Z-80 CROSS ASSEMBLER

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2500 A.D. Z80 CROSS ASSEMBLER - VERSION 4.00

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INTRODUCTION

This section is an overview of the 2500 A.D. Z80 Cross Assembler. The intent of this manual is to describe the operation of the Assembler. It is assumed that the user is familiar with the Z80 operation and instruction set.

The 2500 A.D. Z80 Assembler enables the user to write programs which can then be assembled into relocatable object code and linked to the desired execution address using the 2500 A.D. Linker.

The Assembler will process any size file, as long as enough memory is available. All the buffers used by the Assembler are requested and expanded as needed, with the exception of the Source Code Input Buffer, the Object Code Output Buffer and the Listing Buffer.

The Conditional Assembly section enables the user to direct the Assembler to process different sections of the source file depending on the outcome of assembly time operations. Conditionals may be nested to 248 levels, and the Assembler aids the programmer in detecting conditional nesting errors by not only checking for unbalanced conditional levels, but also by displaying the current active conditional level in the object code field of the listing.

The Assembly Time Calculation section will perform calculations with up to 16 pending operands, using 80 bit arithmetic. The algebraic hierarchy may be changed through the use of parenthesis.

The Listing Control section provides for listing all or just sections of the program, with convenient Assembler error detection overrides, along with Assembly Run Time Commands that may be used to dynamically change the listing mode.

The 2500 A.D. Linker allows files to either be linked together or just used for external reference resolution. As with the Assembler, all buffers used by the Linker are requested as needed. The Linker is capable of outputting several different formats. The format may be changed by using an Assembler Directive or selecting the desired output from the Linker option field. Programs may specify up to 256 user defined section names, and the Linker is capable of processing up to 256 identical section names. See the Linker Description section of this manual for a complete description.

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Z80 CROSS ASSEMBLER OPERATING INSTRUCTIONS

PROMPT MODE

To run the Assembler type : x80

The Assembler responds with :

Listing Destination ? (N, T, P, D, E, L, <CR = N>) :

with the abbreviations as follows:

N = None
T = Terminal
P = Printer (Single User Systems Only)
D = Disk
E = Error Only
L = List On/Off

After this the Assembler prompts the operator for the source code filename as shown below.

Input Filename :

When entering your source filename you may specify an extension or the assembler will look for an extension of 'asm'. Once you have specified your input filename the assembler will prompt you for the output filename.

Output Filename:

If the user responds to the input filename prompt with just a carriage return, the output file will receive the same filename as the input file, with an extension of 'obj'. If the response is a filename with no extension, the output file will be under that filename with an extension of 'obj'.

NOTE for VMS users:

Assuming the assembler is located in a directory named $disk1:[x80], the following command must be entered for the examples shown above to work:

```
x80 == "$disk1:[x80]x80.exe"
```

COMMAND LINE MODE

The Assembler may also be invoked using a command line. In this case, the input filename is specified first, then the output filename, and then a list of options. Both the output filename and the listing destination are optional. The general form of the command, with optional fields shown in brackets, is as follows:

```
x80  [-q] input_filename [output_filename] [-t, -p, -d, -px, -dx]
```

The -q optional stands for Quiet mode. If this option is selected, the only screen messages output from the Assembler will be error messages and the line on which they occur. This option must be placed before the input filename.

Below are some examples of legal command lines.

Input Filename Only

```
x80  input_filename
```

This command causes the Assembler to process the source file 'input_filename'. If no extension is specified, it is assumed to be '.asm'. Since no options are specified, they will default to Error Only listing with the terminal as the destination. The output filename will be the same as the input filename but with an extension of '.obj'.

Input Filename and Output Filename

```
x80  input_filename  output_filename
```

This command is identical to the previous one except that the Assembler will name the object file 'output_filename'.

Listing to Terminal

```
x80  input_filename   output_filename   -t
```

This command will assemble the input file 'input_filename' and send the listing to the terminal. The optional output filename specification causes the assembler to generate an object file named 'output_filename'.

Listing to Printer

```
x80  input_filename   -p
```

This command will assemble the input file 'input_filename' and send the listing to the printer. The optional output filename specification causes the assembler to generate an object file named 'output_filename'.

Listing to Printer with Cross Reference

```
x80  input_filename   output_filename   -px
```

This command will assemble the input file 'input_filename' and send the listing and cross reference table to the printer. The optional output filename specification causes the assembler to generate an object file named 'output_filename'. The printer option is only available on single user systems.

Listing to Disk

```
x80  input_filename   output_filename   -d
```

This command will assemble the input file 'input_filename' and send the listing to the disk. The disk listing file will have the same name as the input file, but will have an extension of '1st'.The optional output filename specification causes the assembler to generate an object file named 'output_filename'.

Listing to Another Drive or Directory

MSDOS

```
x80    input_filename      output_filename -d,a:
x80    input_filename      output_filename -d, \new\
```

UNIX

```
x80    input_filename      output_filename -d, /new/
```

VMS

```
x80    input_filename      output_filename  -d,$disk1:[a]
x80    input_filename      output_filename  -d, [new]
```

This enables the user to send the listing to a different drive or directory other than the current one.

Error Only Listing to the Terminal

```
x80  input_filename   output_filename   -et
```

This command will assemble the input file 'input_filename' and send error messages to the terminal. The optional output filename specification causes the assembler to generate an object file named 'output_filename'.

Listing to Disk with Cross Reference

```
x80  input_filename    output_filename   -dx
```

This command will assemble the input file 'input_filename' and send the listing and cross reference table to the disk. The disk listing file will have the same name as the output file, but will have an extension of 'lst'. The optional output filename specification causes the assembler to generate an object file named 'output_filename'.

Error Only Listing to the Printer

```
x80  input_filename   output_filename   -ep
```

This command will assemble the input file 'input_filename' and send error messages to the printer. The optional output filename specification causes the assembler to generate an object file named 'output_filename'. The printer option is available only on single user systems.

Error Only Listing to the Disk

```
x80  input_filename   output_filename   -ed
```

This command will assemble the input file 'input_filename' and send error messages to the disk. The disk listing file will have the same name as the input file, but will have an extension of 'lst'. The optional output filename specification causes the assembler to generate an object file named 'output_filename'.

List On/Off to Terminal

```
x80  input_filename   -lt
```

This command will assemble the input file 'input_filename' and send LIST ON/OFF blocks to the terminal.

List On/Off to Printer

```
x80  input_filename   -lp
```

This command will assemble the input file 'input_filename' and send the LIST ON/OFF blocks to the printer. This option is only available on single user systems.

List On/Off to Disk

```
x80  input_filename  -ld
```

This command will assemble the input file 'input_filename' and send the LIST ON/OFF blocks to the disk. The disk listing file will have the same name as the input file, but with an extension of 'lst'.

NOTE for VMS users:

Assuming the assembler is located in a directory named $disk1:[x80], the following command must be entered for the examples shown above to work:

```
x80 == "$disk1:[x80]x80.exe"
```

SYSTEM DEFAULTS

The following default filename extensions will be used by the 2500 A.D. programs if no extension is specified by the user.

```
asm  -  Input to the Assembler
obj  -  Output from the Assembler
lst  -  Listing file

obj  -  Input to the Linker

tsk  -  Executable Object Code
hex  -  Intel Hex and Extended Intel Hex
tek  -  Tektronix Hex
s19  -  Motorola S19
s28  -  Motorola S28
s37  -  Motorola S37
```

Note that because of the additional information included in the Assembler output file, the Linker must always be run, even if the program is assembled at the desired run address and there are no external references. This is so that all the additional information can be removed and a file with the desired output format can be generated.

ASSEMBLY ERROR PROCESSING

When an assembly error is encountered, the action taken by the Assembler depends on the listing mode it is currently operating under.

If the No List option was specified, the statement causing the error and the error message will be output to the terminal, the display will be turned on and the Assembler will halt just as if the user had typed ^S. The reason for this is to give the user a chance to see exactly where the error is. This will occur on pass 1 as well as pass 2. Note that some errors are not detectable on pass 1, such as undefined symbols. After the error has been displayed, the output can be turned off using ^N.

If the listing is being sent to the printer or the disk, then errors encountered on pass 1 are sent to the terminal but not the printer or disk, and the Assembler does not halt. On pass 2, the error is output to the printer or disk as well as the terminal and the assembly continues.

If the listing is being sent to the printer or disk under assembler directive control, any errors encountered during pass 1 are output to the terminal but not the printer or disk, and the assembly continues. Errors detected during pass 2 are output to the printer or disk and the terminal, even if the error is not inside a block that was specified to be listed.

ASSEMBLER RUN TIME COMMANDS

The following commands are active during the assembly process. These commands are active during pass 1 as well as pass 2, and override the listing mode specified when the Assembler was first activated.

UNIX ASSEMBLER RUN TIME COMMANDS

```
Ctrl S  -  Stop terminal output
Ctrl Q  -  Start terminal output
Del  C  -  Terminate the assembly
Del  T  -  Display the output at the terminal
Del  D  -  Send the output to the disk
Del  M  -  Multiple output (Terminal & Disk)
Del  N  -  No output
```

MSDOS ASSEMBLER RUN TIME COMMANDS

```
Ctrl S  -  Stop terminal output
Ctrl Q  -  Start terminal output
Esc  C  -  Terminate the assembly
Esc  T  -  Display the output at the terminal
Esc  P  -  Display the output at the printer
Esc  D  -  Send the output to the disk
Esc  M  -  Multiple output (Terminal & Disk)
Esc  N  -  No output
```

VMS ASSEMBLER RUN TIME COMMANDS

The following commands are active during the assembly process. These commands are active during pass 1 as well as pass 2, and override the listing mode specified when the Assembler was first activated.

```
Ctrl S      -  Stop terminal output
Ctrl Q      -  Start terminal output
Ctrl C, C   -  Terminate the assembly
Ctrl C, T   -  Display the output at the terminal
Ctrl C, D   -  Send the output to the disk
Ctrl C, M   -  Multiple output (Terminal & Disk)
Ctrl C, N   -  No output
```

ASSEMBLY LANGUAGE SYNTAX

This section describes the syntax used by the 2500 A.D. Cross Assembler.

