312 | 2313 | 2314 | 2315 | 2316 | 2317 | 2318 | 2319 |
| 910 | 2320 | 2321 | 2322 | 2323 | 2324 | 2325 | 2326 | 2327 | 2328 | 2329 | 2330 | 2331 | 2332 | 2333 | 2334 | 2335 |
| 920 | 2336 | 2337 | 2338 | 2339 | 2340 | 2341 | 2342 | 2343 | 2344 | 2345 | 2346 | 2347 | 2348 | 2349 | 2350 | 2351 |
| 930 | 2352 | 2353 | 2354 | 2355 | 2356 | 2357 | 2358 | 2359 | 2360 | 2361 | 2362 | 2363 | 2364 | 2365 | 2366 | 2367 |
| 940 | 2368 | 2369 | 2370 | 2371 | 2372 | 2373 | 2374 | 2375 | 2376 | 2377 | 2378 | 2379 | 2380 | 2381 | 2382 | 2383 |
| 950 | 2384 | 2385 | 2386 | 2387 | 2388 | 2389 | 2390 | 2391 | 2392 | 2393 | 2394 | 2395 | 2396 | 2397 | 2398 | 2399 |
| 960 | 2400 | 2401 | 2402 | 2403 | 2404 | 2405 | 2406 | 2407 | 2408 | 2409 | 2410 | 2411 | 2412 | 2413 | 2414 | 2415 |
| 970 | 2416 | 2417 | 2418 | 2419 | 2420 | 2421 | 2422 | 2423 | 2424 | 2425 | 2426 | 2427 | 2428 | 2429 | 2430 | 2431 |
| 980 | 2432 | 2433 | 2434 | 2435 | 2436 | 2437 | 2438 | 2439 | 2440 | 2441 | 2442 | 2443 | 2444 | 2445 | 2446 | 2447 |
| 990 | 2448 | 2449 | 2450 | 2451 | 2452 | 2453 | 2454 | 2455 | 2456 | 2457 | 2458 | 2459 | 2460 | 2461 | 2462 | 2463 |
| 9A0 | 2464 | 2465 | 2466 | 2467 | 2468 | 2469 | 2470 | 2471 | 2472 | 2473 | 2474 | 2475 | 2476 | 2477 | 2478 | 2479 |
| 9B0 | 2480 | 2481 | 2482 | 2483 | 2484 | 2485 | 2486 | 2487 | 2488 | 2489 | 2490 | 2491 | 2492 | 2493 | 2494 | 2495 |
| 9C0 | 2496 | 2497 | 2498 | 2499 | 2500 | 2501 | 2502 | 2503 | 2504 | 2505 | 2506 | 2507 | 2508 | 2509 | 2510 | 2511 |
| 9D0 | 2512 | 2513 | 2514 | 2515 | 2516 | 2517 | 2518 | 2519 | 2520 | 2521 | 2522 | 2523 | 2524 | 2525 | 2526 | 2527 |
| 9E0 | 2528 | 2529 | 2530 | 2531 | 2532 | 2533 | 2534 | 2535 | 2536 | 2537 | 2538 | 2539 | 2540 | 2541 | 2542 | 2543 |
| 9F0 | 2544 | 2545 | 2546 | 2547 | 2548 | 2549 | 2550 | 2551 | 2552 | 2553 | 2554 | 2555 | 2556 | 2557 | 2558 | 2559 |

