System 35 Desktop Computer

Assembly Development ROM

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Assembly Development ROM

HP 9835A Desktop Computer

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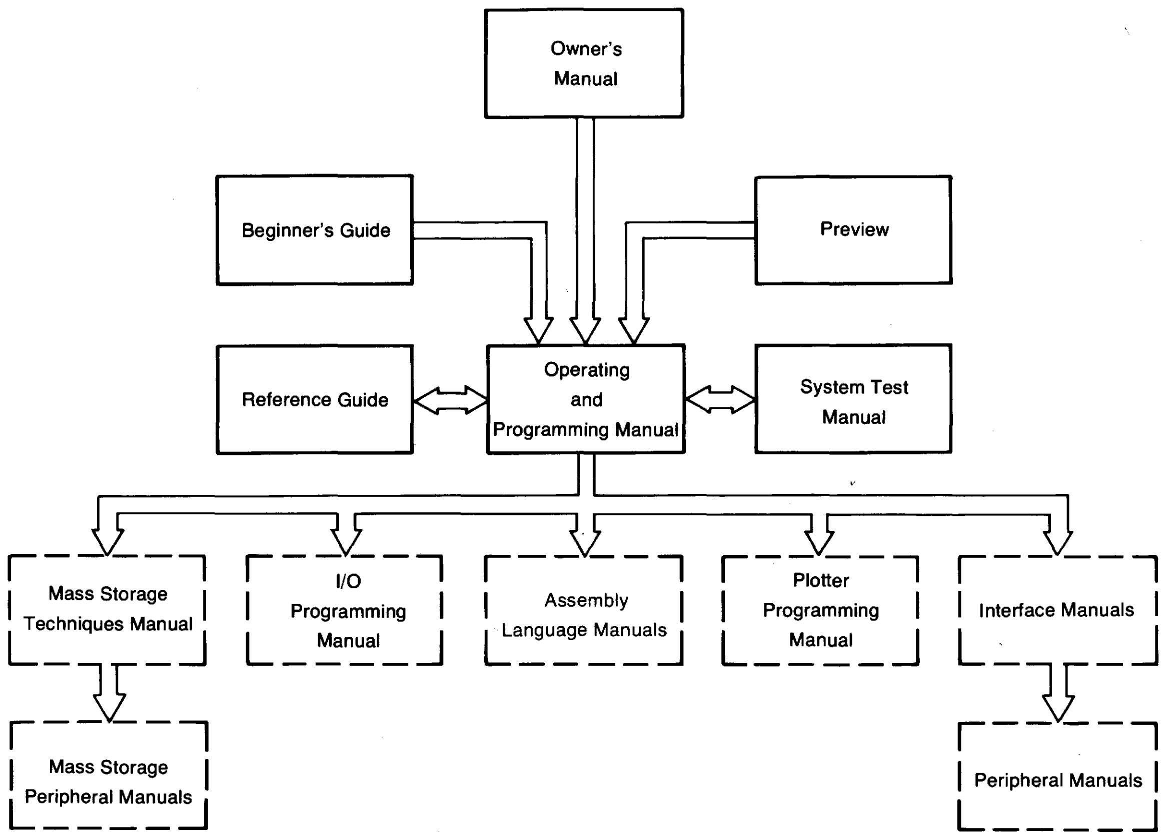
System 35 Manual Reference

The following block diagram shows manuals that are included in the System 35 Documentation scheme and suggested progression. Dotted-line borders indicate those manuals are available with specific options; solid borders indicate those manuals that are shipped with every System 35.



Chapter Summaries

Chapter 1. **General Information**. An introduction to the product and the manual. The purpose and differences of the two Assembly Language ROMs are explained. ROM installation procedures are given. A glossary is provided, along with a discussion of the syntactical forms used in the manual.

Chapter 2. **Getting Started**. A general discussion of the assembly language system. A format for the creation of an assembly language program is presented. Topics such as modules, routines, and memory allocation are discussed, along with methods of using them effectively. Also discussed is the storage and retrieval of modules on mass storage.

Chapter 3. **The Processor and the Operating System**. Necessary information on the structure of the processor and the operating system is presented. Topics covered are: machine architecture, memory organization, data structures and arithmetic, and the machine instructions.

Chapter 4. **Assembly Language Fundamentals**. The basic statements and syntaxes used throughout the assembly language are discussed. Program entry, assembling, symbolic operations, module creation, program and variable storage, and utilities are the topics covered.

Chapter 5. **Arithmetic**. Arithmetic operations are reviewed and the arithmetic utilities are discussed. Floating point and BCD arithmetic are explained.

Chapter 6. **Communicating between Basic and Assembly Language.** The techniques used to pass information to and from the assembly language programs are discussed. Calling assembly routines and passing parameters are presented, along with issues involved with using common. Applicable utilities are also discussed.

Chapter 7. **I/O Handling**. The various techniques of handling the receiving and sending of information to peripheral devices is presented. Topics are: a review of I/O-type machine instructions, registers, applicable utilities, interrupts and interrupt service routines, handshake-type of I/O, direct memory access, and mass storage devices.

Chapter 8. **Debugging**. Techniques for isolating and correcting logic problems in assembly programs are discussed. Included in the discussion are techniques for stepping through programs, getting dumps, patching, and using the keyboard.

Chapter 9. **Errors and Error Processing**. A discussion of Assembly Language ROM and other related errors, and what causes them. Included are methods for trapping errors and possible methods for correcting them.

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General Information

Chapter 1
General Information

Welcome to the world of assembly language programming on the 9835A/B.

It is the design of the Assembly Development Read Only Memory (ROM) to help extend the capabilities of your 9835A/B by giving you greater control and speed through the use of machine instructions, pseudo-instructions, and extensions to the BASIC language.

The assembly language system is provided to you as ROMs which plug into the drawers provided for that purpose in the 9835A/B. There are three physical ROMs, comprising two "logical" ROMs —

- The Assembly Development ROM. Two physical ROMs. This ROM is always provided with an Execution ROM (together comprising HP product number 98339A), and the three ROMs as a unit constitute the assembly language system of the 9835A/B.
- The Assembly Execution ROM, HP product number 98338A. One physical ROM. Since this ROM is an integral part of the assembly language system, the use of the capabilities in this ROM is incorporated into the discussions in this manual. Information on this ROM can be found separately in the Assembly Execution ROM manual (HP part number 09835-90082).

It is assumed throughout this manual that you are familiar with the basic operation and language of the 9835A/B. It is also assumed that you are reasonably well-acquainted with at least one other assembly language.

Structure of the Manual

It is the intent of this manual that you should be able to find between its covers everything you need to know to use the assembly language effectively. However, since assembly language programming is a complex topic, the manual relies a great deal on your past experience. Most of the information is in succinct presentations of a particular topic; it is not the intent to "teach" assembly language programming to someone not familiar with the topic.

The major topics covered are: assembly language program creation (Chapter 2), the processor and relevant operating system constructs (Chapter 3), assembly language fundamentals (Chapter 4), arithmetic (Chapter 5), communications with BASIC (Chapter 6), I/O handling (Chapter 7), debugging tools (Chapter 8), errors and error processing (Chapter 9). Each topic, or chapter, has a summary at the beginning detailing the information to be presented therein. A compilation of these summaries can be found immediately preceding the Table of Contents.

The manual is organized so that each topic can be covered completely within a given chapter. This approach was chosen over the strict syntactical or semantical treatment of the individual statements and instructions. As a consequence, you may find this difficult to use as a "quick reference" for syntax and meaning of the individual commands.

To meet your needs for "quick reference" material, an Assembly Language System Quick Reference Manual (HP part number 09835-90081) is provided. In addition, you will find much of the information in this manual condensed and tabulated in the various appendices of this manual.

A recommended method for using the manuals is to start with this one as your basic learning tool. Then you should be able to use the Quick Reference Manual effectively for all future reference.

Purpose of the ROMs

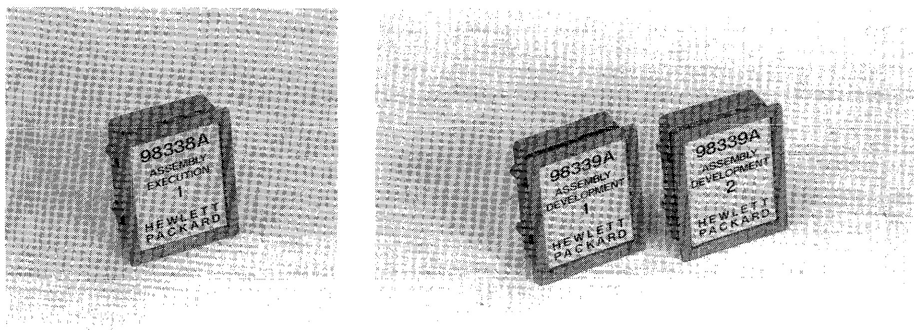
The Development ROM is used to write and debug assembly language programs on the 9835A/B. The Execution ROM, provides the capability to load, run, and store assembled routines and modules.

The Execution ROM can be used independently of the Development ROM. However, the Development ROM cannot be used without the Execution ROM. The latter's capabilities, therefore, are considered in this manual as an inherent part of the Development ROM. Because of the overhead required by the debugging features provided by the Development ROM, programs run more rapidly if the Execution ROM is used without the Development ROM.

ROM Installation

Before assembly language programming can proceed, the ROMs must be in place. The installation is a simple process.

There are several ROM drawers for the computer: one on the right side of the machine and four in front. Each front drawer holds up to four ROMs; the side drawer holds up to fourteen. ROMs may be placed in any ROM slot in any drawer.



Assembly Language System ROMs

To add the ROMs, turn off the computer and remove a ROM drawer (by pulling outwards on it until it is completely separated from the computer). Insert the ROMs, one at a time, following this procedure: you should orient the ROM so that its label reads the same way as the others in the drawer (with the bottom of the lettering toward the "front" of the drawer). Then insert it vertically in one of the unused slots. Make sure that it slides in all the way to the bottom of the connector. There are small raised ribs on both sides of each ROM which will fit into recesses in the slot; if the ribs don't fit, you have not oriented the ROM correctly.

After inserting both ROMs, re-insert the drawer in the machine (by pushing on it until it is flush with the outside cover of the machine). With this done, you are now ready to begin writing assembly language programs.

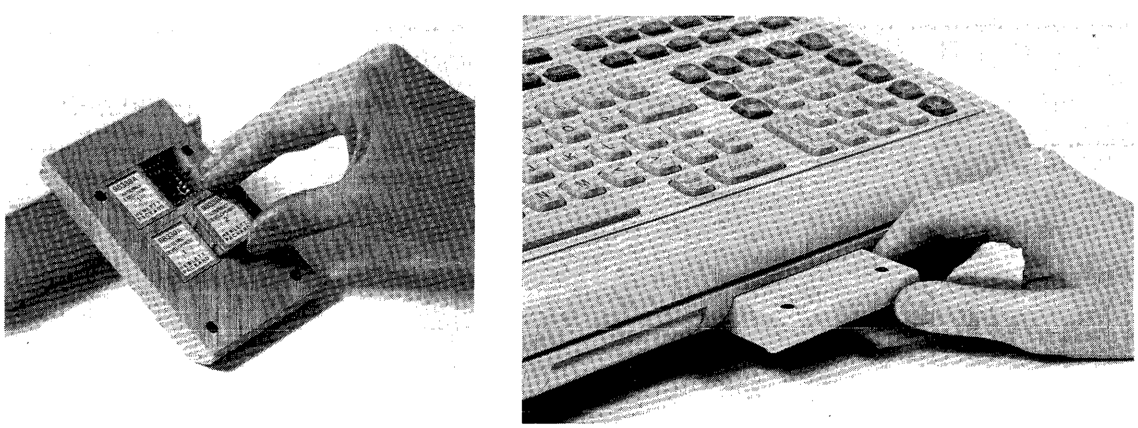


Figure 1. Installing the Development ROM

Buzzwords

During the course of the discussions in this manual, words and phrases are used which are in common circulation among those who are familiar with assembly languages. While the meaning of most are either well-known, or are deducible from the context, there are a few which may be unfamiliar, or unique to the 9835A/B assembly language, or are variable from one assembly language to the next and thus need to be defined for this one. They are —

assembled location — a reference to a location in memory which may be specified in one of the following forms —

{symbol} [, {numeric expression}]
{expression} [, {numeric expression}]

where:
{symbol} is an assembly location. It may be either a label for a particular machine instruction (in which case the address of the associated instruction is used), or an assembler-defined symbol (in which case the associated absolute address is used), or a symbol defined by an EQU instruction (described in the "Symbolic Operations" of Chapter 4).

{expression} may be a numeric expression or a string expression. If numeric, a decimal calculation is performed and the result is interpreted as an octal value; if the result is not an octal representation or an integer, an error results. If a string expression is used, the string must be interpretable as either an octal integer constant or a known assembly symbol (see {symbol} above).

{numeric expression} serves as a decimal offset from the given label or constant.

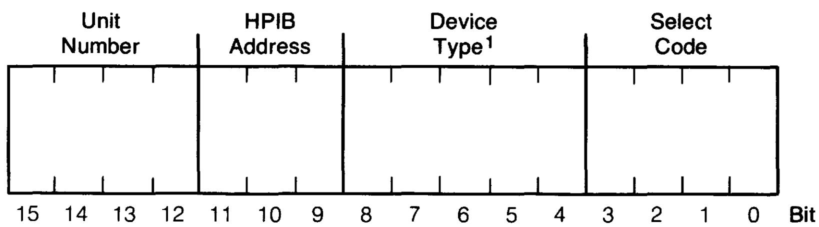
byte — a group of 8 binary digits (bits).

busy bits — each variable located in the BASIC value or common areas has associated with it two bits: a "read" busy bit, and a "write" busy bit. When a busy bit is set, all attempts to perform the associated function on that variable are locked out. When a busy bit is cleared, the function may be performed on the variable.

conditional assembly — an assignation that certain portions of a module are not to be assembled unless a condition has been set. The portions begin with any of the IFA through IFH, and IFP, pseudo-instructions, and end with the next XIF pseudo-instruction. IFA uses the A-condition as a test, and so on. The conditions are set by the statement assembling the module (IASSEMBLE).

interrupt service routine (ISR) — an assembly language routine intended to perform a certain action, or set of actions, when the computer receives a request from an external device. An "active" ISR is one which is currently enabled for a given device.

mass storage unit specifier (msus) — a single word corresponding to the BASIC language mass storage unit specifier as described in either the 9835A/B Operating and Programming Manual — HP part number 09835-90000 — or the Mass Storage Techniques Manual — HP part number 09835-90070. An msus has the following structure —



An msus can designate the current default as its mass storage device (meaning it will use the device indicated by the last MASS STORAGE IS statement executed). This is designated by having the msus be all ones (i.e., equal to − 1).

object module — a section of assembled code stored in the particular region of memory set aside for it. Though the source module for the object code may no longer be resident in memory, when created, the module was delimited by certain pseudo-instructions (NAM and END) and is referenced by the name given to it by the NAM pseudo-instruction.

octal expression — a numeric expression which, when displayed or printed, appears as an octal (base-8) number. Within arithmetic operations, it has a decimal value (base-10). Thus, the value 17_8 will appear as 17 (representing the value 15_{10}), but if arithmetic was performed on it, it would act as if it were 17_{10}. All octal expressions are necessarily integers in the range of 0 to 177777_8.

source module — a section of assembly language source code beginning with a NAM pseudo-instruction and ending with the END pseudo-instruction.

word — two bytes; a group of 16 binary digits (bits).

1 The device type is the ASCII code for the type minus 100_8.

Fundamental Syntax

The syntax conventions used in this manual are those used in the Operating and Programming Manual for the 9835A/B —

`dot matrix`	All syntax items displayed in dot matrix form should be programmed as shown.
[ ]	Items contained in brackets are optional items.
...	Ellipses mean that the previous item may be repeated indefinitely.

In addition, the following convention is employed throughout the Assembly Language series of manuals —

{ }	Items contained in braces are syntax items considered as a unit. The names inside are usually descriptive of the function intended for that item. Whenever an item enclosed in braces appears in the text, the notation refers to the same notation within an earlier syntax.

Chapter 2
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Chapter 2
Getting Started

Summary; This chapter contains a general discussion of the assembly language system. A format for the creation of an assembly language program is presented. Topics such as modules, routines, and memory allocation are discussed, along with methods of using them effectively. Also discussed is the storage and retrieval of modules on mass storage.

The thing to remember about the assembly language system is that it has been thoroughly integrated into the operating system of the 9835A/B. Once the ROMs have been installed, you are able immediately to begin programming in assembly language. In addition, you have the capability to load and store your programs on mass storage, to assemble them separately or leave them in source form, to execute them from BASIC and pass BASIC variables to them, and to debug them, including a full pausing and stepping capability.

Developing Routines for Later Use

Most assembly language programs are written with the intent that they will be used many times, not just at the time they are written. It is for just such program development that the full capabilities of the assembly language system come into play. The development comes in several stages. Each stage has its unique requirements and the tools to meet those requirements.

The first stage is creation of the source program. This is achieved by the use of the editing capabilities of the 9835A/B. Additionally, the basic mass storage capabilities of the computer can be used.

The second stage is the creation of the object (or machine) code. This requires not only an assembly of the source, but the ability to allocate special locations in memory to hold the newly created object code.

The third stage is the validation of the routines as written, commonly known as "debugging". This is enabled by calls from a BASIC driver, followed by application of various debugging tools provided by the assembly system. The capabilities to pause and step a program have been extended to assembly language instructions to assist this process.

The fourth stage is to store away the debugged object code so that it may be used at a later time. A special mass storage statement is provided by the assembly language system. This statement stores object code into a special assembly file.

Finally, the end-user of the routines must be able to retrieve the object code from mass storage as it is needed. He also must be able to access the routines from BASIC programs. Both these needs are met with the Execution ROM, so the capabilities are not only provided, but they are provided independent of the program development capabilities located in the Development ROM.

Each of the topics involved in these stages is discussed at length in this manual.

Figure 2 presents a graphical presentation of this overview.

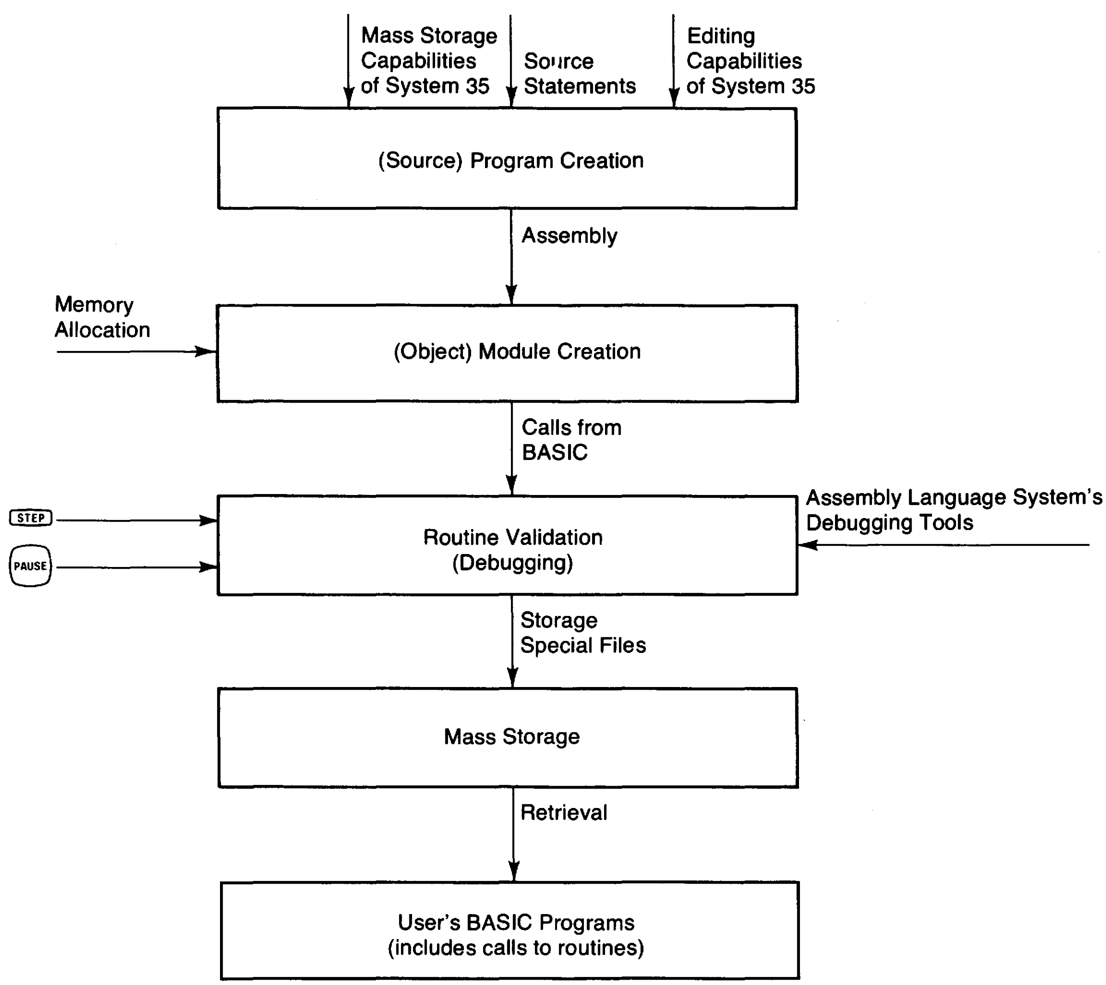


Figure 2. Overview of Assembly Language Routine Development Process

Overview

At this point, there are three fundamental structures to be explained: programs, modules, and routines.

A **program** is the set of source statements from which the object (or machine) code is generated. The assembly source statements are extensions to the BASIC language which is used in the 9835A/B. The statements themselves are stored in the machine as part of the BASIC program in which they reside. At some point, you must take the assembly source statements and assemble them into object code, in order that they can be run. The object code is stored in a specified location in the machine.

A **module** is a subset of the object code. It is a means of separating and identifying parts of the code so that those parts may be used individually (as in mass storage operations). There may be any number of modules present at any one time, limited only by the amount of memory allocated for object code.

A **routine** is a "callable" section of a module. It is analogous to the subprogram in BASIC. It has a named entry point, possibly a parameter list, and (if programmed correctly) a return. A module may contain any number of routines, again limited only by the amount of memory allocated to hold the object code.

In short, the usefulness of each structure is as follows —

- **Programs** contain assembly language source code.
- **Modules** contain object code to be loaded from or stored on mass storage.
- **Routines** are executable sections of object code.

Program Creation

The first matter which is likely to concern you about the assembly language system is how to create an assembly language program.

In general, the process of creating an assembly language subprogram consists of the following steps —

1. Enter and store the source code (program).
2. Create an area in memory which will ultimately contain the object code.

3. Assemble the source code into object code, storing the latter into the area of memory set aside for it.
4. Execute the object code (routines) from BASIC "drivers".

Each of these steps will be discussed at length in the pages of this manual, along with a number of not-so-incidental side-topics (such as "debugging" techniques). The purpose of **this** short section is to give you an impression of the general procedure through which an assembly language subprogram is created.

As an example to use to demonstrate the process, suppose the following task has been assigned to you —

> Requirement: Write an assembly language subprogram which takes two integer values and multiplies them together as integers. If the result overflows the range of an integer (− 32 768 to + 32 767), then the subprogram should return the same error as the system would (i.e., error number 20).

With this task in hand, suppose that you have completed a programming analysis that suggests that the following assembly language source code would fulfill the subprogram's functions —[1]

```
          NAM Multiplication ! Beginning of module
          EXT Error_exit,Get_value,Put_value ! Utilities
Integers: BSS 2             ! Storage area for integers created
          SUB               ! Indicates entry point follows
Input1:   INT               ! Indicates "integer parameters are
Input2:   INT               !   passed in the order given by these
Output:   INT               !   statements and are given names
Multiply: LDA =Integers     ! Actual entry point (name: Multiply);
          LDB =Input1       !   routine begins by fetching actual
          JSM Get_value     !   value of the input parameters
          LDA =Integers+1   !   from BASIC and storing them where
          LDB =Input2       !   the routine can use them
          JSM Get_value
          LDA Integers      ! Then it loads the values into the
          LDB Integers+1    !   arithmetic accumulator and
          MPY               !   finally multiplies them
          SBP *+2           ! A check for overflow is performed
          CMB               !   by checking the result for anything
          SZB *+3           !   in the B register when it should be 0
          LDA =20           !   and if it isn't, Error 20 is selected
          JSM Error_exit    !   and the routine is aborted
          STA Integers      ! If everything is OK, then result stored
          LDA =Integers     ! The product is then returned to the
          LDB =Output       !   output variable in BASIC listed
          JSM Put_value     !   among the arguments
          RET 1             ! We're finished, so return to BASIC
          END Multiplication ! End of module
```

1 The fact that it is rarely possible to create a running program at this stage should not get in the way of accepting the example. Usually there is debugging involved in later stages.

Now that the routine has been developed, it is necessary to get it into the memory of the machine as a program. This is done by preceding each and every assembly language statement with the keyword ISOURCE and entering it as a program line. The process of entering (with the keyword included) is the same as with any other BASIC statement — so you can use EDIT or AUTO and the (STORE) key in the same way you normally enter any BASIC statement. (This process is fully described in the "Program Entry" section of this chapter.)

The final result of entering the routine would look something like —

```
10  ISOURCE             NAM Multiplication ! Beginning of module
20  ISOURCE             EXT Error_exit,Get_value,Put_value ! Utilities
30  ISOURCE  Integers:  BSS 2              ! Storage area for integers created
40  ISOURCE             SUB                ! Indicates entry point follows
50  ISOURCE  Input1:    INT                ! Indicates "integer parameters are
60  ISOURCE  Input2:    INT                !   passed in the order given by these
70  ISOURCE  Output:    INT                !   statements and are given names
80  ISOURCE  Multiply:  LDA =Integers      ! Actual entry point (name: Multiply);
90  ISOURCE             LDB =Input1        !   routine begins by fetching actual
100 ISOURCE             JSM Get_value      !   value of the input parameters
110 ISOURCE             LDA =Integers+1    !   from BASIC and storing them where
120 ISOURCE             LDB =Input2        !   the routine can use them
130 ISOURCE             JSM Get_value
140 ISOURCE             LDA Integers       ! Then it loads the values into the
150 ISOURCE             LDB Integers+1     !   arithmetic accumulator and
160 ISOURCE             MPY                !   finally multiplies them
170 ISOURCE             SBP *+2            ! A check for overflow is performed
180 ISOURCE             CMB                !     by checking the result for anything
190 ISOURCE             SZB *+3            !     in the B register when it should be 0
200 ISOURCE             LDA =20            !    and if it isn't, Error 20 is selected
210 ISOURCE             JSM Error_exit     !   and the routine is aborted
220 ISOURCE             STA Integers       ! If everything is OK, then result stored
230 ISOURCE             LDA =Integers      ! The product is then returned to the
240 ISOURCE             LDB =Output        !   output variable in BASIC listed
250 ISOURCE             JSM Put_value      !   among the arguments
260 ISOURCE             RET 1              ! We're finished, so return to BASIC
270 ISOURCE             END Multiplication ! End of module
```

This source code demonstrates the three critical items in assembly subprograms. First, a routine has to be part of a module; modules are delimited with the NAM and END pseudo-instructions (see lines 10 and 270 in the source). Second, a routine has to have an entry point; this consists of a SUB pseudo-instruction (see line 40), any parameters (see lines 50 through 70), and a name (the label used on the first machine instruction following the SUB, see line 80). Finally, a routine must be able to return to the BASIC program which called it; this is accomplished with the RET 1 instruction (see line 260).

The NAM, END, and SUB pseudo-instructions are discussed in Chapter 4. The RET 1 instruction is discussed in Chapter 3.

The next three steps in program creation are each satisfied with BASIC-executable statements. Creation of a storage area for the object code for the program (which can be estimated at less than 40 words; there is essentially one word of object code per line of source) is accomplished by programming the statement —

```
280  ICOM 40
```

(The ICOM statement is fully discussed in the "Setting Aside Memory" section of this chapter.)

This can be followed in the same program by an instruction to assemble the source code into object code —

```
290  IASSEMBLE Multiplication
```

(The IASSEMBLE statement is fully discussed in Chapter 4.)

If the assembly is successful (and it will be in this example), then the routine can be called and used as desired. A typical call looks like —

```
600  ICALL Multiply(Index,Dimension,Subscript)
610  Array(Subscript)=Value
```

(The ICALL statement is fully discussed in Chapter 6.)

Thus, the final result could easily be —

```
10  ISOURCE              NAM Multiplication ! Beginning of module
20  ISOURCE              EXT Error_exit,Get_value,Put_value ! Utilities
30  ISOURCE  Integers:   BSS 2             ! Storage area for integers created
40  ISOURCE              SUB               ! Indicates entry point follows
50  ISOURCE  Input1:     INT               ! Indicates "integer parameters are
60  ISOURCE  Input2:     INT               !   passed in the order given by these
70  ISOURCE  Output:     INT               !   statements and are given names
80  ISOURCE  Multiply:   LDA =Integers     ! Actual entry point (name: Multiply);
90  ISOURCE              LDB =Input1       !   routine begins by fetching actual
100 ISOURCE              JSM Get_value     !   value of the input parameters
110 ISOURCE              LDA =Integers+1   !   from BASIC and storing them where
120 ISOURCE              LDB =Input2       !   the routine can use them
130 ISOURCE              JSM Get_value
140 ISOURCE              LDA Integers      ! Then it loads the values into the
150 ISOURCE              LDB Integers+1    !   arithmetic accumulator and
160 ISOURCE              MPY               !   finally multiplies them
170 ISOURCE              SBP *+2           ! A check for overflow is performed
180 ISOURCE              CMB               !   by checking the result for anything
190 ISOURCE              SZB *+3           !   in the B register when it should be 0
200 ISOURCE              LDA =20           !   and if it isn't, Error 20 is selected
210 ISOURCE              JSM Error_exit    !   and the routine is aborted
220 ISOURCE              STA Integers      ! If everything is OK, then result stored
```

```
230 ISOURCE              LDA =Integers    ! The product is then returned to the
240 ISOURCE              LDB =Output      !   output variable in BASIC listed
250 ISOURCE              JSM Put_value    !   among the arguments
260 ISOURCE              RET 1            ! We're finished, so return to BASIC
270 ISOURCE              END Multiplication ! End of module
280  ICOM 40
290  IASSEMBLE Multiplication
       .
       .
       .
600  ICALL Multiply(Index,Dimension,Subscript)
610  Array(Subscript)=Value
       .
       .
       .
```

It isn't necessary that a program be assembled in *every* BASIC program which uses it. Object code can be stored on mass storage with a statement like —

```
300  ISTORE Multiplication;"MULT"
```

So if the example were instead made to read —

```
10  ISOURCE              NAM Multiplication ! Beginning of module
20  ISOURCE              EXT Error_exit,Get_value,Put_value ! Utilities
30  ISOURCE   Integers:  BSS 2            ! Storage area for integers created
40  ISOURCE              SUB              ! Indicates entry point follows
50  ISOURCE   Input1:    INT              ! Indicates "integer parameters are
60  ISOURCE   Input2:    INT              !   passed in the order given by these
70  ISOURCE   Output:    INT              !   statements and are given names
80  ISOURCE   Multiply:  LDA =Integers    ! Actual entry point (name: Multiply);
90  ISOURCE              LDB =Input1      !   routine begins by fetching actual
100 ISOURCE              JSM Get_value    !   value of the input parameters
110 ISOURCE              LDA =Integers+1  !   from BASIC and storing them where
120 ISOURCE              LDB =Input2      !   the routine can use them
130 ISOURCE              JSM Get_value
140 ISOURCE              LDA Integers     ! Then it loads the values into the
150 ISOURCE              LDB Integers+1   !   arithmetic accumulator and
160 ISOURCE              MPY              !   finally multiplies them
170 ISOURCE              SBP *+2          ! A check for overflow is performed
180 ISOURCE              CMB              !   by checking the result for anything
190 ISOURCE              SZB *+3          !   in the B register when it should be 0
200 ISOURCE              LDA =20          !   and if it isn't, Error 20 is selected
210 ISOURCE              JSM Error_exit   !   and the routine is aborted
220 ISOURCE              STA Integers     ! If everything is OK, then result stored
230 ISOURCE              LDA =Integers    ! The product is then returned to the
240 ISOURCE              LDB =Output      !   output variable in BASIC listed
250 ISOURCE              JSM Put_value    !   among the arguments
260 ISOURCE              RET 1            ! We're finished, so return to BASIC
270 ISOURCE              END Multiplication ! End of module
280  ICOM 40
290  IASSEMBLE Multiplication
300  ISTORE Multiplication;"MULT"
310  END
```

the object code is consequently stored into the file "MULT".

Later programs can retrieve the object code for use, such as in the following program —

```
10   INTEGER Dimension,Index,Subscript
20   ICOM 40
30   ILOAD "MULT"
        .
        .
        .
600  ICALL Multiply(Index,Dimension,Subscript)
610  Array(Subscript)=Value
        .
        .
        .
```

(Both ISTORE and ILOAD are discussed in the "Retrieving and Storing Modules" section of this chapter.)

Program Entry

The assembly language source statement is an **extension** to the BASIC language used in the 9835A/B. This means that each assembly language statement is entered using a "keyword" — in this case ISOURCE — as a message to the operating system that the line is an assembly language statement.

By looking at an example, you can see what is meant —

```
10   LET A=10
20   LET B=20
30   PRINT A,B
40   ISOURCE   NAM Example
50   ISOURCE   NOP
60   ISOURCE   END Example
70   END
```

Lines 10, 20, 30, and 70, are all recognizable as BASIC statements. The keywords they use — LET, PRINT, and END — direct that certain actions take place. Lines 40, 50, and 60, are all assembly language statements; this was indicated by the ISOURCE keyword used in these lines.

Entering assembly language statements, by using the ISOURCE keyword, is thereby the same process as entering other types of BASIC statements. You may use all of the system editing features that you are used to using in the creation of BASIC programs — EDIT, AUTO, etc. You store each line with the STORE key, as you would any other BASIC line.

Also, assembly lines do not have to be in any special place in the BASIC program. The above example could be re-arranged as follows —

```
10   LET A=10
20   ISOURCE   NAM Example
30   LET B=20
40   ISOURCE   NOP
50   PRINT A,B
60   ISOURCE   END Example
70   END
```

Thus, you are free to enter your assembly statements anywhere in your BASIC program. But, you may ask, what is the effect of spreading them out like this? The answer is, simply, none. When the time comes to use them, assembly statements and BASIC statements are separated by the operating system and treated differently.

When the BASIC program is run, ONLY the BASIC statements are executed. The ISOURCE statements are **ignored**, and, as you will be shown in Chapter 4, when the assembly language lines are assembled, the BASIC statements are ignored. A way to consider it is that there are two programs in one — BASIC's and the assembler's. So you can envision the example above as being this way —

```
BASIC                               ASSEMBLER

10   LET A=10                       20   ISOURCE   NAM Example
30   LET B=20        source         40   ISOURCE   NOP
50   PRINT A,B                      60   ISOURCE   END Example
70   END
```

You should note, then, that ISOURCE statements are not "executable" in the usual BASIC sense. Their location in the program does not indicate the place where they will be executed. Assembly instructions are not executed until a routine is "called"; this is discussed in detail in Chapter 4.

Now that it has been said that the two types of statements can be thoroughly intermixed, it should also be said that the practice is **not recommended**. As a good programming practice — i.e., for readability and to preserve the self-documenting features of BASIC — it is recommended that assembly statements be collected together and placed in one spot in the program.

The first example is a recommended practice over the second, even though the second is permissible.

Other Extensions

In addition to the ISOURCE statement, there are a number of other BASIC language extensions provided by the assembly languge system. Unlike the ISOURCE statement, they are "executable", and their appearances are part of the BASIC lines (as distinguished from the assembler's). Where they appear is where the action associated with them is taken. This is identical to the way the other BASIC statements perform. The statements involved are —

IASSEMBLE
IBREAK
ICALL
ICHANGE
ICOM
IDELETE
IDUMP
ILOAD
INORMAL
IPAUSE OFF
IPAUSE ON
ISTORE
OFF INT
ON INT

Also provided are four numeric functions —

DECIMAL
IADR
IMEM
OCTAL

The functions can be used wherever numeric functions in general may be used.

All of these statements (except ICOM and ISOURCE) and the functions are available to you as live keyboard operations as well as programmable statements. A full discussion of each of the statements and functions can be found within this manual.

Modules, Routines, and Such

There are three basic activities associated with using assembled modules and routines. First, there is the need to retrieve them from wherever they may be stored (including providing a place for them to be kept while they are resident in the memory of the machine). Second, there is the actual execution of the routines. And third, there is the occasional requirement to store, or re-store a module on mass storage (including, perhaps, the need to free up the space in memory it previously occupied).

Names

Routines, modules, and files all have names. The names given them may or may not bear some significance to one another; that depends upon you and the way that you name things.

Conventions for the naming of files and methods of general file manipulation can be found in the Operating and Programming Manual and in the Mass Storage Techniques Manual. The conventions are not any different than for files in general.

Names for modules are assigned with the creation of the source. In the assembly language source code, you have a NAM pseudo-instruction. This serves two purposes — to designate the beginning of the module and to assign the module a name. All of the assembly source statements which follow the NAM are in that module until an END pseudo-instruction is encountered. Thus, recalling the previous example —

```
20   ISOURCE   NAM Example
40   ISOURCE   NOP
60   ISOURCE   END Example
```

All of the ISOURCE statements between lines 20 and 60 (in this case, just the one) form the module called "Example". The formal syntaxes of these pseudo-instructions are —

NAM {module name}
END {module name}

{module name} is a symbol which becomes the name of the module. It follows the same rules as names in BASIC: up to fifteen characters; starts with a capital letter; followed by only non-capital letters, numbers, or the underscore character.

The {module name} in the END statement must correspond to the {module name} of the NAM statement or an assembly error ("EN") results.

You may have any number of modules in your source code. Each module begins with a NAM and ends with an END pseudo-instruction as above.

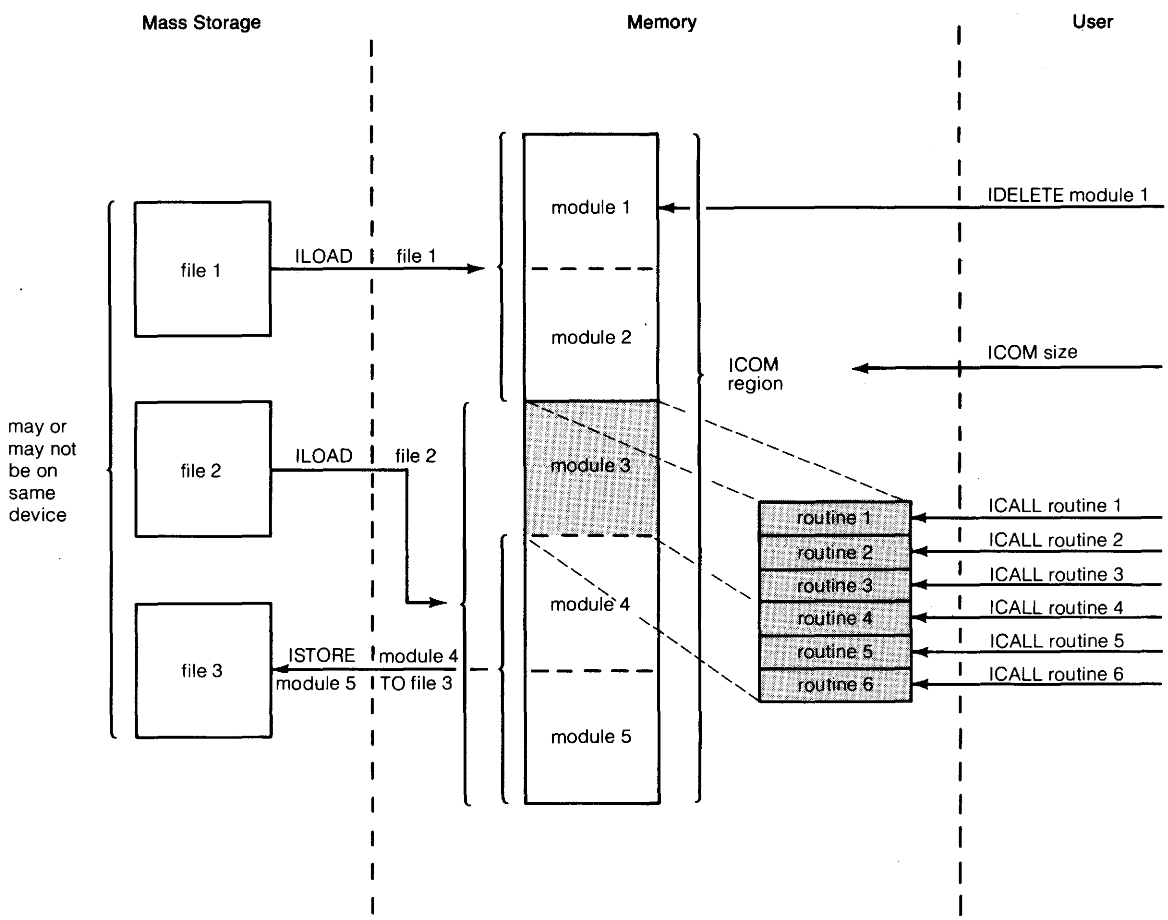


Figure 3. Overview of Routines and Modules.

Survey of Modules and Routines

To sketch the functional relationships of modules and routines, please refer to Figure 3 above.

Modules are stored in files and may be retrieved and placed in memory using the "ILOAD" command. When the ILOAD command is executed, all of the modules in the file are loaded into the memory. Note that many files can be loaded, with many modules each, with all of the modules able to remain resident in the memory.

Alternatively, modules which are already in memory may be stored into a single file using the "ISTORE" command. When the ISTORE command is executed, the designated modules are stored into an "option ROM" (OPRM) type of file (on tape cartridges) or an "Assembly" (ASMB) type of file (on non-tape mass storage media). After storage, the modules are still in memory. They may be removed (i.e., the space they occupy in memory is "freed up") by using the "IDELETE" command.

The area of memory where the modules are stored is called the "ICOM region". It is a particular contiguous area which must be large enough to hold all of the object code you wish to have resident in the memory at any one time.

Each module contains one or more routines. Your access to the routines is through the ICALL statement, which is very similar to the CALL statement used for BASIC subprograms. The ICALL statement may have arguments which you need to "pass" (send down) to the routine itself. What these arguments, if any, may be, and what meaning they hold depends upon what you have in mind for that routine. There are corresponding items in the assembly source code; these are discussed in Chapter 6.

Setting Aside Memory

As indicated by Figure 3, you cannot load a module until there is an ICOM region into which to load it. Neither can you assemble your source code into object code unless there is an ICOM region into which the object code can go.

The statement to use to create an ICOM region is —

```
ICOM {size}
```

where {size} is an integer constant indicating the number of words to be used to form the ICOM region. The maximum size is 32 718 words.

The ICOM statement is a "declaration", that is, it is not executable, but rather is used when assignment of memory takes place just before a program is run. This is similar to a DIM or COM statement. As with a DIM or COM statement, the statement cannot be executed from the keyboard.

Once created, the ICOM region remains in existence until it is explicitly destroyed. But it is possible to change the size by using another ICOM statement.

The order in which modules appear in the ICOM region is determined by the order in which they are loaded using the ILOAD statement discussed in the next section or are created by the IASSEMBLE statement discussed in the next chapter.

In most cases, the space which is freed up by reducing the size of the ICOM region is returned to your available memory space. Sometimes, however, it is not returned, this being caused by the status of the common area allocated in memory, or by other option ROMs. The space is returned whenever —

- There is no common area assigned (with the COM statement); and,
- The requirements of another option ROM do not interfere.

There may be any number of ICOM statements in a program. The current size of the ICOM region is determined by the last one which appears in the program when the (RUN) key is pressed (or the command RUN is executed).

For example, suppose you have a program with the following statements in it —

```
20   ICOM 984
30   DIM A$[100]
       .
       .
       .
300  ICOM 492
       .
       .
       .
610  ICOM 2000
       .
       .
       .
900  END
```

Upon pressing (RUN), the ICOM region would be 2 000 words long. This is because line 610 is the final ICOM appearance.

The region continues to exist even if you load in another program which contains no ICOM statements. All ICOM statements must appear in the **main** program, not in any subprogram.

ICOM statements in a program must appear before any COM statement. This is to insure that the ICOM region will be allocated before the common is allocated.

There are three ways to eliminate the ICOM region —

- Execute SCRATCH A
- Execute ICOM 0 in a program.
- Turn off the machine.

After any of these actions, the region is no longer in existence. If there are any modules in the region, they disappear as well. If any of those modules contain an active interrupt service routine, you get an error (number 193) if you try to eliminate the region using ICOM 0. If any of your routines provided to other users contain active ISRs, your documentation for the routine should warn the users of that fact so they can avoid this error.

The ICOM 0 procedure can be used to assure that all previous modules are deleted. For example, the following sequence —

```
100  ICOM 0
110  ICOM 2000
```

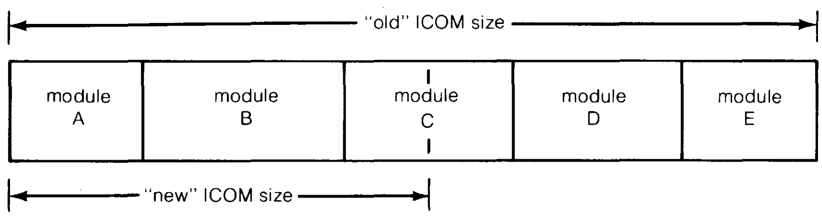
assures that an ICOM region of 2 000 words is in existence at the running of the program, and one completely clear of any previously loaded modules.

When you are altering the size of the ICOM region, the new size specified becomes the size of the region from the moment of running the program. If the size being requested is larger than that which already exists, the additional space needed is requested from the operating system. If the space is available, everything proceeds uneventfully. If the space is not available, an error (number 2) results. To make the space available, one of the following procedures must be followed —

- Execute SCRATCH A.
- Execute SCRATCH C.

Each procedure has its separate effects, and the course selected should be determined by your circumstances at the time. Consult the Operating and Programming Manual for details on the other effects of each of these commands.

If the size being requested is smaller, modules are deleted if they no longer fit into the smaller region. For example, suppose the following situation existed —



Upon compilation of the new ICOM statement, the modules E, D, and C are deleted. None of those modules may contain an active interrupt service routine or an error results (number 193).

Retrieving and Storing Modules

Modules are stored in files on mass storage media as Option ROM (OPRM) or Assembly (ASMB) types of files. On tape media, they are stored in the OPRM type and on non-tape media they are stored in the ASMB type. In this case, the two file types are equivalent.[1]

To retrieve a module, or modules, from mass storage, identify the file name of the file containing the module. Combine the name with the mass storage unit specifier[2] of the device to form a file specifier. Then execute the statement —

ILOAD {file specifier}

This retrieves ALL the modules in the file and stores them in the ICOM region.

If there are modules already loaded in the ICOM region, these additional modules are added to them, (NOT written over them). If an existing module in the ICOM area has the same name as one of the modules being loaded, the existing module is deleted and the loaded version takes its place.

If you do not want all the modules in a given file, you can purge the unwanted ones from the ICOM region using the IDELETE statement —

IDELETE {module name} [,{module name} [,...]]

1 OPRM-type files may be created by other option ROMs for their particular purposes. In those cases, the contents are entirely different.

2 Not to be confused with the single-word msus described in Chapter 1. This form is used by BASIC's Mass Storage statements (see the Operating and Programming Manual or Mass Storage Techniques Manual).

For example, if you had loaded a file which had the routines Larry, Pat, Ed, and Piper, and you want to keep only Larry, then you execute the statements —

```
IDELETE Pat
IDELETE Ed
IDELETE Piper
```

or, more simply —

```
IDELETE Pat, Ed, Piper
```

Deletions do not have to be done immediately after loading. They can be done at any time. After the IDELETE has been executed, the portion of the ICOM region which the module previously occupied is made available for use in loading other modules. The space is NOT returned to the generally available memory; that action is done with an ICOM statement with a smaller size.

Whenever a module is deleted, other modules are moved, as necessary, to take up any slack space in the ICOM region. This is done so that all of the free space in the region is at the end. If a module is being deleted, or being moved as above, and it contains an active interrupt service routine, an error results (number 193).

If you desire at any time to delete all of the modules in your ICOM region, you can do so by executing either of the following statements —

```
IDELETE ALL
IDELETE
```

Sometimes you may desire to move modules in the opposite direction — from memory to mass storage. This is done with the ISTORE statement. The statement has the form —

ISTORE {module name} [, {module name} [, ...]] ; {file specifier}

A {module name} must be the name of a module currently stored in the ICOM region. Upon execution of the statement, a file with the name and mass storage unit specifier given in the {file specifier} is created and the modules are stored in the file, in the order listed.

The file created by an ISTORE statement is an OPRM or ASMB type, as appropriate to the medium involved. It can then be used in ILOAD statements at a later time.

In the case that you might want to store all of the routines currently in the ICOM region into a particular file, you can use either of the following statements —

```
ISTORE ALL; {file specifier}
ISTORE; {file specifier}
```

Chapter 3
Table of Contents

Chapter 3

The Processor and the Operating System

Summary: This chapter contains the necessary information on the structure of the processor and the operating system. Topics covered are: machine architecture, memory organization, data structures, and the machine instructions.

Before proceeding to the actual assembly language, it is useful to discuss the processor and operating system with which you are dealing. This chapter discusses various concepts related to the processor, the machine instruction set, the operating system organization, and data structures.

Machine Architecture

The 9835A/B is developed around a set of processors called a "hybrid". There are actually three processors — the Binary Processor Chip (BPC), the Input-Output Controller (IOC), and the Extended Math Chip (EMC). Each has its own set of instructions, but all three work in conjunction. It is not necessary in using the assembly system that you know on which chip a particular instruction resides. In the presentation of the instruction set — and for all practical purposes while working with the computer — no distinction need be made between the processors, and the entire instruction set may be considered as being resident on a single processor.

In addition to the processors, the hybrid also contains an I/O bus which is controlled by certain instructions. The I/O bus has an "address" part and a "data" part. Some of the instructions (it is indicated which ones) cause an "input cycle" to occur on the bus, which means that an address is given to the address part of the bus, and the data which appears on the data part is considered to be input. Other instructions cause an "output cycle", which means that the data is to be output to the given "address".

Figure 4 is a graphical representation of this architecture.

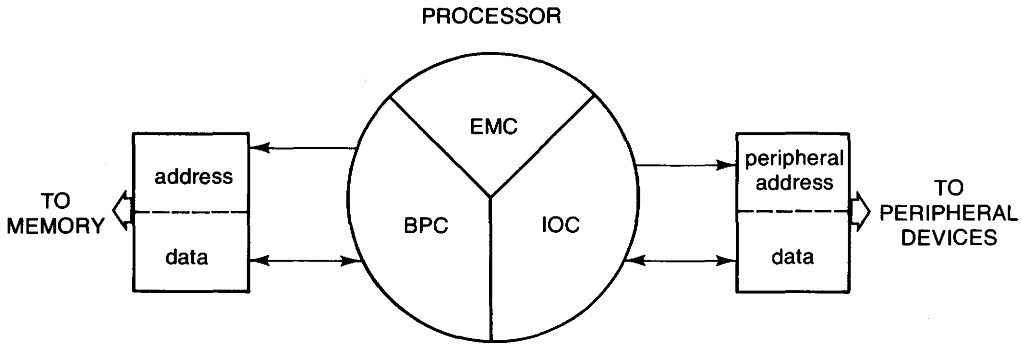


Figure 4. Generalized Machine Architecture

Registers

The memory locations in the machine are addressed from 0 to 177777_8. There are 32 memory locations which are addressed as if they were part of the computer read/write memory, but actually are part of the processor. These locations are called "internal registers". Each register has a specific location and has been given a name. As you will learn in "Symbolic Operations" (Chapter 4), these names have been reserved and cannot be redefined while using the assembly system.

The internal registers are —

Name	Address (Octal)	Description
A	0	Arithmetic accumulator
Ar2	20-23	BCD arithmetic accumulator
B	1	Arithmetic accumulator
C	16	Stack pointer
Cb	13	Block bit for byte pointer in C (use most significant bit only)
D	17	Stack pointer
Db	13	Block bit for byte pointer in D (use second most significant bit only)
Dmac	15	DMA count register
Dmama	14	DMA memory address register
Dmapa	13	DMA peripheral address register (use lower 4 bits only)
P	2	Program counter
Pa	11	Peripheral address register (use lower 4 bits only)
R	3	Return stack pointer
R4	4	I/O (Input/Output) registers
R5	5	
R6	6	
R7	7	
Se	24	Shift-extend register

Figure 5 is a map of where these registers lie. In addition to these registers, the addresses 25_8 through 37_8 are also registers, but are not (except for a few isolated cases) used in assembly programming.

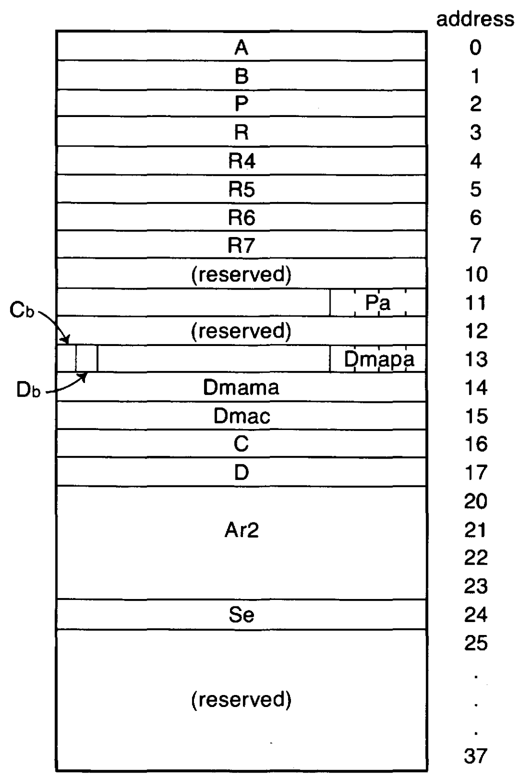


Figure 5. Map of Lowest Memory

All of these registers can be referenced either by their names or by their actual addresses. The two methods are equivalent, though reference by name is recommended as a programming practice.

