Signetics

MCCAP Microcontroller Cross Assembler Program

MICROCONTROLLER CROSS ASSEMBLER PROGRAM (MCCAP)

Development Systems Products Group

Bipolar LSI Division

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FORTRAN MOCAP ERROR

Summary: An error has been identified in the FORTRAN version of the MOCAP CROSS ASSEMBLER (8X300 AS1- *SS). This error can be corrected by adding one statement to the MOCAP SOURCE PROGRAM.

Error: Cannot write extension code to a statement which selects a right bank data field variable using the SEL statement.

```
EXAMPLE - EXT     EQ     100H
          DATA    RIV    123H, 7, 8
                  SEL    DATA/EXT
```

Solution: Add one statement, "GO TO 7500", right after the statement with the label 3240 in subroutine PASS2 of the FORTRAN MOCAP source program as shown below.

```
0
0       PROCESS SEL STATEMENT
0
3200    CALL SCAN (IARG,IVAL)
        MODE = 3
        LEN = 1
        GO TO (3210,9100,9000,3210,9300,9300,9300,3210,9300),IERR
3210    IF(IVIND) 9600,9600,3200
3220    L = IVVAL/8
        ITYPE = 7
        IBYTE = IVAL
        IF(L-2) 9600,3230,3240
3230    IBIN = 1792+IBYTE
        GO TO 7500
3240    IBIN = 3840+IBYTE
       (GO TO 7500<------------- new statement)
0
0       PROCESS MACRO STATEMENT
0
3300    GO TO 8000
```

* = 1, 2, 3 or 4 depending on density or encoding

PREFACE

The MicroController Cross Assembler Program (MCCAP) has been developed to support the Signetics 8X300/8X305 MicroController. MCCAP provides many powerful features including macros, automatic subroutine handling, conditional assembly and extended instructions. These features significantly reduce the time required to compose and assemble MicroController programs. When combined with standard assembler features such as mnemonic op-codes and address labels, these extended features make MCCAP a powerful programming tool.

As input, MCCAP accepts source code written according to the rules presented in this manual. After assembling the source input, MCCAP produces an assembly listing and machine-readable object module.

MCCAP is written in ANSI standard FORTRAN IV and is available on the more popular timesharing services. MCCAP is also available as a fully supported product from Signetics for use on a user's in-house system.

This manual assumes a familiarity with the 8X300/8X305 MicroController and its instruction set. Those unfamiliar with the 8X300/8X305 should read Appendix D before reading the main body of this manual.

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INTRODUCTION

The MicroController Cross Assembler Program (MCCAP) translates symbolic statements into object code that can be executed by the 8X300/8X305 MicroController. The assembler consists of two passes which build a symbol table, issue helpful error messages, produce a detailed program listing, and output a machine-readable object module.

MCCAP is written in ANSI standard FORTRAN and runs on large-scale computers, (MCCAP is also written in Intel 8080 assembly language and runs on the Intel Intellec Microcomputer Development System.) It requires a direct access mass storage device such as disk, an input device for source code, and two output devices--one to output the assembly listing and one to output the object module. The program uses a minimum of memory but is modularized and may be linked to execute in overlays if memory restrictions require.

1.1 MCCAP FEATURES

The MCCAP assembler language has been developed with the following features:

- Free format source code
- Reserved symbols for registers
- ASCII character set
- Symbolic address assignments
- Forward referencing
- Address arithmetic
- Bit or byte manipulation
- Macros nested to three levels
- Conditional assembly
- Automatic procedure/subroutine handling
- Symbolic data field references
- Comments for self-documenting code
- Cross reference of the symbol table
- MicroController instruction words to 32 bits wide
- Versatile object file format specification

1.2 MCCAP ASSEMBLY PROCESS

When a program is assembled with MCCAP, two types of information are produced: an assembly listing and an object module.

The main purpose of the **assembly listing** is to convey all pertinent information about the assembled program; that is, memory addresses and their machine code contents, the original source code, and any error indications. The listing may also be used as a documentation tool through the inclusion of comments. The assembly listing may be displayed on a CRT or printed on a line printer.

The **object module** is the executable machine code produced from the source code. The object module is produced in a computer-readable format.

1.3 MCCAP OPERATION

MCCAP is a two-pass assembler. This means that the source code is scanned twice. During the first pass, symbols are examined and placed in a symbol table. Certain errors may be detected during this pass and will be retained for display in the assembly listing. In the second pass, symbolic addresses are resolved, the object code is generated, and the assembly listing and object module are produced. Errors detected during the second pass are included on the assembly listing with those errors detected during the first pass.

1.4 SOURCE PROGRAM ASSEMBLY

The following steps are used in assembling source programs:

1. Write a source program.
2. Transfer the source program to a computer-readable medium.
3. Assemble the source code program using the MCCAP assembler.
4. Obtain an assembly listing and an object module.

SECTION 2

SYNTAX AND FORMAT RULES

The assembler language has a character set, vocabulary, rules of grammar and allows individuals to define new elements. The rules that describe the language are called the syntax of the language. Likewise, an assembler language also has rules of format. For a MCCAP program to be translated properly, it must be written in accordance with the rules of syntax and format.

2.1 CHARACTER SET

A MCCAP program statement may not be more than 80 characters long and must include only valid MCCAP characters. These characters consist of all alphabetic characters (the letters A-Z), all numbers (0-9) and the special symbols shown in Table 2-1. The use of any other characters will result in errors.

Table 2-1. Valid Special Symbols in MCCAP Programs

Character	Description
b̸	blank character (space)
'	single quote
,	comma
+	plus sign
-	minus sign
/	slash
$	dollar sign
*	asterisk
(	left parenthesis
)	right parenthesis
>	greater than
<	less than
@	commercial "at" sign
.	period
&	ampersand
"	double quote
#	sharp
%	percent
:	colon
;	semi-colon
=	equal
?	question mark
!	exclamation point

2.2 SYMBOLS

A symbol is a sequence of characters that may be used to represent a register, an arithmetic value, a memory address, or an I/O data field. Only the first six characters of a symbol are scanned by MCCAP. Any remaining characters in a symbol will be treated as documentation. **The first character of a symbol must be alphabetic.** Any other character may be alphabetic or numeric. The use of special characters or imbedded blanks within a symbol will result in an error indication.

The number of characters in a symbol and the number of symbols in the symbol table (usually 500) may be modified during the installation of MCCAP. (Refer to MCCAP Installation and Maintenance Manual for details.)

Example 2-1. Examples of Symbols

LOOP1	
GOBACK	
TABPTRS	(MCCAP recognizes this as TABPTR)
LOOP#	(invalid: special character used)
2NDTRY	(invalid: starts with a numeric)
GO BACK	(invalid: imbedded blank)

2.3 RESERVED SYMBOLS

As shown in Table 2-2, the assembler has 18 symbols that are internally defined to save the user the necessity of defining them in each program. Typically, these symbols are used quite frequently, but they are not required.

Table 2-2. Reserved Symbols and Their Values

		Octal	8X300	8X305
Symbols	Register	Value	Usage	Usage
AUX	Auxiliary Reg.	0	S,D	S,D
R1	Register 1	1	S,D	S,D
R2	Register 2	2	S,D	S,D
R3	Register 3	3	S,D	S,D
R4	Register 4	4	S,D	S,D
R5	Register 5	5	S,D	S,D
R6	Register 6	6	S,D	S,D
IVL or R7	Left Bank Address Reg.	7	D Only	S,D
OVF	Overflow Reg.	10	S Only	S Only
R11	Register 11	11	S,D	S,D
R12	Register 12	12	---	S,D
R13	Register 13	13	---	S,D
R14	Register 14	14	---	S,D
R15	Register 15	15	---	S,D
R16	Register 16	16	---	S,D
IVR or R17	Right Bank Address Reg.	17	D Only	S,D

S= Source, D= Destination, ---= Invalid

2.4 CONSTANTS

MCCAP recognizes four types of **numeric constants:** decimal, octal, binary and hexadecimal. These are defined as a sequence of numeric characters optionally preceded by a plus or a minus sign and followed by an alphabetic descriptor that indicates the type. If unsigned, the value is assumed to be positive. If no descriptor is given, the number is assumed to be decimal. The available descriptors are **B for binary, H for octal,** and **X for hexadecimal.**

Hexadecimal constants, in order not to be confused with symbols, must begin with a numeric character.

The size of a constant is limited to the field size specified by the format of the machine instruction being assembled. When a constant is negative, its two's complement representation is generated and placed in the field specified.

Example 2-2. Numeric Constants

```
  300        -1        +52      -1000
100111B   +00111B    -11110B
 7755H     +513H     -5724H
 +OBCX      4F9X      -2CFX     OACEX
```

An ASCII character may be specified as a **character constant** by enclosing the character within single quote marks. (To cause the ASCII code for the single quote mark to be generated, it must be specified by four single quote marks, that is, ''''='.) Each ASCII character converts to an 8-bit value with the high-order bit set to zero.

Example 2-3. Character Constants

```
'G'
'O'
'?'
```

2.5 EXPRESSIONS

An expression is a sequence of operands (symbols, constants, or other expressions) separated by one of the operators shown in Table 2-3.

Table 2-3. Recognized Operators

Operator	Function
+	**Plus:** produces the sum of its operands.
-	**Minus:** produces the difference between its operands, or produces the negative value of its operand when used as a unary minus.
$	**Logical AND:** produces the bit-by-bit logical product of its operands.
.R.	**Right shift:** shifts the first operand right the number of bit positions specified by the second operand. Zeros are shifted into the high-order bit and bits are "dropped off" the low-order bit.
.L.	**Left shift:** shifts the first operand left the number of bit positions specified by the second operand. Zeros are shifted into the low-order bit, and bits are "dropped off" the high-order bit.

These operators are evaluated within an expression in two levels of hierarchy. Level I operators, $, .R., and .L., are evaluated first, from left to right as they are encountered. Level 2 operators, + and -, are then evaluated left to right as they are encountered. There is **no way** to alter the level of hierarchy. That is, parentheses are **not legal delimiters** to define an order of precedence that is not as described above.

Example 2-4. Expression Evaluation

Expression	Algebraic Equivalent
IN.L.A.-B$C	(IN.L.A.)-(B$C)
-A.R.4+B.L.3$C	-(A.R.4)+((B.L.3)$C)
A.R.B.L.C.+D$E	((A.R.B).L.C)+(D$E)

2.6 PROGRAM FORMAT

A complete program is composed of one or more program segments. The first program segment must be the main program, the one in which execution begins.

Procedures (subroutines) are program segments which perform a specific function and which may be executed from several points within the main program or other procedures. By creating the required function as a procedure, the statements associated with that function need be coded only once and then called out as needed.

To transfer to a procedure for execution and then return to the original program, "call" and "return" statements are provided in MCCAP.

The main program starts with a program title statement (PROG) and ends with the appearance of a procedure title statement (PROC) or a program END statement, if no procedures exist. Procedures begin with a procedure title statement (PROC) and are terminated by a procedure END statement. The complete program must be terminated by a program END statement. Only listing control and comment statements may appear

1. before the program title statement (PROG),
2. between a procedure END statement and the next procedure title statement (PROC), or
3. between a procedure END statement and the program END statement.

Example 2-5. General Program Organization

```
PROG name1    (Program Title Statement)
    .
    .
(directives, declarations, executable statements, call statements,
 and comments)
    .
    .
PROC name2    (Procedure Title Statement)
    .
    .
(directives, declarations, executable statements, call and return
 statements, and comments)
    .
    .
END name2     (Procedure End Statement)
PROC name3    (Procedure Title Statement)
    .
    .
(directives, declarations, executable statements, call and return
 statements, and comments)
    .
    .
END name3     (Procedure End Statement)
END name1     (Program End Statement)
```

2.7 STATEMENT FORMAT

MCCAP statements will always follow the general format:

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
field	field	field	field	field

In this manual each statement is explained in terms of this format, showing what data, if any, must appear in the various fields.

Each statement is written as an 80-column free-form image without regard for spacing other than that required to delimit one field from another. Logical columns 73-80 are simply reproduced on the assembly listing without processing. If desired, these columns may be used for sequence numbers, as shown in Appendix B.

The **label field** generally assigns values to symbols. If present, the label field must begin in logical column one.

The **operation field** specifies an executable statement, an assembler declaration, or an assembler directive. The operation field must either begin after column one or be separated from the label field by one or more blanks.

The **operand field** specifies operands for the code in the operation field. The operand field, if present, is separated from the operation field by at least one blank.

The **extension field** specifies code to be generated for parts of the microprocessor system other than the 8X300/8X305. The extension field, if present, is separated from the operand field by a slash.

The **comment field** enables the programmer to enter a message stating the purpose or intent of a statement or a group of statements. The comment field must be separated from the last **required** field of a statement by one or more blanks.

2.8 COMMENT STATEMENTS

A comment statement is a complete line dedicated to a message solely for documentation purposes. It is not processed by the assembler program but is merely reproduced on the assembly listing. A comment statement is indicated by beginning the line with an asterisk in the first column.

Example 2-6. Comment Statements

```
*  DATA AND ADDRESS DECLARATIONS
*  MACRO DEFINITIONS
*  MAIN PROGRAM
```

(Taken from lines 10, 61, and 77 of Appendix B.)

SYMBOLIC REFERENCES

When writing programs in MCCAP assembler language, symbolic references may be used to relieve the programmer of keeping track of absolute addresses and values, therefore reducing programming time. MCCAP recognizes four different types of symbolic references:

1. Location counter
2. Program storage
3. Data fields (typically divided into working storage addresses and I/O addresses)
4. Values (constants and variables)

Figure 3-1 depicts the two areas which may be addressed symbolically in a typical 8X300/8X305 system: program storage and I/O data fields (I/O ports, RAMs, peripherals, etc.).

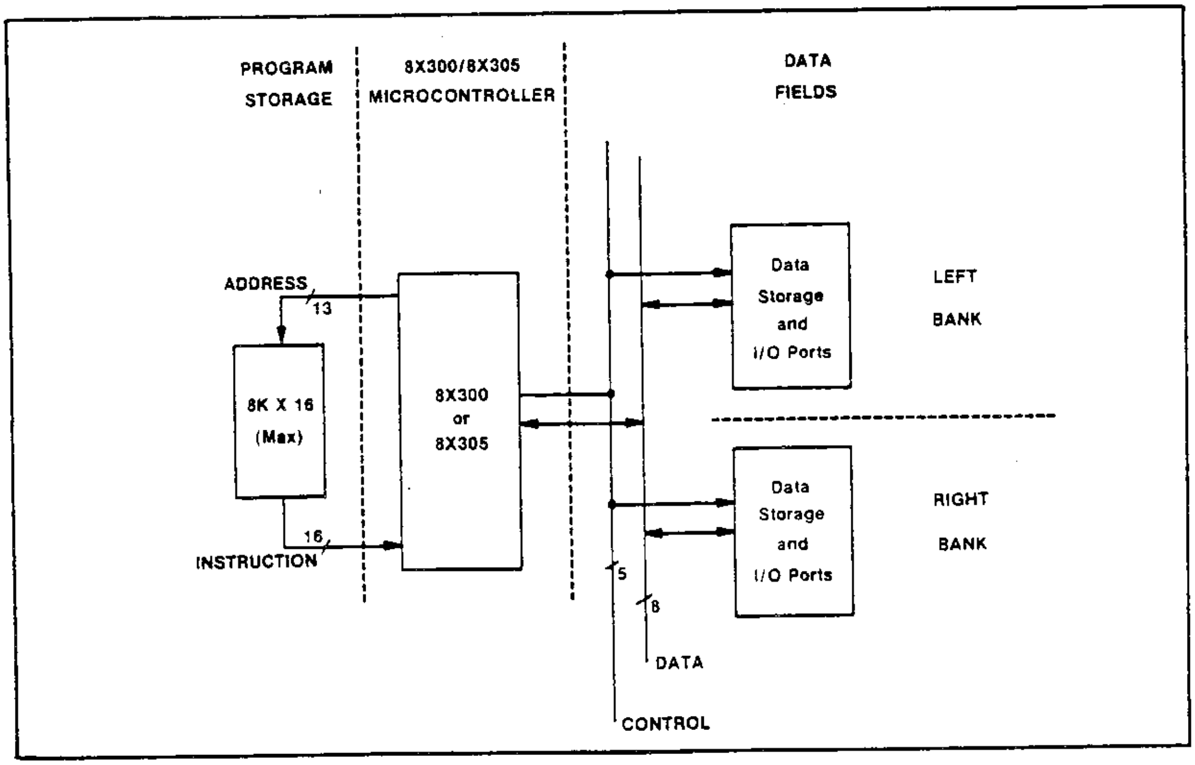


Figure 3-1. Typical 8X300/8X305 Configuration

3.1 ASSEMBLY LOCATION COUNTER

During the assembly process, MCCAP maintains a counter which always contains the address of the current program storage location for which machine code is being assembled. This counter is called the **location counter.** The special character * is the symbolic name of the location counter and it may be used like any other symbol, except that it may **not** be used as such in the label field (an * in column I represents a comment). When using the *, the programmer may think of it as expressing the idea "*" = "this location".