LABELS

Non-Local labels may be any number of characters long, but only 32 characters are significant. Labels may start in any column if the name is terminated by a colon. If no colon is used, the label must start in column 1. All labels must start with an alpha character. Upper and lower case characters are considered to be different.

LOCAL LABELS

A Local Label is a label which can be used like any "non local" label. The difference is that the definition of a Local Label is only valid between "non local" labels. The adjective "local" refers to the area between labels which retain their definition through the entire program. When a program passes from one local area to the next, local label names can be reused. This feature is useful for labels referenced only within a "local area", as defined above, and original label names are not necessary.

The assembler identifies a local label by the ($) prefix or suffix. This identifier can be changed with the LLCHAR directive. Please see the section entitled 'Directive Definition Control' for more information on this directive. Following are some examples of the use of Local Labels.

```
LABEL1                                  OR      LABEL1:
        $1:     NOP                                     1$:     NOP
        $2:     JMP     $1                              2$:     JMP     1$
                JMP     $2                                      JMP     2$

LABEL2:
        $1:     NOP                             LABEL2: 1$      NOP
        $2:     JMP     $1                              2$      JMP     1$
                JMP     $2                                      JMP     2$

LABEL3:                                         LABEL3:
        $1:     NOP                                     1$      NOP
        $2:     JMP     $1                              2$      JMP     1$
                JMP     $2                                      JMP     2$
```

In this example, there are three "non-local" labels, LABEL1, LABEL2, and LABEL3. Local Labels $1 and $2 or 1$ and 2$ have different definitions when referenced in different local areas. Note that $1 is not considered to be the same as 1$. Any character may be used in a Local Label. Local Labels may be up to 32 characters long. Operators such as '+' should never be used in Local Labels. Local labels will not be terminated if the directives VAR, DEFL, SECTION, ENDS and $ are used.

NUMBER BASE DESIGNATIONS

Number bases are specified by the following:

Binary	-	B
Octal	-	O or Q
Decimal	-	D or no base designation
Hex	-	H or preceeding % sign
Ascii	-	Single or double quotes - "X" or 'X'

The two character sequences between single or double quotes shown below are predefined. However, the TWOCHAR ON directive must be used to enable these.

"CR" or 'CR'	-	Carriage return
"LF" or 'LF'	-	Line feed
"SP" or 'SP'	-	Space
"HT" or 'HT'	-	Horizontal tab
"NL" or 'NL'	-	Null

PROGRAM COMMENTS

Comment lines must start with a semi-colon or asterisk in column 1, unless the .'COMMENT' directive is used. Comments after an instruction do not need a semi-colon if at least 1 space or tab preceeds the start of the comment if the assembler is running in Spaces Off mode. If the assembler is running in Spaces On mode, all comments after an instruction must be preceeded by a semi-colon. See the SPACES directive for more information and for the default mode.

PROGRAM COUNTER ($ or *)

The special character '$' or '*' may be used in an expression to specify the program counter. The value assigned to the dollar sign or the asterisk is the program counter value at the start of the instruction.

HIGH BYTE

To load the high byte of a 16 bit value the unary greater than sign, >, should be used. This allows bits 8 through 15 to be used as a byte value which is relocatable.

LOW BYTE

To load the low byte of a 16 bit value the unary less than sign, <, should be used. This allows bits 0 through 7 to be used as a byte value which is relocatable.

UPPER / LOWER CASE

Upper and lower case labels are recognized as different labels. The labels used for section names and macro names are also different if the label is in lower case rather than upper case.

ADDRESSING MODES

IMMEDIATE

The data is contained in the instruction.

Examples:

```
LD      HL,1234H        ; Ld HL with the HEX # 1234
LD      HL,DATA         ; Ld HL with the value associated
                          with the Label 'DATA'
```

REGISTER

The data is contained in a CPU register.

Examples:

```
LD      A,B             ; Ld the contents in register B into
                          register A
SUB     D               ; Subtract the contents of register
                          D from register A
```

REGISTER INDIRECT

The operand address is pointed to by a register.

Examples:

```
LD      A,(HL)          ; Ld A with the contents of the
                          location pointed to by HL.
LD      (HL),B          ; Store the contents of B in the
                          memory address pointed to by HL
```

DIRECT ADDRESS

The address of the operand is contained in the instruction.

Examples:

```
LD      HL,(1234H)      ; Ld HL with the contents of memory
                          location 1234 HEX
LD      (ADDRESS),HL    ; Store HL in the memory location
                          'ADDRESS'
LD      (ABCDH),HL      ; Store HL in the memory location
                          ABCD hexadecimal
```

INDEXED

The operand address is the sum of the 8 bit offset in the instruction and the contents of either IX or IY.

Examples:

```
LD      A,(IX+4)        ; Ld A with contents of the memory
                          location pointed to by adding 4 to
                          the contents of register IX
LD      (IX+DATA8),B    ; Store B in the memory location
                          obtained by adding the value asso-
                          ciated with 'DATA8' to the con-
                          tents of register IX
```

RELATIVE

The operand address is relative to the current instruction. If the address is given using a numerical value, the calculation is from the start of the next instruction.

Examples:

```
DJNZ    LOOP            ; The Assembler calculates the ad-
                          dress by subtracting the address
                          of the label 'LOOP' from the ad-
                          dress of the next instruction
JR      4               ; The destination is 4 BYTES past
                          the start of the next instruction
```

ASSEMBLER DIRECTIVES

This section describes the Assembler Directives. Directives may be preceeded by a decimal point if desired to help differentiate them from program instructions.

STORAGE CONTROL

```
        ORG             VALUE
        ORIGIN
```

Sets the program assembly address. If this directive is not executed, the assembly address defaults to 0000.

```
        END             VALUE
```

This directive defines the end of a program or an included file. The expression following an END statement is optional and if it exists, specifies the program starting address. This address is encoded in the output file if a program starting address record type exists in the output format definition.

```
LABEL:  DB              VALUE
        FCB
        DEFB
        BYTE
        STRING
```

The Assembler will store the value of the expression in consecutive memory locations. The BYTE expression may be any mixture of operand types with each one spearated by a comma. Ascii character strings must be bracketed by apostrophes. If the string contains an apostrophe, this can be specified with two apostrophes in a row. If no expression is given, one byte is reserved and zeroed. A label is optional. Following are some examples of the use of the BYTE directive.

```
        .BYTE                   ;Reserves 1 zeroed byte.
        .BYTE   10              ;Reserves 1 byte = 10 decimal.
        .BYTE   1,2,3           ;Reserves 3 bytes, = to 1,2 &
                                 3 in that order.
        .BYTE   SYMBOL-10       ;Searches the symbol table for
                                 SYMBOL, subtracts 10 decimal
                                 from it's value, and stores
                                 the result.
        .BYTE   'Hello'         ;Stores the Ascii equivalent
                                 of the string Hello in con-
                                 secutive memory locations.
        .BYTE   'Hello', 0DH    ;Same as above example, with
                                 the addition of a carriage
                                 return at the end. Spaces are
                                 ignored before operands, but
                                 the comma is required.
        .BYTE   '2500 A.D.''s'  ;Embedded apostrophe.
```

```
LABEL:      DW          VALUE
            FDB
            DEFW
            WORD
```

This directive will store the value of the expression in a 16 bit storage location. Multiple words may be initialized by separating each expression with a comma. If no expression is given, 1 word is reserved and zeroed. A label is optional.

```
LABEL:      LONG        VALUE
            LONGW
            LWORD
```

This directive will store the value of the expression in a 32 bit storage location. Multiple long words may be initialized by separating each expression with a comma. If no expression is given, 1 long word is reserved and zeroed. A label is optional.

```
LABEL:      ASCII       STRING
```

Stores STRING in memory up to but not including either a carriage return or a broken bar character ("|", Hex 7C). A label is optional. Following are some examples of ASCII.

```
            ASCII   Hello         ;Stores the Ascii representa-
                                   tion of Hello in consecutive
                                   memory locations. Incidental-
                                   ly, this comment would be
                                   stored also.
            ASCII   Hello|        ;Now the comment wouldn't be
                                   stored.  The next example
                                   shows termination with just a
                                   carriage return.
            ASCII   Hello
```

```
LABEL:      FCC         STRING
```

Stores STRING in memory until a character is reached that matches the first character. The first character and the second matching character are not stored. A label is optional. Typical usage is as follows:

```
            FCC     /This is a test string/
```

LABEL: BLKB SIZE, VALUE

Reserves the number of bytes specified by SIZE. If the value field is present, that value is stored in each byte. Otherwise, the reserved bytes are zeroed. A label is optional.

```
BLKB    20          ;Reserves 20 zeroed bytes
BLKB    20,0        ;Reserves 20 zeroed bytes
BLKB    20,FFH      ;Reserves 20 bytes and stores
                     FF Hex in each one
```

LABEL: DS SIZE
RMB
DEFS

This directive will reserve the number of bytes specified by SIZE. No value is stored in the reserved area. This directive differs from the BLKB directive in that if the storage locations are at the end of a program section, the output from the Linker is executable, and the Linker is not required to stack another module on top of this section, the reserved bytes are not included in the output file.

