Advanced Software Development Tools

For the HP-41

Version 2.0

PROGRAMMER'S MANUAL

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ACKNOWLEDGEMENTS

The ASDT project started about a year and a half ago with an early Pascal HP-41 MCODE cross assembler. After switching to 'C', I proceeded to write the other utilities. I also discovered that writing documentation can be harder than writing programs. I would like to thank those who have provided me with assistance, advice and sources of information over the course of the development of ASDT: Brian Walsh, Jeff Brown, Eleanor Furlow, Mike Katz and Ross Cooling. I would also like to thank in advance anyone that has any suggestions or comments that can improve this software.

REFERENCES

The following sources and organizations are very useful for the HP-41 enthusiast:

HP VASM Listings

These are the annotated listings of the operating system of the HP-41 and are available from HPX, send SASE.

Zenrom Programmer's Manual

This book is sold with or without the ZENROM module by EduCalc and is a very good reference to HP-41 MCODE.

HP-41 MCODE for Beginners

This book by Ken Emery is a good tutorial for HP-41 MCODE and is available from Educalc or Synthetix publishers (who also publish a number of other useful books on the HP-41)

Synthetix
P.O. Box 1080
Berkeley, CA 94701-1080.

HPX

HPX is a user's group publishing a periodical journal providing the HP hand-held user with a forum for many areas of common interest, analysis of new products and interesting programs. Yearly dues are $25 in the continental U.S. and $35 elsewhere.

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SECTION 1. INTRODUCTION

The Advanced Software Development Tools (ASDT) package contains all the software needed to develop custom HP-41 ROM images on MS-DOS machines. This ability makes the development of MCODE programs faster and easier than ever for the noncommercial programmer and provides professional quality tools for commercial development. The following basic setup is recommended:

BASIC SETUP

HP-41CV/CX

IBM PC compatible computer; hard disk recommended

MLDL (Machine Language Development Lab) with at least 8K

HP82160 HP-IL module for HP-41

Either HP8297A HP-IL interface card (for IBM compatible) or HP-IL <=> RS232 converter

SECTION 2. FEATURES

ASSEMBLER

- Assembles MCODE instructions from any one of the three instruction sets: HP, Zencode or Jacobs/De Arras
- Contains built-in symbol table of the HP-41's mainframe labels which allows easy referencing to operating system entry points
- Allows generation of internal and external symbolic labels
- Assembles FAT pseudo-instructions for easy ROM image building
- Produces symbol cross reference table, if desired

LINKER

- Resolves external label references and creates a ROM image file suitable for loading into an EPROM or an MLDL
- Can link more than one ROM image at a time
- Produces symbol cross reference table, if desired

DISASSEMBLER

- Disassembles MCODE instructions into any one of the three instruction sets
- Contains built-in symbol table to the HP-41's mainframe labels
- Disassembles FAT pseudo-instructions for easy ROM image decoding
- The source file generated by the disassembler can be immediately re-assembled by the assembler

EMULATOR

- Reads ROM images and allows single stepping and debugging of the instructions which may be in any one of the three instruction sets
- Executes the HP-41 operating system (the HP-41 operating system ROMs are not included and must be loaded by the user with the communications utility)
- Provides Full screen display of the HP-41's internal registers, display and RAM and allows the user to set and clear breakpoints, jump to any address and preload registers
- Incorporates mainframe labels into pages 0-2 and can read and incorporate labels from user-specified label files

INSTRUCTION SET TRANSLATOR

- Translates the instructions in source files from any of the three sets to any other set

COMMUNICATIONS

- Upload and download ROM image files from an HP-41 through HP-IL to a PC (requires basic setup)

SECTION 3. DEFINITIONS

Note: The mnemonics in this manual use the Zencode instruction set.

<address>
Any value in the range 0000-FFFF (hex)

<value>
Any value in the range 0000-FFFF (hex). This is the same as an <address> but is used in a more generalized sense.

<page>
Any value in the range 0 to F (hex). A page is also 4096 words.

<bank>
Any value in the range 1 to 2 (dec). The HP-41 supports bankswitching with special ROM devices.

<+disp>
Any value in the range +0 to +63 (dec).

<-disp>
Any value in the range -1 to -64 (dec).

<local label>
A label that is delimited with parenthesis. Example: (FOOBAR). Local labels are local to the file that they are defined in and are not "visible" outside that file. Any characters except spaces may be contained in the label definition but for convention labels should be limited to uppercase characters and the underscore. If a global label is the same as a local, there will be no conflict, but this should not be done to avoid confusion. Local machine code labels should not be confused with local User Code labels as they are completely different.

<global label>
A label that is delimited with brackets. Example: [FOOBAR]. Global labels are "visible" to all files that are linked together. Any characters except spaces may be contained in the label definition but for convention labels should be limited to uppercase characters and the underscore. Global machine code labels should not be confused with global User Code labels as they are completely different.

<label>
Either a <local label> or a <global label>. This is similar to a <symbol> but is used in the more restrictive sense that labels are not defined with the .EQU directive.

<symbol>
Same as a <label> but used in a more generalized sense to include all symbols including those defined with the .EQU directive.

<operand>
The argument that is given after the instruction. Example: XS is the operand for A=B XS.

SECTION 4. UTILITIES

A41 ASSEMBLER

SYNTAX

A41 [options] <file>

DESCRIPTION

A41 assembles HP-41 MCODE mnemonics from one of three instruction sets and produces an object file that is linkable into a ROM image. A41 expects to find <file.src> that contains the code to assemble and produces <file.obj>. A41 also has the ability to reformat the source file and insert error messages and object data into it.

FILES

<file.src>	source file	(read from and written to)
<file.bak>	backup file	(written to)
<file.obj>	object file	(written to)
<file.lbl>	label file	(written to)

OPTIONS

/S If this option is not specified, the source file is read and not modified. Otherwise, the source file is read and formatted and various useful information such as error messages, object data and cross references are optionally inserted into it. A backup file is created that contains the original source code.

/R Does the same as /S and also produces a complete symbol cross reference table at the end of the source file.

/O This option causes the generation of the <address> and <data> fields into the source file when the /S or /R option is specified. These fields are for the user's benefit and are ignored by the assembler upon subsequent assemblies. This option does nothing if /S or /R is not specified.

/L Generates <file.lbl> that contains all local labels in the source file, but no global labels. See Section 6 for label file format.

/E Erases internal mainframe label table. The internal mainframe label table is a data table in the assembler that holds all of the HP-41's operating system entry points as specified by the VASM listings. This option supports custom HP-41 operating systems.

ASSEMBLER DIRECTIVES

.TITLE "title"

Gives a title to the object code. It this title is longer than 80 characters it will be truncated.

.HP

Specifies the HP instruction set and must be given before the code starts. One source file may contain several instruction set directives and they may be different.

.ZENCODE

Specifies the Zencode instruction set and must be given before the code starts.

.JDA

Specifies the Jacobs/De Arras set and must be given before the code starts.

.FILLTO <address>

Fills from current address to the specified address with zeros. If the .ORG directive is specified, this directive will fill from the current address to the specified address PLUS the origin address. The addresses are considered occupied and are not open for linking any other object code into.

.BSS <number>

Fills the next <number> words with zeros, where <number> is a positive decimal number. The addresses are considered occupied and are not open for linking any other object code into.

.NAME "name"

Macro for defining function names. This is used for construction of the FAT. It converts each character to its LCD equivalent and adds 80 hex to the last character. The order of the characters is automatically reversed as required by the HP-41.

.MESSL "string"

Similar to the NAME directive, the MESSL directive puts the string into the format required for output via the [MESSL] entry point. Each character is converted to its LCD equivalent and the 20 hex is added to the last character.

.ORG <address>

Specifies an absolute address in the range 0000-FFFF (hex) to originate the code at. All symbols defined in a file that contains this directive are absolute and cannot be relocated by the linker. This directive can be specified only once in each source file.

.EQU <global symbol> <value>
.EQU <local symbol> <value>

Equates a symbol with a value in the range 0000-FFFF (hex). This symbol functions just like any label, but is NOT relocatable since it represents an absolute constant.

#000-#3FF

This is not a directive but allows any literal to be entered directly into ROM. This is similar to the CON pseudo-instruction except that only literal values in the range 000-3FF (hex) can be entered and not symbols.

ERROR MESSAGES

*** FATAL ERROR (A01): Code runs past FFF (hex)

The assembler cannot assemble more than FFF (hex) words into one object module since that is the maximum length of a ROM image.

*** FATAL ERROR (A02): Source File Is Empty! Check backup file

The assembler found the source file to be empty which could have been caused by interruption of the assembler when it was running previously. The backup file will contain the original source file.

*** FATAL ERROR (A03): Failure to rename <file x> to <file y>

This error will result if for some reason the operating system prevents the assembler from renaming <file x> to <file y>. Check the file access on the files.

*** FATAL ERROR (A04): Out of memory!
This error occurs when the system's dynamic memory has been all used up. If this occurs, shorten source file.

*** ERROR (A05): Jump address not in same 4K page
The address specified for the quad relative jump is not in the same page as the instruction itself. The instruction is assembled anyway.

*** ERROR (A06): Illegal label definition: <label>
The label is greater than 13 characters or is not delimited by brackets or parenthesis.

*** ERROR (A07): Operand not recognized: <operand>
The operand is not valid for the instruction given. The assembler will still generate code.

*** ERROR (A08): Illegal .EQU definition
The symbol specified is not a legal symbol since it is greater than 13 characters or is not delimited by brackets or parenthesis or the value is not in the range 0000-FFFF (hex).

*** ERROR (A09): FAT names cannot be greater than 11 Characters
The HP-41 does not support FAT names greater than 11 characters long. No data will be generated.

*** ERROR (A10): Illegal address: <address>
The specified address is not in the range 0000-FFFF (hex).

*** ERROR (A11): Illegal number: <number>
The specified number is not a valid positive number.

*** ERROR (A12): .ORG must be specified before code starts
The .ORG directive was specified after the code started and was ignored.

*** ERROR (A13): Illegal .ORG definition
The address specified for the .ORG directive is not in the range 0000-FFFF (hex).

*** ERROR (A14): .ORG specified more than once
The .ORG directive cannot be specified more than once in each source file.