The symbol * is the **only** valid symbol containing a special character that the assembler recognizes.

Example 3-1. Non-Labeled Reference

The use of a * in a program is shown as follows:

```
NZT      23H,4,*+6
RTN
LOOPCT   R5
SEL      DISP1
LOOPCT   DISP1
SEL      DISP2
LOOPCT   DISP2
```

(Taken from lines 229 through 235 of Appendix B.)

The *+6 in line 229 refers to "this location plus six", which is line 235.

3.2 PROGRAM STORAGE SYMBOLIC ADDRESSES

When writing a program, the programmer can optionally place a symbol in the label field of any of the executable statements. The assembler, upon detecting the symbol, assigns the value of the location counter to that symbol. The symbol can then be used in the operand field of any instruction in that program segment to reference the address of the statement in whose label field it appears. The important concept is that the absolute program storage address of an executable statement need not be known when writing in MCCAP; only a symbol is needed to reference the location of that statement.

Example 3-2. Labeled Reference

```
LAST     HALT
```

(Taken from line 91 of Appendix B.)

MCCAP also recognizes **relative addressing** of program locations, which is the use of label field symbols as "landmarks" to other executable statements nearby.

Forward referencing, referring to a symbol prior to its appearance in source code, is also valid in MCCAP but **only** when referencing symbols in label fields of executable statements. All other forward references will result in error indications.

Example 3-3. Relative Addressing

```
START  NOP
       XMIT    0,R1
       XMIT    0,R2
       LOOK    DSTAT,R1
STC    CALL    ARITH
       CALL    MOVMNT
       CALL    TRNSMT
       CALL    EXECT
       LOOPCT  R6
       NZT     OVF,START+3
```

(Taken from lines 81 through 90 of Appendix B.)

The expression START+3 in line 90 refers to three instructions after the statement with a label field of START, which would point to line 84.

3.3 DATA FIELD SYMBOLIC ADDRESSES

In addition to recognizing program storage address symbols, MCCAP recognizes data field address symbols as the operands of executable statements. Whereas program storage symbols are defined and recognized by their appearance in the label field of an executable statement, data field address symbols **must be defined separately** by the programmer in declaration statements prior to being used in any other source statements.

Further explanation is provided in Section 5 under LIV and RIV declaration statements.

3.4 SYMBOLIC VALUES

Assigning constant or variable values to symbols is another type of symbolic referencing in MCCAP. These constants or variables are declared in a fashion similar to that described above for data field symbols. Value symbols **must be defined prior** to being used in any executable statement.

Further explanation is provided in Section 5 under EQU and SET declaration statements.

3.5 GENERAL RULES

The following are additional rules which apply to symbolic references in MCCAP programs. Failure to adhere to these will result in error indications.

1. The program name must appear **only** in the program title and end statements.
2. Procedure and entry point names are global to the entire program.
3. Symbols declared within the main program segment are global to the entire program.
4. Symbols declared within a procedure by any declaration except SET are local to that procedure.
5. Symbols declared **anywhere** in a program by a SET declaration are global.
6. Control storage symbolic addresses are local to the program segment in which they appear.

Table 3-1. Accessibility of Symbol References

Statement Type	Main Program	Procedure (Subroutine)	Main Program Macro Call	Procedure Macro Call
EQU, LIV, RIV	Global	Local	Global	Local
SET	Global	Global	Global	Global
Directives	Error	Error	Error	Error
Executable	Local	Local	Local	Local

EXTENDED INSTRUCTIONS

The MCCAP Assembler assists the user with generating not only the 16-bit 8X300/8X305 instructions, but also an additional sixteen bits of code. These extensions specify code to be used for controlling parts of the microprocessor system other than the 8X300/8X305 instructions. They are addressed simultaneously with the 8X300/8X305 instructions and are used for the hardware selection of I/O ports or working storage. This technique reduces the program length and increases throughput of the system. Further descriptions of their usage are found in the 8X300/8X305 applications literature; here we will simply discuss the generation of these instruction extensions by MCCAP.

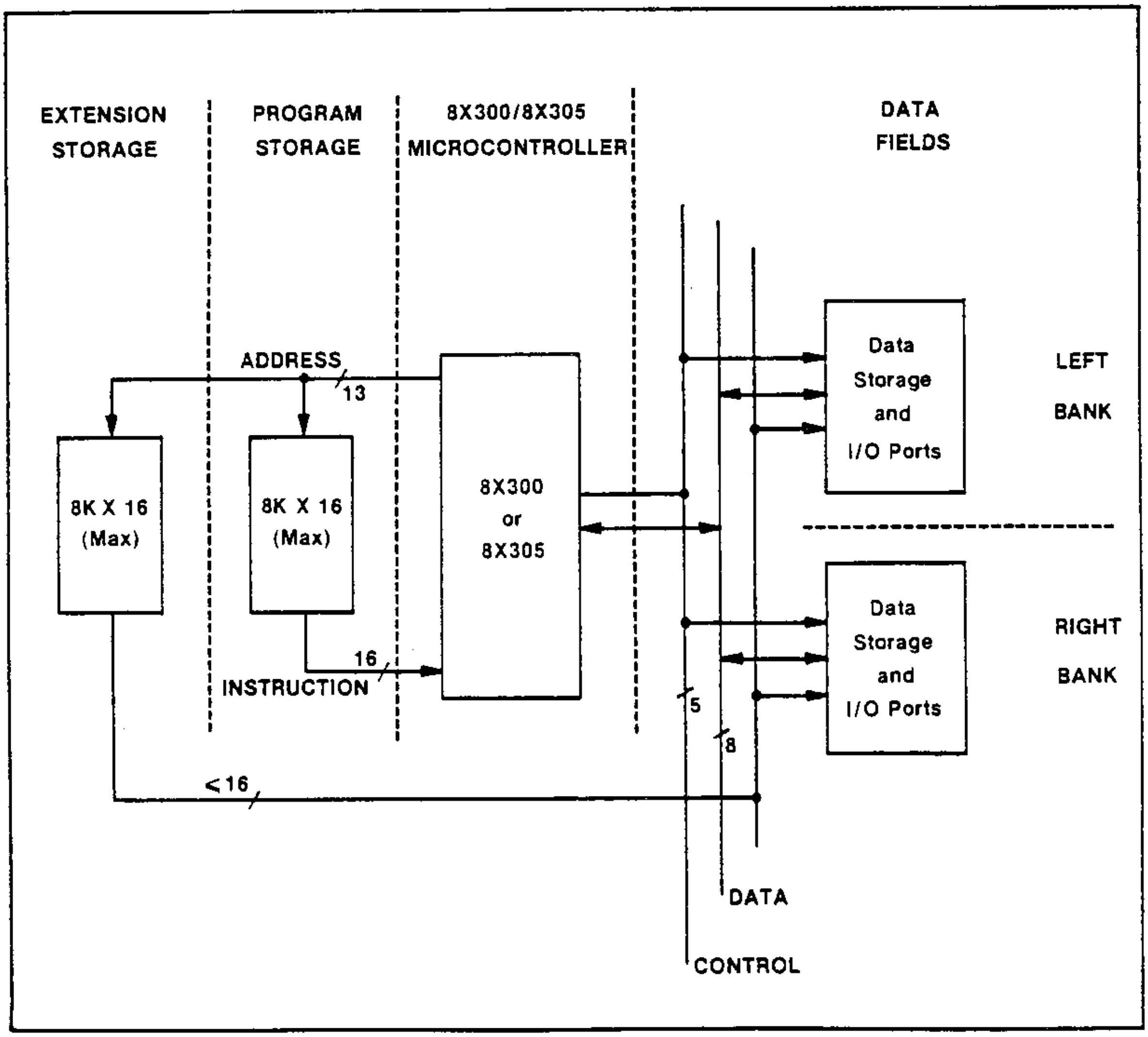


Figure 4-1. Typical Extended 8X300/8X305 Configuration

The DEF directive allows the user to specify as many as sixteen additional fields with a total extension size of sixteen bits. During assembly these fields may be filled with any expression allowable by the assembler. The result will be an object module containing bit patterns which may then be placed into a PROM.

The sample DEF directive shown in Example 4-1 specifies three additional fields. The first is four bits in length and the remaining two are three bits each. Note that the second field has a default value of 2. Because there are ten bits defined, the actual object module will contain twelve bits since only 4- and 8-bit object modules may be produced. The two right-most bits will be set to zero. Also the first field will be truncated to four bits.

Example 4-1. Use of Instruction Extensions

```
            DEF     -4,3(2),3
     IVI    LIV     35
            MOVE    AUX,R1/IV1,1,7
              .
              .
              .
            HALT    /2,4,4
```

The instruction extension of the MOVE command will consist of a 4-bit field containing the lower four bits of the address of IVI, a 3-bit field with the value 1, and another 3-bit field with a value of 7. The actual bit pattern would be $33C_{16}$ (0011001111_2 plus the two low-order zeros). If the user had specified

```
            MOVE AUX,R1/IV1,,7
```

the extended bit pattern would be $35C_{16}$ (0011010111_2). In this case the second field which was not specified in the source statement assumes the value of 2 which was specified as the default in the DEF directive.

The statement

```
            MOVE AUX,RI/IVI
```

would use the default value of 2 for the second field and the default value of 0 for the third field, giving a bit pattern of 340_{16} (0011010000_2) for the extension.

To define instruction extensions during assembly, the user merely places a slash after the standard 8X300/8X305 instruction and specifies the values to be placed into the fields as specified in the DEF directive. For those instructions that do not contain an operand field, the instruction extension will follow the operator directly (with the intervening slash, of course). The user need not specify each field of an extension or even specify any fields. Source statements without an explicit extension field or with only the slash following the 8X300/8X305 instruction will generate an extension that consists of only the default values specified in the DEF statement.

Only standard 8X300/8X305 instructions that generate code (executable statements) may have instruction extensions attached. They may not be specified for directives. An exception to this is the END statement. An instruction extension specified on the END statement for the program will be used as the extension for any instructions in the return jump table.

SECTION 5

ASSEMBLER DECLARATIONS

Declaration statements are used to assign values or addresses to symbols. References to the symbol so declared use the assigned values or addresses as required by the context in which the symbol is used. Assembler declarations do not generate any object code.

The declarations are EQU, SET, LIV, and RIV.

5.1 EQU — DEFINE A CONSTANT

The EQU statement assigns a value to the symbol in the label field, which may subsequently be used in the operand field of any other statement.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	EQU	expression	none	statement

Where:

"symbol". . . . is any valid symbol not previously defined as local to this program segment or global to the entire program.

"expression" . . is any valid expression which uses only pre-defined symbols.

Example 5-1. Use of EQU Statements

```
DEC       EQU       -1
SINMSK    EQU       10000000B
OEMASK    EQU       1B
LSMASK    EQU       7H
SSMASK    EQU       LSMASK.L.3
MSMASK    EQU       LSMASK.R.1.L.6
ROT       EQU       3
```

(Taken from lines 16 through 22 of Appendix B.)

5.2 SET — DEFINE OR REDEFINE A CONSTANT

The SET directive is identical to the EQU directive, except that the symbol defined by the SET directive may be redefined later in the program by another SET directive. Any attempt to redefine a symbol defined by the SET statement in any manner **other than by another SET statement** will result in an error indication.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	SET	expression	none	statement

Where:

"symbol". . . . is any valid symbol not previously defined as local to this program segment or global to the entire program.

"expression" . . is any valid expression which uses only pre-defined symbols.

Example 5-2. Use of SET Statements

```
VAL1        SET         0
VAL2        SET         1
VAL3        SET         2
VAL4        SET         3
VAL1        SET         VAL1+5
VAL2        SET         VAL2+5
VAL3        SET         VAL3+5
VAL4        SET         VAL4+5
```

(Taken from lines 24 through 27 and 217 through 220 of Appendix B.)

5.3 LIV — DEFINE A LEFT BANK DATA FIELD VARIABLE

The LIV declaration assigns a symbolic name to a **left bank** data field and defines the address, position, and precision (length) of that variable.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	LIV	byte,bit,length	none	statement

Where:

"symbol". . . . is any valid symbol not previously defined as local to this program segment or global to the entire program.

"byte", "bit",. . and "length" are constants, symbols or expressions. Any symbols used in an expression must be previously defined. "byte" represents the address, and must evaluate to less than 256; "bit" represents the least significant bit of the variable, and must evaluate to less than 8; and "length" represents the number of bits in the variable, and must evaluate to less than or equal to 8. Values greater than these will result in an error indication. It is also required that "length" be less than or equal to "bit"+1.

If "length" is not specified, it has a default value of 1. If "bit" is not specified, "bit" has a default value of 7 and "length" has a default value of 1. For example: IN1 LIV 10 is the same as IN1 LIV 10,7,1. The use of an expression for "byte" allows data field variables to be defined relative to each other, for example, if A LIV 10,7,8, then B LIV A+1,7,8 is equivalent to B LIV 11,7,8.

When "symbol" is used in a subsequent statement as a source or destination address, the appropriate information "bit" and "length" are used. However, when "symbol" is used as part of the expression, **it has only the value given by "byte".**

Example 5-3. Use of LIV Statements

```
DISC1     LIV       11H,7,8
DSTAT     LIV       DISC1,0
DSCLOK    LIV       DISC1,5
DRDWR     LIV       DISC1,6
DRDAT     LIV       DISC1
```

(Taken from lines 29 through 33 of Appendix B.)

5.4 RIV — DEFINE A RIGHT BANK DATA FIELD VARIABLE

The RIV declaration assigns symbolic names to **right bank** data field variables, but is otherwise identical to the LIV declaration.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	RIV	byte,bit,length	none	statement

Where:
"symbol", "byte", "bit" and "length", have identical meaning to those used in the LIV declaration.

Example 5-4. Use of RIV Statements

```
DATA1     RIV       100H,7,8
D1SIGN    RIV       DATA1,0
D1ODEV    RIV       DATA1
DATA2     RIV       DATA1+1,7,8
D2SIGN    RIV       DATA2,0
D2ODEV    RIV       DATA2
```

(Taken from lines 36 through 41 of Appendix B.)

