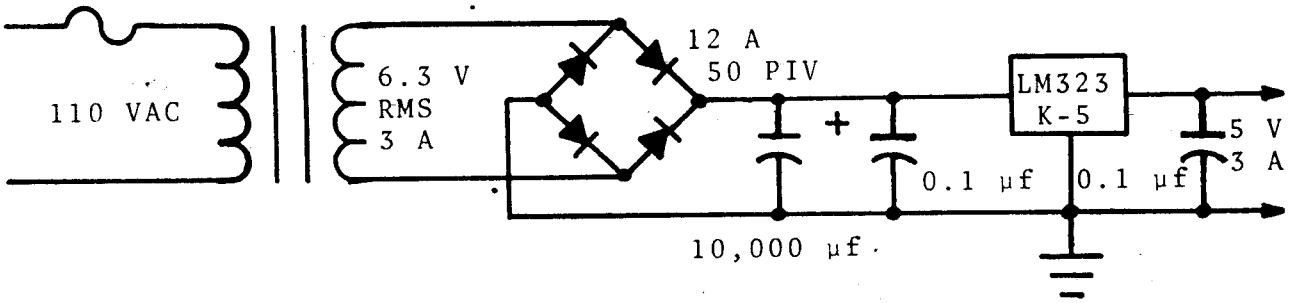
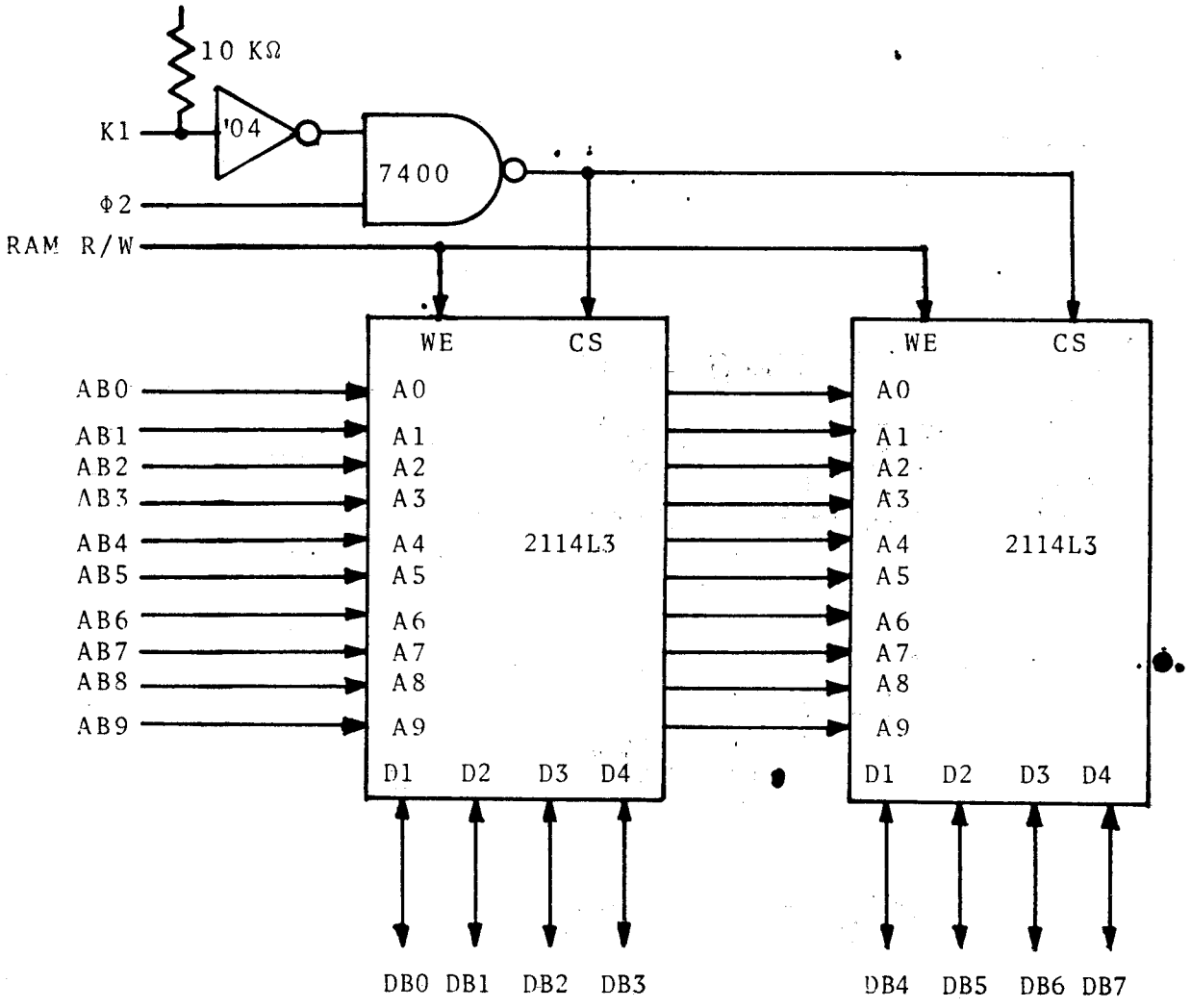


A 2K SYMBOLIC ASSEMBLER FOR THE 6502



A 2K SYMBOLIC ASSEMBLER FOR THE 6502

Robert Ford Denison

A 2K SYMBOLIC ASSEMBLER FOR THE 6502

Copyright 1979
by Robert Ford Denison
RD5 Teeter Rd.
Ithaca, NY 14850

All rights reserved, including the right to reproduce the program or documentation in machine-readable form, including magnetic media and read-only-memory.

Cover: Schematics for a 5V, 3A regulated power supply and a 1K x 8 read/write memory block. The power supply and three such memory blocks can be added to the basic KIM-1 microcomputer to provide the 4K RAM required by this assembler. Parts are available from Jameco Electronics.

TABLE OF CONTENTS

TABLES

1. INTRODUCTION

Microcomputers based on the powerful 6502 microprocessor are becoming increasingly widespread. Business, educational, and word-processing applications generally require expensive disk-based systems running high level languages such as BASIC or Pascal. Inexpensive 6502 systems have mainly been limited to such trivial uses as games, checkbook balancing, and recipe files. Games may, of course, be used for the nontrivial purpose of learning about microcomputers.

Inexpensive systems may, however, be more than adequate for quite sophisticated applications in the field of process control and data acquisition. A simple example is turning a tape recorder on at a specified time to record a radio program. Opening and closing insulated shutters to maximize solar heat gain while minimizing heat loss is more challenging, but could result in considerable savings. An example of a scientific application is collecting data from temperature and pressure sensors in a study of sap flow in sugar maples.

My own experience has been entirely with the MOS Technology KIM-1, which is ideal for such applications. I first used it to control an optical printer which was used to produce special cinematic effects. More recently, my KIM-1 was part of a complex gas analysis system for my research on nitrogen fixation in soybeans.

Neither expensive computer hardware nor years of training is necessary to attempt such projects. My system has only 4K RAM. I use a $30 software-scanned keyboard for input, and use the KIM-1 display as an output device for both numbers and letters. I learned most of what I know in this field from the MOS Technology Programming Manual, Don Lancaster's TTL Cookbook, BYTE magazine, and by trial and error.

The key to process control programming is the use of assembly language. It is much faster than BASIC, and uses far less memory than high level languages. In addition, most process control problems can be solved more easily and directly in assembly language than in a higher level language.

An assembler makes assembly language programming considerably easier by taking over the time-consuming and error-prone task of translating assembly language into machine language. A true assembler, such as the one described herein, allows the programmer to refer to variables, subroutines, and lines within subroutines using descriptive names, rather than their addresses.

This assembler outperforms all other true assemblers for the 6502 with which I am familiar, in terms of speed and memory efficiency. It can assemble a 128 byte module in a fraction

of a second. Programs up to 1K bytes can be assembled in a KIM-1 system with only 4K RAM, including 2K for the assembler itself. I would appreciate being informed of any other symbolic assembler which can match either of these claims.

I would like to thank Dr. H. R. Luxenberg, Professor of Computer Science at the California State University at Chico for modifying the assembler I/O for the SYM, and for pointing out errors in the program and documentation. John Geiger, of Milwaukee, found additional errors and kindly relocated the assembler to start at address 2000. Any errors that remain are my responsibility, and I would appreciate having them brought to my attention.

This book is dedicated to Mike Colyar, of the Evergreen State College, who introduced me to electronics.

2. USE OF THE ASSEMBLER

System requirements. The assembler requires a 650X-based microcomputer with at least 4K RAM and an appropriate I/O device. This documentation is based on a standard system: a KIM-1 with 3K RAM at address 0400 and a conventional computer terminal connected to the serial interface. A second version is available for KIM-1 systems with 4K RAM at address 2000; addresses in parentheses refer to that version.

Other systems. The assembler can be modified for use with other systems by following the guidelines in Section 5. More detailed instructions for specific systems will be made available as demand warrants. SYM owners see Appendix B.

Installing the assembler. To install the assembler in the standard system, load it from cassette or listing. Begin execution at address 05B8 (23B8). The assembler will prompt with a question mark, indicating that it is in control mode.

2.1 Basic Concepts

Modes. The assembler operates in two modes. "Control" mode allows control of the allocation of memory space, definition of variables, and related functions. "Edit" mode is used to actually enter, modify, and assemble modules.

Modules. A "module" is a subroutine or a segment of a program or subroutine. Each use of edit mode corresponds to one module. Modules are limited in length to 128 bytes, but a program may contain many modules. Total program length is limited only by available RAM.

Module pointer. Assembled modules are stored successively in RAM under the control of the "module pointer." This pointer is initialized to 0C80 (2A80). It is then incremented automatically each time a module is stored, to prevent the module from being overwritten by the next module. More information on this and other pointers is given in Table 4.1.

Symbols. A "symbol" is a name given to a specific address. It may refer to a variable, a table, a module, a line within a module, or some other address such as an I/O port. Symbols may be up to six characters in length.

Global vs. local symbols. "Global" symbols are defined in control mode and may be referenced by any module. Symbols defined in edit mode are "local" to the module in which they were created and may not be referenced by other modules. Line labels are local symbols, so two modules may use identical line labels without confusion.

Input format. Input to the assembler must be in a specific format. Each input line is divided into a series of "fields." Each item must be left-justified in the correct field. In practice this is quite easy, because the "space" bar has been programmed to advance automatically to the beginning of the next field each time it is pressed. It may also be used to skip a field.

Special key definitions. Each line must be terminated with a carriage return. A "null line" consists of a carriage return only. "Backspace" may be used to correct errors within a given field; more serious errors require use of the assembler's editing capability. The "escape" key causes the assembler to execute a BRK instruction, and may be used to return to the system monitor. Users whose terminals lack any of the above keys should refer to Section 5.1.

Hexadecimal numbers. The assembler uses hexadecimal (base sixteen) numbers exclusively. All addresses in this documentation are therefore given in hexadecimal. Blanks are read as zeroes.

Arrays. An array is any variable, e.g. a table, that occupies more than one byte. Arrays are limited to 255 bytes. However, two or more arrays may be treated as one large array if an array longer than 255 bytes is needed.

Source vs. object code. "Source code" refers to the assembly language module. Assembly is the process of translating source into "object," or machine language code.

2.2 Control Mode

In this mode the user can define global symbols, allocate space for tables, redefine the module pointer, and enter edit mode to begin a new module. Control mode commands begin with a question mark, which is also a prompt symbol for the mode.

Enter the command in the first field, followed by any additional information required in subsequent fields. The format for each command is given in Table 2.1 and illustrated by example in Section 2.6.

Define global symbols. The ?ASSGN command is used to assign addresses to global symbols. A four-digit address is required. Additional symbols may be defined without typing "?ASSGN" again. Just hit the space bar to skip the first field; then enter the symbol and its address. Enter a null line (carriage return) when all symbols have been defined.

Allocate space for tables. Use the ?TABLE command to reserve space for tables. Enter the name of the table and its length in bytes (two digits). The symbol is assigned the

current value of the module pointer as its address. The pointer is then incremented by the length of the table to prevent overwrite by the next table or module. Additional tables may be defined in a manner similar to that for ?ASSGN.

Redefine the module pointer. The ?REDEF command may be used with caution to change the value of the module pointer. This might be done to allow assembled modules to be stored in memory locations not ordinarily used for program storage. For example, assembled modules might be stored on page zero or one if space were at a premium.

Begin new module. The ?BEGIN command causes the assembler to enter edit mode to start a new module. The name of the module is entered in the second field, and is added to the symbol table as a global symbol. Its address is the current value of the module pointer, since that is where the module will be stored after it is assembled. The module name is also the label for the first line in the module, unless another line label is supplied.

2.3 Assembly Language Format

In edit mode, the user inputs an assembly language module. The module is edited and assembled using commands described in Section 2.4. This process is illustrated in Section 2.6. The prompt for edit mode is a hyphen, followed by the address where the assembly language code for the line will be stored.

To enter a line of assembly language, hit the space bar to skip over the first field. The contents of the other fields are summarized in Table 2.1 and further explained below.

Label. Enter a symbol in the second field if the line will be referenced by a branch instruction elsewhere in the module. Otherwise hit the space bar again.

Opcode. This field must contain the mnemonic and address mode for the desired instruction. The mnemonic is the standard three-letter MOS Technology code, e.g. LDA. Absolute, implied, and relative addressing require no additional information in this field. The other address modes are indicated in the opcode field by one or two characters immediately following the mnemonic, e.g. LDAZX. These mode codes are #,Z,A,IX,IY,ZX, X,Y,I, and ZY for immediate, zero page, accumulator, indexed indirect X, indirect indexed Y, zero page X, absolute X, absolute Y, indirect, and zero page Y addressing. Users who prefer IM for immediate addressing need only change two bytes at 02AC (20AC) to 49,4D.

Operand. For instructions that require no operand, hit carriage return to end the line. Immediate addressing requires a two-digit hexadecimal number in this field. Other address modes use a symbol as their operand.