In addition to the above internal registers, there are some "external" registers which reside in the computer read/write memory. They are —

Name	Address (octal)	Description
Ar1	177770-177773	BCD arithmetic accumulator
Base_page	177620-177701	Base_page temporary area (50 words)
Oper_1	177702	Arithmetic utility operand address registers
Oper_2	177703	
Result	177704	Arithmetic utility result address register

General Memory Organization

In order to find your way around the machine effectively, you should be aware of where things are stored in memory. Occasionally these areas can become considerations in your programming.

First in the memory come the internal registers. They were discussed above.

Next in the memory comes the ICOM area. The starting location is dependent upon system needs, but is always at least 41_8. The size of the ICOM region depends upon the size designated by the ICOM statement. Its maximum ending address is 77756_8. This is the reason for the limitation on the size in the ICOM statement.

Next in the memory comes the area reserved for the system to store programs and the like. This area extends from the end of the ICOM region to 177617_8.

This area is followed by the registers in the read/write memory (see the list in the previous section) with a number of interspersed system-reserved areas.

Figure 6 is a graphical presentation of this organization.

The immediately addressable memory consists of 65 536 words, which is all that can be addressed by a 16-bit word (the basic unit of memory in the system). Note that the memory is divided into two blocks — an "upper" block and a "lower" one. This distinction between blocks becomes significant when addressing individual bytes in memory.

Protected Memory

All of the reserved areas mentioned above are known as "protected memory". To give some measure of security to the operating system, it is advised that no attempt should be made to write or branch into these areas.

Access to certain portions of protected memory (e.g., BASIC variables) is provided by utilities within the assembly system. The user should access those areas only through the utilities.

Some measure of protection against access into these areas is provided during debugging. See Chapter 8 for a discussion of how this is done and the extent of the protection provided.

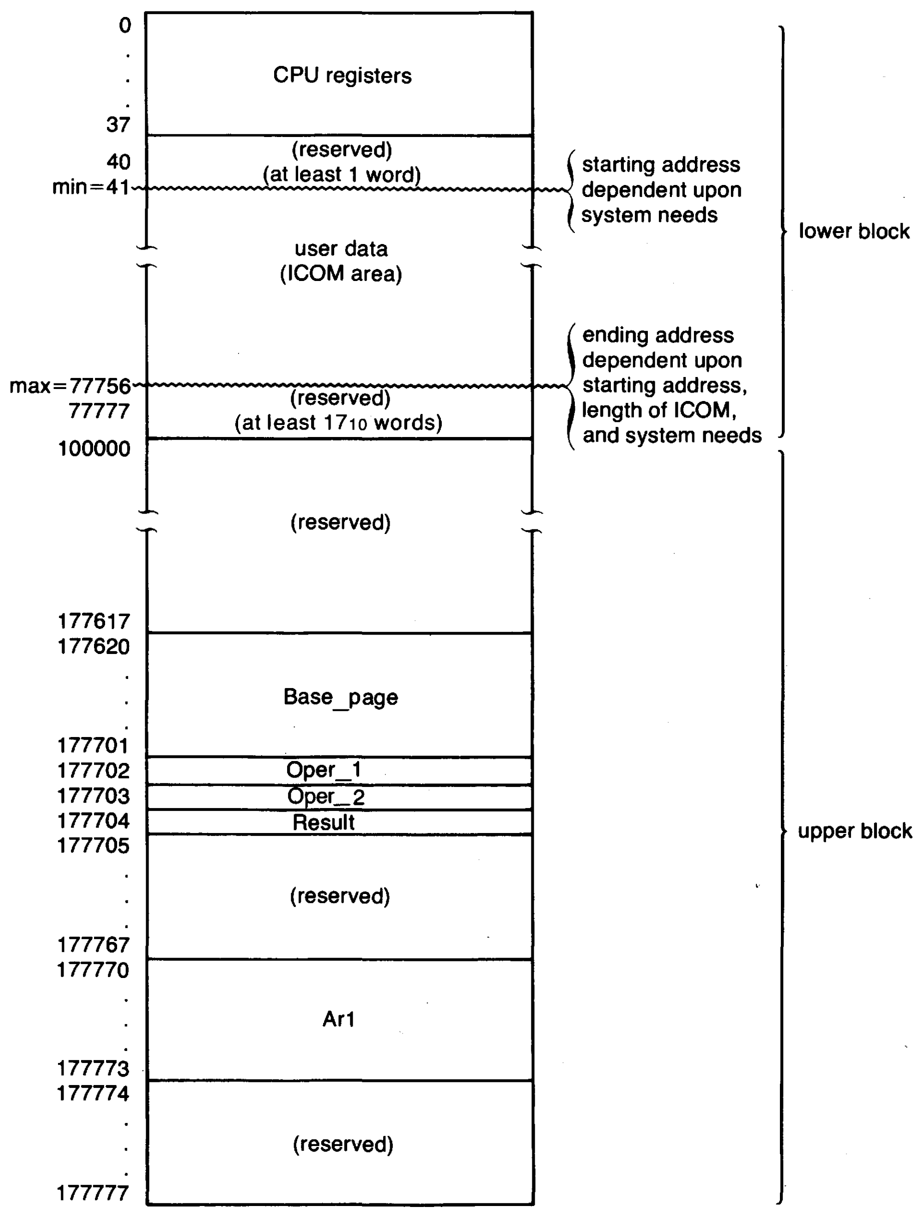


Figure 6. Memory Map

Base and Current Page

A concept that occasionally arises during discussion of the instructions and the assembler is that of the "page", the "base" and "current" pages in particular.

A page is 1 024 words of memory.

The "base" page is a wrap-around page. It consists of the upper half of the last page in the machine (addresses 177000_8 to 177777_8) and the lower half of the zero page (addresses 0 to 777_8). This is the same as a page which runs from − 512 to + 511, effectively "wrapping around" address 0.

During execution, the program counter (P) points to the address of the current instruction. The "current" page is those 1 024 words of memory centered upon the current instruction. Therefore, the current page is a continually changing page, extending from (P) − 512 to (P) + 511.

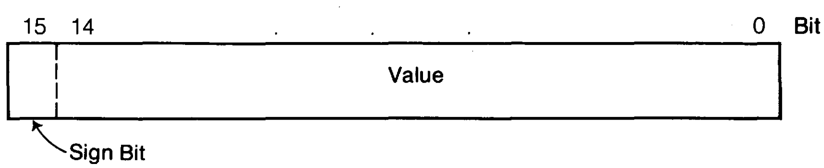
Data Structures

It is common to access BASIC variables from an assembly language routine then retrieve the contents, manipulate them, or alter them. To be effective at it, you should be aware of how BASIC stores a value in each of its data types.

There are four data types in BASIC: full-precision numeric values, short-precision numeric values, integers, and strings. Each is stored in its own unique structure.

Integers

The simplest of the types is the integer. An integer consists of a single word. Values between − 32 768 and + 32 767 can be stored in the word. Negative values are stored in two's complement form. An integer looks like —



Strings

Strings are the next simplest structure. A string is a succession of bytes, one character to a byte. A string may be of variable length. To be able to designate the length, the string is preceded by a word which contains the number of bytes in the string.

If a string has an odd number of bytes in it, then the left-over byte in the word containing the last character of the string is wasted. A typical string of length n looks like —

n(length)	
byte 1	byte 2
byte 3	byte 4
byte 5	byte 6
. . .	
byte n-2	byte n-1
byte n	–

Full-Precision Numbers

Full-precision numeric values are stored as 12-digit, BCD (Binary Coded Decimal), floating point numbers. They occupy four words each. The first word contains the sign of the exponent, a two's-complement 10-bit exponent, and the sign of the mantissa. The other three words contain the twelve mantissa digits, 4 to each word. The words look like this —

<table>
<tr><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>Bit</td></tr>
<tr><td>Exp Sign</td><td colspan="9">Exponent</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>Man Sign</td><td></td></tr>
<tr><td colspan="4">D_1 (most significant digit)</td><td colspan="4">D_2</td><td colspan="4">D_3</td><td colspan="4">D_4</td><td></td></tr>
<tr><td colspan="4">D_5</td><td colspan="4">D_6</td><td colspan="4">D_7</td><td colspan="4">D_8</td><td></td></tr>
<tr><td colspan="4">D_9</td><td colspan="4">D_{10}</td><td colspan="4">D_{11}</td><td colspan="4">D_{12} (least significant)</td><td></td></tr>
</table>

The exponent is always adjusted during arithmetic routines so that there is an implied decimal point following D_1. Thus, every mantissa value looks like —

$$D_1 . D_2 D_3 D_4 D_5 D_6 D_7 D_8 D_9 D_{10} D_{11} D_{12}$$

Short-Precision Numbers

Short-precision numeric values are stored as 6-digit, BCD floating point numbers. Unlike full-precision, they occupy two words each instead of four. The first word contains a 7-bit exponent, the sign of the mantissa and the two most significant mantissa digits. The second word contains the remaining four mantissa digits. The words look like this —

<table>
<tr><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>Bit</td></tr>
<tr><td>Exp Sign</td><td colspan="6">Exponent</td><td>Man Sign</td><td colspan="4">D_1</td><td colspan="4">D_2</td><td></td></tr>
<tr><td colspan="4">D_3</td><td colspan="4">D_4</td><td colspan="4">D_5</td><td colspan="4">D_6</td><td></td></tr>
</table>

As with full-precision, the exponent is stored in two's complement form and the implied decimal point follows D_1.

If you are unfamiliar with BCD arithmetic or need a refresher in floating point operations, it is suggested that you refer to Chapter 5.

Machine Instructions

The machine instruction set underlying the assembly language system consists of 92 instructions, divided into eleven groups. The groups are —

Load/Store	Operations placing values into registers or memory.
Integer Math	Operations involving integer arithmetic.
Branch	Operations altering the execution sequence unconditionally.
Test/Branch	Operations altering the execution sequence, dependent upon some condition.
Test/Alter/Branch	Operations altering the execution sequence and a value, dependent upon some condition.
Shift-Rotate	Operations performing re-arrangments of the bits in the A or B register.
Logical	Operations performing logical functions on the A or B registers.
Stack	Operations managing stacks.
BCD Math	Operations involving BCD arithmetic.
I/O	Operations specifically involving I/O operations.
Miscellaneous	Some unclassifiable operations.

Operands

Most instructions require operands. These operands have general forms which they may assume.

Many instructions contain an operand which is the address on which the function is to be performed. This {location} may be a constant (octal or decimal) or it may be a symbol. It also may be an expression containing any allowable combination of constants and symbols. For a full discussion of allowable expressions and symbols, and the "types" they are allowed to assume, consult "Symbolic Operations" in Chapter 4.

For example, note the operands in the following —

```
LDA 10B
STA Save
JMP Store + 3
AND = 177000B
```

A {location} may be either "relocatable" or "absolute" (see "Relocation" and "Symbolic Operations" in Chapter 4 for a full treatment of these types). If a relocatable {location} is used, the assembler generates machine code which uses "current page" addressing, and thus the {location} must be within — 512 words and + 511 words of the instruction. If an absolute {location} is used, the assembler generates machine code which uses "base page" addressing (meaning it takes the address as an offset from location 0).

An {address} is a {location} the same as above, except the intended location must be relocatable and within − 32 and + 31 words of the current instructions.

A {register} may be specified either through its absolute address or by its pre-defined symbol. The permissible registers are those with addresses between 0 and 7, inclusive. These are registers A, B, P, R, R4, R5, R6, and R7.

A number of instructions are followed by a {value}, which is a numeric expression usually in the range of 1 through 16. This {value} frequently indicates the number of bits involved in the operation. For example —

```
SAR 8
```

right-shifts the A register by 8 bits.

NOTE

Specifying the R4, R5, R6, or R7 registers (absolute locations 4 through 7) in an instruction causes an "I/O bus cycle" to occur. Consult Chapter 7, "I/O Handling", for the proper use of these registers.

Indirect Addressing

Some instructions may also employ "indirect addressing". This is indicated by including the optional indicator , I, such as —

```
LDA 10B,I
STA Save,I
JMP Store+3,I
```

There is only one level of indirect addressing provided with the processor. Of course, if further levels are desired, it is possible to implement them on your own. Some flagging scheme could be adopted, for example. One approach could be to adopt the policy that the sign bit (bit 15) of a word would indicate further indirection, with the remaining bits being the value. In such an approach, a load accumulator instruction would become two instructions —

```
10  ISOURCE  LDA A,I   ! Use current contents as pointer
20  ISOURCE  SAM *-1   ! If bit 15 set, indirection
```

Load/Store Group

This group of instructions allows transfers of data to take place. With the instructions below you can move information to and from the arithmetic accumulators (the A and B registers). You can also transfer the contents of one contiguous set of words in memory to another contiguous set.

Instruction	Description
LDA {location} [, I]	Loads register A with the contents of the specified location.
LDB {location} [, I]	Loads register B with the contents of the specified location.
STA {location} [, I]	Stores the contents of the A register into the specified location.
STB {location} [, I]	Stores the contents of the B register into the specified location.
CLR {value}	Clears (zeroes out) the specified number of words, beginning at the location specified by the A register. {value} must be an integer between 1 and 16.
XFR {value}	Transfers the specified number of words, from one location to another. The starting address of the location being transferred **from** must be stored in the A register. The starting address of the location being transferred **to** must be stored in the B register. {value} must be an integer between 1 and 16.

Integer Math Group

This group of instructions allows you to perform fundamental arithmetic operations on the contents of the arithmetic accumulators (the A and B registers).

Instruction	Description
ADA {location} [, I]	Adds the contents of the specified location to the contents of the A register, leaving the result in A. If a carry occurs, the Extend flag is set in the processor. If an overflow occurs (a carry from bits 14 or 15, but not both), the Overflow flag is set in the processor.
ADB {location} [, I]	Adds the contents of the specified location to the contents of the B register, leaving the result in B. If a carry occurs, the Extend flag is set in the processor. If an overflow occurs (a carry from bits 14 or 15, but not both), the Overflow flag is set in the processor.
TCA	Performs a two's complement of the A register (i.e., one's complement, incremented by 1). If a carry occurs, the Extend flag in the processor is set. If an overflow occurs (a carry from bits 14 or 15, but not both), the Overflow flag in the processor is set.
TCB	Performs a two's complement of the B register (i.e., one's complement, incremented by 1). If a carry occurs, the Extend flag in the processor is set. If an overflow occurs (a carry from bits 14 or 15, but not both), the Overflow flag in the processor is set.
MPY	Binary multiply. Uses Booth's Algorithm. The values of the A and B registers are multiplied together with the product placed into A and B. The A register contains the least significant bits and the B register contains the most significant bits and the sign. (An anomaly in the processor results in an improper result whenever A or B equals − 32 768.)

Branch Group

This group of instructions allows you to alter the execution sequence unconditionally. It includes the "jumps" and "returns" from subroutines.

Instruction	Description
JMP {location} [, I]	Unconditionally branches to the specified location.
JSM {location} [, I]	Jumps to a subroutine. The value of the R register is incremented and the current value of the P register (i.e., the location of the JSM instruction itself) is stored into the address pointed to by the R register. Execution then proceeds to the specified location.
RET {value}	Returns from a subroutine. {value} is added to the contents of the address pointed to by the R register. The results are stored in the P register (i.e., specifying the next location for execution) and the R register is decremented. This is, in effect, a return from a JSM instruction to the instruction which is {value} instructions from the JSM itself. The "usual" return is RET 1. {value} must be an integer between −32 and 31.

Test/Branch Group

Similar to the Branch group, this group of instructions allows you to alter the execution sequence, but conditionally upon the result of some test. Most instructions involve tests on all or part of one of the arithmetic accumulators (the A and B registers), but a couple allow a test on a location in memory which you can specify.

Instruction	Description
CPA {location} [, I]	Compares the contents of the A register with the contents of the specified location. Execution skips over the next word if the contents are not equal.
CPB {location} [, I]	Compares the contents of the B register with the contents of the specified location. Execution skips over the next word if the contents are unequal.
SZA {address}	Skips to {address} if register A is 0.
SZB {address}	Skips to {address} if register B is 0.
RZA {address}	Skips to {address} if register A is not 0.
RZB {address}	Skips to {address} if register B is not 0.
SIA {address}	Skips to {address} if register A is 0, then increments A regardless. The Extend and Overflow flags in the processor are not affected by the incrementing action.
SIB {address}	Skips to {address} if register B is 0, then increments B regardless. The Extend and Overflow flags in the processor are not affected by the incrementing action.
RIA {address}	Skips to {address} if register A is not 0, then increments A regardless. The Extend and Overflow flags in the processor are not affected by the incrementing action.
RIB {address}	Skips to {address} if register B is not 0, then increments B regardless. The Extend and Overflow flags in the processor are not affected by the incrementing action.

Test/Alter/Branch Group

Similar to the Test/Branch group, this group of instructions allows you to conditionally alter the execution sequence. In addition to tests, you can also alter the contents of the item being tested (such as set or clear a bit, or increment or decrement a register). Certain bits in the processor (Extend and Overflow) can be tested with some of these instructions, as well as registers and memory locations.

Some instructions may be followed by either of the following —

```
,S
,C
```

indicating that the bit being tested by the instruction will either be set (S) or cleared (C) after the test has been made.

Instruction	Description
`ISZ` {location} [`,I`]	Increment the contents of the specified location and skip execution of the next word if the result is 0.
`DSZ` {location} [`,I`]	Decrement the contents of the specified location and skip execution of the next word if the result is 0.
`SAP` {address} [`,S`] `SAP` {address} [`,C`]	Skips to {address} if the A register is positive or zero (bit 15 is 0).
`SBP` {address} [`,S`] `SBP` {address} [`,C`]	Skips to {address} if the B register is positive or zero (bit 15 is 0).
`SAM` {address} [`,S`] `SAM` {address} [`,C`]	Skips to {address} if the A register is negative (bit 15 is 1).
`SBM` {address} [`,S`] `SBM` {address} [`,C`]	Skips to {address} if the B register is negative (bit 15 is 1).
`SLA` {address} [`,S`] `SLA` {address} [`,C`]	Skips to {address} if the least significant bit of the A register is 0.

Instruction	Description
SLB {address} [, S] SLB {address} [, C]	Skips to {address} if the least significant bit of the B register is 0.
RLA {address} [, S] RLA {address} [, C]	Skips to {address} if the least significant bit of the A register is not 0.
RLB {address} [, S] RLB {address} [, C]	Skips to {address} if the least significant bit of the B register is not 0.
SOS {address} [, S] SOS {address} [, C]	Skips to {address} if the Overflow flag in the processor is set.
SOC {address} [, S] SOC {address} [, C]	Skips to {address} if the Overflow flag in the processor is cleared.
SES {address} [, S] SES {address} [, C]	Skips to {address} if the Extend flag in the processor is set.
SEC {address} [, S] SEC {address} [, C]	Skips to {address} if the Extend flag in the processor is cleared.

NOTE

The Extend and Overflow flags can be cleared only by using the SEC, SES, SOC, and SOS instructions with the , C option.

Shift / Rotate Group

This group of instructions performs re-arrangements of bits in the arithmetic accumulators (the A and B registers). Circular and non-circular shifts are available.

Instruction	Description
SAR {value}	Shifts the A register right the indicated number of bits with all vacated bit positions becoming 0.
SBR {value}	Shifts the B register right the indicated number of bits with all vacated bit positions becoming 0.
SAL {value}	Shifts the A register left the indicated number of bits with all vacated bit positions becoming 0.
SBL {value}	Shifts the B register left the indicated number of bits with all vacated bit positions becoming 0.
AAR {value}	Shifts the A register right the indicated number of bits with the sign bit filling all vacated bit positions. (Arithmetic right)
ABR {value}	Shifts the B register right the indicated number of bits with the sign bit filling all vacated positions. (Arithmetic right)
RAR {value}	Rotates the A register right the indicated number of bits. Bit 0 rotates into bit 15 each time. (Right circular)
RBR {value}	Rotates the B register right the indicated number of bits. Bit 0 rotates into bit 15 each time. (Right circular)
RAL {value}	Rotates the A register left the indicated number of bits. Bit 15 rotates into bit 0 each time. (Left circular)
RBL {value}	Rotates the B register left the indicated number of bits. Bit 15 rotates into bit 0 each time. (Left circular)

Logical Group

This group of instructions performs logical (Boolean) operations upon the contents of an arithmetic accumulator (on A or B register). Logical "and" and "or" operations are available, along with complementing and clearing operations.

Instruction	Description
AND {address} [, I]	Logical "and" operation. The contents of the A register are compared bit by bit, with the contents of the specified location. For each bit-comparison a 1 results if both bits are 1's, a 0 results otherwise. The 16-bit result is left in A.
IOR {address} [, I]	Logical "inclusive or" operation. The contents of the A register are compared, bit by bit, with the contents of the specified location. For each bit-comparison, a 0 results if both bits are 0's, a 1 otherwise. The 16-bit result is left in A.
CMA	Performs a one's complement of the A register (i.e., bit-by-bit inversion of all 16 bits).
CMB	Performs a one's complement of the B register (i.e., bit-by-bit inversion of all 16 bits).
CLA	Clears register A. This instruction is identical to SAR 16.
CLB	Clears register B. This instruction is identical to SBR 16.

Stack Group

The Stack group of instructions provides you with operations for managing stacks. The instructions withdraw items from (also called "pop" or "pull") or push items onto a stack pointed to by either the C or D register. The items are pushed from or withdrawn into a specified register (other than C or D) and the C or D register is incremented or decremented appropriately.

Pushing instructions increment or decrement the C or D register prior to doing the pushing. Withdrawing instructions increment or decrement the C or D register after doing the withdrawal. Consequently, the pointer is always left pointing to the "top" of the stack after the operation.

Decrementing the C or D register is indicated by including `,D` after the operand. For "withdrawing" instructions, D is the default. For example, the following are equivalent —

```
WWC A,D
WWC A
```

Incrementing is specified by including `,I` after the operand. This is also the default for "pushing" instructions if neither I or D is included. For example, the following are equivalent —

```
PWC A,I
PWC A
```

When using the byte instructions (PBC, PBD, WBC, WBD), the address pointed to by the C or D register must not have an absolute address less than 40_8.

When pushing or withdrawing bytes, the least significant bit of the address register (either C or D) is used to determine which byte is desired in the stack (a 0 implies the left most byte of the word being addressed). To retain the full 16-bit addressing capability, the Cb or Db register is used, as appropriate. These one-bit registers hold the most significant bit of the word address when the byte addressing instructions are used. They should be explicitly set or cleared, depending upon the value of the address involved.

Instruction	Description
PWC {register} , D PWC {register} [, I]	Pushes contents of {register} onto the stack pointed to by the C register.
PWD {register} , D PWD {register} [, I]	Pushes contents of {register} onto the stack pointed to by the D register.
PBC {register{ , D PBC {register} [, I]	Pushes the lower byte (right half) of {register} onto the stack pointed to by the Cb and C registers. If the least significant bit of C is a 1, the byte is placed in the lower byte of the word in the stack; if it is a 0, it is pushed into the upper byte.
PBD {register} , D PBD {register} [, I]	Pushes the lower byte (right half) of {register} onto the stack pointed to by the Db and D registers. If the least significant bit of D is a 1, the byte is placed in the lower byte of the word in the stack; if it is a 0, it is pushed into the upper byte.
WWC {register} [, D] WWC {register} , I	Withdraws a word from the stack pointed to by the C register and stores it into {register}.
WWD {register} [, D] WWD {register} , I	Withdraws a word from the stack pointed to by the D register and stores it into {register}.
WBC {register} [, D] WBC {register} , I	Withdraws a byte from the stack pointed to by the Cb and C registers and places it into the lower byte (right half) of {register}. If the least significant bit of C is a 1, the byte is withdrawn from the lower byte of the word in the stack; if it is a 0, it will be withdrawn from the upper byte.
WBD {register} [, D] WBD {register} , I	Withdraws a byte from a stack pointed to by the Db and D registers and places it into the lower byte (right half) of {register}. If the least significant bit of D is a 1, the byte is withdrawn from the lower byte of the word in the stack; if it is a 0, it is withdrawn from the upper byte.
CBL	Clears the Cb register (indicates lower block of memory).
CBU	Sets the Cb register (indicates upper block of memory).
DBL	Clears the Db register (indicates lower block of memory).
DBU	Sets the Db register (indicates upper block of memory).

BCD Math Group

This group of instructions provides you with BCD arithmetic operations using the Ar1 and Ar2 registers.

In general, the instructions associate the Ar1 register with "X" and the Ar2 register with "Y" in the mnemonic for the instruction. Both registers contain values which are considered BCD full-precision values when operated upon by instructions in this group.

The mantissas referred to below consist of 12 BCD digits. All the shifting operations manipulate the digits as units (i.e., 1 digit — or 4 bits — at a time). In addition, shifting operations involve an additional digit in the A register (located in the lower 4 bits, numbered 0 through 3).

All arithmetic is performed in BCD. The values being operated upon are assumed to be normalized BCD floating-point (full-precision) values. Signs and exponents are left strictly alone. There is a flag in the processor, called Decimal Carry, which is set when an overflow occurs during a BCD operation.

A full discussion of BCD arithmetic techniques can be found in Chapter 5.

Instruction	Description
MRX	Mantissa right shift on Ar1. The number of digits to be shifted is specified in the lower 4 bits (0-3) of the B register. The shift is accomplished in three stages — 1. The digit in bits (0-3) of the A register is right-shifted into the first digit of the mantissa, with the twelfth digit being lost. This is the first shift. 2. The mantissa digits are then right-shifted for the remaining number of digits specified. The twelfth digit, except for the last shift, is lost on each shift and the vacated digits are zero-filled. 3. Finally, the last right-shift takes place with the twelfth digit shifting into the A register. The Decimal Carry flag in the processor is cleared along with the upper 12 bits of the A register (4-15).

Instruction	Description
MRY	Mantissa right-shift on Ar2. The number of digits to be shifted is specified in the lower four bits (0-3) of the B register. The shift is accomplished in three stages — 1. The digit in bits (0-3) of the A register is right-shifted into the first digit of the mantissa, with the twelfth digit being lost. This is the first shift. 2. The mantissa digits are then right-shifted for the remaining number of digits specified. The twelfth digit, except for the last shift, is lost on each shift, and the vacated digits are zero-filled. 3. Finally, the last right-shift takes place, with the twelfth digit shifting into the A register. The Decimal Carry flag in the processor is cleared along with the upper 12 bits of the A register (4-15).
MLY	Mantissa left-shift on Ar2 for one digit. This is a circular shift, with the digit in bits (0-3) of the A register forming a thirteenth digit. The non-digit part of the A register is cleared (i.e., bits 4-15), and the Decimal Carry flag in the processor is cleared.
DRS	Mantissa right-shift on Ar1 for one digit. The twelfth digit is shifted into the A register (bits 0-3). The non-digit part of the A register is cleared (i.e., bits 4-15), and the Decimal Carry flag in the processor is cleared. The first digit in the mantissa is set to 0.
NRM	Normalizes the Ar2 mantissa. The mantissa digits are left-shifted until the first digit of the mantissa is non-zero, or until twelve shifts have taken place, whichever comes first. If the original first digit is already non-zero, no shifts occur. The number of shifts required is stored as the first four bits (0-3) of the B register. If twelve shifts were required, the Decimal Carry flag in the processor is set, otherwise it is cleared.
CMX	Ten's complement of Ar1. The mantissa of Ar1 is replaced with its ten's complement and Decimal Carry is cleared.

Instruction	Description
CMY	Ten's complement of Ar2. The mantissa of Ar2 is replaced with its ten's complement and Decimal Carry is cleared.
FXA	Fixed-point addition. The mantissas of Ar1 and Ar2 are added together, and the result is placed into Ar2. Decimal Carry is added to the twelfth digit. After the addition, Decimal Carry is set if an overflow occurred, otherwise Decimal Carry is cleared.
MWA	Mantissa word addition. The contents of the B register are added to the ninth through twelfth digits of the mantissa of Ar2. Decimal Carry is added to the twelfth digit; if an overflow occurs, Decimal Carry is set, otherwise it is cleared.
FMP	Fast Multiply. Performs the multiplication by repeated additions. The mantissa of Ar1 is added to the mantissa of Ar2 a specified number of times. The number of times is specified in the lower 4 bits (0-3) of the B register. The result accumulates in Ar2. If intermediate overflows occur, the number of times they occur appears in the lower 4 bits of the A register after the operation is complete. The upper 12 bits of the A register are cleared along with Decimal Carry.
FDV	Fast divide. The mantissas of Ar1 and Ar2 are added together until the first decimal overflow occurs. The result accumulates into Ar2. The number of additions without overflow is placed into the lower 4 digits of the B register (0-3). The remainder of the B register is cleared, as is the Decimal Carry flag in the processor.
CDC	Clears the Decimal Carry flag in the processor.
SDS {address}	Skips to {address} if Decimal Carry is set. Decimal Carry is a flag in the processor which may be set as the result of certain BCD arithmetic operations (see Chapter 5 for details).
SDC {address}	Skip to {address} if Decimal Carry is cleared. Decimal Carry is a flag in the processor which may be set as the result of certain BCD arithmetic operations (see Chapter 5 for details).

I/O Group

The I/O group of instructions provides you with some of the operations necessary to accessing peripheral devices through the I/O bus. In addition to the instructions contained here, there are instructions in other groups which can have I/O effects (e.g., LDA, STA...).

The techniques useful to the implementation of I/O operations using the instructions in this group and the other groups are discussed in Chapter 7.

Instruction	Description
SFS {address}	Skips to {address} if the Flag line is set (true). The Flag line is associated with a peripheral on the current select code (see Chapter 7 for details).
SFC {address}	Skips to {address} if the Flag line is clear (false). The Flag line is associated with a peripheral on the current select code (see Chapter 7 for details).
SSS {address}	Skips to {address} if the Status line is set (true). The Status line is associated with a peripheral on the current select code (see Chapter 7 for details).
SSC {address}	Skips to {address} if the Status line is clear (false). The Status flag is associated with a peripheral on the current select code (see Chapter 7 for details).
EIR	Enables the interrupt system. Cancels the DIR instruction.
DIR	Disables the interrupt system. Cancels the EIR instruction.
SDO	Sets DMA outwards. Directs that DMA operations read from memory, write to the peripheral.
SDI	Sets DMA inwards. Directs that DMA operations read from the peripheral, write to memory.
DMA	Enables the DMA mode. Cancels the DDR instruction.
DDR	Disables Data Request. Cancels the DMA instruction.

Miscellaneous

The following instructions are unclassifiable into any of the other groups.

Instruction	Description
NOP	Null operation. This is exactly equivalent to LDA A.
EXE {value} [, I]	The contents of any register can be treated as the current instruction and executed. {value} is a numeric expression in the range 0 through 31, indicating the register to be used. The register is left unchanged, unless the instruction code causes it to be altered. The next instruction to be executed is the one in the word following the EXE, unless the code in the executed register causes a branch.

Chapter 4
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Chapter 4
Assembly Language Fundamentals

Summary: This chapter discusses some of the basic statements and syntaxes used throughout the assembly language system. Program entry, assembling, symbolic operations, module creation, program and variable storage, and utilities are the topics covered.

When writing assembly language programs there are a number of things with which you will be involved constantly. In the beginning, questions arise on how to **use** the language: How do you enter the source code? What kind of symbolic addressing is there? How do you create and distinguish modules? How do you create the object code and where is it stored? What utilities are available and how do you use them?

The answers to those questions form the underlying capabilities through which you write your applications. These are things which nearly every assembly language program uses. As essential as they are, however, none are difficult to master.

Program Entry

You were introduced early in Chapter 2 to the integrated nature of the assembly language with its host language, BASIC. You know from that chapter how assembly language statements can be intermingled with BASIC statements — that you can employ the usual editing features on the assembly statements. However, there is more to the ISOURCE statement than just its integrated nature with BASIC.

As stated in Chapter 2, all assembly language statements are designated with the keyword "ISOURCE". The keyword is followed by {assembly language source}. So the syntax of the entry line is —

{line number} [{BASIC label} :] ISOURCE {assembly language source}

Here's a simple example of this from Chapter 2 —

```
40   ISOURCE   NAM Example
50   ISOURCE   NOP
60   ISOURCE   END Example
```

The {line number} and {BASIC label} are the same as you are used to in BASIC. However, it should be noted that the statement is not an executable one, so the BASIC label is only useful for documentation and EDIT purposes.

To BASIC, the ISOURCE statement appears as a comment. If you were to change the above so that it read —

```
40 Example:  ISOURCE   NAM Example
50           ISOURCE   NOP
60           ISOURCE   END Example
70           END
```

and then executed a statement "GOTO Example", the result would be to simply execute the END statement in line 70. That is because, to BASIC, the lines appear the same as —

```
40 Example:  REM
50           REM
60           REM
70           END
```

or —

```
40 Example:  !
50           !
60           !
70           END
```

The BASIC label on an ISOURCE line finds its most useful characteristic in being able to be referenced, as any other BASIC label on any other type of line may be, with an EDIT command. Thus, if you were to execute —

```
EDIT Example
```

on the above, you would be working in the editor, starting with line 40. This feature will become useful during program development as will be pointed out shortly.

Assembly Language Source

You may have recognized the assembly language instruction and pseudo-instructions to the right of ISOURCE in the examples above. This is where your instructions and pseudo-instructions appear. However, the source is a little more versatile than that. In general, {assembly language source} has the syntax —

[{label} :] {action} [! {comment}]

Or, the action may be omitted and only a comment appears —

[{label} :] ! {comment}

A label is always optional in the source, but either an {action} or a {comment} must be present in every source line.

Actions

An {action} in assembly language source is —

- A machine instruction, with any operand it may require. These were discussed at some length in Chapter 3.
- A pseudo-instruction, with any operand it may require. These are discussed under the topics to which they relate.

The actions contained in the above example were —

```
NAM Example
NOP
END Example
```

Labels

The {label} in assembly language source is part of the symbolic addressing capability of the assembler. This {label} is used by the **assembler** only. Neither the operating system nor BASIC is aware of its existence.

The label follows the same form and rules as do labels in BASIC —

- Up to 15 characters long.
- First character must be a capital letter (A-Z).
- Only the non-capital letters (a-z), the numerals (0 to 9), or the underscore (_) may be used following the first character.

No two labels are allowed to be the same in a given **module**. If your source consists of two or more modules, then the same label may be defined more than once, provided each definition is in a different module. (Distinguishing between modules is discussed in "Creating Modules", later in this chapter.) So you may not code —

```
Rumpelstiltskin: LDA B
```

in one place in the module and later in the same module code —

```
Rumpelstiltskin: LDB A
```

There are other restrictions as well on the choosing of labels. For instance, there are symbols already defined by the assembler and you are not allowed to choose one of them as a label. This is discussed at length in "Symbolic Operations" in this chapter.

Both a BASIC label AND an assembly language source label can appear in the same line, and they are distinct from one another. BASIC does not know about the source label and the assembly language system does not know about the BASIC label.

Since neither BASIC nor the operating system is aware of the existence of source labels, actions ouside the assembler cannot reference these labels. Thus, if you had the source line —

```
100  ISOURCE Rumpelstiltskin:  JMP Bail
```

You can neither say GOTO Rumpelstiltskin nor EDIT Rumpelstiltskin. Neither of these can find "Rumpelstiltskin", since only the assembler can know it is there.

This can be a nuisance in some instances during program development. Many programmers use labels almost exclusively and rarely consider the line number when using the editor to change a line. For instance, in the above, they would not be used to saying, "EDIT 100" to get at the line in order to change it. They are more used to saying, "EDIT Rumpelstiltskin". A way for them to do it would be to change the line to —

```
100 Rumpelstiltskin: ISOURCE Rumpelstiltskin: JMP Bail
```

Note that, as the example demonstrates, the name can be the same in the BASIC label as in the source. This takes advantage of the fact that BASIC and the assembler are unaware of each other's labels. The names do not have to be the same.

Comments

As with any BASIC line, a comment may be included by simply adding an exclamation point (!) and typing your comment after it. Since you have a total of 160 characters for a line, your comment may fill up the remainder of the 160 characters left after the rest of the statement has been provided (line number, ISOURCE keyword, label, action).

Syntaxing the Source

When you are creating your source program, you are either entering it from the keyboard or retrieving it from mass storage (LINK or GET). In either case, as the statement is entered (the STORE key on the keyboard is pressed or a record is read from mass storage), the operating system takes note of any use of the keyword ISOURCE. When a line has this keyword, the operating system turns over the remainder of the line following the keyword to the assembly system. The assembly system, then and there, checks the syntax of the source.

By checking the syntax at the time of entry of the statement, a considerable amount of processing time is saved when the time comes to assemble the source into object code. In addition, it gives you, as the programmer, immediate feedback when a syntactical error occurs. You do not have to wait until assembly time just to find out that you misspelled NOP.

At syntax time, the assembler takes care of capitalization, lower case, and spacing for the source. It's quite similar to the SPACE DEPENDENT mode of entry for BASIC statements (that mode is not required to get the effect with the assembly system). It follows the following rules in syntaxing the source —

- Everything between the ISOURCE and the colon (if present) is the label. Its initial character is capitalized and the remaining letters are converted to lower-case. This is regardless of whether they were entered in that form.
- The label, if present, is left-justified to the second column following the keyword ISOURCE.
- The first three letters following the colon (or just the first three letters, if there is no label) are considered the machine instruction or pseudo-instruction and are capitalized. The instruction will remain in the same column as it was entered, and, if possible, a space is added after it.
- Everything after the instruction or pseudo-instruction is considered the operand for the instruction, up until the exclamation point before the comment (if any). Any label (symbol) in the operand will have its initial character capitalized and the remaining letters converted to lower case automatically.
- Comments are unchanged and remain in the same columns as entered, whenever possible.

In short, simply enter the statement in your most comfortable fashion and the assembly system automatically assures that what you enter is in the proper form (though it still can't guarantee that you have entered the right instruction for what you mean to do.

As a demonstration of this facility, consider the following line ready for syntaxing —

```
100  ISOURCE      rUMPELSTILTSKIN:jMpbail
```

It becomes —

```
100  ISOURCE Rumpelstiltskin:     JMP Bail
```

Creating Modules

When you were introduced in Chapter 2 to the concept of a module, it was said that a module is given a name through the NAM pseudo-instruction.

So, when you enter a source line which has the following form —

    NAM {module name}

you are assigning a name to a module, and you are also delimiting the beginning of the module. By the inclusion of this statement, all source lines which follow are part of the module with the name designated in this source line, that is, all lines until the END pseudo-instruction is encountered in the source. It has the form —

    END {module name}

Its {module} name must be the same as in the NAM pseudo-instruction.

A {module name} follows the same rules for naming as do labels (see above).

It is by the use of these two instructions that modules are created. The source lines which appear between them comprise a single module, and the name assigned to the module is the one with which the module is referenced (with the ILOAD and ISTORE statement for example).

When it comes time to assemble the source into object code, the assembler treats the source lines in a module as a unit.

In actuality, therefore, there are **two** modules — a source module and an object module. When you are assembling a module, the name you use refers to the source module and creates the object module. Later, other statements, such as ISTORE and ILOAD, refer solely to the object module.

Storage

Modules

When assembly converts a source module into an object module, there must be a place to keep the object module. That is the function of the ICOM region.

You were introduced to the ICOM region in Chapter 2 in connection with the loading and storing of modules. It is also used to hold modules which are created through assembly. Once a module has been assembled, the object code appears in the ICOM region just as if you had loaded it from mass storage.

Variables

Within a module, you may want to set aside one or more words of memory for your use. For example, you might need a location to store a variable, or keep a counter, or save a register. This is done with the BSS pseudo-instruction —

`BSS` {number}

where {number} is the number of words to be set aside. {number} can be any absolute expression, provided the expression evaluates to a positive integer (see "Symbolic Operations" below).

This kind of storage is part of the object code and is set aside "in-line". This means that wherever it appears in the source, the storage appears in the same relative location in the object module.

For example, suppose a module contained the following source lines —

```
          .
          .
          .
220   ISOURCE Save_a:  BSS 1
230   ISOURCE Save_4:  BSS 2*2
240   ISOURCE Renras:  BSS Larry
250   ISOURCE Again:   LDA Renras
          .
          .
          .
```

Then, at some appropriate spot in the object module (relative to the other instructions in the module) there would be the following **contiguous** locations —

Save_a	1 word
Save_4	4 words
Renras	some number of words equal to "the absolute symbol, Larry"[1]
Again	1 word

The locations at labels Save_a, Save_4, and Renras are merely reserved by the BSS pseudo-instructions, and their contents are not initialized to any particular value.

It is possible to accidentally execute these locations when the routine is run if you're not careful. Ordinarily, you should place these locations somewhere safely out of the potential execution sequence, since they are used just for storage. Some applications, though, use self-generating code, and a BSS is a way to set aside locations for it.

Data Generators

A "data generator" is very much like a BSS operation. The function, as with the BSS, is to set aside words of memory at a particular location in the object code. But in addition, the words are to be initialized to some value. The initialization occurs at the same time the words are set aside (i.e., at assemble-time).

This is done using the DAT pseudo-instruction which has the form —

```
DAT {expression} [, {expression} [, ...] ]
```

An {expression} may be any absolute or relocatable expression. The various forms that an expression may take are discussed in "Symbolic Operations" later in this chapter.

As an example, suppose you want the value 100 (a decimal integer) to be located at location "X" in the object module. You can achieve this by identifying the location in the source code (ultimately the object code) where you want the value to be, then placing this instruction at that point —

```
X: DAT 100
```

1 Such symbols are discussed at length in the "Symbolic Operations" section later in this chapter.

Upon encountering this pseudo-instruction, the assembler generates the words necessary to store the value (in this case, only 1 word is necessary). It then stores the value (100) into the word(s) and proceeds with the remaining assembly. Thus, the location of the words is dependent upon the instruction's relative position in the source module, the same as with any machine instruction.

The number of data words generated for each {expression} is dependent upon the result of the {expression} —

Result	Words
Full-precision	4
Short-precision	2
Decimal integer	1
Octal integer	1
Address[1]	1
Literal	1
String	actual length (2 characters per word)

If more than one {expression} is present, the necessary data words are generated in the order in which they appear in the list. As an example, if you were to include the instruction —

```
DAT 2,2S,2.0,"2",'2,=2
```

ten words would be set aside and initialized to the appropriate values —

```
000002 —2
000040 }
000000 } 2S
000000 }
020000 }
000000 } 2.0
000000 }
031000 —"2"
000062 —'2
000053 — address of 2 in literal pool
```

1 including "external"

Repeating Instructions

To help relieve the tedium of writing the same instruction many times (which many applications occasionally require), a "repeat" pseudo-instruction is provided —

REP {expression}

The pseudo-instruction causes the immediately following machine instruction to be duplicated in the object code {expression} number of times.

For example, suppose you are writing a real-time application where timing was critical, and to make things work correctly you need 10 NOPs at a certain location. Ordinarily you would type —

```
ISOURCE   NOP
ISOURCE   NOP
ISOURCE   NOP
ISOURCE   NOP
ISOURCE   NOP
ISOURCE   NOP
ISOURCE   NOP
ISOURCE   NOP
ISOURCE   NOP
ISOURCE   NOP
```

But all of this could be replaced with —

```
10   ISOURCE   REP 10
20   ISOURCE   NOP
```

and the same effect would be achieved.

Some pseudo-instructions may not be replicated. They are —

```
COM
END
EQU
EXT
NAM
REP
SUB
```

Assembling

Object code is created by "assembling" the source code. Again, modules are a key factor. The assembly directive is aimed at modules, using the module name as a delimiter in the source code so the assembler can tell which ISOURCE statements to assemble as part of the module. Of course this same name is also used to store the object code using mass storage.

The IASSEMBLE statement is the vehicle for assembling modules. It has the forms —

```
IASSEMBLE {module} [ , {module} [ , ...] ] [ ; {option} [ , {option} [ , ...] ] ]
IASSEMBLE [ ALL ] [ ; {option} [ , {option} [ , ...] ] ]
```

Each {module} indicated is assembled, in the order given by the statement. Only those modules are assembled; any others which may be present in the source at the time are ignored. If the ALL version of the statement is used (with or without the optional word ALL), every module present in the source is assembled.

An {option} falls into one of two categories: listing directives and conditions (for conditional assembly). These are discussed separately below. The options, and their categories, are —

```
EJECT  }
LINES  }
LIST   } Listing directives
XREF   }

    A  }
    B  }
    C  }
    D  } Conditions
    E  }
    F  }
    G  }
    H  }
```

Effect of BASIC Environments

To assemble a module, all of its source lines (between the NAM and END pseudo-instructions) must lie within the same BASIC "environment". That is, the NAM and END for a module must lie within the main program or within the same subprogram or multi-line function. For modules where this is not true, an error ("EN" assemble-time error) occurs.

Source Listing Control

Listings of the source code in a module can be obtained during an assembly. These listings contain the line numbers, instructions, and comments from the source lines along with the associated machine addresses and contents of that address.

Here is part of a typical listing —

```
430  01034 002645   LDA =Array_type
440  01035 006645   LDB =Array
450  01036 142645   JSM Get_info      !Info on the array
460  01037 003005   LDA Array_type    !Look at the type
470  01040 012644   CPA =16           !Is it a file number?
480  01041 066003   JMP *+3           !Must be a file number
490  01042 022643   ADA =-12          !Is it an array data
500  01043 172003   SAP *+3           !  type (ie, >12)?
```

line numbers **absolute addresses** **contents** **actions** **comments**

The addresses and contents are displayed in octal representation.

Listings are not automatic. They are obtained in one of two ways —

- By using the LIST option in the IASSEMBLE statement. This directs that a listing is desired for all the modules in the statement. The statement would look like the following examples —

```
IASSEMBLE Store;LIST
IASSEMBLE Retrieve,Work;LIST
```

- By using the LST pseudo-instruction in the source code itself.

Modules can be just partially listed, if desired. This kind of control is achieved by using the LST and UNL pseudo-instructions within the source code, placing the LST before any instructions which you want listed, and placing the UNL before any instructions you do not want listed. For example, if the following source lines are assembled —

```
420  ISOURCE   LST
430  ISOURCE   LDA =Array_type
440  ISOURCE   LDB =Array
450  ISOURCE   JSM Get_info      !Info on the array
460  ISOURCE   LDA Array_type    !Look at the type
470  ISOURCE   CPA =16           !Is it a file number?
480  ISOURCE   JMP *+3           !Must be a file number
490  ISOURCE   ADA =-12          !Is it an array data
500  ISOURCE   SAP *+3           !  type (ie, >12)?
510  ISOURCE   UNL
```

only lines 430 through 500 would be listed.

The primary purpose of this capability is to allow as much modularity in the listings as you can get in source code. To implement this purpose, a "listing counter" is used.

Whenever an LST instruction is encountered during an assembly, the listing counter is incremented. Whenever an UNL instruction is encountered during an assembly, the listing counter is decremented. Source lines are listed whenever the counter is greater than 0. Whenever it is equal to 0 or negative, then no lines are listed.

The counter is set to 0 upon execution of the IASSEMBLE statement. This is why there is no automatic listing. However, if the LIST option is included in the IASSEMBLE statement, then the counter is initialized to 1. This is why that option creates a listing. Thus, you could defeat a LIST option by placing an UNL instruction at the beginning of a module. This initialization occurs for each module assembled, so if you have more than one module indicated in your IASSEMBLE statement, the counter is set at the beginning of the assembly for each.

This capability sees its greatest usefulness during debugging stages and while working with independently written sections of source code. For example, a number of people could be writing different sections of code, each containing their own LST and UNL instructions. These instructions could then be overridden when they were combined into a single module by preceding the sections with an LST instruction (to get a listing) or an UNL (to suppress the listings).

Page Format

Each and every assembly listing page has the following format —

- The word "PAGE" and the current page number of the listing occurs on the first line starting at column 49.
- A heading occurs on the second line, left-justified. The heading always includes —

  `MODULE:` {name}

  where {name} is the name of the module currently being assembled. Additional heading information can be specified for this line (see "Page Heading" below).

- A blank line follows the heading.
- The text follows the blank line. The number of lines printed depends upon the LINES option in the IASSEMBLE statement, the number of source lines encountered, and the SKP pseudo-instructions which may be encountered while assembling the source. LINES and SKP are described in the following sections.
  - If the EJECT option is **not** included in the IASSEMBLE statement, then a minimum of three blank lines (carriage return/line feed, CR/LF, pairs) will be printed at the end of a page. The number may exceed three if the number of source lines printed on a page is less than the standard length for a listing page (see above).

Page Length

The length of the text in each page of your assembly listings can be specified through the IASSEMBLE statement using the LINES option, which has the form —

`LINES` {numeric expression}

This option directs that any listing of the routines being assembled have pages of the length indicated by {numeric expression}, which must be a positive value. This value becomes the "standard length" of the listing pages, specifying the number of source lines to be printed on a page during listings of the assembly source. It is not necessary that this value be the page length of the printing device being used, though this is frequently the value selected.

If the option is omitted from the IASSEMBLE statement, the value of 60 is assumed for page length, giving an overall page size of 66 lines.

Printer control characters, such as line-feed and form-feed, in a comment can affect the actual printing length of the pages independent of the length you specify. Thus, a page length of 60 could result in actually 61 lines if one of the comments in your ISOURCE statements contains a line-feed character.

End-of-Page Control

At any time during the assembly of a module, you can force the listing to continue printing at the top of the next physical page by including —

`SKP`

at the desired spot in the module. If a listing is being generated when this pseudo-instruction is encountered in the source code, the printer is sent to top-of-form. This is physically done in one of two ways —

- If the EJECT option was included in the IASSEMBLE statement which is assembling the module, then a form-feed character (ASCII character 14_8), is sent to the printer.
- If the EJECT option was not included, sufficient CR/LF pairs (ASCII characters 15_8 and 12_8) are sent to the printer to fill out the standard length of a listing page (plus three at the end of the page). Thus, if you already have printed 10 lines on a page, and an SKP instruction was encountered, the assembler sends (length − 10 + 3) CR/LF pairs.

The SKP instruction is not required to cause pagination to occur when the standard length of a listing page is exceeded. Thus, if you are working with a default length of 60 for your standard length, then each 60 lines from the last page break forces a new page break.

Page Headings

The heading for each listing page is —

```
MODULE: {name}
```

where {name} is the name of the module currently being assembled. This heading can have additional information added to it through the HED pseudo-instruction. This instruction has the form —

```
HED {comment}
```

When this instruction is encountered, and a listing is being generated, pagination immediately occurs, the same as with the SKP instruction (see above). On the new page, and on all pages after it, the indicated {comment} appears after {name} in the heading, replacing any previous information specified by an earlier HED instruction.

You can change the heading any number of times in a listing. This is frequently done in order to generate documentation by sections, even though all sections may reside in a single module.

The heading appears on the page exactly the same as in {comment}, including the positioning of blanks, control characters, etc.

Blank Line Generation

If occasional blank lines are desired in a listing (usually to set off sections of code, or comments), they may be generated by including —

```
SPC {number}
```

at the desired spot in the source statements. {number} designates the number of blank lines desired. {number} can be any absolute expression, provided the expression evaluates to a positive integer (see "Symbolic Operations" below).

Non-Listable Pseudo-Instructions

The following pseudo-instructions do not appear in a listing —

```
LST
UNL
SKP
HED
SPC
```

Conditional Assembly

For reasons of complexity or length, it is occasionally desirable to selectively assemble only parts of a module. This is particularly true during the debugging stage of longer, complex assembly programs. "Conditional assembly" is the ability to designate certain portions of a module for assembly, depending upon conditions established by the IASSEMBLE statement.

You may recall from the description of the IASSEMBLE statement earlier, there are options called "conditions" available with the statement. These conditions —

```
A
B
C
D
E
F
G
H
```

are used to designate which conditions are "set" during the assembly. By including one or more of these conditions, all conditional assembly statements predicated upon that condition are assembled. For example, if the following statement is executed —

```
IASSEMBLE Retrieve;A
```

then any occurrence of conditional assemblies based on "A" are assembled. Also, any conditional assemblies based on B through H are not assembled, since those conditions were not included in the options for the IASSEMBLE statement.

The conditional assembly sections are delimited by pseudo-instructions. A conditional section begins with one of the following —

```
IFA
IFB
IFC
IFD
IFE
IFG
IFH
```

and it concludes with —

```
XIF
```

In addition to the lettered conditions, a numeric condition can be tested by using an IFP pseudo-instruction. It has the form —

IFP {absolute expression}

The condition is considered true if {absolute expression} evaluates as a positive value. It should be noted that this is an assembly-time construct, meaning that the variables contained in the expression are evaluated at the time of assembly.

The IFP instruction performs in the same manner as the IFA through IFH instructions. It also terminates with the XIF instruction.

The conditional assembly is based upon a flag. At the beginning of the assembly for a module the flag is set so that object code is generated for all instructions. An IF conditional encountered during the assembly which does not have its condition set turns off the flag so that no further code is generated. Encountering an XIF statement resets the flag so that code generation can resume. For instance, if the source is —

```
430 ISOURCE   LDA =Array_type
440 ISOURCE   LDB =Array
450 ISOURCE   JSM Get_info       ! Info on the array parameter
460 ISOURCE   LDA Array_type     ! Look at the type
470 ISOURCE      IFA                !
480 ISOURCE      STA Test           ! DEBUGGING SECTION
490 ISOURCE      RET 1              !
500 ISOURCE      XIF                !
510 ISOURCE   IFB
520 ISOURCE   CPA =16            ! A file number (not an array)?
530 ISOURCE   JMP *+3            ! Must be a file number
540 ISOURCE   ADA =-12           ! Is it an array
550 ISOURCE   SAP *+3            !    data type (ie, >12)?
560 ISOURCE   XIF
570 ISOURCE   LDA = Test
```

Then if —

```
IASSEMBLE Retrieve;A
```

is executed, lines 430 through 460, 480, and 490 are assembled, but 520 through 550 are not. Line 570 is assembled.

The one XIF actually affected both conditions. This effect is more dramatically illustrated by —

```
IASSEMBLE Retrieve
```

where neither A nor B is set. In this case 480, 490, 520 through 550 are not assembled. But 550 is assembled!