LABEL: BLKW SIZE, VALUE

Reserves the number of 16 bit words specified by SIZE. If the value field is present, that value is stored in each word. Otherwise, the reserved words are zeroed. A label is optional.

```
BLKW    20          ;Reserves 20 zeroed words
BLKW    20,0        ;Reserves 20 zeroed words
BLKW    20,FFFFH    ;Reserves 20 words and stores
                     FFFF Hex in each one
```

LABEL: BLKL SIZE, VALUE

Reserves the number of 32 bit long words specified by SIZE. If the value field is present, that value is stored in each long word. Otherwise, the reserved long words are zeroed. A label is optional.

```
BLKL    20          ;Reserves 20 zeroed long words
BLKL    20,0        ;Reserves 20 zeroed long words
BLKL    20,FFFFH    ;Reserves 20 long words and
                     stores FFFF Hex in each one
```

LABEL: FLOAT VALUE

Converts the value specified into single precision floating point format. The value is not rounded but is truncated if the mantissa is larger than 24 bits. The directive does not allow scientific notation.

```
FLOAT   178.125
FLOAT   100,.125,-178.125
```

LABEL: DOUBLE VALUE

Converts the value specified into double precision floating point format. The value is not rounded but is truncated if the mantissa is larger than 52 bits. The directive does not allow scientific notation.

```
DOUBLE  178.125
DOUBLE  100,.125,-178.125
```

DEFINITION CONTROL

LABEL: EQU VALUE
EQUAL

Equates LABEL to VALUE. VALUE amy be another symbol or any legal arithmetic expression.

LABEL: VAR VALUE
DEFL

Equates LABEL to VALUE, but may be changed as often as desired throughout the program. A label defined as a variable should not be redefined by an 'EQUAL' directive.

LLCHAR CHARACTER

The default character for designating a Local Label is the ($). This directive changes the character which identifies a particular symbol as a Local Label. Symbols that designate number bases should be avoided, unless they are used on the trailing end of the label.

LABEL: MACRO ARGS

Specifies the start of a Macro Definition.

ENDM
MACEND

Specifies the end of a Macro Definition.

MACEXIT

This directive causes the immediate exit from a macro. The difference between MACEXIT and MACEND is that during the macro definition process, MACEXIT does not terminate the macro, and if MACEXIT is in the path of a false conditional assembly block, it is not executed. All conditional assembly values are restored to the same state as when the macro was invoked.

MACDELIM CHARACTER

This directive is used to pass an argument containing a comma into a macro. The default mode is for commas to always be argument separators. The allowed characters are '{', '(' and '['. All characters between matching delimiter pairs will be passed through as one argument. Please refer to the Macro Examples section of this manual for some examples of the use of this directive.

```
        XDEF        LABEL
        GLOBAL
        PUBLIC
```

Specifies the label as a global label that may be referenced by other programs. Multiple labels may be specified as long as each one is separated by a comma. Below are some examples of the correct use of GLOBAL.

```
GLOBAL    SYM1            ;Declares the label SYM1 to be
                           accessible to other programs.
                           The Linker will resolve the
                           external references.
GLOBAL    SYM1, SYM2      ;Multiple declarations on the
                           same line are legal if sepa-
                           rated by a comma. The spaces
                           are ignored.
```

```
        XREF        LABEL
        EXTERN
        EXTERNAL
```

Specifies the label as being defined in another program. Multiple labels may be specified as long as each one is separated by a comma.

```
LABEL:      ASK         PROMPT
```

Outputs 'PROMPT' to the terminal and waits for a 1 character response, from which 30 hex is subtracted. The purpose of this is usually to introduce a 0/1 flag into the program. 'LABEL' is set equal to the result. A carriage return terminates 'PROMPT'. On pass 2, the line is output along with the response.

The following is an example of 'ASK' :

```
DISK_SIZE:  ASK  ASSEMBLE FOR  8" (=1) OR 5 1/4" (=0) DRIVES ? :
```

ASSEMBLY MODE

LABEL: SECTION

This directive allows user defined section names to be generated. The Assembler has 2 predefined sections, CODE and DATA. The total number of section names allowed per file is 256. Each name may be up to 32 characters long. Lower and upper case are considered to be different. After the section has been defined, the program may switch back and forth simply by using the name as a mnemonic. The default section is CODE. Sections may be nested. As with all directives, a section name may be preceeded by a decimal point. See the Linker Operating Instructions section of this manual for information on how the Linker handles section names. Below are some examples of defining section names and switching between different sections.

```
            NOP                 ;This instruction goes into
                                 the CODE section by default
            .DATA               ;Switch to the predefined DATA
                                 section
            .BYTE               ;This byte goes into the DATA
                                 section
SECTION1:   .SECTION            ;Define a new section. The
                                 definition makes this section
                                 active automatically
            NOP                 ;This instruction goes into
                                 the SECTION1 section
            .CODE               ;Switch back to the section
                                 named CODE
            NOP                 ;This instruction goes into
                                 the CODE section
            .SECTION1           ;Switch to the user defined
                                 section SECTION1
            NOP                 ;This instruction goes into
                                 the SECTION1 section
            .BYTE               ;Any section may contain code
                                 or data or both.
```

ENDS

This directive is used in conjunction with the SECTION directive. ENDS enables the termination of nested sections in a file.

RADIX VALUE

2 or B = Binary
8 or O or Q = Octal
10 or D = Decimal
16 or H = Hexadecimal

No expression = return to default mode which is base 10, and assume all others will be designated with B, Q, D or H after the constant. Note that when base 16 is specified there is no way to define a decimal or binary number, since both D and B are legal hexadecimal numbers.

INCLUDE filename

Directs the Assembler to include the named file in the assembly. Filenames may include pathnames. Filename extensions must be completely specified. Includes may not be nested.

SPACES ON

This directive enables spaces in between operands. When spaces are enabled, comments must begin with a semi-colon. This is the default mode.

SPACES OFF

This directive disables spaces in between operands. When spaces are disabled, comments do not need to start with a semi-colon. The default mode is SPACES ON.

TWOCHAR ON

This directive enables the ascii two character abbreviations shown below. The default mode is TWOCHAR OFF.

"CR" or 'CR' - Carriage return
"LF" or 'LF' - Line feed
"SP" or 'SP' - Space
"HT" or 'HT' - Horizontal tab
"NL" or 'NL' - Null

TWOCHAR OFF

This directive disables the ascii two character abbreviations shown in the previous directive. This is the default mode.

COMMENT CHARACTER

This directive allows the user to write blocks of comments at a time. A comment block is executed as follows:

```
COMMENT X
```

Where 'X' can be any character. The Assembler will treat everything from the first 'X' to the second 'X' as a comment block. Since the terminating character is not scanned for until the next line the comment field must be two lines long.

CONDITIONAL ASSEMBLY

```
IFZ             VALUE
```

The Assembler will assemble the statements following the directive up to an ELSE or ENDIF directive if the VALUE is equal to zero. Conditional statements may be nested up to 248 levels. VALUE can be an arithmetic expression, another symbol or a string.

```
IF              VALUE
IFNZ            VALUE
COND            VALUE
```

Assemble the statements following the directive up to an ELSE or ENDIF directive if the value of VALUE is not equal to zero. Conditional statements may be nested up to 248 levels.

```
IFTRUE          VALUE
IFNFALSE        VALUE
```

This directive is actually the same as IFNZ, but is more logical when using assembly time comparisons. If the specified condition is true, then the following statements are assembled up to an ELSE or ENDIF directive. If the condition is not true, the statements up to an ELSE or ENDIF directive are not assembled.

```
IFNTRUE         VALUE
IFFALSE         VALUE
```

This directive is the same as IFZ, and is the complement to IFTRUE. If the specified condition is false, then the following statements are assembled up to an ELSE or ENDIF directive. If the condition is true, then the statements up to an ELSE or ENDIF directive are not assembled.

```
IFDEF           LABEL
```

This directive will activate a symbol table search, and if LABEL is found, then the statements following this one up to an ELSE or ENDIF directive will be assembled. If LABEL is not found, then the statements following this statement up to an ELSE or ENDIF directive will not be assembled.

IFNDEF LABEL

This directive is the complement of IFDEF. The symbol table is searched and if LABEL is not found, the statements following this one up to an ELSE or ENDIF directive are assembled. If LABEL is found, then the statements following this one up to an ELSE or ENDIF directive are not assembled.

IFSAME STRING1,STRING2
IFNDIFF

This directive compares STRING1 to STRING2, and conditionally assembles the statements following this statement depending on the result of the comparison. If the two strings are identical then the statements up to an ELSE or ENDIF directive are assembled. If the strings are not identical, then the statements up to an ELSE or ENDIF directive are not assembled. The strings may be one of two different types, namely with spaces or without spaces. However, both strings being compared must be of the same type. If the strings contain spaces, then the beginning and end of each string must be denoted with an apostrophe, with embedded apostrophes denoted by the use of two apostrophes. If the strings do not contain spaces, then the apostrophes are not required. This mode is very useful when comparing macro parameter arguments. In both cases, the strings must be separated with a comma. Below are some examples of the use of IFSAME.

```
IFSAME    'test string','test string'
IFSAME    '2500 A.D.''s','2500 A.D.''s'
IFSAME    X,Y
```

In the first example above, the strings contain spaces and therefore must be bracketed by apostrophes. The second example shows embedded apostrophes, which are represented by using two apostrophes. In the third example, a macro might be testing for a certain register, and since the strings do not contain spaces, they do not need to be enclosed in apostrophes.