Table 2.1: Input Format for Commands and Instructions

	Field 1	Field 2	Field 3	Field 4	Field 5
Assign address to symbol.	?ASSGN	symbol	nnnn		
Reserve space for table.	?TABLE	symbol	nn		
Redefine module pointer.	?REDEF	nnnn			
Begin new module.	?BEGIN	symbol			
One-byte instructions.		(symbol)	opcode		
Immediate mode instructions.		(symbol)	opcode	nn	
Other two-byte instructions.		(symbol)	opcode	symbol	
Three-byte instructions.		(symbol)	opcode	symbol	(nn)
Define local symbol.	-LOCAL	symbol	nnnn		
Assemble module.	-ASSEM				
Print lines in range.	-PRINT	nnTOnn			
Insert before line given.	-INSRT	nn			
Replace lines in range.	-INSRT	nnTOnn			
Append to end of module.	-INSRT	FF			
Save module in RAM.	-STORE				

() Optional.
nn Hexadecimal digits.

Offset. Three-byte instructions may use a two-digit hexadecimal number in this field to indicate an offset from the beginning of a table or array. This value is added to the base address of the array on assembly. The offset is optional, and may not be used with two-byte instructions.

2.4 Edit Mode Commands

Commands are used in edit mode to define local symbols and to assemble, list, edit, and save a module. Edit mode commands begin with a hyphen. Their format is given in Table 2.1 and their use is illustrated in Section 2.6.

Define local symbols. The -LOCAL command is identical to ?ASSGN except that the symbols defined are local to the module.

Assemble. The -ASSEM command translates the module into machine language. The assembler will respond quickly with either the normal address prompt, indicating successful assembly, or with one or more undefined symbols. Use the -LOCAL command to define these symbols before assembling again. Undefined global symbols may be temporarily defined locally to allow assembly.

List. An assembled module may be listed using the -PRINT command. Two line numbers must be supplied. The number of a line consists of the two least significant digits of its address prompt. -PRINT will list from the first line number up to, but not including, the second line number. The module must be reassembled before listing each time it is modified.

Test. The assembled module may be tested by hitting "reset" to return to the system monitor. Check the module pointer at 0040,41 to get the start address of the module. The module may be tested using appropriate user or monitor routines. Then return to edit mode by entering the assembler at 05D6 (23D6). Correct any errors (using the -INSRT command) and reassemble.

Insert lines. The -INSRT command can be used to insert, delete, or replace lines. To insert one or more lines, use -INSRT with a line number. New lines are inserted starting at that line number. The line previously at that address, and all lines following it, are automatically moved forward to make room for each new line.

Delete or replace lines. If a second line number is supplied with the -INSRT command, the assembler will delete the lines in the specified range. Lines following the deletion are moved back to fill the resulting gap. New lines can then be inserted starting at the first line number.

Append new lines. After inserting or deleting lines, the user may wish to add lines to the end of the module. To do this, type -INSRT FF (fast forward?). Ignore the resulting error code.

Save. An assembled module is saved using the -STORE command. The module length is added to the module pointer to prevent overwrite by the next module. Memory space is conserved by clearing local symbols from the symbol table. The assembler then returns to control mode, allowing definition of new global symbols, redefinition of the module pointer, or beginning a new module.

Tape storage. Either source or object code can be saved on tape. Saving object code is easy since it only requires dumping the area of memory which contains the code itself. Saving source code requires saving both the symbol table and the module. This is done by dumping 0A00-0C7F (2800-2A7F). In addition, pointers at the following locations must be saved: 003C, 003D, 0050, 0051, 0056. It is probably easiest just to make a note of these pointer values, using the form at the end of this manual.

Retrieving modules from tape requires that the assembler be initialized by running it normally from 05B8 (23B8). Then hit "reset" to leave the assembler. Load the module from tape, restore the pointer values, and enter the assembler at 05D6 (23D6). Ignore any error message on re-entry.

Note that the previous contents of the symbol table are destroyed by this process, so that some global symbols may have to be redefined if the module is loaded for use with a new program. The assembled module will be stored according to the value of the module pointer before the module was loaded. This may not correspond to its previous location. ?REDEF may be used to store the assembled location wherever desired.

Saving and retrieving assembly language modules is a tricky process which requires experience to master. It may be easier to debug the module thoroughly and save the object code.

2.5 Programming Restrictions

The assembler is reasonably immune to user error, other than careless use of the ?REDEF command. Each input line is checked for correctness; when an error is detected, the normal prompt symbol is replaced with an error code (Table 2.2). The restrictions below are designed to eliminate errors at assembly time (other than undefined symbols) and to minimize debugging time.

Commands. Commands may be used at any time, but the result may be order-dependent. For example, ?TABLE will reserve space in a different place if used after ?REDEF. However, ?ASSGN uses absolute addresses and is unaffected by ?REDEF.

Module length. Module length is limited to 128 bytes. This guarantees that relative branches within a module will be within range. It also requires that programs be broken up into short modules which can be debugged more easily. A module listing will generally fit on one page. The length of a module corresponds to the two rightmost digits in the address prompt. Total program length is limited by available RAM.

Relative branches. Relative branches are allowed only within a module, for the reason given above. Line labels may only be referenced by relative branches; this greatly simplifies relocation.

Symbols. All symbols referenced in a module must be defined before assembly. This normally requires that subroutines be assembled and stored before they are referenced by a program or another subroutine. However, they could be assigned an address using ?ASSGN or -LOCAL, and entered later. Zero page symbols must be defined before the first line in which they are referenced.

Other restrictions. Symbol table length is limited to 64 symbols. No offset is permitted with two-byte instructions.

Table 2.2: Error Codes

A	Command does not exist.
B	Module length exceeds 128 bytes.
C	Number of symbols exceeds 64.
D	Symbol already defined.
K	Command legal in edit mode only.
0	Command does not exist.
1	Mnemonic does not exist.
2	Address mode does not exist.
3	Illegal address mode for mnemonic.
4	Operand undefined; must be on page zero.
5	Operand not on page zero.
6	Offset legal for three-byte instructions only.
7	Relative branch illegal outside module.
8	Absolute addressing illegal within module.
9	Command legal in control mode only.
%	Illegal line number.
:	Symbol already defined.

2.6 Sample Run

```
05B8 G
?       ?TABLE  WAVE    0C
?TABLE
?       ?ASSGN  PAD     1700
?ASSGN          PERIOD  0060
?ASSGN
?       ?BEGIN  DELAY
- 0C00          LDX#    2F
1 0C00                  LDX#    2F
- 0C02                  DEX
- 0C03                  BPL     LOOP
- 0C05                  RTS
- 0C06 -ASSEM
LOOP
- 0C06 -INSRT  02T003
- 0C02          LOOP    DEX
- 0C03 -ASSEM
- 0C06 -PRINT  00T006
A22F    DELAY   LDX#    2F          00
CA      LOOP    DEX                 02
10FD            BPL     LOOP        03
60              RTS                 05
- 0C06 -STORE
?       ?REDEF  0070
?       ?BEGIN  WAVGEN
- 0C00 -LOCAL  BASE    0061
-LOCAL
- 0C00                  LDYZ    PERIOD
- 0C02          LOOP    LDAY    WAVE
- 0C05                  ADCIY   BASE
- 0C07                  STA     PAD     02
- 0C0A                  JSR     DELAY
- 0C0D                  DEY
- 0C0E                  BNE     LOOP
- 0C10                  RTS
- 0C11 -ASSEM
- 0C11 -PRINT  00T011
A460    WAVGEN  LDYZ    PERIOD      00
B9800C  LOOP    LDAY    WAVE        02
7161            ADCIY   BASE        05
8D0217          STA     PAD     02  07
208C0C          JSR     DELAY       0A
88              DEY                 0D
D0F2            BNE     LOOP        0E
60              RTS                 10
- 0C11 -STORE
?
```

The array WAVE occupies the first twelve bytes of the program storage area. Thus, the module DELAY will begin at address 0C8C (2A8C).

Two global symbols were defined with a single use of the ?ASSGN command.

The assembler failed to recognize the opcode LDX# when it was entered in the wrong field.

The module could not be assembled at first because of the undefined symbol, L00P. This was corrected using the -INSRT command to replace the unlabeled line.

The first line of a listing is labeled with the name of the module unless another label is given it.

The use of the ?REDEF command means that the module WAVGEN will begin at 0070.

Both L00P and BASE are local symbols. The L00P in one module will not be confused with that in the other, and BASE may not be referenced in another module.

The module WAVGEN may call DELAY as a subroutine since DELAY was entered first.

2.7 Structured Programming

The discipline of structured programming has become increasingly popular with the spread of such languages as Pascal. Structured programming in assembly language is more difficult, but offers the same advantages. Structured programs are more likely to run correctly the first time, easier to debug, and easier for other programmers to understand. Structured programming in machine language requires that the programmer accept the following restrictions on transfer of control.

Blocks. Every forward branch creates a block of one or more lines of assembly language, between the branch instruction and the line referenced by the branch. Execution of the block must begin with the first line of the block; no instruction outside the block may reference a line within the block. On completion of a block, control must pass to the line immediately following the block; no branch in the block may reference a line outside the block. Blocks may contain blocks and loops.

Loops. Every backward branch creates a loop. The loop includes the branch instruction and the line it references. The same restrictions given for blocks also apply to loops. Loops may contain loops and blocks.

Subroutines. Blocks and loops may contain subroutine calls. Since control returns to the calling block or loop, a subroutine may be considered as a nested block or loop.

Format. The structure of a module can be emphasized by indenting blocks and loops. This is illustrated throughout Section 3. Occasional NOP (EA) instructions were inserted to delimit blocks and loops. Nested loops or blocks may require two or three NOPs in a row, but rarely will an assembly language program contain a four EA series.

3. LISTING

Data Tables. MNETAB, MODTAB, etc.

```
0200  42 52 4B 43 4C 43 43 4C 44 43 4C 49 43 4C 56 44
0210  45 58 44 45 59 49 4E 58 49 4E 59 4E 4F 50 50 48
0220  41 50 48 50 50 4C 41 50 4C 50 52 54 49 52 54 53
0230  53 45 43 53 45 44 53 45 49 54 41 58 54 41 59 54
0240  53 58 54 58 41 54 58 53 54 59 41 43 50 58 53 54
0250  58 4C 44 58 43 50 59 4C 44 59 53 54 59 41 44 43
0260  41 4E 44 43 4D 50 45 4F 52 4C 44 41 4F 52 41 53
0270  42 43 53 54 41 41 53 4C 4C 53 52 52 4F 4C 52 4F
0280  52 44 45 43 49 4E 43 42 49 54 4A 4D 50 4A 53 52
0290  42 43 43 42 43 53 42 45 51 42 4D 49 42 4E 45 42
02A0  50 4C 42 56 43 42 56 53 20 20 41 20 23 20 5A 20
02B0  5A 58 5A 59 49 58 49 59 20 20 20 20 58 20 59 20
02C0  49 20 00 27 19 19 1D 1A 1F 1F 30 19 1D 1B 2E 19
02D0  2B 26 2E 2D 1C 27 27 38 30 2D 27 2F 00 F2 04 11
02E0  22 35 32 3A 31 50 63 75 6E 0C 80 0C A5 02 0E 00
02F0  03 02 37 C0 02 11 00 02 01 0C F8 09 15 00 08 05
0300  08 FF FF FF FF 00 18 D8 58 B8 CA 88 E8 C8 EA 48
0310  08 68 28 40 60 38 F8 78 AA A8 BA 8A 9A 98 0A 4A
0320  2A 6A E0 FF A2 C0 A0 FF 69 29 C9 49 A9 09 E9 E4
0330  86 A6 C4 A4 84 65 25 C5 45 A5 05 E5 85 06 46 26
0340  66 C6 E6 24 B4 94 75 35 D5 55 B5 15 F5 95 16 56
0350  36 76 D6 F6 B6 96 61 21 C1 41 A1 01 E1 81 71 31
0360  D1 51 B1 11 F1 91 90 B0 F0 30 D0 10 50 70 EC 8E
0370  AE CC AC 8C 6D 2D CD 4D AD 0D ED 8D 0E 4E 2E 6E
0380  CE EE 2C 4C 20 BC FF 7D 3D DD 5D BD 1D FD 9D 1E
0390  5E 3E 7E DE FE BE FF FF FF 79 39 D9 59 B9 19 F9
03A0  99 6C FF
```

03A3 Subroutine MATCH. Search table for match to reference, X points to search parameters on page zero. Sets z if match found, returns number of matching record in X.

```
86 29              STXZ     ADL          Put address of
A2 00              LDX#     00           search parameter
86 2A              STXZ     ADH          list in ADL, H.
A0 06              LDY#     06
B1 29     PARAM      LDAIY    ADL        Move parameters
99 30 00             STAY     TBL        to workspace.
88                   DEY
10 F8                BPL      PARAM
A6 36              LDXZ     NUM          Compare X records.
A4 35     RECORD     LDYZ     HBC
B1 30     BYTE         LDAIY    TBL      First Y+1 bytes
D1 32                  CMPIY    RFL      must match.
F0 02                  BEQ      OK
A0 FF                    LDY#     FF     Mismatch.
88        OK           DEY
10 F5                  BPL      BYTE
C8                   INY                 All ok?
D0 01                BNE      INCADR
60                     RTS                z set.
38        INCADR     SEC
A5 30                LDAZ     TBL        Find base address
E5 34                SBCZ     LEN        of next record.
85 30                STAZ     TBL
B0 02                BCS      DECNUM
C6 31                  DECZ     TBH
CA        DECNUM     DEX
10 E1                BPL      RECORD     Last record?
60                 RTS                  z clear.
```

03D5 Subroutine HEX. Convert ASCII character pointed to by X to 4 binary bits in A.

```
B5 00            LDAZX    IOBUF       Get character.
C9 40            CMP#     40          Number or letter?
30 03            BMI      NUMER
38                 SEC                Letter; adjust.
E9 07              SBC#     07
29 0F      NUMER   AND#     0F          Convert to binary.
60                 RTS
```