ASSEMBLER DIRECTIVES

An assembler directive is a statement that is not translated into object code, but rather is interpreted as a command to the assembler program to perform some action during the assembly process. By using directives, the programmer may divide the program into logical segments, format the output listing, or specify the format of the object module. The directives are:

PROG	ORG	LIST	IF
PROC	OBJ	NLIST	ENDIF
ENTRY	DEF	EJCT	8X300
END	PROM	SPAC	8X305

6.1 PROG — PROGRAM TITLE STATEMENT

The PROG statement introduces and names the main program. With the exception of listing control directives and comments, it **must be the first statement** of a program and may appear only once.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	PROG	name	none	statement

Where:
"name". . . . . is any valid symbol. It must not appear in any other assembler statement except the main program END statement.

Example 6-1. Use of PROG Statement

```
        PROG        SAMPLE
```

(Taken from line 7 of Appendix B.)

6.2 PROC — PROCEDURE TITLE STATEMENT

The PROC directive begins and names a procedure. A PROC directive may only appear after another procedure has terminated, or after the last executable or declaration statement of the main program segment. The main program segment is considered to be ended upon the occurrence of the first PROC directive.

Since other segments may call this procedure name, it is a global name known to the entire program. Use of the PROC name in the operand field of a procedure CALL statement calls the procedure into execution.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	PROC	name	none	statement

Where:
"name". . . . . is any valid symbol which **must not** be used anywhere else in the program, except as the operand of the procedure CALL and END statements.

Example 6-2. Use of PROC Statements

```
PROC      ARITH
PROC      EXECT
```

(Taken from lines 98 and 163 of Appendix B.)

6.3 ENTRY — SECONDARY ENTRY POINT INTO A PROCEDURE

The ENTRY directive specifies an additional entry point to a procedure. Calls to the procedure by additional names cause execution to start at the first executable statement following the ENTRY directive which defined that additional name. A procedure may contain more than one additional entry point.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	ENTRY	name	none	statement

Where:
"name". . . . . is any valid symbol that **must not** be used anywhere else in the program, except as the operand of the procedure CALL statements.

Example 6-3. Use of ENTRY Statements

```
ENTRY     MOVMNT
ENTRY     TRNSMT
```

(Taken from lines 132 and 143 of Appendix B.)

6.4 END — END THE PROGRAM OR A PROCEDURE

The END directive is required to terminate a procedure or the complete program. If an extension field is added to the END statement of the main program, the extension code will be added to the return jump table that is generated at the end of the program.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	END	name	/code	statement

Where:

"name" . . . . is the same name as was used in the title statement for this program segment (PROG or PROC).

"code". . . . . is an **optional** series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 6-4. Use of END Statements

```
END         NONZXF
END         SAMPLE
```

(Taken from lines 237 and 239 of Appendix B.)

```
END         MAIN/0,0,0,0
```

(Taken from line 284 of Appendix D.)

CAUTION

If "name" is not used in the PROC or PROG statement, or no name appears, **an error will be indicated** and the program terminated.

6.5 ORG — SET LOCATION COUNTER

The ORG directive changes the value of the location counter either conditionally or unconditionally. The first form of the ORG directive **unconditionally** changes the value of the location counter to the value indicated by "address".

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	ORG	address	none	statement

Where:

"address" . . . is any constant, valid symbol, or valid expression which evaluates to a value between 0 and 8191. If the value is outside this range, an error is indicated and the location counter is not changed.

Example 6-5. Use of the Unconditional ORG Statement

```
ORG 0
```

(Taken from line 80 of Appendix B.)

The second form of the ORG directive **conditionally** sets the location counter to the next page or segment boundary if there are insufficient locations in the current page or segment. This is determined by evaluating the operands "space" and "page size".

A conditional ORG may be necessary when using NZT or XEC instructions. If adding the value "space-1" to the location counter would move the location counter into the next page or segment, then the location counter will be set to the beginning of the next page. If the location counter would not move into the next page, then this statement will have no effect on the location counter.

If the location counter is moved to the next page, a jump instruction to that address is inserted in the program at the point where the ORG statement appeared. This added instruction assures the sequential flow of the program.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	ORG	space,page size	none	statement

Where:

"space" . . . . is any constant, valid symbol or valid expression. "space" specifies the number of program locations which **must remain** in this page or segment.

"page size" . . is a constant or valid symbol, or valid expression that evaluates to 256 or 32 (the page and segment sizes of control storage). If "space" is equal to "page size", this statement is an unconditional alignment to the next boundary of length "page size".

Example 6-6. Use of Conditional ORG Statements

```
ORG         256,256
ORG         5,32
ORG         7,32
ORG         16,256
```

(Taken from lines 100, 184, 189, and 221 of Appendix B. Reference also the results of assembling these lines in Appendix C.)

CAUTION

It is the **programmer's responsibility** to avoid setting the location counter to an address which already contains a previously assembled instruction, since **no error is indicated** if this is done.

6.6 OBJ — SPECIFY AN OBJECT FORMAT

The OBJ directive is used to specify to the assembler the format of the object module for both standard 8X300/8X305 instructions and for any instruction extensions. In addition, this directive allows the user to fill any unused addresses in the program.

The output format for an object module may be specified as blocked or unblocked. A **blocked format** implies that when the object module is produced, all words, including unused locations, will be output. The size of the block is specified by the PROM directive. A gap in the program due to an ORG directive will cause the object module to be output if the address is moved beyond the range of the block. If the program is smaller than the PROM size, a complete block will be output.

An **unblocked format** will produce an object module only when the module size specified in the PROM directive has been satisfied, if a program gap occurs, and/or when the program ends.

NOTE

> Object modules produced in the MCSIM format are always unblocked even if the user specifies otherwise. If the ASCII-Hex word format is specified for either the 8X300/-8X305 instructions or the instruction extensions, it will be used for both modules.

A complete description of each format is given in Section 9.3. In the absence of a given specifications, there are three independent defaults:
1. 8X300/8X305 instructions are output in MCSIM format,
2. extensions are output in ASCII-Hex (Space) format, and
3. output is blocked and filled in with NOP's.

If MCSIM format is the case, the output will be unblocked.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	OBJ	format,type	/format,type	statement

Where:

"format". . . . is the object module format required. This may be specified as any of the following characters:
M for MCSIM format,
N for BNPF format,
R for ASCII-Hex (Quote) format,
D for ASCII-Hex (Space) format,
S for ASCII-Hex Word format, or
Z to suppress output of the object module.

"type" . . . . . is optional and determines the type of blocking for the object module. One of the following characters can be specified:
H for block format filled out with HALT's,
B for blocked format filled out with NOP's (all zeros),
O for blocked format filled out with all one's, or
U for unblocked format.

Example 6-7. Use of OBJ Statements

```
        OBJ         M
```

(Taken from line 57 of Appendix B.)

```
        OBJ         R,H/R
```

(Taken from line 12 of Appendix D.)

6.7 IF, ENDIF — CONDITIONAL ASSEMBLY

The conditional assembly statement, IF, allows the programmer to control whether or not certain source statements are assembled. When an IF statement is encountered, the associated expression is evaluated to be either true (not zero) or false (zero). If true, the following source statements are processed until an ENDIF is encountered. If false, the source statements following the IF are **not processed** until an ENDIF is encountered, at which point normal processing resumes.

Conditional assembly constructs may be nested but may not be overlapped; that is, the end of an inner IF construct must be encountered before the end of the outer IF construct is encountered.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	IF	expression	none	statement

Where:
"expression" . . is a constant, a valid symbol, or a valid expression. Any symbols used in "expression" must be previously defined.

The ENDIF directive terminates the source statements subject to conditional assembly. In the case of the nested IF statements, ENDIF is paired with the most recent IF statement.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	ENDIF	none	none	statement

Example 6-8. Use of IF and ENDIF Statements

```
        IF          FINAL
        LIST        I,M,S,O
        OBJ         M
        ENDIF
```

(Taken from lines 55 through 58 of Appendix B.)

6.8 LIST — LIST THE SPECIFIED ELEMENTS

The LIST directive causes files to be generated for listing or punching according to the options specified.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	LIST	options	none	statement

Where:

"options". . . . indicate the output required. The following characters specify the necessary combinations.

S for listing source statements (not including macro expansions and unassembled conditionals).

O for producing output object code.

M for listing statements generated by macro calls.

I for listing statements which would not be assembled due to conditional assembly (IF).

T for listing symbol table.

X for listing cross reference table.

A For printing the addresses and object code in absolute hexadecimal numbers instead of MCSIM format. (Four digits for address and four digits for object code.)

The default options are S, O, and T. If both X and T options are specified, the X option will override.

Example 6-9. Use of the LIST Statement

```
            LIST        I,M,S,O
(Taken from line 56 of Appendix  .)
```

6.9 NLIST — SUPPRESS LISTING OF ELEMENTS

The NLIST directive is the same as the LIST directive, except the specified options **are not produced** for listing or punching. This directive is not printed on the listing if S is an option.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	NLIST	options	none	statement

Where:

"options". . . . indicate the output to be suppressed. The following characters are used for specifying the necessary combinations.

S for not listing source statements (not including macro expansions and unassembled conditionals).

O for not producing output object code.

M for not listing statements generated by macro calls.

I for not listing statements which would not be assembled due to conditional assembly (IF).

T for not listing symbol table.

X for not listing cross reference table. (This option overrides the T option if both are specified.)

A For printing the addresses and object code in MCSIM format instead of absolute hexadecimal.

Example 6-10. Use of the NLIST Statement

```
        NLIST       S,O
```

(Taken from line 52 of Appendix B.)

NOTE

Assembly lines with errors are **always listed,** regardless of the options specified by an NLIST. Also, an NLIST of the source (S) overrides any LIST of macros or unassembled conditionals (M and I), but only until a LIST S is executed.

6.10 EJCT — EJECT THE LISTING PAGE

EJCT is a listing control directive which causes the output listing to be advanced to the next page, thus making it possible to format the assembly listing. For example, each procedure could start on a new page of the assembly listing. EJCT is **not printed** on the assembly listing.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	EJCT	none	none	statement

6.11 SPAC — LINE FEED THE LISTING

SPAC is a listing control directive which inserts blank lines in the assembly listing. The SPAC statement is not printed on the assembly listing.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	SPAC	expression	none	statement

Where:

"expression" . . is a constant, a valid symbol, or a valid expression (constants typically are used). "expression" is evaluated to determine the number of blank lines to insert in the listing. There is **no default** "expression".

Example 6-11. Use of SPAC Statements

```
        SPAC        1
        SPAC        12
```

(Taken from lines 6 and 238 of Appendix B.)

6.12 PROM — SPECIFY PROM SIZE

The PROM directive is used to specify the widths and depth of the PROMs used for the assembled object code. Only those PROMs specified by this directive will be included in the object module. Thus if 8 bits are specified for a PROM and the DEF directive defines an extension to contain 16 bits, only 8 bits will be included in the object module.

This directive must appear prior to any executable statements.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	PROM	d,w,w...	/d,w,w...	statement

Where:

"d" . . . . . specifies the depth of the PROM used and hence the size of the object module format that will be used. "d" may be specified as 128, 256, 512, 1024, 2048. Any other value will generate an error indication. The depth of extension PROMs may differ from that the 8X300/8X305 instruction PROMs.

"w" . . . . . specifies the width of the PROM and hence the size of the object module format that will be used. A width should be specified for each PROM used and may be specified as either 4 bits or 8 bits. Note that some object module formats, e.g. MCSIM, will always work with a 16-bit value regardless of the width specified in this directive. The total width of all PROMs used for 8X300/8X305 instructions must be exactly 16 bits. The width of all PROMs used for the instruction extensions may be any value.

NOTE

The default PROM sizes are a depth of 512 and a width of 8. The user need only specify the extended instruction PROM sizes if desired.

Example 6-12. Use of the PROM Statement

```
PROM        128,8,8/256,4,8,4
```

(Taken from line 11 of Appendix D.)

6.13 DEF — DEFINE INSTRUCTION EXTENSION FIELDS

This directive is used to specify operand fields and default values for instruction extensions. The fields define output module bit positions in order from left to right (bit 0 to 15). This directive may define up to 16 fields with a total length of 16 bits. The length in bits of each field is specified along with an optional default field value and an error checking flag.

No extensions can be generated unless the format has been specified by this directive. This directive must appear before any executable instructions.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	DEF	I(v),I(v),...	none	statement

Where:

"I" . . . . . specifies the number of bits in the field. Any values placed in this field during assembly will be checked to ensure that it fits into the number of bits specified. If not, the value will be truncated and an error indication output. If "I" is preceded by a minus sign, **error checking will not take place.** This is useful when a field will contain the low-order bits of a program address.

"v" . . . . . specifies the default value for the field. The default value must fit within the number of bits specified or an error will be indicated. If no default value is specified, it is assumed to be zero.

Example 6-13. Use of the DEF Statement

```
DEF        4(5),-8(2),2,2
```

(Taken from line 10 of Appendix D.)

6.14 8X300/8X305 MICROCONTROLLER SPECIFIERS

The 8X300 directive specifies assembly of 8X300 instructions. The 8X305 directive specifies assembly of 8X305 instructions. (Use of XML, XMR or R12-R16 cause error diagnostics if 8X305 is not specified.)

NOTE

If neither is specified, 8X300 will be the default option.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	8X300	none	none	statement

Example 6-14. Use of MicroController Specifiers

```
8X300
8X305
```

(Taken from lines 246 and 243 of Appendix D.)

SECTION 7

EXECUTABLE STATEMENTS

The statements described in this section result in object code that is executable by the 8X300/8X305 MicroController. There are fifteen:

MOVE
ADD
AND
XOR
NZT
XEC
JMP
XML
XMIT
HALT
NOP
XMR
CALL
RTN
SEL

It is not intended in this section to describe the operation or execution of the 8X300/8X305 machine codes, but rather **to describe the MCCAP formats.** Machine code information is contained in Appendix D for reference; however, more specific information about operation and execution may be obtained from the available 8X300/8X305 and other peripheral technical and applications literature.

NOTE

There are certain notes generally applicable to each of these statements. They are listed here and subsequently referenced whenever relevant.

1. If a source "s" or destination "d" field is specified by a constant, the value of that constant is evaluated as follows:

    a. Registers are designated by values less than 17_8.
    b. Left bank data fields are designated by values between 20_8 and 27_8.
    c. Right bank data fields are designated by values between 30_8 and 37_8.

    If the value is greater than 37_8, an error is indicated and the value is treated as modulo 40_8.

2. If the value of the expression in the operand field is too large to fit in the 8-bit immediate field (in the case of a register) or 5-bit immediate field (in the case of an I/O data field) of the object code, an error is indicated and the value is truncated (high-order bits dropped) to fit into the appropriate field length.

3. If the high-order five bits (in the case of a register) or eight bits (in the case of an I/O data field) of an indexed value (expression+index) are not equal to the corresponding bits of the location counter, a paging error is indicated.

4. If an optional value within a field is omitted, the associated punctuation must also be eliminated to prevent errors. For example, if a length or size is omitted, the comma preceding it must also be omitted from the statement.

7.1 MOVE, ADD, AND, XOR — DATA MANIPULATION

The MOVE, ADD, AND, and XOR symbolic codes may be written in any of three formats, as required.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	op	s,d	/code	statement

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	op	s(r),d	/code	statement

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	op	s,len,d	/code	statement

Where:

"symbol". . . . is any valid symbol that is not defined as local to the current program segment or global to the entire program.

"op". . . . . . is one of the four data manipulation commands: MOVE, ADD, AND, XOR.

"s" . . . . . . is an I/O data field variable or any of the 8X300/8X305 internal registers that may be used as **source operands.** "s" may be a symbol predefined by a declaration or it may be a constant. (See note 1.)

"d" . . . . . . is an I/O data field variable or any of the 8X300/8X305 internal registers that may be used as **destination operands.** "d" may be a symbol predefined by a declaration or it may be a constant. (See note 1.)

