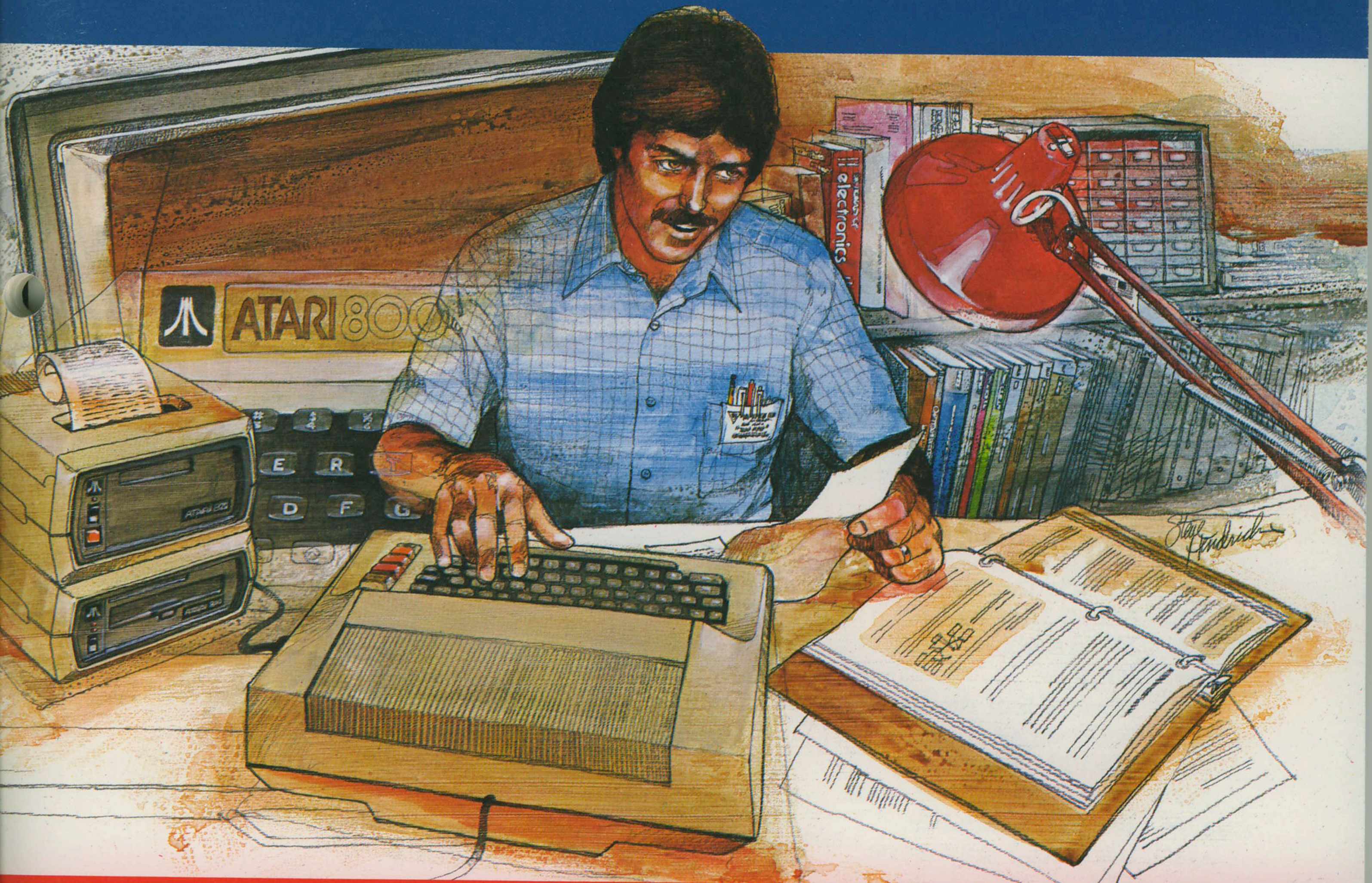
ATARI® 400/800™

# ASSEMBLER EDITOR

## USER'S MANUAL




ATARI®

A Warner Communications Company

Model CXL4003
Use with
ATARI® 400™ or ATARI 800™
PERSONAL COMPUTER SYSTEMS

# ERROR CODES

| ERROR CODE | ERROR CODE MESSAGE |
|---|---|
| 2 | Memory insufficient |
| 3 | Value error |
| 4 | Too many variables |
| 5 | String length error |
| 6 | Out of data error |
| 7 | Number greater than 32767 |
| 8 | Input statement error |
| 9 | Array or string DIM error |
| 10 | Argument stack overflow |
| 11 | Floating point overflow/ underflow error |
| 12 | Line not found |
| 13 | No matching FOR statement |
| 14 | line too long error |
| 15 | GOSUB or FOR line deleted |
| 16 | RETURN error |
| 17 | Garbage error |
| 18 | Invalid string character |

***Note:*** The following are INPUT/OUTPUT errors that result during the use of disk drives, printers, or other accessory devices. Further information is provided with the auxiliary hardware.

| ERROR CODE | ERROR CODE MESSAGE |
|---|---|
| 19 | LOAD program too long |
| 20 | Device number larger |
| 21 | LOAD file error |
| 128 | BREAK abort |
| 129 | IOCB |
| 130 | Nonexistent device |
| 131 | IOCB write only |
| 132 | Invalid command |
| 133 | Device or file not open |
| 134 | Bad IOCB number |
| 135 | IOCB read only error |
| 136 | EOF |
| 137 | Truncated record |
| 138 | Device timeout |
| 139 | Device NAK |
| 140 | Serial bus |
| 141 | Cursor out of range |
| 142 | Serial bus data frame overrun |
| 143 | Serial bus data frame checksum error |
| 144 | Device done error |
| 145 | Read after write compare error |
| 146 | Function not implemented |
| 147 | Insufficient RAM |
| 160 | Drive number error |
| 161 | Too many OPEN files |
| 162 | Disk full |
| 163 | Unrecoverable system data I/O error |
| 164 | File number mismatch |
| 165 | File name error |
| 166 | POINT data length error |
| 167 | File locked |
| 168 | Command invalid |
| 169 | Directory full |
| 170 | File not found |
| 171 | POINT invalid |

For explanation of Error Messages see Appendix 1.

# ASSEMBLER EDITOR MANUAL

ATARI®

A Warner Communications Company

# PREFACE

This manual assumes the user has read an introductory book on assembly language. It is not intended to teach assembly language. Suggested references for assembly language beginners are *6502 Assembly Language Programming* by Lance Leventhal and *Programming the 6502* by Rodney Zaks (see Appendix 8).

The user should also know how to use the screen editing and control features of the ATARI® 400™ and ATARI 800™ Personal Computer Systems. These features are the same as used in ATARI BASIC. Review the ATARI BASIC Reference Manual if you are unsure of how to do screen editing.

This manual starts by showing the structure of statements in assembly language. The manual then illustrates the different types of 6502 operands. The Assembler Editor cartridge contains three separate programs:

- EDIT (Editor program) — Helps you put programming statements in a form the Assembler (ASM) program understands. The EDIT program lets you use a printer to print a listing of your program. Programs can also be stored and recalled using ENTER, LIST and SAVE, LOAD. The Assembler Editor allows automatic numbering, renumbering, delete, find and replace.

- ASM (Assembler program) — Takes the program statements you create in the EDIT step and converts to machine code.

- DEBUGGER — Helps you trace through the program steps by running the program a step at a time while displaying the contents of important internal 6502 registers. The DEBUGGER program also contains programming routines which allow you to display registers, change register contents, display memory, change memory contents, move memory, verify memory, list memory with disassembly, assemble one instruction into memory, go (execute program), exit. The disassembly routine is especially useful in reading and understanding machine language code.

The Assembler Editor cartridge allows you to talk in the computer's natural language — machine language. Assembly language programming offers you faster running programs and the ability to tailor programs to your exact needs.

# CONTENTS

PREFACE v

1 INTRODUCTION

About This Book 1
ATARI Personal Computer Systems 1
How an Assembler Editor Is Used 2

2 GETTING STARTED

Allocating Memory 5
Program Format—How to Write a Statement 8
Statement Number 8
Label 8
Operation Code Mnemonic 8
Operand 8
Comment 8
How to Write Operands 12
Hex Operands 12
Immediate Operands 12
Page Zero Operands 12
Absolute Operands 12
Absolute Indexed Operands 12
Non-indexed Indirect Operands 13
Indexed Indirect Operands 13
Indirect Indexed Operands 13
Indexed Page Zero Operands 13
String Operands 13

3 USING THE EDITOR

Commands to Edit a Program 15
NEW Command 15
DEL Command 15
NUM Command 15
REN Command 15
FIND Command 15
REP Command 17
Commands to Save (or Display) and Retrieve Programs 19
LIST Command 19
PRINT Command 21
ENTER Command 21
SAVE Command 22
LOAD Command 22

## 4 USING THE ASSEMBLER


The ASM Command 25
Directives 27
OPT Directive 27
TITLE and PAGE Directives 28
TAB Directive 29
BYTE, DBYTE, and WORD Directives 30
BYTE 30
DBYTE 30
WORD 31
LABEL = Directive 31
* = Directive 31
IF Directive 32
END Directive 33


## 5 USING THE DEBUGGER


Purpose of Debugger 35
Calling the Debugger 35
Debug Commands 35
DR Display Registers 36
CR Change Registers 36
D or Dmmmm Display Memory 36
C or Cmmmm Change Memory 37
Mmmmm Move Memory 38
Vmmmm Verify Memory 38
L or Lmmmm List Memory With Disassembly 38
A Assemble One Instruction Into Memory 40
Gmmmm Go (Execute Program) 40
Tmmmm Trace Operation 40
S or Smmmm Step Operation 41
X Exit 41


## APPENDICES


1 Errors 43
2 Assembler Mnemonics (Alphabetic List) 45
3 Special Symbols 47
4 Table of Hex Digits with Corresponding Op Code Mnemonics and Operands 49
5 Expressions 51
6 Directives 53
7 ATASCII Code and Decimal/Hexadecimal Equivalents 55
8 References 61
9 Using the ATARI Assembler Editor Cartridge to Best Advantage 63
10 Quick Reference for Commands Recognized by the Assembler Editor 75

11 Modifying DOS I to Make Binary Headers Compatible with Assembly Cartridge **77**

## ILLUSTRATIONS

Figure 1 Relationship of various parts of Assembler Editor cartridge to you and your software **3**
Figure 2 Memory map without use of LOMEM **5**
Figure 3 Memory map with use of LOMEM **7**
Figure 4 Example of how to write Line No., Label, Op Code, Operand, and Comment in the ATARI programming form **9**
Figure 5 Statements as they would appear on the screen when entered on the keyboard with the recommended spacing. **10**
Exhibit I Sample reproducible ATARI programming form **13**
Figure 6 Sample program as you write it on the ATARI programming form **18**
Figure 7 Appearance of the screen as your program is entered on the keyboard **18**
Figure 8 Appearance of the screen as your sample program is assembled **25**
Figure 9 Normal (default) format of assembly listing as it appears on the screen **26**

# 1

# INTRODUCTION

To use the **ATARI® Assembler Editor** cartridge effectively, there are four kinds of information that you must have. First, you need some guidance about how to use the cartridge itself. Second, you need to know about the ATARI Personal Computer System you are using with the cartridge. Third, you need to know something about 6502 Assembly Language programming. And, fourth, the Assembler Editor Cartridge was designed to be used with the ATARI disk drives and DOS II.

## ABOUT THIS MANUAL

This manual explains the operation of the ATARI Assembler Editor cartridge. It does not explain 6502 Assembly Language programming. If you are already familiar with 6502 Assembly Language, you will find this manual amply suited to your needs; otherwise, you should refer to one of the many books that explain 6502 Assembly Language programming; suitable books are listed in Appendix 8.

If you are familiar with ATARI BASIC and have written some programs on your ATARI 400™ or ATARI 800™ Personal Computer System, you will find no better way to learn assembly language than the combination of this manual, the ATARI Assembler Editor cartridge, and a 6502 programming book.

If you have had no experience with computers and no programming experience, then this manual is probably too advanced for you and you should start by writing some programs using ATARI BASIC and your ATARI Personal Computer System to become familiar with programming in general. Reading one of the books recommended in Appendix 8 will help you learn assembly language.

## ATARI PERSONAL COMPUTER SYSTEMS

The ATARI Assembler Editor cartridge is installed in the cartridge slot of the ATARI 400 computer console and in the left cartridge slot of the ATARI 800 computer console. You must be familiar with the keyboard and all the screen-editing functions. That material is covered in the appropriate Operator's Manual supplied with your ATARI Personal Computer System. The special screen-editing keys are described in Section 6 of the Operator's Manual. You should read Section 6 and follow the instructions until you are completely familiar with the keyboard and the screen-editing functions.

You need not have any equipment except the ATARI Personal Computer System console, your television or a video monitor for display, and the ATARI Assembler Editor cartridge. However, without a permanent storage device you will have to enter your program on the keyboard each time you wish to use it. This can be tedious and time-consuming. An ATARI 410™ Program Recorder, ATARI 810™ Disk Drive, or ATARI 815™ Dual Disk Drive (double density) is a practical necessity.

The ATARI 410 Program Recorder is an accessory that functions with the ATARI 400 and the ATARI 800 Personal Computer Systems. The proper operation of your Program Recorder is explained in Section 8 of the ATARI 400 and ATARI 800 Operator's Manuals. Before using the Program Recorder with the Assembler Editor cartridge, be sure you know how to operate the Program Recorder. The disk drives are accessories that function with any ATARI Personal Computer System with at least 16K RAM. To use a disk drive you need a special program, the Disk Operating System (DOS). At least 16K of memory is required to accommodate DOS. Consequently, if you are using an ATARI 400 Personal Computer System, you must upgrade it from 8K to 16K (RAM). This can be done at any ATARI Service Center.

If you are using the ATARI 810 Disk Drive, you should refer to the instructions that come with it. You should also read the appropriate Disk Operating System Reference Manual. If you are currently using the 9/24/79 version of DOS (DOS I), you must use the program in Appendix 11 for the disk drive to be compatible with the Assembler Editor cartridge.

If you are using the ATARI 815 Dual Disk Drive, you should refer to the ATARI 815 Operator's Manual and the Disk Operating System II Reference Manual that come with it.

You can also add the ATARI 820™, the ATARI 825™ or the ATARI 822™ Printer to your Personal Computer System to give you "hard copy"—that is, a permanent record of your program written on paper.

## HOW AN ASSEMBLER EDITOR IS USED

All assembly language programs are divided into two parts: a "source program," which is a human-readable version of the program, and the "object program," which is the computer-readable version of the program. These two versions of the program are distinct and must occupy different areas of RAM. As the programmer, you have three primary tasks:

- To enter your source program into the computer, edit it (make insertions, deletions, and corrections) and save it to or retrieve it from diskette or cassette.
- To translate your source code into object code.
- To monitor and debug the operation of your object program.

These three tasks are handled with three programs included in the ATARI Assembler Editor. The first program, called the Editor, provides many handy features for entering the program and making insertions, deletions, and corrections to it. It also allows you to save and retrieve your source code. The second program, called the Assembler, will translate your source program into an object program. While doing so, it will provide you with an "assembly listing," a useful listing in which your source program is lined up side by side with the resulting object program. The third program is called the Debugger; it helps you to monitor and debug your object program. The relationship between these three programs is depicted as follows:

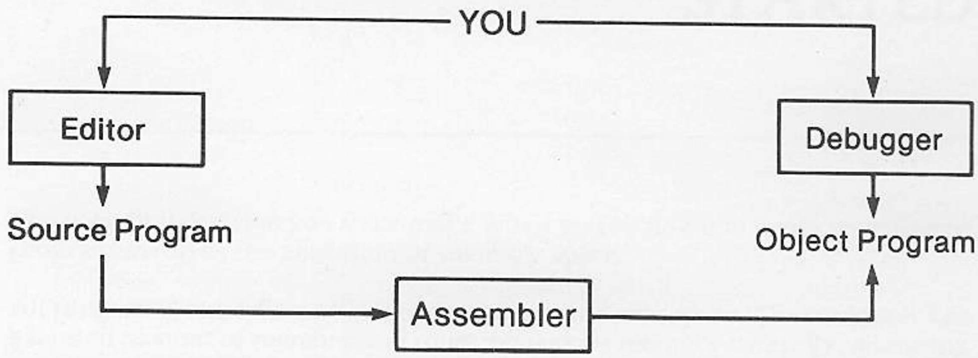



***Figure 1. Relationship of various parts of Assembler Editor cartridge to you and your software.***

In Section 3 we explain the Editor; in Section 4, the Assembler; and in Section 5, the Debugger. There are some fundamental ideas we must explain first.

# NOTES:

# 2
# GETTING STARTED

## ALLOCATING MEMORY

The very first decision you must make when you sit down to write your source program involves the allocation of memory space.

All programs, regardless of language, occupy memory space. The computer has a limited amount of memory and must manage its memory carefully, allocating portions of memory for program, data, display space, and so forth. This is all done automatically in BASIC, so the BASIC user need not worry about where in memory his program and data are stored. Such is not quite the case with the Assembler Editor cartridge. You have the power to place your programs anywhere in memory that you desire. With this power comes the responsibility to allocate memory wisely.

The ATARI computer system uses low memory for its own internal needs. The amount it uses depends on whether or not DOS is loaded into RAM. In any event, the Assembler Editor cartridge will automatically place your source program into the chunk of memory starting with the first free memory location. As you type in more source code, the memory allocated to storing your source code (called the "Edit Text Buffer") grows. If you delete lines of source code, the edit text buffer shrinks. You can visualize the memory allocation with this figure, which is called a memory map:

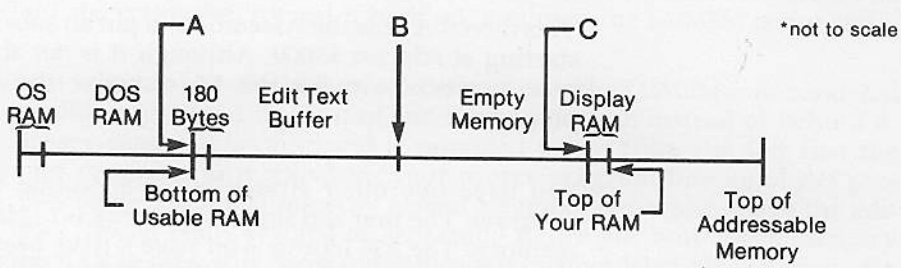



***Figure 2. Memory map without use of LOMEN.***

The edit text buffer always grows towards the right, into the "empty memory" area. The left side of the edit text buffer is fixed in place once you start entering code.

