M aubert D evelopment G roup

META KERNEL

Manual

ROM Version 2.10 – Feb. 1998

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Using the Meta Kernel

1 Installation

Switch off your calculator by pressing  .

Put the ROM card into the slot 1 of the HP48 (it must be the port 1)

Turn the HP48 on.

After a short time, the **Meta Kernel** is installed:

2 General presentation

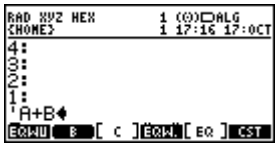
The **Meta Kernel** is an application card that changes the standard environment. A good knowledge of the standard environment is required, as the **MK** uses it, and adds several functions. Please read the HP48 GX User's Guide about it.

With the new stack display and command line, new utilities are provided:

3 Stack display

3.1 Display

The display is divided in three parts: (the command line belongs to the stack)



Command line →

← Status area

← Stack

← Menu

The stack and status area can be resized in height, see below.

3.1.1 Status area

RαZ ;RZ Rαα ;RZZ (0) ;# ▭ ;# ■ ;#The status area shows the current HP48 GX state.

Error messages, current path, calculator modes are displayed in this area.

Here are the new state flags:

DEG : Degrees	ALG : Algebraic entry mode	HEX : Hexadecimal base
RAD : Radians	PRG : Program entry mode	DEC : Decimal base
GRD : Grads	(0) : Beeper	OCT : Octal base
XYZ : Rectangular coordinates	HLT : A program has been halted	BIN : Binary base
RαZ : Polar coordinates	USR : User keyboard	▭ : ROM or write-protected RAM in port 2
Rαα : Spherical coordinates	1US : User keyboard for the next keystroke	■ : Read-write RAM card in port 2

The status area occupies two text lines by default. Its height can be changed to one or zero lines with the **MK** command →HEADER, consult Page 46.

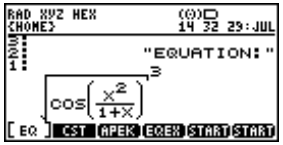
3.1.2 Stack

With the **MK**, up to nine lines can be viewed on the stack, as you can change the font height (6,7 or 8 pixels) and the status area height.

The maximum number of lines displayed by objects can be changed with →NDISP, consult Page 46.

More configuration capabilities are provided by the **Meta Kernel** system flags (**MK**SF), consult Page 14.

Algebraics and grobs may be displayed directly in the stack, use the **MK**SF to configure how and when they are displayed.



3.1.3 Menu labels

Menu-label style depends on the type of the stored object:

DIR Répertoire	PROG Programme, Code
GROB Grob	REAL Réel, complexe, expression algébrique, matrice
LIST Liste, variable, entier binaire	STRN Chaîne de caractères

By default, labels are written using the **MK** mini font. If the **MK** system flag -20 is set (with -20 SF2), standard menu font is used instead:

3.2 Display configuration

New display fonts can be created and used. The number of lines displayed on the stack differs with the font height.

With a font8 (8 pixels height), 5 to 7 lines may be viewed; with a font7, 6 to 8 lines ; with a font6, 7 to 9 lines.

3.2.1 Changing the display font

To use a different font, put it on the stack, and execute →FONT, consult Page 46.

Fonts are displayed on the stack like this:

Example: Ft8_0:SYSTEM 8, this is the standard display font for the **MK**.

The first number (8) is the font height in pixels, the second number (0) is the id of the font, then the name (SYSTEM 8).

Two examples with a font8 and a font6:

If the current font is a font6 (6 pixel-high), the **MK** system flags -8 and -9 force respectively the stack display and the command line to use the mini font:

3.2.2 Modifying the current font

The current display font may be modified with the CHARS menu (

). Consult Page 34.

On the floppy disk, there are two programs, named GRB2FNT.PRG and FNT2GRB.PRG, which convert **MK** fonts to or from common 8x2048 grobs. Consult Page 47.

3.2.3 Changing the mini font

It is possible to change the **MK** mini font, used in the status area and the menu labels.

Use the commands `MINIFONT→` and `→MINIFONT`. A mini font is a `Library Data` object. This format is very popular in the HP48's world, in particularly with programs which use UFL (Universal Font Library). In order to know how to use the UFL with the **Meta Kernel** check the column Tricks and Tips.

4 Configuration

4.1 MK variables

Some programs can be executed on some events, in place of the default programs. They must be stored in the **HOME** directory.

STARTUP	Executed at each reboot (ON - c...).
STARTED	Executed just before entering in command line for editing an object. The object to be edited can be found on stack level 1. **This program must leave the object to be edited on the stack level 1.**
EXITED	Executed when the user stops the command line editing. Level 2 contains the object and level 1 **TRUE** if the user has pressed ENTER, or only **FALSE** for ON. For example, these two programs can be used to change the display while editing (try **STARTED: « 0 →HEADER »** and **EXITED: « 2 →HEADER »**).
STARTOFF	Executed when the automatic OFF is called, after a certain amount of idle time (You can make a screen saver! But remember the HP48 GX works on batteries...).
TOFF	Defines the amount of idle time before an automatic **OFF** (or **STARTOFF**). It must be a binary integer, in Ticks (1 s = 8192 Ticks).
STARTEXT	Contains a string that is the path (using the MASD syntax) to the entries points list. Example: **"4/DIR1/TABLE.EXT** **@"** will refer to the table TABLE.EXT in Port 4, in the backup DIR1 For more details, please read page 38.
STARTSEND	Used by the filer for file transfer. By default, Kermit is used. If **STARTSEND** exists, it is called with the object on level 2 and the name on level 1. Consult page 30.
STARTERR	Used for the error messages display. The error is found in two character strings on levels 2 and 1.
STARTEQW	Called by EQW (equation editor) when CST is pressed.
FILER.CUSTOM	Called by the Filer when CST is pressed.

4.2 MK user and system flags (MKUF, MKSF)

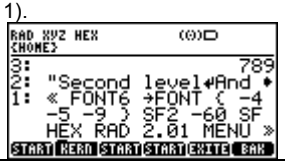
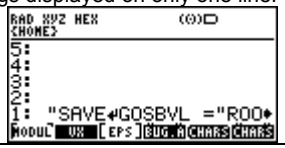
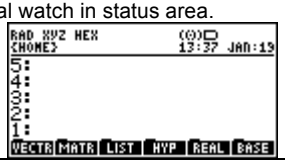
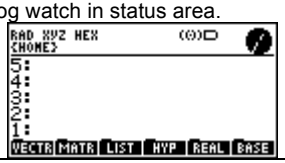
The **Meta Kernel** adds a new series of flags.

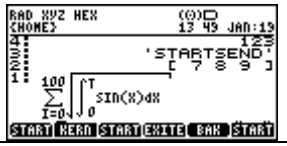
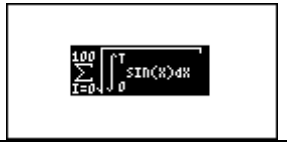
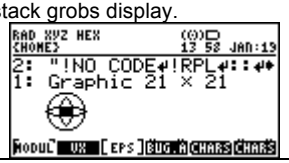
Use **CF**, **SF**, **FC?**, **FS?**, **FC?C**, **FS?C** like the functions **CF**, **SF** ...