03E1 Subroutine HX2BIN. Convert 2 ASCII characters on page zero, pointed to by X, to 8 binary bits in X.

```
20 D5 03         JSR      HEX         Find high byte,
0A               ASLA
0A               ASLA
0A               ASLA
0A               ASLA
85 2D            STAZ     TEMP
E8               INX                  and low byte.
20 D5 03         JSR      HEX
05 2D            ORAZ     TEMP        Combine.
AA               TAX
60               RTS
```

03F2 Subroutine BIN2HX. Convert 4 bits in A to an ASCII character. Store in page zero, X.

```
C9 0A              CMP#    0A          Number or letter?
30 03              BMI     NUMER
18                   CLC               Letter; adjust.
69 07                ADC#     07
18         NUMER   CLC                 Convert to ASCII.
69 30              ADC#    30
95 00              STAZX   IOBUF       Store character.
60                 RTS
```

03FF Subroutine DSPHEX. Convert binary number in A to two ASCII (hexadecimal) characters in page zero locations X, X+1.

```
48                 PHA                 Save number.
4A                 LSRA                Find high character.
4A                 LSRA
4A                 LSRA
4A                 LSRA
20 F2 03           JSR     BIN2HEX
E8                 INX                 Find low character.
68                 PLA
29 0F              AND#    0F
20 F2 03           JSR     BIN2HEX
60                 RTS
```

040F Subroutine SYM. Puts base address of symbol table entry X in MISCL, H.

```
38                  SEC                     Find difference
86 2D               STXZ      TEMP          between last
A5 56               LDAZ      SYMNUM        record and X.
E5 2D               SBCZ      TEMP
85 2B               STAZ      MISCL
A9 00               LDA#      00
85 2C               STAZ      MISCH
18                  CLC
A0 02               LDY#      02
26 2B      X8         ROLZ      MISCL        Multiply by 8
26 2C                 ROLZ      MISCH        bytes per record.
88                    DEY
10 F9                 BPL       X8
38                  SEC                     Subtract from
A5 50               LDAZ      SYMTBL        address of
E5 2B               SBCZ      MISCL         last record.
85 2B               STAZ      MISCL
A5 51               LDAZ      SYMTBH
E5 2C               SBCZ      MISCH
85 2C               STAZ      MISCH
60                  RTS
```

0434 Subroutine ADDRSS. Puts address corresponding to symbol X in ADL, H.

```
20 0F 04            JSR       SYM           Get base address.
A0 06               LDY#      06            Get symbol address.
B1 2B               LDAIY     MISCL
85 29               STAZ      ADL           Put in ADL, H.
C8                  INY
B1 2B               LDAIY     MISCL
85 2A               STAZ      ADH
60                  RTS
```

0443 Subroutine ADDLAB. Add symbol to table. A points to 6 zpage bytes containing symbol. Returns number of new symbol in X.

```
85 29              STAZ     ADL          ADL,H points
A9 00              LDA#     00           to symbol.
85 2A              STAZ     ADH
18                 CLC
A5 50              LDAZ     SYMTBL       Find new base
69 08              ADC#     08           address of
85 50              STAZ     SYMTBL       symbol table.
90 02              BCC      NOADDR
E6 51                INCZ     SYMTBH
A0 07      NOADDR  LDY#     07
A9 FF              LDA#     FF           Set high address
91 50              STAIY    SYMTBL       =FF (unassigned).
88                 DEY
88                 DEY
B1 29      XFRSYM    LDAIY    ADL        Add symbol to
91 50                STAIY    SYMTBL     symbol table.
88                   DEY
10 F9                BPL      XFRSYM
A6 56              LDXZ     SYMNUM       Increment number
E8                 INX                   of symbols.
86 56              STXZ     SYMNUM
60                 RTS
```

0469 Subroutine NEWSYM. Puts base address of symbol table record for symbol pointed to by A in MISCL, H and returns symbol in X. If new, adds to table and sets Z.

```
85 52              STAZ     SYMRFL       Set up search.
A2 50              LDX#     50
20 A3 03           JSR      MATCH        Look up symbol.
F0 05              BEQ      OLD
A5 52                LDAZ     SYMRFL     Not found; add
20 43 04             JSR      ADDLAB     to symbol table.
20 0F 04   OLD     JSR      SYM          Address in MISCL, H.
E4 56              CPXZ     SYMNUM       Set z if new.
60                 RTS
```

047D Subroutine ENCODE (part 1). Put mnemonic code in MNE, address mode in X.

```
A2 42             LDX#    42          Find mnemonic.
20 A3 03          JSR     MATCH
F0 03             BEQ     MNEFND
A9 31               LDA#    31        "1" Error-
60                  RTS               not found.
86 2E       MNEFND STXZ     MNE         Save mnemonic.
A2 49             LDX#    49
20 A3 03          JSR     MATCH       Find address mode.
F0 03             BEQ     MODFND
A9 32               LDA#    32        "2" Error-
60                  RTS               not found.
A5 2E       MODFND LDAZ     MNE         Special cases:
C9 19             CMP#    19
10 02             BPL     NOTIMP
A2 00               LDX#    00        Implied mode.
C9 30       NOTIMP CMP#     30
30 02             BMI     NOTREL
A2 08               LDX#    08        Relative mode.
EA          NOTREL NOP
```

04A2 Subroutine ENCODE (part 2). Check legality of mnemonic/address mode combination.

```
A5 2E             LDAZ    MNE         Legal mnemonic
DD C2 02          CMPX    MIN         for address mode?
10 03             BPL     NOT2LO
A9 33               LDA#    33        "3" Too low.
60                  RTS
DD CF 02    NOT2LO CMPX     MAX
30 03             BMI     NOT2HI
A9 33               LDA#    33        "3" Too high.
60                  RTS
18          NOT2HI CLC
7D DC 02          ADCX    BASE
85 37             STAZ    OPCPTR      Store pointer
AA                TAX                 to opcode
BD 05 03          LDAX    OPCTAB
C9 FF             CMP#    FF
D0 03             BNE     OPCLGL
A9 33               LDA#    33        "3" Illegal.
60                  RTS
EA          OPCLGL NOP                  Continue.
```

04C6 Subroutine ENCODE (part 3). Find operand code, if required, for address modes other than relative and 3-byte address modes.

```
A5 37          LDAZ    OPCPTR      Consider opcode.
C9 1D          CMP#    1D
10 03          BPL     OPRRQD      Operand required?
A9 2D            LDA#    2D        "-"
60               RTS               No; return.
E6 2F    OPRRQD  INCZ    BYTES     At least 2 bytes.
C9 2A          CMP#    2A
10 0A          BPL     NOTIMM
A2 15            LDX#    15        Immediate addressing.
20 E1 03         JSR     HX2BIN    Find binary value
86 38            STXZ    SYMPTR
A9 2D            LDA#    2D        "-"
60               RTS
A2 15    NOTIMM  LDX#    15        Set up operand search.
86 52          STXZ    SYMRFL
C9 61          CMP#    61
10 20          BPL     NOTZPG    Zpage addressing?
A2 50            LDX#    50        Yes.
20 A3 03         JSR     MATCH     Look up operand.
F0 03            BEQ     FOUND
A9 34              LDA#    34      "4" Not found.
60                 RTS
20 34 04 FOUND     JSR     ADDRSS
F0 03              BEQ     OK
A9 35              LDA#    35      "5" Not zpage.
60                 RTS
86 38    OK        STXZ    SYMPTR    Store operand.
A5 1C              LDAZ    OFFSET    Check for offset.
C9 20              CMP#    20        "SP"
F0 03              BEQ     DONE
A9 36              LDA#    36      "6" offset illegal.
60                 RTS
A9 2D    DONE      LDA#    2D        "-"
60                 RTS               OK, return.
EA       NOTZPG  NOP                Continue.
```

0508 Subroutine ENCODE (part 4). Look up operand; add if required.

```
A2 50              LDX#     50           Look up operand.
20 A3 03           JSR      MATCH
F0 05              BEQ      FOUND
A9 15                LDA#     15         Not found; add
20 43 04             JSR      ADDLAB     to symbol table.
86 38      FOUND   STXZ     SYMPTR
A5 37              LDAZ     OPCPTR
C9 69              CMP#     69           Relative addressing?
10 0A              BPL      NOTREL
E4 3C              CPXZ     GLOBAL
10 03                BPL      OK
A9 37                  LDA#     37       "7" Error-
60                     RTS               branch not local.
A9 2D      OK          LDA#     2D       "-"
60                     RTS
EA         NOTREL  NOP
```

0527 Subroutine ENCODE (part 5). For absolute addressing, check legality and find offset.

```
E4 3C              CPXZ     GLOBAL       Operand must
30 0A              BMI      OK           be global or
20 34 04             JSR      ADDRSS     outside block.
C5 3F                CMPZ     CRNTAH
D0 03                BNE      OK
A9 38                  LDA#     38       "8" Absolute
60                     RTS               mode w/in block.
A5 1C      OK      LDAZ     OFFSET
A2 00              LDX#     00
C9 20              CMP#     20           "SP"
F0 05              BEQ      STROFS
A2 1C                LDX#     1C         Find offset.
20 E1 03             JSR      HX2BIN
86 39      STROFS  STXZ     OPRDSP
E6 2F              INCZ     BYTES
A9 2D              LDA#     2D           "-" Stay in
60                 RTS                    edit mode.
```

```
0549  Subroutine CMAND.  Look up and execute command.

A5 3A              LDAZ     MODE          Command legal
C5 00              CMPZ     IOBUF         for mode?
F0 04              BEQ      OK
18                   CLC                  No; illegal.
69 0C                ADC#     0C          Return "9" or "K"
60                   RTS
A9 00        OK    LDA#     00            Look up command.
85 52              STAZ     SYMRFL
A2 50              LDX#     50
20 A3 03           JSR      MATCH
F0 0C              BEQ      FOUND
A5 00                LDAZ     IOBUF       Not found.
C9 3F                CMP#     3F
10 03                BPL      CMODE
A9 30                  LDA#     30        "0" Error-
60                     RTS                input mode.
A9 41        CMODE     LDA#     41        "A" Error-
60                     RTS                command mode.
A9 05        FOUND   LDA#     05          Set up return.
48                   PHA
A9 75                LDA#     75
48                   PHA
20 34 04             JSR      ADDRSS      Get address.
6C 29 00             JMPI     ADL         Execute command.
60                   RTS
```

0577 Subroutine FIN. Add line to program; assign address to label, if any.

```
20 40 09          JSR      INSERT      Adjust if inserting.
A4 2F             LDYZ     BYTES
88                DEY
B9 37 00  ADDLIN    LDAY     OPCPTR     Add line
91 3E               STAIY    CRNTAL     to program.
88                  DEY
10 F8               BPL      ADDLIN
A5 07             LDAZ     LABEL
C9 20             CMP#     20          "SP"
F0 10             BEQ      INCADR      Any label?
A9 07               LDA#     07        Yes.  Add to
20 69 04            JSR      NEWSYM    symbol table
AO 07               LDY#     07        if new, and
A5 3F               LDAZ     CRNTAH    assign address.
91 2B               STAIY    MISCL
88                  DEY
A5 3E               LDAZ     CRNTAL
91 2B               STAIY    MISCL
18        INCADR  CLC
A5 3E             LDAZ     CRNTAL      Increment pointers.
65 2F             ADCZ     BYTES
85 3E             STAZ     CRNTAL
18                CLC
A5 3D             LDAZ     PRGLEN
65 2F             ADCZ     BYTES
85 3D             STAZ     PRGLEN
10 03             BPL      OK
A9 42               LDA#     42        "B" Error-
60                  RTS                program overflow.
24 56     OK      BITZ     SYMNUM
50 03             BVC      OK2
A9 43               LDA#     43        "C" Error-
60                  RTS                symbol overflow.
A9 2D     OK2     LDA#     2D
60                RTS
```

05B8 Main program. Process command, or translate input into source code.

```
D8                    CLD
A2 18                 LDX#     18           Initialize
BD E9 02  INIT          LDAZ     PRMTAB     program parameters.
95 3F                   STAZX    CRNTAH
CA                      DEX
10 F8                   BPL      INIT
A9 3F                 LDA#     3F           "?" Set.
85 00     START       STAZ     IOBUF        command mode.
A0 20                 LDY#     20           "SP"
A2 21                 LDX#     21
94 01     CLEAR         STYZX    IOBUF1     Clear I/O buffer
CA                      DEX                 except error code.
10 FB                   BPL      CLEAR
A2 3F                 LDX#     3F           "?" Command.
C9 3F                 CMP#     3F           Command mode?
10 10                 BPL      GETLIN
A5 3F                   LDAZ     CRNTAH     No; input mode.
A2 02                   LDX#     02         Display address.
20 FF 03                JSR      DSPHEX
A5 3E                   LDAZ     CRNTAL
A2 04                   LDX#     04
20 FF 03                JSR      DSPHEX
A2 2D                   LDX#     2D         "-" Input.
86 3A     GETLIN      STXZ     MODE         Save mode.
A9 01                 LDA#     01           Initialize.
85 2F                 STAZ     BYTES
20 5D 07              JSR      INPUT        Input line.
A5 3A                 LDAZ     MODE         Mode?
C9 2D                 CMP#     2D           "-"
D0 04                 BNE      CMODE        Command mode?
A5 01                   LDAZ     IOBUF1     Input mode command?
C9 20                   CMP#     20         "SP"
D0 0C     CMODE       BNE      EXEC         If neither,
20 7D 04                JSR      ENCODE     translate line.
C9 2D                   CMP#     2D         "-"
D0 03                   BNE      NG         If line legal,
20 77 05                  JSR      FIN      add to program.
A2 00     NG            LDX#     00
F0 03     EXEC        BEQ      DONE         If command,
20 49 05                JSR      CMAND      execute it.
18        DONE        CLC
90 B6                 BCC      START        Repeat until reset.
EA                    NOP
```

```
0610  ? BEGIN.  Add module name to symbol table; enter
input mode.

A9 07              LDA#     07          Add name to
20 69 04           JSR      NEWSYM      symbol table.
F0 03              BEQ      OK
A9 44                LDA#     44        "D" Error-
60                   RTS                label in use.
86 3C       OK     STXZ     GLOBAL      Set local cutoff.
A9 00              LDA#     00          Clear pointers.
85 3E              STAZ     CRNTAL
85 3D              STAZ     PRGLEN
A0 06              LDY#     06
91 2B              STAIY    MISCL       Set start address
A5 3F              LDAZ     CRNTAH      =CRNTAL, H.
C8                 INY
91 2B              STAIY    MISCL
A9 2D              LDA#     2D          "-" Set
60                 RTS                  input mode.
```

```
062E  ? ASSGN.  Assign addresses to labels.

A5 07              LDAZ     LABEL
C9 20      START     CMP#     20          "SP"
D0 03                BNE      MORE        Label supplied?
A9 3F                  LDA#     3F        No; done.
60                     RTS
A9 07      MORE      LDA#     07
20 69 04             JSR      NEWSYM      Add symbol to table.
F0 03                BEQ      NOTOLD
A9 44                  LDA#     44        "D" Error-
60                     RTS                label in use.
A2 0E      NOTOLD    LDX#     0E          Assign address.
20 E1 03             JSR      HX2BIN
A0 07                LDY#     07
8A                   TXA
91 2B                STAIY    MISCL
A2 10                LDX#     10
20 E1 03             JSR      HX2BIN
88                   DEY
8A                   TXA
91 2B                STAIY    MISCL
A9 20                LDA#     20          "SP"
A2 0C                LDX#     0C          clear I/O buffer
95 07      CLEAR       STAZX    LABEL     except prompt.
CA                     DEX
10 FB                  BPL      CLEAR
20 5D 07             JSR      INPUT       Next symbol.
A5 07                LDAZ     LABEL
10 CC                BPL      START
EA                 NOP
```