The effect of the XIF, then, is as a flag for all the conditions. As a consequence, it is not possible to "nest" conditional assemblies. This effect is the same with the IFP conditional.

Relocation

The code talked about in this section is relocatable. You do not have to worry about the absolute location of your module. The assembler automatically generates the appropriate machine codes for each of your instructions to assure that the correct location is reached when referenced.

Some instructions generate relocatable object code in which the operand address is an offset from the current address and the relocating loader has to make no changes to the object code for them as long as they are within − 512 and + 511 of the current address.

For indirect addressing, and for instructions which are more than 512 words away from the current address, it is required of the loader to adjust the address in the intermediate word to reflect the actual address being referenced. For indirect addressing generated by the assembler, this activity is automatic.

Some instructions permit you to specify an absolute machine address for its operand. In those cases, the assembler generates the code necessary to perform the reference to the absolute location.

For example, if the instruction was assembled —

```
LDA B
```

(which essentially says "load register A with the contents of register B) the result would be a machine instruction which references the B register (absolute address 1). This reference would be independent of the actual location of the instruction itself.

There are a couple of ways to produce an absolute address in an operand. The pre-defined symbols are one way. There is a type of expression known as "absolute" which is another way. Both of these are dicussed in the next section, "Symbolic Operations".

You should never try to use absolute addressing within the ICOM region, since not only is the location of the region itself not fixed, but modules can be moved around within the region.

Symbolic Operations

You have been introduced, in small doses, to symbols throughout the chapters preceding this one. The idea of symbols in an assembly language is the same as it is in a higher language such as BASIC — to make operations simpler and the code more understandable.

Several symbolic tools are provided for you in this assembly language system. You have already seen one described in detail in this chapter — labels. There are some pre-defined symbols the assembly system provides for certain locations in the machine (mostly registers). There are ways to define your own symbols (and give them a "type"). And, there are ways to access symbols in other modules.

Symbols can be used as operands in machine instructions and in some pseudo-instructions. They can be part of expressions in an operand.

Pre-Defined Symbols

The assembler has pre-defined a number of symbols and has reserved them as references to special locations in memory. Each of the locations has a special meaning and function. The symbols themselves are "reserved", meaning they cannot be re-defined (by using them as labels on something else). The symbols are —

Symbol	Description
A	Arithmetic accumulator
Ar1	BCD arithmetic accumlators
Ar2	
B	Arithmetic accumulator
Base_page	Global temporary area (50 words)
C	Stack pointer
Cb	Address-extension bit for byte pointer in C
D	Stack pointer
Db	Address-extension bit for byte pointer in D
Dmac	DMA count register
Dmama	DMA memory address register
Dmapa	DMA peripheral address register
End_isr_high	Reserved symbols for writing interrupt service routines
End_isr_low	
Isr_flag	
Isr_psw	

Symbol	Description
Oper_1 Oper_2	Arithmetic utility operand address registers
P	Program counter
Pa	Peripheral address register
R	Return stack pointer
R4 R5 R6 R7	I/O registers
Result	Arithmetic utility result address register
Se	Shift-extend register
Utlcount Utlend Utltemps	Reserved symbols for writing utilities

The meaning of each of these locations is discussed in other chapters. The absolute locations of the registers can be found in Chapter 2. A description of the function of the accumulators and pointers can be found in Chapter 3 as part of the discussion on machine instructions. A discussion of the I/O registers and symbols can be found in Chapter 7. The arithmetic registers are discussed in Chapter 5.

Using a pre-defined symbol in a machine instruction is the same as using its address. For example —

```
ISOURCE   LDA B
```

means simply that register A will be loaded with the contents of register B. The same effect could have been achieved with —

```
ISOURCE   LDA 1
```

except that the symbolic form makes it more obvious what is intended by the operation. This is true with most symbols.

Defining Your Own

You are defining your own symbol each time you specify a label on an instruction or pseudo-instruction. Normally the "value" of the label is the address associated with the instruction. However, in two cases it is possible to create the label and specify what its value is to be. One case is when the label is on the EQU pseudo-instruction; the other case is when the label is on the SET pseudo-instruction.

The EQU is an assembly-time construct. It exists only at the time of assembly to give you value-assigning capability to symbols. It generates no code itself, and it has no implementation or "location" in the object module.

To define a symbol using an EQU, the form is —

{label}: EQU {expression}

the resulting symbol ({label}) has the same "type" as the expression (see "Expressions" below) and it has the same value as the result of the expression.

As an example, assembling the statement —

```
ISOURCE Three:    EQU 3
```

means that in all references in the module to the symbol "Three", it is the same as referring to the **value** 3. Thus —

```
LDA Three
```

means load A with the contents of location 3.

A common use for this instruction is to assign a symbol an address which is an offset from another address. For example, if this sequence were in a module —

```
ISOURCE Save_registers:    BSS 40B
ISOURCE Save_b:            EQU Save_registers+1
```

then Save_b would refer to the second word in the BSS area "Save_registers", and it would probably be used to store away the contents of the B register sometime —

```
ISOURCE   STB Save_b
```

and later retrieve the value —

```
ISOURCE   LDB Save_b
```

The SET pseudo-instruction defines a symbol in identical fashion to an EQU. Consequently, it has the same general form —

{label}: SET {expression}

The difference between the two is that the SET instruction can have its {label} be a symbol which has been previously defined. The effect in that case is to allow a **redefinition** of the symbol. For example, after assembling the following instructions —

```
ISOURCE Three:    SET 3
ISOURCE Three:    SET 30B
```

the symbol "Three" has the value 30B.

Literals

Literals are a special means of defining your own symbols without actually having to go to the trouble to do so. The result is a form of symbolic addressing without the symbol.

The form of a literal is —

= {expression} [, {expression} [, ...]]

where {expression} may be any absolute or relocatable expression (see "Expressions" below).

Evaluation of Literals

When a literal is encountered in an operand, three things occur —

1. The literal is converted to its binary value. If there is more than one expression in the literal, then they are all converted.
2. The binary value is stored in a literal pool. If there is more than one expression in the literal, then they are stored contiguously in the order specified.
3. The address of where the value is stored is then substituted for the literal in the operand.

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

Literals can be part of expressions as well as having expressions as part of them. Since they ultimately are replaced by an address (pointing to a specific location within a literal pool), their "type" is "relocatable". See the section on "Expressions" later in this Chapter.

Basically, a literal means "the address of {expression}". An example should help in the understanding of literals. Suppose that you want to store the value 1 into the A register. There are two ways you could accomplish that purpose. You **could** code —

```
One:  DAT 1
       .
       .
       .
      LDA One
```

or, you could use a literal and code —

```
LDA =1
```

Using the literal method is easier and is more self-documenting. While the literal form strictly says "load A with the contents of the **address of** the constant 1", it can also be read as "load A with the constant 1", and this short-hand version can be an excellent way of self-documenting your programs, not to mention the elimination of a lot of unnecessary symbols.

Nesting Literals

Since literals use expressions, and literals may be used in expressions, it is possible to have a literal within a literal (nesting). In fact, it may be done to any depth, though the most useful form of nesting is a single level.

Suppose you want to initialize a variable to the value of pi each time you enter a routine. A nested literal would be a way of accomplishing this in a clean, straight-forward fashion —

```
Pi:  BSS 4
      .
      .
      .
     LDA ==3.14159265349
     LDB =Pi
     XFR 4
```

and the locations starting at "Pi" now contains the full-precision value indicated (which is a fair approximation to pi). This would replace coding which could have looked like this (without using literals) —

```
A_init:  DAT Init
Init:    DAT 3.14159265349
A_pi:    DAT Pi
Pi:      BSS 4
          .
          .
          .
         LDA A_init
         LDB A_Pi
         XFR 4
```

Nonsensical Uses of Literals

A literal, basically, is an address. Since it can be used in an operand wherever an address may be used, it is possible to use it in instructions where the result is a little nonsensical.

For example, consider the result of doing some of the following —

```
STA =2
JSM ="GARBAGE"
DSZ =- 1
JMP =Neverneverland
SZA =Out_to_lunch
```

Caution dictates that you well consider the appropriateness of the action when using the literal. Literals can be a highly useful tool, but only when properly employed.

Literal Pools

Literals are assemble-time constructs, but they eventually resolve to an actual address in the object code. That address points into a literal "pool".

A literal pool is part of your module where the actual values of literals are stored. There is automatically a literal pool assigned at the end of each module where literals are used. As many literal values as possible are stored there by the assembler. However, in some cases, a literal pool is needed earlier in the program (a need indicated by the assembler with the "LT" assembly-time error). In that case a pool should be created using the LIT pseudo-instruction. This instruction has the form —

`LIT` {size}

where {size} is the number of words to be set aside (it may be a positive numeric expression). The instruction acts very much like a BSS. And, like a BSS, it should be placed at a location in your code where it is not likely to be inadvertently executed.

Most modules do not need assignment of an extra literal pool. However, one is needed where there is a literal used beyond 512 words from the first available space in the literal pool at the end of the module. To alleviate the problem, a literal pool must be created with the LIT statement within 512 words of the instruction.

A common cause of this kind of problem is a large BSS assignment between the instruction and the end of the module. Sometimes moving the BSS to some other location is a solution to the problem.

Expressions

Literals, some pseudo-instructions (particularly EQU), and a number of machine instructions, all permit "expressions" to be used as an operand. These expressions take one of two forms — "absolute" or "relocatable". The type of an expression depends upon the type of the individual **elements** in it.

An element is of the type "absolute" if it is any of the following —

- A decimal integer (like 0, 1, 2, 1 024).
- An octal integer (like 10B, 40B, 100000B).
- A string (enclosed by quote marks) (like "ERROR")
- An ASCII character, preceded by an apostrophe (like 'A).
- A label associated with an EQU or SET pseudo-instruction whose expression is also evaluative as type absolute (like EQU 40B).

An element is of the type "relocatable" if it is any of the following —

- A label not associated with an EQU or SET pseudo-instruction (i.e., it is an "address").
- A literal (like =0).
- An asterisk, symbolizing "current address".
- A label associated with an EQU or SET pseudo-instruction whose expression is also evaluative as type relocatable (like EQU *).

An expression is a list of elements each pair of which is separated by one of the following operators —

+ − / *

meaning addition, subtraction, division, and multiplication, respectively, as in BASIC.

The result of an expression is either absolute or relocatable depending upon the following rules:

An absolute expression is any expression which contains —

- Only absolute elements.
- An even number of relocatable elements, paired in sequence and by sign (i.e., for each relocatable element there is another relocatable element adjacent to it, of opposite sign). These pairs may be in combination with absolute elements.

A relocatable expression is any expression which contains —

- An odd number of relocatable elements, paired in sequence and by sign, except the last, which must be positive.
- An odd number of relocatable elements, as above, in combination with any number of absolute elements.

Any combination of absolute or relocatable elements which does not result in either an absolute or relocatable value, by the rules above, results in an error.

These rules and the rules for using * and / can be summarized as —

The expression is —	**The type is —**	**Example**
absolute ± absolute	absolute	`1000B + 10`
absolute + relocatable	relocatable	`1 + Temp`
relocatable ± absolute	relocatable	`Temp - 1`
relocatable − relocatable	absolute	`Temp 1 - (Temp - 1)`
relocatable + relocatable	error	`Temp + Temp 1`
absolute − relocatable	error	`1000B - Temp`
absolute * absolute	absolute	`100 * 3`
absolute / absolute	absolute	`100/3`
absolute * relocatable	error	`Temp * 3`
relocatable * absolute	error	`3 * Temp`
absolute / relocatable	error	`Temp/3`
relocatable / absolute	error	`3/Temp`

Unlike BASIC, there is no precedence among the operators. All are of equal precedence. Where precedence is desired, parentheses must be used. So where BASIC requires —

2*16+3*8

to result in 56, the same expression in the assembly language results in 280 (assembly language operators are evaluated from left to right). However, 56 would be the result if it were expressed as —

(2*16)+(3*8)

An expression may be of any length and contain as many operators and parentheses as desired, as long as the result can be evaluated and the parentheses are properly paired. All operators are evaluated from left to right. Multiplication and division can only be used with elements that are of type absolute.

External Symbols and Elements

There is an additional relocatable element, called "external". It behaves in almost all respects as does any other relocatable element, except that only one external item may appear in an expression. Also, the expressions containing —

relocatable − relocatable

are not allowed when one of the relocatable elements is external. Externals are defined as symbols appearing in an EXT pseudo-instruction —

EXT {symbol} [, {symbol} [, ...]]

These are entry points in another module or utility. "Entry points" are merely symbols in a module which are listed in an ENT pseudo-instruction in that module —

ENT {symbol} [, {symbol} [, ...]]

If one module contains —

```
ENT Stage_left
```

then that symbol would be available to another module which contains —

```
EXT Stage_left
```

At execution time for a module with EXT instruction, all of the symbols listed in it must be either a utility name or be contained in an ENT or SUB (described in Chapter 6) of another module. It is not necessary that the module be in source form; it may already be an object module assembled from a source module which contained the symbol as an ENT or SUB.

Other Absolute Elements

There are additional **absolute** elements which may be used in expressions. These are "machine addresses", short-precision numbers, and full-precision numbers.

A machine address is one of the following —

- An assembler pre-defined symbol.
- A symbol associated with an EQU or SET pseudo-instruction whose expression is evaluated as a machine address (i.e., it contains a pre-defined symbol or another EQU-associated symbol whose expression contains a pre-defined symbol).

For the most part, machine addresses can be used just like absolutes. However, they remain defined from assembly to assembly. By defining a machine address in one module (with an EQU or SET), it then becomes available to you with the same value in other modules which you assemble.

For example, if you were to assemble a module containing —

```
ISOURCE R100:  EQU A+100
```

then R100 is a machine address following the above rules, just as if the assembler had pre-defined it. If you don't do any SCRATCH or GET statements in the meantime, then the next assembly you do would also have this symbol available without ever having to define it.

When full-precision numbers (like − 2.5, 3E3, 3.141592) and short-precision numbers (like 1S, − 2.5S, 3.14159S, 3E3S) are used in expressions, they become the **entire** expression. This is because these numbers are only intended as simple data-generating devices in literals and in DAT pseudo-instructions. Explicitly, the rules for using full- and short-precision numbers are —

- They may only appear alone in an expression, i.e., they may not be in combination with other elements.
- They may only appear in literals and in DAT pseudo-instructions.

Utilities

A number of utilities have been provided to help make your programming tasks easier and to give you direct access to some of the operating system's capabilities and routines.

Descriptions of the utilities are made in conjunction with those topics where the utilities play a part. The form of the description of a utility is somewhat standardized. Each description will tell you —

- The name of the utility.
- The general procedure for using the utility.
- Any special requirements which must be satisfied for the utility to work properly.
- A step-by-step calling procedure for the utility.
- The exit conditions.

Utilities are a form of subroutine, so to execute them it is necessary to execute a jump-to-subroutine instruction (JSM) if you want the utility to return to the routine which calls it. Most utilities execute a RET 1 instruction to return, so in some cases where you follow a utility call with a RET 1 of your own, you can save the RET instruction by using the JMP (unconditional branch) instruction instead. For example, a typical utility call looks like —

```
 .
 .
 .
LDA =Temp
LDB =Pointer
JSM Get_element
 .
 .
 .
```

but if it happened to be followed by a RET 1 —

```
 .
 .
 .
LDA =Temp
LDB =Pointer
JSM Get_element
RET 1
 .
 .
 .
```

the calling procedure could be changed to —

```
  .
  .
  .
LDA =Temp
LDB =Pointer
JMP Get_element
  .
  .
  .
```

and you save a word of code: the effect is otherwise the same. Check the exit conditions for a utility before using this approach.

Utilities which you use in a module must have their names in an EXT pseudo-instruction for that module. Otherwise, the assembler is unable to tell that you meant a utility and not one of your own labels, causing an "undefined reference" assembly error.

Appendix F contains a short description of the utilities and has cross-references to the location in the manual of the full discussion on each utility.

The utilities currently available are —

Utility	Description
Busy	Tests the busy bits of a BASIC variable
Error_exit	Aborts an ICALL statement with a particular error number
Get_bytes	Accesses substrings (or parts of parameters)
Get_elem_bytes	Same as "Get_bytes", but used for array elements
Get_element	Same as "Get_value", but used for array elements
Get_file_info	Accesses the file-pointer of an assigned file
Get_info	Returns the characteristics of a variable passed as a parameter or existing in common
Get_value	Returns the value of a BASIC variable
Int_to_rel	Data type conversion from integer to full-precision
Isr_access	Establishes hardware linkages for interrupts
Mm_read_start	Prepares to read a physical record from mass storage
Mm_read_xfer	Reads a physical record from mass storage
Mm_write_start	Writes a physical record to mass storage
Mm_write_test	Verifies a physical record was written to mass storage
Printer_select	Changes or interrogates select-code for standard printer
Print_string	Outputs a string to the standard printer
Put_bytes	Replaces substrings (or parts of parameters)
Put_elem_bytes	Same as "Put_bytes", used for elements in an array
Put_element	Same as "Put_value", used for elements in an array
Put_file_info	Manipulates the file-pointer of a file
Put_value	Changes the value of a BASIC variable
Rel_math	Provides access to all the arithmetic routines
Rel_to_int	Data type conversion from full-precision to integer
Rel_to_sho	Data type conversion from full-precision to short
Sho_to_rel	Data type conversion from short-precision to full

Chapter 5
Table of Contents

Chapter 5
Arithmetic

Summary: Arithmetic operations are reviewed and the arithmetic utilities are discussed. Floating point and BCD arithmetic are explained.

Numerical calculations are a large part of any computer's operations. Implemented within the 9835A/B's processor are both integer and primitive Binary Coded Decimal (BCD) floating-point arithmetic operations. This chapter deals with those operations and is intended for those readers who may have no acquaintance with this topic, or perhaps only a passing one. The particular machine instructions involved with such arithmetic are reviewed.

Because the processor provides only rudimentary floating-point operations and because complete floating-point operations (e.g., subtract, divide) are not easy to write, utilities have been provided to perform these calculations. These utilities are discussed later in this chapter. If you are not interested in doing your own BCD arithmetic, it is recommended you skip immediately to "Arithmetic Utilities".

Binary Coded Decimal (BCD) uses four-bit binary codes to represent decimal digits. Thus, the 12-digit mantissa of a full-precision number is represented by 48 bits. The BCD digits are as follows —

DECIMAL	BCD
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

A BCD number within this manual has its digits represented as D_1, D_2, D_3, etc., with each digit corresponding to some BCD digit. D_1 is the most significant digit in a number. Since full-precison numbers within the 9835A/B contain 12-digit BCD mantissas, 12-digit BCD numbers are used as the most frequent examples in this discussion. In that case, D_{12} is the least significant digit in a number.

Arithmetic Machine Instructions

There are some machine instructions which specifically operate upon the BCD registers. The discussions in this chapter will make use of the capabilities of these instructions to develop the techniques to write BCD arithmetic routines. If you have not done so already, you should familiarize yourself with the instructions before moving on in this chapter. A description of the instructions can be found in "Arithmetic Group" in Chapter 3.

BCD Registers

There are two registers in the machine used for BCD arithmetic — Ar1 and Ar2. These symbols are pre-defined by the assembly language to the registers' locations in memory (see Chapter 3). The mnemonics for some instructions occasionally refer to these registers as X and Y respectively (see Chapter 3).

BCD Arithmetic

To understand BCD arithmetic in the context of the 9835A/B, recall from Chapter 3 that a full-precision value is represented in four words which contain its information as follows —

<table>
<tr><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>Bit</td></tr>
<tr><td>Exp Sign</td><td colspan="9">Exponent</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>Man Sign</td><td></td></tr>
<tr><td colspan="4">D_1 (most significant digit)</td><td colspan="4">D_2</td><td colspan="4">D_3</td><td colspan="4">D_4</td><td></td></tr>
<tr><td colspan="4">D_5</td><td colspan="4">D_6</td><td colspan="4">D_7</td><td colspan="4">D_8</td><td></td></tr>
<tr><td colspan="4">D_9</td><td colspan="4">D_{10}</td><td colspan="4">D_{11}</td><td colspan="4">D_{12} (least significant)</td><td></td></tr>
</table>

The exponent is stored in two's complement form. The exponent and the mantissa are always adjusted by arithmetic routines so that there is always an implied decimal point following D_1. Thus, the mantissa of every value stored looks like —

$$D_1 . D_2 D_3 D_4 D_5 D_6 D_7 D_8 D_9 D_{10} D_{11} D_{12}$$

Except possibly for intermediate results within the individual arithmetic algorithms, the most significant digit of a full-precision value (D_1) will never be 0 unless the entire number is 0. Sometimes, after an individual arithmetic operation, the answer needs to be **normalized**, that is, the digits of the answer shifted to the left until D_1 is no longer 0. The exponent then needs to be adjusted to reflect the change.

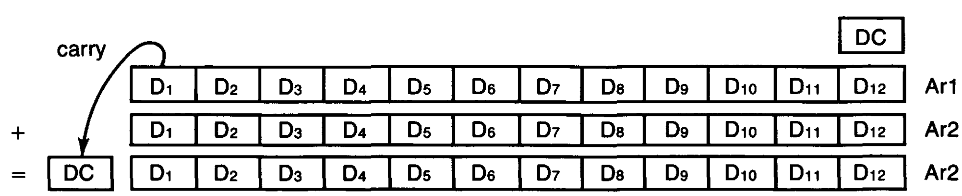
An important thing to keep in mind when examining BCD arithmetic, as implemented by the processor, is that mantissas are represented in a "sign-magnitude" format. This means that the absolute value is stored as the actual mantissa, and the sign of the mantissa is maintained separately.

Addition

There is a one-bit Decimal Carry (DC) flag within the processor which serves a BCD function similar to the Extend flag for binary addition.

DC is set to a one or zero, depending upon the occurrence or absence of a carry from the addition of the two D_1's of the two BCD numbers being added. Since mantissas are represented in a sign-magnitude form (with the sign in the exponent word rather than part of what gets added), DC represents an overflow for 12-digit mantissa additions.

DC itself is part of the addition in the D_{12} position. This gives it potential use with multiple-precision floating point arithmetic. The addition process looks like this —



There are three instructions which concern themselves exclusively with DC. They are — SDS (Skip if DC set), SCD (Skip if DC clear), and CDC (Clear DC).

Ten's Complement for BCD

The addition of the ten's complement of a number is used in lieu of a subtraction mechanism. If the signs of the two numbers to be summed are different, one of the numbers is complemented (it doesn't really matter which one), before the addition.

The ten's complement of a number with n digits to the left of the decimal point is —

$$X = 10_n - X$$

The ten's complement of a floating-point number has the same exponent as the original number. Since the mantissa (M) of a full-precision number can be assumed to have the decimal point implied after D_1, then the number must be less than 10 (but greater than 0) and the ten's complement of a mantissa becomes —

$$M = 10 - M$$

Accordingly, all that is necessary to complement a floating-point number is to complement the mantissa. It is immaterial whether the mantissa is treated as a 12-digit integer or as a number between 0 and 10; the same sequence of digits results.

There are two instructions for doing ten's complements — CMX and CMY. The only difference between them is that CMX operates on the Ar1 register and CMY operates on the Ar2.

CMX and CMY leave the exponent word of a full-precision number completely alone. This means that the sign of the mantissa and the entire exponent are left unchanged in a ten's complement by CMX and CMY.

Ten's complement helps to accomplish addition, too. Rather than go into all of the nuances and subtleties of the arithmetic process, there is a simple rule for accomplishing decimal summations using ten's complements. Assuming the exponents are the same for the numbers to be added —

- If the signs of the numbers are the same, simply add them and leave the signs alone. If DC occurs, the result (Ar2) must be shifted to the right one place, and the exponent adjusted.
- If the signs of the numbers are different, complement, then add. A further complementing action may be necessary: if DC occurs, then the result necessarily has the same sign as the number which was not complemeted; if DC does not occur, then the result must be complemented and then given the sign of the number which was complemented.

The FXA instruction is used to add mantissas. Here is a routine to implement the rule —

```
ISOURCE   LDA Ar1          ! Check the sign
ISOURCE   ADA Ar2
ISOURCE   SLA Just_add     ! Skip if they are the same
ISOURCE   CMX              ! Complement Ar1
ISOURCE   FXA              ! Add the mantissas
ISOURCE   LDB Ar2
ISOURCE   SDS *+3          ! Was there an overflow?
ISOURCE   CMY              !   No, so complement result
ISOURCE   LDB Ar1          !   and switch exponents and signs
ISOURCE   STB Ar2          ! Store the larger sign
ISOURCE   JMP Done
ISOURCE Just_add: ! Do the addition
ISOURCE   FXA
ISOURCE   SDC Done         ! Was there an overflow?
ISOURCE   LDA =1           !   Yes, so shift in a 1
ISOURCE   LDB =1           !   into the most
ISOURCE   MRY              !   significant digit
ISOURCE   LDA Ar2          ! Adjust exponent
ISOURCE   ADA =100B
ISOURCE   STA Ar2
ISOURCE Done:  ! CONTINUE ON
```

Floating Point Summations

In the example just completed, you may have noted that to copy the sign the entire exponent word was copied. What if the exponents were different? The answer is — the exponents must have been the same. In fact, the only reason the example worked at all was that the exponents were the same.

If exponents are different, addition of mantissas cannot proceed properly. To add the numbers it is necessary to make the exponents the same by shifting one of the mantissas an amount equal to the exponent difference.

This difference is easily found by subtracting the smaller exponent from the larger. If the difference is eleven or less (the precision of the 12-digit mantissa), it is possible to offset the mantissa of the number with the **smaller** exponent.

For example suppose there are two numbers to be added —

```
X.XXXXXXXXXXX E6
Y.YYYYYYYYYYY E4
```

By shifting the smaller one to the right by 2 digits (the difference between 6 and 4), it is possible to align the exponents —

```
X.XXXXXXXXXXX     E6
0.0YYYYYYYYYYYYY E6
-------------------
Z.ZZZZZZZZZZZ     E6
```

As can be readily seen from the example, a shift of more than 11 digits would cause the smaller value to be all zeroes in the significant 12 digits.

The digits to the right of the 12 most significant digits are lost in the action of shifting. That is, all except the left-most one. When using the MRX or MRY instructions, this digit is retained in the A register (bits 0-3) so that it can be used later for rounding purposes.

To use the MRX or MRY instructions, the number of digits to be shifted must be present in the B register.

The process for this "justification" of exponents can be summed up as follows:

- Subtract one exponent from the other storing the absolute value of the difference in the B register.
- Execute the MRX shift if the Ar1 register is smaller; execute the MRY shift if the Ar2 register is smaller.

Normalization

The raw result of an arithmetic operation (such as FXA) might not be a floating-point number that fits the standard form. It might have a leading DC needing to be incorporated into the number, as was seen in the "Addition" section earlier. Another possible deviation is a resulting D_1 of zero and no overflow. There could also be several zero-valued digits as left-most digits of the mantissa.

Such situations call for "normalization". One type of normalization is accomplished with the NRM instruction. This instruction shifts register Ar2 left, leaving the number of shifts required in the B register as a binary number. The maximum number of shifts NRM performs is 12. If NRM must do all twelve shifts, Ar2 must have been 0. This is indicated by a value of 12 left in B and DC being set. For any other shift-count, NRM will leave DC at 0.

The rules for the normalization process are —

- Execute the NRM instruction.
- Follow this instruction by adding the complement of the contents of B (shifted left 6 bits) to the Ar2 exponent unless DC is set. If DC is set, store 0 into Ar2.
- Test the exponent result for an underflow.

Rounding

The addition operation (FXA) does not automatically round a result, and there is no instruction which does rounding in one step. Instead, it is necessary that a series of instructions be established to accomplish the result.

Recalling from "Floating Point Summations" (above) that the leftmost digit for rounding purposes (if any) is typically deposited in the A register by an MRX or MRY instruction, this digit can be checked to determine if rounding is required.

The process of rounding, then, would have the following steps —

- Determine from register A if rounding is required (i.e., if it's greater than or equal to 5).
- If rounding is not required, take no further action. If rounding is required, then load register B with 1 and execute an MWA instruction. This has the effect of incrementing the mantissa in Ar2 by 1. This action is an easier method than setting Ar1 to 1 and executing an FXA and it's faster, too. Don't forget to check DC for an overflow.
- One way the sequence of rounding could appear is —

```
10   ISOURCE   ADA =-5   ! Scale A down
20   ISOURCE   SAM *+3   ! If less than 5, no rounding
30   ISOURCE   LDB =1    ! Get ready to add 1 to Ar2
40   ISOURCE   MWA       ! Add 1 to least significant digit of Ar2
```

Floating Point Multiplication

Twelve-digit BCD floating-point multiplication is partially accomplished using the FMP instruction. This instruction effectively multiplies the value in the Ar1 register by a digit contained in B and adds the result to a partial product in Ar2.

Since, in the full multiplication process, exponents are merely added together, that part of the process is trivial. The ultimate sign of the product is also a trivial matter, determined by inspection of the signs of the original operands. Then the only matter of difficulty in the process is the actual multiplication of the mantissas. By way of explanation, assume that there are two mantissas to be multiplied —

multiplicand = A B C D
multiplier = W X Y Z

Just four digits are used to reduce the amount of symbolism required of the example. The same procedures and conclusions are applicable to a full twelve BCD digits.

One symbolic way to indicate how this multiplication is done is —

$$
\begin{array}{ccccccccl}
 & & & & A & B & C & D & \\
 & & & \times & W & X & Y & Z & \\
\cline{4-8}
 & & & & 0 & 0 & 0 & 0 & = \text{partial product } 0 \\
 & & & Z_{ov} & Z_1 & Z_2 & Z_3 & Z_4 & = Z\,(ABCD) \times 10^0 \\
\cline{4-8}
 & & & P_4 & P_5 & P_6 & P_7 & P_8 & = \text{partial product } 1 \\
 & & Y_{ov} & Y_1 & Y_2 & Y_3 & Y_4 & 0 & = Y\,(ABCD) \times 10^1 \\
\cline{3-8}
 & & P_3 & P_4 & P_5 & P_6 & P_7 & P_8 & = \text{partial product } 2 \\
 & X_{ov} & X_1 & X_2 & X_3 & X_4 & 0 & 0 & = X\,(ABCD) \times 10^2 \\
\cline{2-8}
 & P_2 & P_3 & P_4 & P_5 & P_6 & P_7 & P_8 & = \text{partial product } 3 \\
W_{ov} & W_1 & W_2 & W_3 & W_4 & 0 & 0 & 0 & = W\,(ABCD) \times 10^3 \\
\hline
P_1 & P_2 & P_3 & P_4 & P_5 & P_6 & P_7 & P_8 & = \text{partial product 4 (result)}
\end{array}
$$

Notice that at each stage the multiple of ABCD, such as X(ABCD), must be multiplied by an increasing power of ten in order that the digits of the multiple line up appropriately with the digits of the last partial product. An equivalent procedure is to have the partial product shifted right one digit at each stage.

Now, consider for a moment what is necessary within the assembly language to generate partial product 1 = 0 + Z (ABCD). Ar2 must be cleared and Ar1 is loaded with ABCD. Z is stored into B in bits 0 to 3. Then the FMP instruction is executed. Ar1 is added to Ar2 Z times, producing Z (ABCD) in Ar2. The overflow digit, Z_{ov}, ends up in the A register (bits 0 to 3). The overflow digit could be any value from 0 to 9 (each add could cause a carry, and there can be up to nine additions).

To create the next partial product, a mantissa right-shift on Ar2 must occur. Notice that mantissa right-shifting instructions (MRX and MRY) also shift bits 0 to 3 of the A register into D_1. Thus, the right-shifting of the partial product (which must occur to prepare Ar2 for the next partial product) also automatically takes care of retaining the overflow digit.

Next, ABCD is added to Z_{ov} Z_1 Z_2 Z_3 a total of Y times (again by use of the FMP instruction). Partial product 2 is created. The process is repeated for the X and W digits, producing the result in Ar2.

After the final partial product has been calculated by the final execution of the FMP instruction, it is possible that a non-zero digit may be present in bits 0-3 of the A register. Such a digit is necessarily the most significant digit of the final product. In this case, another MRY execution is required. Further, the exponent of the product (which was initially estimated as the sum of the operand's exponents) must be incremented by one to reflect this power-of-ten shift.

Upon each step of partial product summation, a significant digit is lost due to the shift. This can't be helped. In general, the product of two 12-digit numbers has 24 digits of precision, but the bottom 12 digits must be discarded since only 12 BCD digits are stored in a mantissa. An error analysis of the algorithm discloses that dropping these digits causes the answer, on average, to be slightly smaller than it should be. However, rounding introduces a similar error, but in the other direction. Note that the process did not round each partial product.

The discarded digits can be inspected before they are permanently lost. The MRY instruction causes the digit to be placed in the A register (in bits 0 to 3). This provides an easy way for a rounding mechanism to check on those digits as they are discarded. The rounding routine needs to save the last digit discarded for use in rounding in the event the last use of FMP produces no overflow digit.

Finally, it should be noted that you can put WXYZ into B at the very start of the process and simply shift B right 4 bits (with an SBR 4 instruction) between each execution of FMP. After all, FMP uses only bits 0 to 3 of the register as the number of times to add Ar1 and Ar2.

Floating Point Division

There are many possible algorithms to accomplish floating-point division. The one presented here was chosen because of its effective use of the machine instructions and data structures employed by the processor and operating system.

Remembering that full-precision numbers consist of both a signed mantissa and a signed exponent, use can be made of the mathematical properties of both to reduce the division problem to manageable proportions. Suppose that you have two full-precision values to divide —

$$-4.8E3 \div 1.5E-2$$

The mathematical properties of exponents can be utilized and the second exponent can be subtracted from the first giving the exponent of the answer (subject to possible later adjustment). This is the first (and easiest) step in the division algorithm.

Secondly, the mathematical properties of signs within a division process can be used to determine the sign of the quotient from the signs of the divisor and dividend (negative quotient if the signs are different, positive quotient otherwise).

Thus, the problem can be reduced to the division of the mantissas —

$$(-4.8 \div 1.5)\ E5$$

As long as the full-precision numbers have been normalized, this adjustment of the exponents works for any pair of exponents. The normalization of the numbers also assures that the division of the mantissas under the following algorithm is sufficient to produce the mantissa of the result.

Since the decimal point of each mantissa is in the same place, they can be dropped altogether. For example —

$$-4.8 \div 1.5 = -48 \div 15$$

The algorithm can then consider both the divisor and the dividend as 12-digit integers.

The algorithm begins by placing the normalized values into the BCD arithmetic registers. The divisor (1.5E2 in the example) is transferred to register Ar1. The dividend (- 4.8E3 in the example) is transferred to register Ar2. Basically, the algorithm subtracts the absolute value of the mantissa of Ar1 from the absolute value of the mantissa of Ar2 until Ar2 is smaller than Ar1. The number of subtractions required for that to occur becomes the first digit in the quotient (it'll be some value between 0 and 9 because the mantissas are normalized). If there is a (non-zero) remainder, then it is shifted left (multiplied by 10) and the subtraction process is repeated to calculate another digit in the quotient. The process is repeated until either a zero remainder occurs , or sufficient digits have been calculated, whichever occurs first. The resulting digits are merged, in order, to form the complete mantissa of the quotient.

There are some points to keep in mind in following the algorithm —

- Suppose you have a divisor whose normalized mantissa is larger than the normalized mantissa of the dividend, for example —

  15 ÷ 48

  then the first digit of the quotient's mantissa could easily be zero. If calculation of only twelve digits were made, the first digit being zero would mean a loss of a significant digit. To guarantee that there are always at least 12 significant digits calculated for the quotient, it is necessary (and sufficient) to calculate 13 digits. The 13th digit can always be thrown away, or used for rounding, if the first digit is not zero. Thirteen digits are always sufficient because you can never have a quotient with **two** leading zeroes, if the divisor and the dividend are both normalized.

- The number of subtractions during the calculation of any digit in the quotient is always nine or less. Again, this is true because the divisor is normalized and its first digit is always non-zero.

- At times during the algorithm, it is necessary to left-shift the mantissa of Ar2 (the mantissa at this point is the remainder). When shifting the remainder to the left (multiplying it by 10), you are shifting the first digit out of Ar2. If this digit is zero, this is not a problem. But, if the digit is non-zero, you can't ignore it during subtractions of the divisor. This in effect means that you are dealing with a 13-digit dividend! Since the machine instructions deal in 12-digit arithmetic, it is necessary that the algorithm handle the thirteenth.

The FDV Instruction

The FDV instruction provided by the processor is the primary tool used to implement the algorithm in assembly language. The instruction works by accomplishing the equivalent of automatically repeated subtractions of Ar1 (the divisor) from Ar2 (the dividend) until Ar2 is smaller than Ar1. The instruction actually adds the divisor to the ten's complement of the dividend until an overflow occurs. However, this is equivalent to subtracting until an "underflow" occurs. It is easier to understand the procedure if the discussion is in terms of "subtractions", but it should be kept in mind that what is really occurring with the instruction is repeated "complement-additions" until overflow. This process is what is meant by the term "subtractions until overflow".

The FDV instruction returns the number of subtractions without overflowing as a binary number in the B register (bits 0-3). The remaining bits in the B register (4-15) are cleared.[1] In effect, then B contains the next digit in the quotient.

This process is repeated for the number of digits to be calculated. After each FDV execution, the result of the overflow subtraction is left in Ar2. Since Ar2 does not contain the remainder, it is necessary to patch Ar2 so that it will contain the proper value for the next calculation. To get the proper value it is necessary to add Arl back into Ar2 to undo the results of the last subtraction (which caused the overflow).[2]

There is one case, however, where Ar2 does not need to be patched up, and this is when the remainder (Ar2) is zero. This situation implies not only that no patching up is needed, but also that the quotient is complete — no further digits need be calculated. It should be noted that the number of subtractions (which has been stored in the B register) is one count too small, thus B has to be incremented in this case so that it can be used as the last digit in the quotient.

Thirteen-Digit Dividends

The largest difficulty in the algorithm is attempting to deal with those instances where the dividend has thirteen digits. This situation arises when you shift the remainder left a place. The most significant digit must be retained when it is non-zero so that the subtractions are subtracted from the proper amount.

This shifting can be accomplished with the MLY instruction. With the way that the MLY instruction operates, the left-most digit (D_1) ends up being shifted out of Ar2 into register A (in the lower 4 bits, 0-3). Thus, the thirteen-digit algorithm must accomodate the most significant digit residing in the A register and the twelve least significant digits in the Ar2 register. The use of FDV must now take this modified situation into account.

When the FDV instruction is executed, Arl is subtracted from Ar2 until an overflow occurs. When this overflow occurs, it is necessary to decrement A and keep subtracting (without patching up Ar2). Each time an overflow occurs, A must be decremented until finally an overflow occurs when A is 0. This can be handled very neatly within a small loop.

1 Since bits 4-15 of the register are cleared during execution of the FDV instruction, you can't accumulate quotient digits there. After each digit is calculated, it is necessary that you store the digit as part of a quotient which you keep stored in another location.

2 This is equivalent to complementing Ar2, adding in Arl, then complementing Ar2 again.

Another aspect of dealing with thirteen-digit dividends is the count placed in B with each execution of FDV. Since each overflow is a "successful" subtraction in the sense that is part of a proper count of subtractions (at least until A is 0), then that subtraction must be counted, too. The difficulty with this is that FDV does not count this last (overflowing) subtraction. The solution obviously is to add 1 to the value in the B register each time FDV causes an overflow. However, with the last overflow, being the "real" overflow, the 1 shouldn't be added in, so after adding it in (during the loop), you have to subtract it back out again (after leaving the loop). To further complicate matters, if you have a zero remainder, you have to add it right back in again.

For example, if there happened to be three uses of FDV for a certain quotient digit, you form the quotient digit as —

$$Q_n = (B + 1)_{\substack{\text{value after 1st}\\ \text{use of FDV}}} + (B + 1)_{\substack{\text{value after 2nd}\\ \text{use of FDV}}} + B_{\substack{\text{value after final}\\ \text{use of FDV}}}$$

If the same general situation produced a zero remainder, then the quotient digit is formed as —

$$Q_n = (B + 1)_{\substack{\text{value after 1st}\\ \text{use of FDV}}} + (B + 1)_{\substack{\text{value after 2nd}\\ \text{use of FDV}}} + (B + 1)_{\substack{\text{value after final}\\ \text{use of FDV}}}$$

Floating-Point Division Example

An example of a 13-digit division routine follows. The rules which it implements are —

1. Always increment the value returned in B after an FDV operation.
2. After incrementing B, check the contents of A. If non-zero, loop immediately, performing no other tests or activities.
3. When a quotient digit has been found (i.e., A is zero), check to see if the remainder is 0. If so, exit the division loop. Save the last digit found as part of the answer.
4. If the remainder is not 0, decrement the value of the last quotient digit found and save it as part of the answer. Then add back the divisor to the remainder.

The example does not include routines for testing and handling —

- signs
- division by zero
- exponents
- overflow
- rounding

These have to be handled in a real program before or after the division algorithm itself (as appropriate).

```
ISOURCE ! Some useful symbols
                .
                .
                .
ISOURCE Ar21:    EQU Ar2+1     ! First mantissa word
ISOURCE Ar22:    EQU Ar2+2     ! Second mantissa word
ISOURCE Ar23:    EQU Ar2+3     ! Third mantissa word
                .
                .
                .
ISOURCE ! Working area
ISOURCE Quotient:             BSS 5   ! Working storage for quotient
ISOURCE Quotient_1:           EQU Quotient+1   ! for quotient word 1
ISOURCE Quotient_2:           EQU Quotient+2   ! for quotient word 2
ISOURCE Quotient_3:           EQU Quotient+3   ! for quotient word 3
ISOURCE Quotient_4:           EQU Quotient+4   ! for quotient word 4
ISOURCE Quotient_ptr:         BSS 1   ! for quotient word 1
ISOURCE Digit_counter:        BSS 1   ! total digits (1-13)
ISOURCE Within_word_ctr:      BSS 1   ! digit counter (1-4)
                .
                .
                .
ISOURCE ! Dividend already in Ar2, divisor already in Ar1
ISOURCE Divide:                   ! START OF DIVISION LOOP
ISOURCE     LDA =Quotient_1
ISOURCE     STA Quotient_ptr
ISOURCE     CLR 4                 ! In case of early termination, zero
ISOURCE     CMY                   ! Complement the dividend
ISOURCE     LDA =13
ISOURCE     STA Digit_counter     ! Initializes digit count to 13
ISOURCE     LDA =0                ! Initialize FDV repetition counter to 1
ISOURCE !
ISOURCE Next_word:                ! WORKS ON NEXT SET OF 4 BCD DIGITS
ISOURCE     LDB =4
ISOURCE     STB Within_word_ctr   ! Initialize intermediate counter
ISOURCE !
ISOURCE Next_digit:               ! WORKS ON NEXT QUOTIENT DIGIT
ISOURCE     SBL 4                 ! Clear lower bits of B
ISOURCE     STB Quotient_ptr,I    ! Clear next storage word
ISOURCE !
```

```
ISOURCE !
ISOURCE Zero_remainder:          ! ZERO REMAINDER BEFORE 13th DIGIT?
ISOURCE     DSZ Digit_counter
ISOURCE     JMP Shift
ISOURCE     JMP Done
ISOURCE !
ISOURCE Shift_left:   SBL 4
ISOURCE Shift:        DSZ Within_word_ctr    ! Shift digits as necessary
ISOURCE               JMP Shift_left
ISOURCE Fdv_loop:                ! QUOTIENT CALCULATION
ISOURCE     FDV                  ! Ar2=Ar2+Ar1 until overflow
ISOURCE     ADB Quotient_ptr,I   ! Merge new digit with rest of answer
ISOURCE     ADB =1               ! Increment the new digit
ISOURCE     STB Quotient_ptr,I   ! Save this state of the answer
ISOURCE     RIA Fdv_loop         !   Decrement and loop if non-zero
ISOURCE !
ISOURCE ! Check for a zero remainder
ISOURCE !
ISOURCE     LDA Ar21
ISOURCE     IOR Ar22
ISOURCE     IOR Ar23
ISOURCE     SZA Zero_remainder
ISOURCE !
ISOURCE ! No zero remainder, so divide again. But first restore dividend,
        shift it left, and then find new FDV repetition count.
ISOURCE !
ISOURCE     CMY                  ! Decomplement remainder (Ar2)
ISOURCE     FXA                  ! Add back in divisor (Ar1)
ISOURCE     ADB =-1              ! Undo the increment
ISOURCE     STB Quotient_ptr,I   ! Save the corrected partial answer
ISOURCE     CMY                  ! Complement the dividend
ISOURCE     LDA =0               ! Clear A
ISOURCE     MLY                  ! Shift dividend left
ISOURCE     ADA =-9              ! Determine next repetition count
ISOURCE !
ISOURCE ! Bottom of loop maintenance follows
ISOURCE !
ISOURCE     DSZ Digit_counter    ! Decrement number of digits
ISOURCE     JMP Within_word
ISOURCE     JMP Done
ISOURCE !
ISOURCE Within_word:             ! DECREMENT POSITION WITHIN WORD
ISOURCE     DSZ Within_word_ctr
ISOURCE     JMP Next_digit
ISOURCE     ISZ Quotient_ptr
ISOURCE     JMP Next_word
ISOURCE !
ISOURCE Done:                    ! STORE AWAY THE RESULT
ISOURCE     STB Quotient_ptr,I   ! Store last digits of quotient
ISOURCE     LDA =Quotient
ISOURCE     LDB =Ar2
ISOURCE     XFR 4                ! Transfer quotient from working storage
                                   to Ar2
                                   to Ar2
ISOURCE     NRM
ISOURCE     SZB Continue         ! Go on, if all is OK
ISOURCE !
ISOURCE ! If leading digit of quotient was a zero, then old digit 13 must
          be saved as new digit 12
          be saved as new digit 12
ISOURCE !
```

```
ISOURCE      LDA Quotient_4        ! Get digit 13
ISOURCE      AND =17B              ! Lower 4 bits only (in case Quotient_4
                                      is used elswehere for other thi
                                     is used elswehere for other things
ISOURCE      ADA Ar23              ! Add in new digit (old digit 12 was 0)
ISOURCE      STA AR23              ! Save the corrected quotient
ISOURCE ! Proceed to adjust exponent accordingly
                .
                .
                .
ISOURCE Continue:  ! Compute sign, etc.
```

Arithmetic Utilities

Now that you have been introduced to the complexities of BCD arithmetic and floating-point operations, this is the time to present an easier way of accomplishing these operations — the arithmetic utilities.

In order to make BASIC a useful programming tool, the operating system already contains a number of floating-point routines. Recognizing that BCD and floating-point arithmetic can be a difficult and laborious task to implement, the assembly language provides a utility by which the operating system mathematical routines can be accessed. There are also utilities for the conversion of numerical data types.

UTILITY: Rel_math

The Rel_math utility provides access to all of the system floating point routines and functions.

General Procedure: The utility is told the execution address of the desired routine or function and is also told the number of parameters. The parameters are floating-point values stored in full-precision form (4 words each). The result is a full-precision value.

Special Requirements:

- If one operand is passed to the utility, the **address** of the operand is stored in register Oper_1.
- If two operands are passed to the utility, the **address** of the **first** operand is stored in register Oper_1 (as above), and the **address** of the **second** operand is stored in register Oper_2.
- The **address** of where the result should be stored must be stored in the register Result.
- All operands and the result are full-precision values and require 4 words each.

- Values passed must make sense for the routine or function being called (e.g., Oper_2 should not point to a value of 0 when calling the division routine), or else an error results.

- The storage areas for the operands and the result must reside either in the ICOM region or in the Base_page register. Specifically, they cannot be specified as Ar1 or Ar2.

Calling Procedure:

1. Assure that Oper_1, Oper_2, and Result contain the proper addresses as above.
2. Load register A with the number of parameters required for the routine or function (see the table on next page). Note that some routines require this number to be complemented.
3. Load register B with the execution address of the routine or function (see the table on the next page).
4. Call the utility.

Exit Conditions:

- The result is placed into the 4 words starting at the address pointed to by the Result register.

- Register A contains 0 if no error is encountered during execution of the utility.

- Register A contains the error number should an error be encountered during execution of the utility.

Table 1. Routines, Addresses, and Parameters for Rel_Math Utility

Routine	Execution Address (LDB =)	Operands (LDA =)
Addition	30620B	2
Subtraction	30612B	2
Multiplication	30732B	2
Division	31100B	2
Exponentiation	34066B	2
DIV	32574B	2
MOD	32725B	2
SQR	31240B	1
INT	32637B	1
FRACT	33052B	1
EXP	33763B	1
LOG	33773B	1
LGT	34053B	1
PROUND	32015B	−2
DROUND	32037B	−2
ABS	32622B	1
SGN	33441B	1
PI	36057B	0
RND	33377B	0
RES	36077B	0
TYP	6733B	1
SIN	34003B	1
COS	34014B	1
TAN	33741B	1
ASN	34025B	1
ACS	34040B	1
ATN	33751B	1
ERRL[1]	61765B	0
ERRN[1]	61753B	0
DECIMAL[1]	162026B	1
IADR	162167B	−2
IMEM	162150B	−2
OCTAL	162105B	1
AND	31632B	2
OR	31647B	2
EXOR	31615B	2
NOT	31661B	1
Less Than (<)	31667B	2
Less Than or Equal To (<=)	31675B	2
Not Equal (<>)	31727B	2
Equal (=)	31717B	2
Greater Than or Equal To (>=)	31711B	2
Greater Than (>)	31703B	2

1 These functions return an integer value which is stored in the second word of the four words reserved by Result.

By way of example, suppose you have established two full-precision values which need to be multiplied. The call to the Rel_math utility to accomplish the multiplication would look similar to this —

```
ISOURCE  ! Working storage
           .
           .
           .
ISOURCE Operand_1:  BSS 4
ISOURCE Operand_2:  BSS 4
ISOURCE Product:    BSS 4
           .
           .
           .
ISOURCE Multiply:  ! MULTIPLY THE OPERANDS
ISOURCE      LDA =Operand_1
ISOURCE      STA Oper_1
ISOURCE      LDA =Operand_2
ISOURCE      STA Oper_2
ISOURCE      LDA =Product
ISOURCE      STA Result
ISOURCE      LDA =2              ! Call the multiply routine
ISOURCE      LDB =30732B
ISOURCE      JSM Rel_math
ISOURCE      SZA *+2             ! Test for any errors
ISOURCE      JSM Error_exit      ! Error encountered, so leave
           .
           .
           .
```

Note in the last line of the example the call to the Error_exit utility (page 191) is made when register A is not zero. When this occurs, A contains the error number of the error encountered — ready-made for calling the Error_exit utility.

UTILITY: Rel_to_int

The Rel_to_int utility provides for the conversion of a full-precision value into an integer.

General Procedure: The utility is given the address of the location of the full-precision value and the address of the location where the integer is to be stored.

Special Requirements: The full-precision value must be within the range of integers (− 32 768 to + 32 767).

Calling Procedure:

1. Store the address of the full-precision value into register Oper_1.
2. Store the address of where the integer is to be stored into register Result.
3. Call the utility.

Exit Conditions: The overflow bit in the processor is set if the integer is outside the range of integers.

An example —

```
ISOURCE ! Working storage
ISOURCE Operand:  BSS 4   ! Contains a full-precision value
ISOURCE Value:    BSS 1   ! Contains an integer value
                   .
                   .
                   .
ISOURCE           LDA =Operand
ISOURCE           STA Oper_1
ISOURCE           LDA =Value
ISOURCE           STA Result
ISOURCE           JSM Rel_to_int   ! Convert real to integer
ISOURCE           SOC *+3          ! Check for overflow
ISOURCE           LDA =20          ! Set error number to 20
ISOURCE           JSM Error_exit   !   and take error exit
                   .
                   .
                   .
```

UTILITY: Rel_to_sho

The Rel_to_sho utility provides for the conversion of a full-precision value into a short-precision one.

General Procedure: The utility is given the address of the location of the full-precision value and the address of the location where the short-precision value is to be stored.

Special Requirements: A short-precision value requires 2 words to be stored.

Calling Procedure:

1. Store the address of the full-precision value into register Oper_1.
2. Store the address of the storage area for the short-precision value into register Result.
3. Call the utility.

Exit Conditions: No special exit conditions.

As an example —

```
ISOURCE ! Working storage
ISOURCE Operand:  BSS 4    ! Contains full-precision value
ISOURCE Value:    BSS 2    ! Contains short-precision value
                   .
                   .
                   .
ISOURCE           LDA =Operand
ISOURCE           STA Oper_1
ISOURCE           LDA =Value
ISOURCE           STA Result
ISOURCE           JSM Rel_to_sho  ! Convert full to short
                   .
                   .
                   .
```

UTILITY: Int_to_rel

The Int_to_rel utility provides for the conversion of an integer into a full-precision value.

General Procedure: The utility is given the address of the location of the integer and the address where the full-precision value is to be stored.

Special Requirements: None.

Calling Procedure:

1. Store the address of the integer into register Oper_1.
2. Store the address of the storage area for the full-precision value into register Result.
3. Call the utility.

Exit Conditions: No special exit conditions.

An example —

```
ISOURCE ! Working storage
ISOURCE Operand:  BSS 1    ! Contains an integer
ISOURCE Value:    BSS 4    ! Contains full-precision value
                   .
                   .
                   .
ISOURCE           LDA =Operand
ISOURCE           STA Oper_1
ISOURCE           LDA =Value
ISOURCE           STA Result
ISOURCE           JSM Int_to_rel  ! Convert integer to real
                   .
                   .
```

UTILITY: Sho_to_rel

The Sho_to_rel utility provides for the conversion of a short-precision value into a full-precision one.

General Procedure: The utility is given the address of the location of the short-precision value and the address of where the full-precision value is to be stored.

Special Requirements: None.

Calling Procedure:

1. Store the address of the short-precision value into register Oper_1.
2. Store the address of the storage area for the full-precision value into register Result.
3. Call the utility.

Exit Conditions: No special exit conditions.