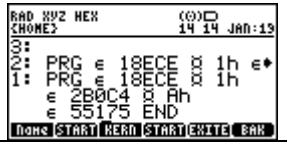
By default, all flags are cleared.

MK System flags -1 to -64 are used by the **MK** to change parameters.

MK User flags 1 to 64 can be used by any program that runs under the **MK**.

Flag	Cleared (CF)	Set (SF)
-1	Multiline for stack display at all levels. 	No multiline for stack display (except level 1). 
-2	Strings displayed on multiple lines. 	Strings displayed on only one line. 
-3	Digital watch in status area. 	Analog watch in status area. 
-4	No auto-indentation in command line editing.	Auto-indentation in command line editing.
-5	Cursor can not go out of the text.	Full page editing.
-6	Strings take only one line for **→GROB?**.	Multi-lines strings for **→GROB?**.
-7	**ASM→** with adresses.	**ASM→** without the adresses (makes labels).
-8	The current font is normally used in stack display. 	Mini-font in stack display (the current font must be a font6). 
-9	The current font is normally used in command line editing. 	Mini-font in command line editing (the current font must be a font6). 
-10	Rightmost stack display format. 	Leftmost stack display format. 
-11	Silent keystrokes.	Keystrokes click.
-12	Purge confirmation in the Filer.	No purge confirmation in the Filer.
-13	(Reserved for internal use).	
-14	(Reserved for internal use).	

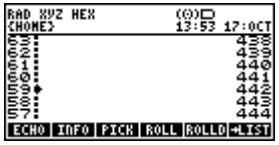
-15	On-stack algebraics display. 	Standard stack display for algebraics. 
-16	Current font for EQW stack display. 	Mini-font for EQW stack display. 
-17	Current font for algebraic →GROB2.	Mini-font for algebraic →GROB2.
-18	Current font for algebraics editing in EQW. 	Mini-font for algebraics editing in EQW. 
-19	On-stack grobs display. 	Standard stack display for grobs. 
-20	**MK** Mini-font menu labels. 	Standard menu labels. 
-21	Normal stack display 	Display the stack using the HP SysRPL syntax 
-22	→S2 adds "!NO CODE<CR>!RPL<CR>" at the beginning of the source, and "@" at the end. Therefor it can be use directly by MASD	→S2 just convert an object into SystemRPL without adding any header.

-23	The stack display is recursiv. When an object contains a reference to an other object, the stack displays it. 	The stack display is not recursiv. 
-24	Object display in the command line is not recursiv. 	Object display in the command line is recursiv (See flag –23) 
-25	In the normal stack display (-21 CF2), displays the addresses of all the unknown objects: 	If the address is in the Entries point table, then use the mnemonic: 
-26	The CHOOSE2 boxes use the current font 	The CHOOSE2 boxes use the mini-font. 
-27	The symbolic matrix writer will give an ARRAY only for the array of real and complex	Matrix Writer gives an array of ? for any object, each time the matrix contains objects of the same type. But beware of memory lost if you try to use a RPL command on it.
-28 à –64	Not used, reserved for future versions.	

5 Interactive stack

The interactive stack works the same way as the standard one, but at a greater speed, and it is possible to edit many objects simultaneously: in the command line editor, it is possible to go temporarily to the interactive stack, and to edit another object recursively. It is also possible to HALT an edition.

Current stack level →



Interactive Stack Operations: (*n* indicates the current level)

ECHO	Copies the current level object on the command line, at the cursor position.
INFO	Shows information about the current level object (size, CRC...).
← INFO	Edits the current level object with the best environment (EDITB).
→ INFO	Edits the object whose name is on the current level, with the best environment (VISITB).
PICK	Equivalent to *n* PICK.
ROLL	Equivalent to *n* ROLL.
ROLLD	Equivalent to *n* ROLLD.
→LIST	Equivalent to *n* →LIST.
DUPN	Equivalent to *n* DUPN.
DROPN	Equivalent to *n* DROPN.
LEVEL	Puts the number of the current level on level 1.
GOTO	Goes directly to a given level.
KEEP	Clears all the levels upper than the current level (Therefore it KEEPs the first stack levels up to the current one).
SLOW / FAST	Selects the cursor speed.

6 Command line

6.1 Generalities

The **Meta Kernel** improves editing with new functions: COPY/PASTE, FIND/REPLACE, text style (Bold, italic, underline, inverse).

Styles can only be used inside strings (they will be ignored and lost in any other object).

You can edit an object by pressing ← EDIT +/- when the object is on stack level 1. There are other ways to edit an object (explained after).

6.2 Editing menu

There are four pages in the menu, plus the Style menu.

6.2.1 Major options

GOTO	Goes to a given line number.
← GOTO	Goes to a given position (in number of characters from the beginning).
→ GOTO	Displays the menu of the text, which is composed of every line that begins with the character *, useful in assembly language.
⇤BEG	Goes to the beginning of the selection.
⇤END	Goes to the end of the selection.
DEL L	Clears the current line.
SLOW / FAST	Selects the cursor speed.
INFO	Displays information about the current text.
← INFO	Edits the selection with the best environment (EDITB).

6.2.2 Operations on the selection

Note: the selection marks are lost when the text is modified.

BEGIN	Sets the beginning of the selection.
END	Sets the end of the selection.
CUT	Copies the selection on the stack level 1, and clears it in the text.
COPY	Copies the selection on the stack level 1.
PASTE	Puts the object on the stack level 1 into the text at the cursor position.
← PASTE	Puts the object on the stack level 1 into the text at the cursor position, and deletes it from the stack.
DEL	Clears the selection.

6.2.3 Search operations

FIND	Displays a screen where you can type the search string. When you press enter, this string is put on stack level 1. The character ? stands for any character. Then the selection is placed on the first occurrence of this string after the cursor position.
REPL	Displays a screen where you can type the search string and the replace string. The search string is put on stack level 1, and the replace string on level 2. Then the selection is placed on the first occurrence of the search string. The change is not done yet !
NEXT	Selects the next occurrence of the search string (the string on stack level 1).
R	Replaces the selection by the replace string (the string on stack level 2).
R/N	Equivalent to R, then NEXT. So it makes one change, and goes to the next occurrence of the search string.
ALL	Equivalent to R and NEXT, repeated until the end of the text. So every occurrence of the search string is replaced by the replace string, from the cursor position to the end of the text, without confirmation.