*** ERROR (A15): Unknown directive: <directive>
The directive is not valid.

*** ERROR (A16): Reference to external local not permitted: <local symbol>
A reference to a local symbol (delimited by parenthesis) was made and that symbol is not in the current source file.

*** ERROR (A17): Illegal instruction: "INSTRUCTION"
The instruction given is not in the current instruction set.

*** ERROR (A18): Missing Operand
An operand is required.

*** ERROR (A19): Illegal characters in NAME string

There were characters found in the FAT function name that are not allowed by the HP-41. The assembler supports all possible characters for NAME strings.

*** ERROR (A20): Illegal characters in MESSL string

There were characters found in the MESSL string that are not mapped to the HP-41. There are characters that can be displayed on the HP-41 that the assembler does not support. These are any characters with punctuation bits set or the extra characters that only the halfnut LCD can display. The MESSL directive cannot be used to encode these; they must be entered manually as literal data using the # token.

*** ERROR (A21): Illegal displacement: <displacement> (dec)

A displacement was specified that was out of the range -64 to +63 (dec).

*** ERROR (A22): Literal Address in relocatable object module

This occurs when a source file does not have the .ORG directive in it and short jump instructions have operands that are literal address. (Such as JNC).

*** WARNING (A50): Operand greater than FFF (hex)

The LC3 macro instruction expected an operand in the range 000-FFF (hex). The operand was truncated to 12 bits.

*** WARNING (A51): Operand greater than 3FF (hex)

The CON pseudo-instruction expected an operand in the range 000-3FF (hex). The operand was truncated to 10 bits.

*** WARNING (A52): Duplicate symbol: <symbol> Address not used <address>

A symbol was defined more than once in the same source file. Only the first occurrence is used, and the others are ignored. The address of all later occurrences are listed in the warning message.

L41 LINKER

SYNTAX

L41 [options] <file>

DESCRIPTION

The linker links the object files together to create one or more ROM files that contain one ROM image each. The commands that direct the linker are contained in <file.lnk>. See Section 6 for more information on the link file. L41 can link SDS format .410 files. (Any use of SDS object files requires the linking of the SDS file MFENTRY.410 since the SDS assembler does not resolve mainframe entry points)

FILES

<file.lnk> link file (read from)
<????.obj> object file(s) (read from)
<file.cfg> config file (written to)
<file.lbl> label file (written to)
Where ???? is a file name specified in the link file
<file.rom> ROM file (written to)
<file#.rom> ROM file(s) (written to)
Where # is a decimal number from 0 to the maximum number of ROM images that are linked MINUS one.

OPTIONS

/L Creates label file containing all global labels in all object modules.

/R Creates symbol cross reference table for the global labels and places it in the config file.

/A Assembles object modules that are out of date. This option causes A41 to be called if source file is newer than object file. Any letters that follow the /A are passed to A41 as options. Example: /ARO calls A41 with the /R and /O options. A41 is also called if /AL is specified and the source file is newer than the LABEL file.

ERROR MESSAGES

*** FATAL ERROR (L02): Object code runs past end of page
Attempted link for code that runs past the end of the current ROM image.

*** FATAL ERROR (L03): <object file> is corrupt
The object file is corrupt and cannot be read by the linker because it contains unexpected data.

*** FATAL ERROR (L04): Out of memory!
This error occurs when the system's dynamic memory has been all used up.

*** FATAL ERROR (L05): Cannot create the same page twice
The link file has more then one page command with the same parameters.

*** FATAL ERROR (L06): Illegal Parameter in $PAGE command
The parameters specified for the page command are not valid.

*** FATAL ERROR (L07): $PAGE Command not given before first object file name
A page command must be specified before the first object file name is given.

*** ERROR (L08): Jump address not in same 4K page
The address specified for the quad relative jump was not in the same page as the instruction itself.

*** ERROR (L09): Illegal displacement: <displacement> (dec)
The short jump instruction is referenced to a symbol that is out of its range of -64 to +63 (dec).

*** ERROR (L10): Symbol not defined: <symbol>
A reference to a non-existent symbol was made. The address used to link is 0000.

*** ERROR (L11): <object file> written to space occupied by <object file>
If the current object file maps to the space that another object file has already been linked to this error results and the new object file will be loaded over the old object file.

*** ERROR (L12): <number> Error(s) in assembly of <source file>
The assembler returned errors from the assembly of a source file. This message appears just before the linker terminates so if there are errors in the assembly they will be more obvious.

*** WARNING (L50): Reference from bank <bank x> to bank <bank y> at address <address>
This warning results when a reference from one bank to another is made. The reference is resolved as if the banks were the same which means unpredictable results are possible at run time.

*** WARNING (L51): Object file <object> originates at <origin page> but has been forced into page <current page>
This results when the address specified for the ORG directive when the file is assembled is not in the same page as the current page. The linker forces the object file into the current page and continues linking.

*** WARNING (L52): Duplicate symbol: <symbol> Address not used <address> from object file <object file>
A symbol was defined more than once. Only the first occurrence is used, and the others are ignored. The address and object file of all later occurrences is listed in the warning message.

*** WARNING (L53): $LOC value <value> has been forced into page <page>
The page specified for the $LOC command is not the same as the current page. The linker forces the <value> into the current page.

D41 DISASSEMBLER

SYNTAX

D41 [options] <file>

DESCRIPTION

The D41 disassembler is capable of disassembling ROM image files into one of the three instruction sets. It expects to find <file.rom> and it produces <file.src>. If the ROM file contains User Code, the User Code instructions are represented as literal data in the range #000 to #3FF.

FILES

<file.rom>	ROM file	(read from)
<file.lbl>	label file	(read from)
<file.src>	source file	(written to)

OPTIONS

/H Disassembles into the HP set (default). This option may not be given in conjunction with /Z or /J

/Z Disassembles into the Zencode set. This option may not be given in conjunction with /H or /J.

/J Disassembles into Jacobs/De Arras set. This option may not be given in conjunction with /H or /Z.

/Pn Maps the ROM into page n, where n is 0 to F (hex). This is used for producing a listing for a ROM that is hard-configured such as one of the operating system pages. See Section 5 for more information on the use of this option. This option does not actually change any code. If this option is not specified, the default is page 8.

/F Causes the ROM image to be disassembled with a FAT. If this is not specified, the ROM is assumed to have no FAT.

/E Erases the internal mainframe label table so that the disassembly does not place the HP-41 operating system entry labels into the source file. This option is only useful if the ROM image maps into pages 0-2 but is not part of the HP-41's operating system. This option supports nonstandard operating systems.

/L:<label file>
Specifies a label file containing labels which are incorporated into the source listing just as the mainframe labels are. See Section 6 for label file format. This option may be used multiple times to specify all label files desired.

DEFAULTS

HP instruction set
Page 8
Does not disassemble with a FAT
Mainframe labels active
No external label files

ERROR MESSAGES

*** FATAL ERROR (D04): Out of memory!
This error occurs when the system's dynamic memory has been all used up.

*** ERROR (D05): Illegal label definition: <label> in: <label file>
The label is greater than 13 characters or is not delimited by brackets or parenthesis.

*** ERROR (D06): Illegal character found in NAME string
The NAME string contains a character that is not allowed by the HP-41. The disassemble supports all possible characters for NAME strings. A tilde (~) character is displayed instead.

*** ERROR (D07): Illegal character found in MESSL string
The MESSL string contains a character that is not supported by the disassembler. The disassembler will produce an error for all characters that have punctuation bits set or the extra characters that only the halfnut LCD can display. A tilde character is displayed instead.

*** ERROR (D08): Illegal $LOC command in label file: <label file>
The address specified for to the LOC command is not in the range 0000-FFFF (hex).

*** ERROR (D09): FAT entry not recognized
The data in the FAT entry differs from the standard HP-41 FAT pseudo-instructions.

*** ERROR (D10): FAT not followed by two NOP instructions
The HP-41 requires that the FAT be followed by two NOP instructions.

*** ERROR (D11): Data at ROM address 1 (number of FAT entries) is incorrect
The data in address 1 of the ROM differs from the actual number of FAT entries disassembled.

M41 EMULATOR

SYNTAX

M41 [options] [<file>]

DESCRIPTION

M41 is a powerful and useful tool for testing and developing custom MCODE programs. It allows single stepping of MCODE programs and also supports a continuous run mode that executes the HP-41 operating system ROMs when they have been loaded with 41COM. (The ROMs are not provided with ASDT since they are owned by HP.)

OPERATION

After loading the operating system ROMs, the 'U' command may be executed and the emulator will mimic an HP-41. There are several things to know when the emulator is in this mode. If a ?KEY instruction is encountered, the emulator will check the PC's keyboard to see if a key is being pressed. If one is not, it will go on without interrupting the execution. If a key is pressed, it will be translated and loaded into the KEY register. Also, the registers and instructions will not be updated on the screen but the display will be. If the 'R' command is executed, the emulator will also run at full speed, but will stop for trap conditions and breakpoints.

The screen is divided into three areas; the instructions, the registers and the display. The pointer at the right hand side of the instructions indicates which instruction will be executed next. After every instruction is executed, it is rewritten to the display. This sometimes causes the instruction to change. An example of this is when a REG=C 3 instruction changes to a WRAB6L instruction. This occurs because no peripheral was selected when the entire screen was disassembled, but a PERSLCT FD was executed after this and that changed the active peripheral.

The display and register parts of the screen are mostly self-explanatory with the following notes. BK stands for BANK and is either 1 or 2. KEY is the KEY register which contains the keycode, while ?KEY is the keydown register and is either 1 or 0. PERPH is the selected peripheral. HEX is 1 if the CPU is in hex mode and 0 if in decimal mode. There are three registers that have different names depending on the active instruction set. SB is also ST, XSB is XST and F is T (This is shown in Appendix G). The block of RAM registers at the bottom left of the screen is the active chip and RAM is the RAM address selected. If the chip is non-existent, dashes are displayed. If an Extended Functions ROM is loaded into page 3 the emulator automatically makes all extended memory available. CODE is the code of the instruction just executed.

FILES

<????.rom> ROM file(s) (read from)
Where ???? is a file name specified in the load file
<file.lod> load file (read from)
If <file> is not given on the command line, DEFAULT.LOD is used instead
<file.lbl> label file (read from)
<file.reg> register file (read from and written to)

OPTIONS

/H Displays instructions using the HP set (default). This option may not be given in conjunction with /Z or /J

/Z Displays instructions using the Zencode set. This option may not be given in conjunction with /H or /J.