Your problem is to determine where to store the object code produced by the Assembler. If you put the object code into the regions marked OS RAM, DOS RAM, or display RAM, you will probably cause the computer to crash and all your typing will be lost. If you put it into the place called the edit text buffer, the object code will overwrite the source code, causing more chaos. The only safe place to put your object code is in the "empty memory" area.

You can find out where this empty memory area is by typing SIZE RETURN. Three hexadecimal numbers will be displayed, like so:

```
SIZE RETURN
0700  0880  5C1F
EDIT
```

The first number (0700 in this example) is the address of the bottom of usable RAM, the point labeled "A" on the memory map. The second number is the address of the top of the edit text buffer, labeled "B" on the memory map. The third number is the address of the top of empty memory, labeled "C" on the memory map. The difference between the second and third numbers (how good are you at hexadecimal subtraction?) is the amount of empty memory. You can use the SIZE command any time you desire to know how much empty memory remains.

Liberally estimate the amount of memory your object program will require, then subtract that amount from the third number. For extra insurance, round the result down. For example, if you thought that your object code might require 1.5K, you'd subtract 2K from $5C1F to get $541F and then for simplicity (and additional insurance) you would round all the way down to $5000. You would therefore store your object code at $5000, confident that it would not encroach on the display memory. More conservative estimates and greater care would be necessary if memory were in short supply.

Having decided to store the object program starting at address $5000, your next task is to declare this to the computer. This is done with *= directive. The very first statement of the source code would read:

```
10  *=$5000
```

This directive tells the Assembler to put all subsequent object code into memory starting at address $5000. Although it is not absolutely necessary, it is always wise practice to make the *= directive the very first line of your source program.

You have two other strategies for allocating memory space for your object program. The first and simplest strategy is to place your object code on page 6 of memory. The 256 locations on page 6 have been set aside for your use. If your object program and its data will all fit into 256 bytes, then you can put it there with the directive:

```
10  *=$0600
```

This is a good safe way to start when you are still learning assembly language programming and are writing only very short programs. As your programs grow larger, you will want to move them off page 6 and use page 6 for data and tables.

The second strategy is to bump the edit text buffer (your source program) upward in memory, leaving some empty memory space below it. You can then place your object code into this empty space. Figure 3 shows the adjustment of the memory map.

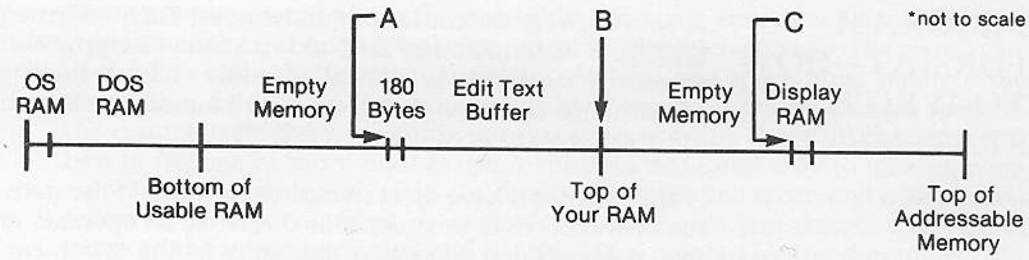



***Figure 3. Memory map with use of LOMEM.***

This bumping is accomplished with a special command called LOMEM. The command is special because it must be the very first command you enter after turning on the computer. Its form is simple:

LOMEM XXXX RETURN

where XXXX is the hexadecimal address of the new bottom edge of the edit text buffer (point A in the memory map). You must not set LOMEM to a smaller value than it normally is, or you will overwrite OS data or DOS and crash the system. Furthermore, if you set LOMEM too high, you will have too little room for your source program. You must estimate how much memory your object code will require, and bump the edit text buffer upward by that much plus some more for insurance. Then your first program instruction becomes:

```
10  *=$YYYY
```

where YYYY is the old value of A given by the SIZE command before you turned off the computer, turned it back on, and used the LOMEM command.

You might wonder why anybody would want to use the LOMEM command and store the object program in front of the source program instead of behind it. The primary reason this command is provided comes from the fact that the Assembler program, as it translates your source program into an object program, uses some additional memory (called a symbol table) just above the edit text buffer. If you really wanted to, you could figure just how much memory the symbol table uses; it is three bytes for each distinct label plus one byte for each character in each label. Most programmers who don't enjoy figuring out how big this symbol table is use the LOMEM command so they won't have to worry about it. (Only the label itself counts, not the number of times it appears in the program.)

Allocating memory can be a confusing task for the beginner. Only two instructions (LOMEM and *=) are used, but if they are misused you can crash the system and lose your work. Fortunately, if you restrict yourself to small programs initially you'll have plenty of empty memory space and fewer allocation problems.

The *= directive will be followed by your source program. The source program is composed of statements. The statements must be written according to a rigorous format. The rules for writing statements are given in the next section.

## PROGRAM FORMAT—HOW TO WRITE A STATEMENT

A source program consists of statements. Each statement is terminated with RETURN. A statement may be 1-106 characters long, or almost three lines on the screen. A statement is also called a line. The distinction is made between a physical line (a line on the screen) and a logical line (the string of characters, up to three physical lines between RETURNs).

A statement can have up to five parts or "fields": the statement number, a label, the operation code mnemonic or directive, an operand, and a comment. These five fields occupy successive positions in the statement, with the statement number coming first and the comment coming last. Fields are separated ("delimited") by single spaces.

### Statement Number

Every statement must start with a number from 0 to 65535. It is customary to number statements in increments of 10, 20, 30, etc. The Editor automatically puts the statements in numerical order for you. Numbering by tens allows you to insert new statements at a later date between existing statements. To assist you, the Editor has several convenient commands for automatically numbering statements (see NUM, REN).

### Label

A label, if used, occupies the second field in the statement. You must leave exactly one space (not a tab) after the statement number. The label must start with a letter and contain only letters and numbers. It can be as short as one character and as long as the limitation of statement length permits (106 less the number of characters in the statement number). Most programmers use labels three to six characters long.

You are not forced to have a label. To go on to the next field, enter another space (or a tab). The Assembler will interpret the entries after a tab as an operation code mnemonic.

### Operation Code Mnemonic

The operation code (or op code) mnemonic must be one of those given in Appendix 2. It must be entered in the field that starts at least two spaces after the statement number, or one space after a label. An operation code mnemonic in the wrong field will not be identified as an error in the Edit mode, but will be flagged when you assemble the program (Error 6).

### Operand

The field of the operand starts at least one space (or a tab) after an operation code mnemonic. Some operation code mnemonics do not require an operand. The Assembler will expect an operand if the op code mnemonic requires one. Each different way of writing an operand is given in the section called HOW TO WRITE OPERANDS.

### Comment

A comment appears on the listing of a program, but does not in any way affect the assembled object code. Programmers use comments to explain to others (and to themselves) how a section of code works.

There are two ways to have the Assembler interpret entries as comments. One way is to make the entries in the comment field, which occupies the remainder of the line after the instruction field(s). At least one space must separate the instruction fields from the comment field. There may not be enough space in the comment field for the comment you wish to write there. In that case it is best to use one or more lines as comment lines dedicated only to making comments and containing no code. To do so, you enter one space and a semicolon followed by any comment or explanatory markings you desire. Everything between the initial semicolon and the RETURN is ignored by the Assembler, but will be printed in the listing of the program.

A sample programming form for assembly language is reproduced as Figure 4. The form shows examples of how to enter line number, label, op code, operand and comments. These classes of entry are lined up vertically on the programming form. Most variation occurs in the method of entering a comment. Therefore, Figure 4 includes examples of the various ways to enter comments.

**Sample, Reproducible**
**ATARI Programming Form**

| PROGRAM SAMPLE.ASM | PAGE 1 OF 1 | DATE 12/31/80 |
|---|---|---|
| | PROGRAMMER JOHN DOE | |

| LINE NO. | LABEL | OP CODE | OPERAND | COMMENT |
|---|---|---|---|---|
| 10 | LABL | LDX | ABS | COMMENT IN COMMENT FIELD |
| 20 | | TXA | | COMMENT IN COMMENT FIELD |
| 30 | | PHA | | COMMENT IN THIS LINE AUTOMA |
| | | | | TICALLY CONTINUES ON THIS LINE |
| 240 | | CLC | | COMMENT ON THIS LINE CONT |
| 250 | | | | ;INUES ON THIS NUMBERED LINE |
| 260 | | ADC | #$B2 | |
| 270 | | | | ;COMMENT ON ITS OWN LINE |
| 280 | ANYTHINGMAKESALABEL | | | |
| 290 | | | | ; |
| 300 | | | | ;PREVIOUS LINE (290) CONTAINS |
| | | | | ONLY BLANKS, (SPACE BAR). LINE |
| | | | | 280 CONTAINS ONLY THE LABEL |
| | | | | "ANYTHINGMAKESALABEL" |

***Figure 4. Example of how to write Line No., Label, Op Code, Operand, and Label on the Atari programming form.***

The spacing on the programming form is not the same as the spacing to be used on the screen, controlled by keyboard entry. On the screen the classes of entry (the fields) are not lined up vertically. The screen has 38 positions (you can change it to a maximum of 40), fewer than the programming form, and that is the main reason not to use many spaces between fields. Another difference between the programming form and screen is the 'wraparound' on the screen—automatic continuation of characters onto the next line.

Figure 5 shows the entries in Figure 4 as they should appear on the screen when entered on the keyboard with the recommended spacing. In general, the spacing recommended in this manual is the minimum spacing that will be correctly interpreted by the Assembler Editor. If you prefer to have more vertical alignment of fields, use TAB, rather than the single spacing between fields that we recommend. The statements below show various examples of comments correctly positioned in the statement. Each comment in the examples starts with "COMMENT" or semicolon(;).

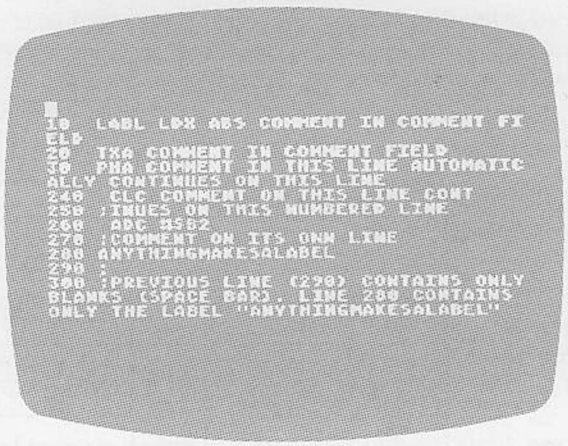



***Figure 5. Statements as they would appear on the screen when entered on the keyboard with the recommended spacing. The various ways to enter comments are illustrated. Compare with Figure 4.***

## HOW TO WRITE OPERANDS

This section shows how to write operands. The examples use statement number XXXX (also called line number XXXX). An instruction entered without a statement number is not allowed by the Editor.

The examples use BY (for byte) and ABS (for absolute) as a one-byte and a two-byte number, respectively. This use implies that the program includes definitions of BY and ABS as, for example:

```
0100  BY=155
0200  ABS=567
```

Please refer to the description of the LABL= directive for an explanation of the definitions of lines 100 and 200.

### Hexadecimal Operands

A number is interpreted as a decimal number unless it is preceded by $, in which case it is interpreted as a hexadecimal number.

**Examples:**

```
  30  STA  $9325
  80  ASL  $15
```

### Immediate Operands

An immediate operand is an operand that contains the data of the instruction. The pound sign (#) must be present to indicate an immediate operand.

**Examples:**

```
  40  LDA  #12
  70  ORA  #$3C
1000  CPY  #BY
```

### Page Zero Operands

When an operand is a number less than 255 decimal, (FF hex) and is not immediate, the number is interpreted as a page zero address.

**Examples:**

```
 150  LDX  $12
 250  ROR  33
 500  DEC  BY
```

### Absolute Operands

Absolute operands are evaluated as 16-bit numbers.

**Examples:**

```
  20  LDX  $1212
  40  CPY  2345
 990  DEC  579
2350  BIT  ABS
```

### Absolute Indexed Operands

An absolute indexed operand uses register X or Y. The operand is written ________,X or ________,Y

**Examples:**

```
  10  AND  $3C26,X
 110  EOR  20955,Y
1110  STA  ABS,Y
```

### Non-Indexed Indirect Operands

In general, an indirect operand is written with parentheses. The address within the parentheses is an intermediate address which itself contains the effective address. The only instruction with a non-indexed indirect operand is Jump Indirect. The operand is a number enclosed in parentheses. The parentheses in the operand enclose a number or an expression that is interpreted as an intermediate address.

**Examples:**

```
JMP  ($6000)
JMP  (ABS)
JMP  (7430)
JMP  (ABS+256*BY)
```

### Indexed Indirect Operands

An indexed indirect instruction uses register X. The operand is written (—,X)

**Examples:**

```
10  INC  ($99,X)
```

### Indirect Indexed Operands

An indirect indexed instruction uses register Y. The operand is written (—),Y

**Examples:**

```
  10  LDA  ($2B),Y
 110  CMP  ($E5),Y
1110  ORA  (BY),Y
```

### Indexed Page Zero Operands

A zero page indexed operand is written —,X or —,Y

**Examples:**

```
  10  INC  $34,X
 110  STX  $AB,Y
1110  LDX  BY,Y
```

### String Operands

Operands or parts of operands enclosed in double quotation marks are translated into the ATASCII codes of the characters between the quotation marks. The use of such operands must of course be appropriate to the type of instruction or directive to which they are appended.

**Examples:**

```
10  ADDR  .BYTE  "9+1 =s TEN"
```

Execution of this directive causes the ATASCII numbers corresponding to "9", "+", etc., to be stored at successive locations starting at ADDR. Note that the ATASCII representation of any character except the quotation mark (") can be stored with the .BYTE directive having a string operand.

**Exhibit I**

## Sample, Reproducible
## ATARI Programming Form

| PROGRAM | PAGE OF | DATE |
|---|---|---|
| | PROGRAMMER | |

| LINE NO. | LABEL | OP CODE | OPERAND | COMMENT |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

# NOTES:

# 3

# USING THE EDITOR

Now that we have explained how to get started writing a program, it is up to you to actually write the program. This manual contains very little information on assembly language programming techniques. We assume that you are already familiar with assembly language. The remainder of the section describes how to use the Assembler Editor cartridge.

## COMMANDS TO EDIT A PROGRAM

A command is not the same thing as an instruction. An instruction has a line number; a command has no line number and is executed immediately.

### NEW Command

This command clears the edit text buffer. After this command you cannot restore your source program; it has been destroyed.

Some programmers have the habit of giving the NEW command (or its equivalent with other assemblers) when they start a programming session. The reason is to remove any "garbage" that may be in memory by mistake. Since the ATARI Personal Computer System clears its memory when it is turned on, such routine use of NEW would be a needless precaution. Because NEW destroys your entire source program, it is more important to develop a habit of NOT using it routinely. You should, rather, use NEW in a very deliberate fashion only when you want to remove a source program from RAM.

### DEL Command

This command deletes statements from your source program.

| | | |
|---|---|---|
| DELxx | RETURN | deletes statement number xx. |
| DELxx,yy | RETURN | deletes statement numbers xx through yy. |

### NUM Command

This command assigns statement numbers automatically.

| | | |
|---|---|---|
| NUM | RETURN | increments statement number by 10 after each RETURN. The new statement number, followed by a space, is automatically displayed. |
| NUMnn | RETURN | has the same effect as NUM, but the increment is nn instead of 10. |
| NUMmm,nn | RETURN | forces the next statement number to be mm and the increment to be nn. |
| RETURN | RETURN | cancels the NUM command. |

The effect of the NUM command stops automatically when a statement number that already exists is reached. For example:

```
10     LDX #$EF
20     CMP MEMORY
NUM    15,5
15
```

After statement number 15, the next statement number would be 20, which already exists, so the NUM command is cancelled. The automatic numbering of statements will continue until the next number is exactly equal to an existing number. A slight change from the above example illustrates this:

```
10     LDX #$EF
20     CMP MEMORY
NUM    15,6
15     TAX
21
```

**Caution:** You cannot use the special keyboard editing keys to change other statements while the NUM command is in effect. You will succeed in changing what appears on the screen, but, in an exception to the general rule, the contents of the edit text buffer will not be changed.

### REN Command

This command renumbers statements in your source program.

| | | |
|---|---|---|
| REN | RETURN | renumbers all the statements in increments of 10, starting with 10. |
| RENnn | RETURN | renumbers all the statements in increments of nn, starting with 10. |
| RENmm,nn | RETURN | renumbers all the statements in increments of nn, starting with mm. |

### FIND Command

This command finds a specified string. The ways to write the command are shown below.

| | | |
|---|---|---|
| FIND/SOUGHT/ | RETURN | finds the first occurrence of the string SOUGHT. The statement that contains the string is displayed. |
| FIND/SOUGHT/,A | RETURN | finds all occurrences of the string SOUGHT. All statements containing such occurrences are displayed. |
| FIND/SOUGHT/xx | RETURN | finds the string SOUGHT if it occurs in statement number xx. Statement xx is displayed if it contains the string. |
| FIND/SOUGHT/xx,yy,A | | finds all occurrences of the string SOUGHT between statement number xx and yy. All the statements that contain the string are displayed. |

In these examples, the string SOUGHT is delimited (marked off) by the character /. Actually, any character except space, tab and RETURN can be used as the delimiter. For example, the command

```
FIND DAD
```

finds the first occurrence of the character A. The delimiter is the character D. The delimiter is defined as the first character (not counting space or tab) after the keyword FIND. This feature is perplexing to beginners; its purpose is to allow you to search for strings that contain slashes (/) or, for that matter, any special characters.

The general form of the command is

FIND delimiter string delimiter [lineno, lineno] [,A]

In the general form, symbols within a pair of brackets are optional qualifiers of the command.