IFNSAME STRING1,STRING2
IFDIFF

This directive is the complement to IFSAME. If the two strings are not identical, the statements after this statement are assembled up to an ELSE or ENDIF directive. If the two strings are identical the statements up to an ELSE or ENDIF directive are not assembled. The syntax rules governing the form of the strings are the same as for IFSAME. See IFSAME for examples of the use of this directive.

IFEXT LABEL

This directive will cause the Assembler to search the symbol table for the label, and assemble the statements following this statement up to an ELSE or ENDIF if the label has been declared external. An error message is generated if the label is not found.

IFNEXT LABEL

This directive will cause the Assembler to search the symbol table for the label, and assemble the statements following this statement up to an ELSE or ENDIF if the label has not been declared external. An error messasge is generated if the label is not found.

IFABS LABEL
IFNREL

This directive will cause the Assembler to search the symbol table for the label, and assemble the statements following this statement up to an ELSE or ENDIF if the label is absolute (i.e. not relocatable). External labels are considered to be relocatable. An error message is generated if the label is not found.

IFREL LABEL
IFNABS

This directive will cause the Assembler to search the symbol table for the label, and assemble the statements following this statement up to an ELSE or ENDIF if the label is relocatable. External labels are considered to be relocatable. An error message is output it the label is not found

IFMA EXP

This directive is intended to be used inside a macro, and will scan the macro call line for the existence of the argument number specified by the value of EXP. If the argument exists, the statements following this one up to an ELSE or ENDIF will be assembled. If the argument does not exist, the statements following this one up to an ELSE or ENDIF will not be assembled. No arguments can be detected by having EXP = 0. In this case, if no arguments are present in the macro call line, the following statements are assembled, and if arguments are present in the macro call line, the following statements are not assembled. See the Macro section of this manual for examples of the use of this directive.

IFNMA EXP

This directive is the complement to IFMA, and checks the macro call line to see if the argument number given by the value of EXP exists. If the argument is not present, the statements following this one up to an ELSE or ENDIF are assembled. If the argument is present, the statements following this up to an ELSE or ENDIF are not assembled. The existence of any arguments at all can be detected by having EXP = 0. In this case, if there is at least one argument in the macro call line, the following statements will be assembled. If there are no arguments in the macro call line, the following statements will not be assembled. See the Macro section of this manual for examples of the use of this directive.

ELSE

Start of statements to be assembled if any of the above IF type of directives are false.

ENDC
ENDIF

Specifies the end of a conditional assembly block. When the Assembler detects unmatched IF - ENDIF pairs, an error message is output. Since recursive macros will almost always be controlled by IF type directives, the IFCLEAR directive may be needed. The difference between the two is that ENDIF is always executed, while IFCLEAR is not executed when it is inside a false conditional assembly block.

IFCLEAR

This directive performs exactly the same function as ENDIF, except that it is not executed when it is inside a false conditional assembly block. This directive can be used in a recursive macro to maintain balanced IF - ENDIF pairs, allowing the macro to eventually terminate, yet still taking advantage of the IF - ENDIF checking performed by the Assembler. This directive can be used to perform the same function when a macro contains a MACEXIT directive for early macro exits, since these would almost always be controlled by an IF directive of some sort. See the Macro section of this manual for examples of the use of this directive.

ASSEMBLY LISTING CONTROL

LIST ON

Turns listing on if LIST ON/OFF was specified as the listing destination when the Assembler was first entered. This directive must always be used before LIST OFF. In other words, at the start of the program, LIST OFF is assumed.

LIST OFF

Turns listing off if LIST ON/OFF was specified and LIST ON was executed. This is the default mode and therefore should only be used following a LIST ON directive.

MACLIST ON

Turns listing of MACRO expansions on. This is the default mode.

MACLIST OFF

Turns listing of MACRO expansions off. The default is on.

CONDLIST ON

Turns on listing of false conditional assembly blocks. This is the default mode.

CONDLIST OFF

Turns off listing of false conditional assembly blocks. The default is on.

ASCLIST ON

Turns on the listing of ascii strings that require more than 1 line of object code on the assembler listing.

ASCLIST OFF

Turns off the listing of ascii strings that require more than 1 line of object code on the assembler listing. Only the first line of the object code will be listed.

PW EXP

Sets the printer page width. The default page width is 132 columns.

PL EXP

Sets the printer page length. The default page length is 61 lines. The Assembler issues a form feed when this limit is reached or exceeded. If an error is encountered, the Assembler will output the form feed after the error message.

TOP EXP

This directive controls the number of lines from the top of the page to the page number. The default is zero.

PASS1 ON

Turns on the listing of pass 1. This can be used to help find errors due to the Assembler taking a different path on Pass 1 as compared to Pass 2. This condition will usually generate a 'Symbol value changed between passes' error. This directive can also be useful for finding nested conditional assembly errors.

PASS1 OFF

Turns off listing of pass 1 assuming PASS1 ON was executed.

PAG
PAGE
EJECT

Outputs a form feed to the listing device.

NAM STRING
TTL
TITLE
HEADING

Causes 'STRING' to be printed at the top of every page. If 'STRING' is not specified the 'TITLE' directive will be turned off. The title may be changed as often as desired and may be turned off at any time. The maximum title length is 80 characters. Also, the first two tabs between the TITLE directive and the start of the string, if they exist, will be ignored. All spaces and tabs after this will be included in the title.

```
STTL        STRING
SUBTITLE
```

Causes 'STRING' to be printed at the top of every page. If 'TITLE' was executed, the subtitle will appear below it. If 'TITLE' was not executed or was turned off, the subtitle will still be output. If 'STRING' is not specified, the directive will be turned off. The subtitle may be changed as often as desired and may be turned off at any time. The maximum subtitle length is 80 characters. As with the TITLE directive, the first two tabs between the SUBTITLE directive and the start of STRING, if they exist, will be ignored and any spaces and tabs that appear after that will be included in the subtitle.

LINKER CONTROL

FILLCHAR VALUE

The linker will fill in gaps which are created by the use of sections or origins with the value specified. This directive is only applicable to the executable output from the Linker. All other output formats will begin a new recored if an origin gap is detected.

RECSIZE VALUE

The record length may be changed for Intel Hex and Motorola S record outputs with this directive. By specifying a value standard 32 data bytes for Intel and 131 data bytes for Motorola will be replaced with VALUE.

SYMBOLS

This enables the symbols to be sent to an output file for the linker. The linker will output the Microtek symbol table if this directive is used.

OPTIONS OPTION LIST

This directive is used to select the options for the Linker. For a list of the options see the Linker Options section of this manual. The default output filetype is Intel Hex. The output from the Linker may still be changed by using the Linker options field.

ASSEMBLY TIME CALCULATIONS

The following list gives the allowed assembly time calculations. Also shown is their priority level. Priority level 7 operations are the first to be performed. Parenthesis may be used to force the calculations to proceed in a different order. Calculations are preformed using 80 bit integer arithmetic with the exception of exponentiation which only uses an 8 bit exponent. The maximum number of pending operations is 16.

OPERATION	PRIORITY	DESCRIPTION
Unary +	7	Optionally specifies a positive operand.
Unary -	7	Negates the following expression.
\ or .NOT.	7	Complements the following expression.
Unary >	7	Keeps the high order byte of the following address. This must be used to obtain relocatable byte address values.
Unary <	7	Keeps the low order byte of the following address. This must be used to obtain relocatable byte address values.
**	6	Unsigned exponentiation
*	5	Unsigned multiplication
/	5	Unsigned division
.MOD.	5	Remainder
.SHR.	5	Shift the preceeding expression right (with 0 fill) the number of times specified in the following expression.
.SHL.	5	Shift the preceeding expression left (with 0 fill) the number of times specified in the following expression.
+	4	Addition
-	4	Subtraction
& or .AND.	3	Logical AND
^ or .OR.	2	Logical OR
.XOR.	2	Logical exclusive OR

ASSEMBLY TIME COMPARISONS

The following list gives the assembly time comparisons which will return all 1's if the comparison is true and all 0's if the comparison is false:

=	or .EQ.	-	Equal
>	or .GT.	-	Greater than
<	or .LT.	-	Less than
	.UGT.	-	Unsigned greater than
	.ULT.	-	Unsigned less than

MACROS

DEFINITION

A macro is a sequence of source lines that will be substituted for a single source line. A macro must be defined before it is used. The Assembler will store the macro definition and, upon encountering the macro name, will substitute the previously defined source lines. Arguments may be included in the macro definition. Arguments may be substituted into any field except the comment field.

For macro definitions, dummy arguments may not contain spaces. However, for actual macro calls, arguments may be any type; direct, indirect, character string or register. Spaces are not allowed in arguments unless it is an Ascii string, in which case the string must be bracketed in apostrophes. If the string contains an apostrophe, this can be specified with two apostrophes in a row. Arguments will be passed through to any nested macros if the dummy argument names are identical. Macro nesting is limited only by the amount of memory space available.

To define a macro the ".MACRO" directive is used. A macro must have the ".MACEND" or ".ENDM" directive following the macro definition. The name of the macro is in the label field.