/J Displays instructions using Jacobs/De Arras set. This option may not be given in conjunction with /H or /Z.

/E Erases the internal mainframe label table so that the disassembly does not place the HP-41 operating system entry labels into the source file. This option is only useful for ROM images that map into pages 0-2 but are not part of the HP-41's operating system. This option supports nonstandard operating systems.

/EGA43
/EGA
/CGA
/MONO

If one of the above video options is given, the emulator will be forced into the specified mode. Otherwise, the emulator will set itself to the highest mode available.

COMMANDS

A Display alpha register.

BC <address>
Clear the breakpoint at <address> if there is one.

BC
Clear the breakpoint at the current address if there is one.

BC <label>
Clear the breakpoint at <label> if there is one.

BS <address>
Set breakpoint at <address>.

BS
Set breakpoint at the current address.

BS <label>
Set a breakpoint at <label> if it exists.

BL List all breakpoints.

C <chip>
Display the specified RAM chip where <chip> is 000 to 3FF (hex) with exceptions as noted in Appendix F.

D DOS shell (Type EXIT to return).

E <code>
Executes a SINGLE byte instruction (Do not execute a multi-byte instruction).

FS <reg file>
Saves all registers to a register file.

FL <reg file>
Loads all register from a register file.

G <address>
Goto the address specified.

G <label>
Goto the label specified, if it exists.

H Change to the HP instruction set.

J Change to the Jacobs/De Arras instruction set.

K <key>
Enter a key to the KEY register and set the keydown register. This maps the PC keyboard to the HP-41 keyboard, just like for the 'U' run mode.

L <register> <value>
Load <register> with <value>, where <register> is the name of the CPU register for the current instruction set as described below:

HP	Zencode	Jacobs/De Arras	Value
C	C	C	14 hex digits
A	A	A	14 hex digits
B	B	B	14 hex digits
M	M	M	14 hex digits
N	N	N	14 hex digits

LR <RAM register> <value>
Load <RAM register> with <value> where a RAM register may be any existing register from 000 to 3FF (hex) and the value is 14 hex digits long.

M Display this menu of commands.

QY Exit from the emulator.

R Run at full speed until a breakpoint, keyboard or POWOFF trap occurs.

U Execute the operating system ROMs (that you loaded) and check the keyboard when a ?KEY instruction is detected (see KEYBOARD MAPPING below). The ESC key will cause a break out of run mode, but it may take several seconds for it to be processed.

Z Change to the Zencode instruction set.

SPACE BAR
Single step the emulator.

KEYBOARD MAPPING

To simulate the HP-41 in USERCODE mode (execute the 'U' command) the PC's keyboard has been mapped to the following specifications. This is not a key for keycode mapping in all cases. For instance, the letters A-Z may only be entered if the emulator sees that ALPHA mode is set. Also, certain keys on the HP-41 keyboard are shifted, but may be entered directly on the PC keyboard WITHOUT first entering a SHIFT on the emulator because the emulator will set shift mode first. An example of this is the % function. The shift key on the PC keyboard does not map to the shift key on the HP-41.

PC Key	HP-41 meaning	MCODE keycode value
F1	ON	18 (hex)
F2	USER	C6
F3	PRGM	C5
F4	ALPHA	C5
F5	SHIFT	C4
F6	SST	C2
F7	<- (BACKARROW)	C3
F8	R/S	87
F9	FUNCTION (described below)	
F10	KEYCODE (described below)	
SHIFT F1	XEQ	32
SHIFT F2	ENTER^	13
SHIFT F3	CHS	73
SHIFT F4	EEX	83
If the emulator is in ALPHA mode:		
A to Z	A to Z	
a b c d e	a b c d e	10, 30, 70, 80, C0
s	Sigma	11
n	Not equal	71
x	Append	32
g	Angle symbol	73
% < > ^ $	% < > ^ $	31, 81, C1, 83
- + * /	- + * /	14, 15, 16, 17
Space , .	Space , .	37, 77, 77
0 to 9	0 to 9	
If the emulator is not in ALPHA mode:		
.	.	77
0 to 9	0 to 9	

FUNCTIONS

All HP-41 keys that are marked with something other than a single digit symbol may be entered with the FUNCTION key (F9). The emulator will prompt for the name of the command to enter. The commands are not case sensitive. The table below lists valid commands for ALPHA mode:

ON	USER	PRGM	ALPHA			
APPEND	ASTO	ARCL	BST	SST	AVIEW	R/S

The following are valid commands when not in ALPHA mode:

ON	USER	PRGM	ALPHA						
s-	s+	1/X	Y^X	SQRT	X^2	LOG	10^X	LN	E^X
CLs	X<>Y	RDN	%	SIN	ASIN	COS	ACOS	TAN	ATAN
SHIFT	XEQ	ASN	STO	LBL	RCL	GTO	SST	BST	
ENTER^	CAT	CATALOG		CHS	ISG	EEX	RTN	CLX	
X=Y?	SF	CF	FS?	X<=Y?	BEEP	P-R	-P		
X>Y?	FIX	SCI	ENG	X=0?	PI	LASTX	VIEW	R/S	

KEYCODES

It is also possible to enter hex keycodes directly by using the F10 key. This will enter any hex value from 00 to FF into the KEY register. If in 'U' mode, F10 toggles keycode entry. See Appendix E for the keycode table.

LIMITATIONS AND WARNINGS

When the Zenrom is loaded, it operate exactly as it should under 'U' mode, but there is one known condition when it will lock up. If the emulator is in ALPHA mode and a SHIFT is entered and then any key other than ALPHA is entered, the Zenrom will get stuck in a loop.

Some of the TEF instructions have undefined behaviors if the emulator is in decimal mode and there is a value greater than 9 in the register being added or subtracted.

ERROR MESSAGES

*** FATAL ERROR (M04): Out of memory! - Too many ROM files
This error occurs when the system's dynamic memory has been all used up.

*** FATAL ERROR (M05): Cannot load the same page twice
The load file has more then one page command with the same parameters.

*** FATAL ERROR (M06): Illegal Parameter in $PAGE command
The parameters specified for the page command are not valid.

*** FATAL ERROR (M07): ROM file name not specified in $PAGE command
The $PAGE command must have a ROM file name specified after it to load.

*** FATAL ERROR (M08): No ROM images loaded
There were not ROM images loaded.

*** FATAL ERROR (M09): Label file is empty: <label file>
The label file specified in the load file was empty.

*** ERROR (M20): Illegal $LOC command in: <label file>
The address specified for to the LOC command is not in the range 0000-FFFF (hex).

*** ERROR (M21): Illegal label definition: <label> in: <label file>
The label is greater than 13 characters or is not delimited by brackets or parenthesis.

*** ERROR (M30): Unknown result
A peripheral I/O instruction was executed that has an unknown result for the current peripheral selected.

*** ERROR (M31): Unknown Peripheral
The peripheral select code is undocumented.

*** ERROR (M32): Timer not implemented
The timer I/O instructions are not supported.

*** ERROR (M33): Card reader not implemented
The card reader I/O instructions are not supported.

*** ERROR (M34): Printer not implemented

T41 INSTRUCTION SET TRANSLATOR

SYNTAX

T41 <file>

DESCRIPTION

The instruction set translator translates the mnemonics in a source file from one instruction set to any of the three. (It is possible to translate from Zencode to Zencode, for instance.) The translator reads the source file until it finds an instruction set directive which specifies the current instruction set. Then, it prompts for the new set with self-explanatory messages. The old source file becomes the backup file. Any errors will be flagged and stored in the new source file. If there is more than one instruction set directive in the file, T41 will prompt for a new instruction set each time it finds one.

FILES

<file.src>	source file	(read from and written to)
<file.bak>	backup file	(written to)

OPTIONS

None

ERROR MESSAGES

*** FATAL ERROR (T02): Source File Is Empty! Check backup file

The translator found the source file to be empty. The backup file should contain the original source file.

*** FATAL ERROR (T03): Failure to rename <file x> to <file y>

This error will result if for some reason the system prevents the translator from renaming <file x> to <file y>. Check the file access on the files.

*** FATAL ERROR (T04): Out of memory!

This error occurs when the system's dynamic memory has been all used up.

*** ERROR (T05): Instruction not given

An instruction was expected on this line and none was found.

*** ERROR (T06): Illegal label definition: <label>

The label is greater than 13 characters or is not delimited by brackets or parenthesis.

*** ERROR (T07): Unknown directive: <directive>

The specified directive is not valid.

*** ERROR (T08): Illegal instruction: "<instruction>"

The instruction given is not in the current instruction set.

41COM COMMUNICATIONS UTILITY

SYNTAX

41COM <file>

DESCRIPTION

This utility transmits and receives 4K ROM image files to and from the HP-41 over the HP-IL loop. It requires two programs on the HP-41 called "ROMIN" and "ROMOUT". For information on loading these programs, see the file "BOOT.SRC". On-line help is available by typing H after running 41COM. This utility requires an HP82973A HP-IL interface card for the PC and an HP82160 HP-IL module for the HP-41.

It is also possible to use an HP-IL module in the HP-41 with an HP-IL <=> RS232 convertor and use the RS232 serial port of the PC to send and receive ROM files. The 41COM utility is not needed in this case since the PC can simply send and receive the ROM file over its serial port using any serial upload/download program that supports 8-bit ASCII. The software on the HP-41 end is the same either way.

FILES

<file.rom> ROM file (read from or written to)

OPTIONS

None

ERROR MESSAGES

*** ERROR: EOT received before all data sent
The HP-41 sent an EOT signal before it sent all 8192 bytes.

*** ERROR: Time out
The HP-41 prematurely terminated its transmission and the PC timed out or the HP-41 failed to respond in time to data sent by the PC. The timeout factor is approximately two seconds.

SECTION 5. LINKING AND DISASSEMBLY

BACKGROUND INFORMATION

Because the smallest unit of ROM memory in HP-41 is one page, the linker builds pages. Each HP-41 page is 4096 words long. Each word is 10 bits long. The HP-41 can address a total of 16 pages which are numbered page 0 through page F (hex). Some of these pages are already hard-wired to the HP-41 operating system (See Appendix B). Other pages are left open for the user's plug-in modules and these map to the four I/O ports. Each port has two 4K pages associated with it so a plug-in module can use either one or two pages. The actual hardware of the module determines which page(s) it uses. Most 4K modules use the lower page (although some use the upper) while all 8K modules use both. These configurations are known as port-configured since the actual pages that the module maps into are dependant on which port it is plugged into. Most of the commercially available ROM equipment is of this variety.