### REP Command

This command replaces a specified string in your source program with a different specified string.

| | | |
|---|---|---|
| REP/OLD/NEW | RETURN | replaces the first occurrence of the string OLD with the string NEW. |
| REP/OLD/NEW/xx,yy | RETURN | replaces the first occurrence of the string OLD between statements number xx to yy with the string NEW. |
| REP/OLD/NEW/,A | RETURN | replaces all the occurrences of the string OLD with the string NEW. |
| REP/OLD/NEW/xx,yy,A | RETURN | replaces all the occurrences of the string OLD between statements xx to yy with the string NEW. |
| REP/OLD/NEW/xx,yy,Q | RETURN | displays, in turn, each occurrence of the string OLD between statements xx and yy.<br>Q stands for "query." To replace the displayed OLD with NEW, type Y, then RETURN. To retain the displayed OLD, press RETURN. |

In these examples, the strings OLD and NEW are delimited by the character "/". As with the FIND command, any character except space, tab and RETURN, can be used as the delimiter. For example, the command

```
REP+RTS+BRK+,A
```

replaces all occurrences of RTS with BRK. The delimiter is the character "+".

The general form of this command is

REP delimiter OLD delimiter NEW delimiter [lineno, lineno] [Q / ,A]

In the general form, symbols within a pair of brackets are optional qualifiers of the command and the symbols within braces (A and Q) are alternatives.

## Sample Program

Let us assume you have written a program on an ATARI Programming Form as shown in Figure 6:

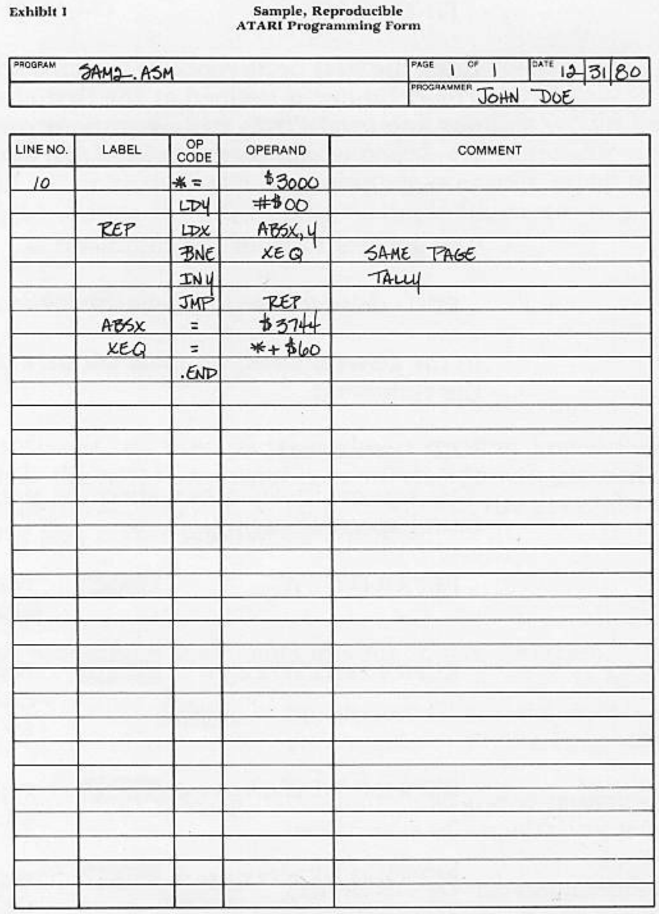


**Exhibit 1**

**Sample, Reproducible ATARI Programming Form**

| PROGRAM | | PAGE | OF | DATE |
|---|---|---|---|---|
| SAM2.ASM | | 1 | 1 | 12/31/80 |
| | | PROGRAMMER JOHN DOE | | |

| LINE NO. | LABEL | OP CODE | OPERAND | COMMENT |
|---|---|---|---|---|
| 10 | | *= | $3000 | |
| | | LDY | #$00 | |
| | REP | LDX | ABSX,Y | |
| | | BNE | XEQ | SAME PAGE |
| | | INY | | TALLY |
| | | JMP | REP | |
| | ABSX | = | $3744 | |
| | XEQ | = | *+$60 | |
| | | .END | | |

*Figure 6. Sample Program as you write it on the ATARI programming form*

Then when you type it in it would appear on the screen as shown in Figure 7:

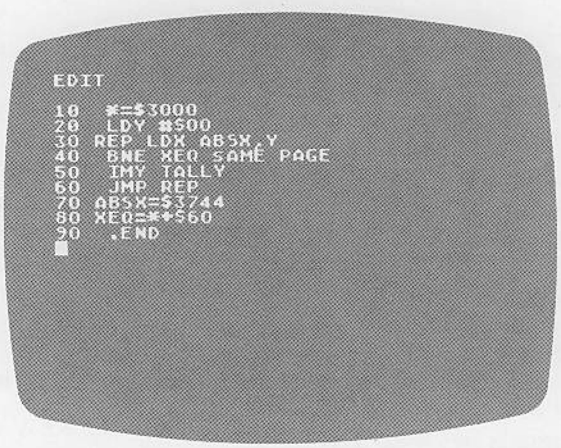



*Figure 7. Appearance of the screen as your program is entered on the keyboard.*

## COMMANDS TO SAVE (OR DISPLAY) AND RETRIEVE PROGRAMS

The commands to save (or display) and retrieve programs are:

| | |
|---|---|
| LIST | saves or displays a source program |
| PRINT | is the same as LIST, but omits line numbers |
| ENTER | retrieves a source program |
| SAVE | saves an object program |
| LOAD | retrieves an object program |

With each of these commands there is a parameter that specifies the device that is the source or destination of the program that is to be saved, displayed or retrieved. The possible devices are different for different commands, and the default device is also different. Some of the commands have optional parameters that limit the application of the command to specified parts of the program.

The parameter that specifies the device that is the source or destination of the program is written as follows:

| | |
|---|---|
| #E: | is the screen editor |
| #P: | is the printer |
| #C: | is the Program Recorder |
| #D[n]:FILENAME | is a disk drive. n is 1, 2, 3 or 4. D: is interpreted as D1:. A program saved on or retrieved from a diskette must be named (FILENAME). |

### LIST Command

**Format:** LIST# { device: / filespec } [,xx,yy]

**Examples:** LIST#E:

LIST#D:MYFILE

This command is used to display or save a source program. The device where the source program is to be displayed or saved is given in the command. If no device is specified, the screen is assumed by default. Other possible devices are the printer (#P:), Program Recorder (#C:) and disk drive (#D1: through #D8: or #D:, which defaults to #D1:). The commands to transfer a program (LIST it) to these various devices are:

| | |
|---|---|
| LIST#E: | (LIST#E: is the same as LIST) |
| LIST#P: | |
| LIST#C: | (Use cassette-handling procedures described in your Program Recorder Operator's Manual.) |
| LIST#D:filename | where filename is an arbitrary name you give to the program. Filename must start with a letter and have no more than eight characters, consisting of letters and numbers only. It may also have an extension of up to three characters. For example, NAME3, ST5, and JOHN.23 are all legal names. |

The forms of the commands to transfer only particular lines (lines xx to yy) to a device are:

| | |
|---|---|
| LIST#E:,xx,yy | (LIST#E:,xx,yy is the same as LIST,xx,yy) |
| LIST#P:,xx,yy | |
| LIST#C:,xx,yy | (Use cassette-handling procedures described in the Program Recorder Operator's Manual.) |
| LIST#D:NAME,xx,yy | where "NAME" is an arbitrary name you give to the program. See the description above. |

A single line may be displayed or saved with the command:

LISTlineno    where lineno is the line number.

**Caution:** The DOS makes sure that every file has a unique name by deleting old files if necessary. Therefore, do not name a file you are listing to diskette with the name of a file that is already stored on the diskette, unless you wish to replace the existing file with the one you are listing.

The LIST command is illustrated below. No device is specified, so the display device is the screen, by default. The small sample program, written in the previous section, is used for illustration.

```
EDIT
LIST RETURN
10  *=$3000
20  LDY #00
30  REP LDX, ABSX, Y
40  BNE XEQ SAME PAGE
50  INY TALLY
60  JMP REP
70  ABSX = $3744
80  XEQ = *+$60
90  .END

EDIT
LIST30  RETURN

30 REP LDX ABSX, Y

EDIT
LIST 60,80  RETURN

60  JMP REP
70  ABSX=$3744
80  XEQ=*+$60

EDIT
▯
```

The examples above show the appearance of the screen, since that is the default device. The program or the particular lines in the examples could be displayed on the printer or saved on cassette or diskette by using the forms of the LIST command described above. Note that the commands tolerate a certain amount of variation in the insertion of blanks.

### PRINT Command

This command is the same as LIST, except that it prints statements without statement numbers.

**Example:**

```
EDIT
PRINT [RETURN]

*=$3000
LDY #00
REP LDX ABSX, Y
BNE XEQ SAME PAGE
INY TALLY
JMP REP
ABSX=$3744
XEQ=*+$60
.END

EDIT
PRINT30 [RETURN]

REP LDX ABSX, Y

[RETURN]
EDIT
PRINT 60,80 [RETURN]

JMP REP
ABSX=$3744
XEQ=*+$60

[RETURN]
EDIT
▯
```

After using a PRINT command, no further command can be entered until you press RETURN, which causes the EDIT message and cursor to be displayed.

### ENTER Command

**Format:** ENTER# {device: | filespec}

**Examples:** ENTER#C:
ENTER#D:MYFILE

The command ENTER is used to retrieve a source program. As with the command LIST, a device has to be specified, in this case the device where the program is stored. There is only one device, the disk drive, on which a named program is stored in a retrievable form. To retrieve a source program from a diskette in a disk drive, the command is:

ENTER#D:NAME

where "NAME" is the arbitrary name you gave to the program when you listed it on the diskette. This command clears the edit text buffer before transferring data from the diskette.

To retrieve a source program from cassette, the command is:

| | |
|---|---|
| ENTER#C: | (Follow the CLOAD procedure given in your 410 Program Recorder Operator's Manual.) Note that ENTER #C: clears the edit textbuffer before retrieving the source program. |

To merge a source program on cassette with the source program in the edit text buffer, the command is:

ENTER#C:,M

In the above command, where a statement number is used twice (in the edit text buffer and on tape), the statement on cassette prevails.

Commands for saving and retrieving an object program are SAVE and LOAD. They correspond to LIST and ENTER, respectively.

### SAVE Command

**Format:** SAVE# {device: / filespec} <address1,address2

**Examples:** SAVE#C:<1235,1736
SAVE#D2:MYFILE<1235,1736

To save an object program residing in hex address1 to address2 on cassette or diskette, the commands are:

SAVE#C:<address1,address2

CAUTION: Use the CSAVE procedure illustrated in your 410 Program Recorder Operator's Manual.

SAVE#D:FILENAME<address1,address2
where FILENAME is an arbitrary name you give to the block of memory that you are saving (where your object program is stored).

### LOAD Command

**Format:** LOAD# device: / filespec

**Examples:** LOAD#C:
LOAD#D:MYFILE

To retrieve an object program that had previously been SAVED and which had previously been called NAME, the command is:

| | |
|---|---|
| LOAD#D:NAME | where NAME is the arbitrary name that you gave to the object program when you saved it on diskette. |
| LOAD#C: | (Use the CLOAD procedure described in your 410 Program Recorder Operator's Manual.) |

These commands will reload the memory locations address1 to address2 with the contents that were previously saved. The numbers address1 and address2 are those that were given in the original SAVE command.

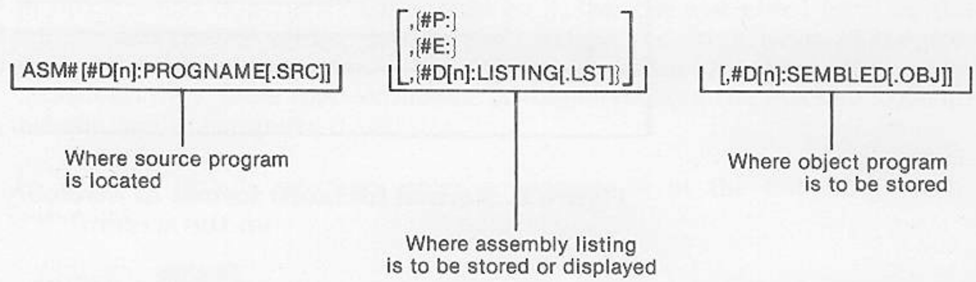
# NOTES:

# 4

# USING THE ASSEMBLER

## THE ASM COMMAND

The general form of the ASSEMBLE command is




The default values of the three parameters of the ASM command are the edit text buffer for the source program, the television screen for the assembly listing, and computer RAM for the object program (the assembled program). To assemble a program using default values of ASM, type

ASM RETURN

On receiving this command, the Assembler translates the source program in the edit text buffer into object code and writes the object code into the memory locations specified in the source program. When this process is completed, the assembled program is displayed on the screen. For an example of assembly with default parameter values, we use the small sample program that we wrote. Figure 8 shows the appearance of the screen after the ASM command.


**Figure 8. Appearance of the screen as your sample program is assembled.**

Using statements 30 and 40 as examples, the format of the assembled program is shown below. Note, however, that some of the spacing can be changed by the TAB directive.

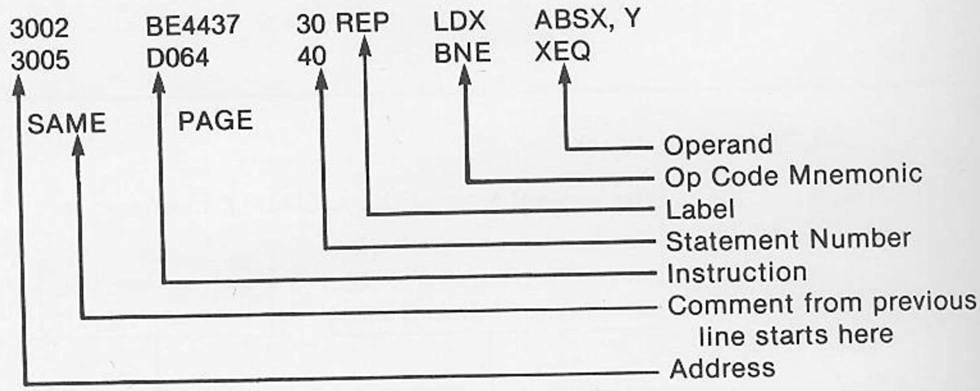



**Figure 9. Normal (default) format of assembly listing as it appears on the screen.**

The general form of the command shown at the beginning of the section shows how to override the default values of the parameters of the command. These override selections are explained below.

### Location of Source Program

You may specify the location of the source program as a named program on diskette. You must have previously stored the source program under that name, using the LIST command. In the general form of the ASM command, the source program on diskette has been given the extension .SRC. Extensions are optional.

### Where Assembly Listing Is To Be Stored

The default value is the screen (#E:). The other possibilities are the printer (#P:), the Program Recorder (#C:), and the disk drive (#D[n]:NAME [.LST]).

### Where Object Program Is To Be Stored

You may specify that the assembled program is to be stored directly on diskette, using any name (subject to the restrictions of DOS). In the general form of the ASM command, the assembled program has been given the extension .OBJ. Extensions are optional.

It is easy to become confused by names of programs when a program may exist in several related forms. To reduce the chance of confusion, we recommend using names that include identifying extensions, such as .SRC, .LST and .OBJ for a source program, an assembly listing and an object program, respectively.

Note that in the ASM command the source program must be in the edit text buffer or on a diskette in the disk drive. It can not be on a cassette in the Program Recorder. The primary reason for this restriction is that the Assembler requires two passes of the source program and the Program Recorder is not controllable to permit two passes. However, you can assemble a source program recorded with your Program Recorder. First transfer the program from Program Recorder to the edit text buffer with the command:

ENTER#C: RETURN (Follow the cassette-handling instructions in your Program Recorder Operator's Manual.)

The ASM command with no default parameters is illustrated in the example below:

ASM#D:SOURCE,#P:,#D2:SEMBLED.OBJ RETURN

The above command takes the source program that you had previously stored on diskette and called SOURCE, assembles it, lists the assembled form on the printer, and records on the diskette the machine code translation of the program (the object program). The object program is given the name "SEMBLED.OBJ." Note that commands of this form store the machine code on diskette, not in computer RAM.

To make a default selection, enter a comma, as in the following useful command:

ASM,#P: RETURN

The above command takes the source program from the default edit text buffer, assembles and lists it on the printer as before, and stores the machine code object program directly into computer RAM.

## DIRECTIVES (PSEUDO OPERATIONS)

Directives are instructions to the Assembler. Directives do not, in general, produce any assembled code, but they affect the way the Assembler assembles other instructions during the assembly process. Directives are also called pseudo operations or pseudo ops.

Directives are identified by the Assembler by the "." at the beginning. The only exceptions are the LABEL= directive and the *= directive.

A directive must have a line number, which it follows by at least two spaces. The directive LABEL= is an exception—there must be only one space before the label.

### OPT Directive

This directive specifies an option. There are four sets of options. These are:

. OPT NOLIST
. OPT LIST (this is the default condition)

. OPT NOOBJ
. OPT OBJ (this is the default condition)

. OPT NOERR
. OPT ERR (this is the default condition)

. OPT NOEJECT
. OPT EJECT (this is the default condition)

The second listed of each pair represents the standard or default condition.

| | |
|---|---|
| 100 . OPT NOLIST<br>(part of source program)<br>200 . OPT LIST | The effect of these directives is to omit from the listed form of the assembled program the lines between lines 100 and 200. (These line numbers are arbitrary.) |
| 100 . OPT NOOOBJ<br>(part of source program)<br>200 . OPT OBJ | Assembly is suppressed between lines 100 and 200. The effect of these directives is to omit from the object program code corresponding to the lines between lines 100 and 200. Memory corresponding to these lines is skipped over, leaving a region of untouched bytes in the object program. (These line numbers are arbitrary.) |
| 100 . OPT NOERR<br>(part of source program)<br>200 . OPT ERR | The effect of these directives is to omit error messages for the assembled program lines between lines 100 and 200. |
| 100 . OPT NOEJECT<br>(part of source program)<br>200 . OPT EJECT | The effect of these directives is to suppress, between lines 100 and 200, the 4-line page spacing that is normally inserted after every 56 lines of the listed form of the assembled program. |

More than one option may appear on a line. Options are then separated by a comma, as follows:

```
1000   . OPT NOLIST,NOOBJ
```

**Title and Page Directives**

```
10  . TITLE "name"
20  . PAGE "optional message"
```

We explain these directives together because they are intended to be used together to provide easily read information about the assembled program.

These directives are most useful when the assembled program is listed on the printer.