ARGUMENT SEPARATORS

In the macro call line arguments must be separated by commas, however leading spaces and tabs are ignored. If no argument is present, a single comma will serve as a place holder. The * as an argument will not be used as the program counter but as the multiplication sign. In a macro body, the following argument separators are allowed:

, + - * / ** \ & ^ = < > ( ) [ ] |

.NOT. .AND. .OR. .XOR. .EQ. .GT. .LT. .UGT.

.ULT. .SHR. .SHL.

CONCATENATION

The broken bar character (| = hex 7C) is used as the string concatenation operator. Concatenation may only be performed inside of a macro.

LABELS IN MACROS

Labels are allowed in macro definitions. Labels may be defined in two ways: explicit or implicit. Explicit labels in the macro definition will not be altered by the Assembler. Implicit labels are followed by a '#'. The Assembler will substitute a 3 digit macro expansion number for the '#'. In this case, the label and the macro expansion number must not exceed 32 characters. A label that ends with a "#" symbol outside of a macro will receive the same expansion number as the last macro. This provides for renaming labels without having to know the actual macro expansion number. An argument may be used to specify a label.

MNEMONIC REDEFINITION

The Assembler tables are searched in the following order:

1st - Mnemonic Table
2nd - Macro Definition Table
3rd - Assembler Directive Table
4th - Section Name Table

To redefine a mnemonic the MACFIRST directive may be used. This will switch the order of the search to Macro Definition Table first and Mnemonic Table second.

MACRO EXAMPLES

A macro could be written to do string comparisons. This macro demonstrates the use of this feature.

```
CMP_STRING:     .MACRO    ARG1
                IFNMA     1
                CMP_STRING NEEDS AN ARGUMENT
                MACEXIT
                ENDIF
                IFSAME    "JANUARY",ARG1
MONTH           BYTE      1
                MACEXIT
                ENDIF
                IFSAME    "FEBRUARY",ARG1
MONTH           BYTE      2
                MACEXIT
                ENDIF
                IFSAME    "MARCH",ARG1
MONTH           BYTE      3
                MACEXIT
                ENDIF
                IFSAME    "APRIL",ARG1
MONTH           BYTE      4
                MACEXIT
                ENDIF
                IFSAME    "MAY",ARG1
MONTH           BYTE      5
                MACEXIT
                ENDIF
                IFSAME    "JUNE",ARG1
MONTH           BYTE      6
                MACEXIT
                ENDIF
                ARGUMENT ERROR IN MACRO STRING
                ENDM
                CMP_STRING     "APRIL"
                END
```

The following example demonstrates the use of argument substitution in the operand field of a macro.

```
EMPLOYEE_INFO: .MACRO     ARG1,ARG2,ARG3
NAME:          DB         ARG1
DEPARTMENT:    ASCII      ARG2
DATE_HIRED:    LONG       ARG3
               .ENDM
               EMPLOYEE_INFO   'JOHN DOE',PERSONNEL,101085
               END
```

This example could be changed to pass the argument into the label field. This enables the structure to be altered.

```
EMPLOYEE_INFO: .MACRO     ARG1,ARG2,ARG3
ARG1:          DS         30H
ARG2:          DS         10H
ARG3:          LONG
               .ENDM
               EMPLOYEE_INFO  NAME,DEPARTMENT,DATE_HIRED
               END
```

The macro section also allows substitution into the mnemonic field. Also, a label can be generated within the macro with the # sign.

```
INSTRUCTION:   .MACRO     ARG,VAL
               ARG
LAB#:          DS         VAL
               .MACEND
               INSTRUCTION     NOP,7
               END
```

To redefine a mnemonic the MACFIRST ON directive must precede the macro.

```
               MACFIRST ON
NOP:           .MACRO     ARG
               DB         ARG
               .ENDM
               NOP        FFH
               END
```

Another macro directive, MACDELIM, can be used to pass commas into a macro. The following examples show the syntax for this directive.

```
            MACDELIM        {

DELIM_EX    MACRO           ARG1 ARG2
            BYTE            FFH,ARG1,ARG2
            ENDM
            DELIM_EX        {,A4H},{,12H}


            MACDELIM        [

DELIM_EX    MACRO           ARG1
            BYTE            FFH ARG1
            ENDM
            DELIM_EX        [,A4H]


            MACDELIM        (

DELIM_EX    MACRO           ARG1
            BYTE            FFH ARG1
            ENDM
            DELIM_EX        (,A4H)
```

RECURSION

When macros are nested, all the information required to return to the previous source code environment is saved on disk. This design is what enables the Assembler to store macros on disk and still allow nesting to any desired level. Recursion (a macro calling itself) is allowed and is achieved by detecting that the macro is already active, and inhibiting the writing of the previous source code environment. However, a macro may not call another macro that in turn calls the first macro. When this occurs, the original return information is destroyed and the Assembler will not be able to return to the previous environment. Furthermore, the Assembler is not able to detect this condition because when the second macro activates the first macro, which is already active, the Assembler assumes a recursive macro condition, and does not record the information needed to return to the second macro.

Below is an example of a recursive macro that reserves the number of data bytes defined by dummy argument ARG1 and fills them with the value specified by ARG2.

```
RESERVE:    .MACRO    ARG1,ARG2,ARG3,ARG4,ARG5
COUNT:      .VAR      ARG1                        ;Store # of bytes
                                                   to save
            .IFZ      COUNT                       ;Check for done
            .IFCLEAR                              ;Clear the pend-
                                                   ing IF
            .MACEXIT                              ;And get out
            .ENDIF
COUNT:      .VAR      COUNT-1                     ;Else dec byte
                                                   count
            .BYTE     ARG2,ARG3,ARG4,ARG5         ;Reserve the byte
            .RESERVE  COUNT,ARG2,ARG3,ARG4,ARG5
            .MACEND
```

This macro would be called with a statement such as the following:

```
            RESERVE   10,AH,BH,CH,DH              ;Fill 40 bytes
                                                   with the sequence
                                                   ABCDEF.
```

It is perfectly legal for a recursive macro, such as the one in the above example, to call another recursive macro and so forth out to whatever level is desired. Also, note the use of the IFCLEAR directive, which maintains the conditional IF - ENDIF pair balance. This is required for the case when the MACEXIT directive is executed since then, the ENDIF directive is not executed.

ASSEMBLER ERROR MESSAGES

Error - CAN'T CREATE OUTPUT FILE - DISK MAY BE FULL
Meaning - The disk may actually be full or the operating system is not allowing enough files to be open at one time. See System Requirements at the end of this manual to correct this error.

Error - CAN'T OPEN INPUT FILE
Meaning - The operating system is not allowing enough files to be open at one time. See System Requirements at the end of this manual to correct this error.

Error - CAN'T FIND FILENAME.OBJ
Meaning - The .OBJ filename does not exist or the operating system is not allowing enough files to be open at one time. See System Requirements at the end of this manual to correct this error.

Error - SYNTAX ERROR
Meaning - Usually a missing comma or parenthesis.

Error - CAN'T RESOLVE OPERAND
Meaning - Can't tell what the programmer intended.

Error - ILLEGAL ADDRESSING MODE
Meaning - Can't address the operand using this form.

Error - ILLEGAL ARGUMENT
Meaning - Operand can't be used here.

Error - MULTIPLY DEFINED SYMBOL
Meaning - Symbol defined previously (not inlcuding '.VAR')

Error - ILLEGAL MNEMONIC
Meaning - Mnemonic doesn't exist and wasn't defined as a Macro.

Error - # TOO LARGE
Meaning - The destination is too small for the operand.

Error - ILLEGAL ASCII DESIGNATOR
Meaning - Bad punctuation on Ascii character.

Error - HEX # AND SYMBOL ARE IDENTICAL
Meaning - A label exists that is exactly identical to a hex number that is being used as an operand. Even the hex number indicator must be in the same place for this error to be generated.

Error - UNDEFINED SYMBOL
Meaning - Symbol wasn't defined during pass 1.

Error - RELATIVE JUMP TOO LARGE
Meaning - Destination address in a different page.

Error - EXTRA CHARACTERS AT END OF OPERAND
Meaning - Usually a syntax or format error.
Note - This error is the last check on any instruction before the Assembler proceeds to the next line and indicates that there are extra characters after a legal operand terminator.

Error - LABEL VALUE CHANGED BETWEEN PASSES
Meaning - Symbol value decode during pass 1 not = pass 2.
Note - This error is usually caused by the Assembler taking different paths on Pass 1 as compared to Pass 2 due to conditional directive arguments changing value. The directive PASS1 ON/OFF can be useful in finding these types of errors.

Error - ATTEMPTED DIVISION BY ZERO
Meaning - Divisor operand evaluated to 0.

Error - ILLEGAL EXTERNAL REFERENCE
Meaning - External reference can't be used here.

Error - NESTED CONDITIONAL ASSEMBLY UNBALANCE DETECTED
Meaning - Any '.IF' type instruction without a matching '.ENDIF'

Error - MACRO STACK OVERFLOW
Meaning - Macros are nested too deeply.
Note - This error can be caused by too many recursive macro calls. The stack has room for approximately 700 nested or recusive macro calls. The number of calls is affected by the number of arguments the macro uses.

Error - ILLEGAL REGISTER
Meaning - The specfied register is not legal for the instruction

Error - CANT RECOGNIZE NUMBER BASE
Meaning - The number base specified is not one the assembler accepts.

Error - NOT ENOUGH PARAMETERS
Meaning - The were more arguments than parameters in a macro.

Error - ILLEGAL LABEL 1ST CHARACTER
Meaning - Labels must start with an alpha character.

Error - MAXIMUM EXTERNAL SYMBOL COUNT EXCEEDED
Meaning - There were too many externals in a module.
Note - There is a maximum of approximately 5000 externals per module.