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A00 | 2560 | 2561 | 2562 | 2563 | 2564 | 2565 | 2566 | 2567 | 2568 | 2569 | 2570 | 2571 | 2572 | 2573 | 2574 | 2575 |
| A10 | 2576 | 2577 | 2578 | 2579 | 2580 | 2581 | 2582 | 2583 | 2584 | 2585 | 2586 | 2587 | 2588 | 2589 | 2590 | 2591 |
| A20 | 2592 | 2593 | 2594 | 2595 | 2596 | 2597 | 2598 | 2599 | 2600 | 2601 | 2602 | 2603 | 2604 | 2605 | 2606 | 2607 |
| A30 | 2608 | 2609 | 2610 | 2611 | 2612 | 2613 | 2614 | 2615 | 2616 | 2617 | 2618 | 2619 | 2620 | 2621 | 2622 | 2623 |
| A40 | 2624 | 2625 | 2626 | 2627 | 2628 | 2629 | 2630 | 2631 | 2632 | 2633 | 2634 | 2635 | 2636 | 2637 | 2638 | 2639 |
| A50 | 2640 | 2641 | 2642 | 2643 | 2644 | 2645 | 2646 | 2647 | 2648 | 2649 | 2650 | 2651 | 2652 | 2653 | 2654 | 2655 |
| A60 | 2656 | 2657 | 2658 | 2659 | 2660 | 2661 | 2662 | 2663 | 2664 | 2665 | 2666 | 2667 | 2668 | 2669 | 2670 | 2671 |
| A70 | 2672 | 2673 | 2674 | 2675 | 2676 | 2677 | 2678 | 2679 | 2680 | 2681 | 2682 | 2683 | 2684 | 2685 | 2686 | 2687 |
| A80 | 2688 | 2689 | 2690 | 2691 | 2692 | 2693 | 2694 | 2695 | 2696 | 2697 | 2698 | 2699 | 2700 | 2701 | 2702 | 2703 |
| A90 | 2704 | 2705 | 2706 | 2707 | 2708 | 2709 | 2710 | 2711 | 2712 | 2713 | 2714 | 2715 | 2716 | 2717 | 2718 | 2719 |
| AA0 | 2720 | 2721 | 2722 | 2723 | 2724 | 2725 | 2726 | 2727 | 2728 | 2729 | 2730 | 2731 | 2732 | 2733 | 2734 | 2735 |
| AB0 | 2736 | 2737 | 2738 | 2739 | 2740 | 2741 | 2742 | 2743 | 2744 | 2745 | 2746 | 2747 | 2748 | 2749 | 2750 | 2751 |
| AC0 | 2752 | 2753 | 2754 | 2755 | 2756 | 2757 | 2758 | 2759 | 2760 | 2761 | 2762 | 2763 | 2764 | 2765 | 2766 | 2767 |
| AD0 | 2768 | 2769 | 2770 | 2771 | 2772 | 2773 | 2774 | 2775 | 2776 | 2777 | 2778 | 2779 | 2780 | 2781 | 2782 | 2783 |
| AE0 | 2784 | 2785 | 2786 | 2787 | 2788 | 2789 | 2790 | 2791 | 2792 | 2793 | 2794 | 2795 | 2796 | 2797 | 2798 | 2799 |
| AF0 | 2800 | 2801 | 2802 | 2803 | 2804 | 2805 | 2806 | 2807 | 2808 | 2809 | 2810 | 2811 | 2812 | 2813 | 2814 | 2815 |
| B00 | 2816 | 2817 | 2818 | 2819 | 2820 | 2821 | 2822 | 2823 | 2824 | 2825 | 2826 | 2827 | 2828 | 2829 | 2830 | 2831 |
| B10 | 2832 | 2833 | 2834 | 2835 | 2836 | 2837 | 2838 | 2839 | 2840 | 2841 | 2842 | 2843 | 2844 | 2845 | 2846 | 2847 |
| B20 | 2848 | 2849 | 2850 | 2851 | 2852 | 2853 | 2854 | 2855 | 2856 | 2857 | 2858 | 2859 | 2860 | 2861 | 2862 | 2863 |
| B30 | 2864 | 2865 | 2866 | 2867 | 2868 | 2869 | 2870 | 2871 | 2872 | 2873 | 2874 | 2875 | 2876 | 2877 | 2878 | 2879 |
| B40 | 2880 | 2881 | 2882 | 2883 | 2884 | 2885 | 2886 | 2887 | 2888 | 2889 | 2890 | 2891 | 2892 | 2893 | 2894 | 2895 |
| B50 | 2896 | 2897 | 2898 | 2899 | 2900 | 2901 | 2902 | 2903 | 2904 | 2905 | 2906 | 2907 | 2908 | 2909 | 2910 | 2911 |
| B60 | 2912 | 2913 | 2914 | 2915 | 2916 | 2917 | 2918 | 2919 | 2920 | 2921 | 2922 | 2923 | 2924 | 2925 | 2926 | 2927 |
| B70 | 2928 | 2929 | 2930 | 2931 | 2932 | 2933 | 2934 | 2935 | 2936 | 2937 | 2938 | 2939 | 2940 | 2941 | 2942 | 2943 |
| B80 | 2944 | 2945 | 2946 | 2947 | 2948 | 2949 | 2950 | 2951 | 2952 | 2953 | 2954 | 2955 | 2956 | 2957 | 2958 | 2959 |
| B90 | 2960 | 2961 | 2962 | 2963 | 2964 | 2965 | 2966 | 2967 | 2968 | 2969 | 2970 | 2971 | 2972 | 2973 | 2974 | 2975 |
| BA0 | 2976 | 2977 | 2978 | 2979 | 2980 | 2981 | 2982 | 2983 | 2984 | 2985 | 2986 | 2987 | 2988 | 2989 | 2990 | 2991 |
| BB0 | 2992 | 2993 | 2994 | 2995 | 2996 | 2997 | 2998 | 2999 | 3000 | 3001 | 3002 | 3003 | 3004 | 3005 | 3006 | 3007 |
| BC0 | 3008 | 3009 | 3010 | 3011 | 3012 | 3013 | 3014 | 3015 | 3016 | 3017 | 3018 | 3019 | 3020 | 3021 | 3022 | 3023 |
| BD0 | 3024 | 3025 | 3026 | 3027 | 3028 | 3029 | 3030 | 3031 | 3032 | 3033 | 3034 | 3035 | 3036 | 3037 | 3038 | 3039 |
| BE0 | 3040 | 3041 | 3042 | 3043 | 3044 | 3045 | 3046 | 3047 | 3048 | 3049 | 3050 | 3051 | 3052 | 3053 | 3054 | 3055 |
| BF0 | 3056 | 3057 | 3058 | 3059 | 3060 | 3061 | 3062 | 3063 | 3064 | 3065 | 3066 | 3067 | 3068 | 3069 | 3070 | 3071 |