TITLE and PAGE allow you to divide your program listing into segments that bear messages written for your own convenience, much as you might add short explanatory notes to any complex material.

The PAGE directive causes the printer to put out six blank lines (printers so equipped will execute a TOP OF FORM), followed by the messages you have given for TITLE and PAGE. This causes the messages to stand out somewhat from the rest of the assembled program listing.

Usually there is only one TITLE directive, giving the program name and date, and different PAGE directives for giving different page messages. Then on listing the assembled program, the same TITLE message on every page would be followed by a different PAGE message.

The blank lines that the PAGE directive produces on the 40-column ATARI 820 Printer can be used to break up a long program into segments that can be mounted in a notebook.

To remove a title, use the following form:

```
1000  . TITLE  " "
```

The above directive removes titles after line 1000.

The PAGE directive on its own causes a page break—the printer simply puts out a number of blank lines.

**Tab Directive**

```
10   . TAB n1,n2,n3
```

The TAB directive sets the fields of the statement as they appear when assembled and listed on the screen or the printer. Let us use the specific example of Statement 40 of the small sample program we previously used for illustration. It was written as follows:

```
30  ...
40  BEQ XEQ SAME PAGE
50  ...
```

Note that one space, rather than a tab, is used between each field. Using spaces rather than tabs lets you write longer programs, since the edit text buffer will not be filled up with the extra spaces that tabs would require.

Compressing the program in this way makes it less easily readable than we might wish, but we can use the TAB directive to give us a more readable assembled version. The form of the directive is

```
lineno  . TAB 10,15,20
```

or, more generally,

```
lineno  . TAB number1,number2,number3
```

The previous example has a source program that was compressed in the above fashion. Note the difference between the spacing of the source listing and the assembled program. This is an example of the default TAB spacing.

The effect of the TAB directive of line xxx is confined to the appearance of lines following xxx when they are assembled and listed on the printer or screen.

In the case of line 40, the appearance on the printer would be as shown below:

```
3005  D064  40     BNE  XEQ  SAME PAGE
              —10—
              ——————15—
              ————————————20—
```

If the TAB directive is not used, then the appearance of the assembler line on the printer will be as shown below in the default mode:

```
3005  D064     40     BNE   XEQ   S
AME PAGE
                —12—
                ——————17—
                ——————————————27—
```

That is, the default setting corresponds to . TAB 12,17,27.

The appearance of this line on the screen will be different only because the screen has 38 characters positions, while the printer has 40.

**BYTE, DBYTE and WORD Directives**

```
100  . BYTE a,b,... ,n
200  . BYTE "A,B,... N"
300  . DBYTE a,b,... ,n
400  .WORD a,b,... ,n
```

These directives are similar in that they are used to insert data rather than instructions into the proper places in the program. Each directive is slightly different in the manner in which it inserts data.

**BYTE Directive**

The BYTE directive reserves a location (at least one) in memory. The directive increments the program counter to leave space in memory to be filled by information required by the program. The operand supplies the data to go into that space.

**Examples:**

```
10  .....
20  . BYTE 34
30  .....
```

Here, the Assembler assembles into successive locations the instruction of line 10, then the decimal number 34, then the instruction of line 30.

```
10  .....
20  . BYTE 34, 56,78
30  .....
```

Here, the Assembler assembles into successive locations the instruction of line 10, then the decimal numbers 34, 56 and 78, then the instruction of line 30. The operand may be an expression more complex than the numbers used in the examples. The rules for writing and evaluating an expression are given in Appendix D.

```
10  .....
20  . BYTE "ATARI"
30  .....
```

Here, the Assembler assembles into successive locations the instruction of line 10, then the (ATASCII code) hex numbers 41, 54, 41, 52 and 49, then the instruction of line 30.

**DBYTE Directive**

The DBYTE directive reserves two locations for each expression in the operand. The value of the expression is assembled with the high-order byte first (in the lower number location). For example:

```
10  *=$4000
20  . DBYTE  ABS+$3000
```

When line 20 is assembled and the value of ABS+$3000 is determined to be (say) $5123, $51 is put in location $4000 and $23 is put in location $4001.

### WORD Directive

The WORD directive is the same as the DBYTE directive except that the value of the expression is stored with the low-order byte first.

For example:

```
10  * = $4000
20  .WORD   ABS + $3000
```

When line 20 is assembled and the value of ABS + $3000 is determined, as before, to be $5123, $23 is put in location $4000 and $51 is put in location $4001.

The WORD directive simplifies some programming since addresses in machine code are always given in the order low byte followed by high byte. Therefore, the WORD directive is useful, for example, in constructing a table of addresses.

## LABEL = DIRECTIVE

100 LABEL = expression

The LABEL = directive is used to give a value to a label. Two examples appear in the sample program we used before. Statements 60 and 70 give values to ABSX and XEQ, as follows:

```
60  ABSX = $3744
70  XEQ = * + $60
```

Since the symbol that is given a value is a label, there must be only one space after the statement number. The expression on the right cannot have a value greater than FFFF (hex). The rules for writing and evaluating an expression are given in Appendix 4.

When the LABEL = directive is used to give a value to a label, the label can be used in an operand, by itself, as in statements 30 and 40 in the sample program.

A defined label may also appear as part of an expression. Our sample program does not contain an example, so we give one below in line 240.

```
100  TAB1 = $3000
..............
..............
..............
240  TAB2 = TAB1 + $20
```

When the program is assembled, TAB2 will be given the value $3020.

You should note that defining a label in this way gives the label a specific address; it does not define the contents of the address. In the example, above, TAB1 and TAB2 might be the location of two tables that contained the values of variables that your program required.

### * = Directive

100  * =   expression

We encountered the * = directive in the "getting started" commands, where it is used to set the starting location of the assembled program. When the Assembler encounters the * = expression, it sets the program counter to the value of the expression.

You write *= without the initial "." that the other directives have (except LABEL=). Also, note that you write *= without any spaces between * and =.

You should not confuse the *= directive with the LABEL= directive. The * in *= is not a label. Note, however, that the *= directive itself may have a label, as follows:

```
200  GO   *=expression
500  JMP  GO
```

The Assembler will assemble statement 500 as a jump to the value the program counter had BEFORE it was changed by line 200.

The *= directive is useful for setting aside space needed by your program. For example, you will frequently want space reserved starting at a particular location. Use the following form:

```
720  TABLE35   *=*+$24
740  ...
```

The effect of the directive is to reserve 24 locations immediately after TABLE35. Other parts of your code will not be assembled into these locations (unless you take pains to do so). Your program can use TABLE35 as an operand and TABLE35 can be used as an element in an expression that your instructions evaluate in accessing the table.

**IF Directive**

```
900. IF expression @LABEL
.
.
.
990  LABEL   End of conditional assembly
```

The IF directive permits conditional assembly of blocks of code. In the illustration above, all the code between lines 900 and 990 will be assembled if and only if the expression is equal to zero. If the expression is not equal to zero, the IF directive has no effect on assembly.

The example given below shows how different parts of a source program may be omitted from assembly according to the value assigned to the LABEL in the IF directive. The source program is assembled with Z=0 in one case and Z=1 in another. With Z=0, the instruction TAX is assembled, and with Z=1 the instruction ASL A is assembled. Obviously, this kind of selective assembly can be extended indefinitely.

***SOURCE CODE***

```
0100  ;CONDITIONAL ASSEMBLY EXAMPLE
0120  Z=0
0130  *=$5000
0140  LDA=$45
0150  . IF Z@ZNOTEQUAL0
0160  TAX ;THIS CODE ASSEMBLED IFF Z=0
0170  ZNOTEQUAL0
0180  . IF Z-1@ZNOTEQUAL1
0190  ASL A   ;THIS CODE ASSEMBLED IFF Z=1
0200  ZNOTEQUAL1
0210  INX ;THIS CODE ALWAYS ASSEMBLED
```

*ASSEMBLY LISTING (40-col. format)*

```
    0100 ;CONDITIONAL ASSEMBLY E
XAMPLE
0000  0120 Z   =   0
0000  0130   *=   $5000
5000 A945  0140  LDA  #$45
5002  0150  . IF  Z@ZNOTEQUA
L0
5002 AA  0160  TAX  ;
THIS CODE ASSEMBLED IFF Z=0
    0170  ZNOTEQUAL0
5003  0180  . IF  Z-1@ZNOTEQ
UAL1
    0190  ASL A
    0200  ZNOTEQUAL1
5003 E8  0210  INX  ;
THIS CODE ALWAYS ASSEMBLED

0100  ;CONDITIONAL ASSEMBLY E
XAMPLE
0001  0120 Z   =   1
0000  0130   *=   $5000
5000 A945  0140  LDA  #$45
5002  0150  . IF  Z@ZNOTEQUA
L0
    0160  TAX  ;THIS CODE ASSEMBL
ED IFF Z=0
    0170 ZNOTEQUAL0
5002  0180  . IF  Z-1@ZNOTEQ
UAL1
5002 OA  0190  ASL A
0200 ZNOTEQUAL1
5003 E8  0210  INX  ;
THIS CODE ALWAYS ASSEMBLED
```

**END Directive**

```
1000  . END
```

Every program should have one and only one END directive. It tells the Assembler to stop assembling. It should come at the very end of your source program. Later, if you decide to add more statements to your program, you should remove the old . END directive and place a new one at the new end of your source program. Failure to do so will result in your added source code not being assembled. This mistake is particularly easy to make when you make your additions with the NUM command. It is not always essential to have an . END directive, but it is good practice.

# NOTES:

# 5

# DEBUGGING

## PURPOSE OF DEBUGGER

The Debugger allows you to follow the operation of an object program in detail and to make minor changes in it.

A knowledge of machine language is helpful when you use the debugger, but it is not essential. The Debugger is able to convert machine code into assembly language (disassemble), so you can make code alterations at particular memory locations. All numbers used by the Debugger, both in input and output, are hexadecimal.

## CALLING THE DEBUGGER

The Debugger is called from the Editor by typing:

BUG RETURN

This produces on the screen:

```
DEBUG
[]
```

The command to return to the Writer/Editor is:

X RETURN

## DEBUG COMMANDS

The debug commands are listed below. In the list, "mmmm" indicates that the form of the command may include memory address(es). The actual methods of specifying the memory address(es) and the default addresses are shown in the examples given later in this section. If you use the commands with no address(es), the Debugger assigns a default address(es):

| | |
|---|---|
| DR | Display Registers |
| CR | Change Registers |
| D or Dmmmm | Display Memory |
| C or Cmmmm | Change Memory |
| Mmmmm | Move Memory |
| Vmmmm | Verify Memory |
| L or Lmmmm | List Memory With Disassembly |
| A | Assemble One Instruction Into Memory |
| Tmmmm | Trace Operation |
| S or Smmmm | Single-Step Operation |
| Gmmmm | Go (Execute Program) |
| X | Return to EDITOR |
| BREAK | Pressing the BREAK key halts certain operations. |

We now give several examples showing how to use the commands. In the examples, the lines ending with RETURN are entered on the keyboard. The other lines show the response of the system, as displayed on the screen.

### DR Display Registers

**Example:**

```
EDIT
BUG RETURN

DEBUG
DR RETURN
      A=BA  X=12  Y=34  P=B0  S=DF
DEBUG
[ ]
```

The registers and contents are displayed as shown. A is the Accumulator, X and Y are the Index Registers, P is the Processor Status Register, and S is the Stack Pointer.

### CR Change Registers

**Example:**

```
EDIT
BUG RETURN

DEBUG
CR<1,2,3,4,5 RETURN

DEBUG
[ ]
```

The effect of the command above is to set the contents of the registers A, X, Y, P, and S to 1, 2, 3, 4 and 5.

You can skip registers by using commas after the <. For example,

```
CR<,,,,E2 RETURN
```

sets the Stack Pointer to E2 and leaves the other registers unchanged. Registers are changed in order up to RETURN. For example,

```
CR<,34 RETURN
```

sets the X Register to 34 and leaves the other registers unchanged.

### D or Dmmmm Display Memory

Dmmmm, yyyy where yyyy is less than or equal to mmmm shows the contents of address mmmm.

**Example:**

```
DEBUG
D5000,0 RETURN

5000  A9
DEBUG
[ ]
```

This shows that address 5000 contains the number A9.

If the second address (yyyy) is omitted, the contents of eight successive locations are shown. The process can be continued by typing D RETURN.

**Example:**

```
DEBUG
D5000  RETURN

5000  A9  03  18  E5  F0  4C  23  91
DEBUG
D  RETURN

5008  18  41  54  41  52  49  20  20
DEBUG
[]
```

Dmmmm,yyyy where yyyy is greater than mmmm, shows the contents of addresses mmmm to yyyy.

**Example:**

```
DEBUG
D5000,500F  RETURN

5000  A9  03  18  E5  F0  4C  23  91
500B  18  41  54  41  52  49  20  20
DEBUG
[]
```

The display can be stopped by pressing the BREAK key.

### C or Cmmmm Change Memory

Cmmmm < yy changes the contents of address mmmm to yy.

**Example:**

```
DEBUG
C5001 <23 RETURN

DEBUG
[]
```

The effect of the command is to put the number 23 in location 5001. A comma increments the location to be changed.

**Example:**

```
DEBUG
C500B <21,EF RETURN

DEBUG
C700B <31,,,87 RETURN

DEBUG
[]
```

The first command puts 21 and EF in locations 500B and 500C, respectively.

The second command puts 34 and 87 in locations 700B and 700E respectively.

You can conveniently use the C command in conjunction with the Display Memory command, and you need not enter the address a second time with the C command. The C command will default to the last specified address.

**Example:**

```
D5000 RETURN

5000 A0 03 18 E5 F0 4C 23 91
C<AA,14 RETURN

D5000 RETURN

5000 AA 14 18 E5 F0 4C 23 91

DEBUG
[]
```

### Mmmmm Move Memory

Mmmmm<yyyy,zzzz copies memory from yyyy to zzzz to memory starting at mmmm. Address mmmm must be less than yyyy or greater than zzzz. If the origin and destination blocks overlap, results may not be correct.

**Example:**

```
DEBUG
M1230<5000,500F RETURN

DEBUG
[]
```

The command copies the data in location 5000-500F to location 1230-123F.

### Vmmmm Verify Memory

Vmmmm<yyyy,zzz compares memory yyyy to zzzz with memory starting at mmmm, and shows mismatches.

**Example:**

```
DEBUG
V7000<7100,7123 RETURN

DEBUG
[]
```

The command compared the contents of 7100-7123 with the contents of 7000-7023. There were no mismatches.

Mismatches would be shown as follows:

```
7101  00  7001  22
7105  18  7005  10
```

### L or Lmmmm List Memory With Disassembly

This command allows you to look at any block of memory in disassembled form.

**Examples:**

| | | |
|---|---|---|
| L7000 | RETURN | List a screen page (20 lines of code) starting at memory location 7000. Pressing the BREAK key during listing halts the listing. |
| L | RETURN | This form of the command lists a screen page starting at the instruction last shown, plus 1. |
| L7000, 0<br>L7000, 7000<br>L7000, 6000 | RETURN<br>RETURN<br>RETURN | These forms list the instructions at address 7000 only. |
| L345, 567 | RETURN | This form lists address 345 through 567. Only the last 20 instructions will actually be visible at the completion of the response of the system. |

The command Lmmmm differs from Dmmmm in that Lmmmm disassembles the contents of memory.

**Example:**

```
EDIT
BUG  RETURN

DEBUG
L5000, 0  RETURN
5000     A9  03     LDA     #$03

DEBUG
[]
```

This example shows that the Debugger examined the contents of memory address 5000 and disassembled A9 to LDA. Since A9 must have a one-byte operand, the Debugger made the next byte (the contents of address 5001) the operand. Therefore, although the debugger was only "asked" for the content of location 5000, it showed a certain amount of intelligence and replied by showing the instruction that started at address 5000.

To illustrate this further, the number 03 corresponds to no machine code instruction, so the Debugger would interpret 03 as an illegal instruction, and alert you to a possible error, as shown below.

**Example:**

```
DEBUG
L5001, 0  RETURN
5001, 03    ???

DEBUG
```

However, if the first instruction you wrote was LDA $8A, then you would have obtained the following, apparently inconsistent, results while debugging:

**Example:**

```
DEBUG
L5000, 00  A9  8A  LDA #$8A

DEBUG
L5001, 0  8A  TXA
```

Because the disassembler starts disassembling from the first address you specify, you have to take care that the first address contains the first byte of a “real” instruction.

### A Assemble One Instruction Into Memory

The DEBUGGER has a mini-assembler, that can assemble one assembly language instruction at a time. To enter the Assemble mode, type:

```
A RETURN
```

Once in the Assemble mode, you stay there until you wish to return to DEBUGGER, which you may do by pressing RETURN (on an empty line).

To assemble an instruction, first enter the address at which you wish to have the machine code inserted. The number that you enter will be interpreted as a hex address. Now type “<” followed by at least one space, then the instruction. You may omit an address if assembly is to be in successive locations.

**Example:**

```
EDIT
BUG  RETURN

DEBUG
A  RETURN
5001<LDY $1234 RETURN
5001  AC3412                Computer Responds.
<INY RETURN
5004  CB                    Computer Responds.
[]  RETURN

DEBUG
[]
```

Since the mini-assembler assembles only one instruction at a time, it cannot refer to another instruction. Therefore, it cannot interpret a label. Consequently, labels are not legal in the mini-assembler.

You can use the directives BYTE, DBYTE, and WORD.

### Gmmmm Go (Execute Program)

This command executes instructions starting at mmmm. For example:

| | | |
|---|---|---|
| G7B00 | RETURN | Executes instructions starting at location 7B00. Execution continues indefinitely. Execution is stopped by pressing the BREAK key (unless the program at 7B00 tricks or crashes the operating system). |

### Tmmmm Trace Operation

This command has the same effect as Gmmmm, except that after execution of each instruction the screen shows the instruction address, the instruction in machine code, the instruction in assembly language (disassembled by the debugger—not necessarily the same as you wrote it in assembly language) and the values of Registers A, X, Y, P and S.

The execution stops at a BRK instruction (machine code 00) or when you press the BREAK key on the keyboard.