12K and 16K modules must be bank-switched as described later in this section.

It is possible to have a module that does not occupy the pages associated with the port it is plugged into. The ROM image(s) in this type of module are hard-configured to always map into the same page(s) regardless of which port it is plugged into. This is the case for several HP-41 peripherals or special modules such as the Mass Storage ROM. For instance, regardless of which port the Mass Storage ROM is plugged into, it will always occupy page 7. (The Mass Storage ROM is inside the HP-IL module.) Since most accessory hardware for the HP-41 on the market today does not support hard-configured ROM images, this is not an alternative to most MCODE programmers. One way to get around this is to pretend that a piece of hardware is hard-configured and always plug it into the same I/O port. This distinction is important since some jump instructions are not position independent.

The linker can link many possible configurations including port- and hard-configurations and bank switching.

LINKING PORT-CONFIGURED ROMS

Most types of user-created ROMs will be of this type. The best way to link these is to start with a $PAGE 8 1 command for the lower ROM. If there is an upper ROM, it would be linked with a command of $PAGE 9 1. If the upper page is bank switched, the hidden page would be linked with a command of $PAGE 9 2. The only reason the linker needs to know a page number is to resolve references that are relative to each other. It would work just as well to specify $PAGE 5 for the lower ROM and $PAGE 6 for the upper. An example of this type of link is the Advantage ROM. It is a 12K bankswitched port-configured module. It could be linked with $PAGE 8 1, $PAGE 9 1 and $PAGE 9 2. If the link file were named ADV.LNK, The ROMs would be named ADV0.ROM, ADV1.ROM and ADV2.ROM, respectively.

LINKING HARD-CONFIGURED ROMS

To link a ROM of this type, the $PAGE command would be specified with the page that the ROM is to be located at. If there is more than one ROM to be linked, simply specify exactly which page and bank each one is to be located at. The hardware will insure that each ROM is mapped to its proper location. For example, the operating system of the HP-41 is 12K of hard-configured non bank switched ROMs. It could be linked with $PAGE 0, $PAGE 1, $PAGE 2. If the link file were named NUT.LNK, the ROMs would be named NUT0.ROM, NUT1.ROM and NUT2.ROM, respectively.

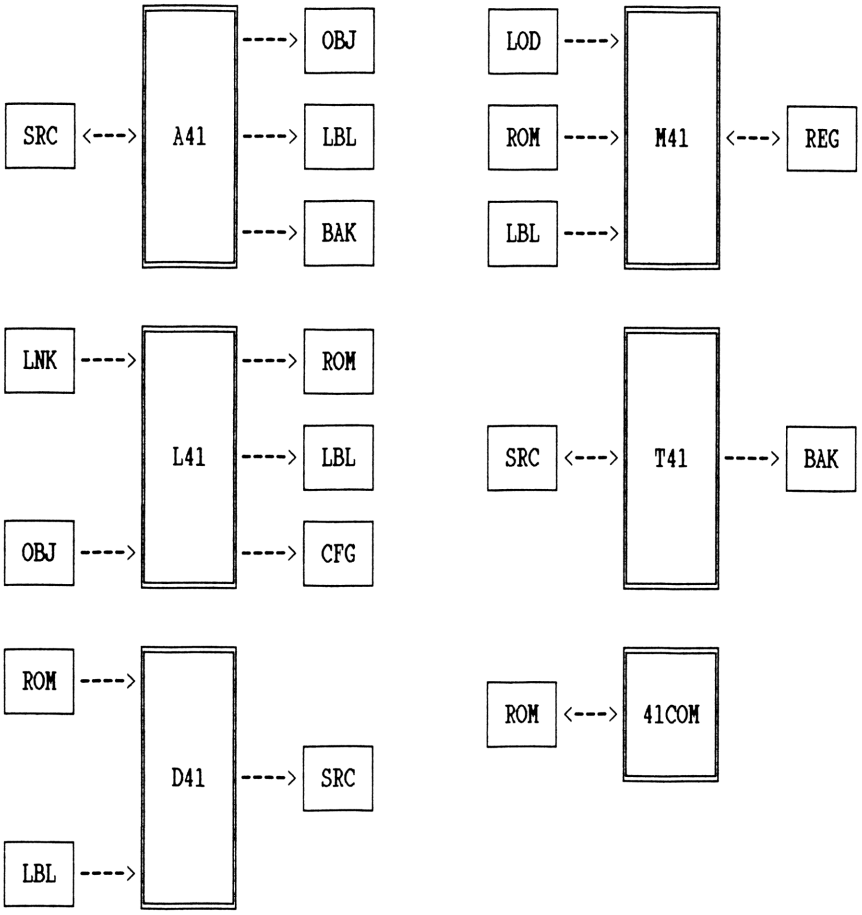
DISASSEMBLY OF PORT-CONFIGURED ROMS

To disassemble a port-configured ROM, it is best to start at page 8 for the first ROM image and if there is a second, disassemble to page 9. For example, to disassemble an 8K port-configured ROM, do not specify the /Pn option (the default is 8) for the first page and specify /P9 for the second.

DISASSEMBLY OF HARD-CONFIGURED ROMS

To disassemble a hard-configured ROM, the page that the ROM was taken from must be specified with the /Pn option. For example, to disassemble the operating system of the HP-41, specify /P0 for the first page and /P1 and /P2 for the other two. If the operating system is disassembled into pages 0-2, the mainframe labels will appear properly at the locations they are defined at.

SECTION 6. FILE TYPES



SOURCE FILE FORMAT

FILE EXTENSION

.SRC

All source files must have a .SRC extension.

FILE TYPE

Normal MS-DOS text file

LINE FORMATS

.<directive>

Directive lines begin with a period and are followed by the directive which must be in all caps.

; Comments ...

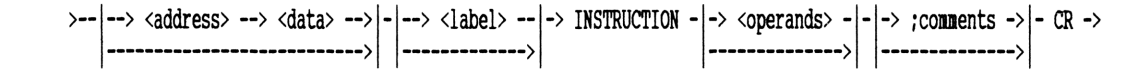
Comment lines begin with a semicolon and may contain anything after the semicolon.

* Error
* Macro

Error and macro lines begin with an asterisk and are removed by the assembler when they are found in the source file. This type of line may contain anything after the asterisk. They are placed in the source file by the utilities to denote errors in code or to denote the code generated by macro expansions.

Instruction lines

Any line that is not one of the above is an instruction line and must follow the syntax diagram below:



Instruction lines have optional fields that may or may not affect assembly. The address and data fields are ignored by the assembler but are rewritten if the source file is rewritten. The user does not place the address and data fields in the source file. The address field is 4 hexadecimal digits long and the data field is 3, 6 or 9 hexadecimal digits long. The label field is next and is where a local or global label is defined. Labels without instructions on the same line will cause an error. Depending on which instruction is used, there may be from zero to three operand fields after the instruction but the assembler uses only the first and the rest are ignored and placed for the user's benefit. Any characters after that must be proceeded by a semicolon and are treated as a comment.

USED BY

A41 The assembler reads the old source file and writes a listing to the new source file if the /S or /R option is given; otherwise it does not modify the source file.

D41 The disassembler writes its disassembly listing to a source file. If there is a source file with the same name as the one the disassembler is about to disassemble into, the original one is made into a backup file.

T41 The instruction set translator reads the old instructions from the source file and writes the translated instructions to a new source file of the same name.

FILE SAFETY

If the assembler or translator are interrupted, it is possible to lose the source file, but it is not possible to lose both the backup and source files.

COMPATIBILITY WITH SDS

There are significant differences in SDS .41A source files and ASDT .SRC files.

EXAMPLE

See any of the .SRC files on the ASDT disk.

BACKUP FILE FORMAT

FILE EXTENSION

.BAK

All backup files must have a .BAK extension.

FILE TYPE

Normal MS-DOS text file

PURPOSE

Backup files are maintained automatically by the utilities as a measure of file safety. It is not possible to interrupt one of the utilities and loose both the source and backup files.

LINE FORMATS

Same as for source files.

USED BY

A41 The assembler will make the old source file into the backup file if /S or /R is given. If a backup file already exists, it is overwritten. If /S is not given the backup file will not be modified.

D41 When the disassembler first executes, it checks for a source file with the same name as the one it is about to disassemble into. If it finds one that already exists, it makes it into a backup file. If a backup file by that same name also exists, it is overwritten. If it does not find a source file it does not do anything to the backup file.

T41 The old source file becomes the backup file every time that the translator is executed. Any preexisting backup file of the same name is overwritten.

ROM FILE FORMAT

FILE EXTENSION

.ROM

All ROM files must have a .ROM extension.

FILE TYPE

Binary data file

DATA FORMAT

HIGH 2, LOW 8

Each 10-bit HP-41 word is stored in two 8-bit bytes in a ROM file. The high 2 bits of the 10-bit word are stored in the low 2 bits of the first byte and the low 8 bits are stored in the second byte. Since there are 4096 10-bit bytes in each ROM image, all ROM files must be exactly 8192 bytes long.

USED BY

L41 The linker writes the final, linked code to one or more ROM files.

D41 The disassembler reads the code from the ROM file and disassembles it.

M41 The emulator can read and execute the ROM image files.

41COM

The HP-41 communications utility reads or writes ROM files over the HP-IL loop.

COMPATIBILITY WITH SDS

ROM files are in the same format as .41R files.

OBJECT FILE FORMAT

FILE EXTENSION

.OBJ

All object files must have a .OBJ extension.

FILE TYPE

Binary data file

USED BY

A41 The assembler writes internal global label definitions (entry points), unresolved external references, relocation fixups, and the object code into each object file along with some other information used by the linker.

L41 The linker reads the object files, locates the code in the ROM image, resolves external references and fixes up all references.

COMPATIBILITY WITH SDS

ASDT .OBJ files may be renamed .410 and used with the SDS LINK41 utility. SDS .410 files may be renamed .OBJ and used with the ASDT L41 utility but the SDS file MFENTRY.410 must be renamed MFENTRY.OBJ and linked in also.