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C00 | 3072 | 3073 | 3074 | 3075 | 3076 | 3077 | 3078 | 3079 | 3080 | 3081 | 3082 | 3083 | 3084 | 3085 | 3086 | 3087 |
| C10 | 3088 | 3089 | 3090 | 3091 | 3092 | 3093 | 3094 | 3095 | 3096 | 3097 | 3098 | 3099 | 3100 | 3101 | 3102 | 3103 |
| C20 | 3104 | 3105 | 3106 | 3107 | 3108 | 3109 | 3110 | 3111 | 3112 | 3113 | 3114 | 3115 | 3116 | 3117 | 3118 | 3119 |
| C30 | 3120 | 3121 | 3122 | 3123 | 3124 | 3125 | 3126 | 3127 | 3128 | 3129 | 3130 | 3131 | 3132 | 3133 | 3134 | 3135 |
| C40 | 3136 | 3137 | 3138 | 3139 | 3140 | 3141 | 3142 | 3143 | 3144 | 3145 | 3146 | 3147 | 3148 | 3149 | 3150 | 3151 |
| C50 | 3152 | 3153 | 3154 | 3155 | 3156 | 3157 | 3158 | 3159 | 3160 | 3161 | 3162 | 3163 | 3164 | 3165 | 3166 | 3167 |
| C60 | 3168 | 3169 | 3170 | 3171 | 3172 | 3173 | 3174 | 3175 | 3176 | 3177 | 3178 | 3179 | 3180 | 3181 | 3182 | 3183 |
| C70 | 3184 | 3185 | 3186 | 3187 | 3188 | 3189 | 3190 | 3191 | 3192 | 3193 | 3194 | 3195 | 3196 | 3197 | 3198 | 3199 |
| C80 | 3200 | 3201 | 3202 | 3203 | 3204 | 3205 | 3206 | 3207 | 3208 | 3209 | 3210 | 3211 | 3212 | 3213 | 3214 | 3215 |
| C90 | 3216 | 3217 | 3218 | 3219 | 3220 | 3221 | 3222 | 3223 | 3224 | 3225 | 3226 | 3227 | 3228 | 3229 | 3230 | 3231 |
| CA0 | 3232 | 3233 | 3234 | 3235 | 3236 | 3237 | 3238 | 3239 | 3240 | 3241 | 3242 | 3243 | 3244 | 3245 | 3246 | 3247 |
| CB0 | 3248 | 3249 | 3250 | 3251 | 3252 | 3253 | 3254 | 3255 | 3256 | 3257 | 3258 | 3259 | 3260 | 3261 | 3262 | 3263 |
| CC0 | 3264 | 3265 | 3266 | 3267 | 3268 | 3269 | 3270 | 3271 | 3272 | 3273 | 3274 | 3275 | 3276 | 3277 | 3278 | 3279 |
| CD0 | 3280 | 3281 | 3282 | 3283 | 3284 | 3285 | 3286 | 3287 | 3288 | 3289 | 3290 | 3291 | 3292 | 3293 | 3294 | 3295 |
| CE0 | 3296 | 3297 | 3298 | 3299 | 3300 | 3301 | 3302 | 3303 | 3304 | 3305 | 3306 | 3307 | 3308 | 3309 | 3310 | 3311 |
| CF0 | 3312 | 3313 | 3314 | 3315 | 3316 | 3317 | 3318 | 3319 | 3320 | 3321 | 3322 | 3323 | 3324 | 3325 | 3326 | 3327 |
| D00 | 3328 | 3329 | 3330 | 3331 | 3332 | 3333 | 3334 | 3335 | 3336 | 3337 | 3338 | 3339 | 3340 | 3341 | 3342 | 3343 |
| D10 | 3344 | 3345 | 3346 | 3347 | 3348 | 3349 | 3350 | 3351 | 3352 | 3353 | 3354 | 3355 | 3356 | 3357 | 3358 | 3359 |
| D20 | 3360 | 3361 | 3362 | 3363 | 3364 | 3365 | 3366 | 3367 | 3368 | 3369 | 3370 | 3371 | 3372 | 3373 | 3374 | 3375 |
| D30 | 3376 | 3377 | 3378 | 3379 | 3380 | 3381 | 3382 | 3383 | 3384 | 3385 | 3386 | 3387 | 3388 | 3389 | 3390 | 3391 |
| D40 | 3392 | 3393 | 3394 | 3395 | 3396 | 3397 | 3398 | 3399 | 3400 | 3401 | 3402 | 3403 | 3404 | 3405 | 3406 | 3407 |
| D50 | 3408 | 3409 | 3410 | 3411 | 3412 | 3413 | 3414 | 3415 | 3416 | 3417 | 3418 | 3419 | 3420 | 3421 | 3422 | 3423 |
| D60 | 3424 | 3425 | 3426 | 3427 | 3428 | 3429 | 3430 | 3431 | 3432 | 3433 | 3434 | 3435 | 3436 | 3437 | 3438 | 3439 |
| D70 | 3440 | 3441 | 3442 | 3443 | 3444 | 3445 | 3446 | 3447 | 3448 | 3449 | 3450 | 3451 | 3452 | 3453 | 3454 | 3455 |
| D80 | 3456 | 3457 | 3458 | 3459 | 3460 | 3461 | 3462 | 3463 | 3464 | 3465 | 3466 | 3467 | 3468 | 3469 | 3470 | 3471 |
| D90 | 3472 | 3473 | 3474 | 3475 | 3476 | 3477 | 3478 | 3479 | 3480 | 3481 | 3482 | 3483 | 3484 | 3485 | 3486 | 3487 |
| DA0 | 3488 | 3489 | 3490 | 3491 | 3492 | 3493 | 3494 | 3495 | 3496 | 3497 | 3498 | 3499 | 3500 | 3501 | 3502 | 3503 |
| DB0 | 3504 | 3505 | 3506 | 3507 | 3508 | 3509 | 3510 | 3511 | 3512 | 3513 | 3514 | 3515 | 3516 | 3517 | 3518 | 3519 |
| DC0 | 3520 | 3521 | 3522 | 3523 | 3524 | 3525 | 3526 | 3527 | 3528 | 3529 | 3530 | 3531 | 3532 | 3533 | 3534 | 3535 |
| DD0 | 3536 | 3537 | 3538 | 3539 | 3540 | 3541 | 3542 | 3543 | 3544 | 3545 | 3546 | 3547 | 3548 | 3549 | 3550 | 3551 |
| DE0 | 3552 | 3553 | 3554 | 3555 | 3556 | 3557 | 3558 | 3559 | 3560 | 3561 | 3562 | 3563 | 3564 | 3565 | 3566 | 3567 |
| DF0 | 3568 | 3569 | 3570 | 3571 | 3572 | 3573 | 3574 | 3575 | 3576 | 3577 | 3578 | 3579 | 3580 | 3581 | 3582 | 3583 |