Error - Dh:Dl CANNOT BE THE SAME
Meaning - The instruction returns a 64 bit result in 2 registers.

Error - MUST BE IN SAME SECTION
Meaning - The instructions operand is in a different section.

Error - NON-EXISTANT INCLUDE FILE
Meaning - The include file could not be found.

Error - ILLEGAL NESTED INCLUDE
Meaning - One included file containing an .INCLUDE directive. This error may also indicate that an included file did not have an END statement.

Error - NESTED SECTION UNBALANCE
Meaning - A nested section definition without an ENDS

Error - MISSING DELIMETER ON MACRO CALL LINE
Meaning - Unmatched delimeters when a macro was invoked.

Error - MULTIPLE EXTERNAL IN THE SAME OPERAND
Meaning - More than one external exists in the same operand.

2500 A.D. LINKER DESCRIPTION

The 2500 A.D. Linker enables the user to write assembly language programs consisting of several modules. The Linker will resolve external references and perform address relocation. The Linker is capable of generating all of the most used file formats, eliminating the need for an additional format conversion utility.

Except for when generating an executable output file, the Linker runs entirely in RAM. There is no limit on the size of file that can be linked, as long as enough memory is available. In the case of an executable file, the Linker creates as many scratchpad files as required to sort the different program sections in ascending order.

Each object file may have up to 256 different user defined sections. The Linker can process a total of 256 input files, and 256 different section names. Therefore, assuming each input file has 256 sections, with each section name the same in each file, the maximum capacity of the Linker is 65,536 different sections, with no limit on the size of each section.

The Linker may be invoked using Prompt mode, Command Line mode or Data File mode. The output format is selectable from a directive in the source file or from the Linker options list. The Load Map, an alphabetized global symbol list and all link errors may be saved in a disk file.

The Linker may be directed to output several different types of symbol table files. These formats are relocated 10 character global symbols, relocated 32 character global symbols, and the Microtek format which includes all symbols.

LINKER OPERATING INSTRUCTIONS

Prompt Mode

The Linker will respond with a prompt requesting an input filename. The default extension for a Linker input file is 'obj'. After opening the object file, the Linker will prompt for the offset address for each program section that has a non-zero size. This offset value is added to the value of any ORG statements in the file. A carriage return only response will cause the Linker to stack each program section on top of the preceeding section. A minus sign causes the Linker to relocate the section, but not include it in the output file. A semi-colon after any offset address causes the Linker to automatically stack each section on top of the previous section. Since the best way to explain all of this is with examples, please refer to the Linker Examples section of this manual.

The input phase can be terminated by responding to the input filename prompt with just a carriage return. The Linker will then prompt for an output filename. A carriage return only response to the output filename prompt will cause the Linker to generate an output file with the same name as the first input file and an extension that is determined by the output file type.

After the output filename has been entered, the Linker will prompt for any Linker options. The Linker options are described in the section entitled Linker Options.

NOTE to VMS users:

Assuming the linker is located in a directory named $disk1:[link],the following command must be entered for the examples shown above to work:

```
link == "$disk1:[link]link.exe"
```

If you use the VMS Link program, one of the linkers should be renamed.

Data File Mode

Data File mode is included for large or complex linking. This mode can be viewed as being identical to prompt mode, except that all of the responses to the prompts are placed in a file and the file is submited to the Linker. The command is as follows:

```
Link data_file
```

This causes the Linker to read the file 'data_file.lnk' and uses the responses in the file, line by line. The Linker assumes an extension of 'lnk' on the data file. Since carriage return only responses may be difficult to see in a data file, an underbar character ('_') may be placed on a carriage return only line. If Linker options are specified, they are placed last in the file, just as they are in prompt mode. The following sample Data File will link 2 files together with the section named CODE starting at 2000H and the section named DATA starting at 4000H. The default Linker output filename is to be used, and the D and 3 options are used to generate a disk map file and a Motorola S37 output file.

```
file1                   First input filename
2000                    Put the CODE section at 2000H
4000                    Put the DATA section at 4000H
file2                   Second input filename
_                       Stack CODE section on top of 1st CODE
_                       Stack DATA section on top of 1st DATA
_                       No more input filenames
_                       Use default output filename
d3                      Create disk file & Motorola S37 file
```

The easiest way to construct a Data File is to run through the link process in Prompt mode, and write down each response. Then, using a text editor, create a file with each response on a line by itself. This file should have an extension of 'lnk'.

Any line that has a semi-colon or an asterisk in column 1 will be considered to be a comment line.

NOTE to VMS users:

Assuming the linker is located in a directory named $disk1:[link],the following command must be entered for the examples shown above to work:

```
link == "$disk1:[link]link.exe"
```

If you use the VMS Link program, one of the linkers should be renamed.

Command Line Mode

The Linker may be invoked by using a command line. The form of this command is shown below, with optional fields shown in brackets.

```
Link [-q] -c file1 [-lnnnn] file2 [-lnnnn] ... [-ofile] [-options]
```

The -q option puts the Linker in Quiet mode. In this case the only output to the terminal from the Linker are link errors.

The -c option is required, and informs the Linker that it is running in Command Line mode instead of Data File mode.

Following the -c is the list of input files, denoted in the above command line by 'file1' and 'file2'. Each input file may be followed by an offset address by using the -l option. If the address offset is not included, each file is stacked on top of the previous file according to matching section names.

The -o option can be used to specify an output filename. This field is optional. If no output filename is specified, the Linker will create an output file with the same name as the first input file, with an extension determined by the output file format.

The 'options' field allows any of the Linker options to be specified. A minus sign is required in front of the list, and as many options as desired may be specified. See the Linker Options section of this manual for a description of the options.

NOTE to VMS users:

Assuming the linker is located in a directory named $disk1:[link],the following command must be entered for the examples shown above to work:

```
link == "$disk1:[link]link.exe"
```

If you use the VMS Link program, one of the linkers should be renamed.

LINKER OPTIONS

In prompt mode, the linker options prompt appears after the output filename prompt. The options below are also available in Command Line and Data File mode. When more than one option is specified the final option will override the previous options.

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = Default)

D - Create a disk file containing any link errors, an alphabetized global symbol table, and the Load Map. The file created has the same name as the Linker output file with an extension of 'map'.

S - Create a symbol file for debugging purposes. The file contains all the global symbols and relocated values. Each symbol is 32 characters in length. See the Symbol Table Output Format section of this manual for exact details.

A - Create a symbol file for debugging purposes, but limit the symbols to the first 10 characters. This is used for compatability with the 3.00 2500 A.D. series of Linkers. See the Symbol Table Output Format section of this manual for exact details.

M - Create a symbol file for debugging purposes in the Microtek format. This file includes all symbols, both local and global. The SYMBOLS ON directive must be included in the source file for this format to be generated.

X - Generate an Executable output file.

H - Generate an Intel Hex output file.

E - Generate an Extended Intel Hex output file.

T - Generate a Tektronix Hex output file.

1 - Generate a Motorola S19 output file.

2 - Generate a Motorola S28 output file.

3 - Generate a Motorola S37 output file.

ADDRESS RELOCATION

Addresses are relocated by adding the offset address to the address decoded by the 2500 A.D. Assembler. Normally the program would be assembled starting at location 0000, but it doesn't have to be. The offset address will simply be added to any address generated by the Assembler.

The Assembler maintains a table of attributes associated with each symbol used in the program. If the label simply preceeds an instruction, then it is tagged as relocatable. If the label is defined in an ".EQUAL" directive, then the relocatability of it depends on the operand field type. If the operand contains no relocatable tokens, then the expression is not relocatable. If the operand contains only one relocatable token, then the expression is relocatable. If the operand contains two or more relocatable tokens, then the expression is not relocatable.

Byte values are only relocatable candidates if the unary greater than '>' sign is used for the high byte and/or the unary less than '<' sign is used for the low byte. These operands are subject to the same relocation rules as full 16 bit address values.

Following are some examples illustrating these points.

```
LABEL1:   NOP                ; The label is defined to be equal
                             ; to the address of an instruction
                             ; and therefore is relocatable.

LABEL2:   .EQUAL   LABEL1    ; The label is defined to equal a
                             ; value that was tagged as relo-
                             ; catable. Therefore, LABEL2 is
                             ; also relocatable.

LABEL3:   .EQUAL   10        ; The label is defined to equal a
                             ; constant. Therefore, LABEL3 is
                             ; not relocatable.

LABEL4:   .EQUAL   $+10      ; The label is defined to equal a
                             ; relocatable value plus a non-
                             ; relocatable value. Since only
                             ; one value is relocatable, the
                             ; symbol LABEL4 is relocatable.

LABEL5:   .EQUAL   10+$      ; The label is defined to equal a
                             ; non-relocatable value plus a re-
                             ; locatable value. Since only one
                             ; value is relocatable, LABEL5 is
                             ; relocatable.
```

```
LABEL6:    .EQUAL    LABEL5-LABEL2
                                  ; The  label is defined to  equal  a
                                  ; relocatable  value minus  another
                                  ; relocatable  value,  producing  a
                                  ; non-relocatable result.
```

The last example is worth remembering when using the Assembler to do things such as calculate data sizes. Consider the following example of a table of data values, with the number of bytes being calculated automatically at assembly time by the Assembler, allowing the programmer to add or delete from the table without having to remember to change the data block size.

```
DATA:          .BYTE      0
               .WORD      10
               .BYTE      20
               .BLKB      5

DATA_SIZE:     .EQUAL     $-DATA
```

The Assembler will calculate the size of the data block, and because the result is not relocatable, the Linker will not alter the data block size.