LINK FILE FORMAT

FILE EXTENSION

.LNK

All link files must have a .LNK extension.

FILE TYPE

Normal MS-DOS text file

PURPOSE

Link files are used to direct the linker in the creation of the ROM files.

LINE FORMATS

<object file name>

This is the file name of the object file to load given without the .OBJ extension. The object data is loaded at the current load address in the current ROM image. The load address is then modified so the next object file will load immediately following the previous.

$PAGE <page>
$PAGE <page> <bank>
$PAGE <page> <ROM name>
$PAGE <page> <bank> <ROM name>

Where <page> is 0 to F (hex) and <bank> is 1 or 2. If <bank> is not given, the default is 1. This command opens a new ROM image at the specified page and bank. All object files specified after this are linked into this ROM image until another $PAGE command is given or the link file ends. When there is only one ROM image it will be named the name of the link file (with a .ROM extension). If there is more than one ROM image, a number from 0 to the number of ROM images MINUS one is appended to this name. If <ROM name> is specified, that name will be used to name the ROM image instead.

$LOC <address>

Where <address> is a value 0000 to FFFF (hex). This command changes the load address so the object files following it are loaded consecutively starting at this address. If <address> is not in the same page as the page given with the current $PAGE command, a warning message will result and the linker will force <address> into the current page. If this command is not given, the initial load address is p000 where p is the current page.

$CH

Compute checksum and place in location FFF (hex) for the current ROM image. This command must be given for each page where a checksum is desired. If location FFF is occupied by any object code, an error message is generated and the checksum is written anyway.

;comment

Any line that begins with a semicolon is ignored.

USED BY

L41 Link files are used to direct the linking of object files.

EXAMPLE

See PCCOM.LNK on the ASDT disk for an example of a link file.

CONFIGURATION FILE FORMAT

FILE EXTENSION

.CFG

All config files must have a .CFG extension.

FILE TYPE

Normal MS-DOS text file

PURPOSE

This type of file is only written by the linker and is used to show which ROM is mapped to which page as specified by the link file. The config file may optionally have the symbol cross reference table written to it.

LINE FORMATS

$PAGE <page> <bank> <rom file>

Where <page> is 0 to F (hex) and <bank> is 1 or 2. This documents the mapping of <rom file> to the specified page and bank.

; anything
* anything
blank line

These three line formats contain information that is for the user's benefit only. The * lines contain the symbol cross reference table if there is one.

USED BY

L41 Config files are written by the linker. The linker will write the ROM image mapping and optionally a symbol cross reference table.

EXAMPLE

After executing the demo on the ASDT disk, a configuration file with the name PCCOM.CFG will be created.

LOAD FILE FORMAT

FILE EXTENSION

.LOD

All load files must have a .LOD extension.

FILE TYPE

Normal MS-DOS text file

PURPOSE

This file is very similar to the config file format. It is only used by the emulator to load the ROM images and label files.

LINE FORMATS

$PAGE <page> <bank> <rom file>

Where <page> is 0 to F (hex) and <bank> is 1 or 2. The ROM file will be loaded into the specified page and bank.

; anything
* anything
blank line

These three line formats contain information that is for the user's benefit only and is not read by the emulator.

$LABELS <label file>

The labels in the <label file> will be read and incorporated into the disassembly listing of the emulator.

USED BY

M41 Load files are read by the emulator and specify the ROM images to read in. The file DEFAULT.LOD is special since the emulator will read it if it exists and a load file name is not specified on the command line.

EXAMPLE

A load file with the name DEFAULT.LOD is included on the ASDT disk although it specifies fictitious ROM images.

LABEL FILE FORMAT

FILE EXTENSION

.LBL

All label files must have a .LBL extension.

FILE TYPE

Normal MS-DOS text file

LINE FORMATS

<label> <address>

Where <label> is any global or local label and <address> is a value 0000 to FFFF (hex). Labels do not have to be in any particular order. If the label file has more than about fifty labels in it, they should NOT be placed in alphabetical or reverse alphabetical order.

$LOC <address>

Where <address> is a value 0000 to FFFF (hex). This address is simply added to each of the addresses of the labels affected. The labels affected are those that appear after each $LOC command and before the next $LOC command or the end of file. This command may be given more than once in the same file and if not given at all the default is 0000.

; comment

Any line that begins with a semicolon is ignored.

USED BY

A41 When the /L option is given, the assembler writes all local labels to a label file that has the same name as the source file. It does not write global labels.

L41 When the /L option is given, the linker writes all global labels read from all object files to one label file that has the same name as the link file. It does not write local labels since they do not appear in the object files.

D41 For each /L:<label file> option specified on the command line of the disassembler, all local and global labels are read from the specified file and incorporated into the source listing just as for the mainframe labels. The addresses specified by each label are used exactly as they appear unless they are offset by the $LOC command.

M41 The emulator reads the label files just like the disassembler and incorporates the labels into its listings.

EXAMPLE

```
[FOOBAR_A] 0023
(FOOBAR_D) 32C2
$LOC B000
[FOOBAR_B] 04A3
$LOC 0200
(FOOBAR_C) 032B
;this is a comment
```

[FOOBAR_A] is interpreted as 0023, (FOOBAR_D) is 32C2, [FOOBAR_B] is B4A3, (FOOBAR_C) is 052B.

REGISTER FILE FORMAT

FILE EXTENSION

.REG

All REG files must have a .REG extension.

FILE TYPE

Binary data file

USED BY

M41 The emulator can read and write the CPU and RAM registers into a register file.

SECTION 7. REFERENCE INSTRUCTION FORMATS

SHORT JUMPS

INSTRUCTIONS

JNC <operand> Jump on no carry, otherwise do nothing
JC <operand> Jump on carry, otherwise do nothing

DESCRIPTION

The short jump instruction jumps -64 to +63 words from where the instruction is. This type of instruction encodes only a relative displacement in its bits.

FORMATS

JNC <+disp>
JNC <-disp>

Where <+disp> is +0 to +63 and <-disp> is -1 to -64 (dec). The actual address that is jumped to is relative to where the short jump instruction is located after it is assembled and linked and the ROM is plugged into the HP-41. Regardless of where the instruction ends up, it always jumps the same number of words forward or backward.

JNC <address>

Where <address> is 0000 to FFFF (hex). The assembler resolves this type by taking the specified address and subtracting the jump instruction's ASSEMBLE TIME ADDRESS to get a positive or negative displacement. This should only be used if the object module is assembled with the .ORG directive so that the assemble time address will be the SAME as the run time address. This is a literal specification and the linker does not relocate anything. It is possible to specify an address that is too far from the jump, causing A41 to report an error.

JNC <label>

Where <label> is any local or global label. The address that will be jumped to is whatever the value of the label is, assuming it is within range. If the label is external, the linker must resolve the reference, otherwise it is completely resolved during assembly.

LONG JUMPS

INSTRUCTIONS

NCGO <operand>	Goto on no carry, otherwise do nothing
CGO <operand>	Goto on carry, otherwise do nothing
NCXQ <operand>	Execute on no carry, otherwise do nothing
CXQ <operand>	Execute on carry, otherwise do nothing

DESCRIPTION

These instructions occupy two words each and can jump to anywhere in the HP-41 address space. The address that they jump to is encoded in the instruction's bits and regardless of where the instruction is located, it always jumps to the same location. The goto types of long jumps simply cause an immediate jump depending on the carry flag. The execute types do the same but also push a return address onto the HP-41's return stack. The value that is pushed is the address of the word that follows the long jump.

FORMATS

NCXQ <address>

Where <address> is 0000 to FFFF (hex). The assembler resolves this type of reference literally and the linker does not change it.

NCXQ <label>

Where <label> is any local or global label. If the label is internal, it is resolved but will be fixed up (resolved again) at link time. If the label is a mainframe label, the assembler resolves it immediately without any relocation possible. If it is not a mainframe label or an internal, then the label is external and the linker must resolve the reference after it relocates all of the object files. If the /E option is specified, the mainframe label table is erased and all references to mainframe labels are treated as references to externals.

OTHER REFERENCE "INSTRUCTIONS"

The rest of the jump and reference instructions use a general format described below:

INSTRUCTION <value>

Where "INSTRUCTION" is one of the other reference "instructions" described below and <value> is some number usually from 0000 to FFFF (hex). This value is used exactly as it appears and is not relocated.

INSTRUCTION <symbol>

Where <symbol> is any local or global symbol. The symbol is relocated by the linker if it is a relative label but is not relocated if it is an absolute symbol.

CON	Enter constant into ROM
DEFP4K	(Not useful - kept for compatibility with SDS)
DEFR4K	Define 4K MCODE FAT entry
DEFR8K	Define 8K MCODE FAT entry
U4KDEF	Define 4K User Code FAT entry
U8KDEF	Define 8K User Code FAT entry
LC3	LC three times
NCGOREL	Goto on no carry relative to current quad
NCXQREL	Execute on no carry relative to current quad

For the descriptions below assume [FOOBAR] resolves to the value 06D2 (hex).

CON This is not an instruction at all but is used to directly enter a 10 bit value into the ROM image. This value could represent data, or even an instruction. CON 123 would make the object data contain the value 123 while CON [FOOBAR] will be 6D2. If the high 6 bits are not all zero a warning message will be displayed and the assembler will only use the low 10 bits.

DEFP4K, DEFR4K, DEFR8K, U4KDEF, U8KDEF

These FAT entry pseudo-instructions are used to define the FAT and should only appear in the first part of the ROM image.

LC3 This is a macro instruction that expands into three LC instructions containing the low three nybbles of the address or symbol. LC3 E2A4 expands to LC 2, LC A, LC 4 and LC3 [FOOBAR] expands to LC 6, LC D, LC 2. If the high 4 bits are not all zero a warning message will be displayed and the assembler will only use the low 12 bits.