An example —

```
ISOURCE ! Working storage
ISOURCE Operand:  BSS 2   ! Contains short-precision value
ISOURCE Value:    BSS 4   ! Contains full-precision value
                   .
                   .
                   .
ISOURCE           LDA =Operand
ISOURCE           STA Oper_1
ISOURCE           LDA =Value
ISOURCE           STA Result
ISOURCE           JSM Sho_to_rel   ! Convert short to real
                   .
                   .
                   .
```

Chapter 6
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Chapter 6
Communication Between BASIC and Assembly Language

Summary: This chapter discusses the techniques used to pass information to and from assembly language programs. Calling assembly language routines and passing parameters are presented, along with issues involved in using common. Applicable utilities are also discussed.

Once assembly language programs have been written, they are executed using the ICALL statement. This statement is very similar to BASIC's CALL statement for subroutines. In fact, the function it performs is nearly identical in effect — the only difference is that the target subroutine has been written in assembly language instead of in BASIC. The ICALL statement also provides a means to pass data between BASIC and assembly programs through its argument list. Data can also be passed through common.

The ICALL Statement

There are two ways to execute an assembly language routine. One way is as an interrupt service routine when an interrupt occurs on the select code to which the service routine has been linked. This way is discussed in Chapter 7. The other way is through executing an ICALL statement, either in a BASIC program or from the keyboard.

The syntax of the statement is —

ICALL {routine name} [({argument} [, {argument} [, ...]])]

{routine name} is the name of the assembly language routine to be executed. {argument} is a data item which has the same characteristics as an argument in BASIC's CALL statement — there may be constants, variables, or expressions. (How these items correspond to instructions in the assembly language will be discussed shortly.)

By way of example, suppose that you have an ICALL which is being used to call a sort routine and the routine was written in such a way as to require two arguments be passed to it — an array to be sorted and the number of elements to be sorted (in that order). Then the following would be valid calls to that routine —

```
ICALL Sort(Test(*),100)
ICALL Sort(Test$(*),Number)
ICALL Sort(Value(*),Events DIV 2)
```

Upon executing the ICALL statement, execution in a program transfers to the routine named. Upon return from the routine, control is passed to the BASIC statement which follows the ICALL. This is identical in effect to the CALL statement in BASIC.

In executing the statement from the keyboard, the routine named is executed just as if it were used in a program. Upon return from the routine, control is passed back to the keyboard. This is unlike BASIC's CALL statement, which cannot be executed from the keyboard.

To execute a routine, whether it be from a program or from the keyboard, its object code must currently reside in the ICOM region.

Corresponding Assembly Language Statements

When the ICALL is executed, it references a routine in the object code. When the module containing the routine was assembled, it declared that routine name as a "subroutine" entry point. ("Subroutine" and "routine" are synonymous in this context.) This is done with a SUB pseudo-instruction and a label.

When a SUB pseudo-instruction appears in the source code, it is a signal to the assembler that a subroutine entry point follows. Then the first machine instruction (or some code-generating pseudo-instruction, such as BSS or DAT) must have a label. That label becomes the routine name. If the label is missing, an error results (assembly-time "SQ" error).

For example, in the above examples of ICALL, the Sort routine could have been defined by the sequence —

```
ISOURCE         SUB
ISOURCE Sort:   LDA =Array_info
```

except that there are arguments involved. (That exception is discussed in a moment.) The joint use of these two statements results in the label "Sort" being identified as a routine name, referenceable with an ICALL statement.

In general, no machine instructions or code-generating pseudo-instructions can be inserted between a SUB pseudo-instruction and the instruction containing the routine name. An exception to this exists when arguments are involved in a call.

Arguments

When a value is placed into an ICALL statement to be sent down to an assembly language routine, that value is called an "argument" (like the argument of a mathematical function). The corresponding structure on the assembly language side is called a "parameter". A parameter "declaration" is an assembly pseudo-instruction by which a parameter is created.

When a routine is to be called with arguments, a parameter declaration pseudo-instruction is required for each one of the arguments. These declarations appear between the SUB pseudo-instruction and the instruction containing the routine name.

Thus, when there is a call like —

```
ICALL Sort(Test$(*),100)
```

the corresponding assembly language entry looks like —

```
ISOURCE        SUB
ISOURCE        STR (*)
ISOURCE        REL
ISOURCE Sort:  LDA =Array_info
```

To accommodate the two arguments, two parameter declarations had to appear between the SUB instruction and the entry point. (In this example, they were the STR and REL declarations.) These declarations may even have labels of their own —

```
ISOURCE                SUB
ISOURCE Parameter_1:   STR (*)
ISOURCE Parameter_2:   REL
ISOURCE Sort:          LDA =Array_info
```

The appearance of these labels does not effect the fact that "Sort" is the name of the routine.

Parameter declarations have "types" just like variables. These types have to correspond to the "types" of the arguments used in the ICALL. The declarations and their types are —

INT	meaning integer
REL	meaning full-precision
SHO	meaning short-precision
STR	meaning string
FIL	meaning a file number

In the above example, STR had to be used as the first parameter declaration because the first argument was a string. Similarly, REL had to be the second declaration because the second argument was a numeric expression (which is always full-precision).

When an array is to be passed, the declaration is followed by an "array identifier" — (*). Thus, when arrays are involved, the declarations appear as —

INT(*)	meaning an integer array
REL(*)	meaning a full-precision array
SHO(*)	meaning a short-precision array
STR(*)	meaning a string array

(File numbers do not come in arrays, so that declaration — FIL — cannot be followed by an array identifier.)

Since the example call above uses a string array as the first argument, the corresponding assembly language parameter declaration uses an array identifier after STR.

The parameter declarations are associated with the arguments in the ICALL in the same order. If the types do not match when the ICALL is executed, an error occurs (number 8).

So, if the subroutine entry looks like —

```
ISOURCE         SUB
ISOURCE         STR (*)
ISOURCE         REL
ISOURCE Sort:   LDA =Array_info
```

then this ICALL executes properly —

```
ICALL Sort(Test$(*),100)
```

but these ICALLs result in run-time errors —

```
ICALL Sort(Test$,100)
ICALL Sort(Test(*),100)
ICALL Sort(Test$(*),"ASCENDING")
```

Each declaration reserves three words in the object code upon assembly. As a result of the ICALL execution, these words contain a descriptor of the corresponding argument. These descriptors are used by the utilities for fetching and storing values. Thus, in the Sort calling example above, when the ICALL is executed, a descriptor for Test$(*) is stored in the three words starting at Parameter_1. Similarly, a descriptor for the constant 100 is stored in the three words starting at Parameter_2.

The types discussed here do not apply just to simple variables, arrays, and constants. They also apply to single elements of arrays and expressions. If you have a STR parameter declaration, for example, any of the following would be valid as arguments in the ICALL statement —

```
Test$(1)
CHR$(127)&Test$
RPT$("A",20)
Test$[1,Stop]
```

It is similar for numerical expressions.

The number of arguments passed by an ICALL statement must be no more than the number of parameter declarations in the subroutine entry. There may be fewer, however. The actual number passed is stored in the word reserved by the SUB pseudo-instruction.

Unlike the CALL statement in BASIC, the ICALL statement can be executed from the keyboard. In doing so, any variables used as arguments pass their current values to the routine, rather than resetting them to 0 (this is the same contrast as between running a program by pressing (RUN) and running it pressing (CONT)).

"Blind" Parameters

With explicit parameter declarations, an error occurs if a different type of variable or expression is passed. In many cases, the error is desirable — you do not want different types of arguments corresponding to a single parameter declaration. But in other cases, the error might not be as desirable. Take the example of a sort. You might want the sort to have the capability of sorting any type of array. You have two choices in that case — you can make different routines, each with the appropriate declarations, or you can use a single entry point and the ANY parameter declaration.

The ANY declaration —

```
ANY
```

is "blind" to the type of the corresponding argument in the ICALL statement. When used, it accepts any type of argument as valid — string, full-precision, short-precision, integer, file number, array. The descriptor for the argument is stored in the three words set aside, just as in the other declarations.

Now, if your entry looks like —

```
ISOURCE         SUB
ISOURCE         ANY
ISOURCE         REL
ISOURCE Sort:   LDA =Array_info
```

then any of the following calls would be valid —

```
ICALL Sort(Test$(*),100)
ICALL Sort(Test(*),100)
ICALL Sort(Test$,100)
ICALL Sort(Test,100)
ICALL Sort(#1,100)
```

When using the ANY declaration, it becomes the responsibility of your assembly language routine to determine what is a valid parameter and what is not. You lose the automatic type-checking available with explicit declarations. Techniques for doing this are discussed in the next section.

Getting Information on Arguments

When an ICALL is executed with an argument, and the corresponding parameter is blind, then it may be necessary for the purposes of your routine to know what type of argument is actually passed. This need can be present even when one of the explicit type declarations is used, since an expression or constant can be passed as easily as a variable.

A utility has been provided for obtaining this information, along with other "vital statistics" which may be useful to know during the execution of your routine. Before describing the utility itself, let's look at the information which it can provide you about an argument.

The information returned by the utility is stored in an area which you set aside for it. The size of the area can vary from 3 words to 30. The information, when returned, is in the following form —

Word #	Description
0	Argument type (see description later)
1	Number of dimensions (0 for non-arrays)
2	Size, in number of bytes (dimensioned length, for strings)
(for arrays only:)	
3	Total number of elements in array[1]
4	Lower bound of first dimension[1]
5	Absolute size of first dimension (upper bound − lower + 1)
6	Lower bound of second dimension (if any)[1]
7	Absolute size of second dimension
8	Lower bound of third dimension (if any)[1]
9	Absolute size of third dimension
10	Lower bound of fourth dimension (if any)[1]
11	Absolute size of fourth dimension
12	Lower bound of fifth dimension (if any)[1]
13	Absolute size of fifth dimension
14	Lower bound of sixth dimension (if any)[1]
15	Absolute size of sixth dimension
16	Element offset
17	Size, in words, of each element (dimensioned length, for strings)
(dependent upon memory size of your machine:)	
18-20	Pointer parameters
21-23	Pointer parameters (only for machines over 64K bytes)
24-26	Pointer parameters (only for machines over 128K bytes)
27-29	Pointer parameters (only for machines over 192K bytes)

1 Stored as a negative number.

The argument type returned in word 0 is as follows —

Value	Type
0	String expression
1	Full-precision expression
2	Short-precision expression
3	Integer expression
4	String simple variable
5	Full-precision simple variable
6	Short-precision simple variable
7	Integer simple variable
8	String array element
9	Full-precision array element
10	Short-precision array element
11	Integer array element
12	String array
13	Full-precision array
14	Short-precision array
15	Integer array
16	File number

The size, in bytes, will be one of the following values —

For an integer	2
Short-precision	4
Full-precision	8
String variables	dimensioned length
String expressions	actual length

The utility which retrieves all this information is called "Get_info".

UTILITY: Get_info

General Procedure: The utility is told the location where the information is to be returned and the address of the parameter declaration. It returns with the information on the argument in the ICALL corresponding to the parameter declaration.

Special Requirements:

- The location where it is to store the information must be adequate to hold all that may be returned. For non-arrays, 3 words will suffice. For arrays, up to 30 words may be required (as above). If you are writing a general routine, it may be wise to play it safe by setting aside a full 30 words.
- An argument must have been passed by the ICALL (in the case of parameters) or a corresponding BASIC COM declaration must exist (in the case of common declarations).

Calling Procedure:

1. Load register A with the address of the storage area for the information to be returned.
2. Load register B with the address of the parameter declaration corresponding to the desired argument.
3. Call the utility.

Exit Conditions: There are no error exits from the utility. It always returns to the instruction following the JSM. Since there are no error exits, and there is no requirement that there be as many arguments as there are parameter declarations, an argument must actually have been passed by the ICALL in order for the utility to work correctly.

Following up on the example in the previous section, suppose the first thing that the Sort routine does is check to see if the first parameter passed is an array. Then, by using the Get_info utility, it is possible to have the instructions look as follows —

```
ISOURCE Array_info:  BSS 30
ISOURCE              SUB
ISOURCE Array:       ANY
ISOURCE Number:      REL
ISOURCE Sort:        LDA =Array_info    ! Get info on argument
ISOURCE              LDB =Array
ISOURCE              JSM Get_info
ISOURCE              LDA Array_info     ! Get the argument's type
ISOURCE              CPA =16            ! Is it a file number?
ISOURCE              JMP Error_8        !   Yes, indicate error 8
ISOURCE              ADA =-12
ISOURCE              SAP *+2            ! An array (types 12-15)?
ISOURCE              JMP Error_8        !   No, indicate error 8
```

The array information returned by the Get_info utility is used for accessing elements in arrays passed as arguments. It is used by the element-retrieval utilities described in a later section of this chapter. Once retrieved, the information is usable any number of times for accessing the array associated with it. It is not necessary to retrieve the information every time you access an array, as long as you have not altered the information (except the pointer) between accesses.

The seventeenth word of the array information (word 16 on the chart) is reserved to hold the offset from the start of the array of the element to be accessed. Therefore, it is permissible (indeed, it is **necessary**) to alter the contents of that location to indicate which element in the array you wish to retrieve. None of the other words returned by the utility should be changed.

In making multiple accesses with the same information, caution should be taken when an array is involved. If a REDIM statement is executed upon the array between accesses, the information may not reflect the true structure of the array. This potentiality can be addressed in one of two ways —

- Advise the BASIC user against using a REDIM on the array between executions of the routine or routines involved.
- Call the Get_info utility each time the array is accessed.

Similar problems exist when a BASIC subprogram is called recursively, and the subprogram uses a local array as an argument in an ICALL, or when a subprogram calls a routine and later exits (causing its local arrays to disappear).

Retrieving the Value of an Argument

At some point during execution of your assembly language routine, you may want to retrieve the value of an argument so that you can use it in your processing. By doing so, you accomplish one of the methods of communicating with assembly language — namely, passing a value TO the assembly language routine from BASIC.

There are a number of utilities for this purpose. The one to use is dependent upon the type of argument passed. The utilities available are —

Name	Used For
Get_value	Simple variables, expressions, individual elements of arrays passed as arguments, and file numbers
Get_element	Elements (from arrays passed as arguments)
Get_bytes	Substrings of strings passed as arguments either as simple string variables, expressions, or individual elements of arrays passed as arguments
Get_elem_bytes	Substrings of individual elements (from string arrays passed as arguments)

How each of these utilities is used is described in the immediately following pages.

UTILITY: Get_value

General Procedure: The utility is given the address of the parameter declaration and the address of where the value of the argument is to be stored. It returns with that value stored in the indicated area. It works on simple variables, expressions, and individual elements of arrays (passed as arguments), of any type.

Special Requirements:

- The storage area set aside for the value must be large enough to hold the value. The size of the storage area must be —

for a file number	1 word
for an integer value	1 word
for a short-precision value	2 words
for a full-precision value	4 words
for a string	maximum length in bytes ÷ 2 + 1 word (+ 1 additional word if the string length is odd)

- An argument must have been passed by the ICALL for the utility to work properly.

Calling Procedure:

1. Load register A with the address of the storage area for the value.
2. Load register B with the address of the parameter declaration.
3. Call the utility.

Exit Conditions: There are no error exits from the utility. It always returns to the instruction following the call.

Here is an example call to the utility, retrieving information from a full-precision argument —

```
ISOURCE Value:     BSS 4
ISOURCE            SUB
ISOURCE Parameter: REL
ISOURCE Entry:     LDA =Value
ISOURCE            LDB =Parameter
ISOURCE            JSM Get_value
```

UTILITY: Get_element

General Procedure: This is similar to the "Get_value" utility. This utility retrieves a value from an element of an array passed as an argument. It works on arrays of any type.

Special Requirements:

- The storage area set aside for the value must be large enough to hold the value. Resultant, the size of the storage area must be —

for an integer	1 word
for a short-precision value	2 words
for a full-precision value	4 words
for a string	maximum length in bytes 2 + word (+ 1 additional word if the string length is odd)

- The array information must be retrieved with the "Get_info" utility before calling this utility.
- The offset of the element in the array must be correct in the array information (word 16 returned by "Get_info"). It should be remembered that the offset of the element is dependent upon the number of dimensions in the array and the length of each. A calculation may be necessary to arrive at the offset when accessing multiple-dimension arrays. The offset is in terms of number of elements.

Calling Procedure:

1. Store the element offset within the array information (word 16 returned by "Get-info").
2. Load register A with the address of the storage area for the value.
3. Load register B with the address of word 0 of the information returned by the "Get_info" utility (see description of that utility).
4. Call the utility.

Exit Conditions: There are no error exits from the utility. It always returns to the instruction following the call.

Here is an example call, retrieving the third element (relative element 2) of an integer array and placing it into Value —

```
ISOURCE Value:       BSS 1
ISOURCE Array_info:  BSS 30
ISOURCE Element:     EQU Array_info+16  ! Element offset
ISOURCE              SUB
ISOURCE Parameter:   INT (*)
ISOURCE Entry:       LDA =Array_info    ! Get the array info
ISOURCE              LDB =Parameter
ISOURCE              JSM Get_info
ISOURCE              LDA =2             ! Set element offset to 2
ISOURCE              STA Element
ISOURCE              LDA =Value         ! Get the value
ISOURCE              LDB =Array_info
ISOURCE              JSM Get_element
```

UTILITY: Get_bytes

General Procedure: This is similar to the "Get_value" utility. This utility retrieves a substring of a string passed as an argument, having been given the starting byte and the number of bytes to be retrieved.

Special Requirements:

- The storage area set aside for the substring must be large enough to hold all of the substring. This includes not only the string itself, but also two extra words. Remember, a word holds two characters.

- A string must have been passed by the ICALL for the utility to work properly.

Calling Procedure:

1. Store the number of the starting **byte** of the substring desired into the first word of the storage area set aside for the substring. (Note that bytes 0 and 1 are the length word of the string.)
2. Store the number of bytes in the substring into the second word of the storage area.
3. Load register A with the address of the storage area.
4. Load register B with the address of the parameter declaration.
5. Call the utility.

Exit Conditions: There are no error exits from the utility. It always returns to the instruction following the call. The substring is returned starting with the third word of the storage area. (Note: Since the second word contains the length of the substring, you have a string data structure starting with the second word!)

For example —

```
ISOURCE Value:      DAT 2    ! 1st character (ignore length)
ISOURCE             DAT 10   ! Transfer 10 characters
ISOURCE             BSS 5    ! Substring storage area
ISOURCE             SUB
ISOURCE Parameter:  STR
ISOURCE Entry:      LDA =Value   ! Info already stored
ISOURCE             LDB =Parameter
ISOURCE             JSM Get_bytes
```

In this example, Value is the storage area. Since 2 has already been generated and stored in the first word, and 10 in the second, the first 10 bytes of the string would be transferred. Of course, the original string must contain at least 10 characters — or the bytes which are returned may be nonsense. Why was the value 2 stored as the byte number? Because bytes in a string are numbered starting with 0, and bytes 0 and 1 contain the length of the string (see "Data Structures" in Chapter 3).

UTILITY: Get_elem_bytes

General Procedure: This is a combination of the "Get_element" and "Get_bytes" utilities. This utility retrieves a substring of an element of a string array passed as an argument. The utility is given the starting byte and the number of bytes to be retrieved.

Special Requirements:

- The storage area set aside for the substring must be large enough to hold all of it. This includes not only the string itself, but also two extra words. Remember, a word holds two characters.

- The array information must be retrieved with the "Get_info" utility before calling this utility.

- The offset of the element in the array must be correct in the array information (word 16 returned by "Get_info"). It should be remembered that the offset of the element is dependent upon the number of dimensions in the array and the length of each. A calculation may be necessary to arrive at the offset when accessing multiple-dimension arrays. The offset is in terms of number of elements.

Calling Procedure:

1. Store the number of the starting byte of the substring desired into the first word of the storage area set aside for the substring. (Note that bytes 0 and 1 are the length word of the string.)
2. Store the number of bytes in the substring into the second word of the storage area.
3. Store the offset within the array information.
4. Load register A with the address of the storage area for the value.
5. Load register B with the address of word 0 of the information returned by the "Get_info" utility (see description of that utility).
6. Call the utility.

Exit Conditions: There are no error exits from the utility. It always returns to the instruction following the call. The substring is returned starting with the third word of the storage area. (Note: since the second word contains the length of the substring, you have a string data structure starting with the second word!)

For example —

```
ISOURCE Value:      DAT 2       ! 1st character (ignore length)
ISOURCE             DAT 10      ! Transfer 10 characters
ISOURCE             BSS 5       ! Substring storage area
ISOURCE Array_info:BSS 30
ISOURCE Element:    EQU Array_info+16 ! Element offset
ISOURCE             SUB
ISOURCE Parameter:  STR (*)
                     .
                     .
                     .
ISOURCE             LDA =Array_info    ! Get array info
ISOURCE             LDB =Parameter
ISOURCE             JSM Get_info
ISOURCE             LDA =2             ! Set offset to 2
ISOURCE             STA Element
                     .
                     .
                     .
ISOURCE             LDA =Value         ! Info already saved
ISOURCE             LDB =Array_info
ISOURCE             JSM Put_elem_bytes
```

In this example, Value is the storage area. Since 2 has already been generated and stored in the first word, and 10 in the second, the first 10 bytes of the string element are transferred. Of course, the string element must contain at least 10 characters — or the bytes which are returned may be nonsense.

Changing the Value of an Argument

At some point during the execution of your assembly language routine, you might want to accomplish the other half of this method of communication with BASIC — namely, changing the value of a BASIC variable which is used as an argument, in effect changing the value of a BASIC variable from the assembly language routine.

As with retrieving a value, there are a number of utilities available for changing a value. The one to use is dependent upon the type of argument passed. The utilities available are —

Name	Used For
Put_value	Simple variables and individual elements of arrays passed as arguments
Put_element	Elements (from arrays passed as arguments)
Put_bytes	Substrings of strings passed as arguments either as simple variables or as individual elements of arrays passed as arguments.
Put_elem_bytes	Substrings of elements (from string arrays passed as arguments)

How each of these utilities is used is described in the immediately following pages.

UTILITY: Put_value

General Procedure: The utility is given the address of the parameter declaration and the address of the value. It changes the value of the BASIC variable associated with the parameter. It works only on simple variables and individual elements of arrays (passed as arguments), of any type.

Special Requirements:

- The value must have the appropriate data structure for the data type of the argument (see "Data Structures" in Chapter 3).
- An actual argument must have been passed by the ICALL for the utility to work properly.

Calling Procedure:

1. Load register A with the address of the storage area of the value.
2. Load register B with the address of the parameter declaration.
3. Call the utility.

Exit Conditions: There are no error exits from the utility. It always returns to the instruction following the call.

Here is an example call to the utility, passing information to an integer argument —

```
ISOURCE Value:      BSS 1
ISOURCE             SUB
ISOURCE Parameter:  INT
                     .
                     .
                     .
ISOURCE             LDA =Value
ISOURCE             LDB =Parameter
ISOURCE             JSM Put_value
```

UTILITY: Put_element
General Procedure: This is similar to the "Put_value" utility. This utility changes the value of a single element in an array passed as an argument. It works on elements of arrays of any type.

Special Requirements:

- The value must have the appropriate data structure for the data type of the argument (see "Data Structures" in Chapter 3).
- The array information must be retrieved with the "Get_info" utility before calling this utility.
- The offset of the element in the array must be correct in the array information for the array (word 16 returned by "Get_info"). It should be remembered that the relative element number of the element is dependent upon the number of dimensions in the array and the length of each. A calculation may be necessary to arrive at the offset when accessing multiple-dimension arrays.

Calling Procedure:

1. Store the element offset into the array information (word 16).
2. Load register A with the address of the storage area for the value.
3. Load register B with the address of word 0 of the information returned by the "Get_info" utility (see description of that utility).
4. Call the utility.

Exit Conditions: There are no error exits from the utility. It always returns to the instruction following the call.

Here is an example call, storing information from Value into element 0 of an integer array —

```
ISOURCE Value:      BSS 1
ISOURCE Array_info:BSS 30
ISOURCE Element:    EQU Array_info+16  ! Element offset
ISOURCE             SUB
ISOURCE Parameter:  INT (*)
                     .
                     .
                     .
ISOURCE             LDA =Array_info    ! Get array info
ISOURCE             LDB =Parameter
ISOURCE             JSM Get_info
ISOURCE             LDA =0             ! Set offset to 0
ISOURCE             STA Element
                     .
                     .
                     .
ISOURCE             STA Value          ! Change the value
ISOURCE             LDA =Value
ISOURCE             LDB =Array_info
ISOURCE             JSM Put_element
```

UTILITY: Put_bytes

General Procedure: This is similar to the "Put_value" utility. This utility changes the value of a substring which is part of a string variable or an individual element of a string array, having been given the starting byte and the number of bytes to be changed as well as the new characters.

Special Requirements:

- The bytes to be transferred are preceded by two words in the storage area. The two words contain the starting byte for the substring and the number of bytes to be transferred.
- A string variable or an element of a string array must have been passed as an argument for the utility to work properly.

Calling Procedure:

1. Store the number of the starting **byte** of the substring to be changed into the first word of the storage area. (Note that bytes 0 and 1 are the length word of the string)
2. Store the number of bytes in the substring into the second word of the storage area.
3. Load register A with the address of the storage area.

4. Load register B with the address of the parameter declaration.
5. Call the utility.

Exit Conditions: There are no error exits from the utility, so it always returns to the instruction following the call.

For example —

```
ISOURCE Value:     DAT 2      ! 1st character (ignore length)
ISOURCE            DAT 10     ! Transfer 10 characters
ISOURCE            BSS 5      ! Substring storage area
ISOURCE            SUB
ISOURCE Parameter: STR
                    .
                    .
                    .
ISOURCE            LDA =Value     ! Other info already saved
ISOURCE            LDB =Parameter
ISOURCE            JSM Put_bytes
```

In this example, Value is the storage area containing the string to be transferred. Since 2 has already been generated and stored in the first word, and 10 in the second, the first 10 bytes of the string are changed. Why was the value 2 stored as the byte number? Because bytes in a string are numbered starting with 0, and bytes 0 and 1 contain the length of the string (see "Data Structures" in Chapter 3).

UTILITY: Put_elem_bytes

General Procedure: This is a combination of the "Put—element" and "Put—bytes" utilities. This utility changes a substring of an element in a string array which has been passed as an argument. The utility is given the starting byte and the number of bytes to be transferred.

Special Requirements:

- The bytes to be transferred are preceded by two words in the storage area. The two words contain the starting byte for the substring and the number of bytes to be transferred.
- The array information for the array must be retrieved with the "Get_info" utility before calling this utility.
- The offset of the element in the array must be correct in the array information for the array (word 16 returned by "Get_info"). It should be remembered that the offset of the element is dependent upon the number of dimensions in the array and the length of each. A calculation may be necessary to arrive at the offset when accessing multiple-dimension arrays. The offset is in terms of number of elements.

Calling Procedure:

1. Store the number of the starting **byte** of the substring to be changed into the first word of the storage area. (Note that bytes 0 and 1 are the length word of the string.)
2. Store the number of bytes in the substring into the second word of the storage area.
3. Store the element offset into the array information (word 16).
4. Load register A with the address of the storage area for the string to be transferred.
5. Load register B with the address of word 0 of the information returned by the "Get_info" utility (see description of that utility).
6. Call the utility.

Exit Conditions: There are no error exits from the utility. It always returns to the instruction following the call.

For example —

```
ISOURCE Value:      DAT 2      ! 1st character (ignore length)
ISOURCE             DAT 10     ! Transfer 10 characters
ISOURCE             BSS 5      ! Substring storage area
ISOURCE Array_info:BSS 30
ISOURCE Element:    EQU Array_info+16 ! Element offset
ISOURCE             SUB
ISOURCE Parameter:  STR (*)
                     .
                     .
                     .
ISOURCE             LDA =Array_info    ! Get array info
ISOURCE             LDB =Parameter
ISOURCE             JSM Get_info
ISOURCE             LDA =2             ! Set offset to 2
ISOURCE             STA Element
                     .
                     .
                     .
ISOURCE             LDA =Value         ! Info already saved
ISOURCE             LDB =Array_info
ISOURCE             JSM Put_elem_bytes
```

In this example, Value is the storage area for the string to be transferred. Since 2 has already been generated and stored in the first word, and 10 in the second, the first 10 bytes of the string element are changed. It is the responsibility of the software (not shown) to assure that 10 characters of valid data are stored in the remainder of the storage area.

Using Common

Another way to pass information between BASIC and assembly language routines is through BASIC's common area.

You may recall from subprograms in BASIC that if you have a COM statement in the main program, the locations named therein can be accessed by other BASIC subprograms and functions through their own COM statements. Though the subprograms may change the names, the locations are the same. The order of appearance in a COM statement is all-important. If a main program has the statement —

```
COM A,B,C
```

and a subprogram has the statement —

```
COM X,Y,Z
```

then X and A are the same storage location, B and Y are the same, and C and Z are the same.

The same kind of operation is available in your assembly language routines with the COM pseudo-instruction —

```
COM
```

As with the SUB pseudo-instruction, the COM only serves as a preface. It is followed by one or more parameter declarations of the same types as in the SUB —

```
ANY
INT
REL
SHO
STR
```

The FIL is not permitted, since there is no corresponding item within BASIC's COM syntax.

Each pseudo-instruction used after an assembly language COM corresponds to an item in the COM declaration in the main BASIC program. Just as in a BASIC subprogram, the types must agree.[1] However, the ANY pseudo-instruction fulfills the same function here as it does with the SUB pseudo-instruction — to allow any type of item to be passed.

1 If the types do not correspond, an error results (number 198).

As with SUB, arrays are designated by following the type with an array identifier — (*). If the type is ANY, the array identifier is not allowed.

Each pseudo-instruction reserves three words of memory when assembled. And, like SUB, the words are used to contain a descriptor. The descriptors are used by the variable retrieval utilities for fetching and storing values in the common area. THE SAME UTILITIES USED IN FETCHING AND STORING ARGUMENT VALUES ARE USED FOR THE SAME PURPOSES FOR VALUES IN THE COMMON AREA. These utilities are —

Get_info
Get_value
Get_element
Get_bytes
Get_elem_bytes
Put_value
Put_element
Put_bytes
Put_elem_bytes

The utilities are called in the same fashion and are subject to the same restrictions. See the description of the utilities in the preceding sections of this chapter to determine how they are used.

The item pseudo-instructions used with the COM pseudo-instruction can have their own labels, just as the parameter declarations used with a SUB may have. And just as in a BASIC subprogram, they need not have the same names as were given the corresponding items in BASIC. For example, suppose the following BASIC common statement exists at the time of a call to an assembly language routine —

```
COM Q(20),Z$[10]
```

then you could access Q(*) and Z$ by using these pseudo-instructions —

```
ISOURCE       COM
ISOURCE X:    REL (*)
ISOURCE Y:    STR
```

Note the differences in names.

If the number of item pseudo-instructions in the assembly language routine exceeds the number of items in common at the time the routine is called, an error results (number 199).

A COM pseudo-instruction sequence need only be set up once per module. Each routine within the module has access to the information within the sequence. The three-word descriptors are filled, and type-checking occurs, only once — at the first ICALL of a routine within the module.

Busy Bits

Overlapped processing in the 9835A/B is partially implemented through the facility of "busy bits".

Each variable located in the BASIC value or common areas has associated with it two bits which are independent of the value — a "read" busy bit, and a "write" busy bit. Each time an I/O operation is executed that cannot be buffered, one of the busy bits is set. If a variable is having its value changed by the I/O operation, then the read busy bit is set. If the variable is outputting its value in the I/O operation, then its write busy bit is set. If a variable is not involved in a pending I/O operation both bits are cleared. When the I/O operation is completed, the busy bits for the variables involved are cleared.

When an I/O operation is encountered during execution of BASIC statements, the appropriate busy bits are set and a request is made by the operating system for the resources to satisfy the operation. Until that operation is complete, BASIC (in OVERLAP mode), continues to execute succeeding lines in the program until it encounters a statement which contains variables with busy bits that are set.

If the statement is attempting to use the value of a variable and its read busy bit is set, then the further execution of the statement waits until the busy bit is cleared. The same is true for a statement attempting to change the value of a variable when either its read or write busy bit is set. When the I/O operation completes, the busy bits are cleared and the waiting statement is executed.

In short, overlapped processing uses busy bits as a signal as to whether a statement can be executed or not.

If an ICALL statement is executed with overlapped processing, it is possible that a BASIC variable in the common area may be "busy" when the routine wants to access it. (The busy bits of variables passed as arguments are checked — and are non-busy — before the ICALL is executed.) Although it is still possible to access the variable without regard to the status of the busy bits, frequently that is not a desirable programming approach. You may on occasion want to check the value of the busy bits when you suspect the user of the routine may be using overlapped processing.

Busy bits are checked from an assembly program using the "Busy" utility to be described shortly. If you are checking the bits for a busy condition, and the busy condition is set, it remains set throughout the time you are in the assembly routine. For it to become un-busy, you must exit the routine and permit the operating system a chance to perform the I/O operation and clear the busy bits.

For example —

```
330  ICALL Sort(Busy)
340  IF Busy THEN 330
```

If the Sort routine exits, setting Busy to 0 if a busy condition is not encountered, and to non-zero otherwise, this is a tight loop which keeps trying to execute Sort until the common variables which are busy become un-busy and it can proceed on its way. By exiting the routine after each unsuccessful attempt, the operating system is given an opportunity to perform the I/O operation which has the variable(s) tied up.

UTILITY: Busy

The Busy utility checks the status of the busy bits of a variable in BASIC's common area. It is not necessary to check the busy bits of a variable passed as an argument since all arguments are checked upon calling a routine (and the call is executed only when all the arguments are not busy).

General Procedure: The utility is given the location of the common declaration for the variable. It returns the value of the busy bits for that variable into the A register.

Special Requirements: This utility should only be used for variables in common.

Calling Procedure:

1. Load register B with the address of the pseudo-instruction of the common declaration to be checked.
2. Call the utility.

Exit Conditions: The utility returns the busy bits in the A register. The "read" busy bit is in bit 0 and the "write" busy bit is in bit 1. The other bits are not disturbed.

In the following example, if any of the busy bits among three common variables is set, a flag is set and the routine is exitted —

```
ISOURCE                COM
ISOURCE  Variable1:    INT
ISOURCE  Variable2:    SHO
ISOURCE  Variable3:    REL
                  .
                  .
                  .
ISOURCE                SUB
ISOURCE  Busy_bits:    INT
ISOURCE  Sort:         LDB =Variable1
ISOURCE                JSM Busy
ISOURCE                SAL 2
ISOURCE                LDB =Variable2
ISOURCE                JSM Busy
ISOURCE                SAL 2
ISOURCE                LDB =Variable3
ISOURCE                SZA *+4
ISOURCE                LDA ==1
ISOURCE                LDB Busy_bits
ISOURCE                JSM Put_value
ISOURCE Work:   ! Continue processing
```

Chapter 7
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Chapter 7
I/O Handling

Summary: This chapter describes the various techniques of handling the receiving and sending of information to peripheral devices. Topics are: a review of I/O machine instructions, registers, applicable utilities, interrupts and interrupt service routines, handshake I/O, direct memory access, and mass storage devices.

A major usage for assembly language programs is to improve or customize the performance of the 9835A/B with respect to data transfers with peripheral devices. The types of devices dealt with are those which communicate via the various interface cards (e.g., HP98032, HPIB, etc.). The types of I/O which the assembly language supports are **programmed** (handshake-type), **interrupt**, and **direct memory access** (or DMA).

A number of detailed examples have been provided demonstrating the various types of I/O on different interfaces. These examples can be found in Appendix H.

Peripheral-Processor Communication

All I/O, except for that to the internal devices (tape cartridge, keyboard, printer, CRT or SLD), necessarily takes place through the "backplane". The backplane is that physical area of the machine where the interface cards are inserted (also known as the I/O "slots").

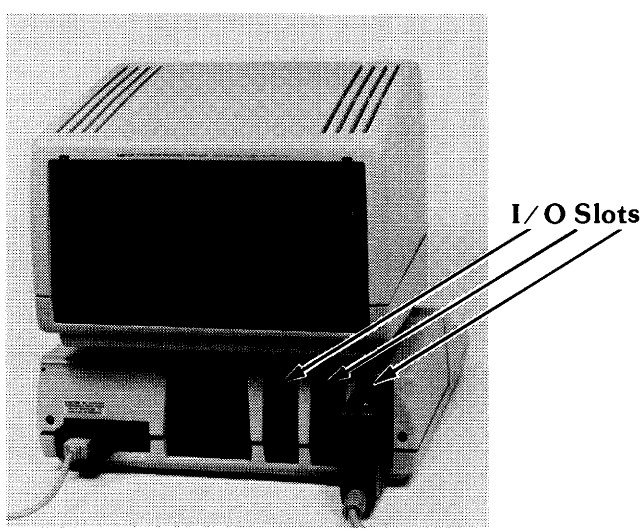


Figure 8. Location of I/O Slots (Backplane)

The backplane serves as an intermediary between the processor and the peripheral interfaces. The internal addressing of the backplane is transparent, both to the interfaces and to the programmer.

Interfaces

The processor does all its talking, through the backplane, to peripheral interfaces, never directly to a peripheral itself. An interface is a complex electronic circuit which provides mechanical, electrical, data format, and timing compatibility between the 9835A/B and the peripheral device to which it is connected. From a programmer's point of view, the primary task of an interface is to provide a means of exchanging data between the 9835A/B and the peripheral. A well-designed interface isolates the programmer from the details of electronics and timing, appearing as a simple "black box" through which information is exchanged.

The processor can talk to as many as 14 peripheral interfaces through the backplane. Each can be talked to individually, and there may be a mix of peripherals using programmed, interrupt, or DMA types of transfers.

Individual I/O operations (i.e., exchanges of single words) occur between the processor and one interface at a time, although interrupt and DMA modes of operation can be programmed to allow automatic interleaving of individual operations.

A peripheral is addressed through a select code and a transfer occurs through four special registers reserved for the purpose. These will each be discussed shortly.

Discussion of the techniques and methods presented in this chapter uses the common HP interfaces as examples. A full discussion of the operation of these interfaces can be found in the Interfacing Concepts manual (HP part number 09825-90060) and also from your Sales and Service office (list in Appendix K).

Example programs utilizing various I/O techniques with a number of the standard interfaces can be found in Appendix H.

Registers

All I/O operations go through a set of four registers maintained by the 9835A/B. The four — R4, R5, R6, and R7 — are the sole means of communicating data between the processor and peripheral interfaces. While the registers are actually on the interface cards, they may be thought of as being in the computer memory. This makes the cards themselves accessible by simple memory referencing instructions.

The 9835A/B sees the registers as single-words and always sends or receives a full word of data when it references one of them. If a particular interface utilizes less than the full sixteen bits (when exchanging 8-bit extended ASCII data bytes, for example), then the most significant bits (8 through 15) are received as zeroes. On output, if fewer than 16 bits are utilized by the interface, it ignores the most significant bits. The value of these bits, in this case, is a "don't care" (i.e., may be any pattern of ones or zeroes).

All of the HP 98030 series of interface cards use the registers as follows —

Register	On Input	On Output
R4	Primary Data In	Primary Data Out
R5	Primary Status In	Primary Status Out
R6	Secondary Data In	Secondary Data Out
R7	Secondary Status In	Secondary Status Out

The R4 register, then, is almost always used for data transfers. R5 is always used for status and control information. The "secondary" registers — R6 and R7 — perform the indicated functions only nominally. The exact interpretation as to how the register is used depends upon the interface card being used (see the Interfacing Concepts manual for details).

In order to give some specific examples for using the registers, the 98032 16-Bit Parallel Interface (sometimes called General Purpose Input/Output — GPIO) is used. This card defines the secondary registers as —

Register	On Input	On Output
R6	High-Byte Data In	High-Byte Data Out
R7	(unused)	Trigger

Select Codes

As mentioned earlier, more than one interface card may be connected to the 9835A/B. It becomes necessary, then, that there be a mechanism whereby a particular interface can be chosen to respond when an I/O register is referenced for either input or output. This mechanism is the Peripheral Address Register (Pa).

Pa holds a binary number in the range 0 to 15 (utilizing only the lower four bits of the word, 0 to 3). Each interface has an externally-settable select code switch which can also be set to a value between 0 and 15. However, since select codes 0 and 15 are reserved for the internal printer and tape cartridge unit, respectively, the permissible select code settings are 1 through 14.

Whenever an operation to one of the I/O registers is performed, the 9835A/B makes the contents of the Pa register available to all the interfaces connected to the backplane. Each card compares the value with its own select code. If they match, the interface responds to the operation.

So, for example, if the following statements are executed in turn —

```
ISOURCE   LDA =8    ! Choose peripheral on select code 8
ISOURCE   STA Pa
ISOURCE   LDA R4    ! Read from the interface
```

then a word of data is read from the interface card set to select code 8. (The data was read in the third line; this is discussed in "Programmed I/O" below.)

The label "Pa" is reserved by the assembler for the Peripheral Address register.

Status and Control Registers

The primary purpose of any interface is to allow data to be exchanged between the computer and the peripheral device to which it is connected. But HP's 98030 series of interface cards are even more versatile, possessing a programmable capability of their own. This in turn provides optional capabilities with the card that can be set and changed by control instructions from the 9835A/B. (For details on what capabilities are provided, consult the Interfacing Concepts manual.)

The programming of the interface is done by the 9835A/B using the R5 register. Some of the interfaces use other registers for extended control bits (these are also described in the Interfacing Concepts manual).

Interface cards can also return information to the 9835A/B about which optional programming features are currently selected. This information, called the status byte, is obtained through an input operation using register R5. The status byte (8 bits) is determined solely by the characteristics of the interface card being addressed in the Pa register. Again, information on particular cards can be found in Interfacing Concepts).

Remembering that these registers are not really memory locations, but instead are registers on the card being addressed by the Pa register, storing information to these locations is not the same as storing to other memory locations or registers. For example, storing a value in R5 to set the control register sends the information to the addressed interface. Later, if you were to read a value from R5, the information you sent would not be what is returned. Instead, the contents of the status register in the interface would be returned.

Status and Flag Lines

Whenever an I/O register is accessed, the interface with the same select code as is in the Pa register responds. The primary response depends upon the nature of the interface and which register is accessed (see discussion above). However, in all cases there is a secondary effect. Part of every interface's response is to set or clear the Status and Flag lines.

The **Status** line (not to be confused with the status register discussed above), is a single bit indicating whether the interface is operational or not. By inclusion, this can also mean the status of the actual peripheral to which the interface is connected. For example, if a peripheral device has a line coming from it that indicates its power is on, it could be connected to the Status line in the interface. Then the program could quickly determine whether the device is turned on or off. As another example, a printer might have the Status line connected to the out-of-paper indicator (should it have one) to indicate to the program when it is inoperable because of lack of paper.

The **Flag** line is a momentary "busy/ready" indicator used to keep the computer from getting ahead of the peripheral. The line shows that the interface is busy processing the last task given it by the 9835A/B or that it is ready for another operation. If the line is set, it indicates "ready"; if the line is cleared, it indicates "busy". For example, if the computer has a sequence of ASCII characters to send to a slow printer, it sends one character (making the Flag line "busy") and then waits for the Flag line to go "ready" again before sending the next character.

There are four instructions, part of the I/O group, which can check these lines —

SFS Skip if Flag line is set (i.e., "ready")
SFC Skip if Flag line is cleared (i.e., "busy")
SSS Skip if Status is set (i.e., "operational")
SSC Skip if Status is cleared (i.e., "non-operational")

These instructions have the capability of skipping up to 31 locations in a forward branch, up to 32 locations in a backward branch, or to the same instruction.

Programmed I/O

Programmed I/O is the process whereby software controls the transfer of information between memory and an interface. In the process the program must decide when and where to make the transfer, how to make it, and how much information to transfer. The decision even to originate the transfer comes under program control.

The Status line can be used to determine the availability of an interface. The interface is selected, under program control, by the contents of the Pa register. Then the Status line is checked to see if the interface (and by inclusion its associated peripheral) is operational.

After an operational interface has been chosen, the Flag line can be used to determine when the interface (i.e., peripheral) is ready for a transfer and when it has not finished with the previous transfer.

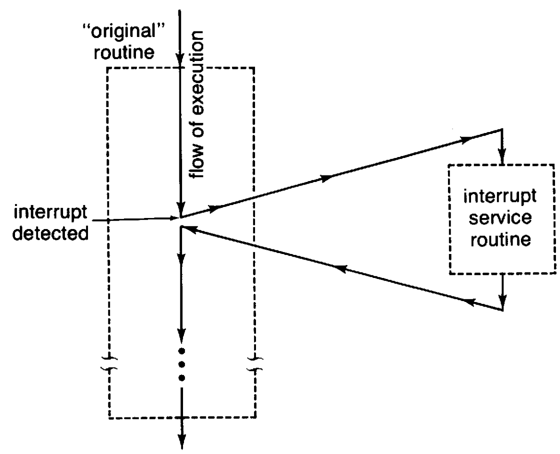
With sufficient checks of Flag and Status before and between I/O operations, it is possible to eliminate initiating an I/O operation to an interface which isn't ready for it. For example, a simple output driver for the 98032 interface is —

```
ISOURCE   STA Pa          ! Choose the peripheral
ISOURCE   SSS *+3         ! Check for operational device
ISOURCE   LDA =164        ! Not operational, error number 164
ISOURCE   JSM Error_exit  ! Inform user
ISOURCE   SFC *           ! Wait until last operation is done
ISOURCE   STB R4          ! Output the next word to the interface
ISOURCE   STB R7          ! Start the handshake
```

Interrupt I/O

Interrupt I/O is a means of allowing control to pass temporarily to an assembly language routine other than the routine (BASIC or assembly language) currently executing. The "interrupt", which causes the control to be passed, is detected through the backplane and is associated with a particular interface. After the "interrupt service" routine completes its tasks, control is passed back to the original routine.

The process looks something like this —



The sequence of events in interrupt I/O can be detailed as follows —

1. The interface sends a request for service to the backplane which passes it along to the processsor.
2. The processor alters the flow of execution so that the routine associated with that interrupting source can be executed. The processor saves its place in the interrupted routine so that it can later return to it.
3. The interrupt service routine is executed, performing whatever functions are desired. Frequently these functions involve some form of programmed I/O or direct memory access. The service routine may signal an end-of-line BASIC branch, indicating to BASIC that some condition occurred (discussed below).
4. The service routine returns the processor to the interrupted routine so that the "original" process can resume.

The uses for interrupt I/O are so diverse that it is difficult to generalize about them. However, one particular use is fairly well-defined and of general applicability — data transfers.

Interrupt I/O is normally used in data transfers whenever a particular data device has a transfer rate which is significantly slower than that of the computer. Since the 9835A/B has a transfer rate of around 10 000 characters per second, peripheral devices with transfer rates slower than this number are candidates for interrupt I/O.

The usual approach is to transfer a word to or from the peripheral device, then go away to do some other processing while waiting for the device to interrupt by becoming "ready" for another transfer.

Priorities

Select codes are assigned hardware "priority" levels to control what should be processed when an interrupt service routine is executing and another interrupt is received, or when two or more simultaneous interrupts are received.

There are two priority levels —

High	for select codes 8 to 15
Low	for select codes 0 to 7

An interrupt received from a high-priority select code may interrupt a service routine which is executing for an interrupt from a low-priority select code. But an interrupt from a low-priority select code may not interrupt any other service routine.

Interrupt Service Routines and Linkage

An interrupt service routine is associated, or "linked", with a select code by the Isr_access utility described later. This linkage establishes where the interrupt service routine resides, and to which select code it applies.

An interrupt service routine may be placed anywhere in the ICOM region. The routine typically does one or more of the following —

- Talks to the interface (i.e., satisfies or acknowledges the interface's interrupt).
- Passes data to (or retrieves data from) the rest of the program, when appropriate.
- Breaks the linkage, if desired.

The method of talking to the interface depends upon the type of interface. Some devices or applications do not require the passage of data; the acknowledgement of the interrupt is usually the desired effect in such cases.

The linkage can be "broken" (or terminated) during an interrupt service routine by executing one of two statements. If the linked select code is high-priority, the statement is —

```
JSM End_isr_high,I
```

If the linked select code is low-priority, the statement is —

JSM End_isr_low,I

The service routine is exited with a RET 1 instruction.

Here is an example of a short interrupt service routine which simply reads a word of data from the interface —

```
ISOURCE  Lf:          EQU 10
                      .
                      .
                      .
ISOURCE  Isr:         LDA R4              ! Retrieve character from interface
ISOURCE               CPA =Lf             ! Is it a line feed?
ISOURCE               JMP Terminate       !    Yes, so jump
ISOURCE               STA R7              !    No, so trigger another handshake
ISOURCE               RET 1
ISOURCE  Terminate:   JSM End_isr_low,I
ISOURCE               RET 1
```

NOTE

Utilities cannot be called from an interrupt service routine. Attempts to do so may lock up the machine.

Access

The operating system (OS) contains a mechanism to regulate requests for hardware capabilities in order to eliminate conflicting uses of these capabilities. For instance, since there is only one DMA channel, it is necessary that there be a mechanism to prohibit two simultaneous DMA transfers.

The OS mechanism which regulates the use of DMA (and also interrupt) transfers either grants or does not grant what is called "access". Before starting either an interrupt or DMA operation, access should be requested from the operating system.

Another example — suppose a device operating on a high priority select code has a relatively slow data rate. This is an ideal situation in which to use interrupt driven I/O. Suppose further that the device operates in such a fashion that the data must be transferred within a fixed time period following its issuance of an interrupt or the data is lost (the internal tape drive is such a device.) If there are other interrupt type transfers operating concurrently on other high priority select codes, it may not be possible to service our slow device within the necessary time frame. When the operating system grants access, this type of conflict is impossible.

Users of the assembly language system are required to request access from the operating system. The OS grants access if granting this access does not compromise any previously granted access.

Devices such as that discussed above which require interrupt service within a specified time frame are called "synchronous", and need "synchronous" access. Devices with no such time constraints are called "asynchronous", and need "asynchronous" access.

The regulation of access incorporates the following points —

- When the operating system grants synchronous access to an operation, it is guaranteeing that the requesting process will have its interrupts serviced with maximum priority.
- DMA conflicts with synchronous access since DMA's cycle stealing causes the processor to run slower and could thus compromise a synchronous process.
- Synchronous access on a low priority select code in conjunction with asynchronous access on a high priority select code is conflicting since the asynchronous device could interrupt the synchronous ISR, thus compromising the timing requirements of the synchronous device.
- Synchronous and asynchronous access on the same priority level is also conflicting. Remember an interrupt request on the same priority level as a currently executing ISR will not be processed until the executing ISR completes.

The following table summarizes the granting of access —

Access Already Granted

Access Requested		Abortive L	Abortive H	ASYN L	ASYN H	DMA	SYN H	SYN L
Abortive	Low							d
Abortive	High						d	d
ASYN	Low							x
ASYN	High						x	x
DMA						x	x	x
SYN	High		d		x	x	x	x
SYN	Low	d	d	x	x	x	x	x

blank = Granted

x = Not granted

d = Dangerous, but granted

BASIC statements also obtain and release access as I/O is performed. The following table lists some of the ways access is used by the system:

Use	Access
Cartridge Operations	SYNC (HIGH select code)
Flexible Disk Operations	DMA
PRINT, PRINT USING	ASYNC
Plotter Drivers	ASYNC
CARD ENABLE	ASYNC
ENTER/OUTPUT INT	ASYNC
ENTER/OUTPUT DMA	DMA
ENTER/OUTPUT FHS[1]	DMA

In general, single BASIC statements could cause access to be granted and released several times. For example, the cartridge operations obtain and release synchronous access once for each physical record transferred.

UTILITY: Isr_access

This utility is used to request access and, if the access is granted, to create the linkage between an interrupt service routine (ISR) and a select code. Pressing RESET (CONT'D STOP) during execution of the utility may cause a SCRATCH A to be issued.

General Procedure: The utility is told where the ISR resides and what kind of access is required. If access is granted, it returns successfully. If access is not granted immediately, it keeps trying periodically until it is successful or until a specified number of attempts have been made (in which case it returns unsuccessfully).

Special Requirements: The B register must contain information as follows —

Bits	Description
0–3	Select code to be linked to the ISR
4–5	Access code (see next page)
8–14	Number of attempts to be made before aborting

1 In addition to obtaining DMA access (which in this case is used just to ensure there is no synchronous access granted), the FHS drivers disable all interrupts during the actual transfer loop.

The access codes are —

0	Abortive access
1	Asynchronous access with programmed I/O
2	Asynchronous access with DMA
3	Synchronous access with programmed I/O

Calling Procedure:

1. Load register A with the address of the ISR.
2. Load register B with the information described above.
3. Call the utility.

Exit Conditions:

RET 2 If the attempt at linkage is successful, the utility returns to the second word following its call. Register Pa is set to the select code; if access code 2 was specified then Dmapa has also been set to the select code.

RET 1 If the attempt at linkage is unsuccessful, the utility returns to the first word following the call. Register A contains an indication of the type of difficulty encountered —

− 1 Access couldn't be obtained after specified number of attempts.

− 2 Select code is still linked to an assembly language ISR.

Note: Access code 0 (abortive access) should be used with caution. An interrupt routine with abortive access can exist on the same priority level as an interrupt routine with synchronous access. If the abortive routine is in progress when an interrupt occurs requiring the synchronous service routine, the abortive routine will finish before the synchronous routine can be serviced. The timing requirements of the synchronous routine might thus be violated.

Access code 0 is intended to be used by routines that will be executed only extremely infrequently. For instance, if the 9835A/B is monitoring a potentially dangerous manufacturing process, it may be necessary to have an interrupt service routine to shut down the process when something goes awry. This could be accomplished with an abortive routine. The advantage (and also the reason for the previously mentioned caution) of access code 0 is that no other modes of access are prohibited by its use. Thus, the infrequently used routine will not prevent another routine from getting the type of access it needs.