0665 -LOCAL. Add local symbols to symbol table; assign addresses.

```
20 2E 06          JSR     ?ASSGN      Add to
C9 44             CMP#    44          symbol table
D0 03             BNE     OK          if new.
A9 3A               LDA#    3A        ":" Error-
60                  RTS               symbol in use.
A9 2D     OK      LDA#    2D          "-" stay in
60                RTS                 input mode.
```

0672 ?REDEF. Redefine module start address.

```
A2 07             LDX#    07          Find high address.
20 E1 03          JSR     HX2BIN
86 41             STXZ    MDLADH      Store.
A2 09             LDX#    09          Find low address.
20 E1 03          JSR     HX2BIN
86 40             STXZ    MDLADL      Store.
A9 3F             LDA#    3F          "?" stay in
60                RTS                 command mode.
```

```
0683  Subroutine ASMBL.  Translate line into machine code;
store result at (OBJECT).  Return length-1 in Y.

A0 00              LDA#     00            Get first byte.
B1 3E              LDAIY    CRNTAL
AA                 TAX
BD 05 03           LDAX     OPCTAB        Look up opcode.
91 57              STAIY    OBJECT
E0 1D              CPX#     1D
10 01              BPL      OPREQ
60                   RTS                  No operand.
C8           OPREQ INY
B1 3E              LDAIY    CRNTAL
E0 2A              CPX#     2A
10 03              BPL      NOTIMM        Address mode?
91 57                STAIY    OBJECT      Immediate.
60                   RTS
86 2E        NOTIMM STXZ     MNE
AA                 TAX
20 34 04           JSR      ADDRSS        Get address.
A5 29              LDAZ     ADL
A0 01              LDY#     01
A6 2E              LDXZ     MNE
E0 61              CPX#     61
10 03              BPL      NOTZPG
91 57                STAIY    OBJECT      Zero page.
60                   RTS
E0 69        NOTZPG CPX#     69
10 09              BPL      NOTREL
38                   SEC                  Relative.
E9 02                SBC#     02          Compute branch.
38                   SEC
E5 3E                SBCZ     CRNTAL
91 57                STAIY    OBJECT
60                   RTS
18           NOTREL CLC                    Absolute.
C8                 INY
71 3E              ADCIY    CRNTAL        Add offset.
88                 DEY
91 57              STAIY    OBJECT
C8                 INY
A5 2A              LDAZ     ADH
69 00              ADC#     00
91 57              STAIY    OBJECT
60                 RTS
```

06CB Subroutine LOCSYM. Displays undefined local symbols.

```
A6 3C             LDXZ     GLOBAL      For local symbols,
E8        NXTSYM    INX
20 34 04            JSR      ADDRSS     see if defined.
C9 FF               CMP#     FF
D0 11               BNE      DEFIND     If not,
A0 05                 LDY#     05       display symbol.
B1 2B     SHOW          LDAIY    MISCL
99 00 00                STAY     IOBUF
88                      DEY
10 F8                   BPL      SHOW
86 2B                 STXZ     MISCL
20 A1 08              JSR      OUTLIN
A6 2B                 LDXZ     MISCL
E4 56     DEFIND    CPXZ     SYMNUM     If more
30 E3               BMI      NXTSYM     symbols, repeat.
60                RTS
```

06EB -ASSEM. Assemble module; store result in RAM locations beginning at (MDLADL, H).

```
20 CB 06          JSR      LOCSYM     Check for local
A9 2D             LDA#     2D         undefined symbols.
C5 00             CMPZ     IOBUF
F0 01             BEQ      ALLOK      If any; return.
60                  RTS
A9 00     ALLOK   LDA#     00         Else, assemble.
85 3E             STAZ     CRNTAL     Initialize pointers.
A5 40             LDAZ     MDLADL
85 57             STAZ     OBJECT
A5 41             LDAZ     MDLADH
85 58             STAZ     OBJCT1
20 83 06  NEXTLN    JSR      ASMBL      Translate a line.
84 2D               STYZ     TEMP       Save bytes -1.
38                  SEC                 Increment pointers.
A5 57               LDAZ     OBJECT     For object code.
65 2D               ADCZ     TEMP
85 57               STAZ     OBJECT
90 02               BCC      SKIP
E6 58                 INCZ     OBJCT1
38        SKIP      SEC                 For source code.
A5 3E               LDAZ     CRNTAL
65 2D               ADCZ     TEMP
85 3E               STAZ     CRNTAL
C5 3D               CMPZ     PRGLEN
30 E5               BMI      NEXTLN     Finished?
A9 2D             LDA#     2D         "-" Stay in
60                RTS                 edit mode.
```

```
071F  ? TABLE.  Allocate space for tables.

A5 07              LDAZ     LABEL
C9 20     START      CMP#     20          "SP"
D0 03                BNE      MORE        Any label?
A9 3F                  LDA#     3F        No; done.
60                     RTS
A9 07     MORE       LDA#     07
20 69 04             JSR      NEWSYM      Add symbol to
F0 03                BEQ      NOTOLD      symbol table.
A9 44                  LDA#     44        "D" Error-
60                     RTS                not new.
A0 06     NOTOLD     LDY#     06          Assign address.
A5 40                LDAZ     MDLADL
91 2B                STAIY    MISCL
C8                   INY
A5 41                LDAZ     MDLADH
91 2B                STAIY    MISCL
A2 0E                LDX#     0E          Allocate space
20 E1 03             JSR      HX2BIN      by incrementing
8A                   TXA                  MDLADL, H.
18                   CLC
65 40                ADCZ     MDLADL
85 40                STAZ     MDLADL
90 02                BCC      NOINC
E6 41                  INCZ     MDLADH
A9 20     NOINC      LDA#     20          "SP"
A2 0C                LDX#     0C
95 07     CLEAR        STAZX    LABEL       Clear I/O buffer
CA                     DEX                  except prompt.
10 FB                  BPL      CLEAR
20 5D 07             JSR      INPUT
A5 07                LDAZ     LABEL       Another symbol?
10 C5                  BPL      START
EA                 NOP
```

075D Subroutine INPUT. Prompt w/ first word in IOBUF.
Input up to 5 words. Special keys: ESC, CR, BKSP, SP.

```
20 2F 1E           JSR      CRLF          New line.
A2 00              LDX#     00            Prompt w/
B5 00     PROMPT     LDAZX    IOBUF       first 6 chars.
20 A0 1E             JSR      OUTCH
E8                   INX
E0 06                CPX#     06
30 F6                BMI      PROMPT
A2 00              LDX#     00            Initialize pointer.
A9 06              LDA#     06            7 chars/word
85 2D              STAZ     TEMP          includes space.
20 5A 1E  START      JSR      GETCH       Input a char.
C9 1B                CMP#     1B          "ESC"
D0 01                BNE      NOTBRK
00                     BRK                 Break.
C9 0D     NOTBRK     CMP#     0D          "CR"
D0 01                BNE      NOTCR
60                     RTS                 End of line.
C9 08     NOTCR      CMP#     08          "BS"
D0 05                BNE      NOTBSP
CA                     DEX                 Backspace.
E6 2D                  INCZ       TEMP
A9 08                  LDA#       08
C9 20     NOTBSP     CMP#     20          "SP"
D0 0D                BNE      NOTSP
EA                     NOP                 Next word.
20 9E 1E  TAB            JSR        OUTSP   Add spaces
E8                       INX                to fill word.
C6 2D                    DECZ       TEMP
10 F8                    BPL        TAB
A9 06                  LDA#       06
85 2D                  STAZ       TEMP
C9 20     NOTSP      CMP#     20          If not a
30 05                BMI      DONE        control char:
95 00                  STAZX      IOBUF   Add char to
E8                     INX                I/O buffer.
C6 2D                  DECZ       TEMP
18        DONE       CLC
90 CD                BCC      START       Next character.
EA                 NOP
```

07A6 -STORE. Clear local symbols; assign address to module. Increment MDLADL,H to prevent overwrite by next module. Return to command mode.

```
A6 3C              LDXZ     GLOBAL      Clear local
20 0F 04           JSR      SYM         symbols from
86 56              STXZ     SYMNUM      symbol table.
A5 2B              LDAZ     MISCL
85 50              STAZ     SYMTBL
A5 2C              LDAZ     MISCH
85 51              STAZ     SYMTBH
A0 07              LDY#     07          Assign address
A5 41              LDAZ     MDLADH      to module.
91 2B              STAIY    MISCL
88                 DEY
A5 40              LDAZ     MDLADL
91 2B              STAIY    MISCL
18                 CLC
65 3D              ADCZ     PRGLEN      Increment MDLADL,H
85 40              STAZ     MDLADL      by length of
90 02              BCC      SKIP        module.
E6 41                INCZ     MDLADH
A9 3F      SKIP    LDA#     3F          "?" Return to
60                 RTS                  command mode.
```

Table MODLIM. Lower opcode pointer limits for modes.

07CC 00 19 1D 2A 3F 4F 51 59 61 69 80 90 9C

07D9 Subroutine DECODE. Decode line pointed to by CRNTAL and OBJECT. Put line in IOBUF, length in BYTES.

```
A9 01              LDA#    01          Assume 1 byte.
85 2F              STAZ    BYTES
A2 22              LDX#    22          Clear I/O buffer.
A9 20              LDA#    20
95 00     CLEAR      STAZX   IOBUF
CA                   DEX
10 FB                BPL     CLEAR
A6 56              LDXZ    SYMNUM      Check for label.
20 34 04  START      JSR     ADDRSS      Compare address
A5 3E                LDAZ    CRNTAL      to current line.
C5 29                CMPZ    ADL
D0 04                BNE     SKIP
A5 3F                  LDAZ    CRNTAH
C5 2A                  CMPZ    ADH
D0 0C     SKIP       BNE     SKIP2       If they match,
A0 05                  LDY#    05          put label in
B1 2B     LABL           LDAIY   MISCL     I/O buffer.
99 07 00                 STAY    LABEL
88                       DEY
10 F8                    BPL     LABL
A2 01                  LDX#    01          End search.
CA        SKIP2      DEX
E4 3C                CPXZ    GLOBAL      Consider local
10 E0                BPL     START       symbols only.
A0 00              LDY#    00          Get opcode.
B1 57              LDAIY   OBJECT
A2 00              LDX#    00          Put opcode in
20 FF 03           JSR     DSPHEX      I/O buffer.
B1 3E              LDAIY   CRNTAL      Decode opcode.
85 37              STAZ    OPCPTR
```

0815 Subroutine DECODE (part 2). Decode address mode and opcode; put in I/O buffer.

```
A2 0C             LDX#    0C          Find mode.
C9 1D             CMP#    1D          Any operand?
10 02             BPL     FNDMOD      If not, only check
A2 01               LDX#    01        implied and accum.
DD CC 07 FNDMOD     CMPX    MODLIM    In range
30 04               BMI     NOPE      for mode?
86 3A                 STXZ    MODE    Yes; save mode.
A2 00                 LDX#    00      End search.
CA       NOPE       DEX
10 F4               BPL     FNDMOD
A5 3A             LDAZ    MODE        Put mode in
0A                ASLA                I/O buffer.
AA                TAX
BD A8 02          LDAX    MODTAB
85 11             STAZ    OPCOD3
BD A9 02          LDAX    MODTAB 01
85 12             STAZ    OPCOD4
B1 3E             LDAIY   CRNTAL      Find mnemonic.
38                SEC
A6 3A             LDXZ    MODE
FD DC 02          SBCX    BASE        Mnemonic number.
85 2D             STAZ    TEMP        Multiply by 3.
0A                ASLA
18                CLC
65 2D             ADCZ    TEMP
AA                TAX                 Get ASCII.
BD 00 02          LDAX    MNETAB      Put mnemonic in
85 0E             STAZ    OPCODE      I/O buffer.
BD 01 02          LDAX    MNETAB 01
85 0F             STAZ    OPCOD1
BD 02 02          LDAX    MNETAB 02
85 10             STAZ    OPCOD2
A5 37             LDAZ    OPCPTR      Operand needed?
C9 1D             CMP#    1D
10 01             BPL     OPRND
60                  RTS               No; finished.
E6 2F    OPRND    INCZ    BYTES       At least 2 bytes.
```