NCGOREL, NCXQREL

The quad relative goto and execute pseudo-instructions are used to jump from one address to another within a port-configured ROM image. They call special mainframe routines that do the actual jump so they are slower and use 1 or 2 return stack levels. (See Section 5 for port-configured ROM images)

APPENDIX A

COMMON ROM ID'S

1	Math
2	Statistics
3	Surveying
4	Finance, ES-41
5	Standard
6	Circuit Analysis, ES-41
7	Structures
8	Stress Analysis
9	Home Management, CCD
10	Games, Auto/Dup, PPC ROM
11	Real Estate, Eramco, CCD, Paname
12	Machine Design
13	Thermal
14	Navigation
15	Petroleum, Mountain Computer
16	Petroleum
17	Plotter, NFCROM
18	Plotter
19	Securities, Structures, Clinical Lab, Aviation
20	PPC ROM
21	Data logger, Assembler 3
22	HP-IL Development, Advantage
23	Extended I/O
24	HP-IL Development, Advantage
25	Extended Functions
26	Time
27	Wand
28	Mass Storage
29	Printer
30	Card Reader
31	Data logger

APPENDIX B

HP-41 ROM MEMORY MAP

	Page	BANK 1	BANK 2
	F	Port 4 upper page	
P	E	Port 4 lower page	
O	D	Port 3 upper page	
R	C	Port 3 lower page	
T	B	Port 2 upper page	
S	A	Port 2 lower page	
	9	Port 1 upper page	
	8	Port 1 lower page	
	7	HP-IL Mass Storage ROM	--Not used
S	6	Printer ROM	--Not used
Y	5	Timer ROM	X-Functions ROM (CX only)
S	4	Reserved by HP	--Not used
T	3	X-Functions ROM (CX only)	--Not used
E	2	Operating system ROM 2	--Not used
M	1	Operating system ROM 1	--Not used
	0	Operating system ROM 0	--Not used

APPENDIX C

FORMAT FOR ROM WITH FAT

```
p000 ROM ID Number
p001 Number of Functions (n)
----------------- FAT ------------------------
p002    Address of First Function
p003        "         "
.
.
p(2n)   Address of Last Function
p(2n+1)      "         "
p(2n+2) FAT Terminator (must be loaded with 000)
p(2n+3)      "                        "
----------------- CODE -----------------------
p(n2+4)
.
.
pFF3
----------------- POLLING VECTORS -------------
pFF4 Pause Loop
pFF5 Main Running Loop
pFF6 Deep Sleep Wake Up With No Key Down
pFF7 Power Off
pFF8 I/O Service
pFF9 Deep Sleep Wake Up
pFFA Cold Start
----------------- ROM TERMINATOR --------------
pFFB Revision Level Characters (optional)
pFFC      "                      "
pFFD      "                      "
pFFE      "                      "
pFFF Checksum (optional)
```

Where p is the number of the page that the ROM maps to. This format is used for ROMs at pages 3 and 5 to F.

APPENDIX D

CHARACTER TRANSLATION TABLE

The HP-41 display characters with values from 00 to 1F (hex) translate directly to the IBM/PC characters with values from 40 to 5F (hex). These are the following PC characters:

@ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_

The HP-41 display characters with values from 20 to 3F (hex) translate directly to the IBM/PC characters with values from 20 to 3F (hex) with the exception of the { } ~ ; characters. These are the following IBM/PC characters:

SPACE !"#$%&'()*{-}/0123456789~;<=>?

The HP-41 display characters with values from 100 to 10F (hex) translate to a number of non-intuitive IBM/PC characters. These are the following PC characters:

xabcdeo`tuvwmnsg

The extra HP-41 display characters supported by the halfnut display (the one with rounded edges) are not supported by ASDT.

The following table further explains the mapping of certain characters:

HP-41 Display Characters	PC Representation
Left goose	{
Right goose	}
Boxed star	~
Comma character	;
Append	x
Overbar	o
Single quote	`
One leg hangman	t
Two leg hangman	u
One arm hangman	v
Full hangman	w
Micro	m
Not equal to	n
Sigma	s
Angle symbol	g

APPENDIX E

KEYCODE TABLE

18	C6		C5	C4
10	30	70	80	C0
11	31	71	81	C1
12	32	72	82	C2
13		73	83	C3
14	34	74	84	
15	35	75	85	
16	36	76	86	
17	37	77	87	

APPENDIX F

RAM CONFIGURATION DATA

M41 emulates extended memory to support the HP-41CX. If ROM is loaded into page 3 when M41 is run, it assumes all possible RAM registers are available.

The following registers are available when emulating any HP-41:

000-00F
0C0-1FF

The following registers are available when the emulator detects a ROM in page 3. This is equivalent to two Extended Memory modules installed in either an HP-41 with one Extended Function module or an HP-41CX.

000-00F
040-1FF
201-2EF
301-3EF

APPENDIX G

INSTRUCTION SET CROSS REFERENCE TABLE

INTRODUCTION

This document contains all of the instructions supported by ASDT and is intended as a reference guide to programming the HP-41.

Note: When the Jacobs/De Arras set failed to contain instructions (such as the display instructions) HP mnemonics were substituted. The mnemonics NCXQREL and NCGOREL were created for ASDT.

REFERENCES

HP-41 MCODE for Beginners, Ken Emory, Synthetix, 1985
The ZENROM Programmer's Manual, Zengrange Ltd., 1984
The HP-41 VASM listings, Hewlett Packard, 1985
Software Development System II Manual, Hewlett Packard, 1986

CPU REGISTERS

HP	ZENCODE	JACOBS/ De ARRAS	Bits	Description
C	C	C	56	Primary accumulator
A	A	A	56	Secondary storage and accumulator
B	B	B	56	Secondary storage and accumulator
M	M	M	56	Alternate storage
N	N	N	56	Alternate storage
P	P	P	4	Nybble Pointer
Q	Q	Q	4	Nybble Pointer
PT	PT	R	4	Either P or Q, whichever is the active pointer
SB	ST	ST	8	Lower CPU flags 7-0
G	G	G	8	Alternate storage (often flags)
F	F	T	8	Beeper register
STK	STK	ADR	16	The first address on the return stack
Upper Flags			6	Upper CPU flags 13-8
Carry Flag			1	Set by some instructions; cleared after all others
Keydown Flag			1	Set when key register has data ready
Key Register			8	Contains the keycode entered by pressing a key
Return Stack			16x4	Contains 4 16-bit words that hold return addresses
Program Counter			16	Points to next instruction to execute

56 BIT REGISTER FORMAT

Nybble: 13 : 12 : 11 : 10 : 9 : 8 : 7 : 6 : 5 : 4 : 3 : 2 : 1 : 0
Nybble 13 is the most significant; 0 is the least
Notation: A[x:y] means all nybbles in A REG from x to y; A[x] is just nybble x

GENERAL PURPOSE INSTRUCTIONS

CODE	HP	ZENCODE	JACOBS/ De ARRAS	OPERAND	
FLAG INSTRUCTIONS					
004	ST=0	CF	CLRF	0 to 13 (dec)	;clear flag
008	ST=1	SF	SETF	0 to 13 (dec)	;set flag
00C	ST=1?	?FS	?FSET	0 to 13 (dec)	;set carry if flag set
3C4	CLRST	ST=0	ST=0		;clear lower CPU flags (7-0)
358	ST=C	ST=C	ST=C		;copy C[1:0] into ST
398	C=ST	C=ST	C=ST		;copy ST into C[1:0]
3D8	CSTEX	C<>ST	C<>ST		;exchange C[1:0] and ST
LOAD CONSTANTS					
010	LC	LC	LD@R	0 to F (hex)	;load constant to C[PT], then decrement pointer
010,010,010	LC3	LC3	LD@R3	000 to FFF (hex)	;Do three LC instructions
130,000	LDI	LDI	LDIS&X	000 to 3FF (hex)	;load next word in ROM into C[2:0]
000	CON	CON	CON	000 to 3FF (hex)	;enter hex constant into ROM
000	FCNS	FCNS	FCNS	0 to 64 (dec)	;decimal constant same as CON
000	XROM	XROM	XROM	1 to 31 (dec)	;decimal constant same as CON
POINTER					
014	?PT=	?PT=	?R=	0 to 13 (dec)	;set carry if active pointer equal
01C	PT=	PT=	R=	0 to 13 (dec)	;set active pointer
0A0	SELP	PT=P	SLCTP		;make P the active pointer
0E0	SELQ	PT=Q	SLCTQ		;make Q the active pointer
120	?P=Q	?P=Q	?P=Q		;set carry if P=Q
3D4	DECPT	-PT	R=R-1		;decrement the active pointer
3DC	INCPT	+PT	R=R+1		;increment the active pointer
RAM ACCESSING					
270	DADD=C	RAMSLCT	RAMSLCT		;select the RAM chip addressed in C[2:0]
2F0	DATA=C	WDATA	WRITDATA		;writes C[13:0] to selected RAM register
038	C=DATA	RDATA	READDATA		;writes selected RAM register to C[13:0]
028	REGN=C	REG=C	WRIT	0 to F (hex)	;write to RAM register in selected chip
038	C=REGN	C=REG	READ	0 to F (hex)	;read from RAM register in selected chip
ROM ACCESSING					
330	CXISA	RDROM	FETCHS&X		;copies the ROM data addressed in C[6:3] into C[2:0]
040	WMLDL	WMLDL	WROM		;write C[2:0] to address C[6:3]
100	ENROM1	ENBANK1	ENROM1		;enable ROM bank 1 for current ROM device
180	ENROM2	ENBANK2	ENROM2		;enable ROM bank 2 for current ROM device
KEYBOARD					
220	C=KEYS	C=KEY	C=KEY		;copy key register to C[4:3]
230	GOKEYS	GTOKEY	GTOKEY		;copy the key register into the low byte of the PC
3C8	RSTKB	CLRKEY	CLRKEY		;clear keydown flag if no key pressed and clear key register
3CC	CHKKB	?KEY	?KEY		;set carry if keydown flag is set

MODE SETTING

060,000	POWOFF	POWOFF	POWOFF		;halt the CPU
260	SETHEX	SETHEX	SETHEX		;set hexadecimal mode
2A0	SETDEC	SETDEC	SETDEC		;set decimal mode
2E0	DISOFF	DISOFF	DSPOFF		;turn display off
320	DISTOG	DISTOG	DSPTOG		;toggle state of display