As an example of the use of the Isr_access utility, suppose the ISR from page 141 is to be linked to select code 2 for asynchronous access. The following would be a sequence to establish such a linkage —

```
ISOURCE        EXT Isr_access
                .
                .
                .
ISOURCE        LDA =Read
ISOURCE        LDB =(64*256)+(1*16)+2  ! 64 trials, asynch, SC 2
ISOURCE        JSM Isr_access
ISOURCE        JMP Error
                .
                .
                .
ISOURCE Error: ISZ A
ISOURCE        JMP Nested_isr     ! Handler for SC busy
ISOURCE        JMP No_access      ! Handler for time-out
                .
                .
                .
```

State Preservation and Restoration

When an interrupt is detected and an interrupt service routine is called, the processor automatically saves the state of some of the registers so that their values can be restored upon return from the ISR. Other registers are left alone and if your service routine uses them, it is up to your ISR to save them and restore them before returning from the ISR.

The registers which are automatically preserved are —

A
B
C
Cb
P
Pa

Also, the state of the Overflow and Extend processor flags are preserved and restored before the return from the interrupt.

If your ISR contains any of the following types of instructions —

Indirect addressing
Stack group
CLR
XFR

and the operand of the instruction(s) is an address in the ICOM region, then it is necessary that the following instruction sequence be executed in the ISR before any such instruction is executed —

```
Save35:  BSS 1
          .
          .
          .
         LDA 35B
         STA Save35
         LDA 34B
         STA 35B
          .
          .
          .
```

Then, before the ISR exits, and after the affected instructions have been executed, the following sequence must be executed —

```
          .
          .
          .
         LDA Save35
         STA 35B
          .
          .
          .
```

Indirect Addressing in ISRs

Indirect addressing in ISRs can produce anomalies unless the following rules are followed —

1. If indirect addressing is employed with the operand being an address in the ICOM region, one of the processor registers must be preserved. For the method of doing this, consult the "State Preservation and Restoration" section immediately above.

2. If indirect addressing is used in a JMP or JSM (including any jumps to external symbols or symbols more than 512 words away from the current instruction, both of which have implied indirect addressing), then the most significant bit must be set in the address. For example, instead of —

```
EXT Sub
 .
 .
 .
JSM Sub
```

in an ISR the procedure must be —

```
EXT Sub
 .
 .
 .
JSM (=Sub+100000B),I
```

Direct Memory Access (DMA)

Direct memory access (DMA) is a means to exchange entire blocks of data between memory and peripherals. A block is a series of consecutive memory locations. Once started, the process is automatic; it is done under processor control, regulated by the interface. Since only the 98032A interface supports DMA, the following discussion is in terms of that interface.

To the peripheral, the DMA operation appears as programmed I/O. The transfer, however, is actually performed by special DMA hardware. Information regarding the transfer is stored in the DMA registers for the DMA hardware to use. This information is the select code, the initial memory location, and the number of words to be transferred. The memory location register and the count register are successively adjusted after each word transferred until the transfer is complete. Upon completion of the transfer, the interface and the DMA hardware stop automatically.

The direction of the transfer is specified before the transfer takes place. It can be specified as either "inward" (i.e., from the peripheral to memory), or "outward" (i.e., from the memory to the peripheral). To set the direction outwards, the instruction —

```
SDO
```

is used. To set the direction inwards, the instruction —

```
SDI
```

is used.

DMA Registers

There are three registers which contain information used by the DMA hardware — Dmapa, Dmama, and Dmac. Before any DMA transfer takes place, the appropriate values must be loaded into these registers.

Dmapa contains the peripheral address of the device requesting DMA. Only the least significant bits of the register specify the select code which is to be the peripheral side of the DMA activity. During DMA transfers, the address bus takes its address from the Dmapa register rather than Pa as in other I/O transfers. The value is supplied to Dmapa by the Isr_access utility when it grants DMA access.

Dmama contains the address of the first word in memory (i.e., lowest address) where the data transferred is (or will be) stored. After each word transferred, this register is automatically incremented.

Dmac is the count register for a DMA transfer. Before the transfer begins, it should be set to n-1, where n is the number of words to be transferred. After each word transfer, the count is decremented. If, during a word transfer, the value of Dmac is 0 (meaning that this is the last word to be transferred), the processor automatically informs the interface that the DMA operation will be complete after the present word is transferred. In the case of inputs where the amount of transferring data is unknown in advance, Dmac should be set to a very large number in order to disable the signal to the interface.

DMA Transfers

DMA transfers are accomplished with six distinct actions.

First, the Isr_access utility is used to obtain access to the DMA channel and to set up the ISR linkage used when the transfer terminates.

Second, the direction is set using an SDO or SDI instruction. If no direction is set, then any previous setting of the direction prevails.

Third, the appropriate values are stored into the DMA registers.

Fourth, the DMA requests are enabled using the instruction —

```
DMA
```

Fifth, a "Start DMA" command is given to the interface using programmed I/O. With the 98032 interface, this command is the value 320_8 using the Primary Control register (R5-Out).

Finally, when the DMA transfer is complete, the interface generates an interrupt which causes the processor to branch to the designated ISR. This ISR should disable the card, and then disable the DMA mode with the instruction —

```
DDR
```

The following is part of an ISR which demonstrates a typical set-up for a DMA inward transfer (in this case 1K words placed into a buffer in memory) —

```
ISOURCE         LDA =1023
ISOURCE         STA Dmac      ! Set up DMA count
ISOURCE         LDA =Buffer
ISOURCE         STA Dmama     ! Establish address of receiving area
ISOURCE         SDI           ! Set DMA as inwards
ISOURCE         SFC *         ! Wait for Flag line to clear
ISOURCE         LDA R4
ISOURCE         STA R7        ! Start input handshake
ISOURCE         DMA           ! Enable DMA request
ISOURCE         LDA =320B     ! "Start DMA" command
ISOURCE         STA R5
```

BASIC Branching on Interrupts

The handling of interrupts can be integrated into BASIC programs by using the ON INT statements. The object is to allow the flexibility of combining the high-level features of BASIC with the capabilities of assembly language in asynchronous I/O applications. And since ISRs cannot use the system utilities, in particular those that access a BASIC variable, a means of taking action on an interrupt after completion of the ISR is a necessity.

ON INT Statement

The ON INT statement is an executable BASIC statement which acts in a similar fashion to the ON KEY statement (see the 9835A/B Operating and Programming Manual). The statement allows the BASIC programmer to specify where, in his BASIC program, to branch whenever an interrupt is signalled for the select code he specifies.

As with the ON KEY statement, there are three ways these branches can be taken —

```
ON INT #{select code} [, {priority} ] CALL {subprogram name}
ON INT #{select code} [, {priority} ] GOSUB {line identifier}
ON INT #{select code} [, {priority} ] GOTO {line identifier}
```

Whenever an interrupt is signalled from an ISR for a particular select code, if ON INT has been executed for that select code, then at the end of execution of the BASIC line which was executing when the signal came, the indicated branch in the ON INT is taken.

In the GOTO version, the branch is "absolute", which is to say that the program goes to the line indicated and picks up its execution there, forgetting where it was before. This has the effect of an "abortive" type of branch, and should only be used by the BASIC programmer when he wants the program to resume execution at some pre-determined point after handling an interrupt, without regard to where the program was before the interrupt occurred.

In the CALL and GOSUB versions, the branch is only temporary. After the subprogram or subroutine has been executed and the SUBEXIT, SUBEND, or RETURN (as appropriate) has been executed, then the program returns to the line following the one where it was interrupted. This is the same as if the CALL or GOSUB was in between the interrupted line and the one following it.

The {line identifier} and {subprogram name} in the CALL, GOSUB, and GOTO statements are the same as elsewhere in BASIC, except that a CALL may not have any parameters.

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Debugging

The {select code} specified in an ON INT statement restricts the branching action to occurring only when the assembly language triggers the ON INT condition for that select code. The interrupt may have occurred in actuality on another select code. This can be a way of allowing more than one branch for interrupts from a single interrupting device.

As an example —

```
100 ON INT#3 GOSUB Print_result
110 ON INT#5 GOSUB End_data
```

Should anywhere in the program an interrupt occur, causing an assembly language interrupt service routine to be executed, that assembly language ISR has the capability to cause either the branch of line 100 or the branch of line 110 to be taken. Thus, an assembly language ISR signals BASIC either to print an intermediate result or to note that all data has been processed.

Signalling

The {select code} specified in an ON INT statement restricts the branching action to occurring only when an interrupt is "signalled" for that select code. In actuality, an interrupt may not have occurred on that select code at all. Conversely, an interrupt may occur on the select code, but BASIC and its ON INT condition may never hear about it. It is necessary for the ISR which does the actual handling of an interrupt to inform, or "signal", the operating system that the interrupt occurred and trigger the ON INT conditions which may be set up at the time.

The responsibility of the ISR to signal the ON INT is also an opportunity. This signalling allows you in an ISR to decide whether or not you want BASIC to know about the interrupt. If you do not want BASIC to know, simply do not signal the condition. The signalling also allows you to signal different interrupt conditions. An example of doing this might be a case where, after an interrupt, a peripheral indicates whether it wants to input or output data. Your routine could signal one select code to execute an input routine and signal another select code to execute an output routine.

To signal an ON INT, your ISR must execute the following instructions —

```
ISOURCE      LDB Isr_psw
ISOURCE      LDA =103B
ISOURCE      STA B,I
ISOURCE      ADB=3
ISOURCE      LDA Mask      ! Determines which SC to signal
ISOURCE      STA B,I
ISOURCE      STA Isr_flag,I
```

Mask necessarily contains the select code to be signalled. Rather than containing the number of the select code, however, it has the bit set for the appropriate select code. For example, if you are signalling select code 2, you set bit 2 to 1 in Mask and leave the others 0. Similarly, if you are signalling select code 5, you set bit 5. Thus, the statement containing Mask in the above could just as easily be a literal. For example —

```
LDA =32
```

would signal select code 5.

When you want to signal a select code after others have already been signalled, a slightly different instruction sequence is required —

```
ISOURCE      LDB Isr_psw
ISOURCE      LDA =103B
ISOURCE      STA B,I
ISOURCE      ADB =3
ISOURCE      LDA Mask
ISOURCE      DIR
ISOURCE      IOR B,I       ! Ors in the select code
ISOURCE      STA B,I
ISOURCE      EIR
ISOURCE      STA Isr_flag,I
```

Mask is the same as above.

As a further example, suppose you want both to signal BASIC when a device sends a line-feed character to the computer, and to terminate the ISR's linkage. Then the ISR might appear as —

```
ISOURCE  Lf:          EQU 10
                      .
                      .
                      .
ISOURCE  Isr:         LDA R4
ISOURCE               CPA =Lf            ! Is it a line feed?
ISOURCE               JMP Terminate      !    Yes, so jump
ISOURCE               STA R7             !    No, so trigger another handshake
ISOURCE               RET 1
ISOURCE  Terminate:   JSM End_isr_low,I
ISOURCE               LDB Isr_psw    ! Signal BASIC
ISOURCE               LDA =103B
ISOURCE               STA B,I
ISOURCE               ADB =3
ISOURCE               LDA =1         ! ON INT #1 signalled
ISOURCE               STA B,I
ISOURCE               STA Isr_flag,I
ISOURCE               RET 1
```

Additional Pre-Defined Symbols

Isr_flag and Isr_psw are pre-defined symbols in the assembler. Also pre-defined are two other symbols used by the assembler — End_isr_low and End_isr_high. These symbols may not be redefined.

Prioritizing ON INT Branches

Since more than one interrupt may occur while a single BASIC statement is executing, it is possible that by the time the line finishes there may be a number of ON INT branches waiting to be executed. In such situations you may want to assure that some ON INT branches are taken before others, or that you finish one routine (caused by an ON INT GOSUB or ON INT CALL) before you start another. This can be achieved by using the {priority} option of the ON INT statement, thereby "prioritizing" the branching caused by interrupts.[1]

There is a "system priority" for ordering this interrupt branching. For an ON INT to be honored at the end of a BASIC line, its priority must be greater than the current system priority.

Initially, the system priority is set to 0. When a BASIC line finishes, and there is at least one ON INT branch pending which is greater than the system priority, then the system takes the branch associated with the ON INT with the greatest {priority}. The values assigned to {priority} may be any integer numeric expression from 1 to 15. If {priority} is omitted, 1 is assumed.

If the ON INT branch to be executed is a GOTO, then the system priority level is unchanged. But if the branch to be executed is a GOSUB or a CALL, then the system priority level is changed to the priority level of the ON INT. Whenever the subroutine or subprogram is finished executing, then the previous system priority level is restored.

Thus, with the GOSUB and CALL versions, there are two effects involving priorities —

- The subroutine or subprogram is not allowed to execute until its priority is the highest one pending.
- Whenever the subroutine or subprogram is executing, it locks out any other interrupting branches unless they have a higher priority.

1 This "prioritizing" also holds between the various types of end-of-line branch statements that have the priority parameter. Thus an ON KEY with high priority is executed before an ON INT with low priority.

With the GOTO version there are also two effects, slightly differing —

- The branch is not taken until it has the highest priority of all pending branches.
- The execution of the branch does not lock out any other branches, so that at the end of the line to which it branches, if there are other pending branches, the highest one of those is executed.

For example, suppose there are these four statements in effect —

```
ON INT #4, 1 GOTO Routine_4
ON INT #5, 9 GOSUB Routine_5
ON INT #6, 5 GOTO 1000
ON INT #7, 15 GOSUB Routine_7
```

and also suppose that at the end of some BASIC line in the program, an interrupt had been received from all four of the interfaces involved. Then the process of dealing with them proceeds like this —

EVENT	NEXT ACTION	SYSTEM PRIORITY
Reaches end of current BASIC line	GOSUB Routine_7	Changes from 0 to 15
Finishes Routine_7	GOSUB Routine_5	Changes from 15 to 9

Suppose at this point another interrupt is received from select code 7.

EVENT	NEXT ACTION	SYSTEM PRIORITY
Reaches end of current BASIC line in Routine_5	GOSUB Routine_7	Changes from 9 to 15
Finishes Routine_7	Returns to interrupted point in Routine_5	Changes from 15 to 9
Finishes Routine_5	GOTO 1000	Changes from 9 to 0
Finishes with line 1000	GOTO Routine_4	Stays at 0

Environmental Considerations

Changes in program environment, i.e., calling a subprogram or returning from one, can affect whether an ON INT is in effect or not.

Once executed, the CALL version of an ON INT is **always** in effect, whether in the main program or in any subprogram, until it is redefined by another ON INT or is specifically disabled (see below).

In the GOSUB or GOTO versions, the statement is in effect **only** in the same program environment. This is to say that if you have executed an ON INT statement in your main program, then it is effective only while your program is executing part of the main program. The instant the program goes into a subprogram (through a CALL statement), the statement is no longer effective until the execution returns to the main program. Similarly, if you define an ON INT in a subprogram, it is effective only while the program is executing that subprogram.

A side-effect occurs here when you use the CALL version of an ON INT. By calling the subprogram with an ON INT, you have the effect of locking out the other interrupts, except those which are executed in the subprogram itself and other CALL versions. This is regardless of priority. In the priority example in the previous section, if the ON INT#5 had been a CALL instead of a GOSUB, then the second interrupt from select code 7 would not have been acknowledged until the subprogram had finished.

Since recursive calls of subprograms are possible, it is also possible that many calls to the same subprogram may be stacked up because an interrupt from a different select code with a CALL version of an ON INT in effect may be received while processing the CALL caused by a previous interrupt.

Disabling ON INT Branching

The branching enabled by an ON INT statement can be disabled using an OFF INT statement for the same select code. It is effective for the ON INT statement within the same program environment (main program or subprogram) or for the CALL versions of the ON INT within any environment.

The statement has the form —

```
OFF INT #{select code}
```

where {select code} is a numeric expression for any valid interface select code between 1 and 14, inclusive.

The effect of the OFF INT statement is to disable the ON INT for that select code within the current environment. If there is no ON INT statement currently in effect for the select code, then the OFF INT has no effect.

The DISABLE and ENABLE statements work the same way for the ON INT statements as they do for the ON KEY statements. They should not be confused with the DIR and EIR machine instructions, which disable and enable the interrupt system.

Mass Storage Activities

For devices meeting the operating system's criteria for mass storage peripherals, the reading and writing of records is simple.

If a device has been specified in a MASS STORAGE IS statement in BASIC, as in —

```
MASS STORAGE IS ":F"
```

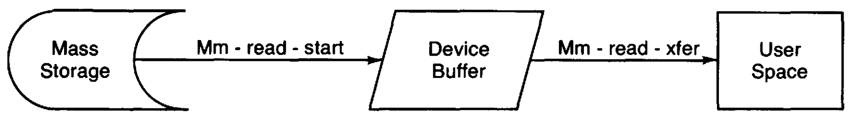
or is capable of being so specified, then it is possible to use utilities to access it.

There are two utilities involved in reading from a mass storage device — Mm_read_start and Mm_read_xfer — and there are two utilities involved in writing to a mass storage device — Mm_write_start and Mm_write_test. The reading utilities are always used together. So, too, are the writing utilities.

Reading from Mass Storage

The flow of data to and from a mass storage device is buffered. For each device there is a "device buffer" in memory which holds data corresponding to a physical record (256 bytes). Device buffers are dynamically allocated by the operating system and their actual locations at any given time are of no concern.

To get information from a mass storage device into its device buffer takes the Mm_read_start utility. Then to get the information out of the buffer and into your user space takes the Mm_read_xfer utility. The transfer of data, therefore, looks something like this —

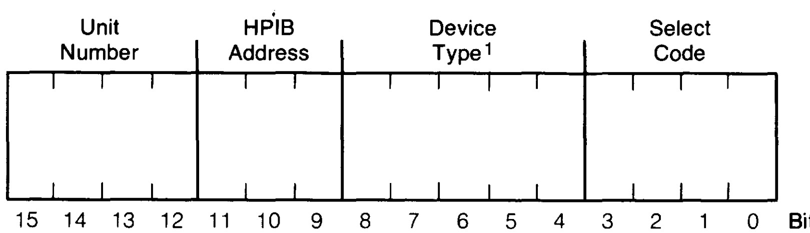


The utilities accomplish their purposes with the help of two locations containing vital information for their use. The first is the Mass Storage Descriptor (MSD) and the second is the Mass Storage Transfer Identifier (MSTID).

The MSD is three words in the ICOM region which contains the following information —

WORD	15 ... 7	6 ... 0
0	MSUS	
1	lower 16 bits of record number	
2	don't care	upper 7 bits of record number

This information must be provided by your program. You must determine this information in advance of attempting the reading operation. The msus is of the form —



1 The device type is the ASCII code for the type minus 100_8.

The MSTID is a single word. The information in it is returned by the Mm_read_start utility and used by the Mm_read_xfer utility.

The usual procedure in reading a record from mass storage (which is all that can be read at one time) is to call the Mm_read_start utility and then, if all goes well with that, to call the Mm_read_xfer utility. Because the latter utility may have to wait on the operating system or the device, it is possible the utility may return without having completed the transfer. In that case, it is your option either to loop back and keep trying, or to do something else and try again later.

UTILITY: Mm_read_start

General Procedure: The record number is determined, then the transfer of the record's contents is made from the device to the device buffer. If the buffer allocation causes a memory overflow, there is an error.

Special Requirements: The record number and msus must be loaded into the MSD in advance of the call. There must be a stable location (not changed by other activities) for the MSTID to be held.

Calling Procedure:

1. Store the msus and record number into the MSD area.
2. Load register A with the address of the MSD area.
3. Call the utility.

Exit Conditions:

RET 1 Occurs if there is a memory overflow during execution of the utility.

RET 2 Occurs if all went normally. Register A contains the MSTID. This should be immediately stored in the location reserved for it.

UTILITY: **Mm_read_xfer**

General Procedure: The MSTID is used to retrieve the record from the device buffer. The record is stored into a location set aside for the purpose.

Special Requirements: The MSTID must be available from a previous call to Mm_read_start. A location of 128 consecutive words must be set aside to hold the contents of the record when they are returned by the utility.

Calling Procedure:

1. Load register A with the contents of the MSTID.
2. Load register B with the address of the storage location for the data.
3. Call the utility. The transfer may not be completed on the first or subsequent calls (see exit conditions). In that case, to successfully complete the transfer, all three steps must be repeated.

Exit Conditions:

RET 1 Occurs when the transfer is not completed. It is up to your routine at this point to decide whether another attempt should be made immediately, or whether something else should be executed (and to come back later).

RET 2 Occurs when the transfer is complete. The location specified contains the data. If register A contains a non-zero value, an error occurred and A is the error number. In addition to mass storage errors (80 through 99), error 19 is returned if the MSTID parameter is invalid.

CAUTION

Pressing RESET (CONT'L STOP) during execution of either of the above utiities may cause a SCRATCH A to occur.

The following is an example of a typical call to these utilities to read a record from mass storage —

```
ISOURCE Number:  BSS 2
ISOURCE Msd:     BSS 3
ISOURCE Mstid:   BSS 1
ISOURCE Record:  BSS 128
                  .
                  .
                  .
ISOURCE          LDA =-1          ! Default MSUS
ISOURCE          STA Msd          ! Create the MSD
ISOURCE          LDA Number       ! Store low-order bits of record number
ISOURCE          STA Msd+1        ! Store high-order bits of record number
ISOURCE          LDA Number+1
ISOURCE          STA Msd+2
ISOURCE          LDA =Msd
ISOURCE          JSM Mm_read_start! From device to buffer
ISOURCE          JMP Memory_overflow
ISOURCE          STA Mstid        ! Keep the MSTID
ISOURCE Fetch:   LDA Mstid
ISOURCE          LDB =Record
ISOURCE          JSM Mm_read_xfer ! Transfer record to ICOM buffer
ISOURCE          JMP Fetch        ! Not completed (RET 1)
ISOURCE          SZA *+2          ! Check for errors (RET 2)
ISOURCE          JSM Error_exit
```

Writing to Mass Storage

Writing to mass storage is very much like reading from it. The flow of data is buffered. To get the data from the user space into the device buffer, and then to transfer the data from the buffer to the mass storage device, the Mm_write_start utility is used. Then a test can be made to determine when the transfer is complete by using the Mm_write_test utility.

As with the reading utilities, these utilities accomplish their purposes with the help of the same two locations — MSD and MSTID. They contain the same information as they do in the reading utilities and are used in a similar fashion.

UTILITY: **Mm_write_start**

General Procedure: The record number is determined, then the transfer of the data is made from the ICOM region to the device buffer. If the buffer allocation causes a memory overflow, there is an error.

Special Requirements: The record number and msus must be loaded into the MSD in advance of the call. There must be a stable location (not changed by other activities) for the MSTID to be held. The data to be transferred must be ready (256 bytes — 128 consecutive words).

Calling Procedure:

1. Store the data to be transferred in its location. Store the msus and record number into the MSD area.
2. Load register A with the address of the MSD area.
3. Load register B with the address of the data location.
4. Call the utility.

Exit Conditions:

RET 1 Occurs if there is a memory overflow during execution of the utility.

RET 2 Occurs if all went normally. Register A contains the MSTID. This should be immediately stored in the location reserved for it.

UTILITY: **Mm_write_test**

General Procedure: The MSTID is used to check to see if the data from the buffer has been transferred to the mass storage device.

Special Requirements: The MSTID must be available from a previous call to Mm_write_start.

Calling Procedure:

1. Load register A with the contents of the MSTID.
2. Call the utility. The transfer may not be completed on the first or subsequent calls (see exit conditions). In that case, to successfully test for a completed transfer, both steps in the calling procedure must be repeated.

Exit Conditions:

RET 1 Occurs when the transfer from the device buffer to the device is not completed. It is up to your routine at this point to decide whether another test should be made immediately, or whether something else should be executed (and to come back later).

RET 2 Occurs when the transfer is complete. If register A contains a non-zero value, an error occurred and A is the error number. In addition to mass storage errors (80 through 99), error 19 is returned if the MSTID parameter is invalid.

CAUTION

Pressing RESET (CONT'D STOP) during execution of either of the above utilities may cause a SCRATCH A to occur.

The following is an example of a typical call to these utilities to write a record to mass storage —

```
ISOURCE Number:  BSS 2
ISOURCE Msd:     BSS 3
ISOURCE Mstid:   BSS 1
ISOURCE Record:  BSS 128
                  .
                  .
                  .
ISOURCE          LDA =-1          ! Default MSUS
ISOURCE          STA Msd          ! Create the MSD
ISOURCE          LDA Number       ! Store low-order bits of record number
ISOURCE          STA Msd+1        ! Store high-order bits of record number
ISOURCE          LDA Number+1
ISOURCE          STA Msd+2
ISOURCE          LDA =Msd
ISOURCE          LDB =Record
ISOURCE          JSM Mm_write_start ! Put record in buffer
ISOURCE          JMP Memory_overflow
ISOURCE          STA Mstid        ! Keep the MSTID
ISOURCE Test:    LDA Mstid
ISOURCE          JSM Mm_write_test ! Is transfer of data complete?
ISOURCE          JMP Test         ! Not completed
ISOURCE          SZA *+2          ! Check for errors
ISOURCE          JSM Error_exit
```

System File Information

As an ASSIGN statement is executed in BASIC, a file-descriptor is created for that assignment in the operating system's files table. The ASSIGN statement essentially has two parameters — the file number and the file name (including the BASIC language mass storage unit specifier).

The file number is, for all practical purposes, an offset into the files table. The file name and the BASIC language mass storage unit specifier are translated and the critical information associated with them comprise an entry in the files table (i.e., the "file descriptor").

The file descriptor consists of 10 words containing the following information —

Word	Description
0	Lower 16 bits of the address of the first physical record in the file
1	Number of logical records in the file
2	Current physical record number (i.e., an offset from the file's beginning.
3	Current word in physical record
4	Size of a logical record (in words)
5	Mass storage unit specifier (msus)
6	Buffer address
7	Check read status (0 = off, 1 = on)
8	Highest 7 bits of the first physical record in the file
9	(Reserved by the operating system)

Note that words 0,5 and 7 contain the information necessary to create an MSD. You may access a file descriptor through two utilities — Get_file_info to obtain the information, and Put_file_info to change the information.

NOTE

A files table is created for each BASIC "environment" (i.e., main program and subprograms). When access is made through utilities to the files table, the table accessed is the one associated with the BASIC environment which called the assembly language program.

UTILITY: Get_file_info

General Procedure: The utility is given the file number and the location of a place to store the file descriptor. It retrieves the designated descriptor and stores it, provided the file has been assigned.

Special Requirements: There must be a ten-word area available for the utility to store the information from the descriptor.

Call Procedure:

1. Load register A with the address of the ten-word area where you desire the information to be stored.
2. Load register B with the file number (an integer from 1 to 10).
3. Call the utility.

Exit Conditions:

RET 1 Occurs if the file has not been assigned by a BASIC ASSIGN statement.

RET 2 Occurs if all went normally.

Here is an example of a routine which has a file number passed to it, and then gets the file descriptor —

```
                                    .
                                    .
                                    .
ISOURCE File_descriptor:  BSS 10
ISOURCE File:             BSS 1
                                    .
                                    .
                                    .
ISOURCE                   SUB
ISOURCE Parameter:        FIL
ISOURCE Routine:          LDA =File
ISOURCE                   LDB =Parameter
ISOURCE                   JSM Get_value          ! Get file number
ISOURCE                   LDA =File_descriptor
ISOURCE                   LDB File
ISOURCE                   JSM Get_file_info      ! Get file descriptor
ISOURCE                   JMP No_file_error      ! File not assigned
                                    .
                                    .
                                    .
```

UTILITY: Put_file_info

General Procedure: The utility is given the file number and the location of the area containing the new file descriptor information. It stores that information into the files table as indicated by the file number, provided that the file has been assigned.

Special Requirements: The new pointer information must be stored in the designated area before calling the utility. This information must be in the correct form and location or file difficulties may ensue. Most of the information is normally returned by the "Get_file_info" utility and only a couple of words are changed to change the pointer in the file (e.g., the current record and word numbers). Only words 2, 3, and 7 should be changed in the descriptor.

Calling Procedure:

1. Load register A with the address of the ten-word area where the information is stored.
2. Load register B with the file number (an integer from 1 to 10).
3. Call the utility.

Exit Conditions:

RET 1 Occurs if the file has not been assigned by a BASIC ASSIGN statement.

RET 2 Occurs if all went normally.

Here is an example where the next physical record in a file is specified —

```
File:            BSS 1    ! File number
File_descriptor: BSS 10   ! File information
                  .
                  .
                  .
                 ISZ File_descriptor+2   ! Increment record number
                 LDA =0
                 STA File_descriptor+3   ! Set word to 0
                 LDA =File_descriptor
                 LDB File
                 JSM Put_file_info
                 JMP No_file_error       ! File not assigned
```

Printing

Two utilities are provided to enable you to gain access to the standard system printer — Printer_select and Print_string.

Printer_select enables you to set the standard system printer to a select code of your choosing. Print_string enables you to print a string to the standard printer.

Utility: Printer_select

General Procedure: The utility is given the select code to be assigned as the standard system printer and the desired printing width. The utility makes the assignment and returns with the previous values of both the select code and printer width.

Special Requirements: The select code value must be in the range of 0 through 17 for the utility to work properly. Neither the previous nor the selcted printer should be on HPIB device.

Calling Procedure:

1. Load register A with the desired select code.
2. Load register B with the desied printer width.
3. Call the utility.

Exit Conditions: There are no error exits from the utility, so it always returns to the instruction following the call. Register A contains the value of the previous select, and register B contains the value of the previous printer width.

The utility can feasibly be used just to interrogate the current value of the printer's select code. However, a second call to the utility is needed in such cases to assure that the select is not changed by the first call. So, for example —

```
ISOURCE LDA = 16
ISOURCE  LDB = 80
ISOURCE  JSM Printer_select
ISOURCE  STA Select_code
ISOURCE  STB Printer_width
ISOURCE  JSM Printer_select
```

This results in an unchanged printer specification and the values for the select code and width being stored in the ICOM area for future use.

Because of the possibility that a RESET (CONT'D STOP), or similar interruption, may occur between the first and second calls to the utility, it is recommended that the first call have a definite valid value for the select code in A (as above). In that way, should there indeed be an interruption, a valid select code for the printer can be assured.

Utility: Print_string

General Procedure: The utility is given the address of a string, and it prints that string to the standard system printer.

Special Requirements: The string to be printed must be in standard string format (see "Data Structures" in Chapter 3). The string must be no longer than 506 characters.

Calling Procedure:

1. Load register A with the address of the string to be printed.
2. Call the utility.

Exit Conditions:

RET 1 If a memory overflow occurs during execution of the utility.

RET 2 If the STOP key is pressed during execution of the utility.

RET 3 If all goes normally.

For example —

```
ISOURCE String:        DAT 13,"ERROR IN CALL"
          .
          .
          .
ISOURCE                LDA = String
ISOURCE                JSM Print_string
ISOURCE                JMP Overflow error          ! Overflow condition
ISOURCE                JMP Stop_routine            ! Stop key pressed
ISOURCE                NOP                         ! Normal exit
```

CAUTION

Pressing RESET (CONT'D STOP) during execution of the Print_string utility may cause a SCRATCH A to occur.

Chapter 8
Debugging

Summary: This chapter describes techniques for isolating and correcting logic problems in assembly programs. Included in the discussion are techniques for stepping through programs, getting dumps, patching, and using the keyboard.

The assembly system has provided you with a number of BASIC language tools to help you debug your assembly language programs during their development stages.

These tools are for run-time debugging, so your source code must have been assembled into object code and stored in the ICOM region before attempting to use any of the debugging features detailed in this chapter.

There are three classes into which these tools fall: stepping through programs, dumps, and value checking. There is also an additional capability provided for the correction of some errors — patching.

The BASIC statements available for debugging are —

```
IBREAK
IBREAK ALL
IBREAK DATA
ICHANGE
IDUMP
INORMAL
IPAUSE OFF
IPAUSE ON
```

and the following BASIC functions are available —

```
DECIMAL
IADR
IMEM
OCTAL
```

Stepping Through Programs

"Logic" difficulties are some of the hardest problems to solve in debugging programs. In batch environments, the usual solution is to print the contents of variables at critical points in the program or to print dumps. The capabilities for both of these methods are provided. However, advantage has been taken of the interactive, "hands-on" nature of the 9835A/B and a feature has been added which allows you to execute the assembly statements individually. This permits you to examine the flow of the program as it executes rather than having to decipher a dump or trying to print the contents of specific variables at what you guess is the critical point.

If you are desirous of looking only at particular points in the program, or at particular variables, there is also the ability to establish "break points" for these items, so that your debugging routines can be invoked only when certain conditions arise. You can also establish different routines for different break points, adding to the flexibility.

Individual Instruction Execution

Normally, all BASIC lines, including the ICALL statement, act as a **unit**. That is to say, whenever you press the (PAUSE) key, the line which is currently executing is allowed to finish before the program is actually interrupted. Thus, if you press (PAUSE) during execution of the line —

```
100  LET A=1+1
```

the line finishes and the variable A contains the value 2. Then the (PAUSE) takes effect. The same is true of a line containing an ICALL statement.

For example, if you press (PAUSE) during the execution of —

```
120  ICALL Sort(A(*))
```

then the assembly routine completes before the (PAUSE) is honored. This is not always desirable; especially not during debugging of the assembly routine. It does not allow you to look at the execution of the routine to help you determine what may be going wrong.

The same problem occurs with the (STEP) key. Pressing (STEP) causes an entire BASIC line to be executed. Thus, if you stepped through line 120 as above, the entire routine Sort would be executed, and you would not be able to observe its execution on an instruction-by-instruction basis.

To permit you to analyze the execution of assembly language routines, an executable BASIC statement has been provided —

```
IPAUSE ON
```

Now, should you have the sequence in your program —

```
110  IPAUSE ON
120  ICALL Sort(A(*))
```

then pressing PAUSE during the execution of line 120 would cause program execution to be interrupted after completion of whatever machine instruction is being executed at the time. Further, the assembly language source line associated with the following instruction is displayed according to certain rules.

If the source lines are still in memory when you press PAUSE (e.g., you just assembled the object code which you are running), then the source line is displayed. If the source is no longer in memory (e.g., the object code was obtained through an ILOAD), then the instruction displayed is the result of a "reverse assembly". If there is an operand with an instruction which is reverse assembled, then the octal value of that operand is displayed (this is because the reverse assembly process has no way of knowing what symbols you might have used to assemble the instruction originally).

After pressing PAUSE, should you press CONT, execution resumes normally. It is not necessary for you to do anything (such as cleaning up the registers, etc.) for execution to resume as if you had never interrupted it.

After pressing PAUSE, you may want to observe the flow of execution of your assembly routine. This can be done by successively pressing the STEP key. Each time the key is pressed, another machine instruction is executed and the assembly source line associated with the next machine instruction is displayed. You may continue this way for as long as you like — until you press CONT to allow processing to proceed uninterrupted until the end of the routine.

Of course, the STEP key can be used to step through the BASIC program as you are used to doing. That feature is unchanged. It is possible, therefore, to "step into" the assembly language routine from the BASIC (i.e., you need only STEP into line 120 above) and not have to use the PAUSE key at all.

In summary, IPAUSE ON allows two unique features —

- The PAUSE key can be used to halt execution within an assembled routine.
- The STEP key can be used to execute individual assembly language instructions.

Some key things to remember in using the IPAUSE ON facility —

- This is an execution-time debugging tool. You must be executing your previously-assembled object code with an ICALL statement.
- If the source code is available for display, it will be displayed, otherwise the line is "reverse assembled".
- Utilities are not stepped instruction-by-instruction, but rather as a unit.
- The STEP key performs in BASIC just as before.
- Keeping the STEP key depressed causes repeated execution of the stepping function, the same as in BASIC.

By way of example, suppose you had the following source code —

```
10   DIM A$[10]
20   ICOM 100
30   IPAUSE ON
40   IASSEMBLE Extract
50 Loop:  LINPUT A$
60   PAUSE
70   ICALL Extract(A$)
80   PRINT "<";A$;">"
90   GOTO Loop
100  ISOURCE           NAM Extract  ! Extracts part of a
110  ISOURCE                        ! string preceding comma
120  ISOURCE           EXT Get_value,Put_value
130  ISOURCE String:   BSS 6
140  ISOURCE           SUB
150  ISOURCE Parameter:STR
160  ISOURCE Extract:  LDA =String      ! Retrieve string
170  ISOURCE           LDB =Parameter
180  ISOURCE           JSM Get_value
190  ISOURCE           LDB String       ! Initialize counter
200  ISOURCE           LDA =String      ! Initialize stack pointer
210  ISOURCE           SAL 1
220  ISOURCE           ADA String
230  ISOURCE           ADA =1
240  ISOURCE           STA C
250  ISOURCE           CBU
260  ISOURCE Loop:     WBC A            ! Retrieve next character
270  ISOURCE           CPA =54B         ! Is it a comma?
280  ISOURCE           JMP Yes
```

```
290  ISOURCE              DSZ B            ! Decrement.  Done?
300  ISOURCE              JMP Loop
310  ISOURCE              RET 1            ! No commee, no extractee
320  ISOURCE Yes:         ADB =-1          ! Found comma, extract
330  ISOURCE              STB String       !    by changing length
340  ISOURCE              LDA =String      !    then extracting
350  ISOURCE              LDB =Parameter
360  ISOURCE              JMP Put_value
370  ISOURCE              END Extract
```

Then the following would be the display lines you would see as you executed this program using the STEP key —

```
10   DIM A$[10]
20   ICOM 100
30   IPAUSE ON
40   IASSEMBLE Extract
50 Loop:  LINPUT A$
?
12345,6789
160  00060 002025 ISOURCE Extract:  LDA =String      ! Retrieve string
170  00061 006025 ISOURCE           LDB =Parameter
180  00062 142025 ISOURCE           JSM Get_value
190  00063 007756 ISOURCE           LDB String       ! Initialize counter
200  00064 002021 ISOURCE           LDA =String      ! Initialize stack pointer
210  00065 170600 ISOURCE           SAL 1
220  00066 023753 ISOURCE           ADA String
230  00067 022021 ISOURCE           ADA =1
240  00070 030016 ISOURCE           STA C
250  00071 070530 ISOURCE           CBU
260  00072 074760 ISOURCE Loop:     WBC A            ! Retrieve next character
270  00073 012016 ISOURCE           CPA =54B         ! Is it a comma?
290  00075 054001 ISOURCE           DSZ B            ! Decrement.  Done?
300  00076 067774 ISOURCE           JMP Loop
260  00072 074760 ISOURCE Loop:     WBC A            ! Retrieve next character
270  00073 012016 ISOURCE           CPA =54B         ! Is it a comma?
290  00075 054001 ISOURCE           DSZ B            ! Decrement.  Done?
300  00076 067774 ISOURCE           JMP Loop
260  00072 074760 ISOURCE Loop:     WBC A            ! Retrieve next character
270  00073 012016 ISOURCE           CPA =54B         ! Is it a comma?
290  00075 054001 ISOURCE           DSZ B            ! Decrement.  Done?
300  00076 067774 ISOURCE           JMP Loop
260  00072 074760 ISOURCE Loop:     WBC A            ! Retrieve next character
270  00073 012016 ISOURCE           CPA =54B         ! Is it a comma?
290  00075 054001 ISOURCE           DSZ B            ! Decrement.  Done?
300  00076 067774 ISOURCE           JMP Loop
260  00072 074760 ISOURCE Loop:     WBC A            ! Retrieve next character
270  00073 012016 ISOURCE           CPA =54B         ! Is it a comma?
280  00074 066004 ISOURCE           JMP Yes
320  00100 026012 ISOURCE Yes:      ADB =-1          ! Found comma, extract
330  00101 037740 ISOURCE           STB String       !    by changing length
340  00102 002003 ISOURCE           LDA =String      !    then extracting
350  00103 006003 ISOURCE           LDB =Parameter
360  00104 166007 ISOURCE           JMP Put_value
80   PRINT "<";A$;">"
<12345>
90   GOTO Loop
50 Loop:  LINPUT A$
```

Note that the address of the instruction, as well as the octal value of the instruction, is displayed along with the source line.

This stepping facility can also be used, quite effectively, with the IBREAK statement (discussed below).

Should the IPAUSE ON facility be no longer desired, it can be turned off with —

```
IPAUSE OFF
```

The two statements can appear repeatedly in a program, allowing the stepping facility to be used in testing some programs but skipping over already proven programs. For example, suppose you had two programs — Sorta and Sortn — but the first was already tested and the second was not. Then this sequence might appear in your program —

```
110  IPAUSE OFF
120  ICALL Sorta(A$(*))
130  IPAUSE ON
140  ICALL Sortn(A(*))
```

Stepping through this sequence results in lines 110, 120, and 130 executing without interruption, but line 140's call to Sortn would be executed instruction-by-instruction.

Executing IPAUSE ON when the facility is already in effect causes no change. Similarly, executing IPAUSE OFF when the facility is already off causes no change.

Both IPAUSE ON and IPAUSE OFF can be executed from the keyboard.

Setting Break Points

It is possible to define points in an assembly language routine where the execution should pause should it ever reach that point. These are called "break points". They can be used to pause execution — allowing you to utilize the stepping activity described above in IPAUSE ON or to investigate the contents of variables, etc. They can also be used to allow branching to some BASIC routine, giving you the power of BASIC in doing some of your debugging.

Simple Pausing

To simply pause at a break point, you need to execute the following statement in advance of reaching that point (either in the program or from the keyboard) —

IBREAK {address}

where {address} is the assembled location[1] for the break point desired. Following execution of this statement, anytime the program execution reaches this address, it pauses. You may do any keyboard operations necessary at this point, or you may start stepping the program, (if IPAUSE ON has been executed), or you may resume execution using the (CONT) key. The address must have been assembled before the IBREAK is executed.

If you were to execute —

```
IBREAK Hook,4
```

then every time the fourth word past assembly label "Hook" is reached during execution, the program execution pauses. If you were to execute —

```
IBREAK Hook+4
```

then Hook is assumed to be a BASIC variable, and the result of the expression is assumed to be an absolute address using whatever the value of Hook is when the statement is executed.

You can also specify the number of occurrences of reaching a break point before pausing should come into effect. This is done by executing —

```
IBREAK {address} ; {counter}
```

where {counter} is a numeric expression; any variables within {counter} are BASIC variables. A pause occurs when {address} has been reached {counter} number of times. {counter} is reset after each pause.

When a break point is reached and a pause is to be taken, the pause takes place **before** execution of the contents of that address.

Transfers

Instead of just pausing at a break point, it is possible to branch to a BASIC routine. The intent of this facility is to give you access to BASIC's capabilities, particularly the printing and variable-testing facilities, during your debugging efforts.

1 See "Buzzwords" in Chapter 1 for the definition of "assembled location".

The branch can be any of the three standard forms of BASIC branching —

```
IBREAK {address} [; {counter} ] CALL {subprogram}
IBREAK {address} [; {counter} ] GOSUB {line identifier}
IBREAK {address} [; {counter} ] GOTO {line identifier}
```

When either CALL or GOSUB has been designated, execution of the assembly language routine is suspended when {address} is reached. Then the designated subprogram or subroutine is executed. When that subprogram or subroutine is completed, then execution of the assembly language routine resumes with {address}.

When GOTO is specified, an unconditional branch is taken when {address} is encountered and execution of the assembly language routine is terminated.

{counter} performs the same as in the simple pausing form.

In the GOSUB and GOTO forms, there is an "environmental" restriction. The {line identifier} must be in the same BASIC environment (i.e., main program or subprogram) as that in which the IBREAK statement is executed. More on this in "Environments" below.

Environments

The GOSUB and GOTO types of break points are related to the BASIC "environment" (i.e., main program or subprogram) in which they are executed. Whenever an IBREAK statement of either type is encountered, the resulting break point is effective only for the environment in which the statement is located. The CALL version of break points is in effect in all environments.

For example —

```
200  SUB Test
210  IBREAK Hook GOTO Check_hook
         .
         .
         .
```

the break point established for "Hook" is good only in the subprogram "Test". Leaving Test causes the break point to be cleared.

Executing an IBREAK statement from the keyboard is effective only for the environment executing at the time the statement is made. For example, if the following program lines had been executed —

```
200  SUB Test
210  PAUSE
```

and while the pause caused by line 210 is still in effect —

```
IBREAK Hook GOTO Check_hook
```

is executed, then the break point established for "Hook" is good only in the subprogram "Test". As with the above, leaving Test causes the break point to be cleared.

If no program is executing when an IBREAK is executed from the keyboard, then the main program is considered to be the environment for the break point. If the program is replaced, as with a GET or a LOAD, then the break point is cleared.

Data Locations

Break points can also be established for data locations. This is done with —

```
IBREAK DATA {address}
```

In this case, {address} is presumed to be a data location referenced by other instructions. Whenever it is referenced by execution of some instruction, the pause occurs.

If you were to say —

```
IBREAK DATA Renras.
```

then whenever "Renras" is referenced, such as in —

```
LDA Renras
```

a pause would occur for that instruction.

A counter can also be specified with this form of break point —

IBREAK DATA {address} ; {counter}

{counter} is of the same form, and operates in an identical fashion, to the counter of the non-DATA form of break point.

Because the XFR machine instruction may access a particular location twice when it is executed, the break point on a data location may not operate correctly if the instruction referencing it is an XFR. The way to avoid this incorrect operation of the break point is to set {counter} to 2. (The only time this problem occurs is when the destination area for the XFR overlaps the origination area.)

Symmetry suggests that you should also be able to branch to BASIC routines with the DATA form of break point just as you can with the non-DATA form. And so you can —

IBREAK DATA {address} [; {counter}] CALL {subprogram}
IBREAK DATA {address} [; {counter}] GOSUB {line identifier}
IBREAK DATA {address} [; {counter}] GOTO {line identifier}

They operate in an identical fashion to transfers of the non-DATA type and are under the same "environmental" restrictions.

In order to determine whether an address is being referenced, each instruction is "interpreted" (that is, analyzed for its components). Resultantly, a program runs much slower while an IBREAK DATA statement is in effect.

In addition to the pausing capability, using IBREAK DATA also allows trapping on "protected memory" violations (see "Protected Memory" section of this chapter).

IBREAK Everywhere

You may have a total of eight (8) break points (regardless of type) in effect at a given time, except for one extreme case. It may be desirable to establish a break point at every location in the ICOM region. This can be accomplished with —

IBREAK ALL

This statement overrides all other IBREAK statements and causes a pause before execution of every instruction in the ICOM region. There are also branching forms —

```
IBREAK ALL CALL {subprogram}
IBREAK ALL GOSUB {line identifier}
IBREAK ALL GOTO {line identifier}
```

Note, however, that there is no {counter} in any of these forms.

Number of Break Points

As was mentioned above, there can be no more than eight (8) IBREAK statements in effect at one time, that is to say within the same environment. And only one IBREAK ALL can be in effect at a given time.

In addition, there can only be one IBREAK or IBREAK DATA each in effect for a given {address}. Executing an IBREAK or IBREAK DATA with the same {address} as specified in an already effective IBREAK or IBREAK DATA statement causes the newly-executed statement to override the previous one. While there may be an IBREAK and IBREAK DATA both for the same {address}, the capability is not a useful one.

Clearing Break Points

There are a number of ways that break points can be cleared. One way as has already been mentioned, is leaving the BASIC environment, which clears any GOSUB or GOTO type of break points. Another way is to reassemble the module containing the break points. A third way is to execute an INORMAL statement. This statement has the form —

```
INORMAL {address}
```

After execution of the statement, whatever form of break point is established for the address (except IBREAK ALL) is cleared.

If {address} is omitted in this statement —

```
INORMAL
```

then all break points are cleared. This is the only way to clear an IBREAK ALL which may be in effect.

Protected Memory

An assembly language program is allowed to access only certain portions of memory during the process of stepping with the STEP key or when an IBREAK DATA statement is in effect. Should you try to step through a program which makes an access outside of the allowed memory, then an error results (number 187). The same is true if an IBREAK DATA statement is in effect. "Access" means jumping to or writing into memory.

The allowed memory is —

- The ICOM region.
- BASIC's "value" area (the region where BASIC variables are stored).
- BASIC's common area (the region where BASIC common variables are stored).
- The processor registers
- The temporary values stored in the base page (pre-defined symbol "Base_page").
- The utilities.

All other memory is considered "protected" memory.

Dumps

A common tool of debugging is the memory "dump". This is a print-out (or display) of the contents of selected locations in the memory. A typical use is to dump areas of the ICOM containing data so that the actual contents at some point during execution can be compared with the expected contents. All of this is in the hope that the comparison yields differences which give a clue as to the source of the difficulties being encountered.

This tool is provided through the IDUMP statement which has the form —

IDUMP {location} [; {location} [; ...]]

This statement can be placed in a program to be executed (perhaps as the result of a branching IBREAK statement) or it can be executed from the keyboard (perhaps during a pause caused by stepping or IBREAK).

Any number of {location}s can be specified. They can take a number of forms. The simplest is —

{address}

Thus, IDUMP {address} prints the contents of {address} to the current system printer. The contents are printed in their octal representation.

{location} can specify a whole range of addresses by using the form —

{address} TO {address}

With this form, the IDUMP statement prints the contents of all addresses starting with the first and ending the last specified {address}. If the second address is numerically smaller than the first, then a "wrap-around" through the end of memory into the top of memory is taken. For example, if you execute —

```
IDUMP 177776 TO 1
```

then the contents of four addresses would be printed — those for 177776, 177777, 0, and 1, in that order. Again, the contents are printed in their octal (base-8) representation.

Addresses are always specified in their octal representation, or symbolically (such as "Hook" or "Loop"). This is the same as for an assembled location, which is what {address} happens to be.

The output of the IDUMP statement is always printed to the current system printer. It is in octal form, unless otherwise specified. This specification is accomplished by preceding {address} with {mode selection}, which is one of the following —

`ASC` for ASCII character representation
`BIN` for binary representation (base-2)
`DEC` for decimal representation (base-10)
`HEX` for hexadecimal representation (base-16)
`OCT` for octal representation (base-8)

Thus, the general form of {location} is —

[{mode selection}] {address} [`TO` {address}]

As an example of all this, take the example program at the beginning of the chapter. If a couple of statements are added so that the main BASIC program reads —

```
10   DIM A$[10]
20   ICOM 100
30   IASSEMBLE Extract
40   IBREAK Loop GOSUB Dump
50   IDUMP 41 TO 104       ! Dump of ICOM region
60   PRINT
70 Loop:  LINPUT A$
80   ICALL Extract(A$)
90   PRINT "<";A$;">"
100  GOTO Loop
110  !
120  ! Dump A,B registers in octal form,
130  ! string length in decimal form, and
140  ! and the string in character form
150  !
160 Dump:  IDUMP A TO B;DEC String;ASC String,1 TO String,8
170  PRINT
180  RETURN
```

then running it results in the following print-out —

```
000041: 000005 030462 031464 032454 033067 034071 022265 100003 022607 000012
000053: 021335 000001 100207 000000 000205 002025 006025 142025 007756 002021
000065: 170600 023753 022021 030016 070530 141714 012016 066004 054001 067774
000077: 170201 026012 037740 002003 006003 166007

000000: 000115 000012
000041: +00010
000042: 12345,6789$5%

000000: 000071 000011
000041: +00010
000042: 12345,6789$5%

000000: 000070 000010
000041: +00010
000042: 12345,6789$5%

000000: 000067 000007
000041: +00010
000042: 12345,6789$5%

000000: 000066 000006
000041: +00010
000042: 12345,6789$5%

<12345>
```

Value Checking

Value checking is a method of tracing the value of variables in your assembly language program using the interactive capabilities of the 9835A/B. You already have been introduced to break points and dumps in earlier sections. The capability of value checking serves as a useful adjunct to these procedures.

The value checking of assembly "variables" is similar to the monitoring of variables in BASIC during a debugging phase. Just as you would use a live-keyboard operation or judiciously placed PRINT statements to trace the execution of a program or the change in value of a variable in a BASIC program, so too can you use the monitoring tools for assembly programs.

Functions

Four additional functions are provided as extensions to BASIC which can be useful in the monitoring of values in an assembly language program. The four are —

```
DECIMAL
IADR
IMEM
OCTAL
```

They can be used as other than monitoring tools, but their descriptions here are primarily in that context. As functions, these items can be easily adapted for use in the special function keys.

DECIMAL

This function has the form —

DECIMAL({octal value})

The function converts an octal integer value into its decimal representation. If the argument given is not octal, then an error (number 184) results.

This can be used as a quick, simple way of converting octal numbers into the more familiar decimal value. Being a function, it can be used anywhere any other BASIC numeric function can be used. Often you will find it useful in PRINT statements which are a part of subroutines called by break points.

OCTAL

This function is the converse of the DECIMAL function. Its role is to convert decimal values into their octal (base-8) representation. The function has the form —

OCTAL({decimal value})

This can be used as a quick, convenient method of converting decimal numbers into their frequently used octal representations (a form which is useful because of its ready conversion into binary representation, and vice-versa).

The values resulting from this function must be treated with care. Though the result of the function is an octal representation, the value is still base-10. This difference is unimportant unless you are going to do arithmetic with the value resulting from the function.

As an example of this, suppose the decimal value 15 is to be converted into octal. The method is —

```
OCTAL(15)
```

and the resultant value is 17, the octal representation of 15. Now, if the result has 1 added to it, as with the expression —

```
OCTAL(15)+1
```

the ultimate result is 18. This can be a surprise since the usual octal arithmetic suggests that the result of $17_8 + 1$ be 20_8. To get the proper octal result, the procedure is —

```
OCTAL(15+1)
```

Note also that the expression —

```
OCTAL(OCTAL(15)+1)
```

still does not yield 20.

IADR

This function yields the numeric value in octal representation of an assembled location. The form is —

```
IADR( {assembled location} )
```

As an example, take the case of the example program at the beginning of this chapter. The result of —

```
IADR(Loop,4)
```

is 76.

This function can be viewed as a convenient method of determining the address of a symbol, or of an offset from a symbol.

IMEM

This function is a quick, convenient way to look at the contents of a specific location in memory. The result is a numeric value, in octal representation, for the contents of a specified address. The form is —

IMEM ({assembled location})

The function is similar in many respects to the IDUMP statement. It is easiest, perhaps, to list the differences —

- IMEM is a function, where IDUMP is a statement.
- IMEM deals only with a single address, where IDUMP can deal with many.
- IMEM represents the value only in octal, where IDUMP can use many different representations.
- IMEM can be displayed and stored, where IDUMP can only be printed.