|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E00 | 3584 | 3585 | 3586 | 3587 | 3588 | 3589 | 3590 | 3591 | 3592 | 3593 | 3594 | 3595 | 3596 | 3597 | 3598 | 3599 |
| E10 | 3600 | 3601 | 3602 | 3603 | 3604 | 3605 | 3606 | 3607 | 3608 | 3609 | 3610 | 3611 | 3612 | 3613 | 3614 | 3615 |
| E20 | 3616 | 3617 | 3618 | 3619 | 3620 | 3621 | 3622 | 3623 | 3624 | 3625 | 3626 | 3627 | 3628 | 3629 | 3630 | 3631 |
| E30 | 3632 | 3633 | 3634 | 3635 | 3636 | 3637 | 3638 | 3639 | 3640 | 3641 | 3642 | 3643 | 3644 | 3645 | 3646 | 3647 |
| E40 | 3648 | 3649 | 3650 | 3651 | 3652 | 3653 | 3654 | 3655 | 3656 | 3657 | 3658 | 3659 | 3660 | 3661 | 3662 | 3663 |
| E50 | 3664 | 3665 | 3666 | 3667 | 3668 | 3669 | 3670 | 3671 | 3672 | 3673 | 3674 | 3675 | 3676 | 3677 | 3678 | 3679 |
| E60 | 3680 | 3681 | 3682 | 3683 | 3684 | 3685 | 3686 | 3687 | 3688 | 3689 | 3690 | 3691 | 3692 | 3693 | 3694 | 3695 |
| E70 | 3696 | 3697 | 3698 | 3699 | 3700 | 3701 | 3702 | 3703 | 3704 | 3705 | 3706 | 3707 | 3708 | 3709 | 3710 | 3711 |
| E80 | 3712 | 3713 | 3714 | 3715 | 3716 | 3717 | 3718 | 3719 | 3720 | 3721 | 3722 | 3723 | 3724 | 3725 | 3726 | 3727 |
| E90 | 3728 | 3729 | 3730 | 3731 | 3732 | 3733 | 3734 | 3735 | 3736 | 3737 | 3738 | 3739 | 3740 | 3741 | 3742 | 3743 |
| EA0 | 3744 | 3745 | 3746 | 3747 | 3748 | 3749 | 3750 | 3751 | 3752 | 3753 | 3754 | 3755 | 3756 | 3757 | 3758 | 3759 |
| EB0 | 3760 | 3761 | 3762 | 3763 | 3764 | 3765 | 3766 | 3767 | 3768 | 3769 | 3770 | 3771 | 3772 | 3773 | 3774 | 3775 |
| EC0 | 3776 | 3777 | 3778 | 3779 | 3780 | 3781 | 3782 | 3783 | 3784 | 3785 | 3786 | 3787 | 3788 | 3789 | 3790 | 3791 |
| ED0 | 3792 | 3793 | 3794 | 3795 | 3796 | 3797 | 3798 | 3799 | 3800 | 3801 | 3802 | 3803 | 3804 | 3805 | 3806 | 3807 |
| EE0 | 3808 | 3809 | 3810 | 3811 | 3812 | 3813 | 3814 | 3815 | 3816 | 3817 | 3818 | 3819 | 3820 | 3821 | 3822 | 3823 |
| EF0 | 3824 | 3825 | 3826 | 3827 | 3828 | 3829 | 3830 | 3831 | 3832 | 3833 | 3834 | 3835 | 3836 | 3837 | 3838 | 3839 |