"len" . . . . . is an **optional** value that specifies the explicit length of an I/O data field. This may be used to override the "length" of a LIV or RIV declaration. More typically, it is used when no LIV or RIV declaration is made and the source or destination operand is given by a constant. If "len" is greater than 8, an error is indicated and the value is taken as modulo 8. A "len" of 8 generates a value of 0. The default value of "len" is 0 (full byte). (See note 4.)

"r" . . . . . . is an **optional** value that specifies the number of bit positions to right rotate the source register **when both source and destination operands are registers.** The default value for "r" is 0.

"code". . . . . is an **optional** series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 7-1. Data Manipulation Commands

```
STMV      MOVE        DSTAT,R1
          MOVE        24H,LEN,R2
          MOVE        DRDAT,LEN,R3
```

(Taken from lines 134 through 136 of Appendix B.)

```
STAD      ADD         R1,R1
          ADD         2,2
          ADD         R3(ROT),R3
```

(Taken from lines 107 through 109 of Appendix B.)

```
STAND     AND         R1,DATA1
          AND         R2,LEN,DATA2
          AND         R3,LEN,37H
          AND         4(4),AUX
```

(Taken from lines 112, 115, 118, and 121 of Appendix B.)

```
STOR      XOR         DATA1,DATA1
          XOR         DATA2,3,DATA2
          XOR         37H,LEN,37H
          XOR         33H,LEN,37H
```

(Taken from lines 124, 126, 128, and 130 of Appendix B.)

```
          MOVE        AUX,AUX/7
          MOVE        R1,R11/1,2,,3
          MOVE        R1,R5/1111B,-1,2
          MOVE        R2,R1/IV3,77H
```

(Taken from lines 40, 43, 47 and 51 of Appendix D.)

CAUTION

Addressing the I/O data fields which are allocated to different locations in the **same** I/O bank is **not valid.** Any attempt to do so will be detected by the assembler and indicated as an error. Also, data movement between data fields allocated to different I/O banks must move full bytes or an error is indicated.

7.2 XMIT — LOAD IMMEDIATE

The XMIT instruction may be written in either of two formats, as follows:

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	XMIT	exp8,reg	/code	statement

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	XMIT	exp5,df,len	/code	statement

Where:

"symbol". . . . is any valid symbol that is **not** defined as local to the current program segment or global to the entire program.

"exp8". . . . . is any valid epxression. "exp8" is evaluated and used as the 8-bit immediate field of the object code. (See note 2.)

"exp5". . . . . is any valid expression. "exp5" is evaluated and used as the 5-bit immediate field of the object code.

"reg" . . . . . is any of the 8X300/8X305 internal registers usable as a **destination operand.** This may be a symbol or a constant. (See note 1.)

"df" . . . . . . is an I/O data field variable used as the **destination operand.** This may be a symbol defined by a LIV or RIV declaration, or it may be a constant. (See note 1.)

"len" . . . . . is an **optional** value that specifies the explicit length of an I/O data field. This may be used to override the "length" operand of a LIV or RIV declaration. More typically, it is used when the destination I/O data field variable is written as a constant. The default value of "len" is 0. (See note 4.)

"code". . . . . is an **optional** series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 7-2. Use of the XMIT Statement

```
XMIT      '!',R5
XMIT      VAL1,DISP1,LEN
XMIT      VAL2,23H,4
```

(Taken from lines 151, 153, and 154 of Appendix B.)

```
XMIT      2,R0/1,*,0
```

(Taken from line 148 of Appendix D.)

7.3 XEC — EXECUTE

The XEC instruction may be written in either of two formats, as required.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	XEC	exp8(reg),size	/code	statement

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	XEC	exp5(df,len),size	/code	statement

Where:

"symbol". . . . is any valid symbol that is not defined as local to the current program segment or global to the entire program.

"exp8". . . . . is any valid expression. "exp8" is evaluated, and is placed in the 8-bit immediate field of the object code. (See note 3.)

"exp5". . . . . is any valid expression. "exp5" is evaluated, and is placed in the 5-bit immediate field of the object code. (See note 3.)

"reg" . . . . . is any of the 8X300/8X305 internal registers usable as a **source operand.** "reg" is used as an index to "exp8" and may be represented symbolically or by a constant. (See note 1.)

"df" . . . . . . represents an I/O data field variable used as an index to "exp5". "df" may be a symbol defined by a LIV or RIV declaration, or it may be a constant. (See note 1.)

"len" . . . . . is an **optional** value that specifies the length of an I/O data field. This may be used to override the "length" operand of a LIV or RIV declaration. More typically it is used when the "df" operand is written as a constant. The default value of "len" is 0. (See note 4.)

"size" . . . . . is the **optional** table length size if the XEC is used with a jump table. The assembler checks to ensure that an XEC and its associated jump table are on the same program storage page. "size" has a default value of 1. The user specifying an XEC preceeding his jump table can obtain error checking on the table size by specifying this operand. (See note 4.)
"code". . . . . is an **optional** series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 7-3. Use of the XEC Statement

```
STXC      XEC       *+1(R6),5
TAB1      XEC       *+1(R1)
          XEC       *+1(T2PTR)
          XEC       *+1(T3PTR,2)
          XEC       *+1(T4PTR),2
          XEC       *+1(T5PTR,2),4
```

(Taken from lines 171, 178, 185, 190, 197 and 202 of Appendix B.)

```
          XEC       *+1(IV1,3)/,L12,0
```

(Taken from line 76 of Appendix D.)

7.4 NZT — NON-ZERO TRANSFER

The NZT symbolic code may be written in either of two formats, as follows:

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	NZT	reg,exp8	/code	statement

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	NZT	df,len,exp5	/code	statement

Where:
"symbol". . . . is any valid symbol that is not defined as local to the current program segment or global to the entire program.
"reg" . . . . . is any of the 8X300/8X305 internal registers usable as a **source operand.** "reg" may be a symbol or a constant. (See note 1.)
"df" . . . . . . is an I/O data field variable used as a **source operand.** "df" may be a symbol defined by a LIV or RIV declaration, or it may be a constant. (See note 1.)
"exp8". . . . . is any valid expression. "exp8" is evaluated and used as the low-order 8-bit immediate field of the object code. (See note 2.)

"exp5". . . . . is any valid expression. "exp5" is evaluated and used as the low-order 5-bit immediate field of the object code. (See note 2.)

"len" . . . . . is an **optional** value that specifies the length of an I/O data field. This may be used to override the "length" operand of a LIV or RIV declaration. More typically, it is used when the I/O data field variable is written as a constant. The default value of "len" is 0. (See note 4.)

"code". . . . . is an **optional** series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 7-4. Use of the NZT Statement

```
STNT      NZT        R5,*+8
          NZT        DISP1,*+7
          NZT        23H,4,*+6
```

(Taken from lines 223, 226, and 229 of Appendix B.)

```
          NZT        IV1,3,*/0,IV1,1,0
```

(Taken from line 110 of Appendix D.)

7.5 JMP — UNCONDITIONAL JUMP

The JMP symbolic code is written in the following format:

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	JMP	address	/code	statement

Where:

"symbol". . . . is any valid symbol that is not defined as local to the current program segment or global to the entire program.

"address" . . . is any valid address in the range 0 to 8191. If "address" is outside this range, an error is indicated and the address field of the object code will be set to the **current value** of the location counter.

"code". . . . . is an **optional** series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 7-5. Use of the JMP Statement

```
            JMP        TAB1
            JMP        DONE
```

(Taken from lines 172 and 179 of Appendix B.)

```
            JMP        8191/0,0,0,0
```

(Taken from line 85 of Appendix D.)

7.6 SEL — I/O DATA FIELD SELECTION

The SEL statement generates code which, upon execution, places the address of an I/O data field into the IVL and IVR register, as appropriate. The generated object code is equivalent to one of the following executable statements.

```
            XMIT       "df", IVL

or          XMIT       "df", IVR
```

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	SEL	df	/code	statement

Where:

"symbol". . . . is any symbol that is not defined as local to the current program segment or global to the entire program.

"df" . . . . . . is a symbol that has been defined by a LIV or RIV declaration. If "df" is not so defined, an error is indicated.

"code". . . . . is an **optional** series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 7-6. Use of SEL Statements

```
STAR        SEL        TEMP1
TAB2        SEL        TABPTRS
```

(Taken from lines 101 and 183 of Appendix B.)

```
            SEL        L12/17H,0,3,3
```

(Taken from line 87 of Appendix D.)

NOTE

In an executable statement, if an I/O data field is referenced, the address of that port must have been already placed in the IVL or IVR select register. This can be accomplished by a SEL or a XMIT. Since the assembler **cannot detect** whether or not a data field has been selected at the time it is addressed, **it is the responsibility of the programmer** to select I/O data fields before they are referenced.

7.7 CALL — PROCEDURE (SUBROUTINE) CALL

The 8X300/8X305 MicroController does not have a provision for storing the program counter before jumping to a subroutine. However, an equivalent technique is used by MCCAP to permit the use of subroutines (or procedures as they are called). Each CALL statement generates a return jump index which is loaded into register R11, then control is transferred to the subroutine. When execution reaches a RTN (return) statement, control passes to a "return jump table" which uses the value in R11 as an index to jump back to the calling program. The entries in the return jump table, which match the CALL statements, are provided automatically by MCCAP. The programmer needs only to call the subroutine and return as he would with any subroutine arrangement. Of course if he wishes to use R11 within the subroutine, he must restore it before returning. For techniques in nesting. subroutines, see the 8X300/8X305 Programming Manual. For subroutine call macros using the 8X310, see Section 8.3.

Example 7-7 illustrates the expansion of the source statements and the position of the return jump table.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	CALL	name	/code	statement

Where:

"symbol". . . . is any valid symbol that is not defined as local to the current program segment or global to the entire program.

"name" . . . . is a procedure name defined by a PROC or an ENTRY statement.

"code". . . . . is an **optional** series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 7-7. Equivalent Code for Procedure CALL's and RTN's

```
            SOURCE                     EQUIVALENT
          STATEMENTS                      CODE

          PROG MAIN
              .                            .
              .                            .
              .                            .
          CALL SUB                     XMIT 0,R11
ONE           .                        JMP  SUB
              .                            .
              .                            .
          CALL SUB                     XMIT 1,R11
TWO           .                        JMP  SUB
              .                            .
              .                            .
              .                            .
              .                            .
          PROC SUB                         .
              .                            .
              .                            .
              .                            .
          RTN                          JMP  TABL
              .                            .
              .                            .
              .                            .
          END MAIN                         .
                               TABL    XEC  *+1(R11)
                                       JMP  ONE
                                       JMP  TWO
```

For actual usage of procedures, see the programs listed in the Appendices.

A program is limited to a maximum of 255 CALL statements; more will result in a "Table Overflow" error indication.

Example 7-8. Use of the CALL Statement

```
STC       CALL        ARITH
          CALL        MOVMNT
          CALL        TRNSMT
          CALL        EXECT
```

(Taken from lines 85 through 88 of Appendix B.)

```
          CALL        PROC3/0,0
```

(Taken from line 126 of Appendix D.)

CAUTION

The programmer is responsible for saving and restoring the value of R11, if it is used within a procedure. **No error** will be indicated from a failure to do so.

7.8 RTN — PROCEDURE RETURN

The RTN statement terminates the **execution** of a procedure and causes a return of control to the calling program segment. The assembler generates a return jump table at the end of the entire program to allow for this return of control. A RTN statement causes a jump to the return jump table, which in turn contains a XEC (with an index value in R11) followed by one jump instruction for each CALL statement in the program. RTN statements are **not valid** in the main program, but **at least one** must appear in each procedure. Example 7-7 shows the equivalence between the source code and the code produced by the assembler for RTN and the return jump table.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	RTN	none	/code	statement

Where:

"symbol". . . . is any valid symbol that is not defined as local to this program segment or global to the entire program.

"code". . . . . is an **optional** series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 7-9. Use of the RTN Statement

```
DONE      RTN
```

(Taken from line 208 of Appendix B.)

```
          RTN/,,3
```

(Taken from line 277 of Appendix D.)

```
RETURN TABLE
     0173  8974
     0174  E008
     0175  E00A
     0176  E00C
     0177  E00E
     0178  E104
```

(Taken from page 8 of Appendix C.)

CAUTION

The programmer is responsible for saving and restoring the value of R11, if it is used within a procedure. **No error** will be indicated from a failure to do so.

7.9 NOP — NO OPERATION

The NOP instruction generates code which commands the 8X300/8X305 to advance to the next instruction without performing any other operation. It typically serves as a time delay. The NOP actually generates a "MOVE AUX,AUX" instruction.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	NOP	none	/code	statement

Where:

"symbol". . . . is any valid symbol that is not defined as local to the current program segment or global to the entire program.

"code". . . . . is an **optional** series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 7-10. Use of the NOP Statement

```
START      NOP
```

(Taken from line 81 of Appendix B.)

```
           NOP/0,WS2
```

(Taken from line 38 of Appendix D.)

7.10 HALT — STOP PROCESSING

The HALT instruction generates code which causes the 8X300/8X305 to stop processing and remain at the current address. The HALT instruction actually generates a "JMP *" instruction. The RESET signal of the 8X300/8X305 must be pulsed to restart the program after the execution of a HALT instruction.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	HALT	none	/code	statement

Where:

"symbol". . . . is any valid symbol that is not defined as local to the current program segment or global to the entire program.

"code". . . . . is an **optional** series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 7-11. Use of the HALT Statement

```
          LAST        HALT
```

(Taken from line 91 of Appendix B.)

```
          STOP        HALT/17H,377H,3,3
```

(Taken from line 249 of Appendix D.)

7.11 XML, XMR - LOAD IMMEDIATE TO LEFT OR RIGHT BANK

NOTE

XML or XMR cause opcode error diagnostics if 8X305 is not specified. These statements are only valid for use with the 8X305.

The XML statement generates code which, upon execution, transmits an 8-bit constant to the left bank. (Right bank for XMR.) The generated object code is equivalent to a XMIT immediate to R12 or R13 respectively.

XML	=	XMIT	IMMED, R12
XMR	=	XMIT	IMMED, R13

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	XML,XMR	immed	/code	statement

Where:

"symbol" . . . . is any valid symbol that is not defined as local to the current program segment or global to the entire program.

"immed" . . . . is an 8-bit constant.

"code" . . . . is an optional series of symbols, constants, or expressions specifying the bit patterns to be generated for placement into the extension field.

Example 7-12. Use of the XML Statement

```
          XML            2
          XMR            0FX
```

(Taken from lines 244 and 245 of Appendix D.)

SECTION 8

MACROS

A macro is a predefined sequence of source statements that can be inserted into a MCCAP program by coding only one statement, the "macro call". The predefined sequence is written in the same program and is called a "macro definition". The macro definition statements must be written prior to a call to the macro. When a macro call is encountered during assembly, the assembler locates the saved macro definition statements, copies them into the source program immediately after the macro call statement, and then assembles them normally. Each macro, once defined, may be called any number of times within a program.

The number of macros that can be defined (initially 500) may be modified during the installation of MCCAP. (Refer to MCCAP Installation and Maintenance Manual and/or the 8X300/8X305 Cross Assembler Installation Guide for 8080 based systems for details.)

Upon encountering a macro definition statement, the assembler saves the body of the definition **as it is.** The statements are not assembled, nor are they checked for errors. When the macro is called, the assembler obtains the saved definition body, places it in-line with the source code immediately following the macro call, and substitutues the actual parameters for the formal parameter symbols. At this point, MCCAP assembles these statements as if they had originally been coded in that position. Therefore, all rules for statements, expressions, and symbols are enforced **only at the point of expansion**, not at the point of definition.

Example 8-1. Macro Usage

The following demonstrates the statements used to implement macros within a program.