An obvious use for the function is in a routine called by an IBREAK statement. By using the function in such a manner, perhaps in a PRINT statement, you can ease the burden of checking variables from the keyboard. You can even use the value returned as a comparison against some set of limits so that you print only when the value exceeds those limits. There are many other possibilities for use.

Interrogating Registers and Flags

Interrogating the processor register A, B, P, R, Pa, Cb, Db, Dmapa, Dmama, Dmac, C, D, Ar2, SE, and Ar1 yields meaningful results only when execution of an assembly language subprogram has been suspended due to detection of a break point, or due to the use of the STEP or PAUSE keys (see Stepping Through Programs).

Further, the values of cetain processor flags are stored in specific memory locations when a subprogram is suspended as described above. The flags are then available for interrogation as follows:

Decimal Carry	least significant bit of location 30_8
Overflow	least significant bit of location 31_8
Extend	most significant bit of location 31_8

It is important to note that interrogating an I/O register (R4, R5, R6, or R7) causes an input I/O bus cycle, using the current Pa register contents as the interface address. See Chapter 7 for details on the effects of such an action.

Patching

Patching is the practice of changing the contents of memory locations without re-assembling.

Patching as a standard procedure does not come highly recommended in the programming world. Nonetheless, there are circumstances which arise that occasionally suggest patching as the most profitable course of action.

To change a particular location in memory in the 9835A/B is not difficult. The statement to use is —

ICHANGE {assembled location} TO {octal expression}

After execution of the statement, the specified {assembled location} contains the specified octal value.

Changing the contents of a register is a common use of this facility. However, it should be remembered that attempting to change the contents of the I/O registers (R4, R5, R6, or R7) causes an output I/O bus cycle to occur, using the Pa register for the interface address. See Chapter 7 for details on the effects of such an action.

Chapter 9
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Errors and Error Processing

Chapter 9
Errors and Error Processing

Summary: This chapter contains a discussion of Assembly Language ROM and other related errors, and what causes them. Included are methods for trapping errors and possible methods for correcting them.

Whether you are writing or accessing an assembly language routine, it is possible to encounter an error resulting from your actions. The intent of this chapter is to give some guidance as to how certain errors can be handled. It is not intended as a definitive checklist of what can go wrong, nor is it an exhaustive treatment of the means to correct the difficulties which are listed. Rather, it is meant as a reference for some of the things which can go wrong, what might cause them, and how to deal with them. Each programmer has a unique method of approaching the problem of error processing and there is no way to anticipate all of them. Even so, the following should offer some assistance in identifying the source of an error.

Not every machine error is covered here — only those directly related to writing or accessing assembly language routines. A complete listing of error messages (though not in the same detail as in this chapter) can be found in Appendix J.

Types of Errors

There are three types of errors associated with assembly language routines: those which occur during the writing (or entering) of the source code (called "syntax-time" errors); those which occur while assembling the source code (called "assembly-time" errors); and those which occur during the execution of an assembly language routine (called "run-time" errors). Some of these errors can be anticipated and trapped, others cannot.

Syntax-Time and Assembly-Time Errors

Syntax errors are caught when entering source code, usually with the message —

```
IMPROPER ISOURCE STATEMENT
```

The error can then be immediately corrected and the statement reentered. A side-effect of this entry-time check of the syntax is that the time required for assembly is greatly shortened over what it would be if syntax-checking were deferred until assembly.

Errors encountered during the assembly process are indicated by the assembler in three ways:

- The message —

  ```
  ERROR 192 IN LINE nn
  ```

  is displayed. **nn** is the line number of the IASSEMBLE statement. This is a fatal BASIC error, unless otherwise trapped.

- Each line in the source code containing an assembly error is printed on the current system printer. Included is the message —

  ```
  **ERROR**
  ```

  followed by the error type.

- The message —

  ```
  ERRORS IN ASSEMBLY
  ```

  follows the listing of the individual errors. The total number of errors is also printed.

An explanation of the individual assembly-time errors can be found at the end of this chapter.

Run-Time Errors

Run-time errors can sometimes be anticipated. They come at two distinct times, and your error processing is different depending upon which of those times are of concern. The times are "program development" and "production run".

During program development, errors normally are handled using the debugging techniques detailed in Chapter 8. Care should be taken in recognizing errors during development. Not all of them are obvious or indicated by an error message — many simply lock up the machine.

During the running of production (debugged) routines, errors can be caused by the users of the routines. For instance, the user may inadvertently assign an argument a value of zero when that argument is to be used as a divisor within the assembly language routine. You should try to anticipate these usage errors and program procedures to trap them.

There are many alternatives for actions to take when your routine encounters and traps a usage error. For example, you may wish to assign a value to a particular return variable, or you may want to print a warning message, or, perhaps, to correct the value and proceed with the routine. Another method is to notify the user by issuing a BASIC error message. Such messages can be issued through the Error_exit utility discussed below.

Of course, you need to tell the users (in the documentation of the routine) what kind of errors can occur, when they can occur, and what to do about them.

UTILITY: Error_exit

The Error_exit utility provides you with the capability of aborting an assembly language routine by "creating" a BASIC error. Two types of BASIC errors can be created — "recoverable", which can be trapped by a BASIC ON ERROR statement; and "non-recoverable" (or "fatal"), which cannot be trapped.

General Procedure: The utility is given the number of the error to be created. Then the utility is called with the JSM instruction, but no return is made to the original assembly language routine from the utility. Instead, the utility uses the information placed on the return stack to help create the error. The return stack is appropriately "cleaned up" and control is returned either to the BASIC driver (if the error is non-fatal) or to the operating system (if the error is fatal).

Special Requirements: Error numbers are passed to the utility in the A register. The value of the error number is placed in bits 0-14. Bit 15 is set if the error is to be non-recoverable. If bit 15 is not set, the error will be recoverable. Error numbers 32 762 through 32 767, with bit 15 set, are reserved by the operating system and should not be used.

Calling Procedure:

1. Load the error number into the A register.
2. Call the utility using the JSM instruction.

Exit Conditions: The utility returns control to the BASIC driver which called the routine, appropriately setting conditions so that ERRL, ERRM$, and ERRN work as expected. Also triggers ON ERROR, if applicable.

The utility can be used anywhere in your assembly language, wherever you would like to abort the execution of the current assembly language routine and where you would like to indicate to BASIC what reason (error) caused the abortion.

For example, suppose somewhere in one of your assembly routines you wanted to abort the routine if a certain variable (Flag) is non-zero at a certain point. Suppose also that the variable, when non-zero, contained the error number, then your program could look like —

```
ISOURCE  LDA Flag
ISOURCE  SZA *+2
ISOURCE  JSM Error_exit
```

Similarly, there are some utilities which, when an error is encountered, return an error number in register A. In these case, a quick two-instruction sequence can give you an error-related abort. For example, the Rel_math utility is such a utility —

```
ISOURCE  JSM Rel_math
ISOURCE  SZA *+2
ISOURCE  JSM Error_exit
```

As an example of a fatal error, suppose the error desired is 8. The error sequence could be —

```
ISOURCE  LDA =100010B
ISOURCE  JSM Error_exit
```

Run-Time Messages

The following is a list of the system error messages you, or the users of your routines, may receive should something go wrong retrieving, using, or storing assembly language routines. A possible corrective action, or actions, is included in the discussion of the error.

ERROR 1 ROM missing, or configuration error. To operate the 9835A/B, all system ROMs must be in place. In addition, to write assembly programs, the Assembly Execution and the Assembly Development ROMs must also be installed. Perform the system test if the problem persists.

ERROR 2 Memory overflow. You may have specified an ICOM which is too large for your current available space. Some things to try: select a smaller ICOM size; execute SCRATCH C (if no important data remain in common), delete modules and reduce the ICOM size; segment your BASIC prorams; segment your assembly programs. The error may also be caused by trying to load modules which are too large for the current ICOM region (either collectively or individually).

ERROR 184 Improper argument in DECIMAL or OCTAL function. The OCTAL function has a range from − 65535 to + 65535. The DECIMAL function has a range for its arguments of − 177777_8 to + 177777_8.

ERROR 185 Break Table overflow. A maximum of eight breaks can be established with the IBREAK statements and be in effect at one time. If eight breaks are in effect, then to allow other breaks to be established it is necessary to clear previous breaks using the INORMAL statement.

ERROR 186 Undefined BASIC label or subprogram name used in IBREAK statement. When the IBREAK statement is executed, an undefined label or name is allowed, but when the break actually occurs, the label or name must exist.

ERROR 187 Attempt to write into protected memory; or, an attempt to execute an instruction not in the ICOM region. This is the result of an attempt to branch outside of permissible areas or to change the contents of memory outside of the permissible areas. There is probably a difficulty in the logic of the program which needs to be corrected. This error only occurs when the STEP key is being used, an IBREAK DATA statement is in effect, or when using the ICHANGE function.

ERROR 188 Label used in an assembled location not found. Symbolic addressing requires that all assembly symbols be resolved by execution time. This error probably results from a misspelling of a label or forgetting to assemble the module containing the label.

ERROR 189 Doubly-defined entry point or routine. A module being assembled (with an IASSEMBLE statement) or loaded from mass storage (with an ILOAD statement) contains a SUB or ENT entry point with the same label as a SUB or ENT entry point within a module already resident within the ICOM region. Check the other routines for the duplicate occurrences.

ERROR 190 Missing ICOM statement. You must include an ICOM statement to create your ICOM region before assembling or loading modules. Program an ICOM statement of adequate size and re-run the program

ERROR 191 Module not found. The module indicated in an ISTORE or IASSEMBLE statement is not currently resident in the ICOM region. Check the module names used in your ISTORE statement to find the one which is missing from memory.

ERROR 192 Errors in assembly. At least one error was encountered while assembling one of the modules in your IASSEMBLE statement.

ERROR 193 Attempt to move or delete module containing an active interrupt service routine. This is the result of trying to reduce the size of the ICOM region (or to eliminate it), or trying to delete a module, when one of the affected modules contains an active interrupt service routine (ISR). The only ways to allow the action to take place are to SCRATCH A (which affects a number of other things) or to inactivate the ISR. To inactivate the ISR, consult the routine's documentation, or press Reset (CONT'L STOP).

ERROR 194 IDUMP specification too large. The resulting dump would be more than 32 768 elements.

ERROR 195 Routine specified in ICALL not found. You are specifying the wrong routine name or you are failing to load the correct module. Double check the documentation indicating the location and name of the routine.

ERROR 196 Unsatisfied externals. Symbolic addressing requires that all references to symbols outside the current module be resolved at the time any routine within the current module is executed. This may possibly be a missing ENT instruction within another module.

ERROR 197 Missing COM statement. The routine you are calling is expecting to find or place some of its data in common, but you are not providing the COM statement required. Add the appropriate COM statement in the BASIC program and re-run it.

ERROR 198 BASIC'S common area does not correspond to assembly module requirements. The routine you have called is expecting to find or place some of its data in common, but your COM statement does not match up with the assembly COM declarations in either type or size. Check both the COM statement in the BASIC program and the COM declarations in the assembly routine.

ERROR 199 Insufficient number of BASIC COM items. The routine you are calling is expecting to find or place some of its data in common, but your BASIC COM statement does not provide enough variables to satisfy the routine's needs. Check both the COM statement in the BASIC program and the COM declarations in the assembly routine.

Assembly-Time Messages

The following is a list of the assembler error messages you may receive while assembling a module. All of these errors cause a "fatal" error, which means that the assembly produced no object code. After the error has been corrected, it is necessary to re-assemble the module containing the error. A possible corrective action, or actions, is included in the discussion of the error.

DD Doubly-defined label. A label can only be defined once in a module. In addition, any label used in an EXT instruction is restricted from being used again as a label in the module. Check all spellings; change a label name to something else, if necessary.

EN END statement missing; or module name does not match. The END statement (in an ISOURCE statement) must be included to signify the end of a module. The name in the END statement must match the name used in the immediately preceding NAM statement. Particular ones to look out for: assembling more than one module at a time, but leaving out the END instruction between modules; or, the END instruction is after the BASIC program's END statement.

EX Expression evaluation error. This is a result of a mismatch of element types in the operand of an instruction. The particular prohibited forms are: relocatable + relocatable; external ± external; using the relocatable or external forms with the * or / operators. Check the spelling and type of your symbols in the expression.

LT Literal pools full or out of range. You may have exhausted the storage given in your literal pool (LIT) declarations. In this case you should add more LIT declarations or increase the size of the ones you have. Another cause of the error can be using a literal in an instruction and there is no literal pool within 512 words of the instruction. Additionally, for some instructions, the assembler attempts to create an indirect reference automatically and requires a literal pool within 512 words of the instruction. In either case, add another literal pool (using a LIT instruction) within range.

MO ICOM region memory overflow. The current module being assembled has caused object code generation which exceeds the current memory allowance for the ICOM region. Either you must re-run the current **main BASIC program** with a new ICOM statement increasing the ICOM size, or you must rearrange your assembly so that the module fits. This latter course can include deleting other modules or rewriting the abortive module so that it requires less memory.

RN Operand out of range. Some instructions using indirection require a relocatable expression to evaluate to an address within 512 words of the current address. Skips must be no more than 32 words in either direction. The EXE instruction requires a register (0 to 31) and the instructions in the Stack Group require registers in the range of 0 to 7. Check to see that the operand used is within the range appropriate for the instruction. Also, check the spelling on all symbols to see that the right symbol was used.

SQ Parameter declaration pseudo-instruction out of sequence. The ANY, FIL, INT, REL, SHO, and STR pseudo-instructions must follow a SUB or COM pseudo-instruction, or be a part of a group of such pseudo-instructions which follow a SUB or COM pseudo-instruction. Any other appearance of these can cause this error. It can also be caused if a SUB sequence does not terminate with a machine instruction with a label. Check to see that you have not inadvertently omitted the SUB or COM, or have placed another instruction in between the pseudo-instruction and its SUB or COM.

TP Incorrect type of operand used. Each instruction requires that its operand be of a certain type — relocatable or absolute. Check the type of all symbols used in the expression in the operand and see that they correspond to the type required by the instruction. If you are using a constant, check to see that a constant is allowed by the instruction.

UN Undefined symbol. By the end of the assembly, all symbols must have been defined, either by use as a label on an instruction or as a symbol associated with a value through an EQU, EXT, or SET pseudo-instruction. A symbol not so defined, except those pre-defined by the assembler, and used in the assembly, causes this error. Check the spelling of all undefined symbols to make sure that you did not intend something else. The symbol otherwise has to be defined, either by label or EQU, EXT, or SET.

Appendices
Table of Contents

Appendix A
ASCII Character Set

The following table and chart show the ASCII character set and the keypresses necessary to obtain the ASCII character codes.

ASCII Character Set

ASCII Character	Comments	Key(s) to Press ☆	Octal Code	Decimal Code
NUL	Null	CONT'L space bar	00	0
SOH	Start of Header	CONT'L A	01	1
STX	Start of Text	CONT'L B	02	2
ETX	End of Text	CONT'L C	03	3
EOT	End of Transmission	CONT'L D	04	4
ENQ	Enquiry	CONT'L E	05	5
ACK	Acknowledgement	CONT'L F	06	6
BEL	Bell	CONT'L G	07	7
BS	Backspace	CONT'L H	10	8
HT	Horizontal Tab	CONT'L I	11	9
LF	Line Feed	CONT'L J	12	10
VT	Vertical Tab	CONT'L K	13	11
FF	Form Feed	CONT'L L	14	12
CR	Carriage Return	CONT'L M	15	13
SO	Shift Out	CONT'L N	16	14
SI	Shift In	CONT'L O	17	15
DLE	Data Link Escape	CONT'L P	20	16
DC1	Device Control	CONT'L Q	21	17
DC2	Device Control	CONT'L R	22	18
DC3	Device Control	CONT'L S	23	19
DC4	Device Control	CONT'L T	24	20
NAK	Negative Acknowledgement	CONT'L U	25	21
SYN	Synchronous Idle	CONT'L V	26	22
ETB	End of Text Block	CONT'L W	27	23
CAN	Cancel	CONT'L X	30	24
EM	End of Media	CONT'L Y	31	25
SUB	Substitute	CONT'L Z	32	26
ESC	Escape	CONT'L :/;	33	27
FS	File Separator	CONT'L SHIFT </,	34	28
GS	Group Separator	CONT'L +/=	35	29
RS	Record Separator	CONT'L ^	36	30
US	Unit Separator	CONT'L SHIFT _/6 *	37	31

☆ Assumes CAPS mode; multiple keys must be pressed simultaneously.

* Also can be found among calculator keys.

ASCII Character Set (continued)

ASCII Character	Comments	Key(s) to Press☆	Octal Code	Decimal Code
SP	Blank	[space bar]	40	32
!	Exclamation Point	[SHIFT] [! 1]	41	33
"	Double Quote	[SHIFT] [L]	42	34
#	Pound Sign	[SHIFT] [# 3]	43	35
$	Dollar Sign	[SHIFT] [$ 4]	44	36
%	Percent Sign	[SHIFT] [% 5]	45	37
&	Ampersand	[SHIFT] [& 7]	46	38
'	Apostrophe	[" ']	47	39
(	Left Parenthesis	[(]	50	40
)	Right Parenthesis	[)]	51	41
*	Asterisk	[SHIFT] [* 8] *	52	42
+	Plus Sign	[SHIFT] [+ =] *	53	43
,	Comma	[< ,] *	54	44
−	Minus Sign (Dash)	[−] *	55	45
.	Period	[> .] *	56	46
/	Forward Slash	[? /] *	57	47
0		[] 0] *	60	48
1		[! 1] *	61	49
2		[@ 2] *	62	50
3		[# 3] *	63	51
4	Numerics	[$ 4] *	64	52
5		[% 5] *	65	53
6		[− 6] *	66	54
7		[& 7] *	67	55
8		[* 8] *	70	56
9		[[9] *	71	57
:	Colon	[SHIFT] [: ;]	72	58
;	Semicolon	[: ;]	73	59
<	Less Than	[SHIFT] [< ,]	74	60
=	Equal	[+ =] *	75	61
>	Greater Than	[SHIFT] [> .]	76	62
?	Question Mark	[SHIFT] [? /]	77	63

☆ Assumes CAPS mode; multiple keys must be pressed simultaneously.

* Also can be found among calculator keys.

ASCII Character Set (continued)

ASCII Character	Comments	Key(s) to Press ☆	Octal Code	Decimal Code
@	Commercial At	SHIFT (@/2)	100	64
A		A	101	65
B		B	102	66
C		C	103	67
D		D	104	68
E		E	105	69
F		F	106	70
G		G	107	71
H		H	110	72
I		I	111	73
J		J	112	74
K		K	113	75
L		L	114	76
M	Capital Letters	M	115	77
N		N	116	78
O		O	117	79
P		P	120	80
Q		Q	121	81
R		R	122	82
S		S	123	83
T		T	124	84
U		U	125	85
V		V	126	86
W		W	127	87
X		X	130	88
Y		Y	131	89
Z		Z	132	90
[	Left Bracket	SHIFT ([/9)	133	91
\	Reverse Slash	Inaccessible from Keyboard	134	92
]	Right Bracket	SHIFT (]/0)	135	93
↑	Up Arrow	^	136	94
—	Underscore	SHIFT (—/6)	137	95

☆ Assumes CAPS mode; multiple keys must be pressed simultaneously.

* Also can be found among calculator keys.

ASCII Character Set (continued)

ASCII Character	Comments	Key(s) to Press*	Octal Code	Decimal Code
'	Grave Mark	Inaccessible from Keyboard	140	96
a	Noncapital Letters	SHIFT A	141	97
b		SHIFT B	142	98
c		SHIFT C	143	99
d		SHIFT D	144	100
e		SHIFT E	145	101
f		SHIFT F	146	102
g		SHIFT G	147	103
h		SHIFT H	150	104
i		SHIFT I	151	105
j		SHIFT J	152	106
k		SHIFT K	153	107
l		SHIFT L	154	108
m		SHIFT M	155	109
n		SHIFT N	156	110
o		SHIFT O	157	111
p		SHIFT P	160	112
q		SHIFT Q	161	113
r		SHIFT R	162	114
s		SHIFT S	163	115
t		SHIFT T	164	116
u		SHIFT U	165	117
v		SHIFT V	166	118
w		SHIFT W	167	119
x		SHIFT X	170	120
y		SHIFT Y	171	121
z		SHIFT Z	172	122
{	Left Brace	Inaccessible from Keyboard	173	123
|	Vertical Line		174	124
}	Right Brace		175	125
~	Tilde		176	126
DEL	Delete		177	127

* Assumes CAPS mode; multiple keys must be pressed simultaneously.

ASCII Character Codes

ASCII Char.	EQUIVALENT FORMS Binary	Oct	Hex	Dec
NULL	00000000	000	00	0
SOH	00000001	001	01	1
STX	00000010	002	02	2
ETX	00000011	003	03	3
EOT	00000100	004	04	4
ENQ	00000101	005	05	5
ACK	00000110	006	06	6
BELL	00000111	007	07	7
BS	00001000	010	08	8
HT	00001001	011	09	9
LF	00001010	012	0A	10
VT	00001011	013	0B	11
FF	00001100	014	0C	12
CR	00001101	015	0D	13
SO	00001110	016	0E	14
SI	00001111	017	0F	15
DLE	00010000	020	10	16
DC1	00010001	021	11	17
DC2	00010010	022	12	18
DC3	00010011	023	13	19
DC4	00010100	024	14	20
NAK	00010101	025	15	21
SYNC	00010110	026	16	22
ETB	00010111	027	17	23
CAN	00011000	030	18	24
EM	00011001	031	19	25
SUB	00011010	032	1A	26
ESC	00011011	033	1B	27
FS	00011100	034	1C	28
GS	00011101	035	1D	29
RS	00011110	036	1E	30
US	00011111	037	1F	31

ASCII Char.	EQUIVALENT FORMS Binary	Oct	Hex	Dec
space	00100000	040	20	32
!	00100001	041	21	33
"	00100010	042	22	34
#	00100011	043	23	35
$	00100100	044	24	36
%	00100101	045	25	37
&	00100110	046	26	38
'	00100111	047	27	39
(	00101000	050	28	40
)	00101001	051	29	41
*	00101010	052	2A	42
+	00101011	053	2B	43
,	00101100	054	2C	44
-	00101101	055	2D	45
.	00101110	056	2E	46
/	00101111	057	2F	47
0	00110000	060	30	48
1	00110001	061	31	49
2	00110010	062	32	50
3	00110011	063	33	51
4	00110100	064	34	52
5	00110101	065	35	53
6	00110110	066	36	54
7	00110111	067	37	55
8	00111000	070	38	56
9	00111001	071	39	57
:	00111010	072	3A	58
;	00111011	073	3B	59
<	00111100	074	3C	60
=	00111101	075	3D	61
>	00111110	076	3E	62
?	00111111	077	3F	63

ASCII Char.	EQUIVALENT FORMS Binary	Oct	Hex	Dec
@	01000000	100	40	64
A	01000001	101	41	65
B	01000010	102	42	66
C	01000011	103	43	67
D	01000100	104	44	68
E	01000101	105	45	69
F	01000110	106	46	70
G	01000111	107	47	71
H	01001000	110	48	72
I	01001001	111	49	73
J	01001010	112	4A	74
K	01001011	113	4B	75
L	01001100	114	4C	76
M	01001101	115	4D	77
N	01001110	116	4E	78
O	01001111	117	4F	79
P	01010000	120	50	80
Q	01010001	121	51	81
R	01010010	122	52	82
S	01010011	123	53	83
T	01010100	124	54	84
U	01010101	125	55	85
V	01010110	126	56	86
W	01010111	127	57	87
X	01011000	130	58	88
Y	01011001	131	59	89
Z	01011010	132	5A	90
[	01011011	133	5B	91
\	01011100	134	5C	92
]	01011101	135	5D	93
^	01011110	136	5E	94
_	01011111	137	5F	95

ASCII Char.	EQUIVALENT FORMS Binary	Oct	Hex	Dec
`	01100000	140	60	96
a	01100001	141	61	97
b	01100010	142	62	98
c	01100011	143	63	99
d	01100100	144	64	100
e	01100101	145	65	101
f	01100110	146	66	102
g	01100111	147	67	103
h	01101000	150	68	104
i	01101001	151	69	105
j	01101010	152	6A	106
k	01101011	153	6B	107
l	01101100	154	6C	108
m	01101101	155	6D	109
n	01101110	156	6E	110
o	01101111	157	6F	111
p	01110000	160	70	112
q	01110001	161	71	113
r	01110010	162	72	114
s	01110011	163	73	115
t	01110100	164	74	116
u	01110101	165	75	117
v	01110110	166	76	118
w	01110111	167	77	119
x	01111000	170	78	120
y	01111001	171	79	121
z	01111010	172	7A	122
{	01111011	173	7B	123
|	01111100	174	7C	124
}	01111101	175	7D	125
~	01111110	176	7E	126
DEL	01111111	177	7F	127

The following table gives the octal value for an ASCII character in the most significant byte ("First Character" column) and the least significant byte ("Second Character" column) of a word. The diagram illustrates the positions of the first and second character positions of a word.

First Character								Second Character							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

ASCII Character	First Character Octal Equivalent	Second Character Octal Equivalent
NUL	000000	000000
SOH	000400	000001
STX	001000	000002
ETX	001400	000003
EOT	002000	000004
ENQ	002400	000005
ACK	003000	000006
BEL	003400	000007
BS	004000	000010
HT	004400	000011
LF	005000	000012
VT	005400	000013
FF	006000	000014
CR	006400	000015
SO	007000	000016
SI	007400	000017
DLE	010000	000020
DC1	010400	000021
DC2	011000	000022
DC3	011400	000023
DC4	012000	000024
NAK	012400	000025
SYN	013000	000026
ETB	013400	000027
CAN	014000	000030
EM	014400	000031
SUB	015000	000032
ESC	015400	000033
FS	016000	000034
GS	016400	000035
RS	017000	000036
US	017400	000037
SP	020000	000040
!	020400	000041
"	021000	000042
#	021400	000043
$	022000	000044

ASCII Character	First Character Octal Equivalent	Second Character Octal Equivalent
%	022400	000045
&	023000	000046
'	023400	000047
(	024000	000050
)	024400	000051
*	025000	000052
+	025400	000053
,	026000	000054
-	026400	000055
.	027000	000056
/	027400	000057
0	030000	000060
1	030400	000061
2	031000	000062
3	031400	000063
4	032000	000064
5	032400	000065
6	033000	000066
7	033400	000067
8	034000	000070
9	034400	000071
:	035000	000072
;	035400	000073
<	036000	000074
=	036400	000075
>	037000	000076
?	037400	000077
@	040000	000100
A	040400	000101
B	041000	000102
C	041400	000103
D	042000	000104
E	042400	000105
F	043000	000106
G	043400	000107
H	044000	000110
I	044400	000111

ASCII Character	First Character Octal Equivalent	Second Character Octal Equivalent
J	045000	000112
K	045400	000113
L	046000	000114
M	046400	000115
N	047000	000116
O	047400	000117
P	050000	000120
Q	050400	000121
R	051000	000122
S	051400	000123
T	052000	000124
U	052400	000125
V	053000	000126
W	053400	000127
X	054000	000130
Y	054400	000131
Z	055000	000132
[	055400	000133
\	056000	000134
]	056400	000135
∧	057000	000136
8	057400	000137
‘	060000	000140
a	060400	000141
b	061000	000142
c	061400	000143
d	062000	000144

ASCII Character	First Character Octal Equivalent	Second Character Octal Equivalent
e	062400	000145
f	063000	000146
g	063400	000147
h	064000	000150
i	064400	000151
j	065000	000152
k	065400	000153
l	066000	000154
m	066400	000155
n	067000	000156
o	067400	000157
p	070000	000160
q	070400	000161
r	071000	000162
s	071400	000163
t	072000	000164
u	072400	000165
v	073000	000166
w	073400	000167
x	074000	000170
y	074400	000171
z	075000	000172
{	075400	000173
⊦	076000	000174
}	076400	000175
∿	077000	000176
DEL	077400	000177

Appendix B
Machine Instructions

Detailed List

Instruction	Form	Group	Description	Page
AAR	AAR {n}	Shift/Rotate	Shifts the A register right the indicated number of bits with the sign bit filling all vacated bit positions. (Arithmetic right)	40
ABR	ABR{n}	Shift/Rotate	Shifts the B register right the indicated number of bits with the sign bit filling all vacated bit positions. (Arithmetic right)	40
ADA	ADA {loc} [, I]	Integer Math	Adds the contents of the specified location to the contents of register A. The result is in A. If a carry occurs, Extend is set, otherwise Extend is unchanged. If an overflow occurs, Overflow is set, otherwise Overflow is unchanged. A carry is from bit 15; an overflow is a carry from bit 15 or 14, but not both. Extend and Overflow are bits in the processor. Specifying register R4, R5, R6, or R7 as the location causes an input I/O bus cycle to the interface addressed by the Pa register. Indirect addressing may be specified. {loc} must be on base or current page.	35
ADB	ADB {loc} [, I]	Integer Math	Adds the contents of the specified location to the contents of register B. The result is in B. If a carry occurs, Extend is set, otherwise Extend is unchanged. If an overflow occurs, Overflow is set, otherwise Overflow is unchanged. A carry is from bit 15; an overflow is a carry from bit 15 or 14, but not both. Extend and Overflow are bits in the processor. Specifying register R4, R5, R6, or R7 as the location causes an input I/O bus cycle to the interface addressed by the Pa register. Indirect addressing may be specified. {loc} must be on base or current page.	35

Instruction	Form	Group	Description	Page
AND	AND {loc} [, I]	Logical	Logical "and" operation. The contents of the A register are compared, bit by bit, with the contents of the specified location. For each bit comparison a 1 results if both bits are 1's, a 0 results otherwise. The 16-bit result is left in A. Specifying register R4, R5, R6, or R7 causes an input bus cycle to the interface addressed by the Pa register. Indirect addressing may be specified. {loc} must be on base or current page.	41
CBL	CBL	Stack	Clears the Cb register. Specifies the lower block of memory for byte-referencing stack instructions.	43
CBU	CBU	Stack	Sets the Cb register. Specifies the upper block of memory for byte-referencing stack instructons.	43
CDC	CDC	BCD Math	Clears Decimal Carry explicitly.	
CLA	CLA	Shift	Clears register A. This is exactly equivalent to SAR 16.	41
CLB	CLB	Shift	Clears register B. This is exactly equivalent to SBR 16.	41
CLR	CLR {n}	Load/Store	Clears the specified number of words, beginning at the location pointed at by the A register. A maximum of 16 words may be cleared.	34
CMA	CMA	Memory	Perform a one's complement of the A register (bit by bit inversion of all 16 bits).	41
CMB	CMB	Memory	Perform a one's complement of the B register (bit by bit inversion of all 16 bits).	41
CMX	CMX	BCD Math	Ten's complement of Ar1. The mantissa of Ar1 is replaced with its ten's complement and Decimal Carry is cleared.	45
CMY	CMY	BCD Math	Ten's complement of Ar2. The mantissa of Ar2 is replaced with its ten's complement and Decimal Carry is cleared.	46
CPA	CPA {loc} [, I]	Test/Branch	Compares the contents of register A with the contents of the specified location and skips if they are unequal. Indirect addressing may be specified. Specifying register R4, R5, R6, or R7 causes an input bus cycle to the interface addressed by the Pa register. {loc} must be on base or current page.	37

Instruction	Form	Group	Description	Page
CPB	CPB {loc} [, I]	Test/Branch	Compares the contents of register B with the contents of the specified location and skips if they are unequal. Indirect addressing may be specified. Specifying register R4, R5, R6, or R7 causes an input bus cycle to the interface addressed by the Pa register. {loc} must be on base or current page. {loc} must be on base or current page.	37
DBL	DBL	Stack	Clears the Db register. Specifies the lower block of memory for byte-referencing stack instructions.	43
DBU	DBU	Stack	Sets the Db register. Specifies the upper block of memory for byte-referencing stack instructions.	43
DDR	DDR	I/O	Disables Data Request. Cancels the DMA instruction.	47
DIR	DIR	I/O	Disables the interrupt system. Cancels the EIR instruction.	47
DMA	DMA	I/O	Enables the DMA mode. Cancels the DDR instruction.	47
DRS	DRS	BCD Math	Mantissa right shift of Ar1 for one digit. The twelfth digit is shifted into bits 0-3 of the A register. The non-digit part of the A register is cleared (bits 4-15), and the Decimal Carry bit in the processor is cleared. The first digit in the mantissa is set to 0.	45
DSZ	DSZ {loc} [, I]	Test/Alter/Branch	Decrements the contents of the specified location and skips if the new contents are 0. Specifying register R4, R5, R6, or R7 causes an input (or an input and an output) bus cycle to the interface addressed by the Pa register. Indirect addressing may be specified. {loc} must be on base or current page.	38
EIR	EIR	I/O	Enables the interrupt system. Cancels the DIR instruction.	47

Instruction	Form	Group	Description	Page
EXE	EXE {reg} [, I]	Miscellaneous	Executes the contents of a register. {reg} is an integer in the range of 0 through 31, indicating the register to be used (see Memory Map for the correspondence between location and register). The register is left unchanged unless the instruction code causes it to be altered. The next instruction to be executed is the one following the EXE, unless the code in the executed register causes a branch. Indirect addressing may be specified.	47
FDV	FDV	BCD Math	Fast divide. The mantissas of Ar1 and Ar2 are added together, along with Decimal Carry, until the first decimal overflow occurs. The result accumulates into Ar2. The number of additions without overflow is placed into the lower 4 bits of the B register (0-3). The remainder of the B register is cleared, as is the Decimal Carry bit in the processor.	46
FMP	FMP	BCD Math	Fast Multiply. Performs the multiplication by repeated additions. The mantissa of Ar1 is added to Ar2 along with Decimal carry, a specified number of times. The number of times is specified in the lower 4 bits (0-3) of the B register. The result accumulates in Ar2. If intermediate overflows occur, the number of times they occur appears in the lower 4 bits of the A register after the operation is complete. The upper 12 bits of the A register are cleared along with Decimal Carry.	46
FXA	FXA	BCD Math	Fixed-point addition. The mantissas of Ar1 and Ar2 are added together and the result placed in Ar2. Decimal Carry is used as the twelfth digit. After the addition, Decimal Carry is set if an overflow occurred, otherwise Decimal Carry is cleared.	46
IOR	IOR {loc} [, I]	Logical	Logical "inclusive or" operation. The contents of the A register are compared, bit by bit, with the contents of the specified location. For each bit comparison, a 0 results if both bits are 0's, a 1 otherwise. The 16-bit result is left in A. Specifying register R4, R5, R6, or R7 causes an input bus cycle to the interface addressed by the Pa register. Indirect addressing may be specified. {loc} must be on base or current page.	41

Instruction	Form	Group	Description	Page
ISZ	ISZ {loc} [, I]	Test/Alter/Branch	Increments the contents of the specified location and skips if the new contents are 0. Specifying register R4, R5, R6, or R7 causes an input (or an input followed by an output) bus cycle to the interface addressed by the Pa register. Indirect addressing may be specified. {loc} must be on base or current page.	38
JMP	JMP {loc} [, I]	Branch	Unconditionally branches to the specified location. Indirect addressing may be specified. {loc} must be on base or current page.	36
JSM	JSM {loc} [, I]	Branch	Jumps to subroutine. The value of the R register is incremented by 1 and the value of the P register (i.e., the location of the JSM instruction itself) is stored in the address pointed to by the R register. Execution then proceeds to the specified location. Return from the subroutine is effected by the RET instruction. Indirect addressing may be specified. {loc} must be on base or current page.	36
LDA	LDA {loc} [, I]	Load/Store	Loads register A with the contents of the specified location. Specifying register R4, R5, R6, or R7 causes an input I/O bus cycle to the interface addressed by the Pa register. Indirect addressing may be specified. {loc} must be on base or current page.	34
LDB	LDB {loc} [, I]	Load/Store	Loads register B with the contents of the specified location. Specifying register R4, R5, R6, or R7 causes an input I/O bus cycle to the interface addressed by the Pa register. Indirect addressing may be specified. {loc} must be on base or current page.	34
MLY	MLY	BCD Math	Mantissa left shift on Ar2 for one digit. This is a circular shift, with the bits 0-3 of the A register forming a thirteenth digit. The non-digit part of the A register is cleared (bits 4-15), and the Decimal Carry bit in the processor is cleared.	45

Instruction	Form	Group	Description	Page
MPY	MPY	Integer Math	Binary multiply. Uses Booth's Algorithm. The values of the A and B registers are multiplied together with the product placed into A and B. The A register contains the least significant bits and the B register contains the most significant bits and the sign. B may contain any integer value except − 32 768.	35
MRX	MRX	BCD Math	Mantissa right shift on Ar1. The number of digits to be shifted is specified in the lower 4 bits (0-3) of the B register. The shift is accomplished in three stages: 1) Bits 0-3 of the A register are right-shifted into D_1 of the mantissa, with the twelfth digit being lost. This is the first shift. This shift always takes place, even if B = 0. 2) The digits are then right-shifted for the remaining number of digits specified. The twelfth digit is lost on each shift (except for the last shift) and the vacated digits are zero-filled. 3) Finally, the last right-shifting takes place, with the twelfth digit shifting into the lower 4 bits (0-3) of the A register. The Decimal Carry bit in the processor is cleared and the non-digit part of the A register is cleared (bits 4-15).	44
MRY	MRY	BCD Math	Mantissa right shift on Ar2. The number of digits to be shifted is specified in the lower 4 bits (0-3) of the B register. The shift is accomplished in three stages: 1) Bits 0-3 of the A register are right-shifted into D_1 of the mantissa, with the twelfth digit being lost. This is the first shift. This shift always takes place, even if B = 0. 2) The digits are right-shifted for the remaining number of digits specified. The twelfth digit is lost on each shift (except for the last shift) and the vacated digits are zero-filled.	45

Instruction	Form	Group	Description	Page
			3) Finally, the last right-shifting takes place, with the twelfth digit shifting into the lower 4 bits (0-3) of the A register. The non-digit part of the A register is cleared (bits 4-15), and the Decimal Carry bit in the processor is cleared.	
MWA	MWA	BCD Math	Mantissa word addition. The contents of the B register are added to the ninth through twelfth digits of the Ar2 register. Decimal Carry is added to the twelfth digit; if an overflow occurs, Decimal Carry is set, otherwise Decimal Carry is cleared.	46
NOP	NOP	Miscellaneous	Null operation. This is exactly equivalent to LDA A.	47
NRM	NRM	BCD Math	Normalizes the Ar2 mantissa. Up to twelve left-shifts of the mantissa are performed until the first digit of the mantissa is non-zero. If the original first digit is already non-zero, no shifts occur. The number of shifts required is stored in the first 4 bits (0-3) of the B register. If 12 shifts are required, the Decimal Carry bit in the processor is set; otherwise, the Decimal Carry bit is cleared. The exponent is not altered.	45
PBC	PBC {reg} [, I]	Stack	Pushes the lower byte (right half) of the specified register onto the stack pointed at by the Cb and C registers. Specifying register R4, R5, R6, or R7 causes an input I/O bus cycle to the interface addressed by the Pa register. Incrementing or decrementing of the C register can be specified. Incrementing is the default. {reg} must be in the range of 0 through 7. The incrementing or decrementing action takes place before pushing.	43
PBD	PBD {reg} , D PBD {reg} [, I]	Stack	Pushes the lower byte (right half) of the specified register onto the stack pointed at by the Db and D registers. Specifying register R4, R5, R6, or R7 causes an input I/O bus cycle to the interface addressed by the Pa register. Incrementing or decrementing the D register can be specified. Incrementing is the default. {reg} must be in the range of 0 through 7.The incrementing or decrementing action takes place before pushing.	43

Instruction	Form	Group	Description	Page
PWC	PWC **{reg}** , D PWC **{reg}** [, I]	Stack	Pushes entire register (full word) onto the stack pointed at by the C register. Specifying register R4, R5, R6, or R7 causes an input I/O bus cycle to the interface addressed by the Pa register. Incrementing or decrementing the C register may be specified. Incrementing is the default. {reg} must be in the range of 0 through 7. The incrementing or decrementing action takes place before pushing.	43
PWD	PWD **{reg}** , D PWD **{reg}** [, I]	Stack	Pushes the entire register (full word) onto the stack pointed at by the D register. Specifying register R4, R5, R6, or R7 causes an input I/O bus cycle to the interface addressed by the Pa register. Incrementing or decrementing the D register may be specified. Incrementing is the default. {reg} must be in the range of 0 through 7. The incrementing or decrementing action taken place before pushing.	43
RAL	RAL **{n}**	Shift/Rotate	Rotates the A register left the indicated number of bits. Bit 15 rotates into bit 0 (left circular). Maximum rotation of 16 bits.	40
RAR	RAR **{n}**	Shift/Rotate	Rotates the A register right the indicated number of bits. Bit 0 rotates into bit 15 (right circular). Maximum rotation of 16 bits.	40
RBL	RBL **{n}**	Shift/Rotate	Rotates the B register left the indicated number of bits. Bit 15 rotates into bit 0 (left circular). Maximum rotation of 16 bits rotated.	40
RBR	RBR **{n}**	Shift/Rotate	Rotates the B register right the indicated number of bits. Bit 0 rotates into bit 15 (right circular). Maximum rotation of 16 bits.	40
RET	RET **{n}**	Branch	Returns from subroutine. {n} is added to the contents of the address pointed to by the R register. The R register is decremented by 1. This is, in effect, a return from a JSM instruction (see above), to {n} instructions following the JSM itself. The "usual" return is RET 1. {n} must be in the range of − 32 through 31.	36

Instruction	Form	Group	Description	Page
RIA	RIA {adrs}	Test/Branch	Skips to {adrs}if register A is not 0, then increments register A by 1. Extend and Overflow are not effected by the incrementing action, even if a carry or overflow occurs. {adrs} must be within − 32 and + 31 of the current location.	37
RIB	RIB {adrs}	Test/Branch	Skips to {adrs} if register B is not 0, then increments register B by 1. Extend and Overflow are not affected by the incrementing action, even if a carry or overflow occurs. {adrs} must be within − 32 and + 31 of the current location.	37
RLA	RLA {adrs} [, S] RLA {adrs} [, C]	Test/Alter/Branch	Skips to {adrs} if the least significant bit of the A register is not 0. Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 of the current location.	39
RLB	RLB {adrs} [, S] RLB {adrs} [, C]	Test/Alter/Branch	Skips to {adrs} if the least significant bit of the B register is not 0. Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 the current location.	39
RZA	RZA {adrs}	Test/Branch	Skips to {adrs} if register A is not 0. {adrs} must be within − 32 and + 31 of the current location.	37
RZB	RZB {adrs}	Test/Branch	Skips to {adrs} if register B is not 0. {adrs} must be within − 32 and + 31 of the current location.	37
SAL	SAL {n}	Shift/Rotate	Shifts the A register left the indicated number of bits with all vacated bit positions becoming 0. Maximum shift is 16 bits.	40
SAM	SAM {adrs} [, S] SAM {adrs} [, C]	Test/Alter/Branch	Skips to {adrs} if the A register is negative (bit 15 is 1). Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 of the current location.	38
SAP	SAP {adrs} [, S] SAP {adrs} [, C]	Test/Alter/Branch	Skips to {adrs} if the A register is positive or zero (bit 15 is 0). Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 of the current location.	38
SAR	SAR {n}	Shift/Rotate	Shifts the A register right the indicated number of bits with all vacated bit positions becoming 0. Maximum shift is 16 bits.	40

Instruction	Form	Group	Description	Page
SBL	SBL {n}	Shift/Rotate	Shifts the B register left the indicated number of bits with all vacated bit positions becoming 0. Maximum shift is 16 bits.	40
SBM	SBM {adrs} [, S] SBM {adrs} [, C]	Test/Alter/Branch Test/Alter/Branch	Skips to {adrs} if the B register is negative (bit 15 is 1). Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 of the current location.	38
SBP	SBP {adrs} [, S] SBP {adrs} [, C]	Test/Alter/Branch	Skips to {adrs} if the B register is positive (bit 15 is 0). Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 of the current location.	38
SBR	SBR {n}	Shift/Rotate	Shifts the B register right the indicated number of bits with all vacated bit positions becoming 0. Maximum shift is 16 bits.	40
SDC	SDC {adrs}	BCD Math	Skips to {adrs} if Decimal Carry is clear. Decimal carry is a single bit in the processor which may have been set by certain arithmetic operations. {adrs} must be within − 32 and + 31 of the current location.	46
SDI	SDI	I/O	Sets DMA inwards. Reads from peripheral, writes to memory.	47
SDO	SDO	I/O	Sets DMA outwards. Reads from memory, writes to peripheral.	47
SDS	SDS {adrs}	BCD Math	Skips to {adrs} if Decimal Carry is set. Decimal carry is a single bit in the processor which may have been set by certain arithmetic operations. {adrs} must be with − 32 and + 31 of the current location.	46
SEC	SEC {adrs} [, S] SEC {adrs} [, C]	Test/Alter/Branch	Skips to {adrs} if Extend is clear. Extend is a single bit in the processor which may have been set by certain arithmetic operations. Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 of the current location.	39

Instruction	Form	Group	Description	Page
SES	SES {adrs} [, S] SES {adrs} [, C]	Test/Alter/Branch	Skips to {adrs} if Extend is set. Extend is a single bit in the processor which may have been set by certain arithmetic operations. Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 of the current location.	39
SFC	SFC {adrs}	I/O	Skips to {adrs} if the Flag line is false (clear). The Flag line is the one associated with a peripheral on the current select code (pointed to by the Pa register). {adrs} must be within − 32 and + 31 of the current location.	47
SFS	SFS {adrs}	I/O	Skips to {adrs} if the Flag line is true (set). The flag line is that associated with the peripheral on the current select code (pointed to by the Pa register). {adrs} must be within - 32 and + 31 of the current location.	47
SIA	SIA {adrs}	Test/Branch	Skips to {adrs} if register A is 0, then increments register A by 1. Extend and Overflow are not affected by the incrementing action, even if a carry or overflow occurs. {adrs} must be within − 32 and + 31 of the current location.	37
SIB	SIB {adrs}	Test/Branch	Skips to {adrs} if register B is 0, then increment register B by 1. Extend and Overflow are not affected by the incrementing action, even if a carry or overflow occurs. {adrs} must be within − 32 and + 31 of the current location.	37
SLA	SLA {adrs} [, S] SLA {adrs} [, C]	Test/Alter/Branch	Skips to {adrs} if the least significant bit of the A register is 0. Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 of the current location.	38
SLB	SLB {adrs} [, C] SLB {adrs} [, S]	Test/Alter/Branch	Skips to {adrs} if the least significant bit of the B register is 0. Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 of the current location.	39

Instruction	Form	Group	Description	Page
SOC	SOC {adrs} [, S] SOC {adrs} [, C]	Test/Alter/Branch	Skips to {adrs} if Overflow is clear. Overflow is a single bit in the processor which may have been set by certain arithmetic operations. Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 of the current location.	39
SOS	SOS {adrs} [, S] SOS {adrs} [, C]	Test/Alter/Branch	Skips to {adrs} if the Overflow is set. Overflow is a single bit in the processor which may have been set by certain arithmetic operations. Setting or clearing the bit after the test can be specified. {adrs} must be within − 32 and + 31 of the current location.	39
SSC	SSC {adrs}	I/O	Skips to {adrs} if Status line is false (clear). The status line is the one associated with the peripheral on the current select code (pointed to by the Pa register). {adrs} must be within − 32 and + 31 of the current location.	47
SSS	SSS {adrs}	I/O	Skips to {adrs} if the Status line is true (set). The status line is the one associated with the peripheral on the current select code (pointed to by the Pa register). {adrs} must be within − 32 and + 31 of the current location.	47
STA	STA {loc} [, I]	Load/Store	Stores the contents of the A register into the spcified location. Specifying register R4, R5, R6, or R7 causes an output bus cycle to the interface addressed by the Pa register. Indirect addressing may be specified. {loc} must be on base or current page.	34
STB	STB {loc} [, I]	Load/Store	Stores the contents of the B register into the specified location. Specifying register R4, R5, R6, or R7 causes an output bus cycle to the interface addressed by the Pa register. Indirect addressing may be specified. {loc} must be on base or current page.	34
SZA	SZA {adrs}	Test/Branch	Skips to {adrs} if register A is 0. {adrs} must be within − 32 and + 31 of the current location.	37
SZB	SZB {adrs}	Test/Branch	Skips to {adrs} if register B is 0. {adrs} must be within − 32 and + 31 of the current location.	37

Instruction	Form	Group	Description	Page
TCA	TCA	Integer Math	Performs a two's complement of the A register (one's complement, incremented by 1). If a carry occurs, Extend is set, otherwise Extend is unchanged. If an overflow occurs, Overflow is set, otherwise Overflow is unchanged. A carry is from bit 15; an overflow occurs when complementing − 32 768. Extend and Overflow are bits in the processor.	35
TCB	TCB	Integer Math	Performs a two's complement of the B register (one's complement, incremented by 1). If a carry occurs, Extend is set, otherwise Extend is unchanged. If an overflow occurs, Overflow is set, otherwise Overflow is unchanged. A carry is from bit 15; an overflow occurs when complementing − 32 768. Extend and Overflow are bits in the processor.	35
WBC	WBC {reg} [, D] WBC {reg} , I	Stack	Withdraws a byte from the stack pointed at by the Cb and C registers and places it into the lower byte (right half) of the specified register. Specifying register R4, R5, R6, or R7 causes an output I/O bus cycle to the interface addressed by the Pa register. Incrementing or decrementing the C register can be specified. Decrementing is the default. {reg} must be in the range of 0 through 31. The incrementing or decrementing routine takes place after the withdrawal.	43
WBD	WBD {reg} [, D] WBD {reg} , I	Stack	Withdraws a byte from the stack pointed at by the Db and D registers and places it into the lower byte (right half) of the specified register. Specifying register R4, R5, R6, or R7 causes an output I/O bus cycle to the interface addressed by the Pa register. Incrementing or decrementing the D register can be specified. Decrementing is the default. {reg} must be in the range of 0 through 31. The incrementing or decrementing routine takes place after the withdrawal.	43

Instruction	Form	Group	Description	Page
WWC	WWC {reg} [, D] WWC {reg} , I	Stack	Withdraws a full word from the stack pointed at by the C register and places it into the specified register. Specifying register R4, R5, R6, or R7 causes an output I/O bus cycle to the interface addressed by the Pa register. Incrementing or decrementing of the C register can be specified. Decrementing is the default. {reg} must be in the range of 0 through 31. The incrementing or decrementing action takes place after the withdrawal.	43
WWD	WWD {reg} [, D] WWD {reg} , I	Stack	Withdraws a full word from the stack pointed at by the D register and places it into the specified register. Specifying register R4, R5, R6, or R7 causes an output I/O bus cycle to the interface addressed by the Pa register. Incrementing or decrementing of the D register can be specified. Decrementing is the default. {reg} must be in the range of 0 through 31. The incrementing or decrementing action takes place after the withdrawal.	43
XFR	XFR {n}	Load/Store	Transfers the specified number of words, from the location starting at the address pointed at by the A register to the location starting at the address pointed at by the B register. A maximum of 16 words can be transferred.	34

Alphabetic List
Bit Patterns and Timings

Instruction	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Timing
AAR n	1	1	1	1	0	0	0	1	0	0	0	0	← n−1 →				n+9
ABR n	1	1	1	1	1	0	0	1	0	0	0	0	← n−1 →				n+9
ADA	D/I	0	1	0	0	B/C	← address →										19
ADB	D/I	0	1	0	1	B/C	← address →										19
AND	D/I	1	0	1	0	B/C	← address →										19
CBL	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	12
CBU	0	1	1	1	0	0	0	1	0	1	0	1	1	0	0	0	12
CDC	0	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	11
CLA	1	1	1	1	0	0	0	1	0	1	0	0	1	1	1	1	25
CLB	1	1	1	1	1	0	0	1	0	1	0	0	1	1	1	1	25
CLR n	0	1	1	1	0	0	1	1	1	0	0	0	← n−1 →				6n+16
CMA	1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	0	9
CMB	1	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0	9
CMX	0	1	1	1	0	0	1	0	0	1	1	0	0	0	0	0	59
CMY	0	1	1	1	0	0	1	0	0	0	1	0	0	0	0	0	23
CPA	D/I	0	0	1	0	B/C	← address →										22
CPB	D/I	0	0	1	1	B/C	← address →										22
DBL	0	1	1	1	0	0	0	1	0	1	0	0	0	0	0	0	12
DBU	0	1	1	1	0	0	0	1	0	1	0	1	0	0	0	0	12
DDR	0	1	1	1	0	0	0	1	0	0	1	1	1	0	0	0	12
DIR	0	1	1	1	0	0	0	1	0	0	0	1	1	0	0	0	12
DMA	0	1	1	1	0	0	0	1	0	0	1	0	0	0	0	0	12
DRS	0	1	1	1	1	0	1	1	0	0	1	0	0	0	0	1	56
DSZ	D/I	1	0	1	1	B/C	← address →										25
EIR	0	1	1	1	0	0	0	1	0	0	0	1	0	0	0	0	12
EXE	D/I	1	1	1	0	0	0	0	0	0	0	← register →					14
FDV	0	1	1	1	1	0	1	0	0	0	1	0	0	0	0	1	37+13B
FMP	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	42+13B (note 2)
FXA	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	40
IOR	D/I	1	1	0	0	B/C	← address →										19
ISZ	D/I	1	0	0	1	B/C	← address →										25
JMP	D/I	1	1	0	1	B/C	← address →										14
JSM	D/I	1	0	0	0	B/C	← address →										23
LDA	D/I	0	0	0	0	B/C	← address →										19
LDB	D/I	0	0	0	1	B/C	← address →										19
MLY	0	1	1	1	1	0	1	1	0	1	1	0	0	0	0	1	32
MPY	0	1	1	1	1	0	1	1	1	0	0	0	1	1	1	1	65+2T (note 3)
MRX	0	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	62+4B (note 4)
MRY	0	1	1	1	1	0	1	1	0	1	0	0	0	0	0	0	33+4B (note 4)
MWA	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	28
NOP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
NRM	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0	23+Z (note 5)
PBC r	0	1	1	1	1	0	0	1	I/O	1	1	0	0	← r →			23
PBD r	0	1	1	1	1	0	0	1	I/O	1	1	0	1	← r →			23
PWC r	0	1	1	1	0	0	0	1	I/O	1	1	0	0	← r →			23
PWD r	0	1	1	1	0	0	0	1	I/O	1	1	0	1	← r →			23

Instruction	15	14	13	12	11	10	9	8
RAL n	1	1	1	1	0	0	0	1
RAR n	1	1	1	1	0	0	0	1
RBL n	1	1	1	1	1	0	0	1
RBR n	1	1	1	1	1	0	0	1
RET	1	1	1	1	0	0	0	0
RIA	0	1	1	1	0	1	0	0
RIB	0	1	1	1	1	1	0	0
RLA	0	1	1	1	0	1	1	1
RLB	0	1	1	1	1	1	1	1
RZA	0	1	1	1	0	1	0	0
RZB	0	1	1	1	1	1	0	0
SAL n	1	1	1	1	0	0	0	1
SAM	1	1	1	1	0	1	0	1
SAR n	1	1	1	1	0	0	0	1
SBL n	1	1	1	1	1	0	0	1
SBM	1	1	1	1	1	1	0	1
SBP	1	1	1	1	1	1	0	0
SBR n	1	1	1	1	1	0	0	1
SDC	0	1	1	1	0	1	0	1
SDI	0	1	1	1	0	0	0	1
SDO	0	1	1	1	0	0	0	1
SDS	0	1	1	1	0	1	0	0
SEC	1	1	1	1	1	1	1	0
SES	1	1	1	1	1	1	1	1
SFC	0	1	1	1	0	1	0	1
SFS	0	1	1	1	0	1	0	0
SIA	0	1	1	1	0	1	0	1
SIB	0	1	1	1	1	1	0	1
SLA	0	1	1	1	0	1	1	0
SLB	0	1	1	1	1	1	1	0
SOC	1	1	1	1	0	1	1	0
SOS	1	1	1	1	0	1	1	1
SSC	0	1	1	1	1	1	0	1
SSS	0	1	1	1	1	1	0	0
STA	D/I	0	1	1	0	B/C	←	
STB	D/I	0	1	1	1	B/C	←	
SZA	0	1	1	1	0	1	0	1
SZB	0	1	1	1	1	1	0	1
TCA	1	1	1	1	0	0	0	0
TCB	1	1	1	1	1	0	0	0
WBC r	0	1	1	1	1	0	0	1
WBD r	0	1	1	1	1	0	0	1
WWC r	0	1	1	1	0	0	0	1
WWD r	0	1	1	1	0	0	0	1
XFR n	0	1	1	1	0	0	1	1

Instruction	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Timing
RAL n	1	1	1	1	0	0	0	1	1	1	0	0	← 15−n →				25−n
RAR n	1	1	1	1	0	0	0	1	1	1	0	0	← n−1 →				n+9
RBL n	1	1	1	1	1	0	0	1	1	1	0	0	← 15−n →				25−n
RBR n	1	1	1	1	1	0	0	1	1	1	0	0	← n−1 →				n+9
RET	1	1	1	1	0	0	0	0	1	0	← skip →						16
RIA	0	1	1	1	0	1	0	0	0	1	← skip →						14
RIB	0	1	1	1	1	1	0	0	0	1	← skip →						14
RLA	0	1	1	1	0	1	1	1	$H/\overline{H}$	C/S	← skip →						14
RLB	0	1	1	1	1	1	1	1	$H/\overline{H}$	C/S	← skip →						14
RZA	0	1	1	1	0	1	0	0	0	0	← skip →						14
RZB	0	1	1	1	1	1	0	0	0	0	← skip →						14
SAL n	1	1	1	1	0	0	0	1	1	0	0	0	← n−1 →				n+9
SAM	1	1	1	1	0	1	0	1	$H/\overline{H}$	C/S	← skip →						14
SAR n	1	1	1	1	0	0	0	1	0	1	0	0	← n−1 →				n+9
SBL n	1	1	1	1	1	0	0	1	1	0	0	0	← n−1 →				n+9
SBM	1	1	1	1	1	1	0	1	$H/\overline{H}$	C/S	← skip →						14
SBP	1	1	1	1	1	1	0	0	$H/\overline{H}$	C/S	← skip →						14
SBR n	1	1	1	1	1	0	0	1	0	1	0	0	← n−1 →				n+9
SDC	0	1	1	1	0	1	0	1	1	1	← skip →						14
SDI	0	1	1	1	0	0	0	1	0	0	0	0	1	0	0	0	12
SDO	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	12
SDS	0	1	1	1	0	1	0	0	1	1	← skip →						14
SEC	1	1	1	1	1	1	1	0	$H/\overline{H}$	C/S	← skip →						14
SES	1	1	1	1	1	1	1	1	$H/\overline{H}$	C/S	← skip →						14
SFC	0	1	1	1	0	1	0	1	1	0	← skip →						14
SFS	0	1	1	1	0	1	0	0	1	0	← skip →						14
SIA	0	1	1	1	0	1	0	1	0	1	← skip →						14
SIB	0	1	1	1	1	1	0	1	0	1	← skip →						14
SLA	0	1	1	1	0	1	1	0	$H/\overline{H}$	C/S	← skip →						14
SLB	0	1	1	1	1	1	1	0	$H/\overline{H}$	C/S	← skip →						14
SOC	1	1	1	1	0	1	1	0	$H/\overline{H}$	C/S	← skip →						14
SOS	1	1	1	1	0	1	1	1	$H/\overline{H}$	C/S	← skip →						14
SSC	0	1	1	1	1	1	0	1	1	0	← skip →						14
SSS	0	1	1	1	1	1	0	0	1	0	← skip →						14
STA	D/I	0	1	1	0	B/C	← address →										19
STB	D/I	0	1	1	1	B/C	← address →										19
SZA	0	1	1	1	0	1	0	1	0	0	← skip →						14
SZB	0	1	1	1	1	1	0	1	0	0	← skip →						14
TCA	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	9
TCB	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	9
WBC r	0	1	1	1	1	0	0	1	I/O	1	1	1	0	← r →			23
WBD r	0	1	1	1	1	0	0	1	I/O	1	1	1	1	← r →			23
WWC r	0	1	1	1	0	0	0	1	I/O	1	1	1	0	← r →			23
WWD r	0	1	1	1	0	0	0	1	I/O	1	1	1	1	← r →			23
XFR n	0	1	1	1	0	0	1	1	0	0	0	0	← n−1 →				12n+21

Notes on bit patterns:

B/C (Base Page/Current Page)
C/S (Clear/Set)
D/I (Direct/Indirect)
$H/\overline{H}$ (Hold/Don't Hold)
I/D (Increment/Decrement)
} All are coded 0/1 respectively

skip
address
} if the high bit in the field is 1, the field is negative (2's complement)

Notes on timings:

All timings are maximum clock times. The clock rate is 6 megahertz. Clock times may vary up to ± 5% from the clock rate.