M, N, G, F REGISTERS

070	N=C	N=C	N=C		;copy C[13:0] into N
0B0	C=N	C=N	C=N		;copy N into C[13:0]
0F0	CNEX	C<>N	C<>N		;exchange C[13:0] and N
158	M=C	M=C	M=C		;copy C[13:0] into M
198	C=M	C=M	C=M		;copy M[13:0] into C
1D8	CMEX	C<>M	C<>M		;exchange C[13:0] and M
058	G=C	G=C	G=C		;copy C[PT+1:PT] into G (if PT= 13, high byte is undefined)
098	C=G	C=G	C=G		;copy G into C[PT+1:PT] (if PT= 13, high byte is undefined)
0D8	CGEX	C<>G	C<>G		;exchange C[PT+1:PT] and G (if PT= 13, high byte is undefined)
258	F=SB	F=ST	T=ST		;copy ST into beeper register
298	SB=F	ST=F	ST=T		;copy beeper register into ST
2D8	FEXSB	ST<>F	ST<>T		;exchange ST and beeper register

OTHER

000	NOP	NOP	NOP		;no operation
160	?LLD	?BAT	?LOWBAT		;set carry if battery is low
03C	RCR	RCR	RCR	0 to 13 (dec)	;rotate C reg right by the nybble
370	C=CORA	C=CORA	C=CORA		;C[13:0] = C bitwise or A
3B0	C=C&A	C=CANDA	C=CANDA		;C[13:0] = C bitwise and A
1A0	CLRABC	ABC=0	A=B=C=0		;clear all nybbles of A,B,C registers

TIME ENABLE FIELD INSTRUCTIONS

HP	ZENCODE	JACOBS/ De ARRAS	Nybble(s)	Time Enable Fields
PT	PT	@R	[PT]	Nybble pointed to by active pointer
X	X	S&X	[2:0]	Sign and exponent
WPT	WPT	R<	[PT:0]	Nybbles pointed to by active pointer through nybble 0
W	ALL	ALL	[13:0]	Entire register
PQ	PQ	P-Q	[Q:P]	Nybbles from pointer Q to pointer P subject to: if P<=Q then [Q:P]; if P>Q then [13:P]
XS	XS	XS	[2]	Exponent sign
M	M	M	[12:3]	Mantissa
S	S	MS	[13]	Mantissa sign

Nybble:	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	S	M	M	M	M	M	M	M	M	M	M	X XS	X	X

All of the instructions in the following group work on the above Time Enable Fields (TEF). C[TEF] is the C register with whatever field is selected from above. Ex: A[PT], A[XS] etc.

Any of the arithmetic TEF instructions set the carry flag if either an overflow or underflow occurs.

TEF

002	A=0	A=0	A=0	TEF	;clear A[TEF]
022	B=0	B=0	B=0	TEF	;clear B[TEF]
042	C=0	C=0	C=0	TEF	;clear C[TEF]
062	ABEX	A<>B	A<>B	TEF	;exchange A[TEF] and B[TEF]
082	B=A	B=A	B=A	TEF	;copy A[TEF] into B[TEF]
0A2	ACEX	A<>C	A<>C	TEF	;exchange A[TEF] and C[TEF]
0C2	C=B	C=B	C=B	TEF	;copy B[TEF] into C[TEF]
0E2	BCEX	B<>C	B<>C	TEF	;exchange B[TEF] and C[TEF]
102	A=C	A=C	A=C	TEF	;copy C[TEF] into A[TEF]
122	A=A+B	A=A+B	A=A+B	TEF	;add B[TEF] to A[TEF]
142	A=A+C	A=A+C	A=A+C	TEF	;add C[TEF] to A[TEF]
162	A=A+1	A=A+1	A=A+1	TEF	;add one to A[TEF]
182	A=A-B	A=A-B	A=A-B	TEF	;subtract B[TEF] from A[TEF]
1A2	A=A-1	A=A-1	A=A-1	TEF	;subtract one from A[TEF]
1C2	A=A-C	A=A-C	A=A-C	TEF	;subtract C[TEF] from A[TEF]
1E2	C=C+C	C=C+C	C=C+C	TEF	;double C[TEF]
202	C=A+C	C=A+C	C=C+A	TEF	;add A[TEF] to C[TEF]
222	C=C+1	C=C+1	C=C+1	TEF	;add one to C[TEF]
242	C=A-C	C=A-C	C=A-C	TEF	;subtract C[TEF] from A[TEF] store in C[TEF]
262	C=C-1	C=C-1	C=C-1	TEF	;subtract one from C[TEF]
282	C=-C	C=-C	C=0-C	TEF	;16's complement of C if in hex mode; 10's complement if in dec mode
2A2	C=-C-1	C=-C-1	C=-C-1	TEF	;15's complement if hex mode; 9's complement if dec mode
2C2	?B≠0	?B≠0	?B≠0	TEF	;set carry if B[TEF] is not equal to 0
2E2	?C≠0	?C≠0	?C≠0	TEF	;set carry if C[TEF] is not equal to 0
302	?A<C	?A<C	?A<C	TEF	;set carry if A[TEF] is less than C[TEF]

322	?A<B	?A<B	?A<B	TEF	;set carry if A[TEF] is less than B[TEF]
342	?A≠0	?A≠0	?A≠0	TEF	;set carry if A[TEF] is not equal to 0
362	?A≠C	?A≠C	?A≠C	TEF	;set carry if A[TEF] is not equal to C[TEF]
382	ASR	ASR	RSHFA	TEF	;shift A right by one nybble (leftmost byte set to 0)
3A2	BSR	BSR	RSHFB	TEF	;shift B right by one nybble (leftmost byte set to 0)
3C2	CSR	CSR	RSHFC	TEF	;shift C right by one nybble (leftmost byte set to 0)
3E2	ASL	ASL	LSHFA	TEF	;shift A left by one nybble (rightmost byte set to 0)

TEF TWO BYTE

062,082	A=B	A=B	A=B	TEF	;copy B[TEF] into A[TEF]
0E2,0C2	B=C	B=C	B=C	TEF	;copy C[TEF] into B[TEF]
0A2,102	C=A	C=A	C=A	TEF	;copy A[TEF] into C[TEF]

JUMPING INSTRUCTIONS

There are duplicate mnemonics for three of the HP jump instructions. GONC is the same as GOTO, GSUBNC is the same as GOSUB, and GOLNC is the same as GOLONG. HP's assemblers will check the instruction proceeding a GOTO, GOSUB or GOLONG to be sure that it cannot set the carry. This insures that these mnemonics cause an unconditional jump and not a just a jump on no carry. ASDT does not do this and assembles the duplicates exactly the same.

SHORT JUMPS

```
007         GOC     JC      JC      -64 to +63 (dec)    ;short relative jump on carry
003         GONC    JNC     JNC     -64 to +63 (dec)    ;short relative jump on no carry
```

LONG JUMPS

```
001,000     GSUBNC  NCXQ    ?NCXQ   ADDRESS            ;execute on no carry
001,001     GSUBC   CXQ     ?CXQ    ADDRESS            ;execute on carry
001,002     GOLNC   NCGO    ?NCGO   ADDRESS            ;goto on no carry
001,003     GOLC    CGO     ?CGO    ADDRESS            ;goto on carry
```

QUAD RELATIVE JUMPS

```
349,08C,000 GSB41C  NCXQREL ?NCXQREL ADDRESS           ;execute relative to current quad
341,08C,000 GOL41C  NCGOREL ?NCGOREL ADDRESS           ;goto relative to current quad
```

The HP instructions GSBSAM and GOLSAM are three byte jumps just like GSB41C and GOL41C, but they are limited to jumping into the current 1K quad. ASDT does not implement GSBSAM and GOLSAM since GSB41C and GOL41C are assembled intelligently by ASDT to use the same-quad mainframe routines if they can or else use the quad-specific mainframe routines.

The following tables show which addresses are used to decide which quad relative routines to assemble to.

Quad Relative Branch Instruction Bytes

	Quad 0	Quad 1	Quad 2	Quad 3	Same Quad
	0-3FF	400-7FF	800-BFF	C00-FFF	
NCXQREL	349 08C	36D 08C	391 08C	3B5 08C	379 03C
NCGOREL	341 08C	365 08C	389 08C	3AD 08C	369 03C

* These are followed by the third byte containing the low 10 bits of the address to jump to.

Actual Instruction for Quad Relative Branches

	Quad 0	Quad 1	Quad 2	Quad 3	Same Quad
NCXQ	[GOSUB0]	[GOSUB1]	[GOSUB2]	[GOSUB3]	[GOSUB]
(Address)	23D2	23DB	23E4	23ED	0FDE
NCXQ	[GOL0]	[GOL1]	[GOL2]	[GOL3]	[GOLONG]
(Address)	23D0	23D9	23E2	23EB	0FDA

Actual Instruction in HP mnemonics

	Quad 0	Quad 1	Quad 2	Quad 3	Same Quad
GOSUB	[GOSUB0]	[GOSUB1]	[GOSUB2]	[GOSUB3]	[GOSUB]
GOSUB	[GOL0]	[GOL1]	[GOL2]	[GOL3]	[GOLONG]

Note that the actual instruction is always NCXQ to the appropriate label and the mainframe routine at the label determines if a return will be pushed or not making either a NCXQREL or a NCGOREL. You can't use a NCGO or a CGO to jump to one of these routines because these instructions do not push the return address, which is needed to know which page the jump was in.

It is possible to make a three byte jump that jumps on carry using CXQ [FOOBAR]. These are not really useful since the carry must always be set or the program will execute the third byte of the jump instruction after skipping the first two. Likewise, never set the carry before a NCGOREL or NCXQREL. The address that is pushed on the return stack for a three byte jump is the address to the THIRD word, so if the jump crosses a quad boundary, it will jump into the quad that contains the third word.