| F00 | 3840 | 3841 | 3842 | 3843 | 3844 | 3845 | 3846 | 3847 | 3848 | 3849 | 3850 | 3851 | 3852 | 3853 | 3854 | 3855 |
| F10 | 3856 | 3857 | 3858 | 3859 | 3860 | 3861 | 3862 | 3863 | 3864 | 3865 | 3866 | 3867 | 3868 | 3869 | 3870 | 3871 |
| F20 | 3872 | 3873 | 3874 | 3875 | 3876 | 3877 | 3878 | 3879 | 3880 | 3881 | 3882 | 3883 | 3884 | 3885 | 3886 | 3887 |
| F30 | 3888 | 3889 | 3890 | 3891 | 3892 | 3893 | 3894 | 3895 | 3896 | 3897 | 3898 | 3899 | 3900 | 3901 | 3902 | 3903 |
| F40 | 3904 | 0905 | 0906 | 0907 | 3908 | 3909 | 3910 | 3911 | 3912 | 3913 | 3914 | 3915 | 3916 | 3917 | 3918 | 3919 |
| F50 | 3920 | 0921 | 0922 | 0923 | 3924 | 3925 | 3926 | 3927 | 3928 | 3929 | 3930 | 3931 | 3932 | 3933 | 3934 | 3935 |
| F60 | 3936 | 0937 | 0938 | 0939 | 3940 | 3941 | 3942 | 3943 | 3944 | 3945 | 3946 | 3947 | 3948 | 3949 | 3950 | 3951 |
| F70 | 3952 | 0953 | 0954 | 0955 | 3956 | 3957 | 3958 | 3959 | 3960 | 3961 | 3962 | 3963 | 3964 | 3965 | 3966 | 3967 |
| F80 | 3968 | 0969 | 0970 | 0971 | 3972 | 3973 | 3974 | 3975 | 3976 | 3977 | 3978 | 3979 | 3980 | 3981 | 3982 | 3983 |
| F90 | 3984 | 0985 | 0986 | 0987 | 3988 | 3989 | 3990 | 3991 | 3992 | 3993 | 3994 | 3995 | 3996 | 3997 | 3998 | 3999 |
| FA0 | 4000 | 4001 | 4002 | 4003 | 4004 | 4005 | 4006 | 4007 | 4008 | 4009 | 4010 | 4011 | 4012 | 4013 | 4014 | 4015 |
| FB0 | 4016 | 4017 | 4018 | 4019 | 4020 | 4021 | 4022 | 4023 | 4024 | 4025 | 4026 | 4027 | 4028 | 4029 | 4030 | 4031 |
| FC0 | 4032 | 4033 | 4034 | 4035 | 4036 | 4037 | 4038 | 4039 | 4040 | 4041 | 4042 | 4043 | 4044 | 4045 | 4046 | 4047 |
| FD0 | 4048 | 4049 | 4050 | 4051 | 4052 | 4053 | 4054 | 4055 | 4056 | 4057 | 4058 | 4059 | 4060 | 4061 | 4062 | 4063 |
| FE0 | 4064 | 4065 | 4066 | 4067 | 4068 | 4069 | 4070 | 4071 | 4072 | 4073 | 4074 | 4075 | 4076 | 4077 | 4078 | 4079 |
| FF0 | 4080 | 4081 | 4082 | 4083 | 4084 | 4085 | 4086 | 4087 | 4088 | 4089 | 4090 | 4091 | 4092 | 4093 | 4094 | 4095 |