LINKER EXAMPLES

This section consists of examples intended to demonstrate the use of the Linker. The <cr> symbol denotes a carriage return and is shown only when no other response to a prompt is desired. Otherwise, all inputs are assumed to be terminated with a carriage return. In all cases, a Data File can be constructed with exactly the same responses as when running in Prompt mode.

Single File Assembled At Desired Run Address

The first example is the case of just one file which has been assembled at the desired run address by the use of the ORIGIN directive. Also, assume the default output file type is Executable, and no Linker options are desired. If no additional sections were defined, and there was no switching between the predefined sections, the Linker prompts would be as follows:

```
Input  Filename : filename
       Enter Offset for 'CODE'          : 0
Input  Filename : <cr>

Output Filename : <cr>

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = None) :
```

The above will cause the Linker to read the file 'filename.obj', add 0 to all relocatable addresses, and output a file with the name 'filename.tsk'.

The following example shows the case where everything is the same as in the previous example except the desired output format is Intel Hex. Note that the default Linker output format may be changed with the OPTIONS Assembler directive.

```
Input  Filename : filename
       Enter Offset for 'CODE'          : 0
Input  Filename : <cr>

Output Filename : <cr>

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = None) : h
```

The last example for this type of file is the sames as in the previous example with the addition of a disk Load Map file and a user specified output filename. The options may be specified in any order.

```
Input  Filename : filename
       Enter Offset for 'CODE'          : 0
Input  Filename : <cr>

Output Filename : user_filename

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = None) : hd
```

Single File With Multiple Sections

This example demonstrates how the Linker handles multiple program sections. If the predefined CODE and DATA sections were used, and the DATA section is to be stacked on top of the CODE section, then the Linker prompts would be as follows:

```
Input  Filename : filename
       Enter Offset for 'CODE'          : 0
       Enter Offset for 'DATA'          : <cr>
Input  Filename : <cr>

Output Filename : <cr>

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = None) :
```

If instead of using the predefined sections CODE and DATA, the user defined sections Program_section1 and Program_section2 were used, and Program_section2 is to be stacked on top of Program_section1, the prompts would be as follows:

```
Input  Filename : filename
       Enter Offset for 'Program_section1' : 0
       Enter Offset for 'Program_section2' : <cr>
Input  Filename : <cr>

Output Filename : <cr>

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = None) :
```

One important item to keep in mind is that sections are stacked in the order in which they are defined. Therefore, in this example there is no way to stack Program_section2 on top of Program_section1. If the need arises to reverse the order, then order of the SECTION directives in the source file must be changed.

If in the above example, Program_section1 was to be relocated to run at 2000H and Program_section2 was to be relocated to run at 4000H, the following responses would be used.

```
Input  Filename : filename
       Enter Offset for 'Program_section1' : 2000
       Enter Offset for 'Program_section2' : 4000
Input  Filename : <cr>

Output Filename : <cr>

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = None) :
```

Note that the addresses are always specified in Hexadecimal. If the output file format was Executable, the gap from the end of Program_section1 to the start of Program_section2 would be filled in with the default fill character, which is FF Hex. This may be changed with the FILLCHAR Assembler directive.

Multiple Files With Multiple Sections

This example illustrates how the Linker handles section names in multiple files. Assume file1 and file2 use both CODE and DATA sections, and the file is to be linked starting at 0. The prompts will appear as follows:

```
Input  Filename : file1
       Enter Offset for 'CODE'          : 0
       Enter Offset for 'DATA'          : <cr>
Input  Filename : file2
       Enter Offset for 'CODE'          : <cr>
       Enter Offset for 'DATA'          : <cr>

Output Filename : <cr>

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = None) :
```

This will produce a file with both CODE sections stacked on top of each other, followed by both DATA sections being stacked on top of each other, then stacked on top of both CODE sections. This shows the general rule of stacking sections. Sections are stacked according to name, and are stacked in the order in which they are defined in the source file. All CODE sections will be grouped together, then all DATA sections, etc. CODE sections will always be stacked before DATA sections, since that is the order they are predefined in. If DATA must be placed before CODE, then CODE should not be used and a user defined section should be used. This is true for stacking only. If CODE and DATA are to be stacked, but placed at specific addresses, this would be done as follows, assuming CODE is to start at E000H and DATA is to start at 1000H.

```
Input  Filename : file1
       Enter Offset for 'CODE'          : E000
       Enter Offset for 'DATA'          : 1000
Input  Filename : file2
       Enter Offset for 'CODE'          : <cr>
       Enter Offset for 'DATA'          : <cr>

Output Filename : <cr>

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = None) :
```

The rules described in this example hold true regardless of how many input files there are. Sections can be used to separate program sections according to function, or to assist in complex linking, since any section may be placed at any address.

Single File With One Section Used For Reference Only

A reference only section is a section that is relocated so that any globals defined in the section can be used for linking purposes, however the section is not included in the output file. Reference only sections are useful is cases such as where the program resides in ROM or EPROM and the data areas reside in RAM. It is desirable to have the output file contain only that part of the program that is to be stored in ROM. Using an example along the same lines as the previous examples, assume that the program only uses the predefined CODE and DATA sections, that the CODE is to start at 1000H and the DATA is to be stacked on top of the CODE, used for linking purposes, and then discarded. A minus sign before a section address specifies that section as reference only. A minus sign before the section name indicates a reference only section in the Load Map.

```
Input  Filename : filename
       Enter Offset for 'CODE'              : 1000
       Enter Offset for 'DATA'              : - <cr>
Input  Filename : <cr>

Output Filename : <cr>

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = None) :
```

If the DATA section was to be placed at 4000H instead of stacked on top of the CODE section, and was to be used for refernece only, this could be accomplished as follows:

```
Input  Filename : filename
       Enter Offset for 'CODE'              : 1000
       Enter Offset for 'DATA'              : -4000
Input  Filename : <cr>

Output Filename : <cr>

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = None) :
```

Any section of any file may be used for reference only with one exception. The first section in the first file may not be used for reference only, since it is used as the basis for all other Linker calculations. Therefore, it is a good idea not to use the CODE section for reference only. Instead, defined a section with the SECTION Assembler directive, and make it reference only. If that section was named Ref_only, this would appear as follows:

```
Input  Filename : filename
       Enter Offset for 'DATA'              : 1000
       Enter Offset for 'Ref_only'          : -4000
Input  Filename : <cr>

Output Filename : <cr>

Options (D, S, A, M, X, H, E, T, 1, 2, 3, <CR> = None) :
```

GLOBAL SYMBOL TABLE OUTPUT FORMAT

This section describes the format of the Global Symbol Table that is produced when the S Linker option is selected. The Symbol Table always receives the same filename as the Linker output filename, with an extension of SYM. This first byte of this file is the i.d. code, which is E0H. The following bytes, relative to the start of each entry, are repeated for each entry.

Bytes	0 - 31	Global Symbol Name. The name is padded with zeros to fill out the 32 character positions. The end of the entries can be detected by an FFH in byte 0.
Byte	32	Most significant byte of relocated Global Symbol value.
Byte	33	Least significat byte of relocated Global Symbol value.
Byte	34	File number in which the Global was defined. This is used by the Linker to output the filename along with the value. This byte may be deleted or used for other purposes if desired.
Byte	35	Flag byte. This byte is unused at the current time but may be used in the future by 2500 A.D. products.