6.2.4 Miscellaneous

⇤SKIP	Goes to the beginning of the previous word.
SKIP⇥	Goes to the beginning of the next word.
⇤DEL	Clears the text between the cursor and the beginning of the previous word.
DEL⇥	Clears the text between the cursor and the beginning of the next word.
Style	Displays the style menu.
↑STK	Goes to the interactive stack. Consult Page 16.
← ↑STK	EVALuates the selection and replaces it with the result. E.g. if 20 SIN is selected, it will be replaced by .342020143326.
→ ↑STK	Equivalent to HALT. The current editing is suspended, you can do what you want (except a reboot) and get back to the text with ← CONT ON.

6.3 Styles

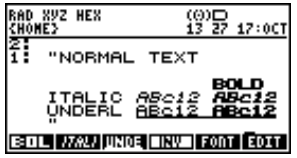
6.3.1 Generalities

Styles can be used inside text strings. There are four styles: Bold, italic, underlined, inversed.

Several styles can be used on the same portion of text.

More than one font can also be used in the same text (but they must have the same height).

6.3.2 Style menu



B-OL	Sets/clears the **bold** style.
/ITAL/	Sets/clears the *italic* style.
UNDE	Sets/clears the underlined style.

INV	Sets/clears the inversed style.
FONT	Displays the font list.
EDIT	Gets back to the Edit menu.

6.3.3 Using styles

You can modify the style of the current selected text by pressing a style menu key. If there is no selection, the text you will then type will be of the chosen style (If you move the cursor, the style will be the one under the cursor).

6.3.4 Using fonts

If you press the FONT menu key, a choose box shows all the fonts which have the same height as the current editing font.

If there is a selection, the font will be applied on this selection, otherwise it will be used for the text you will then type (If you move the cursor, the font will be the one under the cursor).

The **Meta Kernel** can use up to 247 fonts inside one text.

For a font to be recognized by the **MK** (so that it will appear in the FONT choose box), it just has to be saved in the HOME directory, or in a port (0, 2 to 31)

If several fonts use the same ID, the **MK** only takes the first one, in the order of the search (HOME, then 0, 2 ... 31). ID 0 is reserved for the system font. ID > 247 will be ignored.

Example:

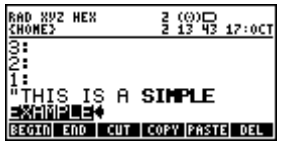
Type the text: `THIS IS A SIMPLE EXAMPLE`

Put the cursor on the 11th character (`S` in `SIMPLE`). Press the menu key BEGIN

Press ▶ six times. Press END

Go to the Style menu and press EDL

Now, select the word `EXAMPLE`



Go to the Style menu and press FONT (There may be other fonts than shown below)

Choose the font you want (here ROBOT 8) with the up and down arrows and press ENTER.

6.4 Miscellanous command line options

6.4.1 Full screen mode

By default, if you press the ▶ key at the end of a line, the cursor will be placed on the first character of the next line. With the **MK**, it is possible to go 'out' of the lines, with the **MK** system flag -5.

Type `-5 SF2` to enable the full screen mode (if you like this mode, a good idea is to place a `-5 SF2` in the program `STARTUP`).

If you go beyond the end of a line and press a character key, spaces will automatically be inserted before the character you type.

6.4.2 Auto-indent mode

By default, when you press ↵ to insert a carriage return, the cursor is then always placed on the first column of the display. The **MK** implements the auto-indent mode, so that when you type a carriage return, the cursor will be placed under the first character of the upper line (Useful when programming).

Type `-4 SF2` to enable auto-indent mode.

6.4.3 Special keystokes for System RPL

In the command line, some keystokes help to type characters that are specific to System RPL, and also to easilly find System RPL commands only by typing the first letters of the command.

These keystrokes are detailled on page 39.

6.4.4 Big strings editing

As specified in the HP48 GX User's Manual, you can not type character strings that are bigger than the half of the free memory.

The **MK** uses a new memory handler, so that when you edit strings (and only strings), you can have more characters than the half of the free memory, and still press ENTER, because the **MK** does not evaluate the string, but places it directly on the stack. You will never get an Insufficient Memory when validating a character string.

For other objects types, the **MK** built-in →STR will usually works if there is more or less as much free memory as the object size, so the object may be viewed. But when ENTER is pressed, the STR→ may have Insufficient Memory.

7 Command library

A command library is a special library which extends the **STRO** function. The **MK** command library adds new keywords (they can be typed on the command line and used in programs):

TRUE	External boolean true.
FALSE	External boolean false.
$ *binary*	External of the given address. E.g. **$ 3188h** (external **DUP**). To type **$**, press α ◀ 4.
∈ *Hexa*	External of the given address. **U 3188** is equivalent to **$ 3188h**. To type **∈**, press α ▶ E.
¤ *binary*	System binary of the given number. To type , press α ◀ 6.
K$ *number*	Character of the given ASCII code.
XLIB *LibNumber PrgNumber*	Program *#PrgNumber* of the library *#LibNumber*.
INCLUDE *VarName*	Includes a given variable content in the line.
PRG	External program beginning (**$ 02D9Dh**), a **END** must close the program.
~	NoEval (**$ 06E97h**), which causes the next object not to be evaluated. To type **~**, press α ▶ √x V.
PROG	**~ PRG** (To edit an external program, begin it with **PROG**, so it won't be evaluated when ENTER is pressed).
CODE *Hexa*	Creates a CODE object with the following binary data. Length is calculated.
OBJ *Hexa*	Creates an object with the following binary data.
GREY *X Y Hexa*	Creates a four-grayscale grob XxY.
∂ *Name*	Puts the address of the corresponding name, if it exists in the entry points table. Consult page 38. To type **∂**, press α ▶ D.

8 Equation editor

The program EQW can easily create, edit and manipulate algebraic objets, in their hand-written style.

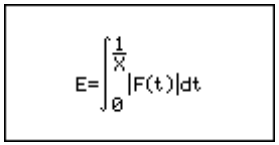
For example, here is a mathematical equation:

$$E = \int_0^{\frac{1}{X}} |F(t)| dt$$

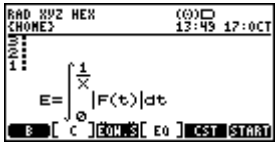
Here is how it usually appears on the stack:

```
E=∫(0,1/X,ABS(F(t)),t)
```

And now, here is the same equation typed with EQW:



This EQW display is also used in the stack display:



8.1 First view of EQW

In this document, ‘equation’ stands for all algebraic objects.

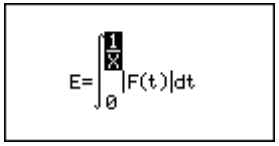
8.1.1 Introduction

EQW is a special environment in which the keyboard is redefined and limited to specific operations.

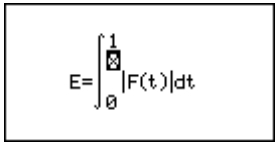
8.1.2 Modes

EQW provides three modes of operation:

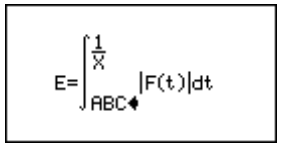
- Selection mode



or

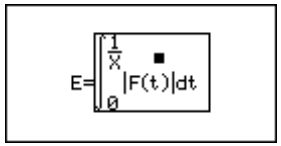


- Editing mode



In most cases, selection and edit modes are used to enter equations.