**Example:**

```
DEBUG
T5000 RETURN
5000      A9      03              LDA      #$03
   A=03   X=02    Y=03    P=34    S=05
5002      18                      CLC
   A=03   X=02    Y=03    P=34    S=05
5003      E5      F0              SBC      $F0
   A=03   X=02    Y=03    P=34    S=05
5005      4C      23      71      JMP      $7123
   A=03   X=02    Y=03    P=34    S=05
7123      00                      BRK
   A=03   X=02    Y=03    P=34    S=05
DEBUG
```

### S or Smmmm Step Operation

This command has the same effect as T or Tmmmm, except that only one instruction is executed. To step through a program, type S RETURN repeatedly after the first command of Smmmm RETURN

### X Exit

To return to the Editor type:

X RETURN

# NOTES:

# APPENDIX 1

# ERRORS

When an error occurs, the console speaker gives a short "beep" and the error number is displayed.

Errors numbered less than 100 refer to the Assembler Editor cartridge, as follows:

**ERROR NUMBER**

| | |
|---|---|
| 1. | The memory available is insufficient for the program to be assembled. |
| 2. | For the command "DEL xx,yy" the number xx cannot be found. |
| 3. | There is an error in specifying an address (mini-assembler). |
| 4. | The file named cannot be loaded. |
| 5. | Undefined label reference. |
| 6. | Error in syntax of a statement. |
| 7. | Label defined more than once. |
| 8. | Buffer overflow. |
| 9. | There is no label or * before "=". |
| 10. | The value of an expression is greater than 255 where only one byte was required. |
| 11. | A null string has been used where invalid. |
| 12. | The address or address type specified is incorrect. |
| 13. | Phase error. An inconsistent result has been found from Pass 1 to Pass 2. |
| 14. | Undefined forward reference. |
| 15. | Line is too large. |
| 16. | Assembler does not recognize the source statement. |
| 17. | Line number is too large. |
| 18. | LOMEM command was attempted after other command(s) or instruction(s). LOMEM, if used, must be the first command. |
| 19. | There is no starting address. |

**Errors**

Errors numbered more than 100 refer to the Operating System and the Disk Operating System. For a complete list of DOS errors, refer to the DOS manual.

| | |
|---|---|
| 128 | BREAK key pressed during an I/O operation. |
| 130 | A nonexistent device specified for I/O. |
| 132 | The command is invalid for the device. |
| 136 | EOF. End of file read has been reached. This error may occur when reading from cassette. |
| 137 | A record was longer than 256 characters. |
| 138 | The device specified in the command does not respond. Make sure the device is connected to the console and powered. |
| 139 | The device specified in the command does not return an Acknowledge signal. |

| | |
|---|---|
| 140 | Serial bus input framing error. |
| 142 | Serial bus data frame overrun. |
| 143 | Serial data checksum error. |
| 144 | Device done error. |
| 145 | Diskette error: Read-after-write comparison failed. |
| 146 | Function not implemented. |
| 162 | Disk full. |
| 165 | File name error. |

# APPENDIX 2

# ASSEMBLER MNEMONICS (Alphabetic List)

| | |
|---|---|
| ADC | Add Memory to Accumulator with Carry |
| AND | AND Accumulator with Memory |
| ASL | Shift Left (Accumulator or Memory) |
| BCC | Branch if Carry Clear |
| BCS | Branch if Carry Set |
| BEQ | Branch if Result = Zero |
| BIT | Test Memory Against Accumulator |
| BMI | Branch if Minus Result |
| BNE | Branch if Result ≠ Zero |
| BPL | Branch on Plus Result |
| BRK | Break |
| BVC | Branch if V Flag Clear |
| BVS | Branch if V Flag Set |
| CLC | Clear Carry Flag |
| CLD | Clear Decimal Mode Flag |
| CLI | Clear Interrupt Disable Flag (Enable Interrupt) |
| CLV | Clear V Flag |
| CMP | Compare Accumulator and Memory |
| CPX | Compare Register X and Memory |
| CPY | Compare Register Y and Memory |
| DEC | Decrement Memory |
| DEX | Decrement Register X |
| DEY | Decrement Register Y |
| EOR | Exclusive-OR Accumulator with Memory |
| INC | Increment Memory |
| INX | Increment Register X |
| INY | Increment Register Y |
| JMP | Jump to New Location |
| JSR | Jump to Subroutine |
| LDA | Load Accumulator |
| LDX | Load Register X |
| LDY | Load Register Y |
| LSR | Shift Right (Accumulator or Memory) |
| NOP | No Operation |
| ORA | OR Accumulator with Memory |
| PHA | Push Accumulator on Stack |
| PHP | Push Processor Status Register (P) onto Stack |
| PLA | Pull Accumulator from Stack |
| PLP | Pull Processor Status Register (P) from Stack |
| ROL | Rotate Left (Accumulator or Memory) |
| ROR | Rotate Right (Accumulator or Memory) |
| RTI | Return from Interrupt |
| RTS | Return from Subroutine |
| SBC | Subtract Memory from Accumulator with Borrow |
| SEC | Set Carry Flag |
| SED | Set Decimal Mode Flag |
| SEI | Set Interrupt Disable Flag (Disable Interrupt) |

| | |
|---|---|
| STA | Store Accumulator |
| STX | Store Register X |
| STY | Store Register Y |
| TAX | Transfer Accumulator to Register X |
| TAY | Transfer Accumulator to Register Y |
| TSX | Transfer Register SP to Register X |
| TXA | Transfer Register X to Accumulator |
| TXS | Transfer Register X to Register SP |
| TYA | Transfer Register Y to Accumulator |

# APPENDIX 3

# SPECIAL SYMBOLS

Below we give a list of special symbols that have a restricted meaning to the Assembler. You should avoid using these symbols as a matter of course. Most attempts to use these symbols in any but their special sense will result in errors. They may be used, without their special meaning, in comments and in the operands of memory reservation directives.

**;** The semicolon is used to indicate the start of a comment. Everything between the semicolon and RETURN appears in the listed form of the program and is ignored by the Assembler. When comments take more than one line, start each new line with a semicolon.

**#** The # sign is used as the first symbol of an immediate operand, as in LDX #24.

**$** The $ sign is used before numbers to signify that they are to be interpreted as hex numbers. For example, LDX #$34.

***** The asterisk is used to signify the value of the current location counter. For example, the instruction in line 50 gives the symbol HERE a value equal to 5 or more than the number in the current location counter:

```
50  HERE=*+5
```

Example:

```
18  *=$911
19  RTS
20  *=*+$F
21  TAX
```

When this example is assembled, line 18 causes the location counter to be $0911, RTS is placed in location $0911, line 20 causes the location counter to be increased from $0912 to $0921, and TAX is placed in $0921. This leaves 15 empty bytes between the RTS and the TAX.

The asterisk also signifies multiplication (see Appendix 6). The Assembler uses the syntax of the statement to distinguish the two meanings of the asterisk.

Register names:

**A** Accumulator
**X** X Register
**Y** Y Register
**S** Stack Pointer
**P** Processor Status Register

# NOTES:

# APPENDIX 4

# TABLE OF HEX DIGITS WITH CORRESPONDING OP CODE MNEMONICS AND OPERANDS

| MSD \ LSD | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | LSD / MSD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | BRK | ORA-IND, X | | | | ORA-Z, Page | ASL-Z, Page | | PHP | ORA-IMM | ASL-A | | | ORA-ABS | | | 0 |
| 1 | BPL | ORA-IND, Y | | | | ORA-Z, Page, X | ASL-Z, Page, X | | CLC | ORA-ABS, Y | | | | ORA-ABS, X | ASL-ABS, X | | 1 |
| 2 | JSR | AND-IND, X | | | BIT-Z, Page | AND-Z, Page | ROL-Z, Page | | PLP | AND-IMM | ROL-A | | BIT-ABS | AND-ABS | ROL-ABS | | 2 |
| 3 | BMI | AND-IND, Y | | | | AND-Z, Page | ROL-Z, Page, X | | SEC | AND-ABS, Y | | | | AND-ABS, X | ROL-ABS, X | | 3 |
| 4 | RTI | EOR-IND, X | | | | EOR-Z, Page | LSR-Z, Page | | PHA | EOR-IMM | LSR-A | | JMP-ABS | EOR-ABS | LSR-ABS | | 4 |
| 5 | BVC | EOR-IND, Y | | | | EOR-Z, Page, X | LSR-Z, Page, X | | CLI | EOR-ABS, Y | | | | EOR-ABS, X | LSR-ABS, X | | 5 |
| 6 | RTS | ADC-IND, X | | | | ADC-Z, Page | ROR-Z, Page | | PLA | ADC-IMM | ROR-A | | JMP-IND | ADC-ABS | ROR-ABS | | 6 |
| 7 | BVS | ADC-IND, Y | | | | ADC-Z, Page, X | | | SEI | ADC-ABS, Y | | | | ADC-ABS, X | | | 7 |
| 8 | | STA-IND, X | | | STY-Z, Page | STA-Z, Page | STX-Z, Page | | DEY | | TXA | | STY-ABS | STA-ABS | STX-ABS | | 8 |
| 9 | BCC | STA-IND, Y | | | STY-Z, Page, X | STA-Z, Page, X | STX-Z, Page, Y | | TYA | STA-ABS, Y | TXS | | | STA-ABS, X | | | 9 |
| A | LDY-IMM | LDA-IND, X | LDX-IMM | | LDY-Z, Page | LDA-Z, Page | LDX-Z, Page | | TAY | LDA-IMM | TAX | | LDY-ABS | LDA-ABS | | | A |
| B | BCS | LDA-IND, Y | | | LDY-Z, Page, X | LDA-Z, Page, X | LDX-Z, Page, Y | | CLV | LDA-ABS, Y | TSK | | LDY-ABS, X | LDA-ABS, X | LDX-ABS, Y | | B |
| C | CPY-IMM | CMP-IND, X | | | CPY-Z, Page | CMP-Z, Page | DEC-Z, Page | | INV | CMP-IMM | DEX | | CPY-ABS | CMP-ABS | DEC-ABS | | C |
| D | BNE | CMP-IND, Y | | | | CMP-Z, Page, X | DEC-Z, Page, X | | CLD | CMP-ABS, Y | | | | CMP-ABS, X | DEC,ABS, X | | D |
| E | CPX-IMM | SBC-IND, X | | | CPX-Z, Page | SBC-Z, Page | INC-Z, Page | | INX | SBC-IMM | NOP | | CPX-ABS | SBC-ABS | INC-ABS | | E |
| F | BEQ | SBC-IND, Y | | | SBC-Z, Page, X | INC-Z, Page, X | | | SED | SBC-ABS, Y | | | | SBC-ABS, X | INC-ABS, X | | F |

**IMM · IMMEDIATE ADDRESSING** — THE OPERAND IS CONTAINED IN THE SECOND BYTE OF THE INSTRUCTION.

**ABS · ABSOLUTE ADDRESSING** — THE SECOND BYTE OF THE INSTRUCTION CONTAINS THE 8 LOW ORDER BITS OF THE EFFECTIVE ADDRESS. THE THIRD BYTE CONTAINS THE 8 HIGH ORDER BITS OF THE EFFECTIVE ADDRESS (EA).

**Z, PAGE · ZERO PAGE ADDRESSING** — SECOND BYTE CONTAINS THE 8 LOW ORDER BITS OF THE EFFECTIVE ADDRESS. THE 8 HIGH ORDER BITS ARE ZERO.

**A, · ACCUMULATOR** — ONE BYTE INSTRUCTION OPERATING ON THE ACCUMULATOR.

**Z, PAGE X · Z PAGE, Y · ZERO PAGE INDEXED** — THE SECOND BYTE OF THE INSTRUCTION IS ADDED TO THE INDEX (CARRY IS DROPPED) TO FORM THE LOW ORDER BYTE OF THE EA. THE HIGH ORDER BYTE OF THE EA IS ZEROS.

**ABS, X ABS, Y ABSOLUTE INDEXED** — THE EFFECTIVE ADDRESS IS FORMED BY ADDING THE INDEX TO THE SECOND AND THIRD BYTE OF THE INSTRUCTION.

**(IND, X) · INDEXED INDIRECT** — THE SECOND BYTE OF THE INSTRUCTION IS ADDED TO THE X INDEX, DISCARDING THE CARRY, THE RESULTS POINTS TO A LOCATION ON PAGE ZERO WHICH CONTAINS THE 8 LOW ORDER BITS OF THE EA. THE NEXT BYTE CONTAINS THE 8 HIGH ORDER BITS.

**(IND) Y · INDIRECT INDEXED** — THE SECOND BYTE OF THE INSTRUCTION POINTS TO A LOCATION IN PAGE ZERO. THE CONTENTS OF THIS MEMORY LOCATION ARE ADDED TO THE Y INDEX, THE RESULT BEING THE LOW ORDER 8 BITS OF THE EA. THE CARRY FROM THIS OPERATION IS ADDED TO THE CONTENTS OF THE NEXT PAGE ZERO LOCATION, THE RESULTS BEING THE 8 HIGH ORDER BITS OF THE EA.

# NOTES:

# APPENDIX 5

# EXPRESSIONS

When an instruction or directive calls for a number in the operand, the number may be given as an "expression," the number used being the value of the expression. An expression is really just a formula.

Expressions are made up of operators and terms. Terms are either numbers or labels which stand for numbers. An expression containing a label term that does not have a numeric value will be flagged as an error.

There are five operators; four are arithmetic, and one is logical.

| | |
|---|---|
| Addition is signified by the sign | + |
| Subtraction is signified by the sign | – |
| Multiplication is signified by | * |
| Division is signified by | / |
| Logical AND is signified by | & |

Expressions must not contain parentheses.

Expressions are evaluated from left to right.

**Examples:**

| | |
|---|---|
| 100 *=$90+1007<br>200 JMP 3+2*25*4/5–3<br>300 JMP 0097<br>400 JMP $0061 | These instructions are equivalent. |
| 100 LDA #NUM1+NUM2 | NUM1 and NUM2 must be defined somewhere in the program. The instruction loads the Accumulator with the sum of the numbers in the locations NUM1 and NUM2. |
| 600 LDA LABEL & $00FF<br>610 STA $CC | This yields the low order byte of the value of LABEL. |
| 620 LDA LABEL/256<br>630 STA $CD | This yields the high order of byte of the value of LABEL. |

# NOTES:

# APPENDIX 6

# DIRECTIVES

| | |
|---|---|
| . OPT Operand | specifies an option. Operand can be LIST or NOLIST, OBJ or NOOBJ, ERRORS or NOERRORS, EJECT or NOEJECT. (Default options are LIST, OBJECT, ERRORS, and EJECT.) |
| . TITLE "NAME" | causes NAME to be printed at the top of each page. |
| . PAGE 'MESSAGE" | produces a blank space in the listing, then causes MESSAGE to be printed after NAME. |
| . TAB n1,n2,n3 | controls the spacing of the fields of Op Code Mnemonic, Operand, and Comment as they appear in the listing. |
| . BYTE a,b...n | places in successive memory locations the values of the expressions a, b, ..., n (one byte for each value). |
| . BYTE "AB...N" | places in successive memory locations the ATASCII values of A, B, ..., N. |
| . DBYTE a, b,...n | places in successive pairs of memory locations the values of the expressions a, b, ..., n (two bytes for each value, high byte first). |
| . WORD a, b,...,n | places in successive pairs of memory locations the values of the expressions a, b, ..., n (two bytes for each value, low byte first). |
| AB = Expression | makes the Label AB equal to the value of the expression (up to FFFF hex). |
| * = Expression | makes the Program Counter equal to the value of the expression (up to FFFF hex). |
| . IF Expression<br>. LABEL | assembles following code, up to . LABEL, if and only if expression evaluates to zero. |
| . END | indicates the end of the program to be assembled. |

# NOTES:

# APPENDIX 7

# ATASCII CHARACTER SET AND HEXADECIMAL TO DECIMAL CONVERSION

| DECIMAL CODE | HEXADECIMAL CODE | CHARACTER |
|---|---|---|
| 0 | 0 |  |
| 1 | 1 |  |
| 2 | 2 |  |
| 3 | 3 |  |
| 4 | 4 |  |
| 5 | 5 |  |
| 6 | 6 |  |
| 7 | 7 |  |
| 8 | 8 |  |
| 9 | 9 |  |
| 10 | A |  |
| 11 | B |  |
| 12 | C |  |

| DECIMAL CODE | HEXADECIMAL CODE | CHARACTER |
|---|---|---|
| 13 | D |  |
| 14 | E |  |
| 15 | F |  |
| 16 | 10 |  |
| 17 | 11 |  |
| 18 | 12 |  |
| 19 | 13 |  |
| 20 | 14 |  |
| 21 | 15 |  |
| 22 | 16 |  |
| 23 | 17 |  |
| 24 | 18 |  |
| 25 | 19 |  |

| DECIMAL CODE | HEXADECIMAL CODE | CHARACTER |
|---|---|---|
| 26 | 1A |  |
| 27 | 1B |  |
| 28 | 1C |  |
| 29 | 1D |  |
| 30 | 1E |  |
| 31 | 1F |  |
| 32 | 20 | Space |
| 33 | 21 | ! |
| 34 | 22 | " |
| 35 | 23 | # |
| 36 | 24 | $ |
| 37 | 25 | % |
| 38 | 26 | & |

| DECIMAL CODE | HEXADECIMAL CODE | CHARACTER | DECIMAL CODE | HEXADECIMAL CODE | CHARACTER | DECIMAL CODE | HEXADECIMAL CODE | CHARACTER |
|---|---|---|---|---|---|---|---|---|
| 39 | 27 | ’ | 55 | 37 | 7 | 71 | 47 | G |
| 40 | 28 | ( | 56 | 38 | 8 | 72 | 48 | H |
| 41 | 29 | ) | 57 | 39 | 9 | 73 | 49 | I |
| 42 | 2A | * | 58 | 3A | : | 74 | 4A | J |
| 43 | 2B | + | 59 | 3B | ; | 75 | 4B | K |
| 44 | 2C | , | 60 | 3C | < | 76 | 4C | L |
| 45 | 2D | - | 61 | 3D | = | 77 | 4D | M |
| 46 | 2E | . | 62 | 3E | > | 78 | 4E | N |
| 47 | 2F | / | 63 | 3F | ? | 79 | 4F | O |
| 48 | 30 | 0 | 64 | 40 | @ | 80 | 50 | P |
| 49 | 31 | 1 | 65 | 41 | A | 81 | 51 | Q |
| 50 | 32 | 2 | 66 | 42 | B | 82 | 52 | R |
| 51 | 33 | 3 | 67 | 43 | C | 83 | 53 | S |
| 52 | 34 | 4 | 68 | 44 | D | 84 | 54 | T |
| 53 | 35 | 5 | 69 | 45 | E | 85 | 55 | U |
| 54 | 36 | 6 | 70 | 46 | F | 86 | 56 | V |