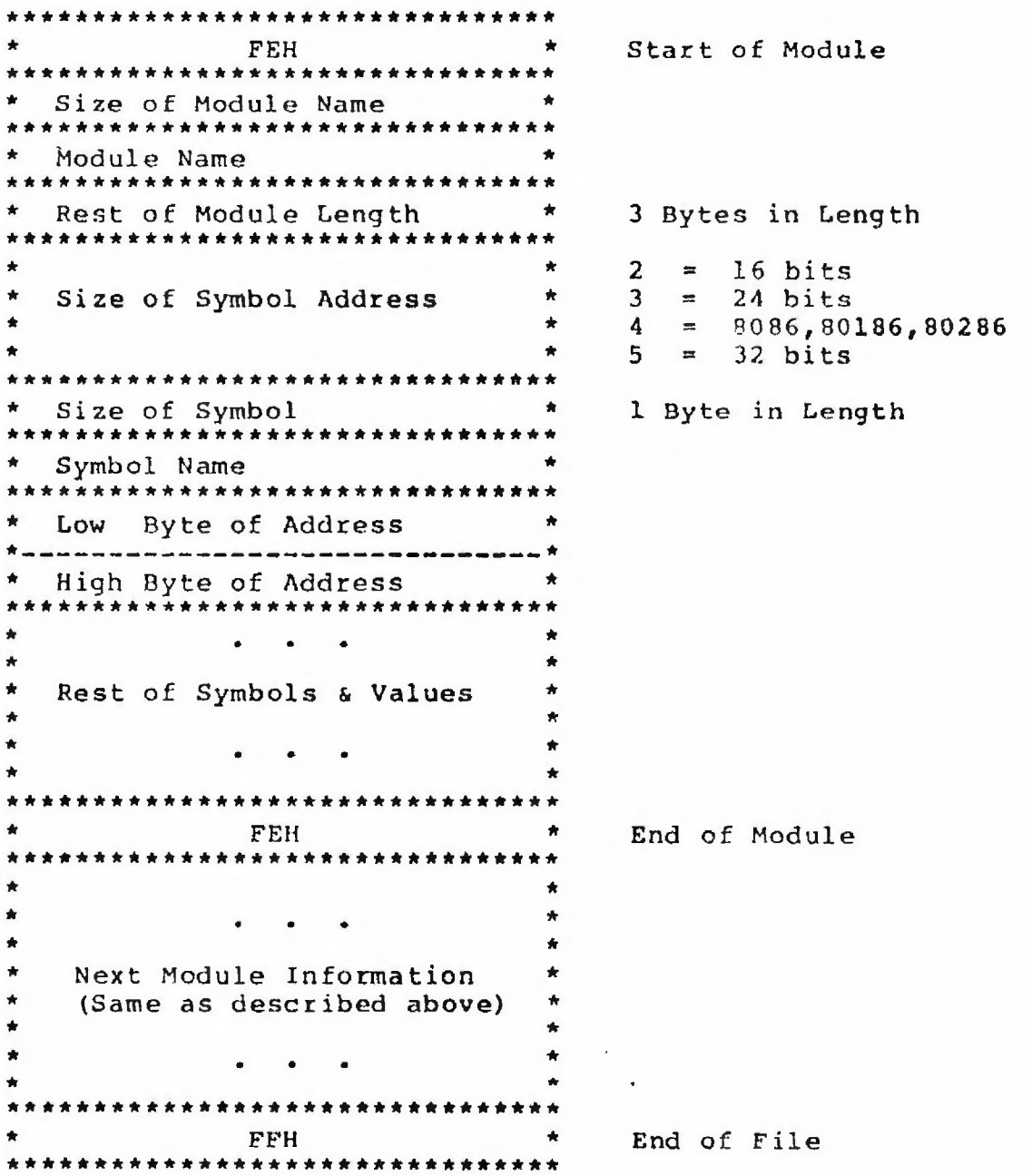
ABBREVIATED GLOBAL SYMBOL TABLE OUTPUT FORMAT

This section describes the format of the Global Symbol Table that is produced when the A Linker option is selected. The Symbol Table always receives the same filename as the Linker output filename, with an extension of SYM. This is the same symbol table as produced by the 3.00 series of 2500 A.D. Linkers.

Bytes	0 - 9	Global Symbol Name. The name is padded with zeros to fill out the 10 character positions. The end of the entries can be detected by an FFH in byte 0.
Byte	10	Most significant byte of relocated Global Symbol value.
Byte	11	Least significant byte of relocated Global Symbol value
Byte	12	File number in which the Global was defined. This is used by the Linker to output the filename along with the value. This byte may deleted or used for other purposes if desired.
Byte	13	Flag byte. This byte is unused at the current time but may be used in the future by 2500 A.D. products.

MICROTEK SYMBOL TABLE OUTPUT FORMAT

This section describes the MicroTek Symbol Table format which is selected by the M Linker option. The Symbol Table always receives the same filename as the Linker output filename, with an extension of SYM.



INTEL HEX FORMAT

The Intel Hex Format is described below.

Record Mark Field - This field signifies the start of a record, and consists of an Ascii colon (:).

Record Length Field - This field consists of two Ascii characters which indicate the number of data bytes in this record. The characters are the result of converting the number of data bytes in binary to two Ascii characters, high digit first. An end of file record contains two Ascii zeros in this field. The maximim number of data bytes in a record is 255. This can be changed by using the RECSIZE directive.

Load Address Field - This field consists of the four Ascii characters which result from converting the binary value of the address in which to begin loading this record. The order is as follows:

High digit of high byte of address.
Low digit of high byte of address.
High digit of low byte of address.
Low digit of low byte of address.

In an end of file record, this field consists of either four Ascii zeros, or the program entry address.

Record Type Field - This field identifies the record type, which is either 00 for data records or 01 for an end of file record. It consists of two Ascii characters, with the high digit of the record type first, followed by the low digit of the record type.

Data Field - This field consists of the actual data, converted to two Ascii characters, high digit first. There are no data bytes in the end of file record.

Checksum Field - The checksum field is the 8 bit binary sum of the record length field, the load address field, the record type field and the data field. This sum is then negated (2's complement) and converted to two Ascii characters, high digit first.

MOTOROLA S19 FORMAT

The Motorola S1 - S9 Format is described below.

Record Type Field - This field signifies the start of a record and identifies the record type as follows:

Ascii S1 - Data Record
Ascii S9 - End of File Record

Record Length Field - This field specifies the record length which includes the Address, Data and Checksum fields. The 8 bit Record Length value is converted to two Ascii characters, high digit first. Since the smallest object file record size is 128 bytes, the Record Length field always consists of 128 data bytes, 2 address bytes and 1 checksum byte, resulting in a record length of 131 bytes. This can be changed with the RECSIZE directive.

Load Address Field - This field consists of the four Ascii characters which result from converting the binary value of the address in which to begin loading this record. The order is as follows:

High digit of high byte of address
Low digit of high byte of address
High digit of low byte of address
Low digit of low byte of address

In an end of file record, this field consists of four Ascii zeros.

Data Field - This field consists of the actual data, converted to two Ascii characters, high digit first. There are no data bytes in an end of file record.

Checksum Field - The checksum field is the 8 bit binary sum of the record length field, the load address field and the data field. This sum is then complemented (1's complement) and converted to two Ascii characters, high digit first.

MOTOROLA S28 FORMAT

The Motorola S2 - S8 Format is described below.

Record Type Field - This field signifies the start of a record and identifies the record type as follows:

Ascii S2 - Data Record
Ascii S8 - End of File Record

Record Length Field - This field specifies the record length which includes the Address, Data and Checksum fields. The 8 bit Record Length value is converted to two Ascii characters, high digit first.

Load Address Field - This field consists of the six Ascii characters which result from converting the binary value of the address in which to begin loading this record. The order is as follows:

High digit of high byte of address
Low digit of high byte of address
High digit of mid byte of address
Low digit of mid byte of address
High digit of low byte of address
Low digit of low byte of address

In an end of file record, this field consists of six Ascii zeroes.

Data Field - This field consists of the actual data, converted to two Ascii characters, high digit first. There are no data bytes in an end of file record.

Checksum Field - The checksum field is the 8 bit binary sum of the record length field, the load address field and the data field. This sum is complemented (1's complement) and converted to two Ascii characters, high digit first.

MOTOROLA S37 FORMAT

The Motorola S3 - S7 Format is described below.

Record Type Field - This field signifies the start of a record and identifies the record type as follows:

Ascii S3 - Data Record
Ascii S7 - End of File Record

Record Length Field - This field specifies the record length which includes the Address, Data and Checksum fields. The 8 bit Record Length value is converted to two Ascii characters, high digit first.

Load Address Field - This field consists of the eight Ascii characters which result from converting the binary value of the address in which to begin loading this record. The order is as follows:

High digit of high byte of high word
Low digit of high byte of high word
High digit of low byte of high word
Low digit of low byte of high word
High digit of high byte of low word
Low digit of high byte of low word
High digit of low byte of low word
Low digit of low byte of low word

In an end of file record, this field consists of eight Ascii zeroes.

Data Field - This field consists of the actual data, converted to two Ascii characters, high digit first. There are no data bytes in an end of file record.

Checksum Field - The checksum field is the 8 bit binary sum of the record length field, the load address field and the data field. This sum is complemented (1's complement) and converted to two Ascii characters, high digit first.

2500 A.D. 8080 TO Z80 SOURCE CODE CONVERTER - VERSION 2.01

8080 TO Z80 SOURCE CODE CONVERTER

The 2500 A.D. 8080 to Z80 Source Code Converter will convert standard Intel 8080 source code to Zilog source code, which can be subsequently assembled on the 2500 A.D. Z80 Cross Assembler. Since the 8080 source buffer, Z80 source buffer and symbol table buffer overflow to disk, the size of any file that can be converted is limited only by the available disk storage space. Is should be noted that this only runs under Msdos and Zeus.

To run the Converter type : CONV

The Converter will respond with the following prompt.

INPUT FILENAME ? :

After the user enters the 8080 source code filename the Converter will ask for the Z80 output filename as shown below.

OUTPUT FILENAME ? :

The Converter will display the 8080 source line, followed by the Z80 equivalent at the terminal. Any source lines which the Converter does not recognize are assumed to be macros. Although only macros will normally fall into this class, it may be possible to actually define macros in the Z80 file to handle some of the non-standard Z80 instruction extensions added to existing 8080 assemblers.

Part of the conversion process includes building a symbol table. This table is deleted at the end of a normal converter run, but if for some reason the conversion is aborted, a file of the name SYMBOL.CON may be left on the disk and should be deleted by the operator.

The Converter recognizes two types of comment lines. The first is a single line with a semi-colon in column 1. For large comment blocks, some assemblers have a special assembler directive. The Converter will recognize a comment block as follows:

```
.COMMENT    X
```

where "X" can be any character. The Converter will treat everything from the first "X" to the second "X" as a comment block.

SYSTEM REQUIREMENTS

For MSDOS systems, the minimum system requirement is 512k of available memory, minus the amount used by the operating system. Unix systems require at least 1 megabyte of memory.

For MSDOS systems, up to 20,000 lines of source code have been assembled with 512k of memory, and 30,000 line programs have been assembled with 640k of memory without running out of space.

The Linker assumes 15 files may be open at once. On MSDOS systems there is a file called CONFIG.SYS that is on the system disk. The default value is 5 files, therefore, this must be changed to at least 15. Since the Linker will open and close files when the number exceeds 15, raising the number higher than 15 will have no effect on the Linker. However, if any memory resident programs open files, the number should be increased by the number of files used by the memory resident programs.

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