Macro definition as it would appear in the source code:

```
INPUT   MACRO   R,S,T,LAB        (Title Statement)
        MOVE    R,S
        XMIT    1,T
        ADD     R,S
LAB     RIV     22,3,1
        MOVE    LAB,S
        ENDM                     (Terminator)
```

Macro call as it would appear in the source code:

```
        LIST    M
        XMIT    -1,R3
        MOVE    OVF,AUX
LOOP    INPUT   R1,R2,IV1,IV2    (Macro Call)
        JMP     GO
```

Expansion of the macro call as it would appear in the assembly listing:

```
          LIST      M
          XMIT      -1,R3
          MOVE      OVF,AUX
 LOOP     INPUT     R1,R2,IV1,IV2      (Macro Call)
+         MOVE      R1,R2
+         XMIT      1,IV1
+         ADD       R1,R2
+IV2      RIV       22,3,1
+         MOVE      IV2,R2
          JMP       GO
```

NOTE

The LIST M directive is necessary to produce the expansion of the macro in the listing.

8.1 THE MACRO DEFINITION

The macro definition consists of a title statement, a body of assembly statements, and a terminator statement, as shown in Example 8-1.

8.1.1 The Title Statement

The title statement marks the beginning of a macro definition, it names the macro and provides a list of format parameters to be passed to the macro.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
name	MACRO	p1,p2,...pn	none	statement

Where:

"name" . . . . is a valid symbol that defines the name of the macro. This "name" must not be used as a symbol anywhere else in the program except in the **operation** fields of macro call statements.

"p1,p2,...pn" . . is an **optional** formal parameter list. These formal parameters can be any valid symbols. The number of formal parameters per definition is a factor of the number of characters per source code line. If no formal parameters are included in the title statement, each call of the macro captures an exact copy of the macro definition body.

8.1.2 The MACRO Body

The body of a macro definition is composed of any number of assembler statements (and comments). These statements perform the function defined by the macro, and may include any valid assembler statements, **with the following limitations:**

1. The PROG directive are not valid.
2. Definitions of other macros, or calls to the same macro are not valid.
3. Nesting of macros is valid to three levels, but the innermost macros **must** be defined first.
4. Symbols that appear as statement labels within a macro are local to that macro.
5. Symbolic references to labels outside the macro are not valid.
6. Symbols defined by declarations within a macro are local if the macro call is made from a procedure, and global if made from the main program.

> CAUTION
>
> The assembler operation codes PROC, ENTRY, END, ORG, EQU, LIV and RIV are valid in a macro, but are difficult to implement without error.

8.1.3 The Terminator Statement

The terminator statement marks the end of a macro definition.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
none	ENDM	none	none	statement

8.2 THE MACRO CALL

The macro call statement marks a point in the program where the saved macro definition is expanded.

LABEL	OPERATION	OPERAND	EXTENSION	COMMENT
symbol	name	p1,p2,...pn	none	statement

Where:

"symbol". . . . is any valid symbol that is not defined as local to this program segment or global to the entire program.

"name" . . . . is the name of a macro which has appeared in the label field of a MACRO statement.

"p1,p2,...pn" . . is a list of the actual parameters to be substituted for the formal parameters that appear in the macro definition. These parameters may be constants, symbols, or expressions. Any symbols must be either previously defined, or defined within the macro definition prior to their use there. (Refer to the parameters IV1 and IV2 of Example 8.1.)

Example 8-2. Substitution of Macro Parameters

MACRO definition showing dummy parameters REPL1 and RX:

```
     LOOK    MACRO   REPL1,RX
             ORG     4,256
             SEL     DISC1
             MOVE    REPL1,RX
             NZT     RX,*-2
```

MACRO call with the actual parameters substituted for the dummy parameters:

```
             LOOK    DSTAT,R1
      +      ORG     4,256
      +      SEL     DISC1
      +      MOVE    DSTAT,R1
      +      NZT     R1,*-2
```

(Taken from lines 63 through 67 and line 84 of Appendix C.)

8.3 MACRO EXAMPLES FOR USE WITH 8X310 Interrupt Control Coprocessor (ICC)

```
*8X310 CLEAR INTERRUPT

CLRI            MACRO
                MOVE R2, R2
                ENDM

*8X310 SUBROUTINE CALL (ONLY AT ODD LOCATION)

JSR             MACRO
                IF * $ 1 - 1
                NOP
                ENDIF
                MOVE R3, R3
                ENDM

*8X310 CLEAR MASK

CLRM            MACRO
                MOVE R4, R4
                ENDM

*8X310 SET MASK

SETM            MACRO
                MOVE R5, R5
                ENDM

*8X310 RETURN FROM SUBROUTINE OR INTERRUPT

RETN            MACRO
                MOVE R6, R6
                ENDM
```

SECTION 9

ASSEMBLY PROCESS

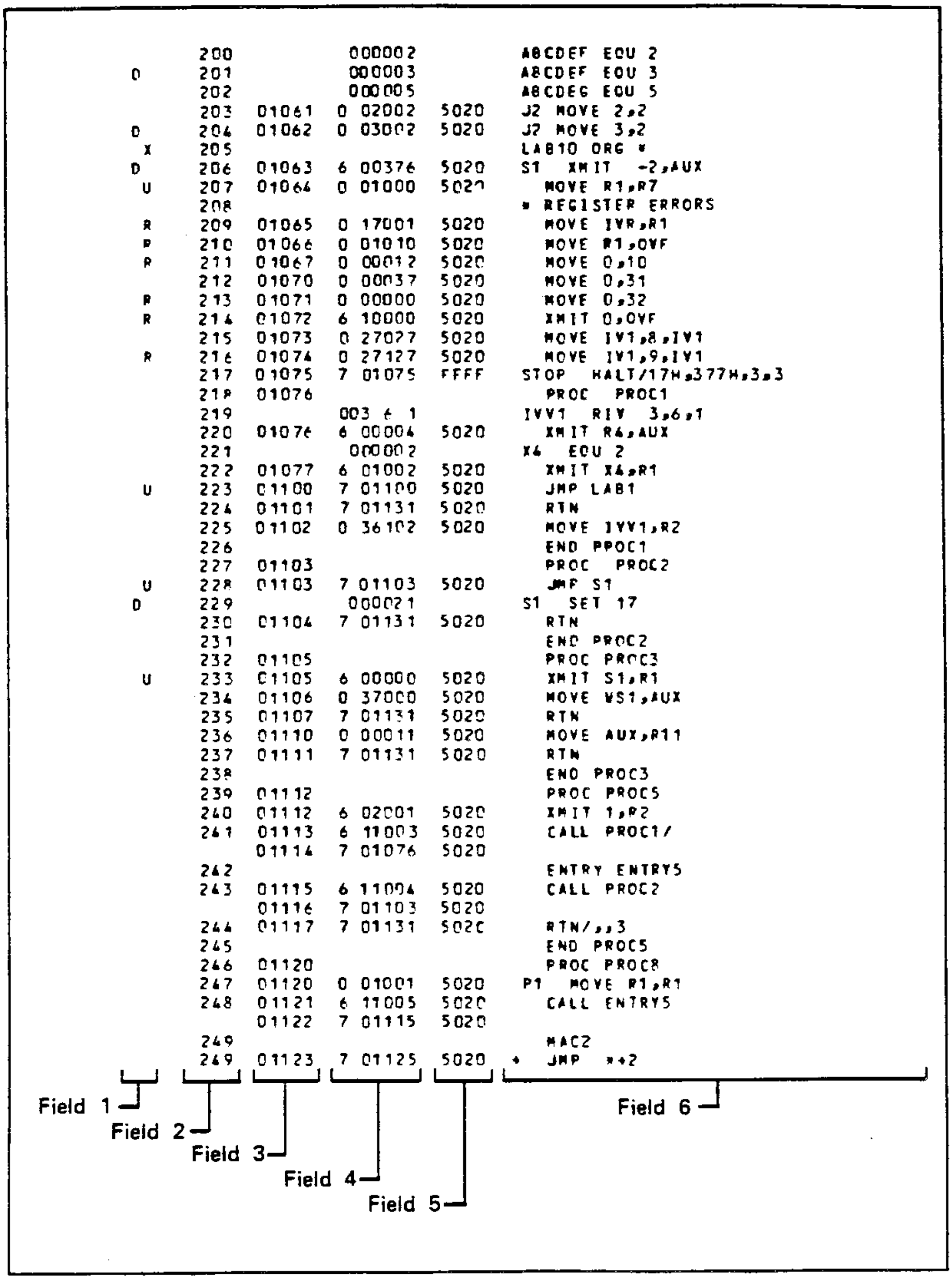
There are three results of assembling a program with MCCAP: the assembly listing, an object module, and the error codes.

9.1 THE ASSEMBLY LISTING

The most important function of the listing is to provide a record of all that occurred during the assembly process: source codes, object codes with addresses, and error codes. Typically, the assembly listing also serves as a documentation tool through the inclusion of descriptive comments with the source statements.

The following description refers to the partial assembly listing provided in Figure 9-1.

1. The first field, if present, contains alphabetic characters to indicate any errors during assembly.
2. The second field contains decimal numbers which are the listing line numbers. The maximum line number is 9999.
3. The third field contains a 5-digit octal number or a 4-digit hexadecimal number which represents the program memory address of the instruction generated.
4. The fourth field represents the code that was assembled or the value assigned in a symbol declaration. The code is written in the MCSIM object module format or in absolute hexadecimal format.
5. If extended instructions have been defined by the user, the fifth field will contain the instruction extension. Otherwise, the field is blank.
6. The sixth field contains the user's original source statements, without alteration.
7. A "+" in the sixth field indicates that the line was generated by a MACRO call and is the expansion of the macro.
8. After the END statement for the complete program, the return jump table is listed if any procedure calls were made.
9. After the return jump table the assembler prints the message "TOTAL ASSEMBLY ERRORS =", followed by a cumulative count of the errors.
10. The final part of the output is the symbol table or cross reference listing.



```
       200              000002          ABCDEF EQU 2
D      201              000003          ABCDEF EQU 3
       202              000005          ABCDEG EQU 5
       203   01061   0 02002    5020    J2 MOVE 2,2
D      204   01062   0 03002    5020    J2 MOVE 3,2
 X     205                              LAB10 ORG *
D      206   01063   6 00376    5020    S1   XMIT  -2,AUX
 U     207   01064   0 01000    5020      MOVE R1,R7
       208                              * REGISTER ERRORS
 R     209   01065   0 17001    5020      MOVE IVR,R1
 R     210   01066   0 01010    5020      MOVE R1,OVF
 R     211   01067   0 00012    5020      MOVE 0,10
       212   01070   0 00037    5020      MOVE 0,31
 R     213   01071   0 00000    5020      MOVE 0,32
 R     214   01072   6 10000    5020      XMIT 0,OVF
       215   01073   0 27077    5020      MOVE IV1,8,IV1
 R     216   01074   0 27127    5020      MOVE IV1,9,IV1
       217   01075   7 01075    FFFF    STOP  HALT/17H,377H,3,3
       218   01076                        PROC  PROC1
       219              003 6 1         IVV1  RIV  3,6,1
       220   01076   6 00004    5020      XMIT R4,AUX
       221              000002          X4   EQU 2
       222   01077   6 01002    5020      XMIT X4,R1
 U     223   01100   7 01100    5020      JMP LAB1
       224   01101   7 01131    5020      RTN
       225   01102   0 36102    5020      MOVE IVV1,R2
       226                                END PPOC1
       227   01103                        PROC  PROC2
 U     228   01103   7 01103    5020      JMP S1
D      229              000021          S1   SET 17
       230   01104   7 01131    5020      RTN
       231                                END PROC2
       232   01105                        PROC PROC3
 U     233   01105   6 00000    5020      XMIT S1,R1
       234   01106   0 37000    5020      MOVE WS1,AUX
       235   01107   7 01131    5020      RTN
       236   01110   0 00011    5020      MOVE AUX,R11
       237   01111   7 01131    5020      RTN
       238                                END PROC3
       239   01112                        PROC PROC5
       240   01112   6 02001    5020      XMIT 1,R2
       241   01113   6 11003    5020      CALL PROC1/
             01114   7 01076    5020
       242                                ENTRY ENTRY5
       243   01115   6 11004    5020      CALL PROC2
             01116   7 01103    5020
       244   01117   7 01131    5020      RTN/,,3
       245                                END PROC5
       246   01120                        PROC PROC8
       247   01120   0 01001    5020    P1   MOVE R1,R1
       248   01121   6 11005    5020      CALL ENTRY5
             01122   7 01115    5020
       249                                MAC2
       249   01123   7 01125    5020  +   JMP  *+2
```

Figure 9-1. Interpretation of the Assembly Listing

9.2 THE CROSS REFERENCE TABLE

The accumulation of references may be started or stopped through use of the X parameter on the LIST and NLIST directives. If it is desired to list a complete cross reference table, the LIST X directive must be placed before the first symbol is used in the program. References during certain portions of a program will not be accumulated if the user specifies the NLIST X directive. Thus by use of the LIST and NLIST directives, the user may accumulate references wherever desired in the program. Typically a cross reference table will be generated for the entire program. References to internally defined Reserved Symbols are not accumulated. For a cross reference table to be generated at the end of the assembly listing, the LIST X directive must not have been turned off before the END directive.

The format of the cross reference table is shown in Example 9-1. A minus sign preceding a reference indicates that the symbol was defined on that line. A symbol may be defined on multiple lines by use of the SET directive. When 0 is given as a reference, it indicates that the symbol is a Reserved Symbol.

Example 9-1. Cross Reference Table Listing

LABEL	VALUE	REFERENCES			
AUX	000000	0			
IVL	000007	0			
MAIN	000000	-2	18		
TABLE	001057	105	-149	200	205

9.3 THE OBJECT MODULE

The object module is a machine readable output produced in either MCSIM, BNPF or ASCII-Hex format, as selected by the OBJ directive.

9.3.1 MCSIM Format

The MCSIM format is utilized by some 8X300/8X305 Development Systems, and can be loaded directly into it. This format is illustrated in Example 9-2.

Example 9-2. MCSIM Format

```
leader
program name (CR)(LF)
00000:  0 00000,6 01000,6 02000,6 07011,...,7 00400,
00010:  6 11000,7 00400,...
   .
   .
   .
(TAPE OFF)
END program name
```

9.3.2 BNPF Format

The BNPF format is used to produce paper tapes which can be used on most PROM programmers. This format is illustrated in Example 9-3.

Example 9-3. BNPF Format

```
leader
program name
leader (CR)(LF)
MODULE nn (STX)(CR)(LF)
0      BPNPNNNNNF      BNNNPNPNPF      BNPPNPNNNF
BNNPNPNNNF (CR)(LF)
4       BPNNPPPPPF     BNNNNNPNNF      BNPNPNPPPF
BNNNPNPNNF (CR)(LF)
   .
   .
   .
508      BPPNPNNNPF     BNNNNPNNPF     BPNNPNNNPF
BNNPNPNPNF (CR)(LF)(ETX)
leader (CR)(LF)
MODULE nn (STX)(CR)(LF)
   .
   .
   .
leader
END program name
```

The object module is divided into blocks according to the PROM statements in the MCCAP program. If a 512 by 8 PROM were defined, module 01 would represent 8X300/8X305 program storage locations 0 through 511, bits 0 through 7; and module 02 would represent locations 0 through 511, bits 8 through 15.

Note that since the program name may contain the letter B, the tape contains a leader following the program name so that the tape can be conveniently positioned in the programmer tape reader after the name.

9.3.3 ASCII-Hex (Quote) Format

The ASCII-Hex (Quote) format is one of three MCCAP formats which represent data as ASCII characters. The object module is divided into sections corresponding to the ROM size as specified in the PROM statement. A leader of blanks and the program name precede the module.