This test program sorts, in ascending sequence, the 16 hexadecimal characters located at 'IN' and stores them at 'OUT'. (The following example is used to demonstrate instruction mix rather than model coding.)

```
FLAGS      LOC.CTR.     OBJECT    V1L0   SOURCE STATEMENT
                                                ICTL  25
           000000                        SAMPLE START 0          STARTING ADDR
           000000  05 D0                 GO     BALR  13,0       SET UP BASE REGISTER
                                  000002        USING *,13
           000002  D2 3F D 09E D 05E            MVC   OUT(64),IN MOVE DATA TO OUT
           000008  41 60 D 09E                  LA    6,OUT      POINT TO TABLE TOP
           00000C  41 70 0 00F                  LA    7,15       SET FOR 15 PASSES
           000010  41 40 0 038           SET    LA    4,56       SET INDEX REGISTER
           000014  58 20 6 000                  L     2,0(0,6)   LOAD FROM TABLE TOP
           000018  58 34 6 004           LOAD   L     3,4(4,6)   LOAD FROM TABLE
           00001C  15 23                        CLR   2,3        COMPARE VALUES
           00001E  47 C0 D 02A                  BC    12,SUB     TOP = OR LESS BRANCH
           000022  17 23                        XR    2,3        EXCHANGE VALUES
           000024  17 32                        XR    3,2        EXCHANGE VALUES
           000026  17 23                        XR    2,3        EXCHANGE VALUES
           000028  50 34 6 004                  ST    3,4(4,6)   STORE LARGER BACK
           00002C  5B 40 D 05A           SUB    S     4,CON4     REDUCE INDEX
           000030  47 A0 D 016                  BC    10,LOAD    LOOP IF MORE TO SORT
           000034  50 20 6 000                  ST    2,0(0,6)   STORE IN TABLE TOP
           000038  5B 70 D 056                  S     7,CON1     REDUCE PASS COUNTER
           00003C  47 70 D 042                  BC    7,LOOP
           000040  82 00 D 0DE                  LPSW  ENDRUN     END OF RUN
           000044  41 66 0 004           LOOP   LA    6,4(6)
           000048  48 20 D 010                  LH    2,SET+2    MODIFY
           00004C  5B 20 D 05A                  S     2,CON4      INDEX
           000050  40 20 D 010                  STH   2,SET+2      INSTRUCTION
           000054  47 F0 D 00E                  BC    15,SET     RETURN
           000058  00000001              CON1   DC    F'1'       CONSTANT OF 1
           00005C  00000004              CON4   DC    F'4'       CONSTANT OF 4
           000060  00000005              IN     DC    X'00000005'
           000064  0000000A                     DC    X'0000000A'
           000068  00000001                     DC    X'00000001'
           00006C  00000007                     DC    X'00000007'
           000070  00000003                     DC    X'00000003'
           000074  0000000C                     DC    X'0000000C'
           000078  0000000F                     DC    X'0000000F'
           00007C  00000009                     DC    X'00000009'
           000080  0000000B                     DC    X'0000000B'
           000084  00000004                     DC    X'00000004'
           000088  00000000                     DC    X'00000000'
           00008C  0000000E                     DC    X'0000000E'
           000090  00000006                     DC    X'00000006'
           000094  0000000D                     DC    X'0000000D'
           000098  00000002                     DC    X'00000002'
           00009C  00000008                     DC    X'00000008'
           0000A0                        OUT    DS    16F        OUTPUT AND WORK AREA
                                                CNOP  0,8  ENSURE BOUNDARY ALIGNMENT
           0000E0  0002000000000000      ENDRUN DC    X'0002000000000000'    PSW
           000000                               END   GO
```