085E Subroutine DECODE (part 3). Decode operands and offset, if any.

```
A0 01             LDY#    01
B1 57             LDAIY   OBJECT      Machine code
A2 02             LDX#    02          for operand in
20 FF 03          JSR     DSPHEX      I/O buffer.
A5 37             LDAZ    OPCPTR
C9 2A             CMP#    2A          Immediate mode?
10 08             BPL     NOTIMM
B1 3E               LDAIY   CRNTAL    Yes; put hex
A2 15               LDX#    15        number in
20 FF 03            JSR     DSPHEX    I/O buffer.
60                  RTS
B1 3E     NOTIMM  LDAIY   CRNTAL      No; look up
AA                TAX                 operand.
20 0F 04          JSR     SYM
A0 05             LDY#    05          Put operand
B1 2B     SHOWOP    LDAIY   MISCL     in IOBUF.
99 15 00            STAY    OPRAND
88                  DEY
10 F8               BPL     SHOWOP
A5 37             LDAZ    OPCPTR      3-byte instruction.
C9 69             CMP#    69
10 01             BPL     ABS
60                  RTS               No; done
E6 2F     ABS     INCZ    BYTES       Yes.
A0 02             LDY#    02
B1 57             LDAIY   OBJECT      Add code to
A2 04             LDX#    04          I/O buffer.
20 FF 03          JSR     DSPHEX
B1 3E             LDAIY   CRNTAL      Offset?
F0 05             BEQ     DONE
A2 1C               LDX#    1C        Show offset.
20 FF 03            JSR     DSPHEX
60        DONE    RTS
```

08A1 Subroutine OUTLIN. Output line from IOBUF.

```
20 2F 1E          JSR     CRLF        New line.
A2 00             LDX#    00
B5 00     NXTCHR    LDAZX   IOBUF     Output one
20 A0 1E            JSR     OUTCH     character at
E8                  INX               a time,
E0 23               CPX#    23        until done.
30 F6               BMI     NXTCHR
60                RTS
```

08B1 Subroutine PRNTCK. Check that FIRST and LAST are legal line numbers. Print lines in range if PRNTOK=1.

```
A9 00              LDA#    00              Initialize.
85 3E              STAZ    CRNTAL
A5 40              LDAZ    MDLADL
85 57              STAZ    OBJECT
A5 41              LDAZ    MDLADH
85 58              STAZ    OBJCT1
A2 07              LDX#    07              Decode range.
20 E1 03           JSR     HX2BIN
86 59              STXZ    FIRST
A2 0B              LDX#    0B
20 E1 03           JSR     HX2BIN
86 5A              STXZ    LAST
A9 02              LDA#    02              Initialize flag
85 39              STAZ    WRONG           for mismatch.
20 D9 07  NXTLIN     JSR     DECODE        Decode line.
A5 3E                LDAZ    CRNTAL
C5 59                CMPZ    FIRST         Decrement WRONG
D0 02                BNE     SKIP          each time a
C6 39                  DECZ    WRONG       match is found.
C5 5A     SKIP       CMPZ    LAST
D0 02                BNE     SKIP2
C6 39                  DECZ    WRONG
C5 59     SKIP2      CMPZ    FIRST         In range
30 12                BMI     LOW           for print?
C5 5A                  CMPZ    LAST
10 0D                  BPL     HIGH
24 38                    BITZ    PRNTOK    Yes, but
30 08                    BMI     NOPRNT    print wanted?
A2 1F                      LDX#    1F      Yes; add
20 FF 03                   JSR     DSPHEX  line number.
20 A1 08                   JSR     OUTLIN  Print line.
EA        NOPRNT         NOP
EA        HIGH           NOP
18        LOW          CLC                 Update pointers.
A5 57                  LDAZ    OBJECT
65 2F                  ADCZ    BYTES
85 57                  STAZ    OBJECT
90 02                  BCC     NOINC
E6 58                    INCZ    OBJCT1
18        NOINC        CLC
A5 3E                  LDAZ    CRNTAL
65 2F                  ADCZ    BYTES
85 3E                  STAZ    CRNTAL
C5 3D                  CMPZ    PRGLEN        Last line?
30 C3                  BMI     NXTLIN        If not, repeat.
60                   RTS
```

090D -PRINT. Output lines in specified range.

```
A9 01             LDA#    01          Set print flag.
85 38             STAZ    PRNTOK
20 B1 08          JSR     PRNTCK      Run print routine.
A9 2D             LDA#    2D          "-" Stay in
60                RTS                 edit mode.
```

0917 Subroutine FIXSYM. Adds BYTES to addresses of line labels. Used by -INSRT and subroutine INSERT.

```
A6 56             LDXZ    SYMNUM      For local symbols,
20 34 04 START      JSR     ADDRSS    find address.
C5 3F               CMPZ    CRNTAH    Line label?
D0 1A               BNE     NOTLAB
A5 29                 LDAZ    ADL     Yes, but in
C5 3E                 CMPZ    CRNTAL  move zone?
30 13                 BMI     NOREV
A4 29                   LDYZ    ADL   Yes.
C4 5A                   CPYZ    LAST  Line deleted?
10 06                   BPL     NEWADR
A9 FE                     LDA#    FE  Yes.
A0 07                     LDY#    07  Delete symbol.
91 2B                     STAIY   MISCL
18        NEWADR          CLC         Fix address
65 2F                     ADCZ    BYTES
A0 06                     LDY#    06
91 2B                     STAIY   MISCL
EA        NOREV         NOP
CA        NOTLAB      DEX             More local
E4 3C                 CPXZ    GLOBAL  symbols?
10 DA                 BPL     START
60                  RTS
```

0940 Subroutine INSERT. Open gap in program to insert current line. Adjust symbol table.

```
A5 3E            LDAZ    CRNTAL      Inserting line?
C5 3D            CMPZ    PRGLEN
D0 01            BNE     INS
60                 RTS                 Nope.
85 5A     INS    STAZ    LAST
20 17 09         JSR     FIXSYM      Fix symbols.
18               CLC
A5 3E            LDAZ    CRNTAL      Set up offset
65 2F            ADCZ    BYTES       pointer for move.
85 29            STAZ    ADL
A5 3F            LDAZ    CRNTAH
85 2A            STAZ    ADH
A5 3D            LDAZ    PRGLEN
38               SEC
E5 3E            SBCZ    CRNTAL
A8               TAY
B1 3E     MOVE     LDAIY   CRNTAL      Move lines to
91 29              STAIY   ADL         open gap.
88                 DEY
10 F9              BPL     MOVE
60               RTS
```

0965 -INSRT. Check supplied line numbers for legality.
Set program pointer to first line number; delete to second.

```
A9 FF             LDA#    FF            Legal line?
85 38             STAZ    PRNTOK
20 B1 08          JSR     PRNTCK
C5 5A             CMPZ    LAST          Last+1 is
D0 02             BNE     NOTLST        legal line
C6 39               DECZ    WRONG       number.
A5 39     NOTLST  LDAZ    WRONG
F0 03             BEQ     OK
A9 25               LDA#    25          "%" Error-
60                  RTS                 illegal address.
A5 59     OK      LDAZ    FIRST
85 3E             STAZ    CRNTAL
A6 5A             LDXZ    LAST          Deletion needed?
F0 26             BEQ     DONE
38                  SEC                 Fix addresses
E5 5A               SBCZ    LAST        for labels.
85 2F               STAZ    BYTES
20 17 09            JSR     FIXSYM
A5 3F               LDAZ    CRNTAH      Set pointer
85 5B               STAZ    LAST1       for move.
A5 3D               LDAZ    PRGLEN      Find bytes
38                  SEC                 to move.
E5 3E               SBCZ    CRNTAL
85 2D               STAZ    TEMP
A5 3D               LDAZ    PRGLEN      Correct length
18                  CLC                 of program.
65 2F               ADCZ    BYTES
85 3D               STAZ    PRGLEN
A0 00               LDY#    00          Move lines to
B1 5A     MOVE        LDAIY   LAST      close gap.
91 3E               STAIY   CRNTAL
C8                  INY
C4 2D               CPYZ    TEMP
30 F7               BMI     MOVE
EA                  NOP
A9 2D     DONE    LDA#    2D            "-" Stay in
60                RTS                   edit mode.
```

09AA Move first nine entries in symbol table to RAM.
Entry point for assembler in ROM.

```
A2 47             LDX#    47
BD B8 09  MOVSYM    LDAX    ROM
9D B8 09            STAX    RAM
CA                  DEX
10 F7               BPL     MOVSYM
4C B8 05          JMP     MAIN
```

Table COMAND. First nine entries in symbol table; commands.

```
                                        09B8  3F 41 53 53 47 4E 2E 06
09C0  3F 42 45 47 49 4E 10 06   09C8  2D 4C 4F 43 41 4C 65 06
09D0  3F 52 45 44 45 46 72 06   09D8  2D 41 53 53 45 4D EB 06
09E0  3F 54 41 42 4C 45 1F 07   09E8  2D 53 54 4F 52 45 A6 07
09F0  2D 50 52 49 4E 54 0D 09   09F8  2D 49 4E 53 52 54 65 09
```

4. THEORY OF OPERATION

4.1 Encoding Scheme

The assembler owes its speed and memory efficiency to the encoding scheme by which each line of assembly language is stored. As each line is entered, it is translated into an encoded form which is the same length as its machine language equivalent. This is done by Subroutine ENCODE. The result may be seen at the address given in the prompt for each line.

Opcode. The first byte in the coded assembly language for a line is a pointer to the opcode for the instruction. The opcodes are found in OPCTAB, but in an unusual order. They are grouped by address mode, with the address modes in the order given in Section 2.3. This arrangement simplifies coding, since the modes are arranged in order of number of bytes required. The mnemonics have also been rearranged, to eliminate gaps in the table.

Operand. For two- and three-byte instructions, the second byte in the assembly code is for the operand. This is just a hexadecimal number for immediate addressing. For the other address modes, it is the number of the symbol table entry for the operand. Each symbol table entry is eight bytes--six ASCII characters followed by the low and high address for the symbol. Hexadecimal FF for the high address indicates that no address has yet been assigned to the symbol.

Offset. For three-byte instructions, the third byte in the assembly code is the offset described in Section 2.3. This will be zero unless an offset is supplied.

Listing. When the -PRINT command is used, the encoded assembly language must be translated back into strings of ASCII characters. This is done by Subroutine DECODE.

Assembly. With this encoding scheme, final assembly is reduced to one or two table look-ups for each line. Most of the work is done during the carriage return time as each line is entered.

4.2 Useful Subroutines

Some of the subroutines in the assembler may be of use in user programs. HX2BIN and DSPHEX are examples. Subroutine MATCH is a powerful string-search routine. It requires the following information from the calling routine: base address of the last record in the table to be searched, start address of the string to be compared, record length for the table, number of the highest byte which must match (the record may contain additional information), and the number of the last record in the table. This information is passed in the form

of a single byte in the X register, which points to a page-zero array of these parameters. These correspond to the symbols TBL through NUM in Table 4.2. X is also used to return the number of the record which matches the supplied string. The zero flag is cleared if no match is found.

Table 4.1: Important Arrays and Pointers.

Array	Assembly language module	Assembled program	Symbol table
Address range	0C00-0C7F (2A00-2A7F)	0C80- ?? (2A80- ??)	09B8-0BB7 (27B8-29B7)
Pointer	CRNTAL,H 003E,003F	MDLADL,H 0040,0041	SYMTBL,H 0050,0051
Points to	current line	first line of module	latest symbol
Initial value	0C00 (2A00)	0C80 (2A80)	09F8* (27F8)
Initialized from	02E9** (20E9)	02EA,02EB (20EA,20EB)	02FA,02FB (20FA,20FB)

?? Limited by available RAM.
() Address for version beginning at 2000.
* First part of symbol table reserved by assembler.
** High order address; low order initialized to zero.

Table 4.2: Global Symbols on Page Zero

IOBUF	0000	I/O buffer; prompt or command field.
LABEL	0007	I/O buffer; label field.
OPCODE	000E	I/O buffer; opcode field.
OPRAND	0015	I/O buffer; operand field.
USER	0023	Six bytes available for use by user commands.
ADL	0029	Low address pointer for various subroutines.
ADH	002A	High address pointer.
MISCL	002B	Miscellaneous uses.
MISCH	002C	Ditto.
TEMP	002D	Various temporary uses.
MNE	002E	Mnemonic code.
BYTES	002F	Lengths of lines, etc.
TBL	0030	Low address pointer for table; used by MATCH.
TBH	0031	High address pointer (Subroutine MATCH).
RFL	0032	Low address pointer for string to be matched.
RFH	0033	High address pointer (MATCH).
LEN	0034	Length of each record in table (MATCH).
HBC	0035	Number of highest byte in record which must match.
NUM	0036	Number of highest record in table (MATCH).
OPCPTR	0037	Pointer to opcode in OPCTAB.
PRNTOK	0038	Flag to enable printing by Subroutine PRNTCK.
WRONG	0039	Flag for illegal line numbers (PRNTCK).
MODE	003A	Code for address mode.
SAVX	003B	Used to preserve X register.
GLOBAL	003C	Number of last global symbol.
PRGLEN	003D	Length of source code.
CRNTAL	003E	Low address pointer to current source code line.
CRNTAH	003F	High address pointer.
MDLADL	0040	Module pointer, low address.
MDLADH	0041	Module pointer, high address.
MNETBL	0042	Parameters for MNETAB (see TBL to NUM above).
MODTBL	0049	Parameters for MODTAB.
SYMTBL	0050	Low address pointer to last entry in symbol table.
SYMTBH	0051	High address pointer.
SYMRFL	0052	Low address pointer for symbol to be compared.
SYMRFH	0053	High address pointer.
SYMNUM	0056	Number of last symbol.
OBJECT	0057	Low address pointer to object code.
OBJCT1	0058	High address pointer.
FIRST	0059	First line in range for print (PRNTCK).
LAST	005A	First line after print range.
LAST1	005B	High order address; same as CRNTAH.