| DECIMAL CODE | HEXADECIMAL CODE | CHARACTER | DECIMAL CODE | HEXADECIMAL CODE | CHARACTER | DECIMAL CODE | HEXADECIMAL CODE | CHARACTER |
|---|---|---|---|---|---|---|---|---|
| 87 | 57 | W | 103 | 67 | g | 119 | 77 | w |
| 88 | 58 | X | 104 | 68 | h | 120 | 78 | x |
| 89 | 59 | Y | 105 | 69 | i | 121 | 79 | y |
| 90 | 5A | Z | 106 | 6A | j | 122 | 7A | z |
| 91 | 5B | [ | 107 | 6B | k | 123 | 7B |  |
| 92 | 5C | \ | 108 | 6C | l | 124 | 7C | \| |
| 93 | 5D | ] | 109 | 6D | m | 125 | 7D |  |
| 94 | 5E | ^ | 110 | 6E | n | 126 | 7E |  |
| 95 | 5F | _ | 111 | 6F | o | 127 | 7F |  |
| 96 | 60 |  | 112 | 70 | p | 128 | 80 | *(inverse characters begin)* |
| 97 | 61 | a | 113 | 71 | q | 129 | 81 | |
| 98 | 62 | b | 114 | 72 | r | 130 | 82 | |
| 99 | 63 | c | 115 | 73 | s | 131 | 83 | |
| 100 | 64 | d | 116 | 74 | t | 132 | 84 | |
| 101 | 65 | e | 117 | 75 | u | 133 | 85 | |
| 102 | 66 | f | 118 | 76 | v | 134 | 86 | |

| DECIMAL CODE | HEXADECIMAL CODE | CHARACTER | DECIMAL CODE | HEXADECIMAL CODE | CHARACTER | DECIMAL CODE | HEXADECIMAL CODE | CHARACTER |
|---|---|---|---|---|---|---|---|---|
| 135 | 87 | | 151 | 97 | | 167 | A7 | |
| 136 | 88 | | 152 | 98 | | 168 | A8 | |
| 137 | 89 | | 153 | 99 | | 169 | A9 | |
| 138 | 8A | | 154 | 9A | | 170 | AA | |
| 139 | 8B | | 155 | 9B | (EOL) RETURN | 171 | AB | |
| 140 | 8C | | 156 | 9C | ↑ | 172 | AC | |
| 141 | 8D | | 157 | 9D | ↓ | 173 | AD | |
| 142 | 8E | | 158 | 9E | ← | 174 | AE | |
| 143 | 8F | | 159 | 9F | → | 175 | AF | |
| 144 | 90 | | 160 | A0 | | 176 | B0 | |
| 145 | 91 | | 161 | A1 | | 177 | B1 | |
| 146 | 92 | | 162 | A2 | | 178 | B2 | |
| 147 | 93 | | 163 | A3 | | 179 | B3 | |
| 148 | 94 | | 164 | A4 | | 180 | B4 | |
| 149 | 95 | | 165 | A5 | | 181 | B5 | |
| 150 | 96 | | 166 | A6 | | 182 | B6 | |

| DECIMAL CODE | HEXADECIMAL CODE | CHARACTER | DECIMAL CODE | HEXADECIMAL CODE | CHARACTER | DECIMAL CODE | HEXADECIMAL CODE | CHARACTER |
|---|---|---|---|---|---|---|---|---|
| 183 | B7 | | 199 | C7 | | 215 | D7 | |
| 184 | B8 | | 200 | C8 | | 216 | D8 | |
| 185 | B9 | | 201 | C9 | | 217 | D9 | |
| 186 | BA | | 202 | CA | | 218 | DA | |
| 187 | BB | | 203 | CB | | 219 | DB | |
| 188 | BC | | 204 | CC | | 220 | DC | |
| 189 | BD | | 205 | CD | | 221 | DD | |
| 190 | BE | | 206 | CE | | 222 | DE | |
| 191 | BF | | 207 | CF | | 223 | DF | |
| 192 | C0 | | 208 | D0 | | 224 | E0 | |
| 193 | C1 | | 209 | D1 | | 225 | E1 | |
| 194 | C2 | | 210 | D2 | | 226 | E2 | |
| 195 | C3 | | 211 | D3 | | 227 | E3 | |
| 196 | C4 | | 212 | D4 | | 228 | E4 | |
| 197 | C5 | | 213 | D5 | | 229 | E5 | |
| 198 | C6 | | 214 | D6 | | 230 | E6 | |

| DECIMAL CODE | HEXADECIMAL CODE | CHARACTER | DECIMAL CODE | HEXADECIMAL CODE | CHARACTER | DECIMAL CODE | HEXADECIMAL CODE | CHARACTER |
|---|---|---|---|---|---|---|---|---|
| 231 | E7 | | 240 | F0 | | 249 | F9 | |
| 232 | E8 | | 241 | F1 | | 250 | FA | |
| 233 | E9 | | 242 | F2 | | 251 | FB | |
| 234 | EA | | 243 | F3 | | 252 | FC | |
| 235 | EB | | 244 | F4 | | 253 | FD |  *(Buzzer)* |
| 236 | EC | | 245 | F5 | | 254 | FE |  *(Delete character)* |
| 237 | ED | | 246 | F6 | | 255 | FF |  *(Insert character)* |
| 238 | EE | | 247 | F7 | | | | |
| 239 | EF | | 248 | F8 | | | | |

***Notes:***

1. ATASCII stands for ATARI ASCII. Letters and numbers have the same values as those in ASCII, but some of the special characters are different.

2. Except as shown, characters from 128-255 are reverse colors of 1 to 127.

3. Add 32 to upper case code to get lower case code for same letter.

4. To get ATASCII code, tell computer (direct mode) to PRINT ASC ("______") Fill blank with letter, character, or number of code. Must use the quotes!

# APPENDIX 8

# REFERENCES

ATARI PUBLICATIONS

Obtainable from your ATARI dealer, or ATARI Consumer Division, Customer Support, 1195 Borregas Avenue, Sunnyvale, CA 94086

| | |
|---|---|
| ATARI 400™ Operator's Manual | CO14768 |
| ATARI 800™ Operator's Manual | CO14769 |
| ATARI 810™ Operator's Manual | CO14760 |
| ATARI 815™ Operator's Manual | CO16377 |
| ATARI Disk Operating System II Reference Manual | |
| ATARI 410™ Operator's Manual | CO14810 |

OTHER PUBLICATIONS

*6502 Programming Manual*
SYNERTEK, 3050 Coronado Drive, Santa Clara, CA 95051 or
MOS Technology, 950 Rittenhouse Road, Norristown, PA 19401

*6502 Assembly Language Programming* by Lance Leventhal
Osborne/McGraw-Hill, 630 Bancroft Way, Berkeley, CA 94710

*Programming the 6502* by Rodney Zaks
Sybex, 2020 Milvia Street, Berkeley, CA 94704

# NOTES:

# APPENDIX 9

# USING THE ASSEMBLER CARTRIDGE TO BEST ADVANTAGE

The Assembler Editor cartridge is designed to support intermediate-level assembly language software development. It is good enough in this function to be used by ATARI's own programmers for some software development.

The Assembler is powerful and it can do a great deal, but it is not a professional software development system. It is not well suited for development of large assembly language programs. A good rule of thumb is: take the amount of RAM you have in your system and divide by ten to find the largest amount of object code you can comfortably develop with this cartridge. Thus, an ATARI Personal Computer System with 16K of RAM can be used to develop object code programs up to about 1600 bytes in size. Of course, you can stretch your memory by eliminating all explanatory comments and using very short labels. This will allow you to fit in much more code, but it will make your program difficult to revise at a later time.

Our recommendation is that this cartridge is best used to develop machine language subroutines that enhance the speed and power of BASIC programs. Assembly language complements BASIC very well; the combination of BASIC and machine language is extremely powerful. You can unleash almost all of the power inside your ATARI Personal Computer System with this combination. You should use BASIC for most of your programming; it is easy to write and debug. You should use assembly language only when necessary. There are five applications of machine language that are particularly appropriate:

- To provide certain special logical operations not readily available from BASIC
- To generate special sound effects that BASIC is too slow to generate
- To generate high-speed graphics and animation
- To utilize the interrupt capabilities of the machine
- To accomplish high-speed complex logical calculations and manipulations

Most of these applications are situations that call for high speed; in general, the primary advantage of machine language is its higher speed. Machine language averages about ten times faster than BASIC and in special cases, can be up to a thousand times faster. We do not recommend using machine language for floating point arithmetic or for I/O to and from peripherals (except the screen). In general, one should use machine language only when its speed advantages outweigh the difficulties of programming in assembly language.

Extensive use of assembly language requires a thorough knowledge of the layout and operating system of the host machine. Unfortunately, the ATARI Personal Computer System is far too complex to cover adequately in a brief appendix. We therefore provide four commented sample programs which show how to execute some of the most commonly used functions. These programs are meant only for demonstration purposes; they certainly do not exercise the full power of the machine. You may wish to enhance them, adding whatever features you desire. In this way you will learn more about the ATARI Personal Computer System.

All four programs have been written to reside on page 6 of memory. These 256 bytes have been reserved for your use. On page zero, only 7 bytes have been reserved for your use by the BASIC cartridge; they are locations $CB through $D1 (203 through 209). Locations $D4 and $D5 (212 and 213) are also usable; they are used to return parameters from machine language routines to BASIC through the USR function. Furthermore, locations $D6 through $F1 are used only by the floating point package; you may use them from BASIC USR calls if you do not mind having them altered every time an arithmetic operation is performed. If your program runs only with the Assembler Editor cartridge and not the BASIC cartridge you may use zero page locations $B0 through $CF. You will have to be very sparing in your use of page zero locations, as nine safe locations will not take you far. It is not wise to usurp other locations on page zero, as they are used by the operating system and BASIC; there is no way to know if you thereby sabotage some vital function and crash the system until it is too late. For the moment, we recommend that you limit yourself to programs that fit onto page 6 and use less than 9 bytes of page zero. The four sample programs meet that restriction; later we will show you how to make larger programs with BASIC.

Our first sample program is very simple: it takes two 16-bit numbers, exclusive OR's them together, and returns the resulting 16-bit number to BASIC. It is only 17 bytes long and uses only 4 bytes of page zero. We will use it as a vehicle to show you the rudiments of interfacing machine language to BASIC. Here's how: First, type in the program with the Assembler Editor cartridge in place. Make sure that you have typed it in properly by assembling the program (the command ASM) and verifying that no errors are flagged to you. If it squawks unpleasantly, you have offended its delicate sensitivities; note the line number where the error occurred (CONTROL-1 is a handy way to stop the listing so you can see what happened). Then list the offending line and correct the typo. You may rest assured that the program as we list it will indeed assemble without errors; if you type it in exactly as listed it will work fine. Now assemble the program with the object code going to your nonvolatile storage medium (either diskette or cassette). If you have a disk drive, type in:

```
ASM,,#D:EXCLOR.OBJ
```

If you have a Program Recorder, type in:

```
ASM,,#C:
```

Follow normal procedures for using these devices. After the object code is stored to your diskette or cassette, open the cartridge slot cover and replace the Assembler Editor cartridge with the BASIC cartridge. Close the cover and when you see the READY prompt, load the program from diskette or cassette tape into RAM.

If you have a diskette, type DOS to call DOS, then type L to load a binary file. When it asks what file to load, respond with:

EXCLOR.OBJ RETURN

When it returns the SELECT ITEM prompt, type B RETURN to return to BASIC. If you have a cassette, type in CLOAD and follow the normal procedures for loading from cassette tape. When the machine language program is fully loaded and you are back in BASIC's READY mode, you are ready to use your program. Your program begins at address $0600, or 1536 decimal. Confirm this by the command:

```
?PEEK(1536) RETURN
```

The computer should respond with the value 104, which, if you care to cipher it out, is the opcode for the PLA instruction at the beginning of the program. If it doesn't, you blew it; start backtracking to figure out where you went wrong. If it comes up correct, then try this command:

```
A=USR(1536, 1, 3): ?A RETURN
```

The computer should respond by printing the value 2, because 1 exclusive OR'ed with 3 equals 2. If you are not familiar with the exclusive OR operator, look it up in any beginning book on assembly language programming. You now have a new function to use. The first parameter is the address of the machine language routine. The second and third parameters are the two numbers to be exclusive OR'ed together. They must be integers between 0 and 65535.

Our second sample program generates notes with controllable attack and decay properties. You may have toyed with the SOUND command in BASIC; if so, perhaps you have noticed that the sounds you can produce with BASIC are somewhat primitive. With assembly language it is easier to produce higher quality sounds. With this routine you can come much closer to the ideal by directly specifying the attack and decay characteristics of each note. It only controls one sound channel, and its algorithm is very simple, so there is plenty of opportunity for improvement. Four parameters are used: the frequency, the attack time, the peak plateau time, and the decay time. All three times are specified in units of 1.6 milliseconds. Using the same procedure as before, enter the program with the Assembler Editor cartridge, save it, switch to BASIC, and load the machine language code. Then run the program with:

```
A=USR(1536, 50, 10, 50, 200) RETURN
```

Make sure the volume on your television set is turned up and you will hear a note with a very short attack, a short plateau, and a long decay. Experiment with different values of the last four parameters to see what effects can be generated with this technique. Of course, do not change the first parameter (1536) or the program will almost surely crash.

Our third sample program is a much longer affair which generates a pleasing animated pattern on the screen. If you study it carefully you will learn a great deal about the display system of your ATARI Personal Computer System. This program only scratches the surface. There is much more to the ATARI display system than is evident here. Follow the same procedure to set up the program as before; you activate the program with:

```
GR. 19: A=USR(1536) RETURN
```

There is no termination point in the program; you must press the S RESET key to terminate the program. After you press the S RESET key, the program will still be intact and usable.

The last sample program demonstrates a very useful capability of the ATARI Personal Computer System—the display list interrupt. Perhaps you have been itching to have more than five colors on the screen. With display list interrupts you can have up to 128 colors. Here's the idea behind it: the ATARI display system uses a display list and display memory. The display list is a sequence of instructions that tell the computer what graphics format to use in putting information onto the screen. The display memory is the information going onto the screen. The address of the beginning of the display list can be found in locations 560 and 561 (decimal).The address of the beginning of the display memory can be found in locations 88 and 89 (decimal). Wondrous things can be done by changing the display list; this program demonstrates only one of the capabilities of the display list system. If bit 7 of a display list instruction is set (equal to 1), then the computer will generate a non-maskable interrupt for the 6502 when it encounters that display list instruction.

If we place an interrupt routine which changes the color values in the color registers, the color on the screen will be changed each time a display list interrupt is encountered. This program consists of two parts: an initializing routine which sets up the display list interrupt vectors, sets all of the display list instructions to generate display list interrupts, and lastly, enables the display list interrupts. The second routine actually services the display list interrupts by changing the color value in the color registers every time it is called. This routine is designed to operate in GRAPHICS 5 mode; it will put all 128 colors onto the screen. (Is that enough for you?) To see it in action, follow the familiar procedure for entering, assembling, saving, and loading the program. Then key in the following BASIC immediate instruction:

```
GR. 5: FOR I= 0 TO 3: COLOR I: FOR J=20*I TO 20*I+19: PLOT J, 3:
DRAWTO J, 39: NEXT J: NEXT I: A=USR(1536)
```

We hope that these four sample programs have given you a clearer idea of how your ATARI Assembler Editor cartridge might be useful. There are some more advanced techniques for getting even more use out of your cartridge. The first problem many programmers encounter arises when they attempt to write a program larger than 256 bytes long. It will no longer fit onto page 6 and the programmer must find a new place to put the program. The problem is made worse by the fact that the Operating System and BASIC use memory all over the address space. The programmer will have a hard time finding a safe place in memory where the machine language routine will not be wiped out by BASIC or the Operating System. There are a number of solutions to this problem; each solution has advantages and disadvantages. We recommend the following approach, which is difficult to understand but is also the most useful and safest route. What we are going to do is store the machine language program inside a BASIC program and then touch it up so that it will run from anywhere in memory.

We begin by writing an assembly language program with the Assembler Editor cartridge. Originate the program near the top of your available memory. For example, if you have 2K of object code and a 16K machine, originate the program at the 12K boundary with the directive '* =$3000'. This leaves 4K of space—2K for your program, 1K for a GRAPHICS mode 0 display, and 1K of extra space for good measure. Now go through the procedure of assembling the object code to diskette or cassette, changing the cartridges, and loading the object code into memory. Calculate the decimal addresses of the beginning and end of your object code. Let us say that your program is 2179 bytes long. It begins at $3000 or 12288 decimal, so the last byte is at 14466. Print PEEK(12288) and PEEK(14466) to verify that these addresses really do contain the first and last bytes of your program. Remember, the computer will print the results in decimal, not hexadecimal, so you will have to convert in your head or with the computer.

Now start writing a BASIC program, begin with:

```
2 DIM E$(2179)
```

Then add this subroutine (which you can delete later):

```
25000 A=90*J+1:B=A+89: IF B>LIMIT THEN B=LIMIT:?"LAST LINE"
25010?J+5;"E$(";A;",",B,")=";CHR$(34);
25020 FOR I=A TO B:?"ESC ESC";CHR$(PEEK)I+C));:NEXT I
25030 ?CHR$(34):J=J+1:RETURN
```

Here the ESC ESC symbol means that you press the escape key twice. Now type in the following direct commands:

```
J=0 RETURN
C=12287 RETURN
LIMIT=2179 RETURN
```

The value of C is the address of the byte before the first byte of your program. The value of LIMIT is the length of your object program. Now type GOSUB 25000 RETURN.

The computer will print a BASIC line onto the screen. It will look very strange—all sorts of strange characters inside a string. They are the screen representation of your object code. To make this line part of your BASIC prgram simply move the cursor up to the line and press RETURN. You might reassure yourself that you were successful by entering:

```
LIST 5 RETURN
```

and verifying that line 5 really did go in. Now type GOSUB 25000 RETURN again and another line will be printed. Enter this one the same way as before. Continue this process of printing and entering lines until the entire object program has been encoded inside BASIC statements. You will know you have reached this point when the computer prints "LAST LINE" onto the screen.