Features not shown below are common to all assemblers. In the chart:

Dash = Not allowed.
X = as defined in Operating System/360 Assembler Language Manual.

| Feature | Basic Programming Support/360: Basic Assembler | 7090/7094 Support Package Assembler | Other System/360 Assemblers[1] | OS/360 Assembler |
|---|---|---|---|---|
| No. of Continuation Cards/Statement (exclusive of macro-instructions) | 0 | 0 | 1 | 2 |
| Input Character Code | EBCDIC | BCD or EBCDIC | EBCDIC | EBCDIC |
| ELEMENTS: | | | | |
| Maximum Characters per symbol | 6 | 6 | 8 | 8 |
| Character self-defining terms | 1 Char. only | X | X | X |
| Binary self-defining terms | -- | -- | X | X |
| Length attribute reference | -- | -- | X | X |
| Literals | -- | -- | X | X |
| Extended mnemonics | -- | X | X | X |
| Maximum Location Counter value | $2^{16}-1$ | $2^{24}-1$ | $2^{24}-1$ | $2^{24}-1$ |
| Multiple Control Sections per assembly | -- | -- | X | X |
| EXPRESSIONS: | | | | |
| Operators | +-* | +-*/ | +-*/ | +-*/ |
| Number of terms | 3 | 16 | 3 | 16 |
| Number of parentheses | -- | -- | 1 Level | 5 Levels |
| Complex relocatability | -- | -- | X | X |
| ASSEMBLER INSTRUCTIONS: | | | | |
| DC and DS | | | | |
| Expressions allowed as modifiers | -- | -- | -- | X |
| Multiple operands | -- | -- | -- | X |
| Multiple constants in an operand | -- | -- | Except Address Consts. | X |

(Continued)