Table 4.3: Other Global Symbols

*MNETAB	0200	Three-character ASCII mnemonics for instructions.
*MODTAB	02A8	Two-character ASCII mode codes.
*MIN	02C2	Minimum legal value for MNE for each mode.
*MAX	02CF	Lowest illegal value of MNE for each mode.
*BASE	02DC	Base value for mode added to MNE to get OPCPTR.
*PRMTAB	02E9	Initialization values for CRNTAH through SYMNUM.
*USRPRM	0301	Four bytes available for user parameters.
*OPCTAB	0305	Machine language opcodes pointed to by OPCPTR.
MATCH	03A3	Search table for match to reference.
HEX	03D5	ASCII character to four bits.
HX2BIN	03E1	Two ASCII characters on page zero to eight bits.
BIN2HX	03F2	Four bits to ASCII character on page zero.
DSPHEX	03FF	Eight bits to two ASCII characters, page zero.
SYM	040F	Address of symbol table entry X in MISCL, H.
ADDRSS	0434	Address for symbol X in ADL, H.
ADDLAB	0443	Add symbol to table; return number in X.
NEWSYM	0469	Add symbol if new; call SYM.
ENCODE	047D	Encode assembly language line; update symbols.
CMAND	0549	Look up and transfer control to command.
FIN	0577	Add encoded line to program.
MAIN	05B8	Main program; do command or encode line.
?BEGIN	0610	Add name to symbols; enter edit mode.
?ASSGN	062E	Assign addresses to global symbols.
-LOCAL	0665	Assign addresses to local symbols.
?REDEF	0672	Redefine module pointer.
ASMBL	0683	Translate line into machine code.
LOCSYM	06CB	Display undefined symbols.
-ASSEM	06EB	Assemble module; store at MDL,H.
?TABLE	071F	Reserve space for arrays.
INPUT	075D	Prompt with IOBUF; accept input line.
-STORE	07A6	Save module; clear local symbols; end edit mode.
*MODLIM	07CC	Lower OPCPTR limit for each address mode.
DECODE	07D9	Convert source code to ASCII line.
OUTLIN	08A1	Output line from IOBUF as ASCII.
PRNTCK	08B1	Check line numbers; print lines if enabled.
-PRINT	090D	Output lines in range.
FIXSYM	0917	Revise addresses of symbols in move range.
INSERT	0940	Open gap in source code for insert; fix symbols.
-INSRT	0965	Insert and/or delete lines.

* Table.

Table 4.4: Hierarchy of Modules

```
MAIN PROGRAM
  DSPHEX
    BIN2HX
  INPUT
  ENCODE
    MATCH
    HX2BIN
      HEX
    ADDRSS
      SYM
    ADDLAB
  FIN
    INSERT
      FIXSYM
        ADDRSS
          SYM
    NEWSYM
      MATCH
      ADDLAB
      SYM
  CMAND
    MATCH
    ADDRSS
      SYM
    (Commands)

?TABLE
  NEWSYM
    MATCH
    ADDLAB
    SYM
  HX2BIN
    HEX
  INPUT

?BEGIN
  NEWSYM
    MATCH
    ADDLAB
    SYM

?ASSGN
  NEWSYM
    MATCH
    ADDLAB
    SYM
  HX2BIN
    HEX
  INPUT

-LOCAL
  ?ASSGN
    NEWSYM
      MATCH
      ADDLAB
      SYM
    HX2BIN
      HEX
    INPUT

?REDEF
  HX2BIN
    HEX

-ASSEM
  LOCSYM
    ADDRSS
      SYM
    OUTLIN
  ASMBL
    ADDRSS
      SYM

-STORE
  SYM

-PRINT
  PRNTCK
    HX2BIN
      HEX
    DECODE
      ADDRSS
        SYM
      DSPHEX
        BIN2HX
      SYM
    DSPHEX
      BIN2HX
    OUTLIN

-INSRT
  PRNTCK
    HX2BIN
      HEX
    DECODE
      ADDRSS
        SYM
      DSPHEX
        BIN2HX
      SYM
    DSPHEX
      BIN2HX
    OUTLIN
  FIXSYM
    ADDRSS
      SYM
```

5. MODIFICATION

Some users may wish to modify the assembler to expand its capabilities, or for use on another system. Sections 3 and 4 should prove particularly useful to these users. Some comments on specific modifications are given below. To use the assembler on another 650X system, different I/O routines would probably be required. The assembler might also have to be relocated.

5.1 Changing Special Key Definitions

Some terminals lack "escape" or "backspace" keys. Another key may be used by storing its ASCII code at 0776 (2576) for escape, or 0780 (2580) for backspace. Refer to Subroutine INPUT in Section 3.

5.2 Moving Tables

The ?REDEF command temporarily changes the memory location for storage of assembled modules. The assembler can also be permanently modified to store the assembled modules, assembly language, or symbols at a different location.

Initialization value. The location of each array is determined by the initial value of its corresponding pointer. The last line in Table 4.1 gives the source of this initialization value for each array. By changing these values, the array(s) can be initialized to a different location. The current line pointer low order address is always initialized to zero; only the high address can be changed in this way. Both low (first byte) and high (second byte) order addresses can be changed for the other pointers.

Symbol table. The first nine entries (72 bytes) in the symbol table are essential to the assembler, because they are symbols and addresses for the assembler commands. They must be moved if the initialization value for the symbol table is changed. Note that the initialization value points to the ninth symbol, not the first.

5.3 Adding Custom Commands

User commands may be added in the form of subroutines.

Prompt symbols. Command subroutines must return the appropriate prompt symbol in the accumulator: 3F (?) for control mode or 2D (-) for edit mode. Or, an error code may be returned; these must be greater than 3F for control mode, and less than 3F for edit mode. Error codes should be printing ASCII characters.

Adding to symbol table. The ASCII code for the command, beginning with the correct mode prompt symbol, should be entered

in the first six bytes available in the symbol table. This would start at 0A00 (2800) for the first user command. The subroutine address should be stored in the next two bytes, low order first. The initialization value at 02FA, 02FB (20FA,20FB) must be incremented by eight. (See Section 5.2) The initialization value for the top symbol number at 0300 (2100) must be incremented by one.

5.4 Relocation

The assembler may be relocated using a relocation routine such as that in The First Book of KIM. The 0200 version of the assembler starts at address 0200 and ends at 09FF. It contains blocks of data at 0200-03A2, 07CC-07D8, and 09B8-09FF inclusive. The assembler should be relocated an even multiple of 256 bytes, so that it begins at a page boundary, e.g. 0200, 2000, 0400, etc.

The relocation routine mentioned above will correct addresses for subroutine calls, but table references and pointers must be corrected by hand. Since the assembler is relocated an even number of pages, only the high order address must be corrected. For example, to relocate the 0200 version to start at 0800, add six to the number currently at each of the addresses below.

Pointers. Addresses 02ED, 02F4, and 02FB contain initialization values for pointers, as do addresses 02E9 and 02EB.

Command return. The value at address 056B is pushed on the stack as the high order address for return from a command.

Data. Addresses 04A6, 04AE, 04B7, 04BD, 05BD, 068A, 083E, 082F, 0834, 081F, 0848, 084D, and 0852 contain high order addresses for table references.

Symbol table. Each of the first nine entries in the symbol table contains six ASCII characters, corresponding to a command, followed by the low and high order address for the command subroutines. The high addresses, at 09BF to 09FF must be corrected.

5.5 I/O Requirements

The assembler uses standard I/O routines in the KIM monitor. Functionally equivalent user routines may be substituted for use with another I/O device or 6502 system. Table 5.1 gives a brief description of each of these routines, together with the addresses of lines in the assembler which call each subroutine.

Table 5.1: I/O Routines

KIM Routine	Function	Assembler References
CRLF 1E2F	Carriage return, line feed	075D (255D) 08A1 (26A1)
OUTCH 1EA0	Output ASCII from A. Preserve X.	0764 (2564) 08A8 (26A8)
GETCH 1E5A	Input ASCII to A. Preserve X.	0772 (2572)
OUTSP 1E9E	Output one space.	078D (258D)

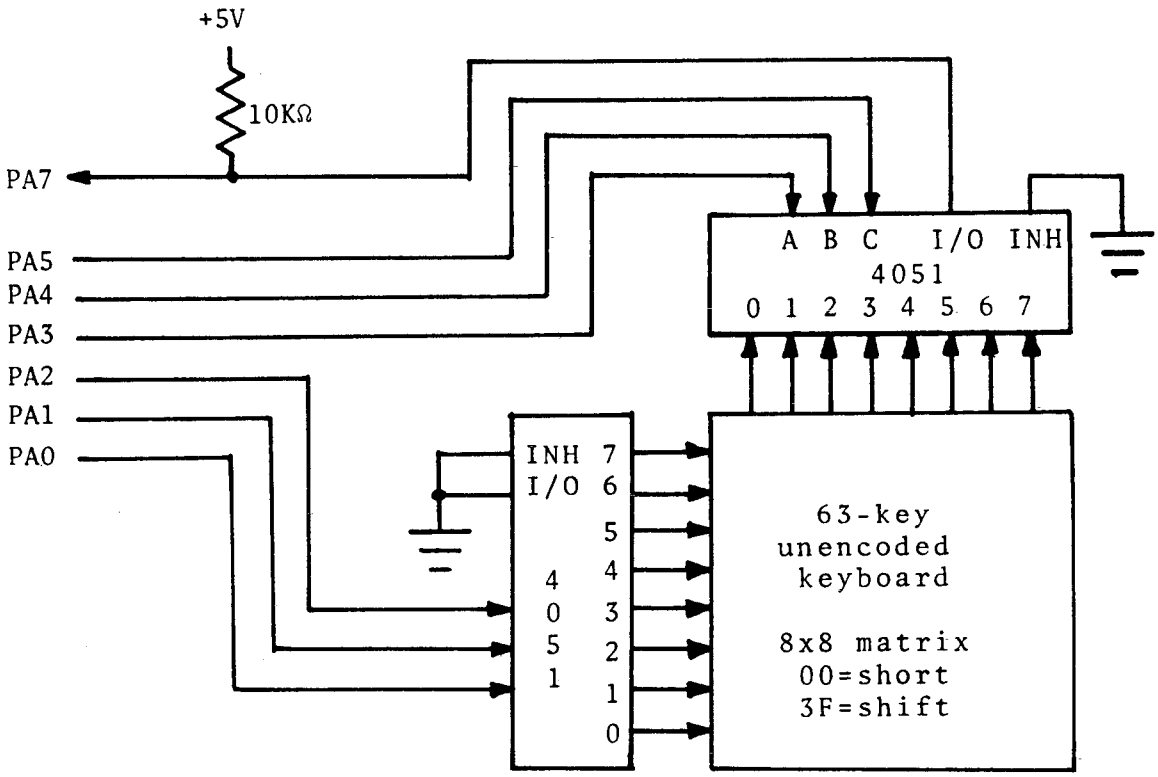


Figure A.1: Keyboard Interface

APPENDIX A: AN INEXPENSIVE I/O SYSTEM

Many 6502 users, myself included, do not have a computer terminal. I have developed a very inexpensive "terminal substitute." I use a $30 unencoded keyboard for input, and display a 64-character ASCII subset on the KIM-1 display.

The keyboard is scanned using software, which allows keys and combinations of keys to be defined arbitrarily. For example, multiple key depressions could be used for playing chords in music synthesis applications. The I/O software given here simulates a simple ASCII keyboard with "shift" but without "control" or "repeat." The required software decreases the space available for program storage. Using the KIM-1 display for output of ASCII characters can be frustrating, but it is a big improvement over no ASCII output at all. The keyboard interface might also be of interest to those planning to add one of Lancaster's "cheap video" displays.

Keyboard interface. Figure A.1 is a schematic for the keyboard interface. The unencoded keyboard must be wired as a matrix of eight rows and eight columns. One CMOS 4051 is used as a multiplexer and the other as a demultiplexer. Output lines PA0 to PA5 select the row and column of interest. PA7 goes low if the corresponding key is depressed.

The "shift" key must be connected to channel 7 of each 4051. Channel 0 of one 4051 must be shorted to channel 0 of the other. Other row and column assignments are arbitrary, since assignment of ASCII codes is done in software.

The keyboard, 4051 chips, and wire-wrap sockets are available from Jameco Electronics, 1021 Howard Ave., San Carlos, CA 94070 for under $35. They also sell a wire-wrapping kit for $13.

Testing the interface. Load and run the relocatable test routine below. With no key depressed, the data display should read 00. Pressing the "shift" key should cause 3F to be displayed. If not, the keyboard interface is connected incorrectly. When another key is pressed, the hexadecimal code for its row and column will be displayed. Record this key number for each key. Then make a table giving the ASCII equivalent for each key number from 00 to 3F. Key numbers 00 and 3F correspond to "end of scan" and "shift," respectively, so the value entered for them will be ignored. This 64 byte table should be loaded at address 0E80. There may be more than one key for a given ASCII code, and not all ASCII codes will be used.

I/O routines. Next, load the rest of the I/O software, beginning with Table SEGTAB and ending with Subroutine CRLF. SEGTAB gives the pattern of lit segments to display a 64 character ASCII subset (ASCII 20 through 5F) on the KIM-1 display.

Some characters will look strange at first, but recognition becomes easy with very little practice. The subroutines GETCH, OUTCH, OUTSP, and CRLF are functionally equivalent to the KIM monitor routines of the same names. Their addresses must be substituted in the assembler I/O subroutine calls as explained in Section 5.5. These routines could also be used in other terminal-based programs.