- Cursor mode, used to navigate rapidly through the equation.



8.1.3 Editing

During editing, keys behave in different ways, depending on the current mode.

In selection mode, a part of the equation is inverted or inboxed. If a function key is pushed, the function is applied on the selection.

In edit mode, a flashing cursor is ready to insert new characters.

The next sections explain how to enter and edit an equation.

8.2 Creating equations

8.2.1 Running EQW

Type [↩] [EQUATION] [ENTER] to run EQW with a new equation.

8.2.2 Exiting EQW

To validate the current equation on the stack, press [ENTER].

To get out of EQW, and lose all changes made on the equation, press [ON].

There may be some times when EQW can’t draw the equation as fast as you type, but all keystrokes are processed, none are lost. In this case, EQW draws the equation only when there is enough time to do so.

8.2.3 Numbers and names

Type real numbers and names the same way as in the command line.

In edit mode (with the flashing cursor), the character X is directly available by pressing [DEL].

Note: in EQW, the [α] key locks the alpha mode by pressing it once (corresponding to `-60 SF`). Therefore, to type a name, either hold [α] and press the character keys, or press [α] once, then press the character keys and press [α] to unlock the alpha mode.

8.2.4 Additions, subtractions, and multiplications

To enter +, − and ▪, press [+], [−] and [×].

The operation is applied on the edited number or name, or the current selection.

To enter implicit multiply, do not press [×]. An implicit multiply is automatically inserted in the following cases:

- A number followed by an alpha character or a prefix function (a function whose name is before arguments, for example [7] [SIN]).
- An alpha character followed by a prefix function.

8.2.5 Complex numbers and expressions

To enter a complex number or expression, type in the real part, then [←] [,] and then the imaginary part.

A complex expression is considered as a two-argument function (equivalent to +).

A complex number is stored directly in the final equation, whereas a complex expression like (A,B) is converted to A+B*i .

8.2.6 Moving in the equation

Before going further, here are the movement keys. In fact, entering an equation with EQW is not far from the RPN way: no parenthesis are needed. For example, to type (X+5)·2, press [α] - [1/x] [+] [5], then select X+5 by typing [▲], and then type [×] [2]. See the examples at the end of this chapter to handle more cases.

Arrow keys move the selection. They behave different ways, depending on the type of selection.

Here are the movement keys when the selection is inverted:

- [▼] selects the first argument of the current function, or if the selection is already a number or a name, then selection becomes a box.
- [▲] selects the upper function of the selection.
- [◀] and [▶] select the previous or next argument of the upper function.

Here are the movement keys when the selection is in a box:

- [▲] goes back into inverted selection mode.
- [◀] and [▶] select the previous or next number or name, in hierarchical order. This keys are useful to rapidly move around the whole equation.

To rapidly select a part of the equation, even far from the selection, use the cursor mode (see the Cursor Mode section).

8.2.7 Divisions

Press [÷] to insert a division.

Division is applied on the edited object or the current selection.

To 'go out' of the division, use [▲] or [▶] until the whole division is selected.

8.2.8 Exponents

[y^x] begins the exponent on the edited object or the selection.

Use [▲] or [▶] to go out of the exponent.

8.2.9 Square root

- In selection mode, [√x] applies a square root on the selection.
- In edit mode, [√x] inserts a square root, eventually with an implied multiply.

8.2.10 Nth square root

- In selection mode, [→] [$\sqrt[x]{y}$] places the selection under the root. Press [◀] and type the outside term. To exchange the two arguments, read the Modifications section.
- In edit mode, [→] [$\sqrt[x]{y}$] inserts a root. Type the outside term. Press [▶] and then type the inside expression.

8.2.11 Parenthesized-argument functions

- In selection mode, press the function key to apply it on the selection. If the function needs more than one argument, the selection is used as the first one. press [▶] to go and type the next arguments.
- In edit mode, press the function key or type its name followed by [←] [( )] [÷], and then the arguments.

8.2.12 User functions

These functions are created by the user and are not handled directly by the HP 48GX.

Type the function name, press [←] [( )] [÷] and type the first argument.

To add an argument, press [SPC].

8.2.13 Parenthesized terms

EQW draws equations with the fewest possible parentheses. To add explicit parentheses around the selection, press [←] [( )] [÷].

8.2.14 Differentiations

- In selection mode, press [→] [∂] [SIN] to insert a differentiate sign, the selection is the function to be differentiated. Press [◀] and type the variable of differentiation.
- In edit mode, press [→] [∂] [SIN] to insert a differenciate sign, type the variable of differentiation, press [▶] and type the equation to be differentiated.

See the Evaluations section to discover how to differentiate a function without exiting from EQW.

8.2.15 Integrations

- In selection mode, press [→] [∫] [COS] to add an integral sign. The current selection is the equation to be integrated. Press [◀] and [▶] to move around the integral arguments and type them.
- In edit mode, press [→] [∫] [COS] to insert an integral sign. Type the arguments, press [▶] to move to the next one.

8.2.16 Summations

- In selection mode, press [→] [Σ] [TAN] to add a summation sign. The selection is the function to be summed. Press [◀] and [▶] to move around the arguments and type them.

- In edit mode, press [→] [Σ TAN] to insert a summation sign. Type the arguments, press [▶] to move to the next one.

8.2.17 Where function |

- In selection mode, press [α] [→] [VAR] to add a where function. The current selection is the base expression. Press [▶] to move to the next argument (the variable and its value).
- In edit mode, press [α] [→] [VAR] to insert a where sign. Type the arguments, press [▶] to move to the next one.

8.3 Manipulating equations

8.3.1 Modifying equations with EQW

To edit an equation with EQW, press [▼] when the equation is on level 1 of the stack.

8.3.2 Modifications

To edit a variable name or a bigger expression with the command line editor, select it and press [←] [EDIT +/-].

It can also be edited with HP's EQUATION WRITER by typing [←] [EQUATION ENTER].

8.3.3 Temporary exit to the stack

It is possible to go temporarily to the stack by pressing [←] [CONT ON]. Press [←] [CONT ON] again to get back to EQW, in the same state as before halting.

8.3.4 Copy paste functions

Copy and paste functions are available. SUB copies the selected expression on the stack. REPL pastes the expression on level 1 either onto the selection, or where the edit cursor is. These commands are accessible in the menu or on keyboard:

Sub : [→] [RCL STO],

Repl : [←] [DEF STO].

8.3.5 Deletions

There are different ways to delete a part of an equation.

- In selection mode, typing numbers or characters suppresses the current selection. To enter a new expression that does not begin with a number or a name, pressing [←] [DROP ◀] deletes the selection and goes into edit mode.
- To delete a one-argument function, just select this function and press [DEL].
- To delete one argument of a two-argument function, select it and press [←] [CLEAR DEL].
- Press [→] [CLEAR DEL] to delete all arguments but the one selected.