FAT DEFINITION

```
000,100     DEFP4K   DEFP4K   DEFP4K   ADDRESS          ;Obsolete
000,000     DEFR4K   DEFR4K   DEFR4K   ADDRESS          ;define MCODE function in same 4K ROM
000,000     DEFR8K   DEFR8K   DEFR8K   ADDRESS          ;define MCODE function in next 8K ROM
200,000     U4KDEF   U4KDEF   U4KDEF   ADDRESS          ;define USER CODE function in same 4K ROM
200,000     U8KDEF   U8KDEF   U8KDEF   ADDRESS          ;define USER CODE function in next 8K ROM
```

RETURN STACK AND RETURNS

```
1E0         GOTOC    GTOC     GOTOADR                  ;jump to the address in C[6:3]
170         STK=C    STK=C    PUSHADR                  ;push C[6:3] onto the return stack
1B0         C=STK    C=STK    POPADR                   ;pop the return stack into C[6:3]; put 0 in last location of stack
020         SPOPND   CLRRTN   XQ>GO                    ;pop first address off return stack
360         RTNC     CRTN     ?CRTN                    ;return if carry set
3A0         RTNNC    NCRTN    ?NCRTN                   ;return if carry not set
3E0         RTN      RTN      RTN                      ;unconditional return
```

PERIPHERAL INSTRUCTIONS

Peripheral addresses for PERSLCT
00 No peripheral enabled
FB Timer
FC Card Reader
FD Display
FE Wand
10 Special display for halfnut versions

PERIPHERAL ACCESSING

```
3F0         PFAD=C   PERSLCT  PRPHSLCT                ;select the peripheral addressed in C[1:0]
024         SELPF    PERTCT   SELPF    0 to F (hex)    ;allow peripheral to take control
```

PERIPHERAL FLAGS

```
02C         FLG=1?   ?PF      ?FI=     0 to 13 (dec)   ;set carry if peripheral flag set
02C         ?F3=1    ?PF 3    ?FI= 3                   ;set carry if peripheral flag 3 set
06C         ?F4=1    ?PF 4    ?FI= 4                   ;set carry if peripheral flag 4 set
0AC         ?F5=1    ?EDAV    ?FI= 5                   ;set carry if peripheral flag 5 set
0EC         ?F10=1   ?ORAV    ?FI= 10                  ;set carry if HP-IL output register available
12C         ?F8=1    ?FRAV    ?FI= 8                   ;set carry if HP-IL frame available
16C         ?F6=1    ?IFCR    ?FI= 6                   ;set carry if HP-IL interface clear received
1AC         ?F11=1   ?TFAIL   ?FI= 11                  ;set carry if timer clock access failure
22C         ?F2=1    ?WNDB    ?FI= 2                   ;set carry if wand has data in wand buffer
26C         ?F9=1    ?FRNS    ?FI= 9                   ;set carry if HP-IL frame not received as sent
2AC         ?F7=1    ?SRQR    ?FI= 7                   ;set carry if service request received
2EC         ?F13=1   ?SERV    ?FI= 13                  ;set carry if service request
32C         ?F1=1    ?CRDR    ?FI= 1                   ;set carry if card reader flag set
36C         ?F12=1   ?ALM     ?FI= 12                  ;set carry if alarm due
3AC         ?F0=1    ?PBSY    ?FI= 0                   ;set carry if peripheral flag 0 set
```

DISPLAY INSTRUCTIONS

Zencode display instructions:
WR/RD - Write/Read
A/B/C - to/from display registers A/B/C
1/4/6/12 - 1/4/6/12 characters to/from
R/L - Right/Left of display

Writing instructions cause the new characters to be pushed on the specified side which pushes the characters on the other end off into oblivion.

Reading instructions cause the characters to be taken off the specified side and pushed on the other side.

DISPLAY READING

```
038        FLLDA    RDA12L   FLLDA
078        FLLDB    RDB12L   FLLDB
0B8        FLLDC    RDC12L   FLLDC
0F8        FLLDAB   RDAB6L   FLLDAB
138        FLLABC   RDABC4L  FLLABC
178        READEN   READAN   READEN                ;copy annunciators into C[2:0]
1B8        FLSDC    RDC1L    FLSDC
1F8        FRSDA    RDA1R    FRSDA
238        FRSDB    RDB1R    FRSDB
278        FRSDC    RDC1R    FRSDC
2B8        FLSDA    RDA1L    FLSDA
2F8        FLSDB    RDB1L    FLSDB
338        FRSDAB   RDAB1R   FRSDAB
378        FLSDAB   RDAB1L   FLSDAB
3B8        RABCR    RDABC1R  RABCR
3F8        RABCL    RDABC1L  RABCL
```

DISPLAY WRITING

```
028        SRLDA    WRA12L   SRLDA
068        SRLDB    WRB12L   SRLDB
0A8        SRLDC    WRC12L   SRLDC
0E8        SRLDAB   WRAB6L   SRLDAB
128        SRLABC   WRABC4L  SRLABC
168        SLLDAB   WRAB6R   SLLDAB
1A8        SLLABC   WRABC4R  SLLABC
1E8        SRSDA    WRA1L    SRSDA
228        SRSDB    WRB1L    SRSDB
268        SRSDC    WRC1L    SRSDC
2A8        SLSDA    WRA1R    SLSDA
2E8        SLSDB    WRB1R    SLSDB
328        SRSDAB   WRAB1L   SRSDAB
368        SLSDAB   WRAB1R   SLSDAB
3A8        SRSABC   WRABC1L  SRSABC
3E8        SLSABC   WRABC1R  SLSABC
2F0        WRTEN    WRITAN   WRTEN                 ;copy bits from C[2:0] into annunciators
```

TIME MODULE

028	WRTIME	WTIME	WRTIME
068	WDTIME	WTIME-	WDTIME
0A8	WRALM	WALM	WRALM
0E8	WRSTS	WSTS	WRSTS
128	WRSCR	WSCR	WRSCR
168	WSINT	WINTST	WSINT
1E8	STPINT	STPINT	STPINT
228	DSWKUP	WKUPOFF	DSWKUP
268	ENWKUP	WKUPON	ENWKUP
2A8	DSALM	ALMOFF	DSALM
2E8	ENALM	ALMON	ENALM
328	STOPC	STOPC	STOPC
368	STARTC	STARTC	STARTC
3A8	PT=B	TIMER=A	PT=B
3E8	PT=A	TIMER=B	PT=A

TIME MODULE

038	RDTIME	RTIME	RDTIME
078	RCTIME	RTIMEST	RCTIME
0B8	RDALM	RALM	RDALM
0F8	RDSTS	RSTS	RDSTS
138	RDSCR	RSCR	RDSCR
178	RDINT	RINT	RDINT

CARD READER

028	ENWRIT	ENDWRIT	ENWRIT
068	STWRIT	STWRIT	STWRIT
0A8	ENREAD	ENDREAD	ENREAD
0E8	STREAD	STREAD	STREAD
168	CRDWPF	CRDWPF	CRDWPF
1E8	CRDOHF	CRDOHF	CRDOHF
268	CRDINF	CRDINF	CRDINF
2E8	TSTBUF	TSTBUF	TSTBUF
328	TRPCRD	SETCTF	TRPCRD
368	TCLCRD	TCLCTF	TCLCRD
3E8	CRDFLG	CRDEXF	CRDFLG

INTELLIGENT PERIPHERAL

200	HPIL=C	HPIL=C	HPIL=C	0 to 7	;copy C[1:0] to HP-IL register

VARIATIONS

062	BAEX	B<>A	B<>A	TEF
0A2	CAEX	C<>A	C<>A	TEF
0E2	CBEX	C<>B	C<>B	TEF
202	C=C+A	C=C+A	C=A+C	TEF
1D8	MCEX	M<>C	M<>C	
0F0	NCEX	N<>C	N<>C	

VARIATIONS AND DUPLICATES

2E2	C≠0?	?C≠0	?C≠0	TEF
2C2	B≠0?	?B≠0	?B≠0	TEF
302	A<C?	?A<C	?A<C	TEF
322	A<B?	?A<B	?A<B	TEF
342	A≠0?	?A≠0	?A≠0	TEF
362	A≠C?	?A≠C	?A≠C	TEF
370	C=C!A	C=CORA	C=CORA	
3B0	C=C.A	C=CANDA	C=CANDA	
3B8	FRSABC	RDABC1R	FRSABC	
0EC	ORAV?	?ORAV	?FI= 10	
12C	FRAV?	?FRAV	FRAV?	
16C	IFCR?	?IFCR	?FI= 6	
26C	FRNS?	?FRNS	?FI= 9	
2AC	SRQR?	?SRQR	SRQR?	
36C	ALARM?	?ALM	?FI= 12	
160	LLD?	?BAT	?LOWBAT	
120	P=Q?	?P=Q	?P=Q	
014	PT=?	?PT=	?R=	0 to 13 (dec)
001,000	GOSUB	NCXQ	?NCXQ	ADDRESS
001,002	GOLONG	NCGO	?NCGO	ADDRESS
003	GOTO	JNC	JNC	-64 to +63 (dec)
024	HPL=CH	PERTCT	SELPF	0 to F (hex)
384	S0= 0	CF 0	CLRF 0	
304	S1= 0	CF 1	CLRF 1	
204	S2= 0	CF 2	CLRF 2	
004	S3= 0	CF 3	CLRF 3	
044	S4= 0	CF 4	CLRF 4	
084	S5= 0	CF 5	CLRF 5	
144	S6= 0	CF 6	CLRF 6	
284	S7= 0	CF 7	CLRF 7	
104	S8= 0	CF 8	CLRF 8	
244	S9= 0	CF 9	CLRF 9	
0C4	S10= 0	CF 10	CLRF 10	
184	S11= 0	CF 11	CLRF 11	
344	S12= 0	CF 12	CLRF 12	
2C4	S13= 0	CF 13	CLRF 13	
388	S0= 1	SF 0	SETF 0	
308	S1= 1	SF 1	SETF 1	
208	S2= 1	SF 2	SETF 2	
008	S3= 1	SF 3	SETF 3	
048	S4= 1	SF 4	SETF 4	

088	S5= 1	SF 5	SETF 5
148	S6= 1	SF 6	SETF 6
288	S7= 1	SF 7	SETF 7
108	S8= 1	SF 8	SETF 8
248	S9= 1	SF 9	SETF 9
0C8	S10= 1	SF 10	SETF 10
188	S11= 1	SF 11	SETF 11
348	S12= 1	SF 12	SETF 12
2C8	S13= 1	SF 13	SETF 13
38C	?S0=1	?FS 0	?FSET 0
30C	?S1=1	?FS 1	?FSET 1
20C	?S2=1	?FS 2	?FSET 2
00C	?S3=1	?FS 3	?FSET 3
04C	?S4=1	?FS 4	?FSET 4
08C	?S5=1	?FS 5	?FSET 5
14C	?S6=1	?FS 6	?FSET 6
28C	?S7=1	?FS 7	?FSET 7
10C	?S8=1	?FS 8	?FSET 8
24C	?S9=1	?FS 9	?FSET 9
0CC	?S10=1	?FS 10	?FSET 10
18C	?S11=1	?FS 11	?FSET 11
34C	?S12=1	?FS 12	?FSET 12
2CC	?S13=1	?FS 13	?FSET 13