Listing A. Test program for Qwerty keyboard. Displays hexadecimal code of active key.

```
A9 7F             LDA#    7F          Define I/O.
8D 01 17          STA     PADD
A9 00             LDA#    00          Initialize pointer
85 FA             STAZ    POINTL      for display routine.
A9 17             LDA#    17
85 FB             STAZ    POINTH
A9 40     START     LDA#    40        Scan 63 keys.
8D 00 17            STA     PAD
CE 00 17  SCANKB      DEC     PAD     Find active key.
AD 00 17              LDA     PAD
30 F8                 BMI     SCANKB
20 19 1F            JSR     SCAND     Display key.
18                  CLC
90 ED               BCC     START     Repeat for new key.
EA                NOP
```

0EC0 Table SEGTAB. Seven-segment code to display 64-character ASCII subset. Modify as desired.

```
00 0A 22 1B 36 24 5F 02 39 0F 21 18 0C 40 08 52
3F 06 5B 4F 66 6D 7D 07 7F 6F 41 45 60 48 42 53
7B 77 7C 58 5E 79 71 3D 76 04 1E 70 38 37 54 5C
73 67 50 2D 78 1C 6A 3E 14 6E 49 39 44 0F 77 61
```

0F00 Subroutine DSPLAY. Display 6 characters on KIM readout for about 3 msec.

```
A9 7F          LDA#    7F          Define I/O.
8D 41 17       STA     PCDD
A9 15          LDA#    15          Initialize char.
8D 42 17       STA     PDD
A2 05          LDX#    05          Display 6 chars.
CE 42 17 CHAR    DEC     PDD       Select next char.
CE 42 17         DEC     PDD
B5 23            LDAZX   DSPBUF    Get segment code.
8D 40 17         STA     PCD       Turn segments on.
A0 64            LDY#    64        Wait 500 msec.
88       WAIT      DEY
10 FD              BPL     WAIT
A9 00            LDA#    00        Turn segments off.
8D 40 17         STA     PCD
CA               DEX
10 E8            BPL     CHAR      Another char?
60             RTS
```

0F25 Subroutine GETKEY. Scan kybd; return ASCII in A, key in Y.

```
A2 3F          LDX#    3F          Define I/O.
8E 01 17       STX     PADD
8E 00 17       STX     PAD
CE 00 17 NXTKEY  DEC     PAD       Scan 2 keys.
AD 00 17         LDA     PAD       for active key.
30 F8            BMI     NXTKEY
29 3F          AND#    3F          Mask input bit.
A8             TAY                 Return if no key.
D0 01          BNE     ANYKEY
60               RTS
B9 80 0E ANYKEY LDAY   KEYTAB      Get ASCII.
8E 00 17       STX     PAD         Check shift key.
2C 00 17       BIT     PAD
10 01          BPL     SHFTKY
60               RTS               No shift; return.
C9 21      SHFTKY CMP#    21        shift legal?
10 01          BPL     NOT2LO
60               RTS
C9 40      NOT2LO CMP#    40
30 01          BMI     NOT2HI
60               RTS
49 10      NOT2HI EOR#    10        Find shift char.
60             RTS
```

0F54 Subroutine ADDCH. Shift ASCII character in A into display from right.

```
A2 00              LDX#    00          Shift display
B4 24     LEFT       LDYZX   DSPBFI    to left.
94 23                STYZX   DSPBUF
E8                   INX
E0 05                CPX3    05
30 F7                BMI     LEFT
E9 20              SBC#    20          Find segment
AA                 TAX                 code.
BD C0 0E           LDAX    SEGTAB
85 28              STAZ    DSPBF5      Add at right.
60                 RTS
```

0F68 Subroutine GETCH. Get character from keyboard. Return ASCII in A. Add to display or backspace as required. X is preserved.

```
86 3B              STXZ    SAVX        Save X.
20 00 0F  OLD        JSR     DSPLAY    Wait for release
20 25 0F             JSR     GETKEY    of old key.
D0 F8                BNE     OLD
EA                 NOP
20 00 0F  NONE       JSR     DSPLAY    Wait for new
20 25 0F             JSR     GETKEY    key depressed.
F0 F8                BEQ     NONE
C9 08              CMP#    08          Backspace?
D0 10              BNE     NOTBSP
A2 04                LDX#    04        Yes. Shift
B4 23     RIGHT        LDYZX   DSPBUF  display right.
94 24                  STYZX   DSPBFI
CA                     DEX
10 F9                  BPL     RIGHT
A0 00                LDY#    00        Add blank
84 23                STYZ    DSPBUF    at left.
A6 3B                LDXZ    SAVX      Restore X.
60                   RTS
48         NOTBSP  PHA                 Else, add char
20 54 0F           JSR     ADDCH       to display.
A6 3B              LDXZ    SAVX
68                 PLA
60                 RTS
```

0F97 Subroutine OUTCH. Add ASCII character in A to display. Display for about 0.2 sec. Preserve X.

```
86 3B              STXZ     SAVX          Save X.
20 54 0F           JSR      ADDCH         Add char.
A9 40              LDA#     40            Wait 0.2 sec
85 5C              STAZ     TIME          before returning.
20 00 0F  SHOW       JSR      DSPLAY
C6 5C                DECZ     TIME
10 F9                BPL      SHOW
A6 3B              LDXZ     SAVX          Restore X.
60                 RTS
```

0FAA Subroutine OUTSP. Output one space.

```
A9 20              LDA#     20
20 97 0F           JSR      OUTCH
60                 RTS
```

0FB0 Subroutine CRLF. Clear display.

```
A9 00              LDA#     00
A2 05              LDX#     05
95 23     CLEAR      STAZX    DSPBUF
CA                   DEX
10 FB                BPL      CLEAR
60                 RTS
```

APPENDIX B: ANSWERS TO USER QUESTIONS

Q. Can the assembler be stored in read only memory?

A. Yes; it will just fit in a 2K ROM. Presumably it will have to be relocated, following the instructions in Section 5.4. In addition, the assembler must be entered at the relocated equivalent of 09AA. This routine, which is unused in the RAM version of the assembler, transfers the first nine entries in the symbol table from ROM to RAM. These symbols correspond to commands and are essential to the assembler. The correct source and destination addresses must be substituted in this initialization routine. Permission to reproduce the assembler in ROM may be obtained from the author.

Q. If I have enough memory, can I expand the symbol table?

A. Yes. The standard version of the assembler allows 64 symbols, including nine for assembler commands. Space is available for nine additional symbols if overflow error detection is defeated by setting 05B4 (23B4) = EA. The assembler can also be modified to give an overflow error message when the number of symbols exceeds 128, by setting 05B0 (23B0) = 10. Expanding the symbol table to 128 entries requires moving the module and assembled program storage areas. See Section 5.2. Actually, quite lengthy programs can be assembled within the limit of 55 user symbols, since local symbols are cleared each time a module is stored.

Q. My video terminal only has 32 characters per line, so your print routine runs over by one character. Any advice?

A. Make the following changes at the addresses indicated: 0870(2670)=14, 0880(2680)=14, 089C(269C)=1B, 08AD(26AD)=20, 08ED=1E. Input lines may still exceed 32 characters.

Q. Can the assembler be used with the SYM microcomputer?

A. Easily. The I/O routine addresses must be changed as explained in Section 5.5. The SYM monitor addresses are 834D (CRLF), 8A47(OUTCH), 8A1B(GETCH), and 8342(OUTSP).

Q. How about a command to give the starting address of the module without having to check 0040, 0041?

A. This is just one example of a number of commands that could easily be implemented by users who don't insist on fitting the assembler in a 2K ROM. It is also possible to add features by sacrificing existing commands. For example, some users may rarely use ?REDEF. Others may use ?ASSGN and ?REDEF to name and reserve space for tables. Either command could be replaced by a user-written command. Reviewers disagreed on some of the most desired features in a 2K assembler. The assembler is sufficiently easy to modify that the final choice can be left to the user.

```
A541     --TEST LDAZ    MDLADH     00
A202            LDX#    02         02
20FF03          JSR     DSPHEX     04
A540            LDAZ    MDLADL     07
A204            LDX#    04         09
20FF03          JSR     DSPHEX     0B
20A108          JSR     OUTLIN     0E
A21A            LDX#    1A         11
B53C     SAVE   LDAZX   GLOBAL     13
9DE00B          STAX    COPY       15
CA              DEX                18
10F8            BPL     SAVE       19
4C001C          JMP     MONITR     1B
A21A     ENTER  LDX#    1A         1E
BDE00B RESTR   LDAX    COPY       20
953C            STAZX   GLOBAL     23
CA              DEX                25
10F8            BPL     RESTR      26
4CD605          JMP     WARM       28
```

2K SYMBOLIC ASSEMBLER: REVISIONS

Here are the corrections for all bugs found so far, along with some optional modifications to the 2KSA.

BACKSPACE BUG

The "backspace" key does not delete the last character, but only moves a pointer to allow typing over it. It is not possible to blank out a character using the "space" key, because that is used to advance it to the next field. One solution is to use "tab" to advance to the next field, freeing "space" for use as a blanking character. (Thanks to Nelson Edwards for finding this bug.)

ADDRESS ASSIGNMENT PROBLEMS

The 2KSA is designed to prevent accidental re-assignment of an address to a symbol. Early versions were a bit overzealous in this area, and should be fixed by loading at 0478: 34, 04, C9, FF. The re-assignment check can also be defeated completely, if desired, by loading at 047A: A9, 00. Just don't forget and use the same symbol twice.

EASIER RELOCATION

Relocation of modules in edit mode is possible if ?REDEF is changed to -REDEF. Set 09D0=2D and 0681=2D.

EASIER TESTING

The command --TEST (facing page) can be used to print the start address of the module and leave the assembler for testing. The extra hyphen is required because the I/O buffer isn't cleared. --TEST also automatically saves the pointers required for source code storage starting at address 0BE0. Source code can then be saved by simply dumping 0A00-0C80.

The listing also contains a re-entry routine (starting at ENTER) which restores the pointers before entering edit mode. This would ordinarily be used after loading source code from tape.

To substitute --TEST for ?TABLE, load it at 071F and load at 09E0: 2D, 2D, 54, 45, 53, 54. MONITR should be the warm start address for the monitor of your particular computer.

SOURCE CODE TAPE RECORD FORM

To save:

Record pointer values below.
Dump 0A00 through 0C7F.

To retrieve:

Initialize assembler.
Hit reset.
Load module from tape.
Restore pointers.
Enter assembler from 05D6.
Ignore any error code.

Module Name	ID	GLOBAL 003C	PRGLEN 003D	SYMTBL 0050,51	SYMNUM 0056

Permission is hereby granted to photocopy this page.