8.3.6 Evaluations

Selected expressions can be processed by RPL commands `EVAL`, `COLCT` and `EXPAN`. The result replaces the old selection. These commands are accessible through menus or on keyboard:

Eval : [EVAL],

Colct : [←] [▼],

Expan : [←] [▲].

8.3.7 Custom program evaluation

An external program may be applied on the current selection. By pressing [CST], the program `STARTEQW` situated in the HOMEDIR is called, with the current selection on the stack level 1. This program must return the new expression on the stack level 1.

For example, the following program transforms all the INV functions by 1/ :

```
« « 'INV(&X)' '1/&X' » ↑MATCH DROP »
```

8.4 Cursor mode

8.4.1 Switching to cursor mode

To get into cursor mode, press ['].

8.4.2 Movement

Arrow keys direct the cursor movement. The movement is faster when [←] is held. To go directly to a border, hold [→] and press one arrow key.

When the cursor stops, a box is drawn around the underlying expression.

8.4.3 Exiting cursor mode

There are two ways to return to selection mode.

['] returns to the same state prior to entering in cursor mode, whereas [ENTER] makes the expression under the cursor (which appears in a box) the new selection. This is a fast way to select a particular part of an equation.

8.5 Miscellaneous functions

8.5.1 Menu use

To show the menu, press a menu key, or [NXT]. The menu may be hidden by pressing [→] [MENU NXT] . When switching to cursor mode, the menu is automatically hidden.

8.5.2 Zoom

EQW can draw the equation using the system mini-font, by pressing [PRG] or [ZOOM]. This key can be used in any mode. A second keystroke returns to the stack font.

8.5.3 -→Grob

The current selection may be pushed onto the stack as a graphic object by pressing [STO] or [→Grob]. This function is the same as the RPL command `0 →GROB2`.

8.6 Error messages

An error message remains displayed as long as a key is pressed, to keep from destroying the expression.

`Incomplete`	One cannot exit from EQW, or perform certain functions when the

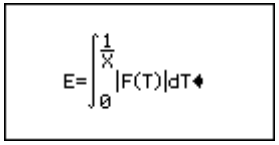
Expression	equation is not complete.
Global Expected	For some functions (e.g. differentiate, integrate), one of the arguments must be a variable name.
First Argument Missing	Two-argument functions must be typed after the first argument.
Two Arguments Expected	↶ CLEAR DEL (One argument delete) must be applied on a two-arguments or user function.
Edit Mode	RPL commands (EVAL, COLCT...) require selection mode.
1 Arg Function Needed	DEL must be used on a one-argument function like SIN.
Select An Argument	↷ CLEAR DEL can not be used on the whole equation.
Algebraic Expected	To paste an expression, the first level of the stack must contain an algebraic object.
Too Few Arguments	The stack is empty.
Command Forbidden	RPL commands like SWAP, DUP... are forbidden in equations.

8.7 Examples

$$E = \int_0^{\frac{1}{X}} |F(t)| dt$$

Press:

E=∫(α - E ↶ = 0 ↷ ∫ COS
0,1/X 0 ▶ 1 ÷ DEL ▶
ABS(α - A B SIN S ↶ ( ) ÷
F(T α F ↶ ( ) ÷ α - COS T ▶
dT α COS T



ENTER

```
1: E=∫(0,1/X,ABS(F(T)),T)
```

$$\partial x\left(\frac{\cos x}{\sin^2 x}\right)$$

Type the expression:

COS(X) COS DEL ▶
/SIN(X) ÷ SIN DEL
^2 ▶ y^x 2
∂ ↷ ▲ ↷ SIN DEL ▲ ▲

Save it on the stack:

MTH NXT Sub

Differentiate it:

EVAL EVAL EVAL EVAL

Simplify it:

Expan Expan Colct

Rebuild the expression:

↶ = 0 Repl ↶ ◀

Change INV into 1/:

', move on the last INV, ENTER DEL ÷ 1 ▲ ↶ ▶

8.8 Key reference for EQW

8.8.1 Selection mode

	Inverted selection	Boxed selection
◀	Previous argument.	Previous variable or number.
▶	Next argument (if on last argument, go to upper function).	Next variable or number (if on last argument, go to upper function).
▲	Upper function.	Inverted selection.
▼	First argument of the selected function.	
↷ ◀	First argument.	
↷ ▶	Last argument.	
↶ ◀	Argument left roll.	
↶ ▶	Argument right roll.	
↷ ▲	Whole equation selection.	
↷ ▼	First name or number of the selection, boxed selection.	
↷ RCL STO	SUB, copies the selection to the stack.	

↶ ▲	EXPANDs the selection.
↶ ▼	COLCTs the selection.
EVAL	EVALuates the selection.
STO	→GROB on the selection.
↶ EDIT +/-	Line command editing.
↶ EQUATION ENTER	HP's Equation Writer editing.
↶ ( ) ÷	Adds/removes parentheses.
DEL	One-argument function deletion.
↶ CLEAR DEL	Argument deletion in a two-argument function or in a user function.
↷ CLEAR DEL	Deletes all but the selection.
←	Variable or name edition.
↶ DROP ←	Clears selection, goes into edit mode.
SIN, COS, TAN, √x…	Inserts a one-argument function.
↷ SIN, ↷ COS, ↷ ∜x…	Inserts a function, the selection becomes the first argument (except for ∫ and Σ where the selection becomes the main argument).
SPC	Next argument, or create another argument in a user function.
↶ , •	Creates a complex number, selection is the real part.
Digit, character	Deletes the selection, starts editing.

8.8.2 Edit mode

Digit, character	Adds a character; a number followed by an alpha inserts an implicit multiply.
DEL	Fast access to the character X (α not needed).
↶ ( ) ÷	Creates user function.
SPC	Next argument, or creates another argument in a user function.

8.8.3 Selection and edit mode - common keys

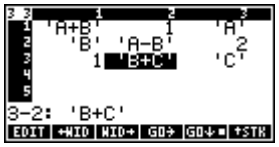
ENTER	Saves changes and exits.
ON	Discards changes and exits.
↶ CONT ON	HALT, temporary exit, a second ↶ CONT ON returns to EQW, at the same place.
↷ OFF ON	OFF.
PRG	Switches between stack font and little font.
MTH	Display the first page of the menu.
NXT	Menu, next page.
↶ PREV NXT	Menu, previous page.
↷ MENU NXT	Turn off the menu.
↶ DEF STO	REPLaces the expression from the stack in the equation.

8.8.4 Cursor mode

Arrows ◀, ▶, ▲, and ▼	Movement.
Arrows with ↶	Fast movement.
Arrows with ↷	Border movement.
'	Back in selection mode, no changes to the selection.
ENTER	Back in selection mode, the new selection is the part of the equation that is pointed to by the cursor.
ON	Discards changes and exits.

9 Matrix editor

The Matrix Editor is a matrix-oriented environment.