Any operation using register R4, R5, R6, or R7, should add 7 clock times.

Any operation using register R8, R9, R10, R11, R12, R13, R14, or R15 should add 5 clock times.

Maximum interrupt lockout time is 239.
Minimum interrupt lockout time is 2.

Maximum DMA lockout time is 10.
Minimum DMA lockout time is 2.

Interrupt execution is 36.

DMA read = 3 + 10n + lockout time
DMA write = 3 + 9n + lockout time
} n is the number of words transferred during a request

Note 1. B is the current value in bits 0 through 3 of the B register.

Note 2. If bits 0 through 3 (B) of the B register are 0 then the total timing is 34.

Note 3. T is the total number of 0 → 1 and 1 → 0 transitions in the A register (using an imaginary 0 to the right of bit 0).

Note 4. B is the current value in bits 0 through 3 of the B register. If B = 0, then the total timing is 26.

Note 5. Z is the number of leading zeroes in the mantissa of Ar2. If Z = 12, then the total timing is 69.

Approximate Numerical List
Bit Patterns

Instruction	Bit Pattern															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NOP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LD$^{A}/_{B}$	D/I	0	0	0	A/B	Address Field										
CP$^{A}/_{B}$	D/I	0	0	1	A/B											
AD$^{A}/_{B}$	D/I	0	1	0	A/B											
ST$^{A}/_{B}$	D/I	0	1	1	A/B											
JSM	D/I	1	0	0	0											
AND	D/I	1	0	1	0											
$^{I}/_{O}$SZ	D/I	1	0	I/O	1											
IOR	D/I	1	1	0	0											
JMP	D/I	1	1	0	1											
EXE	D/I	1	1	1	0	0	0	0	0	0	0	0	Register Address			
SD$^{O}/_{I}$	0	1	1	1	0	0	0	1	0	0	0	0	O/I	0	0	0
$^{E}/_{D}$IR	0	1	1	1	0	0	0	1	0	0	0	1	E/D	0	0	0
DMA	0	1	1	1	0	0	0	1	0	0	1	0	0	0	0	0
DDK	0	1	1	1	0	0	0	1	0	0	1	1	1	0	0	0
$^{D}/_{C}$B$^{U}/_{L}$	0	1	1	1	0	0	0	1	0	1	0	U/L	D/C	0	0	0
$^{P}/_{W}$$^{W}/_{B}$$^{C}/_{D}$	0	1	1	1	W/B	0	0	1	I/O	1	1	P/W	C/D	Register Address		
MWA	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0
CM$^{Y}/_{X}$	0	1	1	1	0	0	1	0	0	Y/X	1	0	0	0	0	0
FXA	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0
XFR	0	1	1	1	0	0	1	1	0	0	0	0	N=# of words			
CLR	0	1	1	1	0	0	1	1	1	0	0	0	binary=(n−1)			
NRM	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0
CDC	0	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0
FMP	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0
FDV	0	1	1	1	1	0	1	0	0	0	1	0	0	0	0	1
MRX	0	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0
DRS	0	1	1	1	1	0	1	1	0	0	1	0	0	0	0	1
MRY	0	1	1	1	1	0	1	1	0	1	0	0	0	0	0	0
MLY	0	1	1	1	1	0	1	1	0	1	1	0	0	0	0	1
MPY	0	1	1	1	1	0	1	1	1	0	0	0	1	1	1	1
S$^{F}/_{D}$$^{S}/_{C}$	0	1	1	1	0	1	0	S/C	1	F/D	Skip Field					
$^{R}/_{S}$$^{Z}/_{I}$$^{A}/_{B}$	0	1	1	1	A/B	1	0	R/S	0	Z/I	if bit 5 is 0, then skip to(P+n),					
$^{S}/_{R}$L$^{A}/_{B}$	0	1	1	1	A/B	1	1	S/R	$H/\bar{H}$	C/S	n=bits 0-4					
SS$^{S}/_{C}$	0	1	1	1	1	1	0	S/C	1	0	if bit 5=1, then skip to(P−n),					
S$^{A}/_{B}$$^{P}/_{M}$	1	1	1	1	A/B	1	0	P/M	$H/\bar{H}$	C/S	n=two's complement of bits 0-4					
S$^{O}/_{E}$$^{C}/_{S}$	1	1	1	1	O/E	1	1	C/S	$H/\bar{H}$	C/S						
RET	1	1	1	1	0	0	0	0	1	0	complemented skip field					
TC$^{A}/_{B}$	1	1	1	1	A/B	0	0	0	0	0	1	0	0	0	0	0
CM$^{A}/_{B}$	1	1	1	1	A/B	0	0	0	0	1	1	0	0	0	0	0
CL$^{A}/_{B}$	1	1	1	1	A/B	0	0	1	0	1	0	0	1	1	1	1
A$^{A}/_{B}$R	1	1	1	1	A/B	0	0	1	0	0	0	0	Shift Field			
$^{R}/_{S}$$^{A}/_{B}$R	1	1	1	1	A/B	0	0	1	R/S	1	0	0	in source,n=1-16			
S$^{A}/_{B}$L	1	1	1	1	A/B	0	0	1	1	0	0	0	binary=(n−1)			
R$^{A}/_{B}$L	1	1	1	1	A/B	0	0	1	1	1	0	0	complemented shift			

Appendix C
Pseudo-Instructions

The following table lists the available assembler pseudo-instructions with a short description of each, and the page number of the more detailed description listed elsewhere in this manual.

Instruction	Form	Description	Page
ANY	ANY	Specifies a common or subroutine declaration to be any type	112
BSS	BSS {expression}	Reserves a block of memory	56
COM	COM	Preface for assembly language common declarations	128
DAT	DAT {expression} [, {expression} [, ...]]	Defines data generators	57
END	END {name}	Designates the end of a module	17
ENT	ENT {symbol} [, {symbol} [, ...]]	Identifies entry points in the module	77
EQU	EQU {expression}	Defines a symbol	71
EXT	EXT {symbol} [, {symbol} [, ...]]	Identifies external entry points	77
FIL	FIL	Specifies a subroutine declaration to be a file number	110
HED	HED {comment}	Source listing control for top-of-page with change of heading	64
IFA IFB IFC IFD IFE IFF IFG IFH IFP	IFA IFB IFC IFD IFE IFF IFG IFH IFP {numeric expression}	Beginning of conditional assembly	66
INT	INT [(*)]	Specifies a common or subroutine declaration to be an integer	110
LIT	LIT {expression}	Reserve memory for literals and links	74
LST	LST	Source listing control for enabling the listing	61
NAM	NAM {name}	Designates the beginning of a module	17
REL	REL [(*)]	Specifies a common or subroutine declaration to be full-precision	110
REP	REP {expression}	Repeats instructions	59
SHO	SHO [(*)]	Specifies a common or subroutine declaration to be short-precision	110
SKP	SKP	Source listing control for top-of-page	63
SPC	SPC {integer expression}	Source listing control for printing blank lines	65
STR	STR [(*)]	Specifies a common or subroutine declaration to be a string	110
SUB	SUB	Preface for a subroutine entry point	108
UNL	UNL	Source listing control for disabling the listing	61
XIF	XIF	End of a conditional-assembly block	66

Appendix D
Assembly Language BASIC Language Extensions Formal Syntax

The following is an alphabetical list of the BASIC Language extensions provided by the Assembly Language ROMs. For a full discussion of their semantical meanings and applications, consult the indicated pages in this manual.

Assembled Location (page 4)

{symbol} [, {BASIC numeric expression}]
{expression} [, {BASIC numeric expression}]

where:
{BASIC numeric expression} serves as a decimal offset from the given label or constant.

{symbol} is an assembly location. It may be either a label for a particular machine instruction (in which case the address of the associated instruction is used), or an assembler-defined symbol (in which case the associated absolute address is used), or a symbol defined by an EQU instruction (in which case the associated **value** is used).

{expression} may be a numeric expression or a string expression. If numeric, a decimal calculation is performed and the result is interpreted as an octal value; if the result is not an octal representation or an integer, an error results. If a string expression is used, the string must be interpretable as either an octal integer constant or a known assembly symbol (see {symbol} above).

DECIMAL Function (page 184)

DECIMAL ({BASIC numeric expression})

IADR Function (page 185)

IADR ({assembled location})

IASSEMBLE (pages 60-67)

IASSEMBLE {module} [, {module} [, ...]] [; {option} [, {option} [, ...]]]
IASSEMBLE [ALL] [; {option} [, {option} [, ...]]]

where {module} is the name of an existing module in the source program.

{option} may be any of the following:

A
B
C
D
E
EJECT
F
G
H
LINES {numeric expression}
LIST
P
XREF

IBREAK (pages 174-180)

IBREAK [DATA] {address} [, {counter}] [CALL {subprogram}]
IBREAK [DATA] {address} [, {counter}] [GOSUB {line identifier}]
IBREAK [DATA] {address} [, {counter}] [GOTO {line identifier}]
IBREAK ALL [CALL {subprogram}]
IBREAK ALL [GOSUB {line identifier}]
IBREAK ALL [GOTO {line identifier}]

where:

{address} is an assembled location.
{subprogram} is the name of a BASIC subprogram.
{counter} is a numeric expression.
{line identifier} is a line in the BASIC program.

ICALL (pages 107-111)

ICALL {routine} [({data item} [, {data item} [, ...]])]

where {routine} is the label associated with a SUB pseudo-instruction sequence and {data item} takes on the same forms and attributes as parameters in BASIC's CALL statement.

ICHANGE (page 187)

ICHANGE {assembled location} TO {octal expression}

ICOM (pages 19-22)

ICOM {integer constant}

IDELETE (pages 22-23)

IDELETE {module} [, {module} [, ...]]
IDELETE ALL

where {module} is the name of an existing module in the ICOM region.

IDUMP (pages 181-183)

IDUMP {location} [; {location} [; ...]]

where {location} has the following syntax:

[{mode selection}] {address} [TO {address}]

with {address} an assembled location and {mode selection} taking on any of the following forms —

ASC	for ASCII character representation
BIN	for binary representation
DEC	for decimal representation
HEX	for hexadecimal representation
OCT	for octal representation

ILOAD (page 22)

ILOAD {file specifier}

where {file specifier} is of the same form as elsewhere in BASIC (see Mass Storage Techniques manual, or Operating and Programming manual).

IMEM Function (page 186)

IMEM ({assembled location})

INORMAL (page 179)

INORMAL [{address}]
where {address} is an assembled location.

IPAUSE OFF (page 174)

IPAUSE OFF

IPAUSE ON (pages 171-174)

```
IPAUSE ON
```

ISOURCE (pages 49-54)

`ISOURCE` {source line}

where {source line} may take either of the following forms —

[{label} :] {action} [! {comment}]
[{label} :] ! {comment}

and:

{label} is of the same form as elsewhere in BASIC;
{action} is a machine instruction, pseudo-instruction, or data generator;
{comment} is any combination of characters

ISTORE (pages 23-24)

`ISTORE` {module} [, {module} [, ...]] ; {file specifier}
`ISTORE [ALL];` {file specifier}

where:

{module} is the name of a module currently existing in the ICOM region.

{file specifier} is of the same form as elsewhere in BASIC (see the Mass Storage Techniques manual or the Operating and Programming manual).

LITERALS (pages 72-75)

= {expression} [, {expression} [, ...]]
{expression} may be absolute or relocatable

OCTAL Function (page 184)

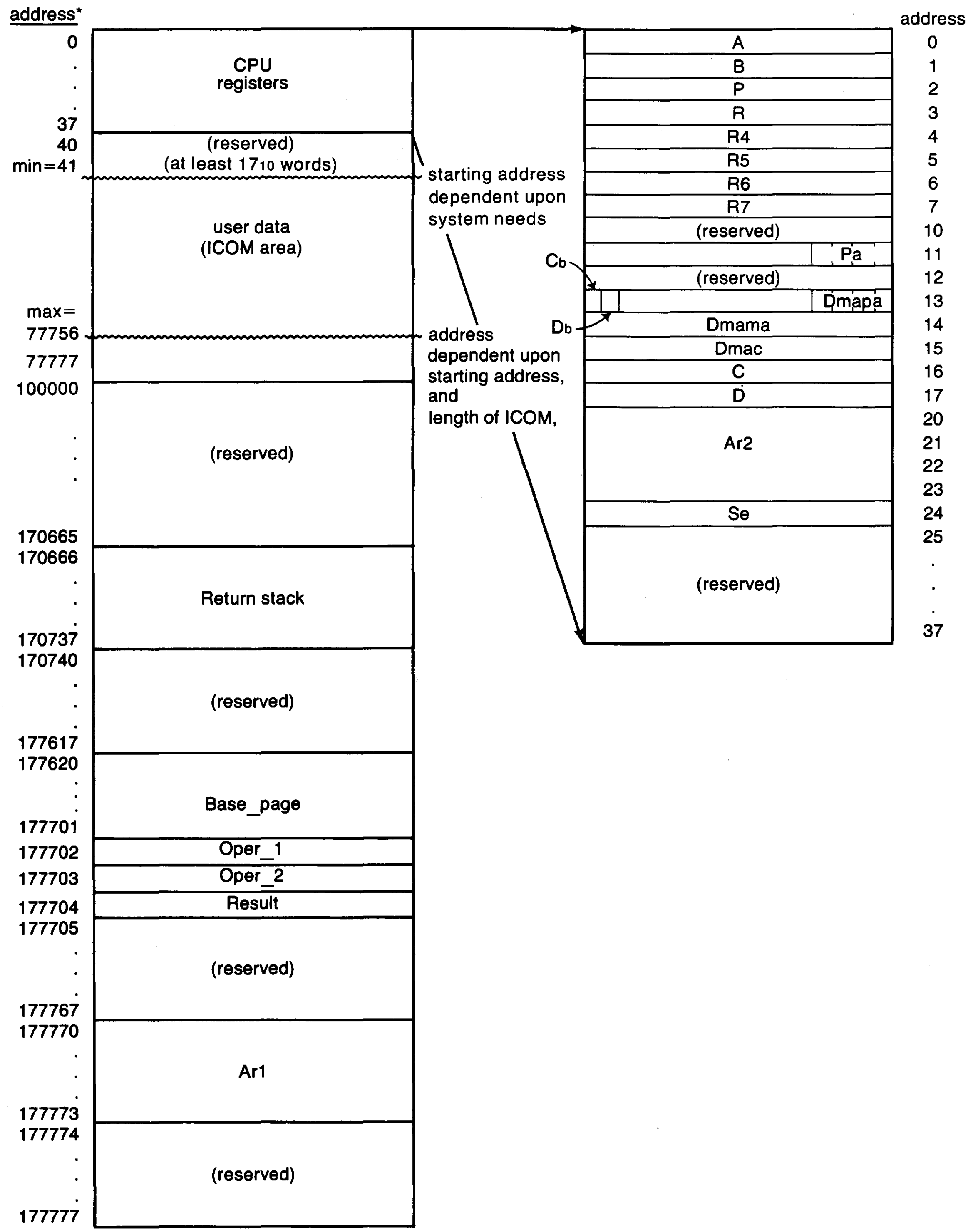
`OCTAL (` {numeric expression} `)`

Appendix E
Predefined Assembler Symbols

The assembler has predefined a number of symbols and has reserved them as references to special locations in memory. Each of these locations has a special meaning and function. You may not redefine these symbols. They are —

Name	Description
A	Arithmetic accumulator
Ar1	BCD arithmetic accumulators
Ar2	
B	Arithmetic accumulator
Base_page	Base page temporary area (50 words)
C	Stack pointer
Cb	Block bit for byte pointer in C(most significant bit of address 13_8)
D	Stack pointer
Db	Block bit for byte pointer in D(second most significant bit of address 13_8)
Dmac	DMA count register
Dmama	DMA memory address register
Dmapa	DMA peripheral register (lower 4 bits of address 13_8)
End_isr_high	Reserved symbols for use with interrupt service routines
End_isr_low	
Isr_flag	
Isr_psw	
Oper_1	Arithmetic utility operand address registers
Oper_2	
P	Program counter
Pa	Peripheral address register (lower 4 bits of address 11_8)
R	Return stack pointer
R4	I/O registers
R5	
R6	
R7	
Result	Arithmetic utility result address register
Se	Shift-extend register
Utlcount	Reserved symbols for writing utilities
Utlend	
Utltemps	

Each predefined symbol references a particular location in memory, except for the Utlend symbol, which refers to an execution address of a system routine. A graphical representation of these locations, plus others of interest, is presented on the next page.



* in octal representation

Utility Name	LDA with:	LDB with:	Exits	Other	Description	Page
Busy	address of bit pattern	address of parameter	RET 1		Retrieves busy bits for a BASIC variable	130
Error_exit	error number	N/A	None — returns to BASIC		Aborts execution of ICALL statement, setting an error number	191
Get_bytes	address of storage area	address of parameter	RET 1	Storage area consists of: lst word — starting byte 2nd word — number of bytes to be transferred 3rd word on — sufficient space for string	Accesses substrings (or parts of arguments)	119
Get_elem_bytes	address of storage area	address of array info	RET 1	Array info obtained by Get_info utility. Relative element number must be stored in array pointer (word 16) of array info. Storage area same as in Get_bytes.	Same as "Get_bytes" used for accessing elements of string arrays	120
Get_file_info	address of storage area	file number	RET 2 — normal RET 1 — file unassigned	Storage area contents after return: word 0 – lower 16 bits of file address word 1 – number of defined records word 2 – current record number word 3 – current word in current record word 4 – size of defined record word 5 – mass storage unit specifier word 6 – buffer address word 7 – check read (0=off, 1=on) word 8 – high 7 bits of file address word 9 – (reserved by system)	Accesses a file-pointer	164
Get_info	address of storage area	address of array info	RET 1	Storage area must be at least: 3 words — simple variables 18 words — arrays for arrays, add 3 words for each 64K bytes in your machine's memory	Returns the characteristics of a variable passed as a parameter or existing in common	114
Get_element	address of storage area	address of parameter	RET 1	Array info obtained by Get_info utility. Relative element_number must be stored in array pointer (word 16) of array info. Storage area must be sufficient size to hold value.	Same as "Get_value", used for elements in an array	118
Get_value	address of storage area	address of parameter	RET 1	Storage area must be sufficient size to hold value	Returns the value of a BASIC variable	117
Int_to_rel	N/A	N/A	RET 1	Load address of integer into Oper_1 and address of storage area into Result. Storage area must be at least 4 words.	Data type conversion from integer to full-precision	104
Isr_access	address of ISR	select code in bits 0-3; access code in bits 4-5; trial counter bits 8-14	RET 1 — linkage not established for reason found in register A: – 1 = resources unobtainable – 2 = select code linked to another ISR RET 2 — normal	select code is 0-7 for low-level or 8-15 for high-level; resource code is: 0 — no resources 1 — asynchronous access 2 — asynchronous access with DMA 3 — synchronous access trial counter is number of attempts before aborting (RET 1, with A set to – 1)	Establishes linkages for interrupts	143
Mm_read_start	address of mass storage descriptor	N/A	RET 1 — memory overflow RET 2 — normal (A contains mass storage transfer ID)	Mass storage descriptor is 3 words containing: word 1 — mass storage unit specifier word 2 — least significant 16 bits of record number word 3 — most significant 7 bits of record number	Prepares to read a physical record from mass storage	158

Appendix F
Utilities

Utility Name	LDA with:	LDB with:	Exits	Other	Description	Page
Mm_read_xfer	mass storage transfer ID	address of storage area	RET 1 — transfer incomplete RET 2 — transfer complete (A contains 0, or error number encountered during transfer)	Storage area must be at least 128 words Mass storage transfer ID would be returned from Mm_read_start utility. Storage area receives transferred information	Reads a physical record from mass storage	159
Mm_write_start	address of mass storage descriptor	address of storage area	RET 1 — memory overflow RET 2 — normal (A contains mass storage transfer ID)	Mass storage descriptor same as in Mm_read_start. Storage area must be at least 128 words and contain information to be transferred	Writes a physical record to mass storage	161
Mm_write_test	mass storage transfer ID	N/A	RET 1 — transfer incomplete RET 2 — transfer complete (A contains 0, or error number encountered during transfer)	Mass storage transfer ID is returned from Mm_write_start utility.	Verifies a physical record was written to mass storage	161
Printer_select	select code	printer width	RET 1 (A contains previous printer select code; B contains previous printer width)		Changes or interrogates select-code for standard printer	166
Print_string	address of string	N/A	RET 1 — memory overflow RET 2 — STOP pressed RET 3 — normal	String must be in same form as standard string	Outputs a string to the standard printer	167
Put_bytes	address of storage area	address of parameter	RET 1	Storage area same as Get_bytes	Replaces substrings (or parts of arguments)	124
Put_elem_bytes	address of storage area	address of array info	RET 1	Same as Get_elem_bytes	Same as "Put_bytes", used for accessing elements of string arrays	125
Put_element	address of storage area	address of array info	RET 1	Same as Get_element	Same as "Put_value", used for elements in an array	123
Put_file_info	address of storage area	file number	RET 1 — file unassigned RET 2 — normal	Same as Get_file_info	Manipulates a file-pointer	165
Put_value	address of storage area	address of parameter	RET 1		Changes the value of a BASIC variable	122
Rel_math	number of operands	execution address	RET 1 (A contains 0, or an error number)	Address of first operand into Oper_1 and address of second operand into Oper_2. Address of result area into Result. Execution address is for the desired routine.	Provides access to all the arithmetic routines	99
Rel_to_int	N/A	N/A	Overflow bit may be set	Address of the value to be converted should be stored in Oper_1, address of storage area of integer into Result	Data type conversion from full-precision to integer	102
Rel_to_sho	N/A	N/A		Address of the value to be converted should be stored in Oper_1; address of storage area for converted number should be stored in Result	Data type conversion from full-precision to short	103
Sho_to_rel	N/A	N/A		Same as Rel_to_sho	Data type conversion from short-precision to full	105

Appendix G
Writing Utilities

A utility, essentially, is a "special" assembly language subroutine. What makes it special is a set of instructions which keeps it from being displayed when a program is being stepped through using the STEP key. This provides some manner of security for the code in the routine from the casual user.

The following must be done to make a section of code into a utility —

1. The entry point for the utility must consist of the instruction —

   `ISZ Utlcount`

2. Each exit point from the utility must consist of the following instructions —

   `DSZ Utlcount`
   `RET` n (n may be any number, – 32 through + 31, depending upon the desired returning point)
   `JSM Utlend`

For example, here is a simple utility to increment a private counter —

```
ISOURCE  User_counter:  BSS 1
                         .
                         .
                         .
ISOURCE  Users:   ISZ Utlcount
ISOURCE           ISZ User_counter
ISOURCE           DSZ Utlcount
ISOURCE           RET 1
ISOURCE           JSM Utlend
                   .
                   .
                   .
```

It is not required that a utility actually be a subroutine. It may also be in-line code by replacing the RET with JMP *+2. By making a section of in-line code a utility, you can make your STEP actions in debugging simpler. If you already know what a section does and don't want to have to step through each instruction in that section each time it is encountered, you can make it into a utility as above. Then, whenever it is encountered, the section is stepped through as if it were a single statement.

Utilities, and calls to utilities, are not allowed in interrupt service routines (ISRs).