2K SYMBOLIC ASSEMBLER VERSION 1.0 - SYM USERS' GROUP

Begin session with G 5B8. Block checksum: 0405

```
     00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
0200 42 52 4B 43 4C 43 43 4C 44 43 4C 49 43 4C 56 44,85  BRKCLCCLDCLICLVD
0210 45 58 44 45 59 49 4E 58 49 4E 59 4E 4F 50 50 48,68  EXDEYINXINYNOPPH
0220 41 50 48 50 50 4C 41 50 4C 50 52 54 49 52 54 53,42  APHPPLAPLPRTIRTS
0230 53 45 43 53 45 44 53 45 49 54 41 58 54 41 59 54,09  SECSEDSEITAXTAYT
0240 53 58 54 58 41 54 58 53 54 59 41 43 50 58 53 54,20  SXTXATXSTYACPXST
0250 58 4C 44 58 43 50 59 4C 44 59 53 54 59 41 44 43,FD  XLDXCPYLDYSTYADC
0260 41 4E 44 43 4D 50 45 4F 52 4C 44 41 4F 52 41 53,9C  ANDCMPEORLDAORAS
0270 42 43 53 54 41 41 53 4C 4C 53 52 52 4F 4C 52 4F,68  BCSTAASLLSRROLRO
0280 52 44 45 43 49 4E 43 42 49 54 4A 4D 50 4A 53 52,15  RDECINCBITJMPJSR
0290 42 43 43 42 43 53 42 45 51 42 4D 49 42 4E 45 42,7C  BCCBCSBEQBMIBNEB
02A0 50 4C 42 56 43 42 56 53 20 20 41 20 23 20 5A 20,3C  PLBVCBVS  A # Z
02B0 5A 58 5A 59 49 58 49 59 20 20 20 20 58 20 59 20,55  ZXZYIXIY    X Y
02C0 49 20 00 27 19 19 1D 1A 1F 1F 30 19 1D 1B 2E 19,54  I  '       0   .
02D0 2B 26 2E 2D 1C 27 27 38 30 2D 27 2F 00 F2 04 11,5C  +&.- ''80-'/ r
02E0 22 35 32 3A 31 50 63 75 6E 0C 80 0C A5 02 0E 00,33  "52:1Pcun   %
02F0 03 02 37 C0 02 11 00 02 01 0C F8 09 15 00 08 05,74    7@       x
```

```
     00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
0300 08 FF FF FF FF 00 18 D8 58 B8 CA 88 E8 C8 EA 48,AC     XX8J hHjH
0310 08 68 28 40 60 38 F8 78 AA A8 BA 8A 9A 98 0A 4A,A8   h(@`8xx*(:    J
0320 2A 6A E0 FF A2 C0 A0 FF 69 29 C9 49 A9 09 E9 E4,3F  *j`"@ i)II) id
0330 86 A6 C4 A4 84 65 25 C5 45 A5 05 E5 85 06 46 26,71   &D$ e%EE% e  F&
0340 66 C6 E6 24 B4 94 75 35 D5 55 B5 15 F5 95 16 56,83  fFf$4 u5UU5 u  V
0350 36 76 D6 F6 B6 96 61 21 C1 41 A1 01 E1 81 71 31,71  6vVv6 a!AA! a q1
0360 D1 51 B1 11 F1 91 90 B0 F0 30 D0 10 50 70 EC 8E,51  QQ1 q  0p0P Ppl
0370 AE CC AC 8C 6D 2D CD 4D AD 0D ED 8D 0E 4E 2E 6E,E3  .L, m-MM- m  N.n
0380 CE EE 2C 4C 20 BC FF 7D 3D DD 5D BD 1D FD 9D 1E,78  Nn,L <}=]]= }
0390 5E 3E 7E DE FE BE FF FF FF 79 39 D9 59 B9 19 F9,D8  ^>~^~>y9YY9 y
03A0 99 6C FF 86 29 A2 00 86 2A A0 06 B1 29 99 30 00,26   l )"  *  1) 0
03B0 88 10 F8 A6 36 A4 35 B1 30 D1 32 F0 02 A0 FF 88,68    x&6$510Q2p
03C0 10 F5 C8 D0 01 60 38 A5 30 E5 34 85 30 B0 02 C6,B9   uHP `8%0e4 00 F
03D0 31 CA 10 E1 60 B5 00 C9 40 30 03 38 E9 07 29 0F,56  1J a`5 I@0 8i )
03E0 60 20 D5 03 0A 0A 0A 0A 85 2D E8 20 D5 03 05 2D,9A  ` U       -h U  -
03F0 AA 60 C9 0A 30 03 18 69 07 18 69 30 95 00 60 48,20  *`I 0  i   i0  `H
```

```
     00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
0400 4A 4A 4A 4A 20 F2 03 E8 68 29 0F 20 F2 03 60 38,92  JJJJ r hh)  r `8
0410 86 2D A5 56 E5 2D 85 2B A9 00 85 2C 18 A0 02 26,3C   -%Ve- +)  ,   &
0420 2B 26 2C 88 10 F9 38 A5 50 E5 2B 85 2B A5 51 E5,12  +&,  y8%Pe+ +%Qe
0430 2C 85 2C 60 20 0F 04 A0 06 B1 2B 85 29 C8 B1 2B,56  , ,`     1+ )H1+
0440 85 2A 60 85 29 A9 00 85 2A 18 A5 50 69 08 85 50,BE   *` ))  * %Pi  P
0450 90 02 E6 51 A0 07 A9 FF 91 50 88 88 B1 29 91 50,82    fQ  ) P  1) P
0460 88 10 F9 A6 56 E8 86 56 60 85 52 A2 50 20 A3 03,C2    y&Vh V` R"P #
0470 F0 05 A5 52 20 43 04 20 0F 04 E4 56 60 A2 42 20,E6  p %R C    dV`"B
0480 A3 03 F0 03 A9 31 60 86 2E A2 49 20 A3 03 F0 03,11  # p )1` ."I # p
0490 A9 32 60 A5 2E C9 19 10 02 A2 00 C9 30 30 02 A2,82  )2`%.I   " I00 "
04A0 08 EA A5 2E DD C2 02 10 03 A9 33 60 DD CF 02 30,15   j%.]B   )3`]O 0
04B0 03 A9 33 60 18 7D DC 02 85 37 AA BD 05 03 C9 FF,BA   )3` }\  7*=  I
04C0 D0 03 A9 33 60 EA A5 37 C9 1D 10 03 A9 2D 60 E6,A4  P )3`j%7I    )-`f
04D0 2F C9 2A 10 0A A2 15 20 E1 03 86 38 A9 2D 60 A2,31  /I*  "  a  8)-`"
04E0 15 86 52 C9 61 10 20 A2 50 20 A3 03 F0 03 A9 34,00    RIa  "P # p )4
04F0 60 20 34 04 F0 03 A9 35 60 86 38 A5 1C C9 20 F0,41  ` 4 p )5` 8% I p
```

```
     00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
0500 03 A9 36 60 A9 2D 60 EA A2 50 20 A3 03 F0 05 A9,F9   )6`)-`j"P # p )
0510 15 20 43 04 86 38 A5 37 C9 69 10 0A E4 3C 10 03,8E    C  8%7Ii  d<
0520 A9 37 60 A9 2D 60 EA E4 3C 30 0A 20 34 04 C5 3F,A4  )7`)-`jd<0  4 E?
0530 D0 03 A9 38 60 A5 1C A2 00 C9 20 F0 05 A2 1C 20,D7  P )8`% " I p "
0540 E1 03 86 39 E6 2F A9 2D 60 A5 3A C5 00 F0 04 18,75  a  9f/)-`%:E p
0550 69 0C 60 A9 00 85 52 A2 50 20 A3 03 F0 0C A5 00,23  i `)  R"P # p %
0560 C9 3F 10 03 A9 30 60 A9 41 60 A9 05 48 A9 75 48,1D  I?  )0`)A`) H)uH
0570 20 34 04 6C 29 00 60 20 40 09 A4 2F 88 B9 37 00,1E   4 1) ` @ $/ 97
0580 91 3E 88 10 F8 A5 07 C9 20 F0 10 A9 07 20 69 04,4F   >  x% I p )  i
0590 A0 07 A5 3F 91 2B 88 A5 3E 91 2B 18 A5 3E 65 2F,4C    %? + %> + %>e/
05A0 85 3E 18 A5 3D 65 2F 85 3D 10 03 A9 42 60 24 56,37   > %=e/ =  )B`$V
05B0 50 03 A9 43 60 A9 2D 60 D8 A2 18 BD E9 02 95 3F,1A  P )C`)-`X" =i  ?
05C0 CA 10 F8 A9 3F 85 00 A0 20 A2 21 94 01 CA 10 FB,46  J x)?    "!  J (
05D0 A2 3F C9 3F 10 10 A5 3F A2 02 20 FF 03 A5 3E A2,7E  "?I?  %?"   %>"
05E0 04 20 FF 03 A2 2D 86 3A A9 01 85 2F 20 5D 07 A5,BA     "- :)  / ] %
05F0 3A C9 2D D0 04 A5 01 C9 20 D0 0C 20 7D 04 C9 2D,C0  :I-P % I P  ) I-

     00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
0600 D0 03 20 77 05 A2 00 F0 03 20 49 05 18 90 B6 EA,7A  P  w " p  I   6j
0610 A9 07 20 69 04 F0 03 A9 44 60 86 3C A9 00 85 3E,25  )  i p )D` <)  >
0620 85 3D A0 06 91 2B A5 3F C8 91 2B A9 2D 60 A5 07,93   =   +%?H +)-`%
0630 C9 20 D0 03 A9 3F 60 A9 07 20 69 04 F0 03 A9 44,B4  I P )?`)  i p )D
0640 60 A2 0E 20 E1 03 A0 07 8A 91 2B A2 10 20 E1 03,6B  `"  a     +"  a
0650 88 8A 91 2B A9 20 A2 0C 95 07 CA 10 FB 20 5D 07,A5     +) "   J ( ]
0660 A5 07 10 CC EA 20 2E 06 C9 44 D0 03 A9 3A 60 A9,37  %  Lj . IDP ):`)
0670 2D 60 A2 07 20 E1 03 86 41 A2 09 20 E1 03 86 40,AD  -`"  a  A"  a  @
0680 A9 3F 60 A0 00 B1 3E AA BD 05 03 91 57 E0 1D 10,E8  )?`  1)*=   W`
0690 01 60 C8 B1 3E E0 2A 10 03 91 57 60 86 2E AA 20,E3   `H1)`*   W` .*
06A0 34 04 A5 29 A0 01 A6 2E E0 61 10 03 91 57 60 E0,DA  4 %)  &.`a   W``
06B0 69 10 09 38 E9 02 38 E5 3E 91 57 60 18 C8 71 3E,B1  i  8i 8e) W` Hq)
06C0 88 91 57 C8 A5 2A 69 00 91 57 60 A6 3C E8 20 34,87    WH%*i  W`&<h 4
06D0 04 C9 FF D0 11 A0 05 B1 2B 99 00 00 88 10 F8 86,64   IP   1+      x
06E0 2B 20 A1 08 A6 2B E4 56 30 E3 60 20 CB 06 A9 2D,9D  + ! &+dV0c` K )-
06F0 C5 00 F0 01 60 A9 00 85 3E A5 40 85 57 A5 41 85,4B  E p `)  )%@ W%A

     00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
0700 58 20 83 06 84 2D 38 A5 57 65 2D 85 57 90 02 E6,17  X    -8%We- W  f
0710 58 38 A5 3E 65 2D 85 3E C5 3D 30 E5 A9 2D 60 A5,D1  X8%)e- )E=0e)-`%
0720 07 C9 20 D0 03 A9 3F 60 A9 07 20 69 04 F0 03 A9,B5   I P )?`)  i p )
0730 44 60 A0 06 A5 40 91 2B C8 A5 41 91 2B A2 0E 20,DA  D`  %@ +H%A +"
0740 E1 03 8A 18 65 40 85 40 90 02 E6 41 A9 20 A2 0C,FA  a   e@ @  fA) "
0750 95 07 CA 10 FB 20 5D 07 A5 07 10 C5 EA 20 4D 83,4A    J ( ] %  Ej M
0760 A2 00 B5 00 20 47 8A E8 E0 06 30 F6 A2 00 A9 06,D7  " 5  G h` 0v" )
0770 85 2D 20 1B 8A C9 1B D0 01 00 C9 0D D0 01 60 C9,D3   -   I P  I P `I
0780 08 D0 05 CA E6 2D A9 08 C9 20 D0 0D EA 20 42 83,D3   P Jf-) I P j B
0790 E8 C6 2D 10 F8 A9 06 85 2D C9 20 30 05 95 00 E8,B2  hF- x)  -I 0   h
07A0 C6 2D 18 90 CD EA A6 3C 20 0F 04 86 56 A5 2B 85,4A  F-  Mj&<    V%+
07B0 50 A5 2C 85 51 A0 07 A5 41 91 2B 88 A5 40 91 2B,B3  P%, Q  %A + %@ +
07C0 18 65 3D 85 40 90 02 E6 41 A9 3F 60 00 19 1D 2A,93   e= @  fA)?`   *
07D0 3F 4F 51 59 61 69 80 90 9C A9 01 85 2F A2 22 A9,0C  ?OQYai   )  /"")
07E0 20 95 00 CA 10 FB A6 56 20 34 04 A5 3E C5 29 D0,8B     J (&V 4 %)E)P
07F0 04 A5 3F C5 2A D0 0C A0 05 B1 2B 99 07 00 88 10,F7   %?E*P   1+
```

```
      00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
0800  F8 A2 01 CA E4 3C 10 E0 A0 00 B1 57 A2 00 20 FF,D5  x" Jd< `  1W"
0810  03 B1 3E 85 37 A2 0C C9 1D 10 02 A2 01 DD CC 07,7C   1> 7" I   " ]L
0820  30 04 86 3A A2 00 CA 10 F4 A5 3A 0A AA BD A8 02,DA  0  :" J t%: *=(
0830  85 11 BD A9 02 85 12 B1 3E 38 A6 3A FD DC 02 85,D6    =)   1>8&:)\
0840  2D 0A 18 65 2D AA BD 00 02 85 0E BD 01 02 85 0F,07  -  e-*=    =
0850  BD 02 02 85 10 A5 37 C9 1D 10 01 60 E6 2F A0 01,46  =    %7I   `f/
0860  B1 57 A2 02 20 FF 03 A5 37 C9 2A 10 08 B1 3E A2,8C  1W"   %7I*  1>"
0870  15 20 FF 03 60 B1 3E AA 20 0F 04 A0 05 B1 2B 99,09     `1>*     1+
0880  15 00 88 10 F8 A5 37 C9 69 10 01 60 E6 2F A0 02,E4     x%7Ii  `f/
0890  B1 57 A2 04 20 FF 03 B1 3E F0 05 A2 1C 20 FF 03,78  1W"   1>p "
08A0  60 20 4D 83 A2 00 B5 00 20 47 8A E8 E0 23 30 F6,21  ` M " 5  G h`#0v
08B0  60 A9 00 85 3E A5 40 85 57 A5 41 85 58 A2 07 20,3A  `)  >%@ W%A X"
08C0  E1 03 86 59 A2 0B 20 E1 03 86 5A A9 02 85 39 20,17  a  Y"  a  Z)  9
08D0  D9 07 A5 3E C5 59 D0 02 C6 39 C5 5A D0 02 C6 39,B9  Y %>EYP F9EZP F9
08E0  C5 59 30 12 C5 5A 10 0D 24 38 30 08 A2 1F 20 FF,C9  EY0 EZ  $80 "
08F0  03 20 A1 08 EA EA 18 A5 57 65 2F 85 57 90 02 E6,65    ! jj %We/ W  f


      00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
0900  58 18 A5 3E 65 2F 85 3E C5 3D 30 C3 60 A9 01 85,93  X %>e/ >E=0C`)
0910  38 20 B1 08 A9 2D 60 A6 56 20 34 04 C5 3F D0 1A,1C  8 1 )-`&V 4 E?P
0920  A5 29 C5 3E 30 13 A4 29 C4 5A 10 06 A9 FE A0 07,7F  %)E>0 $)DZ  )~
0930  91 2B 18 65 2F A0 06 91 2B EA CA E4 3C 10 DA 60,67    + e/   +jJd< Z`
0940  A5 3E C5 3D D0 01 60 85 5A 20 17 09 18 A5 3E 65,FC  %>E=P ` Z    %>e
0950  2F 85 29 A5 3F 85 2A A5 3D 38 E5 3E A8 B1 3E 91,D1  / )%? *%=8e>(1>
0960  29 88 10 F9 60 A9 FF 85 38 20 B1 08 C5 5A D0 02,1A  )  y`) 8 1 EZP
0970  C6 39 A5 39 F0 03 A9 25 60 A5 59 85 3E A6 5A F0,C9  F9%9p )%`%Y >&Zp
0980  26 38 E5 5A 85 2F 20 17 09 A5 3F 85 5B A5 3D 38,38  &8eZ /   %? [%=8
0990  E5 3E 85 2D A5 3D 18 65 2F 85 3D A0 00 B1 5A 91,99  e> -%= e/ =  1Z
09A0  A0 3E C8 C4 2D 30 F7 EA A9 2D 60 A2 47 BD B8 09 9D,DB  >HD-0wj)-`"G=8
09B0  B8 09 CA 10 F7 4C B8 05 3F 41 53 53 47 4E 2E 06,65  8 J wL8 ?ASSGN.
09C0  3F 42 45 47 49 4E 10 06 2D 4C 4F 43 41 4C 65 06,22  ?BEGIN  -LOCALe
09D0  3F 52 45 44 45 46 72 06 2D 41 53 53 45 4D EB 06,D6  ?REDEFr -ASSEMK
09E0  3F 54 41 42 4C 45 1F 07 2D 53 54 4F 52 45 A6 07,0A  ?TABLE  -STORE&
09F0  2D 50 52 49 4E 54 0D 09 2D 49 4E 53 52 54 65 09,05  -PRINT  -INSRTe
```