A STX character followed by a carriage return and a line feed indicates the start of each object module section. Each record in the object module consists of an address and eight words of data followed by a carriage return and a line feed. The address is a 4-digit hexadecimal number. Each word contains two hexadecimal characters written in pairs followed by a quote mark. An ETX character indicates the end of each object module section. The trailer consisting of the characters END and the program name follow each object module. This format is illustrated in Example 9-4.

Example 9-4. ASCII-Hex (Quote) Format

```
leader
program name (CR)(LF)
MODULE nn'
(STX)(CR)(LF)
$A0000,  A0'15'68'28'9F'04'57'14' (CR)(LF)
$A0008,  05'F2'B3'21'00'81'DD'C2' (CR)(LF)
  .
  .
  .
$A01F8,  B1'26'79'36'D1'09'91'2A' (CR)(LF)
(ETX)

MODULE nn nn'
(STX)(CR)(LF)
  .
  .
  .
(ETX)
END program name
```

9.3.4 ASCII-Hex (Space) Format

The ASCII-Hex (Space) format also represents data as ASCII characters. This format is identical to the ASCII-Hex (Quote) format, with a space separating the data rather than a quote mark.

9.3.5 ASCII-HEX Word Format

The ASCII-Hex word format is a hexadecimal format widely used by development systems, ROM simulators, and PROM programmers. For word widths wider than eight bits, this format permits the entire word to be output as a single record.

The format generates a modified memory image, blocked into discrete records with length equal to one word. A word is defined to be one-user memory location and with MCCAP may be from 16 to 32 bits in width. Each record starts with a record mark and header consisting of length, type, and memory address (in user memory space) and is followed by a trailer consisting of two checksum characters. Data frames consist of ASCII-Hex characters where each character represents 4 bits. In cases where the micro. word width is an odd number of nibbles, leading zeros are used to fill out the most significant byte of the data word to ensure that data records always contain a whole number of data bytes. A frame-by-frame description of the record is shown in Table 9-1.

Table 9-1. ASCII-Hex Word Format

Frame	Contents
0	**Record Mark.** Signals the start of a record. The ASCII character colon, 3AX, is used as the record mark.
1,2	**Record Length.** Two digits representing a hexadecimal number in the range 0 to FFX (0-255). This is the number of data bytes in the data frames. A record length of 0 indicates end of file.
3 to 6	**Load Address.** Four digits that represent the memory location where the data will begin loading.
7,8	**Record Type.** Two ASCII digits. Data records are type 00 and the end record is type 01 (length 0).
9 to 9+2*Length-1	**Data.** Each byte of memory is represented by two digits to represent 8 bits of binary data. These proceed from most significant nibble to least significant nibble. The number of data bytes is specified in Frames 1 and 2.
9+2*Length and 9+2*Length+1	**Checksum.** Two ASCII characters. The checksum is the two's complement of the 8-bit binary summation of all previous bytes in the record since the record mark (colon).

Example 9-5. ASCII-Hex Word Format

The 16-bit binary value 0101001111111000 is 53F8 in hexadecimal. To encode this, the first frame would contain the ASCII code for the character 5 (35X), the second frame would contain the ASCII code for the character 3 (33X), and so on.

If memory locations 1C40 through 1C42 contain 32-bit data of

```
    53F8 EC40
    1111 2222
    3333 4444
```

the hex file produced (including control characters) would be:

```
    :041C400053F8EC4029
    :041C41001111222239
    :041C420033334444B0
    :00000001FF
```

9.4 ERROR CODES

If format or syntax errors are detected in the source code during the assembly process, an indication of the type of error is printed on the listing on the same line as the statement in error. Certain errors are considered to be catastrophic to the statement itself. Of these, some cause a "JMP *" to be assembled, while others enter a truncated or modulo value into a field if the specified value is too large. An error associated with a procedure definition will be reflected in references to the procedure. In all cases, however, object code is produced for every executable statement that is assembled, regardless of its validity.

Appendix D is a test program used to check for proper operation of the MCCAP assembler. Examples of error codes are presented in that test program.

Table 9-2. MCCAP Error Codes

Code	Error
A	**Argument Error:** 1. An operand (argument) is missing or contains an invalid character. 2. A PROG or PROC name is included in an expression.
B	**Bank Error:** In a MOVE, ADD, AND, or XOR, source and destination were data fields in the same bank but with different addresses.
C	**Context Error:** 1. A source or destination field contains a register or I/O data field variable used in an illegal context (that is, MOVE IV(2),A1; ADD R1,3,R3). 2. The name in a CALL statement is not a procedure name.
D	**Duplicate Definition:** 1. The symbol in the label field of a statement has been previously defined. 2. The procedure name has been previously defined.
F	**Format Error:** An instruction has a trailing comma or slash. (The instruction is assembled correctly.)
H	**Heading Error:** The program does not follow the correct format. That is, 1. no PROC statement after an END procedure statement; or 2. PROG is not the first statement in the program. (Some heading errors associated with the END statement will terminate the program.)

Code	Error
I	**I/O Data Field Error:** 1. I/O data fields whose precisions are not both eight and are in different banks are referenced in the same instruction. 2. I/O data fields within the same address but of different precisions are referenced in the same instruction.
L	**Label Error:** The symbol in the label field has 1. special characters, or 2. does not begin with an alphabetic character.
M	**Missing Symbol or RTN Statement:** 1. A statement requires a symbol. 2. A procedure does not have an RTN statement.
N	**Nesting Error:** An attempt was made to nest macros to more than three levels.
O	**Opcode Error:** 1. The code in the operation field has not been recognized as valid. 2. A RTN statement is used in the main program. 3. A macro definition is nested within another macro definition. 4. XML or XMR were used as opcodes without specifying 8X305 (See Sections 6.14 and 7.11).
P	**Paging Error:** An attempt was made to access a control storage address which is not in this page or segment (as applicable).
R	**Register Error:** 1. The register expression could not be evaluated. 2. The register expression is not in the proper range. 3. The register is not valid as used. (See Table 2-2.) 4. A rotate or a length field is out of range.
S	**Syntax Error:** A rule of syntax has been violated (for example, 4+*VAR).
T	**Table Overflow:** 1. The symbol table has overflowed. 2. More than 255 CALL statements were encountered by the Assembler. 3. The depth specified in a PROM directive is greater than the PROM buffer.

Code	Error
U	**Undefined Symbol:** There is a symbol in the operand field which 1. does not appear in any label field of this program segment or 2. has not been defined in a declaration statement.
V	**Value Error:** 1. An evaluated expression or constant is out of range for the field of the actual machine instruction in which it is to be contained. 2. For the LIV or RIV statements, the required length "bit+1" is not satisfied. 3. The PROM directive specifies more than 16 bits for instruction extension PROM's. 4. The number of bits in the PROM directive for standard 8X300/8X305 instructions does not total 16 bits. 5. More than 16 bits are defined in a DEF directive or a default value is too large for the field.
X	**Symbol Error:** A symbol is included in the label field of a statement for which it is not allowed.
"CROSS REFERENCE OVERFLOW AT LINE nnnn."	The cross reference table was filled at the line number specified.

APPENDIX A

STATEMENT/DEFINITION REFERENCE

ASSEMBLER DECLARATIONS

EQU	-	Define a statement
SET	-	Define or redefine a constant
LIV	-	Define a left bank data field variable
RIV	-	Define a right bank data field variable

ASSEMBLER DIRECTIVES

PROG	-	Program title statement
PROC	-	Procedure title statement
ENTRY	-	Secondary entry point into a procedure
END	-	End the program or a procedure
ORG	-	Set location counter
OBJ	-	Specify an objective format
IF, ENDIF	-	Conditional assembly
LIST	-	List the specified elements
NLIST	-	Suppress listing of elements
EJCT	-	Eject the listing page
SPAC	-	Line feed the listing
PROM	-	Specify PROM size
DEF	-	Define instruction extension fields

EXECUTABLE STATEMENTS

MOVE, ADD, AND, XOR	-	Data manipulation
XMIT	-	Load immediate
XEC	-	Execute
NZT	-	Non zero transfer
JMP	-	Unconditional jump
SEL		I/O data field selection
CALL	-	Procedure (subroutine) call
RTN	-	Procedure return
NOP	-	No operation
HALT	-	Stop processing
XML	-	8 bit load immediate to left bank (8X305 only)
XMR	-	8 bit load immediate to right bank (8X305 only)

APPENDIX B

UNASSEMBLED SAMPLE PROGRAM

```
***********************************
*  THIS PROGRAM SERVES ONLY AS A  *
*  DEMONSTRATION OF ALL MCCAP     *
*  STATEMENTS.                    *
***********************************
        LIST    A
        SPAC    1
        PROG    SAMPLE
        SPAC    2
***********************************
*  DATA AND ADDRESS DECLARATIONS  *
***********************************
        SPAC    1
FINAL   EQU     1
PRELIM  EQU     0
INC     EQU     1
DEC     EQU     -1
SINMSK  EQU     10000000B
OEMASK  EQU     1B
LSMASK  EQU     7H
SSMASK  EQU     LSMASK.L.3
MSMASK  EQU     LSMASK.R.1.L.6
ROT     EQU     3
LEN     EQU     4
VAL1    SET     0
VAL2    SET     1
VAL3    SET     2
VAL4    SET     3
DISCO   LIV     10H,7,8
DISCI   LIV     11H,7,8
DSTAT   LIV     DISCI,0
DSCLOK  LIV     DISCI,5
DRDWR   LIV     DISCI,6
DRDAT   LIV     DISCI
DISP1   LIV     20H,7,8
DISP2   LIV     DISP1+1,7,8
DATA1   RIV     100H,7,8
D1SIGN  RIV     DATA1,0
D1ODEV  RIV     DATA1
DATA2   RIV     DATA1+1,7,8
D2SIGN  RIV     DATA2,0
D2ODEV  RIV     DATA2
TEMP1   RIV     200H,7,8
TEMP2   RIV     TEMP1+1,7,8
        SPAC    3
        EJCT
***********************************
*  CONDITIONALS AND SPECIAL       *
*  DIRECTIVES                     *
***********************************
        SPAC    1
        IF      PRELIM
        NLIST   S,O
        ENDIF
        SPAC    1
        IF      FINAL
        LIST    I,M,S,O
        OBJ     M
        ENDIF
        SPAC    1
***********************************
*  MACRO DEFINITIONS              *
***********************************
```

```
LOOK     MACRO    REPL1,RX
         ORG      4,256
         SEL      DISCI
         MOVE     REPL1,RX
         NZT      RX,*-2
         ENDM
         SPAC     1
LOOPCT   MACRO    RX
         XMIT     -1,AUX
         ADD      RX,RX
         ENDM
         SPAC     19
         EJCT
***********************************
*   MAIN PROGRAM                  *
***********************************
         SPAC     1
         ORG      0
START    NOP
         XMIT     0,R1
         XMIT     0,R2
         LOOK     DSTAT,R1
STC      CALL     ARITH
         CALL     MOVMNT
         CALL     TRNSMT
         CALL     EXECT
         LOOPCT   R6
         NZT      OVF,START+3
LAST     HALT
         SPAC     24
         EJCT
***********************************
*   ARITH PROCEDURE               *
***********************************
         SPAC     1
         PROC     ARITH
         SPAC     1
         ORG      256,256
STAR     SEL      TEMP1
         MOVE     R11,TEMP1
CANT     CALL     NONZXF
         SEL      TEMP1
         MOVE     TEMP1,R11
         XMIT     40H,AUX
STAD     ADD      R1,R1
         ADD      2,2
         ADD      R3(ROT),R3
         SEL      DATA1
         XMIT     LSMASK,AUX
STAND    AND      R1,DATA1
         SEL      DATA2
         XMIT     SSMASK,AUX
         AND      R2,LEN,DATA2
         XMIT     DATA2+1,IVR
         XMIT     MSMASK,AUX
         AND      R3,LEN,37H
         XMIT     DATA2+2,17H
         XMIT     263H,AUX
         AND      4(4),AUX
         SEL      DATA1
         XMIT     -1,AUX
STOR     XOR      DATA1,DATA1
```

```
        SEL     DATA2
        XOR     DATA2,3,DATA2
        XMIT    DATA2+1,IVR
        XOR     37H,LEN,37H
        XMIT    DATA2+2,17H
        XOR     33H,LEN,37H
        SPAC    1
        ENTRY   MOVMNT
        SEL     DISCI
STMV    MOVE    DSTAT,R1
        MOVE    24H,LEN,R2
        MOVE    DRDAT,LEN,R3
        SPAC    4
        EJCT
***********************************
*  ARITH PROCEDURE (CONT'D)       *
***********************************
        SPAC    1
        ENTRY   TRNSMT
        SEL     DISP1
STXT    XMIT    'G',R5
        MOVE    R5,DISP1
        SEL     DISP2
        XMIT    'O',R5
        MOVE    R5,DISP2
        SEL     DISP1
        XMIT    '!',R5
        MOVE    R5,DISP1
        XMIT    VAL1,DISP1,LEN
        XMIT    VAL2,23H,4
EAR     RTN
        END     ARITH
        SPAC    26
        EJCT
***********************************
*  EXECT PROCEDURE                *
***********************************
        SPAC    1
        PROC    EXECT
        SPAC    1
TABPTRS RIV     240H,7,8
T2PTR   RIV     TABPTRS
T3PTR   RIV     TABPTRS,5
T4PTR   RIV     TABPTRS,3
T5PTR   RIV     TABPTRS,1
        ORG     7,256
STXC    XEC     *+1(R6),5
        JMP     TAB1
        JMP     TAB2
        JMP     TAB3
        JMP     TAB4
        JMP     TAB5
        ORG     6,256
TAB1    XEC     *+1(R1)
        JMP     DONE
        JMP     DONE
        JMP     DONE
        JMP     DONE
TAB2    SEL     TABPTRS
        ORG     5,32
        XEC     *+1(T2PTR)
        JMP     DONE
```

```
          JMP     DONE
TAB3      SEL     TABPTRS
          ORG     7,32
          XEC     *+1(T3PTR,2)
          JMP     DONE
          JMP     DONE
          JMP     DONE
          JMP     DONE
TAB4      SEL     TABPTRS
          ORG     5,32
          XEC     *+1(T4PTR),2
          JMP     DONE
          JMP     DONE
TAB5      SEL     TABPTRS
          ORG     7,32
          XEC     *+1(T5PTR,2),4
          JMP     DONE
          JMP     DONE
          JMP     DONE
          JMP     DONE
          ORG     32,32
DONE      RTN
          END     EXECT
          SPAC    1
***********************************
*  NONZXF PROCEDURE               *
***********************************
          SPAC    1
          PROC    NONZXF
          SPAC    1
VAL1      SET     VAL1+5
VAL2      SET     VAL2+5
VAL3      SET     VAL3+5
VAL4      SET     VAL4+5
          ORG     16,256
          XMIT    VAL1,R5
STNT      NZT     R5,*+8
          SEL     DISP1
          XMIT    VAL2,DISP1
          NZT     DISP1,*+7
          SEL     DISP2
          XMIT    VAL3,DISP2
          NZT     23H,4,*+6
          RTN
          LOOPCT  R5
          SEL     DISP1
          LOOPCT  DISP1
          SEL     DISP2
          LOOPCT  DISP2
ENT       RTN
          END     NONZXF
          SPAC    12
          END     SAMPLE

R;
```