Appendix D:  Assembler Languages--Features Comparison Chart  (Continued)

| Feature | Basic Programming Support/360: Basic Assembler | 7090/7094 Support Package Assembler | Other System/360 Assemblers[1] | OS/360 Assembler |
|---|---|---|---|---|
| Bit length specifications | -- | -- | -- | X |
| Scale modifier | -- | -- | X | X |
| Exponent Modifier | -- | -- | X | X |
| DC types | Except B, P, Z, V, Y, S | Except B, Y, V | X | X |
| DC duplication factor | Except A | Except A, S | Except S | X |
| DC duplication factor of zero | -- | -- | Except S | X |
| DC length modifier | Except H, E, D | Except S | X | X |
| DS types | Only C, H, F, D | Only C, H, F, D | X | X |
| DS length modifier | Only C | Only C | X | X |
| DS maximum length modifier | 256 | 256 | 256 | 65,535 |
| DS constant subfield permitted | -- | -- | X | X |
| COPY | -- | -- | -- | X |
| CSECT | -- | -- | X | X |
| DSECT | -- | -- | X | X |
| ISEQ | -- | -- | X | X |
| LTORG | -- | -- | X | X |
| PRINT | -- | -- | X | X |
| TITLE | -- | X | X | X |
| COM | -- | -- | -- | X |
| ICTL | 1 oprnd 1 or 25 only | 1 oprnd | X | X |
| USING | 2 oprnds oprnd 1 reloc only | 2 oprnds oprnd 1 reloc only | 6 oprnds | X |
| DROP | 1 oprnd only | 1 oprnd only | 5 oprnds | X |

(Continued)

Appendix D: Assembler Languages--Features Comparison Chart (Continued)

| Feature | Basic Programming Support/360: Basic Assembler | 7090/7094 Support Package Assembler | Other System/360 Assemblers[1] | OS/360 Assembler |
|---|---|---|---|---|
| CCW | oprnd 2 reloc only | oprnd 2 reloc only | X | X |
| ORG | no blank oprnd | no blank oprnd | X | X |
| ENTRY | 1 oprnd only | 1 oprnd only | 1 oprnd only | X |
| EXTRN | max 14 1 oprnd only | 1 oprnd only | 1 oprnd only | X |
| CNOP | 2 dec digits | 2 dec digits | 2 dec digits | X |
| PUNCH | -- | -- | -- | X |
| REPRO | -- | -- | X | X |
| Macro Instructions | -- | -- | X | X |

## APPENDIX E. HEXADECIMAL TO MNEMONIC OPERATION CODE TABLE

The table in this appendix provides for easy conversion from the hexadecimal equivalent of the actual machine operation codes to their associated assembler mnemonic operation codes.

Second Hexadecimal Digit

First Hexadecimal Digit

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | SPM | BALR | BCTR | BCR | SSK | ISK | SVC | | | | | | |
| 1 | LPR | LNR | LTR | LCR | NR | CLR | OR | XR | LR | CR | AR | SR | MR | DR | ALR | SLR | RR |
| 2 | LPDR | LNDR | LTDR | LCDR | HDR | | | | LDR | CDR | ADR | SDR | MDR | DDR | AWR | SWR | |
| 3 | LPER | LNER | LTER | LCER | HER | | | | LER | CER | AER | SER | MER | DER | AUR | SUR | |
| 4 | STH | LA | STC | IC | EX | BAL | BCT | BC | LH | CH | AH | SH | MH | | CVD | CVB | |
| 5 | ST | | | | N | CL | O | X | L | C | A | S | M | D | AL | SL | RX |
| 6 | STD | | | | | | | | LD | CD | AD | SD | MD | DD | AW | SW | |
| 7 | STE | | | | | | | | LE | CE | AE | SE | ME | DE | AU | SU | |
| 8 | SSM | | LPSW | | WRD | RDD | BXH | BXLE | SRL | SLL | SRA | SLA | SRDL | SLDL | SRDA | SLDA | |
| 9 | STM | TM | MVI | TS | NI | CLI | OI | XI | LM | | | | SIO | TIO | HIO | TCH | RS or SI |
| A | | | | | | | | | | | | | | | | | |
| B | | | | | | | | | | | | | | | | | |
| C | | | | | | | | | | | | | | | | | |
| D | | MVN | MVC | MVZ | NC | CLC | OC | XC | | | | | TR | TRT | ED | EDMK | SS |
| E | | | | | | | | | | | | | | | | | |
| F | | MVO | PACK | UNPK | | | | | ZAP | CP | AP | SP | MP | DP | | | |

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