9.1 Presentation

The **MK** Matrix Editor can be used like the standard Matrix Writer, but it adds new features. Not only real and complex matrixes can be edited, but also symbolic, character strings, program, etc., arrays.

For example, here is how the following symbolic matrix:

'A+B'	1	'A'
'B'	'A-B'	2
1	'B+C'	'C'

is represented on the stack as a list of lists:

```
{{ 'A+B' 1 'A' }
 { 'B' 'A-B' 2 }
 { 1 'B+C' 'C' }}
```

To view and edit it under the Matrix Editor, press the down arrow ▼, or execute the command **EDITB**.

The symbolic Matrix Writer is powerful enough to manage any knid of datas. For example you can edit you contacts list.

With some external tools you can also transform the Symbolic Matrix Writer into a spreadsheet.

9.2 Usage

Two modes are available, one to create a new matrix, the other to edit an existing matrix.

To create a new matrix, press → MATRIX ENTER. An empty matrix is displayed, where any object can be entered. When ENTER is pressed, if all the elements in the matrix are of the same type, an **Array of *type*** is pushed on the stack (the content is displayed for real and complex numbers and strings), otherwise a list of list is created (this is a multi-typed array).

In the second mode, when an existing array is edited, if a new element is entered outside the matrix, the other empty cells will be filled with "null" elements corresponding to the matrix type (0 for reals, **""** for strings, **NOVAL** for multi-typed arrays, etc.).

*PS: For some security reasons, only arrays of real and complex are created. If you want to create an array of an other type, set the **MK** flag –27.*

9.3 Reference

9.3.1 Keys

Arrows ◀, ▶, ▲, and ▼	Movement.
Arrows with ↶	Page by page movement.
Arrows with →	Border movement.
DEL	Clears the current cell (fills it with the "null" element).

9.3.2 Menu keys

EDIT	Edits the current cell in the command line editor.
↶ EDIT	Edits the current cell in the best environment (**EDITB**).
+WID	Makes the cells narrower and displays one additional column.
WID→	Makes the cells wider and displays one less column.
GO→■ / GO→	If the box is visible, makes the cursor move to the next column after entry (on by default).
GO↓ / GO↓■	If the box is visible, makes the cursor move to the next row after entry.
FAST / SLOW	Selects the cursor speed.
+ROW	Inserts a row of "null" elements.
-ROW	Deletes the current row.
+COL	Inserts a column of "null" elements.
-COL	Deletes the current column.
→STK	Copies the current cell to stack level 1.
↶ →STK	Copies the object on stack level 1, to the current cel
↑STK	Activates the interactive stack.
BEGIN	Set the selection's upper left corner
END	Set the selection's lower right corner
COPY	Copies the selection on the stack level 1 as a symbolic matrix
PASTE	Copies the matrix on the stack level 1 to the current position
DEL	Erase the selection

10 Grob editor (Picture2)

PICTURE2 creates and modifies graphic objects, similarily to PICTURE, but is more powerful for bitmap creation. Grobs can be in two or four-level grayscale, and every drawing is made in real-time, with or without zoom.

10.1 Usage

In this part, basis functions will be used to create a sample grob. See the reference part for a complete list of functions.

First create a four-level grayscale grob. Type `GREY 131 64` ENTER

The blank grob is displayed on the stack.

Then edit it. Press ▼

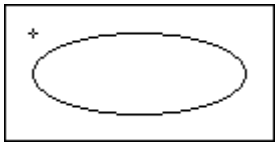
There are two ways to use PICTURE2 functions.

- Using the menu. To display the menu, press −. NXT and ← PREV NXT cycle through the menu pages.
- With Shortcut keys. Hold α and press the first letter of a function to launch it. When you don't know the letter corresponding to a function, search the function in the menu, the shortcut letter is displayed bold.

Now draw an ellipse, using the menu. Press − to display the menu if necessary. The ellipse is called by the menu key ELLIPS. Press − to hide the menu.

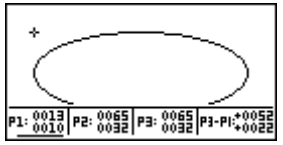
To call an ellipse with the shortcut keys, hold α and press E (E for Ellipse, remember the bold E on the menu key).

The ellipse can be shaped, using the arrow keys.



Press EEX Z anytime to Zoom. Press EEX Z a second time to get back to the normal view.

Press + to display the cursors coordinates.



There are three coordinates shown: P1, P2 and P3. P1 is the current cursor position (it is underlined). To put the cursor on one coordinate, press 1, 2 or 3. In the case of the ellipse, P3 is the center of the ellipse, and P1 is a corner of the enclosing box. P2 is not used.

When the ellipse is correctly positioned (with P1 and P3), it is necessary to fix it on the grob. With no menu displayed, press:

A to fix it in white,

B to fix it in light gray (white for a two-level grayscale),

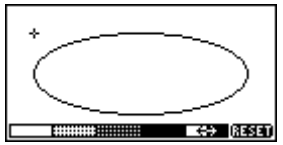
C to fix it in dark gray (black for a two-level grayscale),

D to fix it in black,

E to fix it in XOR mode (every pixel of the ellipse will be the opposite of the underlying pixel).

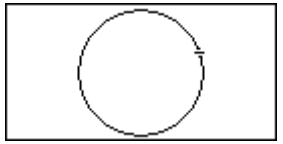
Or press ← or F to cancel the ellipse.

These color keys are displayed in the third page of the menu:

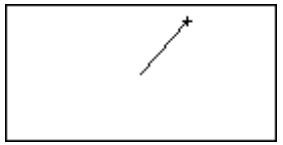


The other simple shapes are: (with the α shortcut keys):

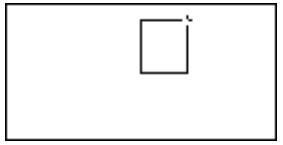
C Circle. P3 is the center and P1 is a point of the circle.



NXT L Line. P1 and P3 are the two ends.

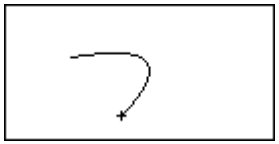


B Box. P1 and P3 are two opposite corners.

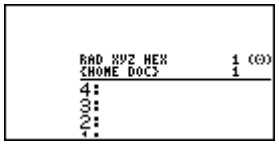


◀ P Plan (filled box). P1 and P3 are two opposite corners.

SIN S Spline curve. P1 and P3 are the ends, P2 is the tangential point.



MTH G GXOR. Merges another grob, see the reference part (here with a **LCD0** grob).



A surface can be filled with a given color: Place the cursor on the surface to be filled, press α - F (Fill), and then, in case of a four-level grayscale grob, the corresponding color key A, B, C or D. A pattern can be used to fill a surface, see the reference part.

To leave a trail behind the cursor (like DOT+), press a color key A, B, C, D or E. To stop the trail, press ◀.

To change only one pixel, press MTH G, PRG H, CST I or VAR J, corresponding to the color keys A, B, C, D.