There is one possible hitch with this process. If you have a hex code of $22 (decimal value 34) anywhere in your code it will be put onto the screen as a double quotation mark. This will confuse the BASIC interpreter, which will give you a syntax error when you try to enter the line. If this happens, carefully count which byte is the offender and write down the index of the array which should contain the double quotation mark. Then go back and replace the offending quotation mark with a blank space; that will keep the BASIC interpreter happy. Make note of all such occurrences. When you are done entering the characters, type in a few more lines like:

```
30 E$(292, 292)=CHR$(34)
```

This line puts the double quotation mark into the 292nd array element by brute force. It should come immediately after the lines that declare the string. You should have a line similar to this for each instance of the double quotation mark. Make sure that you have counted properly and put the double quotation marks into the right places.

Now your object program is a part of the BASIC program. You can SAVE and LOAD the BASIC program and the object program will be saved and loaded along with it—a great convenience. You can run the object program by running the BASIC program and then executing the command:

A=USR(ADR(E$))

But there is still another possible hitch. The 6502 machine language code is not fully relocatable; any absolute memory references to the program are certain to fail. For example, suppose your program has a jump-to-subroutine (JSR) instruction that refers to a subroutine within the object code. This instruction would tell it to jump to a specific address. Unfortunately, your program has no way of knowing at what specific address that subroutine is stored and thus will almost certainly jump to the wrong address. The problem arises from the fact that BASIC might move your object program almost anywhere in memory.

There are several solutions to this problem. The simplest solution is to write fully relocatable code; that is, code with no JMP's, no JSR's and no data tables enclosed within it. Put all data tables and subroutines onto page 6. If you still need more space, put very large data tables into the BASIC string and point to them indirectly. Replace long JMP's with a bucket brigade of branch instructions. These techniques should allow you to write large machine language programs.

**Example 1.**

```
                ;
                ; ROUTINE EXCLOR
                ; PERFORMS EXCLUSIVE OR OPERATION ON
                ; TWO BYTES PASSED THROUGH THE STACK
                ; PASSES RESULTS DIRECTLY THROUGH USR FUNCTION
                ;
                ;
0000                            *=    $0600
00CC            TEMPL           =     $CC      TEMPORARY HOLDING LOCATION
00CD            TEMPH           =     $CD      TEMPORARY HOLDING LOCATION
00D4            RESLTL          =     $D4      ADDRESS FOR PASSING RESULTS
00D5            RESLTH          =     $D5      ADDRESS FOR PASSING HIGH RESULT
0600  68        EXCLOR          PLA
0601  68                        PLA
0602  85CD                      STA   TEMPH    SAVE HIGH BYTE
0604  68                        PLA
0605  85CC                      STA   TEMPL    SAVE LOW BYTE
0607  68                        PLA
0608  45CD                      EOR   TEMPH    PERFORM HIGH EXCLUSIVE OR
060A  85D5                      STA   RESLTH   STORE RESULT
060C  68                        PLA
060D  45CC                      EOR   TEMPL    PERFORM LOW EXCLUSIVE OR
060F  85D4                      STA   RESLTL   STORE RESULT
0611  60                        RTS            WHAT COULD BE SIMPLER?
0612                            .END
```

**Example 2.**

```
                ;
                ; ROUTINE NOTE
                ; GENERATES NOTES WITH CONTROLLABLE ATTACK AND DECAY
                ; TIMES
                ; CALL FROM BASIC WITH COMMAND:
                ; A=USR(1536, F, A, P, D)
```

```
                   70    ; WHERE
                   80    ; F IS THE FREQUENCY
                   90    ; A IS THE ATTACK TIME
                   0100  ; P IS THE PEAK TIME
                   0110  ; D IS THE DECAY TIME
                   0120  ;
                   0130  ; ALL TIMES GIVEN IN UNITS OF 1.6 MILLISECONDS
0000               0140            *=    $0600
D200               0150  AUDF1     =     $D200     AUDIO FREQUENCY REGISTER
D201               0160  AUDC1     =     $D201     AUDIO CONTROL REGISTER
00CC               0170  ATTACK    =     $CC       ATTACK TIME
00CD               0180  PEAK      =     $CD       PEAK OR PLATEAU TIME
00CE               0190  DECAY     =     $CE       DECAY TIME
0600   68          0200  NOTE      PLA
0601   68          0210            PLA
0602   68          0220            PLA
0603   8D00D2      0230            STA   AUDF1     SET FREQUENCY
0606   68          0240            PLA
0607   85CC        0250            STA   ATTACK    SET ATTACK TIME
0608   68          0260            PLA
060A   68          0270            PLA
060B   68          0280            PLA
060C   85CD        0290            STA   PEAK      SET PEAK TIME
060E   68          0300            PLA
060F   68          0310            PLA
0610   85CE        0320            STA   DECAY     SET DECAY TIME
                   0330  ;
                   0340  ; ATTACK LOOP
                   0350  ;
0612   A9A0        0360            LDA   #$A0      START WITH ZERO VOLUME
0614   8D01D2      0370  ATLOOP    STA   AUDC1
0617   A6CC        0380            LDX   ATTACK
0619   204106      0390            JSR   DELAY
061C   18          0400            CLC
061D   6901        0410            ADC   #$01
061F   C9B0        0420            CMP   #$BO
0621   D0F1        0430            BNE   ATLOOP
                   0440  ;
                   0450  ; PEAK LOOP
                   0460  ;
0623   A90E        0470            LDA   #$OE
0625   A6CD        0480  PKLOOP    LDX   PEAK
0627   204106      0490            JSR   DELAY
062A   38          0500            SEC
062B   E901        0510            SBC   #$01
062D   D0F6        0520            BNE   PKLOOP
                   0530  ;
                   0540  ; DECAY LOOP
                   0550  ;
062F   A9AF        0560            LDA   #$AF
0631   8D01D2      0570  DCLOOP    STA   AUDC1
0634   A6CE        0580            LDX   DECAY
0636   204106      0590            JSR   DELAY
```

```
0639  38      0600          SEC
063A  E901    0610          SBC    #$01
063C  C99F    0620          CMP    #$9F
063E  D0F1    0630          BNE    DCLOOP
0640  60      0640          RTS
              0650  ;
0641  A013    0660  DELAY   LDY    #$13
0643  88      0670  DELAY2  DEY
0644  D0FD    0680          BNE    DELAY2
0646  CA      0690          DEX
0647  D0F8    0700          BNE    DELAY
0649  60      0710          RTS
064A          0720          .END
```

**Example 3.**

```
              10    ;
              20    ;
                    ; ROUTINE SPLAY
              40    ; PUTS A PRETTY DISPLAY ONTO THE SCREEN
              50    ; CALL FROM BASIC WITH THE FOLLOWING COMMANDS
              60    ; GR. 19: A=USR(1536)
              70    ; EXIT PROGRAM WITH S RESET
              80    ;
              90    ;
              0100          *=      $0600
00CC          0110  TEMP    =       $CC      TEMPORARY LOCATION
00CD          0120  XLOC    =       $CD      HORIZONTAL POSITION OF PIXEL
00CE          0130  YLOC    =       $CE      VERTICAL POSITION OF PIXEL
00CF          0140  DIST    =       $CF      DIST. OF PIXEL FROM SCREEN CENTER
00D0          0150  PHASE   =       $D0      COLOR PHASE
00D1          0160  COLOR   =       $D1      COLOR CHOICE
0058          0170  SAVMSC  =       $58      POINTER TO BEG. OF DISPLAY MEMORY
02C4          0180  COLORO  =       $02C4    LOCATION OF COLOR REGISTERS
D20A          0190  RANDOM  =       $D20A    HARDWARE RANDOM NUMBER LOCATION
0600  68      0200  SPLAY   PLA              POP A ZERO FROM STACK
0601  85D0    0210          STA     PHASE    STORE IT IN PHASE
0603  AA      0220          TAX              SET COUNTER
              0230  ;
              0240  ; THIS IS THE MAIN PROGRAM LOOP
              0250  ; FIRST WE RANDOMLY CHOOSE THE SCREEN LOC. TO MODIFY
              0260  ; SCREEN IS 40 PIXELS HORIZONTALLY BY 24 PIXELS VERTICALLY
              0270  ; WITH 4 HORIZONTALLY ADJACENT PIXELS PER BYTE
              0280  ; HENCE THERE ARE 10 BYTES PER HORIZONTAL ROW
              0290  ; AND 24 ROWS FOR A TOTAL OF 240 BYTES
              0300  ; TO REPRESENT THE SCREEN
              0310  ;
              0320  ;
              0330  ;
0604  AD0AD2  0340  BEGIN   LDA     RANDOM   GET A RANDOM NUMBER
0607  290F    0350          AND     #$0F     MASK OFF LOWER NYBBLE
0609  C90A    0360          CMP     #$0A     MUST BE SMALLER THAN 10
060B  B0F7    0370          BCS     BEGIN    IF NOT, TRY AGAIN
```

```
060D  85CD    0380            STA  XLOC     STORE THE RESULT
060F  38      0390            SEC
0610  E905    0400            SBC  #$05     GET X-DISTANCE FROM CENTER
0612  1005    0410            BPL  XA       IS IT POSITIVE OR NEGATIVE?
0614  49FF    0420            EOR  #$FF     IF NEGATIVE, MAKE IT POSITIVE
0616  18      0430            CLC
0617  6901    0440            ADC  #$01
0619  85CF    0450  XA        STA  DIST     SAVE THE ABSOLUTE VALUE
061B  AD0AD2  0460  TRYAGN    LDA  RANDOM   GET ANOTHER RANDOM NUMBER
061E  291F    0470            AND  #$1F     MASK OFF LOWER 5 BITS
0620  C918    0480            CMP  #$18     MUST BE SMALLER THAN 24
0622  B0F7    0490            BCS  TRYAGN   (BECAUSE THERE ARE ONLY 24 ROWS)
0624  85CE    0500            STA  YLOC     STORE THE RESULT
0626  38      0510            SEC
0627  E90C    0520            SBC  #$0C     GET Y-DIST FROM CENTER OF SCREEN
0629  1005    0530            BPL  XB       IS IT POSITIVE OR NEGATIVE?
062B  49FF    0540            EOR  #$FF     IF NEGATIVE, MAKE IT POSITIVE
062D  18      0550            CLC
062E  6901    0560            ADC  #$01
              0570  ;
              0580  ; NOW CALCULATE THE COLOR TO PUT INTO THIS POSITION
              0590  ;
0630  18      0600  XB        CLC
0631  65CF    0610            ADC  DIST     TOTAL DIST FROM CENTER OF SCREEN
0633  65D0    0620            ADC  PHASE    COLOR PHASE OFFSET
              0630  :
              0640  : BITS 3 AND 4 NOW GIVE THE COLOR TO USE
              0650  ;
0635  291F    0660            AND  #$1F     MASK OUT BITS 5, 6, AND 7
0637  4A      0670            LSR  A
0638  4A      0680            LSR  A
0639  4A      0690            LSR  A        SHIFT OFF BITS 0, 1, AND 2
063A  85D1    0700            STA  COLOR    STORE RIGHT-JUSTIFIED RESULT
              0710  ;
              0720  ; NOW WE MUST DETERMINE WHICH OF THE 4 PIXELS
              0730  ; IN THE BYTE GET THE COLOR
              0740  ;
063C  AD0AD2  0750            LDA  RANDOM
063F  2903    0760            AND  #$03     GET A RANDOM NO. BETWEEN 0 AND 3
0641  A8      0770            TAY           USE IT AS A COUNTER
0642  F007    0780            BEQ  NOSHFT   SKIP AHEAD IF IT IS 0
              0790  ;
              0800  ; SHIFT OVER TWICE FOR EACH STEP IN Y
              0810  ;
0644  06D1    0820  SHFTLP    ASL  COLOR
0646  06D1    0830            ASL  COLOR
0648  88      0840            DEY
0649  D0F9    0850            BNE  SHFTLP
              0860  ;
              0870  ; NOW WE MUST CALCULATE WHERE IN MEMORY TO PUT OUR
              0880  ; SQUARE
064B  A5CE    0890  NOSHFT    LDA  YLOC     GET VERTICAL POSITION
064D  0A      0900            ASL  A        YLOC*2
```

```
064E  85CC     0910          STA   TEMP      SAVE IT FOR A FEW MICROSECONDS
0650  0A       0920          ASL   A
0651  0A       0930          ASL   A         YLOC*8
0652  65CC     0940          ADC   TEMP      ADD IN YLOC*2
               0950 ;
               0960 ; RESULT IN ACCUMULATOR IS YLOC*10
               0970 ; REMEMBER, THERE ARE TEN BYTES PER SCREEN ROW
               0980 ;
0654  65CD     0990          ADC   XLOC
               1000 ;
               1010 ; RESULT IS MEMORY LOCATION OF DESIRED PIXEL GROUP
0656  A8       1020          TAY
0657  A5D1     1030          LDA   COLOR     GET COLOR BYTE
0659  9158     1040          STA   (SAVMSC),Y PUT IT ONTO THE SCREEN
065B  CA       1050          DEX             WE SHALL PUT 254 MORE SQUARES
065C  D0A6     1060          BNE   BEGIN     ONTO THE SCREEN
               1070 ;
               1080 ; END OF MAIN INNER LOOP
               1090 ;
065E  C6D0     1100          DEC   PHASE     STEP COLOR PHASE FOR EXPLOSION
0660  A5D0     1110          LDA   PHASE
0662  291F     1120          AND   #$1F      EVERY 32 PHASE STEPS
0664  D09E     1130          BNE   BEGIN     WE CHANGE COLOR REGISTERS
               1140 ; THIS SECTION USES BITS 5 AND 6 OF PHASE
               1150 ; TO CHOOSE WHICH COLOR REGISTER TO MODIFY
               1160 ;
0666  A5D0     1170          LDA   PHASE
0668  4A       1180          LSR   A
0669  4A       1190          LSR   A
066A  4A       1200          LSR   A
066B  4A       1210          LSR   A
066C  4A       1220          LSR   A
066D  2903     1230          AND   #$03
066F  AA       1240          TAX
               1250 ;
0670  AD0AD2   1260          LDA   RANDOM CHOOSE A RANDOM COLOR
0673  9DC402   1270          STA   COLOR0,X PUT NEW COLOR INTO COLOR REG.
0676  4C0406   1280          JMP   BEGIN     START ALL OVER
0679           1290          .END
```

**Example 4.**

```
               10   ;
               20   ; KATHY'S COLOR PALETTE
               30   ; PUTS ALL 128 COLORS ONTO THE SCREEN
               40   ; CALL FROM BASIC WITH THE FOLLOWING COMMANDS:
               50   ; GR. 5
               60   ; FORI=0 TO 3: COLOR I: FOR J=20*I TO 20*I+19: PLOT J, 3:
               65   ; DRAWTO J, 39: NEXT J: NEXT I
               70   ; A=USR(1536)
               80   ; BASIC IS STILL USABLE
               90   ; EXIT WITH SYSTEM RESET KEY
               0100 ;
```

```
                    ;
0000                          *=     $0600
00CC                POINTA    =      $CC          POINTER TO DISPLAY LIST
00CE                COLCNT    =      $CE          KEEPS TRACK OF COLOR WE ARE ON
00CF                DECK      =      $CF          BIT 0 KEEPS TRACK OF WHICH DECK
0230                DSLSTL    =      $0230        O. S. DISPLAY LIST ADDRESS
D40E                NMIEN     =      $D40E        NON-MASKABLE INTERRUPT ENABLE
D40F                NMIRES    =      $D40F        NON-MASKABLE INTERRUPT RESET
D40F                NMIST     =      $D40F        NON-MASKABLE INTERRUPT STATUS
0200                VDSLST    =      $0200        DISPLAY LIST INTERRUPT VECTOR
D01A                COLBAK    =      $D01A        BACKGROUND COLOR REGISTER
D016                COLPF0    =      $D016        COLOR REGISTER #0
D017                COLPF1    =      $D017        COLOR REGISTER #1
D018                COLPF2    =      $D018        COLOR REGISTER #2
D40A                WSYNC     =      $D40A        WAIT FOR HORIZONTAL SYNC
0600    68          SETUP     PLA                 CLEAN STACK
                    ;
                    ; SET UP POINTER ON PAGE ZERO
                    ;
0601    AD3002                LDA    DSLSTL
0604    85CC                  STA    POINTA
0606    AD3102                LDA    DSLSTL+1
0609    85CD                  STA    POINTA+1
                    ;
060B    A007                  LDY    #$07         POINT TO 3RD MODE BYTE
060D    A98A                  LDA    #$8A         NEW MODE BYTE
                    ;
                    ; STORE 16 DISPLAY LIST INTERRUPT MODE BYTES
                    ;
060F    91CC        LOOP 1    STA    (POINTA), Y
0611    C8                    INY
0612    C017                  CPY    #$17
0614    D0F9                  BNE    LOOP1
                    ;
                    ; SKIP FOUR BLANK LINES
                    ;
0616    C8                    INY
0617    C8                    INY
0618    C8                    INY
0619    C8                    INY
                    ;
                    ; STORE 16 MORE DISPLAY LIST INTERRUPT MODE BYTES
                    ;
061A    91CC        LOOP2     STA    (POINTA), Y
061C    C8                    INY
061D    C02B                  CPY    #$2B
061F    D0F9                  BNE    LOOP2
                    ;
                    ; SET UP DISPLAY LIST INTERRUPT VECTOR
                    ;
0621    A950                  LDA    #$50
0623    8D0002                STA    VDSLST
0626    A906                  LDA    #$06
```

```
0628  8D102     0640          STA  VDSLST+1
                0650  ;
062B  A900      0660          LDA  #$00
062D  85CE      0670          STA  COLCNT  INITIALIZE COLOR COUNTER
062F  85CF      0680          STA  DECK    INITIALIZE DECK COUNTER
0631  8D0FD4    0690          STA  NMIRES  RESET INTRPT. STATUS REGISTER
0634  AD0FD4    0700  WAIT    LDA  NMIST   GET INTERRUPT STATUS REGISTER
0637  2940      0710          AND  #$40    HAS VERTICAL BLANK OCCURRED?
0639  F0F9      0720          BEQ  WAIT    NO, KEEP CHECKING
063B  AD0ED4    0730          LDA  NMIEN   YES, ENABLE DISPLAY LIST
063E  0980      0740          ORA  #$80
0640  8D0ED4    0750          STA  NMIEN   THIS ENABLES DLI
0643  60        0760          RTS          ALL DONE
                0770  ;
                0780  ; DISPLAY LIST INTERRUPT SERVICE ROUTINE
                0790  ;
0644            0800          *=   $0650
0650  48        0810  DLISRV  PHA          SAVE ACCUMULATOR
0651  A5CE      0820          LDA  COLCNT  GET CURRENT COLOR
0653  18        0830          CLC
0654  6910      0840          ADC  #$10    NEXT COLOR
0656  85CE      0850          STA  COLCNT  SAVE IT
0658  D013      0860          BNE  OVER    END OF DECK?
                0870  ;
                0880  ; END OF DECK, BLACKEN SCREEN
                0890  ;
065A  8D0AD4    0900          STA  WSYNC   WAIT FOR NEXT SCAN LINE
065D  8D0AD0    0910          STA  COLBAK  BLACKEN ALL REGISTERS
0660  8D16D0    0920          STA  COLPF0
0663  8D17D0    0930          STA  COLPF1
0669  E6CF      0940          STA  COLPF2
066B  68        0950          INC  DECK    NEXT DECK
066C  40        0960          PLA          RESTORE ACCUMULATOR
                0970          RTI          DONE
                0980  ;
                0990  ; PUT OUT NEXT COLOR, WITH FOUR LUMINOSITIES
                1000  ;
066D  A5CF      1010  OVER    LDA  DECK    UPPER OR LOWER DECK?
066F  2901      1020          AND  #$01    MASK OFF RELEVANT BIT
0671  0A        1030          ASL  A       SHIFT INTO HIGH LUMINOSITY
0672  0A        1040          ASL  A
0673  0A        1050          ASL  A
0674  05CE      1060          ORA  COLCNT  MERGE WITH COLOR NYBBLE
0676  8D0AD4    1070          STA  WSYNC   WAIT FOR NEXT SCAN LINE
0679  8D1AD0    1080          STA  COLBAK  STORE COLOR
067C  6902      1090          ADC  #$02    NEXT HIGHER LUMINOSITY
067E  8D16D0    1100          STA  COLPF0  STORE COLOR
0681  6902      1110          ADC  #$02    NEXT HIGHER LUMINOSITY
0683  8D17D0    1120          STA  COLPF1  STORE COLOR
0686  6902      1130          ADC  #$02    NEXT HIGHER LUMINOSITY
0688  8D18D0    1140          STA  COLPF2  STORE COLOR
068B  68        1150          PLA          RESTORE ACCUMULATOR
068C  40        1160          RTI          DONE
```