APPENDIX C

ASSEMBLED SAMPLE PROGRAM

```
     PROG      SAMPLE                MICROCONTROLLER CROSS ASSEMBLER VER 3.0

 1                          ***********************************    1
 2                          *  THIS PROGRAM SERVES ONLY AS A  *    2
 3                          *  DEMONSTRATION OF ALL MCCAP     *    3
 4                          *  STATEMENTS.                    *    4
 5                          ***********************************    5
 6                                   LIST     A

 8                                   PROG     SAMPLE                7


10                          ***********************************    9
11                          *  DATA AND ADDRESS DECLARATIONS  *   10
12                          ***********************************   11

14            0001          FINAL    EQU      1                   13
15            0000          PRELIM   EQU      0                   14
16            0001          INC      EQU      1                   15
17            FFFF          DEC      EQU      -1                  16
18            0080          SINMSK   EQU      10000000B           17
19            0001          OEMASK   EQU      1B                  18
20            0007          LSMASK   EQU      7H                  19
21            0038          SSMASK   EQU      LSMASK.L.3          20
22            00C0          MSMASK   EQU      LSMASK.R.1.L.6      21
23            0003          ROT      EQU      3                   22
24            0004          LEN      EQU      4                   23
25            0000          VAL1     SET      0                   24
26            0001          VAL2     SET      1                   25
27            0002          VAL3     SET      2                   26
28            0003          VAL4     SET      3                   27
29            0238          DISCO    LIV      10H,7,8             28
30            0278          DISCI    LIV      11H,7,8             29
31            0241          DSTAT    LIV      DISCI,0             30
32            0269          DSCLOK   LIV      DISCI,5             31
33            0271          DRDWR    LIV      DISCI,6             32
34            0279          DRDAT    LIV      DISCI               33
35            0438          DISP1    LIV      20H,7,8             34
36            0478          DISP2    LIV      DISP1+1,7,8         35
37            1038          DATA1    RIV      100H,7,8            36
38            1001          D1SIGN   RIV      DATA1,0             37
39            1039          D1ODEV   RIV      DATA1               38
40            1078          DATA2    RIV      DATA1+1,7,8         39
41            1041          D2SIGN   RIV      DATA2,0             40
42            1079          D2ODEV   RIV      DATA2               41
43            2038          TEMP1    RIV      200H,7,8            42
44            2078          TEMP2    RIV      TEMP1+1,7,8         43


     PROG      SAMPLE                MICROCONTROLLER CROSS ASSEMBLER VER 3.0
```

```
        PROG     SAMPLE                  MICROCONTROLLER CROSS ASSEMBLER VER 3.0

47                                ***********************************      46
48                                *  CONDITIONALS AND SPECIAL        *      47
49                                *  DIRECTIVES                      *      48
50                                ***********************************      49

52                                        IF      PRELIM                   51
53                                        ENDIF                            53

55                                        IF      FINAL                    55
56                                        LIST    I,M,S,O                  56
57                                        OBJ     M                        57
58                                        ENDIF                            58

60                                ***********************************      60
61                                *  MACRO DEFINITIONS               *      61
62                                ***********************************      62
63                                LOOK    MACRO   REPL1,RX                 63
64                                        ORG     4,256                    64
65                                        SEL     DISCI                    65
66                                        MOVE    REPL1,RX                 66
67                                        NZT     RX,*-2                   67
68                                        ENDM                             68

70                                LOOPCT  MACRO   RX                       70
71                                        XMIT    -1,AUX                   71
72                                        ADD     RX,RX                    72
73                                        ENDM                             73
```

```
76                              ************************************  76
77                              *  MAIN PROGRAM                    *  77
78                              ************************************  78

80                                       ORG      0                   80
81   0000    0000               START    NOP                          81
82   0001    C100                        XMIT     0,R1                82
83   0002    C200                        XMIT     0,R2                83
84                                       LOOK     DSTAT,R1            84
84                              +        ORG      4,256               64
84   0003    C709               +        SEL      DISCI               65
84   0004    1021               +        MOVE     DSTAT,R1            66
84   0005    A103               +        NZT      R1,*-2              67
85   0006    C900               STC      CALL     ARITH               85
     0007    E100
86   0008    C901                        CALL     MOVMNT              86
     0009    E11F
87   000A    C902                        CALL     TRNSMT              87
     000B    E123
88   000C    C903                        CALL     EXECT               88
     000D    E12F
89                                       LOOPCT   R6                  89
89   000E    C0FF               +        XMIT     -1,AUX              71
89   000F    2606               +        ADD      R6,R6               72
90   0010    A803                        NZT      OVF,START+3         90
91   0011    E011               LAST     HALT                         91
```

```
 94                           **********************************    94
 95                           *  ARITH PROCEDURE               *    95
 96                           **********************************    96

 98   0012                           PROC    ARITH                 98

100   0012    E100                   ORG     256,256              100
101   0100    CF80           STAR    SEL     TEMP1                101
102   0101    091F                   MOVE    R11,TEMP1            102
103   0102    C904           CANT    CALL    NONZXF               103
      0103    E161
104   0104    CF80                   SEL     TEMP1                104
105   0105    1F09                   MOVE    TEMP1,R11            105
106   0106    C020                   XMIT    40H,AUX              106
107   0107    2101           STAD    ADD     R1,R1                107
108   0108    2202                   ADD     2,2                  108
109   0109    2363                   ADD     R3(ROT),R3           109
110   010A    CF40                   SEL     DATA1                110
111   010B    C007                   XMIT    LSMASK,AUX           111
112   010C    411F           STAND   AND     R1,DATA1             112
113   010D    CF41                   SEL     DATA2                113
114   010E    C038                   XMIT    SSMASK,AUX           114
115   010F    429F                   AND     R2,LEN,DATA2         115
116   0110    CF42                   XMIT    DATA2+1,IVR          116
117   0111    C0C0                   XMIT    MSMASK,AUX           117
118   0112    439F                   AND     R3,LEN,37H           118
119   0113    CF43                   XMIT    DATA2+2,17H          119
120   0114    C0B3                   XMIT    263H,AUX             120
121   0115    4480                   AND     4(4),AUX             121
122   0116    CF40                   SEL     DATA1                122
123   0117    C0FF                   XMIT    -1,AUX               123
124   0118    7F1F           STOR    XOR     DATA1,DATA1          124
125   0119    CF41                   SEL     DATA2                125
126   011A    7F7F                   XOR     DATA2,3,DATA2        126
127   011B    CF42                   XMIT    DATA2+1,IVR          127
128   011C    7F9F                   XOR     37H,LEN,37H          128
129   011D    CF43                   XMIT    DATA2+2,17H          129
130   011E    7B9F                   XOR     33H,LEN,37H          130

132                                  ENTRY   MOVMNT               132
133   011F    C709                   SEL     DISCI                133
134   0120    1021           STMV    MOVE    DSTAT,R1             134
135   0121    1482                   MOVE    24H,LEN,R2           135
136   0122    1783                   MOVE    DRDAT,LEN,R3         136
```

```
139                       ***********************************  139
140                       *  ARITH PROCEDURE (CONT'D)        *  140
141                       ***********************************  141

143                             ENTRY   TRNSMT                  143
144   0123     C710             SEL     DISP1                   144
145   0124     C547       STXT  XMIT    'G',R5                  145
146   0125     0517             MOVE    R5,DISP1                146
147   0126     C711             SEL     DISP2                   147
148   0127     C54F             XMIT    'O',R5                  148
149   0128     0517             MOVE    R5,DISP2                149
150   0129     C710             SEL     DISP1                   150
151   012A     C521             XMIT    '!',R5                  151
152   012B     0517             MOVE    R5,DISP1                152
153   012C     D780             XMIT    VAL1,DISP1,LEN          153
154   012D     D381             XMIT    VAL2,23H,4              154
155   012E     E173       EAR   RTN                             155
156                             END     ARITH                   156
```

```
159                         **********************************  159
160                         *  EXECT PROCEDURE               *  160
161                         **********************************  161

163   012F                          PROC    EXECT               163

165          2838           TABPTRS RIV     240H,7,8            165
166          2839           T2PTR   RIV     TABPTRS             166
167          2829           T3PTR   RIV     TABPTRS,5           167
168          2819           T4PTR   RIV     TABPTRS,3           168
169          2809           T5PTR   RIV     TABPTRS,1           169
170                                 ORG     7,256               170
171   012F   8630           STXC    XEC     *+1(R6),5           171
172   0130   E135                   JMP     TAB1                172
173   0131   E13A                   JMP     TAB2                173
174   0132   E13E                   JMP     TAB3                174
175   0133   E145                   JMP     TAB4                175
176   0134   E149                   JMP     TAB5                176
177                                 ORG     6,256               177
178   0135   8136           TAB1    XEC     *+1(R1)             178
179   0136   E160                   JMP     DONE                179
180   0137   E160                   JMP     DONE                180
181   0138   E160                   JMP     DONE                181
182   0139   E160                   JMP     DONE                182
183   013A   CFA0           TAB2    SEL     TABPTRS             183
184                                 ORG     5,32                184
185   013B   9F3C                   XEC     *+1(T2PTR)          185
186   013C   E160                   JMP     DONE                186
187   013D   E160                   JMP     DONE                187
188   013E   CFA0           TAB3    SEL     TABPTRS             188
189   013F   E140                   ORG     7,32                189
190   0140   9D41                   XEC     *+1(T3PTR,2)        190
191   0141   E160                   JMP     DONE                191
192   0142   E160                   JMP     DONE                192
193   0143   E160                   JMP     DONE                193
194   0144   E160                   JMP     DONE                194
195   0145   CFA0           TAB4    SEL     TABPTRS             195
196                                 ORG     5,32                196
197   0146   9B27                   XEC     *+1(T4PTR),2        197
198   0147   E160                   JMP     DONE                198
199   0148   E160                   JMP     DONE                199
200   0149   CFA0           TAB5    SEL     TABPTRS             200
201                                 ORG     7,32                201
202   014A   994B                   XEC     *+1(T5PTR,2),4      202
203   014B   E160                   JMP     DONE                203
204   014C   E160                   JMP     DONE                204
205   014D   E160                   JMP     DONE                205
206   014E   E160                   JMP     DONE                206
207   014F   E160                   ORG     32,32               207
208   0160   E173           DONE    RTN                         208
209                                 END     EXECT               209
```

```
211                            ***********************************  211
212                            *  NONZXF PROCEDURE               *  212
213                            ***********************************  213

215   0161                              PROC     NONZXF             215

217             0005           VAL1     SET      VAL1+5             217
218             0006           VAL2     SET      VAL2+5             218
219             0007           VAL3     SET      VAL3+5             219
220             0008           VAL4     SET      VAL4+5             220
221                                     ORG      16,256             221
222   0161      C505                    XMIT     VAL1,R5            222
223   0162      A56A           STNT     NZT      R5,*+8             223
224   0163      C710                    SEL      DISP1              224
225   0164      D706                    XMIT     VAL2,DISP1         225
226   0165      B70C                    NZT      DISP1,*+7          226
227   0166      C711                    SEL      DISP2              227
228   0167      D707                    XMIT     VAL3,DISP2         228
229   0168      B38E                    NZT      23H,4,*+6          229
230   0169      E173                    RTN                         230
231                                     LOOPCT   R5                 231
231   016A      C0FF           +        XMIT     -1,AUX              71
231   016B      2505           +        ADD      R5,R5               72
232   016C      C710                    SEL      DISP1              232
233                                     LOOPCT   DISP1              233
233   016D      C0FF           +        XMIT     -1,AUX              71
233   016E      3717           +        ADD      DISP1,DISP1                 72
234   016F      C711                    SEL      DISP2              234
235                                     LOOPCT   DISP2              235
235   0170      C0FF           +        XMIT     -1,AUX              71
235   0171      3717           +        ADD      DISP2,DISP2                 72
236   0172      E173           ENT      RTN                         236
237                                     END      NONZXF             237




239                                     END      SAMPLE             239
```

```
PROG     SAMPLE                  MICROCONTROLLER CROSS ASSEMBLER VER 3.0

 0173     8974
 0174     E008
 0175     E00A
 0176     E00C
 0177     E00E
 0178     E104

  ASSEMBLER ERRORS =      0
```

```
              PROG     SAMPLE               MICROCONTROLLER CROSS ASSEMBLER VER 3.0

                                     SYMBOL TABLE

     *   1

     ARITH     0100        AUX       0000        D1ODEV    1039        D1SIGN    1001
     D2ODEV    1079        D2SIGN    1041        DATA1     1038        DATA2     1078
     DEC       FFFF        DISCI     0278        DISCO     0238        DISP1     0438
     DISP2     0478        DRDAT     0279        DRDWR     0271        DSCLOK    0269
     DSTAT     0241        EXECT     012F        FINAL     0001        INC       0001
     IVL       0007        IVR       000F        LAST      0011        LEN       0004
     LOOK      0001        LOOPCT    0006        LSMASK    0007        MOVMNT    011F
     MSMASK    00C0        NONZXF    0161        OEMASK    0001        OVF       0008
     PRELIM    0000        R0        0000        R1        0001        R11       0009
     R12       000A        R13       000B        R14       000C        R15       000D
     R16       000E        R17       000F        R2        0002        R3        0003
     R4        0004        R5        0005        R6        0006        R7        0007
     ROT       0003        SAMPLE    0000        SINMSK    0080        SSMASK    0038
     START     0000        STC       0006        TEMP1     2038        TEMP2     2078
     TRNSMT    0123        VAL1      0005        VAL2      0006        VAL3      0007
     VAL4      0008

     *   2


     *   3


     *   4

     CANT      0102        EAR       012E        STAD      0107        STAND     010C
     STAR      0100        STMV      0120        STOR      0118        STXT      0124

     *   5

     DONE      0160        STXC      012F        T2PTR     2839        T3PTR     2829
     T4PTR     2819        T5PTR     2809        TAB1      0135        TAB2      013A
     TAB3      013E        TAB4      0145        TAB5      0149        TABPTR    2838

     *   6

     ENT       0172        STNT      0162

     *   7


     *   8


     *   9
```