To exit, press ON, the modified grob will be put on the stack.

10.2 Reference

10.2.1 Commands

These commands can be typed in the command line, or called from RPL programs.

PICTURE2	The graphic editor which works with the PICT.
EDITB	The graphic editor which works with the grob on stack level 1.
→PICT	Stores the grob on stack level 1 in the PICT (like **PICT STO**, but it also works the four-level grayscale grobs).
PICT→	Puts the current PICT grob on the stack.
?GREY	If the grob on stack level one is in four-level grayscale, returns 1, else 0.
GBLANK	Equivalent to **BLANK**, but creates a four-level grayscale grob.
→GREY	Takes two B&W grobs on the stack and creates one four-level grayscale grob with them. The grob on level 2 defines the low-weighted bits (a pixel in this grob becomes a light gray pixel in the gray-grob, a pixel in the grob on level 1 becomes a dark gray pixel in the gray-grob; if both or set, they become a black pixel). To convert a two-level grayscale grob into a four-level one, type **DUP →GREY**.
GREY→	Contrary of **→GREY**, takes a four-level grayscale grob and returns two B&W grobs.

10.2.2 Keys

ON	Exits PICTURE2.
↱ OFF ON	Switches off the calculator.
+	Switches on or off the menu display.
−	Switches on or off the coordinates display.
1	Position the cursor at P1, and set P1 as the current cursor.
↰ 1	Stores the current cursor position in P1.
↱ 1	Position the cursor at P1.
2	Position the cursor at P2, and set P2 as the current cursor.
↰ 2	Stores the current cursor position in P2.
↱ 2	Position the cursor at P2.
3	Position the cursor at P3, and set P3 as the current cursor.
↰ 3	Stores the current cursor position in P3.
↱ 3	Position the cursor at P3.
•	Inverts the color of the pixel under the cursor.
×	Copies P1 coordinates in P3.
÷	Switches between P1 and P3 as cursor (No effects if P2 is the current cursor).
ENTER	Puts the cursor coordinates on the stack, as a complex number.
↰ ENTER	Puts the cursor coordinates on the stack, as a list of two binary numbers.
↱ ENTER	Does a SUB. The grob enboxed between P1 and P3 is put on the stack, as a grob.
◀	Cancels the current shape (line, circle...) and returns to normal cursor mode.
↰ CLEAR DEL	Clears the whole grob.
EEX Z	Switches between the zoomed and the normal view.
STO	Puts the current grob on the stack.
Arrows ◀, ▶, ▲ and ▼	Cursor movement.
↰ +Arrows	Page by page cursor movement.
↱ +Arrows	Position the cursor on a border.
NXT −	Menu keys.
A	In cursor mode, DOT+ in white. In shape mode, fixes the shape in white.
B	In cursor mode, DOT+ in light gray (white in B&W). In shape mode, fixes the shape in light gray.
C	In cursor mode, DOT+ in dark gray (black in B&W). In shape mode, fixes the shape in dark gray.

D	In cursor mode, DOT+ in black. In shape mode, fixes the shape in black.
E	In cursor mode, DOT+ in XOR mode. In shape mode, fixes the shape in XOR mode.
↩ E	like E, but only inverses the high-weighted bit plan (try it!).
F	Cancels the current shape and returns to normal cursor mode.
MTH G	Puts a white pixel.
PRG H	Puts a light gray pixel (white in B&W).
CST I	Puts a dark gray pixel (black in B&W).
VAR J	Puts a black pixel.

10.2.3 ALPHA keys

To use these keys, hold α down.

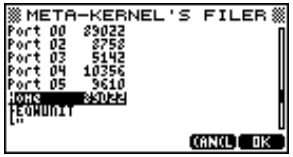
1	Suspends the current editing, and edits the grob found on stack level 1 (Useful to edit a pattern for a pattern fill). Press ON to return to the other grob editing.
B	Box. P1 and P3 are two opposite corners.
C	Circle. P3 is the center, P1 is a point on the circle.
D	Executes the program stored in DOPICT.
E	Ellipse. P3 is the center, P1 is a corner of the enclosing box.
F	Surface Fill. In B&W, inverses the surface color. In grayscale, the wanted color must be then defined with A, B, C, or D. Press F or ← to cancel.
▲ K	Goes to the interactive stack. Press ON to return to PICTURE2.
NXT L	Line. P1 and P3 are the ends.
' M	Pattern fill (*Motif*). The pattern must be a 8x8 grob found on the stack level 1, in B&W or in grayscale.
◀ P	Filled box (Plan). P1 and P3 are two opposite corners.
▶ R	REPL. Takes the grob on stack level 1. It may be positioned with the arrow keys. It is validated by pressing: C does a REPL and drops the grob. D does a GOR and drops the grob. E does a GXOR and drops the grob. F or ← cancels.
SIN S	Spline curve. P1 and P3 are the ends, P2 defines the tangent lines.

11 Filer

The Filer is a file utility that eases directory and port access.

Press [→] MEMORY [VAR] to execute it. The first screen lets you choose the directory.

11.1 Ports and directories screen



The tree screen shows a list of ports and directories.

Press [▲], [▼] to go throughout the list.

Press [▶], [ENTER] or [OK] to go in the selected location.

Press [ON] or [CANCL] to exit to Filer.

11.2 File selection screen

On this screen are shown: the free memory, the total size of the selected files, a list of files and the menu.

Press [▲] and [▼] to move in the file list.

In each line, there are five fields: the selection number (if the object is selected), an icon depending on the file type, the name, the type and the size of the file.

Press [ENTER] to select or deselect a file.

Press [▶] on a directory or a library to go into it.

Press [◀] to go out of the current directory of library.

For all the commands that require a list of files, if there is no selection, the current line will be taken as the selection.

You can change the header in order to display the number of objects available and the working path (here port 0 home): [→] MENU [NXT]

To hide the type and the size of every objects press [VAR]

11.3 Menu

Some commands work only in a special mode, for example only in the HOME directory. When you try to run these commands in an incorrect mode, a beep is produced.

EDIT [←] EDIT [+/-]	Edits the current object.
COPY	Copies the selected objects. You define the destination with the tree screen: select the destination (a port or a directory) and press [ENTER] or [OK].
MOVE	Moves the selected objects to the destination you selects in the tree screen.
RCL [→] RCL [STO]	Puts the selected objects on the stack.
INFO [α] [CST]	Gives information about the current object: Name, type, size, address, CRC.
ARBO [→] [◀]	To go to the tree screen.
PURG [←] PURG [EEX]	Clears the selected objects. If the **MK** flag –12 is clear (default) you will be prompt for a confirmation
RENAM	Renames the current object. This command is available only in the VAR
ORDER [α] [EVAL] 0	Orders the selected files in the order of the selection. The other files follow.
EVAL [EVAL]	Evaluates the current object (Some programs that normally do not work in port 2, can work using this command).
SEND	Sends the selected files with KERMIT, with the current I/O settings. If the variable **STARTSEND** exists in the HOME directory, it is used to send the files (level 2: the object, level 1: the name).
HALT [α] [◀] P	Supend the Filer and return to the RPL stack
HEXA	Goes to the hexadecimal editor, at the beginning of the current object.
VIEW	Views the current file if it is a string.