Appendix H
I/O Sample Programs

```
10    ! THIS PROGRAM OUTPUTS A STRING USING HANDSHAKE TO A GPIO-LIKE INTERFACE.
20    !
30    ! INTERFACE CARDS APPLICABLE ARE:
31    !
40    !      98032   16 BIT PARALLEL
50    !      98035   REAL TIME CLOCK
60    !      98036   SERIAL INTERFACE
70    !
80    ICOM 1000
90    DIM Input$[160]                        ! ALLOW FOR 160 CHARACTER STRING
100   INTEGER Select_code                    ! BASIC VARIABLE TO HOLD THE SELECT CODE
110   IASSEMBLE
120   INPUT "SELECT CODE TO WRITE TO?",Select_code
130   !
140 Input:  LINPUT "STRING TO WRITE?",Input$ ! ASK USER FOR STRING TO OUTPUT
150   ICALL Output_gpio_hs(Select_code,Input$)
160   GOTO Input
170   !
180        ISOURCE              NAM Output_gpio_hs
190        ISOURCE              EXT Get_value,Error_exit
200        ISOURCE Select_code:BSS 1                  ! RESERVED TO HOLD SELECT CODE
210        ISOURCE String:      BSS 81                 ! RESERVED FOR 160 CHAR STRING
220        ISOURCE Cr:          EQU 13                 ! EQUATES FOR CR/LF
230        ISOURCE Lf:          EQU 10
240        ISOURCE !
250        ISOURCE ! ROUTINE TO OUTPUT A STRING FOLLOWED BY CR/LF TO A GPIO-LIKE
260        ISOURCE ! INTERFACE USING HANDSHAKE.
270        ISOURCE !
280        ISOURCE ! ENTRY POINT:  OUTPUT_gpio_hs
290        ISOURCE !
300        ISOURCE ! PARAMETERS:  1)  INTEGER CONTAINING SELECT CODE ( 1 TO 14 )
310        ISOURCE !              2)  STRING TO BE OUTPUT
320        ISOURCE !
330        ISOURCE ! POSSIBLE ERRORS:  19  SELECT CODE OUT OF RANGE
340        ISOURCE !                  164  CARD OR PERIPHERAL DOWN
350        ISOURCE !
360        ISOURCE              SUB
370        ISOURCE Parm_sc:     INT
380        ISOURCE Parm_str:    STR
390        ISOURCE Output_gpio_hs: LDA =Select_code ! GET THE SELECT CODE PARM
400        ISOURCE              LDB =Parm_sc
410        ISOURCE              JSM Get_value
420        ISOURCE              LDA Select_code      ! COPY TO PA
430        ISOURCE              STA Pa
440        ISOURCE              ADA =-1              ! CHECK FOR VALID RANGE (1-14)
450        ISOURCE              SAM Sc_error
460        ISOURCE              ADA =-15+1
470        ISOURCE              SAM Sc_ok
480        ISOURCE Sc_error:    LDA =19              ! GIVE ERROR 19 IF SELECT_CODE
490        ISOURCE              JSM Error_exit       ! IS OUT OF RANGE
500        ISOURCE !
```

```
510      ISOURCE Sc_ok:      LDA =String         ! GET THE STRING PARAMETER
520      ISOURCE             LDB =Parm_str
530      ISOURCE             JSM Get_value
540      ISOURCE             LDA =String+1       ! SET UP C TO GET BYTES FROM
550      ISOURCE             SAL 1               ! THE STRING
560      ISOURCE             STA C
570      ISOURCE             CBL
580      ISOURCE             LDA String          ! IF THE STRING LENGTH IS ZERO
590      ISOURCE             SZA Done            ! THEN THERE IS NOTHING TO DO.
600      ISOURCE Write_loop: WBC A,I             ! GET THE NEXT CHAR FOR OUTPUT
610      ISOURCE             JSM Write_byte      ! OUTPUT THE CHARACTER TO CARD
620      ISOURCE             DSZ String          ! SEE IF DONE
630      ISOURCE               JMP Write_loop    ! IF NOT, REPEAT
640      ISOURCE Done:       LDA =Cr             ! NOW OUTPUT CR/LF
650      ISOURCE             JSM Write_byte
660      ISOURCE             LDA =Lf
670      ISOURCE             JSM Write_byte
680      ISOURCE             RET 1               ! RETURN TO BASIC
690      ISOURCE !
700      ISOURCE ! SUBROUTINE TO OUTPUT ONE CHARACTER TO GPIO-LIKE CARD.
710      ISOURCE !     CHARACTER IS PASSED IN A
720      ISOURCE !
730      ISOURCE Write_byte: SSC Card_down       ! SKIP IF CARD IS DOWN
740      ISOURCE             SFC Write_byte      ! ELSE WAIT FOR CARD
750      ISOURCE             STA R4              ! OUTPUT DATA TO CARD
760      ISOURCE             STA R7              ! TRIGGER HANDSHAKE
770      ISOURCE             RET 1
780      ISOURCE !
790      ISOURCE Card_down:  LDA =164            ! RETURN ERROR 164 TO BASIC
800      ISOURCE             JSM Error_exit
810      ISOURCE !
820      ISOURCE             END Output_gpio_hs
```

```
10   ! THIS PROGRAM INPUTS A STRING USING HANDSHAKE FROM A GPIO-LIKE DEVICE.
20   !
30   ! INTERFACE CARDS APPLICABLE ARE:
40   !     98032   16 BIT PARALLEL
50   !     98033   BCD
60   !     98035   REAL TIME CLOCK
70   !     98036   SERIAL INTERFACE
80   !
90   ICOM 200
100  DIM Input$[160]                      ! ALLOW FOR 160 CHARACTER STRING
110  INTEGER Select_code                  ! BASIC VARIABLE TO HOLD THE SELECT CODE
120  IASSEMBLE
130  INPUT "SELECT CODE TO READ FROM?",Select_code
140  !
150  ICALL Read_gpio(Select_code,Input$)
160  PRINT "STRING READ=";Input$
170  END
180  !
190       ISOURCE              NAM Gpio_input
200       ISOURCE              EXT Get_value,Put_value,Error_exit
210       ISOURCE Select_code:BSS 1                 ! RESERVED TO HOLD SELECT CODE
220       ISOURCE String:      BSS 81                ! RESERVED FOR 160 CHAR STRING
230       ISOURCE Cr:          EQU 13                ! EQUATES FOR CR/LF
240       ISOURCE Lf:          EQU 10
250       ISOURCE !
260       ISOURCE ! ROUTINE TO INPUT A STRING FOLLOWED BY LF FROM A GPIO-LIKE
270       ISOURCE ! INTERFACE.
280       ISOURCE ! A MAX OF 160 CHARACTERS WILL BE READ. CR'S ARE IGNORED.
290       ISOURCE !
300       ISOURCE ! ENTRY POINT:  READ_gpio
310       ISOURCE !
320       ISOURCE ! PARAMETERS:  1)  INTEGER CONTAINING SELECT CODE ( 1 TO 14 )
330       ISOURCE !              2)  STRING TO HOLD RESULT
340       ISOURCE !
350       ISOURCE ! POSSIBLE ERRORS:  19  SELECT CODE OUT OF RANGE
360       ISOURCE !                  164  CARD OR PERIPHERAL DOWN
370       ISOURCE !
380       ISOURCE              SUB
390       ISOURCE Parm_sc:     INT
400       ISOURCE Parm_str:    STR
410       ISOURCE Read_gpio:   LDA =Select_code      ! GET THE SELECT CODE PARM
420       ISOURCE              LDB =Parm_sc
430       ISOURCE              JSM Get_value
440       ISOURCE              LDA Select_code       ! COPY TO PA
450       ISOURCE              STA Pa
460       ISOURCE              ADA =-1               ! CHECK FOR VALID RANGE (1-14)
470       ISOURCE              SAM Sc_error
480       ISOURCE              ADA =-15+1
490       ISOURCE              SAM Sc_ok
500       ISOURCE Sc_error:    LDA =19               ! GIVE ERROR 19 IF SELECT_CODE
510       ISOURCE              JSM Error_exit        ! IS OUT OF RANGE
520       ISOURCE !
530       ISOURCE Sc_ok:       LDA =0                ! INITIALIZE THE STRING LENGTH
540       ISOURCE              STA String
550       ISOURCE              LDA =String           ! SET UP C TO PUT BYTES INTO
560       ISOURCE              SAL 1                 ! THE STRING
570       ISOURCE              ADA =1
580       ISOURCE              STA C
590       ISOURCE              CBL
600       ISOURCE              SSC Card_down         ! SKIP IF CARD/PERIPH ARE DOWN
610       ISOURCE              SFC *-1               ! ELSE WAIT FOR CARD
```

```
620    ISOURCE              LDA R4           ! SIGNAL THIS IS AN INPUT
630    ISOURCE Read_loop:   STA R7           ! TRIGGER THE INPUT HANDSHAKE
640    ISOURCE              SFC *            ! WAIT FOR CARD TO COMPLETE
650    ISOURCE              LDA R4           ! THEN GET THE BYTE
660    ISOURCE              CPA =Lf          ! IF LINE FEED
670    ISOURCE               JMP Done        !    THEN WE ARE DONE
680    ISOURCE              CPA =Cr          ! IF CARRIAGE RETURN
690    ISOURCE               JMP Read_loop   ! THEN IGNORE IT
700    ISOURCE              PBC A,I          ! ELSE PUT CHARACTER IN STRING
710    ISOURCE              LDA String       ! AND BUMP STRING LENGTH
720    ISOURCE              ADA =1
730    ISOURCE              STA String
740    ISOURCE              CPA =160         ! HAVE WE INPUT 160 CHARS?
750    ISOURCE               JMP Done        ! YES! SO QUIT NOW
760    ISOURCE              JMP Read_loop    ! IF NOT THEN REPEAT
770    ISOURCE Done:        LDA =String      ! SEND THE STRING TO BASIC
780    ISOURCE              LDB =Parm_str
790    ISOURCE              JSM Put_value
800    ISOURCE              RET 1            ! RETURN TO BASIC
810    ISOURCE !
820    ISOURCE Card_down:   LDA =164         ! RETURN ERROR 164 TO BASIC
830    ISOURCE              JSM Error_exit
840    ISOURCE !
850    ISOURCE              END Gpio_input
```

```
10   ! THIS PROGRAM OUTPUTS A STRING USING INTERRUPT TO A GPIO-LIKE INTERFACE.
20   !
30   ! INTERFACE CARDS APPLICABLE ARE:
40   !
50   !      98032   16 BIT PARALLEL
60   !      98036   SERIAL INTERFACE (INTERRUPT ENABLE BYTE SHOULD BE CHANGED)
70   !
80   ICOM 1000
90   DIM Input$[160]                       ! ALLOW FOR 160 CHARACTER STRING
100  INTEGER Select_code                   ! BASIC VARIABLE TO HOLD THE SELECT CODE
110  IASSEMBLE
120  INPUT "SELECT CODE TO WRITE TO?",Select_code
130  ON INT #Select_code GOTO Isr_done   ! SET UP END OF LINE BRANCH
140  !
150 Input:  LINPUT "STRING TO WRITE?",Input$ ! ASK USER FOR STRING TO OUTPUT
160  ICALL Output_gpio_int(Select_code,Input$)
161  !
170  DISP I                                ! DO OTHER WORK WHILE INTERRUPT
180  I=I+1                                 ! OUTPUT IS IN PROGRESS
190  GOTO 170
191  !
200 Isr_done:  DISP " OUTPUT COMPLETE...NEXT "; ! GET HERE WHEN ISR OUTPUT IS
210  GOTO Input                            ! COMPLETE...SO REPEAT
220  !
230       ISOURCE              NAM Output_gpio_int
240       ISOURCE              EXT Get_value,Error_exit,Isr_access
250       ISOURCE Select_code:BSS 1                  ! RESERVED TO HOLD SELECT CODE
260       ISOURCE String:      BSS 81                 ! RESERVED FOR 160 CHAR STRING
270       ISOURCE Byte_pointer:BSS 1                 ! BYTE POINTER FOR ISR
280       ISOURCE Eol_mask:    BSS 1                  ! TEMP FOR ISR
290       ISOURCE Save35:      BSS 1                  ! TEMP FOR ISR
300       ISOURCE Cr:          EQU 13                 ! EQUATES FOR CR/LF
310       ISOURCE Lf:          EQU 10
320       ISOURCE Enable_mask:EQU 200B               ! 98032 INTERRUPT ENABLE MASK
330       ISOURCE !
340       ISOURCE ! ROUTINE TO OUTPUT A STRING FOLLOWED BY CR/LF TO A GPIO-LIKE
350       ISOURCE ! INTERFACE USING INTERRUPT.
360       ISOURCE !
370       ISOURCE ! ENTRY POINT:  Output_gpio_int
380       ISOURCE !
390       ISOURCE ! PARAMETERS:  1)  INTEGER CONTAINING SELECT CODE ( 1 TO 14 )
400       ISOURCE !              2)  STRING TO BE OUTPUT
410       ISOURCE !
420       ISOURCE ! POSSIBLE ERRORS:  19  SELECT CODE OUT OF RANGE
430       ISOURCE !                  164  CARD OR PERIPHERAL DOWN
440       ISOURCE !
450       ISOURCE              SUB
460       ISOURCE Parm_sc:     INT
470       ISOURCE Parm_str:    STR
480       ISOURCE Output_gpio_int:LDA =Select_code ! GET THE SELECT CODE PARM
490       ISOURCE              LDB =Parm_sc
500       ISOURCE              JSM Get_value
510       ISOURCE              LDA Select_code      ! LOAD A WITH SELECT CODE
520       ISOURCE              ADA =-1              ! CHECK FOR VALID RANGE (1-14)
530       ISOURCE              SAM Sc_error
540       ISOURCE              ADA =-15+1
550       ISOURCE              SAM Sc_ok
560       ISOURCE Sc_error:    LDA =19              ! GIVE ERROR 19 IF SELECT_CODE
570       ISOURCE              JSM Error_exit       ! IS OUT OF RANGE
580       ISOURCE !
590       ISOURCE Sc_ok;       LDA Select_code      ! SEE IF CARD IS OK
600       ISOURCE              STA Pa               ! FIRST COPY SELECT CODE TO PA
```

```
610  ISOURCE             SSC Card_down        ! SKIP IF DOWN
620  ISOURCE             LDA =Isr             ! SET UP AN ISR
630  ISOURCE             LDB =(10*256)+(1*16)! 10 TRIES, RESOURCE=1=ASYNC
640  ISOURCE             ADB Select_code
650  ISOURCE             JSM Isr_access
660  ISOURCE              JMP Sc_ok           ! IF COULDN'T GET IT, RETRY
670  ISOURCE             LDA =String          ! GET THE STRING PARAMETER
680  ISOURCE             LDB =Parm_str
690  ISOURCE             JSM Get_value
700  ISOURCE             LDA =String+1        ! SET UP BYTE POINTER FOR ISR
710  ISOURCE             SAL 1                ! TO GET CHARS FROM STRING
720  ISOURCE             STA Byte_pointer
730  ISOURCE             ADA String           ! ADD CR/LF TO END OF STRING
740  ISOURCE             ADA =-1
750  ISOURCE             STA C
760  ISOURCE             CBL
770  ISOURCE             LDA =Cr
780  ISOURCE             PBC A,I
790  ISOURCE             LDA =Lf
800  ISOURCE             PBC A,I
810  ISOURCE             LDA String           ! BE SURE AND ADD 2 TO LENGTH
820  ISOURCE             ADA =2               ! SO ISR WILL OUTPUT CR/LF
830  ISOURCE             STA String
840  ISOURCE             LDA =Enable_mask     ! ENABLE THE CARD TO INTERRUPT
850  ISOURCE             STA R5
860  ISOURCE             RET 1                ! GO BACK TO BASIC.
870  ISOURCE !
880  ISOURCE Card_down:  LDA =164
890  ISOURCE             JSM Error_exit
900  ISOURCE !
910  ISOURCE Isr:        LDA 35B              ! SINCE I AM GOING TO DO STACK
920  ISOURCE             STA Save35           ! OPERATIONS, I MUST SAVE 35
930  ISOURCE             LDA 34B              ! AND INITIALIZE IT
940  ISOURCE             STA 35B
950  ISOURCE             LDA Byte_pointer     ! SET UP THE BYTE POINTER
960  ISOURCE             STA C                ! SO I CAN GET A DATA BYTE
970  ISOURCE             CBL
980  ISOURCE             WBC R4,I             ! SEND THE DATA BYTE TO CARD
990  ISOURCE             STA R7               ! DO HANDSHAKE
1000 ISOURCE             LDA C                ! RESAVE BYTE POINTER
1010 ISOURCE             STA Byte_pointer
1020 ISOURCE             DSZ String           ! SEE IF DONE
1030 ISOURCE               JMP Exit           ! IF NOT, THEN EXIT THE ISR
1040 ISOURCE             LDA =0               ! DISABLE THE CARD
1050 ISOURCE             STA R5
1060 ISOURCE             LDA Pa               ! DEPENDING ON WHETHER THE
1070 ISOURCE             ADA =-8              ! SELECT CODE IS HIGH, OR LOW
1080 ISOURCE             SAP *+3              ! CALL THE CORRECT TERMINATION
1090 ISOURCE             JSM End_isr_low,I    ! ROUTINE
1100 ISOURCE             JMP *+2
1110 ISOURCE             JSM End_isr_high,I
1120 ISOURCE             LDA Pa               ! AND NOW TRIGGER AN END OF
1130 ISOURCE             ADA =-1              ! LINE BRANCH. TO DO THIS, THE
1140 ISOURCE             IOR Sb11             ! CORRECT MASK WORD MUST BE
1150 ISOURCE             LDB =1               ! CALCULATED BY A COMPUTED
1160 ISOURCE             EXE A                ! SHIFT INSTRUCTION
1170 ISOURCE             STB Eol_mask         ! SAVE THIS MASK
1180 ISOURCE             LDB Isr_psw          ! AND USE MAGIC CODE TO
1190 ISOURCE             LDA =103B            ! TRIGGER THE EOL BRANCH
1200 ISOURCE             STA B,I
1210 ISOURCE             ADB =3
```

```
1220    ISOURCE              LDA Eol_mask
1230    ISOURCE              DIR
1240    ISOURCE              IOR B,I
1250    ISOURCE              STA B,I
1260    ISOURCE              EIR
1270    ISOURCE              STA Isr_flag,I
1280    ISOURCE Exit:        LDA Save35          ! RESTORE 35
1290    ISOURCE              STA 35B
1300    ISOURCE              RET 1               ! RETURN FROM INTERRUPT
1310    ISOURCE Sbl1:        SBL 1               ! BIT MASK FOR INSTRUCTION
1320    ISOURCE !
```

```
10  ! THIS PROGRAM INPUTS A STRING USING INTERRUPT FROM A GPIO-LIKE INTERFACE.
20  !
30  ! INTERFACE CARDS APPLICABLE ARE:
40  !
50  !     98032   16 BIT PARALLEL
60  !     98033   BCD
70  !     98036   SERIAL INTERFACE (INTERRUPT ENABLE BYTE SHOULD BE CHANGED)
80  !
90  ICOM 1000
100 DIM Input$[160]                    ! ALLOW FOR 160 CHARACTER STRING
110 INTEGER Select_code                ! BASIC VARIABLE TO HOLD THE SELECT CODE
120 IASSEMBLE
130 INPUT "SELECT CODE TO READ FROM?",Select_code
140 ON INT #Select_code GOTO Isr_done  ! SET UP END OF LINE BRANCH
150 ICALL Enter_gpio_int(Select_code)  ! START THE READ OPERATION
160 !
170 ICALL Read_result(Input$)          ! WHILE WAITING FOR IT TO COMPLETE,
180 DISP "PARTIAL RESULT=";Input$      ! DISPLAY THE PARTIAL RESULTS
190 GOTO 170
200 !
210 Isr_done:  ICALL Read_result(Input$)
220 DISP " INPUT COMPLETE...STRING=";Input$
230 END
240 !
250      ISOURCE             NAM Enter_gpio_int
260      ISOURCE             EXT Get_value,Put_value,Error_exit,Isr_access
270      ISOURCE Select_code:BSS 1                ! RESERVED TO HOLD SELECT CODE
280      ISOURCE String:     BSS 81               ! RESERVED FOR 160 CHAR STRING
290      ISOURCE Byte_pointer:BSS 1               ! BYTE POINTER FOR ISR
300      ISOURCE Eol_mask:   BSS 1                ! TEMP FOR ISR
310      ISOURCE Save35:     BSS 1                ! TEMP FOR ISR
320      ISOURCE Cr:         EQU 13               ! EQUATES FOR CR/LF
330      ISOURCE Lf:         EQU 10
340      ISOURCE Enable_mask:EQU 200B             ! 98032 INTERRUPT ENABLE MASK
350      ISOURCE !
360      ISOURCE ! ROUTINES TO INPUT A STRING FOLLOWED BY LF FROM A GPIO-LIKE
370      ISOURCE ! INTERFACE USING INTERRUPT.
380      ISOURCE !
390      ISOURCE ! ENTRY POINT:  Enter_gpio_int
400      ISOURCE !
410      ISOURCE ! PARAMETER:   1)  INTEGER CONTAINING SELECT CODE ( 1 TO 14 )
420      ISOURCE !
430      ISOURCE ! POSSIBLE ERRORS:  19  SELECT CODE OUT OF RANGE
440      ISOURCE !                  164  CARD OR PERIPHERAL DOWN
450      ISOURCE !
460      ISOURCE ! ENTRY POINT:  Read_result
470      ISOURCE !
480      ISOURCE ! PARAMETER:   1)  STRING TO CONTAIN THE INPUT DATA
490      ISOURCE !
500      ISOURCE             SUB
510      ISOURCE Parm_sc:    INT
520      ISOURCE Enter_gpio_int: LDA =Select_code ! GET THE SELECT CODE PARM
530      ISOURCE             LDB =Parm_sc
540      ISOURCE             JSM Get_value
550      ISOURCE             LDA Select_code      ! LOAD A WITH SELECT CODE
560      ISOURCE             ADA =-1              ! CHECK FOR VALID RANGE (1-14)
570      ISOURCE             SAM Sc_error
580      ISOURCE             ADA =-15+1
590      ISOURCE             SAM Sc_ok
600      ISOURCE Sc_error:   LDA =19              ! GIVE ERROR 19 IF SELECT_CODE
610      ISOURCE             JSM Error_exit       ! IS OUT OF RANGE
620      ISOURCE !
```

```
630   ISOURCE Sc_ok:       LDA Select_code      ! SEE IF CARD IS OK
640   ISOURCE              STA Pa               ! FIRST COPY SELECT CODE TO PA
650   ISOURCE              SSC Card_down        ! SKIP IF DOWN
660   ISOURCE              LDA =Isr             ! SET UP AN ISR
670   ISOURCE              LDB =(10*256)+(1*16)! 10 TRIES, RESOURCE=1=ASYNC
680   ISOURCE              ADB Select_code
690   ISOURCE              JSM Isr_access
700   ISOURCE               JMP Sc_ok           ! IF COULDN'T GET IT, RETRY
710   ISOURCE              LDA =0               ! INITIALIZE BYTE COUNT OF
720   ISOURCE              STA String           ! STRING BUFFER AREA
730   ISOURCE              LDA =String          ! SET UP BYTE POINTER FOR ISR
740   ISOURCE              SAL 1                ! TO PUT CHARS INTO STRING
750   ISOURCE              ADA =1
760   ISOURCE              STA Byte_pointer
770   ISOURCE              SFC *                ! WAIT FOR CARD
780   ISOURCE              LDA R4               ! START FIRST INPUT OPERATION
790   ISOURCE              STA R7
800   ISOURCE              LDA =Enable_mask     ! ENABLE THE CARD TO INTERRUPT
810   ISOURCE              STA R5
820   ISOURCE              RET 1                ! GO BACK TO BASIC.
830   ISOURCE !
840   ISOURCE Card_down:   LDA =164
850   ISOURCE              JSM Error_exit
860   ISOURCE !
870   ISOURCE              SUB
880   ISOURCE Parm_str:    STR
890   ISOURCE Read_result:LDA =String
900   ISOURCE              LDB =Parm_str
910   ISOURCE              JSM Put_value
920   ISOURCE              RET 1
930   ISOURCE !
940   ISOURCE Isr:         LDA 35B              ! SINCE I'M GOING TO DO STACK
950   ISOURCE              STA Save35           ! OPERATIONS, I MUST SAVE 35
960   ISOURCE              LDA 34B              ! AND INITIALIZE IT
970   ISOURCE              STA 35B
980   ISOURCE              LDA Byte_pointer     ! SET UP THE BYTE POINTER
990   ISOURCE              STA C                ! SO I CAN PUT A DATA BYTE
1000  ISOURCE              CBL                  ! INTO THE STRING
1010  ISOURCE              LDA R4               ! GET THE NEXT CHARACTER FROM
1020  ISOURCE              CPA =Cr              ! THEN CARD...IGNORE CR'S
1030  ISOURCE               JMP Do_another
1040  ISOURCE              CPA =Lf              ! IF LINE FEED, THE TERMINATE
1050  ISOURCE               JMP Terminate       ! THE ISR TRANSFER
1060  ISOURCE              PBC A,I              ! ELSE PUT CHARACTER IN STRING
1070  ISOURCE              LDA C                ! SAVE NEW BYTE POINTER
1080  ISOURCE              STA Byte_pointer
1090  ISOURCE              LDA String           ! AND BUMP STRING LENGTH
1100  ISOURCE              ADA =1
1110  ISOURCE              STA String
1120  ISOURCE              CPA =160             ! HAVE WE RECEIVED 160 CHARS
1130  ISOURCE               JMP Terminate       ! IF YES, THEN SHUT DOWN
1140  ISOURCE Do_another: STA R7                ! START ANOTHER HANDSHAKE
1150  ISOURCE              JMP Exit             ! THEN EXIT THE ISR
1160  ISOURCE !
1170  ISOURCE Terminate:   LDA =0               ! DISABLE THE CARD
1180  ISOURCE              STA R5
1190  ISOURCE              LDA Pa               ! DEPENDING ON WHETHER THE
1200  ISOURCE              ADA =-8              ! SELECT CODE IS HIGH, OR LOW
1210  ISOURCE              SAP *+3              ! CALL THE CORRECT TERMINATION
1220  ISOURCE              JSM End_isr_low,I    ! ROUTINE
1230  ISOURCE              JMP *+2
1240  ISOURCE              JSM End_isr_high,I
```

```
1250    ISOURCE           LDA Pa          ! AND NOW TRIGGER AN END OF
1260    ISOURCE           ADA =-1         ! LINE BRANCH. TO DO THIS, THE
1270    ISOURCE           IOR Sbl1        ! CORRECT MASK WORD MUST BE
1280    ISOURCE           LDB =1          ! CALCULATED BY A COMPUTED
1290    ISOURCE           EXE A           ! SHIFT INSTRUCTION
1300    ISOURCE           STB Eol_mask    ! SAVE THIS MASK
1310    ISOURCE           LDB Isr_psw     ! AND USE MAGIC CODE TO
1320    ISOURCE           LDA =103B       ! TRIGGER THE EOL BRANCH
1330    ISOURCE           STA B,I
1340    ISOURCE           ADB =3
1350    ISOURCE           LDA Eol_mask
1360    ISOURCE           DIR
1370    ISOURCE           IOR B,I
1380    ISOURCE           STA B,I
1390    ISOURCE           EIR
1400    ISOURCE           STA Isr_flag,I
1410    ISOURCE Exit:     LDA Save35      ! RESTORE 35
1420    ISOURCE           STA 35B
1430    ISOURCE           RET 1           ! RETURN FROM INTERRUPT
1440    ISOURCE Sbl1:     SBL 1           ! BIT MASK FOR INSTRUCTION
1450    ISOURCE !
1460    ISOURCE           END Enter_gpio_int
```

```
10   ! THIS PROGRAM OUTPUTS A STRING USING DMA TO A GPIO INTERFACE.
20   !
30   ! INTERFACE CARDS APPLICABLE ARE:
40   !
50   !      98032   16 BIT PARALLEL
60   !
70   ICOM 1000
80   DIM Input$[160]                   ! ALLOW FOR 160 CHARACTER STRING
90   INTEGER Select_code               ! BASIC VARIABLE TO HOLD THE SELECT CODE
100  IASSEMBLE
110  INPUT "SELECT CODE TO WRITE TO?",Select_code
120  ON INT #Select_code GOTO Dma_done  ! SET UP END OF LINE BRANCH
130  !
140 Input:  LINPUT "STRING TO WRITE?",Input$ ! ASK USER FOR STRING TO OUTPUT
150  ICALL Output_gpio_dma(Select_code,Input$)
160  !
170  DISP I                            ! DO OTHER WORK WHILE INTERRUPT
180  I=I+1                             ! OUTPUT IS IN PROGRESS
190  GOTO 170
200  !
210 Dma_done:  DISP " OUTPUT COMPLETE...NEXT "; ! GET HERE WHEN ISR OUTPUT IS
220  GOTO Input                        ! COMPLETE...SO REPEAT
230  !
240       ISOURCE              NAM Output_gpio_dma
250       ISOURCE              EXT Get_value,Error_exit,Isr_access
260       ISOURCE Select_code:BSS 1                  ! RESERVED TO HOLD SELECT CODE
270       ISOURCE String:      BSS 81                 ! RESERVED FOR 160 CHAR STRING
280       ISOURCE              BSS 80                 ! RESERVED TO EXPAND STRING
290       ISOURCE Eol_mask:    BSS 1                  ! TEMP FOR ISR
300       ISOURCE Save35:      BSS 1                  ! TEMP FOR ISR
310       ISOURCE Cr:          EQU 13                 ! EQUATES FOR CR/LF
320       ISOURCE Lf:          EQU 10
330       ISOURCE Enable_mask:EQU 320B               ! 98032 DMA/INT/AH ENABLE MASK
340       ISOURCE !
350       ISOURCE ! ROUTINE TO OUTPUT A STRING FOLLOWED BY CR/LF TO A GPIO-LIKE
360       ISOURCE ! INTERFACE USING DMA.
370       ISOURCE !
380       ISOURCE ! ENTRY POINT:  Output_gpio_dma
390       ISOURCE !
400       ISOURCE ! PARAMETERS:  1)  INTEGER CONTAINING SELECT CODE ( 1 TO 14 )
410       ISOURCE !              2)  STRING TO BE OUTPUT
420       ISOURCE !
430       ISOURCE ! POSSIBLE ERRORS:  19  SELECT CODE OUT OF RANGE
440       ISOURCE !                  164  CARD OR PERIPHERAL DOWN
450       ISOURCE !
460       ISOURCE              SUB
470       ISOURCE Parm_sc:     INT
480       ISOURCE Parm_str:    STR
490       ISOURCE Output_gpio_dma:LDA =Select_code ! GET THE SELECT CODE PARM
500       ISOURCE              LDB =Parm_sc
510       ISOURCE              JSM Get_value
520       ISOURCE              LDA Select_code      ! LOAD A WITH SELECT CODE
530       ISOURCE              ADA =-1              ! CHECK FOR VALID RANGE (1-14)
540       ISOURCE              SAM Sc_error
550       ISOURCE              ADA =-15+1
560       ISOURCE              SAM Sc_ok
570       ISOURCE Sc_error:    LDA =19              ! GIVE ERROR 19 IF SELECT_CODE
580       ISOURCE              JSM Error_exit       ! IS OUT OF RANGE
590       ISOURCE !
600       ISOURCE Sc_ok:       LDA Select_code      ! SEE IF CARD IS OK
610       ISOURCE              STA Pa               ! FIRST COPY SELECT CODE TO PA
620       ISOURCE              SSS Card_ok          ! SKIP IF CARD IS UP
```

```
630    ISOURCE                LDA =164             ! ELSE GIVE ERROR 164
640    ISOURCE                JSM Error_exit
650    ISOURCE !
660    ISOURCE Card_ok:       LDA =Isr             ! SET UP AN ISR
670    ISOURCE                LDB =(10*256)+(2*16)! 10 TRIES, RESOURCE=2=DMA
680    ISOURCE                ADB Select_code
690    ISOURCE                JSM Isr_access
700    ISOURCE                 JMP Sc_ok           ! IF COULDN'T GET IT, RETRY
710    ISOURCE                LDA =String          ! GET THE STRING PARAMETER
720    ISOURCE                LDB =Parm_str
730    ISOURCE                JSM Get_value
740    ISOURCE ! FOR DMA, THE NORMAL STRING FORMAT WON'T DO. THE DATA MUST
750    ISOURCE ! BE STORED ONE BYTE PER WORD, SO THE FOLLOWING LOOP WILL
760    ISOURCE ! EXPAND THE STRING AND ADD A CR/LF
770    ISOURCE                LDA =String+1        ! FIRST SET UP BYTE POINTER TO
780    ISOURCE                SAL 1                ! WITHDRAW THE LAST CHARACTER
790    ISOURCE                ADA String           ! FIRST
800    ISOURCE                ADA =-1
810    ISOURCE                STA C                ! USE C FOR THE BYTE POINTER
820    ISOURCE                CBL
830    ISOURCE                LDA =String+3        ! NOW COMPUTE A WORD POINTER
840    ISOURCE                ADA String           ! TO WHERE TO PLACE THE LF
850    ISOURCE                STA D
860    ISOURCE                LDA =Lf              ! MOVE IN A LF
870    ISOURCE                PWD A,D
880    ISOURCE                LDA =Cr              ! AND CR
890    ISOURCE                PWD A,D
900    ISOURCE                LDB String           ! NOW LOOP TO COPY ALL BYTES
910    ISOURCE                TCB
920    ISOURCE                SIB *+4
930    ISOURCE                WBC A,D
940    ISOURCE                PWD A,D
950    ISOURCE                RIB *-2
960    ISOURCE                LDA String           ! SET UP DMA CONTROL REGISTERS
970    ISOURCE                ADA =1               ! COUNT = #CHARS-1
980    ISOURCE                STA Dmac
990    ISOURCE                LDA =String+1        ! DMAA = DATA ADDRESS
1000   ISOURCE                STA Dmama
1010   ISOURCE                SDO                  ! SET DMA OUTWARDS
1020   ISOURCE                LDA =Enable_mask     ! ENABLE THE CARD TO INTERRUPT
1030   ISOURCE                STA R5
1040   ISOURCE                DMA
1050   ISOURCE                RET 1                ! GO BACK TO BASIC.
1060   ISOURCE !
1070   ISOURCE Isr:           LDA 35B              ! I WILL GET THE INTERRUPT
1080   ISOURCE                STA Save35           ! THE DMA TRANSFER IS COMPLETE
1090   ISOURCE                LDA 34B
1100   ISOURCE                STA 35B
1110   ISOURCE                LDA =0               ! SO DISABLE THE CARD
1120   ISOURCE                STA R5
1130   ISOURCE                DDR                  ! DISABLE DMA
1140   ISOURCE                LDA Pa               ! DEPENDING ON WHETHER THE
1150   ISOURCE                ADA =-8              ! SELECT CODE IS HIGH, OR LOW
1160   ISOURCE                SAP *+3              ! CALL THE CORRECT TERMINATION
1170   ISOURCE                JSM End_isr_low,I    ! ROUTINE
1180   ISOURCE                JMP *+2
1190   ISOURCE                JSM End_isr_high,I
1200   ISOURCE                LDA Pa               ! AND NOW TRIGGER AN END OF
1210   ISOURCE                ADA =-1              ! LINE BRANCH. TO DO THIS, THE
1220   ISOURCE                IOR Sb11             ! CORRECT MASK WORD MUST BE
1230   ISOURCE                LDB =1               ! CALCULATED BY A COMPUTED
1240   ISOURCE                EXE A                ! SHIFT INSTRUCTION
```

```
1250       ISOURCE            STB Eol_mask         ! SAVE THIS MASK
1260       ISOURCE            LDB Isr_psw          ! AND USE MAGIC CODE TO
1270       ISOURCE            LDA =103B            ! TRIGGER THE EOL BRANCH
1280       ISOURCE            STA B,I
1290       ISOURCE            ADB =3
1300       ISOURCE            LDA Eol_mask
1310       ISOURCE            DIR
1320       ISOURCE            IOR B,I
1330       ISOURCE            STA B,I
1340       ISOURCE            EIR
1350       ISOURCE            STA Isr_flag,I
1360       ISOURCE            LDA Save35           ! RESTORE 35
1370       ISOURCE            STA 35B
1380       ISOURCE            RET 1                ! RETURN FROM INTERRUPT
1390       ISOURCE Sbl1:      SBL 1                ! BIT MASK FOR INSTRUCTION
1400       ISOURCE !
1410       ISOURCE            END Output_gpio_dma
```

```
10   ! THIS PROGRAM INPUTS A STRING USING DMA FROM A GPIO INTERFACE.
20   !
30   ! INTERFACE CARDS APPLICABLE ARE:
40   !
50   !      98032   16 BIT PARALLEL
60   !
70   ICOM 1000
80   DIM Input$[160]                      ! ALLOW FOR 160 CHARACTER STRING
90   INTEGER Select_code                  ! BASIC VARIABLE TO HOLD THE SELECT CODE
100  INTEGER Character_count              ! VARIABLE TO HOLD INPUT CHARACTER COUNT
110  INTEGER A,C                          ! VARIABLES FOR "BACKGROUND PROCESS"
120  IASSEMBLE
130  INPUT "SELECT CODE TO READ FROM?",Select_code
140  ON INT #Select_code GOTO Isr_done  ! SET UP END OF LINE BRANCH
150  INPUT "NUMBER OF CHARACTERS TO READ?",Character_count
160  ICALL Enter_gpio_dma(Select_code,Character_count)  ! START THE READ
170  !
180  ICALL Test_dma(C,A)                  ! WHILE WAITING, DISPLAY DMA COUNT AND
190  DISP "DMA COUNT=";C,"ADDRESS=";A,I ! ADDRESS
200  I=I+1
210  GOTO 180
220  !
230 Isr_done:  ICALL Read_result(Input$)
240  DISP " INPUT COMPLETE...STRING=";Input$
250  END
260  !
270       ISOURCE               NAM Enter_gpio_dma
280       ISOURCE               EXT Get_value,Put_value,Error_exit,Isr_access
290       ISOURCE Select_code:BSS 1                  ! RESERVED TO HOLD SELECT CODE
300       ISOURCE String:       BSS 81                 ! RESERVED FOR 160 CHAR STRING
310       ISOURCE               BSS 80                 ! RESERVED FOR EXPANDED STRING
320       ISOURCE Eol_mask:     BSS 1                  ! TEMP FOR ISR
330       ISOURCE Save35:       BSS 1                  ! TEMP FOR ISR
340       ISOURCE Enable_mask:EQU 320B               ! 98032 DMA/INT/AH ENABLE MASK
350       ISOURCE !
360       ISOURCE ! ROUTINES TO INPUT A FIXED LENGTH STRING FROM A GPIO
370       ISOURCE ! INTERFACE USING DMA.
380       ISOURCE !
390       ISOURCE ! ENTRY POINT:  Enter_gpio_dma
400       ISOURCE !
410       ISOURCE ! PARAMETER:    1)  INTEGER CONTAINING SELECT CODE ( 1 TO 14 )
420       ISOURCE !               2)  NUMBER OF CHARACTERS TO READ ( 1 TO 80 )
430       ISOURCE !
440       ISOURCE ! POSSIBLE ERRORS:  19  SELECT CODE OR CHAR COUNT OUT OF RANGE
450       ISOURCE !                   164  CARD OR PERIPHERAL DOWN
460       ISOURCE !
470       ISOURCE ! ENTRY POINT:  Test_dma
480       ISOURCE !
490       ISOURCE ! PARAMETERS:   1)  INTEGER TO HOLD CURRENT DMA COUNT
500       ISOURCE !               2)  INTEGER TO HOLD CURRENT DMA ADDRRESS
510       ISOURCE !
520       ISOURCE ! ENTRY POINT:  Read_result
530       ISOURCE !
540       ISOURCE ! PARAMETER:    1)  STRING TO CONTAIN THE INPUT DATA
550       ISOURCE !
560       ISOURCE               SUB
570       ISOURCE Parm_sc:      INT
580       ISOURCE Parm_count: INT
590       ISOURCE Enter_gpio_dma: LDA =Select_code ! GET THE SELECT CODE PARM
600       ISOURCE               LDB =Parm_sc
610       ISOURCE               JSM Get_value
620       ISOURCE               LDA Select_code        ! LOAD A WITH SELECT CODE
```

```
630     ISOURCE               ADA =-1             ! CHECK FOR VALID RANGE (1-14)
640     ISOURCE               SAM Sc_error
650     ISOURCE               ADA =-15+1
660     ISOURCE               SAM Sc_ok
670     ISOURCE Sc_error:     LDA =19             ! GIVE ERROR 19 IF SELECT_CODE
680     ISOURCE               JSM Error_exit      ! IS OUT OF RANGE
690     ISOURCE !
700     ISOURCE Sc_ok:        LDA =String         ! GET BYTE COUNT PARAMETER
710     ISOURCE               LDB =Parm_count
720     ISOURCE               JSM Get_value
730     ISOURCE               LDA String          ! CHECK IT FOR RANGE
740     ISOURCE               SAM Sc_error
750     ISOURCE               SZA Sc_error
760     ISOURCE               ADA =-81
770     ISOURCE               SAP Sc_error
780     ISOURCE Check_card:   LDA Select_code     ! SEE IF CARD IS OK
790     ISOURCE               STA Pa              ! FIRST COPY SELECT CODE TO PA
800     ISOURCE               SSS Card_ok         ! SKIP IF CARD IS OK
810     ISOURCE               LDA =164            ! ELSE GIVE ERROR 164
820     ISOURCE               JSM Error_exit
830     ISOURCE !
840     ISOURCE Card_ok:      LDA =Isr            ! SET UP AN ISR
850     ISOURCE               LDB =(10*256)+(2*16)! 10 TRIES, RESOURCE=2=DMA
860     ISOURCE               ADB Select_code
870     ISOURCE               JSM Isr_access
880     ISOURCE                JMP Check_card     ! IF COULDN'T GET IT, RETRY
890     ISOURCE               LDA String          ! INITIALIZE DMA REGISTERS
900     ISOURCE               ADA =-1
910     ISOURCE               STA Dmac
920     ISOURCE               LDA =String+1
930     ISOURCE               STA Dmama
940     ISOURCE               SDI
950     ISOURCE               SFC *               ! WAIT FOR CARD
960     ISOURCE               LDA R4              ! START FIRST INPUT OPERATION
970     ISOURCE               STA R7
980     ISOURCE               LDA =Enable_mask    ! ENABLE THE CARD TO INTERRUPT
990     ISOURCE               STA R5
1000    ISOURCE               DMA                 ! ENABLE PROCESSER FOR DMA
1010    ISOURCE               RET 1               ! GO BACK TO BASIC.
1020    ISOURCE !
1030    ISOURCE               SUB
1040    ISOURCE C_parm:       INT
1050    ISOURCE A_parm:       INT
1060    ISOURCE Test_dma:     LDA Dmac
1070    ISOURCE               STA Temp
1080    ISOURCE               LDA =Temp
1090    ISOURCE               LDB =C_parm
1100    ISOURCE               JSM Put_value
1110    ISOURCE               LDA Dmama
1120    ISOURCE               STA Temp
1130    ISOURCE               LDA =Temp
1140    ISOURCE               LDB =A_parm
1150    ISOURCE               JSM Put_value
1160    ISOURCE               RET 1
1170    ISOURCE Temp:         BSS 1
1180    ISOURCE !
1190    ISOURCE               SUB
1200    ISOURCE Parm_str:     STR
1210    ISOURCE Read_result:LDA =String+1         ! I MUST PACK THE STRING FROM
1220    ISOURCE               STA D               ! FROM 1 BYTE TO 2 BYTES PER
1230    ISOURCE               SAL 1
1240    ISOURCE               ADA =-1
```

```
1250    ISOURCE             STA C
1260    ISOURCE             CBL
1270    ISOURCE             LDA String          ! GET CHARACTER COUNT
1280    ISOURCE             TCA
1290    ISOURCE             SIA *+4
1300    ISOURCE             WWD B,I             ! GET A BYTE
1310    ISOURCE             PBC B,I             ! PACK IT
1320    ISOURCE             RIA *-2
1330    ISOURCE             LDA =String         ! RETURN RESULT TO BASIC
1340    ISOURCE             LDB =Parm_str
1350    ISOURCE             JSM Put_value
1360    ISOURCE             RET 1
1370    ISOURCE !
1380    ISOURCE Isr:        LDA 35B             ! I WILL GET AN INTERRUPT WHEN
1390    ISOURCE             STA Save35          ! THE DMA IS COMPLETE
1400    ISOURCE             LDA 34B
1410    ISOURCE             STA 35B
1420    ISOURCE             LDA Dmac            ! I GET TO HERE WHEN DMA DONE
1430    ISOURCE             ADA =1              ! COMPUTE ACTUAL NUMBER OF
1440    ISOURCE             TCA                 ! CHARACTERS TRANSFERED
1450    ISOURCE             ADA String
1460    ISOURCE             STA String          ! SAVE IN STRING LENGTH WORD
1470    ISOURCE             LDA =0              ! DISABLE THE CARD
1480    ISOURCE             STA R5
1490    ISOURCE             DDR                 ! DISABLE DMA
1500    ISOURCE             LDA Pa              ! DEPENDING ON WHETHER THE
1510    ISOURCE             ADA =-8             ! SELECT CODE IS HIGH, OR LOW
1520    ISOURCE             SAP *+3             ! CALL THE CORRECT TERMINATION
1530    ISOURCE             JSM End_isr_low,I   ! ROUTINE
1540    ISOURCE             JMP *+2
1550    ISOURCE             JSM End_isr_high,I
1560    ISOURCE             LDA Pa              ! AND NOW TRIGGER AN END OF
1570    ISOURCE             ADA =-1             ! LINE BRANCH. TO DO THIS, THE
1580    ISOURCE             IOR Sbl1            ! CORRECT MASK WORD MUST BE
1590    ISOURCE             LDB =1              ! CALCULATED BY A COMPUTED
1600    ISOURCE             EXE A               ! SHIFT INSTRUCTION
1610    ISOURCE             STB Eol_mask        ! SAVE THIS MASK
1620    ISOURCE             LDB Isr_psw         ! AND USE MAGIC CODE TO
1630    ISOURCE             LDA =103B           ! TRIGGER THE EOL BRANCH
1640    ISOURCE             STA B,I
1650    ISOURCE             ADB =3
1660    ISOURCE             LDA Eol_mask
1670    ISOURCE             DIR
1680    ISOURCE             IOR B,I
1690    ISOURCE             STA B,I
1700    ISOURCE             EIR
1710    ISOURCE             STA Isr_flag,I
1720    ISOURCE             LDA Save35
1730    ISOURCE             STA 35B
1740    ISOURCE             RET 1               ! RETURN FROM INTERRUPT
1750    ISOURCE Sbl1:       SBL 1               ! BIT MASK FOR INSTRUCTION
1760    ISOURCE !
1770    ISOURCE             END Enter_gpio_dma   3333333---'  ,
```

```
10   ! 98034A HPIB CARD DRIVER
20   !
30   ! TWO ASSEMBLY LANGUAGE DRIVERS ARE PROVIDED...ONE FOR OUTPUT AND ONE
40   ! FOR INPUT.  BOTH HAVE PROVISIONS FOR INCLUDING A BUS COMMAND STRING
50   ! FOR ADDRESSING THE BUS.
60   !
70   ! SYNTAX:
80   !
90   !   ICALL Hpib_output( <ISC>, <CMD$>, [ <DATA$> ] )
100  !   ICALL Hpib_enter ( <ISC>, <CMD$>, [ <VAR$> ] )
110  !
120  !        <ISC>   ::= INTERFACE SELECT CODE (1 TO 14) (INTEGER)
130  !        <CMD$>  ::= STRING TO OUTPUT WITH ATN TRUE
140  !        <DATA$> ::= STRING TO OUTPUT WITH ATN FALSE
150  !        <VAR$>  ::= STRING VARIABLE TO HOLD DATA READ FROM BUS
160  !
170  !   POSSIBLE ERRORS:
180  !
190  !     164   CARD WAS NOT AN HPIB CARD
200  !     500   <CMD$> WAS NON-NULL BUT THE CARD WAS NOT ACTIVE CONTROLLER
210  !     501   <DATA$> WAS NON-NULL BUT THE CARD WAS NOT ACTIVER TALKER
220  !     502   <VAR$> WAS SPECIFIED BUT THE CARD WAS NOT ACTIVE LISTENER
230  !
240  ICOM 1000
250  INTEGER Select_code
260  DIM Cmd$[160],Data$[160],Var$[160]
270  IASSEMBLE
280  INPUT "HPIB SELECT CODE?",Select_code
290  ON KEY #0 GOSUB Output
300  ON KEY #1 GOSUB Enter
310  PRINT "KEY0 = OUTPUT    KEY1 = ENTER"
320  DISP "IDLE"
330  GOTO 320
340 Output:  GOSUB Linput_cmd
350  LINPUT "DATA TO SEND?",Data$
360  ICALL Hpib_output(Select_code,Cmd$,Data$)
370  PRINT "      DATA SENT  =";Data$
380  RETURN
390 Enter:  GOSUB Linput_cmd
400  ICALL Hpib_enter(Select_code,Cmd$,Var$)
410  PRINT "      DATA READ  =";Var$
420  RETURN
430  !
440 Linput_cmd:  LINPUT "COMMAND BYTES?",Cmd$
450  RETURN
460  !
470       ISOURCE              NAM Hpib
480       ISOURCE              EXT Get_value,Put_value,Error_exit
490       ISOURCE Cmd:         BSS 81              ! STRING TO HOLD CMD BYTES
500       ISOURCE Data:        EQU Cmd             ! STRING TO HOLD DATA BYTES
510       ISOURCE Select_code:BSS 1                ! INTERFACE SELECT CODE
520       ISOURCE Parm_ptr:    BSS 1               ! POINTER TO PARM PSEUDO OPS
530       ISOURCE Lf:          EQU 10              ! EQUATES
540       ISOURCE Cr:          EQU 13
550       ISOURCE Status1:     BSS 1               ! 4 WORDS TO CONTAIN STATUS
560       ISOURCE Status2:     BSS 1               ! BYTES FROM 98034
570       ISOURCE Status3:     BSS 1
580       ISOURCE Status4:     BSS 1
590       ISOURCE !
600       ISOURCE Out_parm:    SUB
610       ISOURCE     ,        INT
```

```
620   ISOURCE             STR
630   ISOURCE P_data:     STR
640   ISOURCE Hpib_output:LDB =Out_parm      ! CALL SETUP ROUTINE
650   ISOURCE             JSM Hpib_setup
660   ISOURCE             LDA Out_parm       ! IS THERE A DATA PARAMETER?
670   ISOURCE             CPA =2
680   ISOURCE No_output:   RET 1             ! NO, RETURN TO BASIC
690   ISOURCE             LDA =Data          ! YES, FETCH IT
700   ISOURCE             LDB =P_data
710   ISOURCE             JSM Get_value
720   ISOURCE             LDA Data           ! CHECK BYTE COUNT
730   ISOURCE             SZA No_output      ! IF ZERO, DO NOTHING
740   ISOURCE             JSM Hpib_status    ! MAKE SURE WE ARE ADDRESSED
750   ISOURCE             LDA Status4        ! TO TALK
760   ISOURCE             AND =40B
770   ISOURCE             RZA *+3
780   ISOURCE              LDA =501          ! ELSE GIVE ERROR 501
790   ISOURCE              JSM Error_exit
800   ISOURCE             LDA =Data+1        ! ELSE COMPUTE BYTE POINTER
810   ISOURCE             SAL 1              ! SO WE CAN WITHDRAW BYTES
820   ISOURCE             STA C              ! FROM THE STRING
830   ISOURCE             CBL
840   ISOURCE Data_loop:  SFC *              ! WAIT FOR CARD
850   ISOURCE             WBC R4,I           ! OUTPUT A BYTE
860   ISOURCE             DSZ Data           ! SEE IF DONE WITH STRING
870   ISOURCE              JMP Data_loop     ! NO
880   ISOURCE             RET 1              ! DONE, SO GO BACK TO BASIC
890   ISOURCE !
900   ISOURCE Ent_parm:   SUB
910   ISOURCE             INT
920   ISOURCE             STR
930   ISOURCE Ent_var:    STR
940   ISOURCE Hpib_enter: LDB =Ent_parm      ! CALL SETUP ROUTINE
950   ISOURCE             JSM Hpib_setup
960   ISOURCE             LDA =Ent_parm      ! IS THERE A DATA PARAMETER?
970   ISOURCE             CPA =2
980   ISOURCE              RET 1             ! NO, THEN I'D DONE
990   ISOURCE             JSM Hpib_status    ! MAKE SURE I'M A LISTENER
1000  ISOURCE             LDA Status4
1010  ISOURCE             AND =20B
1020  ISOURCE             RZA *+3
1030  ISOURCE              LDA =502          ! ELSE GIVE ERROR 502
1040  ISOURCE              JSM Error_exit
1050  ISOURCE             LDA =0             ! CLEAR DATA STRING COUNTER
1060  ISOURCE             STA Data
1070  ISOURCE             LDA =Data          ! SET UP BYTE POINTER FOR DATA
1080  ISOURCE             SAL 1
1090  ISOURCE             ADA =1
1100  ISOURCE             STA C
1110  ISOURCE             CBL
1120  ISOURCE Enter_loop: SFC *              ! WAIT FOR CARD
1130  ISOURCE             LDA R4             ! START ACCEPTOR HANDSHAKE
1140  ISOURCE             SFC *              ! WAIT FOR DATA
1150  ISOURCE             LDA R6             ! READ DATA FROM CARD
1160  ISOURCE             CPA =Cr            ! IS IT A RETURN?
1170  ISOURCE              JMP Enter_loop    ! IF SO, IGNORE IT
1180  ISOURCE             CPA =Lf            ! IS IT TERMINATOR?
1190  ISOURCE              JMP Ent_done      ! YES, SKIP
1200  ISOURCE             PBC A,I            ! ELSE PUT BYTE INTO STRING
1210  ISOURCE             ISZ Data           ! BUMP STRING LENGTH
1220  ISOURCE             JMP Enter_loop     ! REPEAT FOR NEXT BYTE
```

```
1230    ISOURCE Ent_done:   LDA =Data          ! RETURN DATA TO PARAMETER
1240    ISOURCE             LDB =Ent_var
1250    ISOURCE             JSM Put_value
1260    ISOURCE             RET 1
1270    ISOURCE !
1280    ISOURCE ! HPIB SETUP ROUTINE
1290    ISOURCE !     B POINTS TO SUB PSEUDO OP (CONTAINS PARM COUNT)
1300    ISOURCE !    1) VERIFY PARAMETER COUNT >=2
1310    ISOURCE !    2) FETCH SELECT CODE AND VERIFY CARD IS A 98034A
1320    ISOURCE !    3) FETCH COMMAND STRING PARAMETER AND OUTPUT IT
1330    ISOURCE !
1340    ISOURCE Hpib_setup: LDA B,I            ! CHECK PARM COUNT
1350    ISOURCE             ADA =-2
1360    ISOURCE             SAP *+3            ! SKIP IF >=2
1370    ISOURCE              LDA =8            ! IF <2, GIVE ERROR 8
1380    ISOURCE              JSM Error_exit
1390    ISOURCE             ADB =1             ! POINT TO SELECT CODE PARM
1400    ISOURCE             STB Parm_ptr
1410    ISOURCE             LDA =Select_code   ! FETCH IT
1420    ISOURCE             JSM Get_value
1430    ISOURCE             LDA Select_code    ! CHECK RANGE FOR 1 TO 14
1440    ISOURCE             ADA =-1
1450    ISOURCE             SAM Sc_error
1460    ISOURCE             ADA =-15+1
1470    ISOURCE             SAM *+3
1480    ISOURCE Sc_error:    LDA =19           ! IF OUT OF RANGE, GIVE ERROR
1490    ISOURCE              JSM Error_exit    ! 19
1500    ISOURCE             LDA Select_code    ! SET UP PA AND DO STATUS SEQ
1510    ISOURCE             STA Pa             ! ON CARD TO VERIFY IT IS A
1520    ISOURCE             JSM Hpib_status    ! 98034A INTERFACE
1530    ISOURCE             LDB Parm_ptr       ! NOW FETCH COMMAND STRING
1540    ISOURCE             ADB =3
1550    ISOURCE             LDA =Cmd
1560    ISOURCE             JSM Get_value
1570    ISOURCE             LDA Cmd            ! SEE IF THERE IS ANYTHING
1580    ISOURCE             SZA No_cmd         ! OUTPUT, IF NOT, SKIP
1590    ISOURCE             LDA Status4        ! MAKE SURE I AM ACTIVE
1600    ISOURCE             AND =100B          ! CONTROLLER
1610    ISOURCE             RZA *+3            ! SKIP IF YES
1620    ISOURCE              LDA =500          ! ELSE GIVE ERROR 500
1630    ISOURCE              JSM Error_exit
1640    ISOURCE             LDA =Cmd+1         ! NOW OUTPUT THE COMMANDS
1650    ISOURCE             SAL 1
1660    ISOURCE             STA C
1670    ISOURCE             CBL
1680    ISOURCE Cmd_loop:   SFC *
1690    ISOURCE             WBC R6,I           ! SEND OUT CMD BYTE
1700    ISOURCE             DSZ Cmd            ! SEE IF DONE
1710    ISOURCE              JMP Cmd_loop      ! NOT YET
1720    ISOURCE No_cmd:     RET 1              ! DONE!
1730    ISOURCE !
1740    ISOURCE ! STATUS SEQUENCE FOR 98034 CARD. NOTE THAT THIS SEQUENCE
1750    ISOURCE ! COULD FORCE THE CARD TO VIOLATE THE IFC TIME SPECS IF
1760    ISOURCE ! THE FOLLOWING CONDITIONS EXIST:
1770    ISOURCE !     1) CARD IS NOT SYSTEM CONTROLLER
1780    ISOURCE !     2) A HARDWARE INTERRUPT OCCURS AFTER THE LDA R5 BUT
1790    ISOURCE !        BEFORE THE DIR
1800    ISOURCE !     3) THE CONTROLLER PULLS IFC AFTER THE LDA R5 BUT BEFORE
1810    ISOURCE !        THE DIR
1820    ISOURCE ! THE ONLY ALTERNATIVE TO THIS IS TO DIR BEFORE THE LDA R5.
1830    ISOURCE ! THIS HOWEVER COULD COMPROMISE ANY SYNCHRONUS INTERRUPT
```

```
1840     ISOURCE ! TRANSFER IN PROGRESS ( FOR EXAMPLE THE TAPE CARTRIDGE ).
1850     ISOURCE !
1860     ISOURCE Hpib_status:SFC *                ! GET THE CARD INTO
1870     ISOURCE             LDA R5               ! IT'S STATUS SEQUENCE.
1880     ISOURCE             AND =60B             ! MAKE SURE IT IS A 98034
1890     ISOURCE             CPA =60B
1900     ISOURCE              JMP *+3             ! YES
1910     ISOURCE             LDA =164             ! IF NOT, GIVE ERROR 164
1920     ISOURCE             JSM Error_exit
1930     ISOURCE             SFC *                ! (THIS IS THE CRITICAL TIME)
1940     ISOURCE             DIR                  ! MADE IT, SO DISABLE MY
1950     ISOURCE             SFC *                ! INTERRUPTS FOR THE REST OF
1960     ISOURCE             LDA R6               ! THE STATUS SEQUENCE.
1970     ISOURCE             STA Status1
1980     ISOURCE             SFC *
1990     ISOURCE             LDA R6
2000     ISOURCE             STA Status2
2010     ISOURCE             SFC *
2020     ISOURCE             LDA R6
2030     ISOURCE             STA Status3
2040     ISOURCE             SFC *
2050     ISOURCE             LDA R6
2060     ISOURCE             EIR
2070     ISOURCE             STA Status4
2080     ISOURCE             RET 1
2090     ISOURCE             END Hpib
```

```
10   ! PROGRAM TO DEMONSTRATE USING THE CLOCK FOR INTERRUPTS
20   !
30   ! THIS EXAMPLE SHOWS HOW TO USE THE CLOCK INTERRUPT TO PUT THE TIME
40   ! OF DAY INTO THE SYSTEM MESSAGE AREA AS LONG AS THE PROGRAM IS RUNNING.
50   !
60   ! THE CLOCK IS PROGRAMMED TO GENERATE AN INTERRUPT EVERY SECOND. THE
70   ! ASSEMBLY INTERRUPT SERVICE ROUTINE TRIGGERS AN END OF LINE BRANCH. THE
80   ! EOL BRANCH ROUTINE CALLS AN ASSEMBLY ROUTINE TO PUT THE TIME OF DAY
90   ! INTO THE SYSTEM MESSAGE AREA.
100  !
110  ICOM 200
120  IASSEMBLE
130  ICALL Setup_clock                    ! SET UP ISR AND START CLOCK
140  ON INT #9 CALL Time                  ! SET UP EOL BRANCH
150  !
160  ! BACKGROUND PROGRAM:
170  !
180  DISP I
190  I=I+1
200  GOTO 180
210  !
220  SUB Time
230  ICALL Display_time
240  SUBEXIT
250       ISOURCE              NAM Time
260       ISOURCE              EXT Error_exit,Printer_select,Print_string
270       ISOURCE              EXT Isr_access
280       ISOURCE Select_code:EQU 9
290       ISOURCE Eol_mask:    SET 1                ! GET ASSEMBLER TO COMPUTE
300       ISOURCE              REP Select_code      ! THE EOL MASK FOR TRIGGERING
310       ISOURCE Eol_mask:    SET Eol_mask*2       ! EOL BRANCHES
320       ISOURCE Cr:          EQU 13               ! OTHER EQUATES
330       ISOURCE Lf:          EQU 10
340       ISOURCE String:      BSS 20               ! AREA TO HOLD TIME OF DAY
350       ISOURCE Old_pi:      BSS 1                ! TWO WORDS TO HOLD CURRENT
360       ISOURCE Old_pw:      BSS 1                ! PRINTER IS AND PRINTER WIDTH
370       ISOURCE !
380       ISOURCE              SUB
390       ISOURCE Setup_clock:LDA =Select_code      ! MAKE SURE THE CLOCK CARD
400       ISOURCE              STA Pa               ! IS ALIVE
410       ISOURCE              SSS Card_ok
420       ISOURCE Card_down:    LDA =164            ! IF NOT, GIVE ERROR 164
430       ISOURCE               JSM Error_exit
440       ISOURCE Card_ok:     LDA =Isr             ! SET UP ISR LINKAGE
450       ISOURCE              LDB =(10*256)+(1*16)+Select_code
460       ISOURCE              JSM Isr_access
470       ISOURCE               JMP *+2             ! IF ERROR, THEN JUMP
480       ISOURCE               JMP Start_card      ! ELSE GO START UP THE CARD
490       ISOURCE              CPA =-1              ! IF DIDN'T GET RESOURCES
500       ISOURCE               JMP Setup_clock     ! THEN TRY AGAIN
510       ISOURCE              RET 1                ! IF ISR ALREADY LINKED,RETURN
520       ISOURCE Start_card: LDA =="U4H/U4=04/U4P1000/U4G"+Lf
530       ISOURCE              SAL 1                ! SET UP C TO POINT TO STRING
540       ISOURCE              STA C                ! WHICH I WILL OUTPUT TO THE
550       ISOURCE              CBL                  ! CLOCK TO PROGRAM IT.
560       ISOURCE              LDB =-21             ! B IS -(CHAR COUNT-1)
570       ISOURCE Out_loop:    SFC *                ! WAIT FOR CARD
580       ISOURCE              WBC R4,I             ! SHOVE NEXT BYTE OUT TO CARD
590       ISOURCE              STA R7               ! TRIGGER HANDSHAKE
600       ISOURCE              RIB Out_loop         ! LOOP UNTIL DONE
610       ISOURCE              LDA =200B            ! ENABLE THE CARD TO INTERRUPT
```

```
620    ISOURCE                STA R5
630    ISOURCE                RET 1
640    ISOURCE !
650    ISOURCE                SUB
660    ISOURCE Display_time:LDA =Select_code    ! FETCH TIME FROM CLOCK
670    ISOURCE                STA Pa
680    ISOURCE                SSC Card_down       ! OOPS...CARD WENT DOWN
690    ISOURCE                LDA ='R             ! OUTPUT "R" TO CLOCK TO GET
700    ISOURCE                SFC *               ! IT TO GIVE ME THE TIME
710    ISOURCE                STA R4
720    ISOURCE                STA R7
730    ISOURCE                LDA =Lf
740    ISOURCE                SFC *
750    ISOURCE                STA R4
760    ISOURCE                STA R7
770    ISOURCE                LDA =String         ! SET UP C TO PUT TIME OF DAY
780    ISOURCE                SAL 1               ! DATA INTO STRING
790    ISOURCE                ADA =1
800    ISOURCE                STA C
810    ISOURCE                CBL
820    ISOURCE                LDA =0              ! CLEAR THE STRING COUNT
830    ISOURCE                STA String
840    ISOURCE                SFC *               ! WAIT FOR CARD
850    ISOURCE                LDA R4              ! START INPUT OPERATION
860    ISOURCE Read_loop:     STA R7              ! TRIGGER HANDSHAKE
870    ISOURCE                SFC *               ! WAIT FOR CARD
880    ISOURCE                LDA R4              ! GET THE NEXT BYTE
890    ISOURCE                CPA =Cr             ! IGNORE CR'S
900    ISOURCE                 JMP Read_loop
910    ISOURCE                CPA =Lf             ! TERMINATE ON LINEFEED
920    ISOURCE                 JMP Got_time
930    ISOURCE                PBC A,I             ! ELSE PUT CHARACTER INTO
940    ISOURCE                ISZ String          ! STRING AND BUMP COUNT
950    ISOURCE                JMP Read_loop       ! REPEAT
960    ISOURCE Got_time:      LDA =18             ! SET UP "PRINTER IS" FOR THE
970    ISOURCE                LDB =80             ! MESSAGE AREA
980    ISOURCE                JSM Printer_select
990    ISOURCE                STA Old_pi          ! SAVE OLD
1000   ISOURCE                STB Old_pw
1010   ISOURCE                LDA =String         ! DO THE PRINT
1020   ISOURCE                JSM Print_string
1030   ISOURCE                 JMP Memov          ! JUMP IF MEMORY OVERFLOW
1040   ISOURCE                 NOP                ! IGNORE STOP KEY
1050   ISOURCE Restore_pi: LDA Old_pi             ! RESET "PRINTER IS"
1060   ISOURCE                LDB Old_pw
1070   ISOURCE                JSM Printer_select
1080   ISOURCE                RET 1               ! RETURN TO BASIC
1090   ISOURCE Memov:         JSM Restore_pi      ! RESTORE THE PRINTER IS
1100   ISOURCE                LDA =2              ! AND GIVE ERROR 2
1110   ISOURCE                JSM Error_exit
1120   ISOURCE !
1130   ISOURCE Isr:           LDA =0              ! SIGNAL CARD THAT WE GOT THE
1140   ISOURCE                STA R5              ! INTERRUPT BY DISABLING AND
1150   ISOURCE                LDA =200B           ! THEN RE-ENABLING THE CARD
1160   ISOURCE                STA R5
1170   ISOURCE                LDB Isr_psw         ! TRIGGER EOL BRANCH
1180   ISOURCE                LDA =103B
1190   ISOURCE                STA B,I
1200   ISOURCE                ADB =3
1210   ISOURCE                LDA =Eol_mask
1220   ISOURCE                DIR
1230   ISOURCE                IOR B,I
```

```
1240    ISOURCE          STA B,I
1250    ISOURCE          EIR
1260    ISOURCE          STA Isr_flag,I
1270    ISOURCE          RET 1              ! DONE
1280    ISOURCE          END Time
```

Appendix I
Demonstration Cartridge

Along with the Assembly Language Development and Execution ROMs, a tape cartridge has been provided to demonstrate the capabilities of the assembly language system. This Demonstration Cartridge (HP part number 11141-10154) is specifically intended to —

- Graphically display the kind of speed increases which can be obtained by using assembly language subprograms for certain types of applications.
- Provide a number of programs which can serve as examples of how to write assembly language subprograms.[1]
- Provide a set of definitions for some of the special function keys so that those keys can be used as typing aids.

Using the Tape

To run any of the demonstration programs, execute the statement —

```
LOAD "DEMO",1
```

A set of instructions is displayed which can then be followed interactively.

Typing Aids

The starting and final cursor positions of the typing aids were chosen with assembly listings in mind. The intent in selecting these positions was to make it easy to enter source as it would appear when listed within an assembly listing.

The following table gives, for each key; the typing aid, the position where the typing aid begins, and the position where the cursor will finally reside. Because some typing aids end with a blank, the triangle (Δ) has been chosen to indicate the end of the typing aid. All blanks after the start of the typing aid, and before the triangle, will appear when the key is pressed.

1 The commented source for the chess program is contained in file CHESSS.

Key	Typing Aid	Typing Aid Starting Position	Final Cursor Position
0	ISOURCE Δ	11	31
1	ISOURCE Δ	11	19
2	ISOURCE ! Δ	11	21
3	CLEAR LINE PRINT "A=: "; IMEM(A), "B=: "; IMEM(B) EXEC	home	
4	! Δ	current	current + 2
5	ISOURCE Δ(followed by next line)	11	–
	! Δ	51	53
6	CLEAR LINE GET " "Δ	home	6 (over second quote mark in insert character mode)
7	CLEAR LINE LOAD " "Δ	home	7 (over second quote mark in insert character mode)
8	CLEAR LINE SAVE " "Δ	home	7 (over second quote mark in insert character mode)
9	CLEAR LINE STORE " "Δ	home	8 (over second quote mark in insert character mode)
10	CLEAR LINE CAT " "Δ	home	6 (over second quote mark in insert character mode)
11	CLEAR LINE SCRATCH Δ		
12	(used by other keys)		
13	ISOURCE Δ(followed by next line)	11	–
	: Δ	30	32
14	(Undefined)		
15	(Undefined)		
16	(Undefined)		
17	! Δ	41	43
18	CLEAR LINE PRINTER IS Δ	home	12

Key	Typing Aid	Typing Aid Starting Position	Final Cursor Position
19	BIN Δ[1] (use only after using Key 7 or 9)	current − 1	current + 4 (over second quote mark in insert character mode)
20	CLEAR LINE RE-SAVE ""Δ	home	10 (over second quote mark in insert character mode)
21	KEY Δ (use only after using key 7 or 9)[2]	current − 1	current + 4 (over second quote mark in insert character mode)
22	:F8Δ	current	current + 3
23	:T15Δ	current	current + 4
24	(used by other keys)		
25	(used by other keys)		
26	CLEAR LINE MASS STORAGE IS ""Δ	home	18 (over second quote mark in insert character mode)
27	CLEAR LINE PRINTALL IS Δ	home	13
28	CLEAR LINE NORMAL EXEC	home	—
29	CLEAR LINE CONT Δ	home	6
30	CLEAR LINE PURGE ""Δ	home	8 (over second quote mark in insert character mode)
31	CLEAR LINE CREATE "" Δ	home	9 (over second quote mark in insert character mode)

1 For example, in the insert character mode with the cursor in each case located over the second quote mark:
- Pressing Key 7 results in – LOAD ""
- Pressing Key 19 results in – LOAD BIN ""

2 This key performs for the keyword "KEY" as key 19 does for the keyword "BIN". See Note 1.

Appendix J
Error Messages

The following is a numerical list of the system error messages. A brief description of the error is given. For those errors involving the assembly language system, also consult Chapter 9. For all other errors, reference the Operating and Programming Manual.

1	Missing ROM; or configuration error
2	Memory overflow; or subprogram larger than block of memory
3	Line not found or not in current program segment
4	Improper return
5	Abnormal program termination; no END or STOP statement
6	Improper FOR/NEXT matching
7	Undefined function or subroutine
8	Improper parameter matching
9	Improper number of parameters
10	String value required
11	Numeric value required
12	Attempt to redeclare variable
13	Array dimensions not specified
14	Multiple OPTION BASE statement or OPTION BASE statement preceded by variable declarative statements
15	Invalid bounds on array dimension or string length in memory allocation statement
16	Dimensions are improper or inconsistent; or more than 32 767 elements in an array
17	Subscript out of range

18	Substring out of range; or, string too long
19	Improper value
20	Integer precision overflow
21	Short precision overflow
22	Real precision overflow
23	Intermediate result overflow
24	TAN (π*3/2), when n is odd
25	Magnitude of argument of ASN or ACS is greater than 1
26	Zero raised to negative power
27	Negative base raised to non-integer power
28	LOG or LGT of negative number
29	LOG or LGT of zero
30	SQR of negative number
31	Division by zero; or,X MOD Y with Y = 0
32	String does not represent valid number; or string response when numeric data required
33	Improper argument for NUM, CHR$, or RPT$ function
34	Referenced line is not IMAGE statement
35	Improper format string
36	Out of DATA
37	EDIT string longer than 160 characters
38	I/O function not allowed
39	Function subprogram not allowed
40	Improper replace, delete, or REN command
41	First line number greater than second
42	Attempt to replace or delete a busy line or subprogram
43	Matrix not square

44	Illegal operand in matrix transpose or matrix multiply
45	Nested keyboard entry statements
46	No binary in memory for STORE BIN; or no program in memory for SAVE
47	Subprogram COM declaration is not consistent with main program
48	Recursion in single-line function
49	Line specified in ON declaration not found
50	File number less than 1 or greater than 10
51	File not currently assigned
52	Improper mass storage unit specifier
53	Improper file name
54	Duplicate file name
55	Directory overflow
56	File name is undefined
57	Mass Storage ROM is missing
58	Improper file type
59	Physical or logical end-of-file found
60	Physical or logical end-of-record round in random mode
61	Defined-record size is too small for data item
62	File is protected; or, wrong protect code specified
63	The number of physical records is greater than 32 767
64	Medium overflow (out of user storage space)
65	Incorrect data type
66	Excessive rejected tracks during a mass storage initialization
67	Mass storage parameter less than or equal to 0
68	Invalid line number in GET or LINK operation
69-79	(See Mass Storage ROM errors)

80	Cartridge out; or door open
81	Mass storage device failure
82	Mass storage device not present
83	Mass storage medium is write-protected
84	Record not found
85	Mass storage medium is not initialized
86	Not a compatible tape cartridge
87	Record address error; or, information can't be read
88	Read data error
89	Check read error
90	Mass storage system error
91-99	(See Mass Storage ROM errors)
100	Item in PRINT USING list is string but IMAGE specifier is numeric
101	Item in PRINT USING list is numeric but IMAGE specifier is string
102	Numeric field specifier wider than printer width
103	Item in PRINT USING list has no corresponding IMAGE specifier
104	(See I/O ROM errors)
105-109	(Unused)
110-113	(See Plotter ROM errors)
114-149	(Unused)
150-167	(See I/O ROM errors)
168-183	(Unused)
184-199	(See Assembly Language ROM errors)

System Error {octal number} ; {octal number}

This error indicates an error in the machine's firmware system; it is a fatal error. If reset does not bring control back, the machine must be turned off, then on again. If the problem persists, contact your Sales and Service Office.

Mass Storage ROM Errors

69	Format switch off
70	Not a disk interface
71	Disk interface power off
72	Incorrect controller address; or, controller power off
73	Incorrect device type in mass storage unit specifier
74	Drive missing; or power off
75	Disk system error
76	Incorrect unit code in mass storage unit specifier
77-79	(Unused)
91-99	(Unused)

Plotter ROM Errors

110	Plotter type specification not recognized
111	Plotter has not been specified
112	(Unused)
113	LIMIT specifications out of range
114-119	(Unused)

Assembly Language ROM Errors

184	Improper argument in OCTAL or DECIMAL function
185	Break Table overflow
186	Undefined BASIC label or subprogram name used in IBREAK statement
187	Attempt to write into protected memory; or, attempt to execute instruction not in ICOM region
188	Label used in an assembled location not found
189	Doubly-defined entry point or routine
190	Missing ICOM statement
191	Module not found
192	Errors in assembly
193	Attempt to move or delete module containing an active interrupt service routine
194	Address out of range in IDUMP statement
195	Routine not found
196	Unsatisfied externals
197	Missing COM statement
198	BASIC's common area does not correspond to assembly module requirements
199	Insufficient number of BASIC COM items

Assembly-Time Errors

DD	Doubly-defined label
EN	END instruction missing; or module name does not match
EX	Expression evaluation error
LT	Literal pools full or out of range
MO	ICOM region overflow
RN	Operand out of range
SQ	Argument declaration pseudo-instruction out of sequence
TP	Incorrect type of operand used
UN	Undefined symbol

Appendix K
Maintenance

Maintenance Agreements

Service is an important factor when you buy Hewlett-Packard equipment. If you are to get maximum use from your equipment, it must be in good working order. An HP Maintenance Agreement is the best way to keep your equipment in optimum running condition.

Consider these important advantages —

- Fixed Cost — The cost is the same regardless of the number of calls, so it is a figure that you can budget.
- Priority Service — Your Maintenance Agreement assures that you receive priority treatment, within an agreed-upon response time.
- On-Site Service — There is no need to package your equipment and return it to HP. Fast and efficient modular replacement at your location saves you both time and money.
- A Complete Package — A single charge covers labor, parts, and transportation.
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- Individualized Agreements — Each Maintenance Agreement is tailored to support your equipment configuration and your requirements.

After considering these advantages, we are sure you will see that a Maintenance Agreement is an important and cost-effective investment.

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Assembly Language ROM Errors

184	Improper argument in OCTAL or DECIMAL function
185	Break Table overflow
186	Undefined BASIC label or subprogram name used in IBREAK statement
187	Attempt to write into protected memory; or, attempt to execute instruction not in ICOM region
188	Label used in an assembled location not found
189	Doubly-defined entry point or routine
190	Missing ICOM statement
191	Module not found
192	Errors in assembly
193	Attempt to move or delete module containing an active interrupt service routine
194	Address out of range in IDUMP statement
195	Routine not found
196	Unsatisfied externals
197	Missing COM statement
198	BASIC's common area does not correspond to assembly module requirements
199	Insufficient number of BASIC COM items

Assembly-Time Errors

DD	Doubly-defined label
EN	END instruction missing; or module name does not match
EX	Expression evaluation error
LT	Literal pools full or out of range
MO	ICOM region overflow
RN	Operand out of range
SQ	Argument declaration pseudo-instruction out of sequence
TP	Incorrect type of operand used
UN	Undefined symbol

HP System 35 Assembly Development ROM

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