APPENDIX D

ASSEMBLER ERROR TEST PROGRAM

```
PROG   MAIN                         MICROCONTROLLER CROSS ASSEMBLER VER 3.0

 1                                  *
 2                                  *
 3                                  * THIS PROGRAM IS USED TO TEST THE ASSEMBLER
 4                                  * FOR PROPER OPERATION.  IT SHOWS THE VARIOUS
 5                                  * INSTRUCTION FORMATS, ASSEMBLER DIRECTIVES,
 6                                  * AND ERROR CONDITIONS.
 7                                  *
 8                                      PROG  MAIN
 9                                    LIST    X      GENERATE CROSS REF TABLE
10                                    DEF     4(5),-8(2),2,2
11                                    PROM    128,8,8/256,4,8,4
12                                    OBJ     R,H/R
13                                  *
14                                   LIST M,I,A
15                                  MAC3  MACRO  A1,A2
16                                    MOVE  A1,A2
17                                    XEC   *(A1)
18                                    XMIT  1,A2
19                                    ENDM
20                                  MAC2  MACRO
21                                    JMP   *+2
22                                    MOVE  R1,IVL
23                                    SEL  WS1
24                                    MAC3  R1,R11
25                                    ENDM
26                                  MAC1  MACRO  P1,P2
27                                    MOVE P1,P2
28                                    MOVE P2,P1
29                                    ENDM
30                                  *
31               00B8               IV1  LIV 2,7,8
32               00FE               IV2   LIV  3,7,6
33               00F6               IV3   LIV  3,6,6
34               1938               WS1  RIV  100,7,8
35               1977               WS2  RIV  101,6,7
36               19AE               WS3  RIV  WS2+1,5,6
37      0000     E000     5020        HALT
38      0001     0000     0650        NOP/0,WS2
39      0002     0000     5020        NOP
40      0003     0000     7020        MOVE  AUX,AUX/7
41      0004     0100     5020        MOVE R1,R0/
42      0005     0101     5020        MOVE R1,R1
43      0006     0109     1023        MOVE R1,R11/1,2,,3
44      0007     0102     2070        MOVE R1,R2/IV1,7
45      0008     0103     5A00        MOVE R1,R3/,LAB1
46      0009     0104     5020        MOVE R1,R4
47      000A     0105     FFF8        MOVE R1,R5/1111B,-1,2
48      000B     0106     0FFF        MOVE R1,R6/0,X1,3,3
49      000C     0107     5021        MOVE R1, IVL/,,,1
50      000D     010F     5020        MOVE R1, IVR
51      000E     0201     33F0        MOVE R2,R1/IV3,77H
52      000F     0802     20F5        MOVE OVF,R2/2,*,1,1
53      0010     0000     0000        MOVE AUX,AUX/0,0,0,0
54      0011     0001     5020        MOVE 0,1
```

```
     55   0012     0007    5020      MOVE 0,7
     56   0013     0009    5020      MOVE 0,9
     57   0014     000F    5020      MOVE 0,15
     58   0015     0010    5020      MOVE 0,16
     59   0016     0017    5020      MOVE 0,23
     60   0017     2121    5020      ADD R1(1),R1
     61   0018     2101    5020      ADD R1(8),R1
     62   0019     4017    5020      AND AUX,IV1
     63   001A     4117    5020      AND R1,IV1+1
     64   001B     4237    5020      AND R2,1,IV1
     65   001C     42F7    5020      AND R2,7,IV1
     66   001D     4217    5020      AND R2,8,IV1
     67   001E     7702    5020      XOR  IV1,R2
     68   001F     7702    5020      XOR IV1,0,R2
     69   0020     7722    5020      XOR IV1,1,R2
     70   0021     77E2    5020      XOR IV1,7,R2
     71   0022     C141    102F      XMIT 'A',R1/1,2,3,3
     72   0023     C25A    5020      XMIT 'Z',R2
     73   0024     C030    5020      XMIT '0',AUX
     74   0025     C927    5020      XMIT '''',R11
     75   0026     9707    5020      XEC  *+1(IV1)
     76   0027     9768    5160      XEC  *+1(IV1,3)/,LI2,0
     77   0028     C51F    5020      XMIT 1FX,R5
     78   0029     C7C4    5020      XMIT 0C4X,R7
     79   002A     C0E5    5020      XMIT -1BX,R0
     80   002B     C4FF    5020      XMIT -1,R4
V    81   002C     C900    5020      XMIT -256,R11
     82   002D     C700    5020      XMIT 0,IVL
     83   002E     CF01    5020      XMIT 1,IVR
     84   002F     D71E    5020      XMIT 30,IV1
     85   0030     FFFF    0000      JMP 8191/0,0,0,0
     86            05A1            LI2 LIV 22,4
     87   0031     C716    F00F      SEL LI2/17H,0,3,3
     88   0032     0234    5020      MOVE R2,LI2
     89            0699            LI4  LIV  LI2+4,3,1
     90   0033     C71A    5020      SEL LI4
     91   0034     3323    5020      ADD LI4,R3
     92                            * PAGING ERROR
     93                                ORG  128
     94                               NLIST A
P    95  00200  4 01200    5020      XEC  *(R1),256
P    96  00201  4 01201    5020      XEC  *(R1),253
     97  00202  4 01240    5020       XEC  LAB1(R1)
P    98  00203  4 27000    5020      XEC  LAB1(IV1)
     99  00204  4 27037    5020      XEC  LAB1-1(IV1)
P   100  00205  4 27037    5020      XEC  LAB1-1(IV1),32
    101  00206  4 27006    5020      XEC *(IV1),LAB1-*
P   102  00207  4 27010    5020      XEC  *+1(IV1),LAB1-*
    103  00210  4 27010    2640      XEC  *(IV1),LAB1-*/2,100
    104                               ORG  128+32
    105  00240  0 00000    5020    LAB1  MOVE AUX,AUX
    106  00241  5 01300    5020      NZT  R1,LAB2
P   107  00242  5 27000    5020      NZT  IV1,LAB2
    108  00243  5 27037    5020      NZT  IV1,LAB2-1
```

```
     109  00244  5 27435   5020      NZT   IV2,4,LAB2-3
     110  00245  5 27305   0024      NZT   IV1,3,*/0,IV1,1,0
     111                             ORG   128+32+32
     112  00300  0 00001   5020    LAB2  MOVE AUX,R1
     113  00301  6 01000   5020     XMIT 0,R1
     114  00302  4 27002   5020      XEC   *(IV1,8)
     115  00303  4 01303   5020      XEC   *(R1),2
     116                           * EXPAND MACRO
     117                               MAC1  R1,AUX
     117  00304  0 01000   5020   +  MOVE R1,AUX
     117  00305  0 00001   5020   +  MOVE AUX,R1
     118          000026           S1   SET 22
U    119  00306  7 00306   5020       JMP S1
     120          000031           S1 SET S1+3
U    121  00307  7 00307   5020       JMP S1
     122  00310  6 11000   5020        CALL PROC1
          00311  7 01121   5020
     123  00312  0 00001   5020      MOVE AUX,R1
     124  00313  6 11001   5020      CALL PROC2
          00314  7 01126   5020
     125  00315  0 02000   5020      MOVE 2,AUX
     126  00316  6 11002   0000      CALL PROC3/0,0
          00317  7 01130   0000
     127                           *  SPACE 5 LINES




     129                              ORG 512
     130  01000  0 00000   5020        MOVE AUX,AUX
     131  01001  6 01001   5020      XMIT 1,R1
     132                           * IF DIRECTIVE
     133                              IF 0
     134                              MOVE  R1,1
     135                              XMIT 2,R4
     136                              ENDIF
     137                              IF 1
     138  01002  0 02003   5020       MOVE  2,R3
     139                              ENDIF
     140                           * VARIOUS EXPRESSIONS AND OPERATORS
     141  01003  7 00100   5020       JMP 2.L.5
     142  01004  7 00000   5020       JMP 2.R.5
     143  01005  6 00004   5020       XMIT  31$4,AUX
     144  01006  6 01020   5020       XMIT 2+3-6+17,R1
     145  01007  6 00017   5020       XMIT 1001B+6,AUX
     146  01010  6 00025   5020       XMIT R5+2.L.3,AUX
     147  01011  6 02027   5020       XMIT  27H,R2
     148  01012  6 00002   10A0     XMIT 2,R0/1,*,0
     149                           *  EJECT TO NEXT PAGE
     151                              *  ARGUMENT ERRORS
A    152  01013  6 00000   5020         XMIT ,IV2,8
A    153  01014  7 01014   5020         XEC ,R1
A    154  01015  6 00000   5020         XMIT -1,
A    155  01016  7 01016   5020         JMP MAIN
A    156  01017  7 01017   5020         JMP PROC1
A    157  01020  6 02377   0001         XMIT -1,R2/1,28H,1,0
     158           001237             K1  EQU  1237H
A    159           000000             K3  EQU  1238H
A    160           000000             K4  EQU 1002B
     161                              * SYNTAX ERRORS
S    162  01021  7 01021   5020         XEC  *,R1
S    163  01022  6 00000   5020          XMIT  1++2,R1
S    164  01023  6 00001   0005         XMIT 1,R0/,IV1+,
     165                              * IV BYTE AND BYTE ERRORS
     166  01024  0 27027   5020         MOVE IV1,IV1
     167  01025  0 37027   5020         MOVE WS1,IV1
I    168  01026  0 36027   5020         MOVE WS2,IV1
     169  01027  0 27626   5020         MOVE IV2,IV3
I    170  01030  0 27627   5020         MOVE IV1,IV2
     171  01031  0 27036   5020         MOVE IV2,8,WS2
     172  01032  0 27036   5020         MOVE IV2,0,WS2
B    173  01033  0 27027   5020         MOVE IV1+1,IV1
     174                              * VALUE ERRORS
     175                                LIST A
V    176   021C     E21C   5020         XEC  *(IV1,9)
     177   021D     B71D   5020         NZT  IV1,8,*
V    178   021E     E21E   5020         NZT  IV1,9,*
V    179   021F     C300   5020         XMIT -257,R3
V    180   0220     D780   5020         XMIT 32,IV2,4
V    182   0221     D700   5020         XMIT -32,IV1
V    183   0222     D7C0   5020         XMIT -33,IV2
V    184   0223     E223   5020         JMP 8192
V    186   0225     C000   5020         XMIT 256,AUX
     187                                LIST S
     188   0226     C105   F020         XMIT 5,R1/15
V    189   0227     C2FF   0020         XMIT -1,R2/16
     190                                NLIST A
V    191  01050  1 01000   5021       ADD  R1,AUX/,,,5
     192           020000             X5  EQU 8192
V    193  01051  7 01051   5020         JMP X5
     194          377 7 1             RI2  RIV 255
V    195          000 0 0             RI3  RIV 256
V    196          000 0 0             RI5  RIV 2,8,0
     197                              * CONTEXT ERRORS
C    198  01052  6 01002   5020         XMIT  2,R1,3
C    199  01053  7 01053   5020         NZT  R1,2,*
C    200  01054  6 07037   5020         XMIT 31,IVL,3
C    201  01055  7 01055   5020         XEC  *+1(R1,2)
     202           177777             X1  EQU -1
C    203  01056  7 01056   5020         SEL X1
     204                              * UNDEFINED LABELS, LABEL ERRORS,
     205                              * AND DUPLICATE LABELS.
```

```
U    206  01057  6 00000  5020     XMIT K7,R1
L    207  01060  0 00000  5020   LABEL, EQU 2
     208           000002          ABCDEF EQU 2
D    209           000003          ABCDEF EQU 3
     210           000005          ABCDEG EQU 5
     211  01061  0 02002  5020   J2 MOVE 2,2
D    212  01062  0 03002  5020   J2 MOVE 3,2
 X   213                           LAB10 ORG *
D    214  01063  6 00376  5020   S1  XMIT  -2,AUX
     215  01064  0 01007  5020     MOVE R1,R7
     216                         * REGISTER ERRORS
R    217  01065  0 17001  5020     MOVE IVR,R1
R    218  01066  0 01010  5020     MOVE R1,OVF
R    219  01067  0 00012  5020     MOVE 0,10
     220  01070  0 00037  5020     MOVE 0,31
R    221  01071  0 00000  5020     MOVE 0,32
R    222  01072  6 10000  5020     XMIT 0,OVF
     223  01073  0 27027  5020     MOVE IV1,8,IV1
R    224  01074  0 27127  5020     MOVE IV1,9,IV1
     225                            8X305
     226  01075  0 07007  5020     MOVE R7,IVL
     227  01076  0 15007  5020     MOVE R15,R7
     228  01077  0 12013  5020     MOVE R12,R13
     229  01100  0 13015  5020     MOVE R13,R15
     230  01101  0 14005  5020     MOVE R14,R5
     231  01102  0 00016  5020     MOVE R0,R16
     232  01103  0 17001  5020     MOVE R17,R1
     233                            8X300
     234  01104  0 01007  5020     MOVE R1,R7
R    235  01105  0 07001  5020     MOVE R7,R1
R    236  01106  0 12001  5020     MOVE R12,R1
R    237  01107  0 07013  5020     MOVE IVL,R13
     238  01110  0 00017  5020     MOVE R0,IVR
R    239  01111  0 02014  5020     MOVE R2,R14
R    240  01112  0 15017  5020     MOVE R15,R17
R    241  01113  0 16000  5020     MOVE R16,R0
     242                         * OP CODE ERRORS
     243                            8X305
     244  01114  6 12002  5020     XML 2
     245  01115  6 13017  5020     XMR 0FX
     246                            8X300
O    247  01116  0 00000  5020     XML 7
O    248  01117  0 00000  5020     XMR 11
     249  01120  7 01120  FFFF   STOP  HALT/17H,377H,3,3
     250  01121                    PROC  PROC1
     251           003 6 1       IVV1  RIV  3,6,1
     252  01121  6 00004  5020     XMIT R4,AUX
     253           000002        X4  EQU 2
     254  01122  6 01002  5020     XMIT X4,R1
U    255  01123  7 01123  5020     JMP LAB1
     256  01124  7 01154  5020     RTN
     257  01125  0 36102  5020     MOVE IVV1,R2
     258                           END PROC1
     259  01126                    PROC  PROC2
 U    260  01126  7 01126  5020      JMP S1
D     261          000021          S1  SET 17
      262  01127  7 01154  5020      RTN
      263                            END PROC2
      264  01130                     PROC PROC3
      265                            LIST A
 U    266   0258    C000   5020      XMIT S1,R1
      267   0259    1F00   5020      MOVE WS1,AUX
      268   025A    E26C   5020      RTN
      269   025B    0009   5020      MOVE AUX,R11
      270   025C    E26C   5020      RTN
      271                            END PROC3
      272   025D                     PROC PROC5
      273   025D    C201   5020      XMIT 1,R2
      274   025E    C903   5020      CALL PROC1/
            025F    E251   5020
      275                            ENTRY ENTRY5
      276   0260    C904   5020      CALL PROC2
            0261    E256   5020
      277   0262    E26C   502C      RTN/,,3
      278                            END PROC5
      279   0263                     PROC PROC8
      280   0263    0101   5020   P1  MOVE R1,R1
      281   0264    C905   5020      CALL ENTRY5
            0265    E260   5020
      282                            MAC2
      282   0266    E268   5020   +  JMP   *+2
      282   0267    0107   5020   +  MOVE  R1,IVL
      282   0268    CF64   5020   +  SEL   WS1
      282                         +  MAC3  R1,R11
      282   0269    0109   5020   +  MOVE  R1,R11
      282   026A    816A   5020   +  XEC   *(R1)
      282   026B    C901   5020   +  XMIT  1,R11
 M    283                             END PROC8
      284                            END  MAIN/0,0,0,0


 RETURN TABLE

            026C    896D   0000
            026D    E0CA   0000
            026E    E0CD   0000
            026F    E0D0   0000
            0270    E260   0000
            0271    E262   0000
            0272    E266   0000


 ASSEMBLER ERRORS =   66
```

```
                          CROSS REFERENCE

LABEL       VALUE        REFERENCE


*   1

ABCDEF      0002        -208    -209
ABCDEG      0005        -210
AUX         0000           0
ENTRY5      0260        -275     281
IV1         00B8         -31      44      62      63      64      65      66      67
                          68      69      70      75      76      84      98      99
                         100     101     102     103     107     108     110     110
                         114     164     166     166     167     168     170     173
                         173     176     177     178     182     223     223     224
                         224
IV2         00FE         -32     109     169     170     171     172     180     183
IV3         00F6         -33      51     169
IVL         0007           0
IVR         000F           0
J2          0231        -211    -212
K1          029F        -158
K3          0000        -159
K4          0000        -160
LAB1        00A0          45      97      98      99     100     101     102     103
                        -105
LAB2        00C0         106     107     108     109    -112
LI2         05A1          76     -86      87      88      89
LI4         0699         -89      90      91
MAC1        000A           0
MAC2        0005           0
MAC3        0001           0
MAIN        0000         155     284
OVF         0008           0
PROC1       0251         122     156    -250     258     274
PROC2       0256         124    -259     263     276
PROC3       0258         126    -264     271
PROC5       025D        -272     278
PROC8       0263        -279     283
R0          0000           0
R1          0001           0
R11         0009           0
R12         000A           0
R13         000B           0
R14         000C           0
R15         000D           0
R16         000E           0
R17         000F           0
R2          0002           0
R3          0003           0
R4          0004           0
R5          0005           0
1
R6          0006           0
R7          0007           0
RI2         3FF9        -194
RI3         0000        -195
RI5         0000        -196
S1          0019        -118     119    -120     120     121    -214     260    -261
                         266
```

```
STOP      0250      -249
WS1       1938       -34   167   267   283
WS2       1977       -35    36    38   168   171   172
WS3       19AE       -36
X1        FFFF        48  -202   203
X5        2000      -192   193

*  2

*  3

IW1       00F1      -251   257
X4        0002      -253   254

*  4

*  5

*  6

*  7

P1        0263      -280

*  8

*  9
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