# APPENDIX 10

# QUICK REFERENCE: COMMANDS RECOGNIZED BY THE ASSEMBLER EDITOR

The following list includes all commands and directives recognized by the Assembler Editor cartridge. However, not all options, parameters, or defaults are presented. In most cases only the most useful or interesting version is presented.

| | | Reference Page No. |
|---|---|---|
| **EDITOR** | | |
| NUMxx, yy | provides auto line numbering starting at xx in increments of yy | 15 |
| RENxx, yy | renumbers all statements in increments of yy, starting with xx | 16 |
| DELxx, yy | deletes statement numbers xx through yy | 15 |
| NEW | wipes out source program | 15 |
| FIND/SOUGHT/xx, yy, A | finds and displays all occurrences of the string SOUGHT between xx and yy | 16 |
| REP/OLD/NEW/xx, yy, A | replaces all occurrences between lines xx and yy of the string OLD with the string NEW | 17 |
| LIST #P: | lists source program to printer | 19 |
| PRINT #P: | prints source program on printer | 21 |
| ENTER #D: NAME | retrieves source program from diskette | 21 |
| SAVE #C: xxxx, yyyy | saves data in addresses xxxx through yyyy to cassette | 22 |
| LOAD #C: | retrieves data from cassette | 22 |
| **ASSEMBLER** | | |
| ASM#D: NAME. SRC, #P:, #D: NAME. OBJ | retrieves source file called NAME. SRC on diskette, lists assembly listing to printer, and saves object program to diskette under filename NAME. OBJ | 25 |
| **DEBUGGER** | | |
| DR | displays 6502 registers A, X, Y, P, and S. | 36 |
| CR<,,x | puts an x into the Y-register. | 36 |
| Dxxxx, yyyy | displays contents of addresses xxxx through yyyy | 36 |

| | | |
|---|---|---|
| Cxxxx<yy | puts yy into address xxxx. | 37 |
| Mxxxx<yyyy, zzzz | copies memory block yyyy through zzzz into block starting at xxxx. | 38 |
| Vxxxx<yyyy, zzzz | compares memory block yyyy through zzzz with block starting at xxxx, displaying mismatches. | 38 |
| Lxxxx | disassembles memory starting at address xxxx. | 38 |
| A | activates mini-assembler (no labels, one line at a time). | 40 |
| Gxxxx | runs object program at xxxx. | 40 |
| Txxxx | trace; displays 6502 registers while running object program at address xxxx at readable speed. | 40 |
| Sxxxx | single-steps object program at xxxx, displaying registers. | 41 |
| X | return to EDIT mode | 41 |

# APPENDIX 11

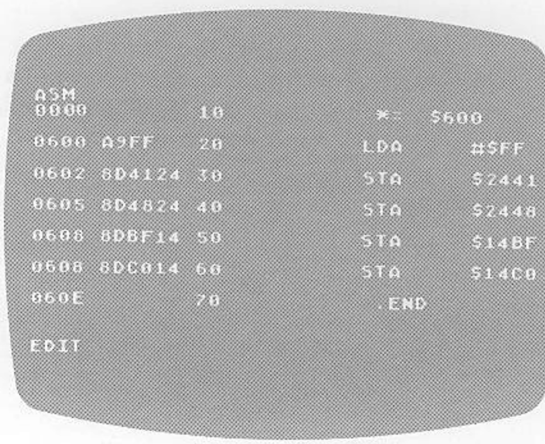
# MODIFYING DOS I TO MAKE BINARY HEADERS COMPATIBLE WITH ASSEMBLER EDITOR CARTRIDGE

The following assembly language program modifies four memory locations in DOS I to make binary file headers compatible with the Assembler Editor cartridge. There are two headers (each two bytes long)—one for SAVE and one for LOAD. To change the header bytes from hex 8409 to hex FFFF for full compatibility, type the following modification program.

```
EDIT

10                    *=600
20        LDA         #$FF
30        STA         $2441
40        STA         $2448
50        STA         $14BF
60        STA         $14C0
70                    END
```

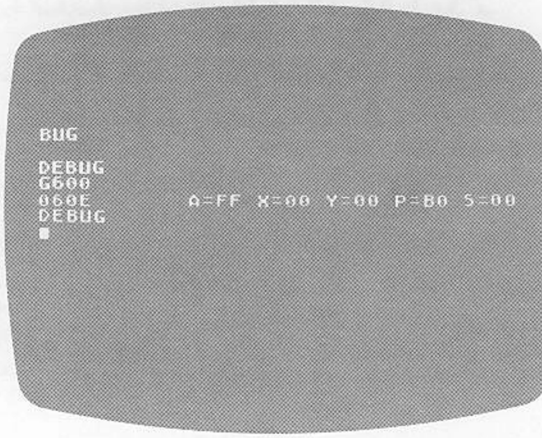
To assemble the modification program, type ASM and press RETURN.



To run this program, you must be in DEBUG mode so, type the following.

- Type BUG and press RETURN.
- Type G600 and press RETURN.

The screen will display:




DOS I will now have header bytes that are fully compatible with the Assembler Editor cartridge.

To change DOS I permanently on your diskette:

1. Run the Modification Program.
2. Type X RETURN to get out of BUG.
3. Type DOS RETURN to enter DOS.
4. Type H RETURN to write a fully compatible DOS on diskette.

**CHANGES AND LOCATIONS**

| LOCATION | | PRESENT CONTENTS | | CHANGE TO | |
|---|---|---|---|---|---|
| DECIMAL | HEX | DECIMAL | HEX | DECIMAL | HEX |
| 9281 | 2441 | 132 | 84 | 255 | FF |
| 9288 | 2448 | 9 | 09 | 255 | FF —LOAD |
| 5311 | 14BF | 132 | 84 | 255 | FF |
| 5312 | 14CO | 9 | 09 | 255 | FF —SAVE |

Instead of using the Modification Program, you could use BASIC to POKE decimal 255 into memory locations 9281, 9288, 5311, and 5312. After making the pokes, type DOS RETURN to display the DOS Menu. Type H RETURN to write the DOS modification onto diskette.

# NOTES:

# INSTRUCTION SET (OPERATION CODES)

| TYPE OF INSTRUCTION | MNEMONIC | OPERATION | TYPE OF ADDRESSING | | | | | | | | | | MISCELLANEOUS | | CONDITION FLAGS (Affected-●) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NON-INDEXED | | | | INDEXED | | | | | | Register (A,X,Y,P, PC or SP) Flag (F) Relative (R) Stack (S) None (N) | | | | | | | | | |
| | | | INDIRECT | DIRECT | | | DIRECT | | | | INDIRECT | | | | | | | | | | | |
| | | | Indirect | Immed. | Page 0 | Absolute | Abs ,X | Abs, Y | Indexed, X Page 0 | Indexed, Y Page 0 | Indexed Indirect | Indirect Indexed | | | | | | | | | | |
| | | Operand ► | ($hhhh) (ABS) | #$hh #BY | $hh BY | $hhhh ABS | $hhhh,X ABS,X | $hhhh,Y BY,Y | $hh,X BY,X | $hh,Y BY,Y | ($hh,X) (BY,X) | ($hh),Y (BY),Y | | | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | | Bytes ► | 3 | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 2 | N | V | | B | D | I | Z | C |
| LOAD & STORE | LDA | M→A Note 1 | | A9 | A5 | AD | BD | B9 | B5 | | A1 | B1 | | | | | | | | | | |
| | STA | A→M | | | 85 | 8D | 9D | 99 | 95 | | 81 | 91 | | | ● | | | | | | ● | |
| | LDX | M→X | | A2 | A6 | AE | | BE | | B6 | | | | | | | | | | | | |
| | STX | X→M | | | 86 | 8E | | | | 96 | | | | | ● | | | | | | ● | |
| | LDY | A→Y | | A0 | A4 | AC | BC | | B4 | | | | | | | | | | | | | |
| | STY | Y→M | | | 84 | 8C | | | 94 | | | | | | ● | | | | | | ● | |
| | Machine cycles | | | ② | ③ | ④ | ④ | ④ | ④ | ④ | ⑥ | ⑤ | | | | | | | | | | |
| ARITHMETIC & LOGICAL | AND | A∧M→A Note 1 | | 29 | 25 | 2D | 3D | 39 | 35 | | 21 | 31 | | | | | | | | | | |
| | BIT | A∧M | | | 24 | 2C | | | | | | | | | ● | | | | | | ● | |
| | CMP | A−M | | C9 | C5 | CD | DD | D9 | D5 | | C1 | D1 | | | M7 | M6 | | | | | ● | |
| | CPX | X−M | | E0 | E4 | EC | | | | | | | | | ● | | | | | | ● | 4 |
| | CPY | Y−M | | C0 | C4 | CC | | | | | | | | | ● | | | | | | ● | 4 |
| | ADC | A+M+C→A Note 1,3 | | 69 | 65 | 6D | 7D | 79 | 75 | | 61 | 71 | | | ● | | | | | | ● | 4 |
| | SBC | A−M−C→A Note 1,3 | | E9 | E5 | ED | FD | F9 | F5 | | E1 | F1 | | | ● | ● | | | | | ● | ● |
| | ORA | A∨M→A | | 09 | 05 | 0D | 1D | 19 | 15 | | 01 | 11 | | | ● | ● | | | | | ● | ● |
| | EOR | A⊻M→A | | 49 | 45 | 4D | 5D | 59 | 55 | | 41 | 51 | | | ● | | | | | | ● | |
| | INC | M+1→M | | | E6⑤ | EE⑥ | FE⑦ | | F6⑥ | | | | | | ● | | | | | | ● | |
| | DEC | M−1→M | | | C6⑤ | CE⑥ | DE⑦ | | D6⑥ | | | | | | ● | | | | | | ● | |
| | INX | X+1→X | | | | | | | | | | | | | ● | | | | | | ● | |
| | DEX | X−1→X | | | | | | | | | | | E8(X) | | ● | | | | | | ● | |
| | INY | Y+1→Y | | | | | | | | | | | CA(X) | | ● | | | | | | ● | |
| | DEY | Y−1→Y | | | | | | | | | | | C8(Y) | | ● | | | | | | ● | |
| | Machine cycles | | | ② | ③ | ④ | ④ | ④ | ④ | | ⑥ | ⑤ | 88(Y) | | ● | | | | | | ● | |
| SHIFT & ROTATE | ASL | C←[7 0]←0 | | | 06 | 0E | 1E | | 16 | | | | ② | | | | | | | | | |
| | ROL | ←[7 0]←[C]← | | | 26 | 2E | 3E | | 36 | | | | 0A(A) | | ● | | | | | | ● | ● |
| | LSR | 0→[7 0]→C | | | 46 | 4E | 5E | | 56 | | | | 2A(A) | | ● | | | | | | ● | ● |
| | ROR | →[C]→[7 0]→ | | | 66 | 6E | 7E | | 76 | | | | 4A(A) | | 0 | | | | | | ● | ● |
| | Machine cycles | | | | ⑤ | ⑥ | ⑦ | | ⑥ | | | | 6A(A) | | ● | | | | | | ● | ● |
| REGISTER TRANSFER | TAX | A→X | | | | | | | | | | | ② | | | | | | | | | |
| | TXA | X→A | | | | | | | | | | | AA(A) | | ● | | | | | | ● | |
| | TAY | A→Y | | | | | | | | | | | 8A(X) | | ● | | | | | | ● | |
| | TYA | Y→A | | | | | | | | | | | A8(A) | | ● | | | | | | ● | |
| | TSX | SP→X | | | | | | | | | | | 98(Y) | | ● | | | | | | ● | |
| | TXS | X→SP | | | | | | | | | | | BA(SP) | | ● | | | | | | ● | |
| | Machine cycles | | | | | | | | | | | | 9A(X) | | | | | | | | | |
| | | | | | | | | | | | | | ② | | | | | | | | | |
| SET & CLEAR FLAGS | CLV | 0→V | | | | | | | | | | | | | | | | | | | | |
| | CLD | 0→D | | | | | | | | | | | B8(F) | | | 0 | | | | | | |
| | SED | 1→D | | | | | | | | | | | D8(F) | | | | | | 0 | | | |
| | CLI | 0→I | | | | | | | | | | | F8(F) | | | | | | 1 | | | |
| | SEI | 1→I | | | | | | | | | | | 58(F) | | | | | | | 0 | | |
| | CLC | 0→C | | | | | | | | | | | 78(F) | | | | | | | 1 | | |
| | SEC | 1→C | | | | | | | | | | | 18(F) | | | | | | | | | 0 |
| | Machine cycles | | | | | | | | | | | | 38(F) | | | | | | | | | 1 |
| BRANCH | BPL | Branch if N=0 Note 2 | | | | | | | | | | | ② | | | | | | | | | |
| | BMI | Branch if N=1 Note 2 | | | | | | | | | | | | 10(R) | | | | | | | | |
| | BVC | Branch if V=0 Note 2 | | | | | | | | | | | | 30(R) | | | | | | | | |
| | BVS | Branch if V=1 Note 2 | | | | | | | | | | | | 50(R) | | | | | | | | |
| | BCC | Branch if C=0 Note 2 | | | | | | | | | | | | 70(R) | | | | | | | | |
| | BCS | Branch if C=1 Note 2 | | | | | | | | | | | | 90(R) | | | | | | | | |
| | BNE | Branch if Z=0 Note 2 | | | | | | | | | | | | B0(R) | | | | | | | | |
| | BEO | Branch if Z=1 Note 2 | | | | | | | | | | | | D0(R) | | | | | | | | |
| | JMP | Jump | 6C | | | 4C③ | | | | | | | | F0(R) | | | | | | | | |
| | JSR | Jump to Subrout. | | | | 20⑥ | | | | | | | | | | | | | | | | |
| | RTS | Return fr. Subrout. | | | | | | | | | | | | | | | | | | | | |
| | BRK | Break (Interrupt) | | | | | | | | | | | | 60(S)⑥ | | | | | | | | |
| | RTI | Return fr. Interrupt | | | | | | | | | | | | 00(P,PC)⑦ | | | | | | 1 | | |
| | Machine cycles | | ⑤ | | | | | | | | | | | 40(S)⑥ | From Stack | | | | | | | |
| STACK | PHP | P→S;SP−1→SP | | | | | | | | | | | | ② | | | | | | | | |
| | PLP | SP+1→S;S→P | | | | | | | | | | | | 08(P)③ | | | | | | | | |
| | PHA | A→S; SP−1→SP | | | | | | | | | | | | 28(S)④ | From Stack | | | | | | | |
| | PLA | SP+1→SP;S→A | | | | | | | | | | | | 48(A)③ | | | | | | | | |
| NO. OP | NOP | No operation | | | | | | | | | | | | 68(S)④ | ● | | | | | | ● | |
| | | | | | | | | | | | | | | EA(N)② | | | | | | | | |

| | |
|---|---|
| A | Accumulator, or contents |
| X, Y, P | Registers X, Y, P, or contents |
| SP | Stack Pointer, or contents |
| S | Stack |
| M | Memory location (effective address), or contents |
| M7 | Bit 7 of M |
| ∧ V, ⊻ | Logical AND, OR, XOR |
| P→Q | P is copied to Q; P unchanged |

NOTES: At the head of each column, under TYPE OF ADDRESSING, the correct way to write an Operand is given, in hex, where 'h' represents a hex digit, and symbolically, where 'BY' and 'ABS' represent numbers of one and two bytes, respectively. The number at the head of each column is the number of bytes of that type of instruction.

The circled number at the foot of a column is the number of machine cycles for the instructions in that block; exceptions are indicated by the circled numbers after the Op Code.

1. If the page boundary is crossed, the number of machine cycles is one more than shown.
2. If the condition is true and the branch is taken, the number of machine cycles is one more than shown when the branch is to the same page and two more than shown when the branch is to a different page.
3. Effects of ADC and SBC may be confusing if the D Flag is set. Check results carefully.
4. C=0 when A or X or Y < M; C=1 when A or X or Y ≥ M.

ATARI®

A Warner Communications Company



C014189-03 REV. 2