α √x V	
EDITB CMD +/-	Edits the current object with the best environment.
CUSTO CST	Starts the curstom mode if the FILER.CUSTOM is defined
HEAD MENU NXT	By default, the Filer displays the memory available and the selected objets's number. It can display the number of objects and the working path

11.4 HEXA Editor

The screen shows 64 nibbles and their ASCII value. Each line represents 16 nibbles (separated by 8).

On the bottom of the screen are written the assembly instruction, and the RPL object at the current address.

Press ◄ and ► to go one nibble backward or forward. Press ▲ and ▼ to move by 16 nibbles.

11.4.1 Menu

FIND	Searches an hexadecimal string
NEXT	Searches the next occurrence.
GOTO	Goes to a given address.
PSOBJ	Pushes the current object on the RPL stack. This command is very useful to recover datas in a corrupted card ((`Invalid Card Data`)
PSADR	Pushes the current addres on the RPL stack as a binary integer
EXIT	Exits the Hexa Editor.

11.4.2 Keys

NXT	Jumps to the next assembly instruction.
VAR	Jumps to the next RPL object.
EDIT +/-	Goes in edit mode.

11.4.3 Edit mode

Very dangerous, use at your own risk !

Use the arrow keys to move, press a hexadecimal key from 0 to F to put the digit at the cursor position. Press EDIT +/- again to exit the Edit Mode.

Utilities

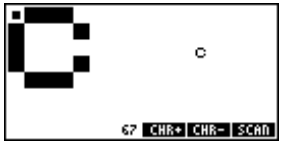
1 Font Editor (EDF)

EDF is a font editor. It is accessed throught the CHARS menu, where the current font can be edited. Any font can be edited by pushing it on the stack and pressing [▼].

1.1 Font editing

When EDF is launched, scan mode is active, the font is displayed on the screen and the cursor is moved by the arrow keys. The current character number is displayed on the bottom of the screen (here 67: C).

MODIF Switches to edit mode. On the left of the screen, the character is displayed eight times bigger, on the right in its normal size.



SCAN gets back to the CHARS mode.

The cursor is in the big character view, on the left. It is moved with the arrow keys, and [•] inverts the pixel under it.

1.2 CHARS mode

The chars mode is the default mode when EDF is launched. The cursor is moved by the arrow keys.

ECHO pushes the current character on the command line. Press [ON] to exit.

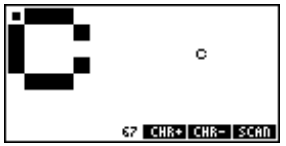
ECHO1 pushes the current character on the command line and exits to the command line.

1.3 A session with CHARS

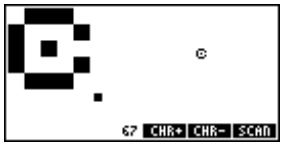
We will add a point inside the character C.

Press [⇨] [CHARS] [PRG] to enter in CHARS. Use the arrows to move to the C character:

Press MODIF to edit it:



Use the arrows to move to the center of the character, press [•] to put a point:



Press [ON] to return to the stack display. See how the C characters have changed.

Note that this only affects the current font. The next →FONT will destroy the changes. To make them permanent, do a FONT→ and store the changed font.

2 Machine Language Compiler (Masd)

2.1 Generalities on ML (Machine Language)

As the Saturn processor directly executes ML, the operating system can not control what a ML program is doing.

On the HP 48 calculator, user data are stored in the same area as temporary data. When there is a bug in a ML program, you have best chance to lost your data's. So be very careful when programming in ML.

ML is a processor dependent language, so what you will learn on the HP 48 will not be useful on other processor. On the other hand, the programming techniques you will acquire are not dependent of the hardware and then will be reusable.

2.2 Launching Masd

To compile a program, put the string on the top of the stack and type `ASM` or use the `ASM` menu of the `MDGK` library.

2.3 Generalities on Masd Syntax

Masd expects a character string (called source) on the top of the stack.

A source is a set of instructions, comments, and separation characters and ends with a carriage return and an arobas `@`.

Masd is case sensitive, so be careful, as « `boucle` » and « `BOUCLE` » are two different labels.

Separation characters are those with an ASCII number below 32. They include spaces, tabs, line feed and carriage return.

Some instructions need a parameter, called field. Separation characters between an instruction and the field, are spaces, tabs, and points. Therefore `A+B.A` can be used instead of `A+B A`.

Comments can be placed everywhere between two instructions. They begin with `%` or `;` and finish at the end of the current line.

Directives change the way Masd interprets your source. Theses instructions begin with a `!` and will be explained later.

While Masd is working, it displays messages on the screen to explain what is processed.

`Linking FileName`	Compiles the FileName file. The main file is called Main.
`Uplink`	Ends the compilation of a file.
`Compil. Glab`	Compiles global jumps.
`Compil. Exp`	Calculates expressions.
`Garbage`	Reconfigures the memory.
`Ghost LabelName`	Detects an unused label.

If Masd detects one or more syntax error, it will push a list describing all errors on the stack. This list is used by `ER` to find the location of errors, and let the user correct them.

Errors may be notified at the wrong place. For example if a label is not correctly defined, the errors will be located on the calling instructions.

2.4 Links

Links are source files that can be linked during compile time (equivalent to the {$I} directive in PASCAL and #include in C).

When a link call is encountered, Masd stops compiling the current link, compiles the new one and then continues compiling the first one.

Syntax:

`'FileName` links the file called FileName.

Note 1: A link can call other links.

Note 2: You can not use more than 256 links in your project.

Note 3: To know how Masd looks for files, see the File search section.

Note 4: Links are useful to cut projects in independent parts to allow fast and easy access to source code.

2.5 Using labels

A label is a marker in the program. The principal use of labels is to determine jump destinations.

A label is a set of less than 128 characters different from space, '`+`', '`-`', '`*`'and '`/`'. A label begins with a star '`*`' and ends with a separation character.

`*BigLoop` is the BigLoop label declaration.

Be careful about upper and lower cases!

Three types of labels can be used:

- Global labels

  A glocal label is a label that can be used everywhere in the project, like global variables in Pascal or C.

- Local labels

  A Local lab is a label that is only accessible in a local section like local variables in Pascal or C.

  A local section starts at the beginning of a source, after a global label, after a link (see link section) or after a `!LOCAL` directive.

  A local section finishes at the end of a source, before a link, before a global label or before a `!LOCAL` directive.

  A local label is identified by a '`.`' as the first character.

- Link labels

  A link label is a label that exists only in the link where it is declared, like a private clause in Object Pascal.

  A link label is identified by a '`_`' as the first character.

  Note 1: In projects, using less global labels is better because a global label is longer to compile and because it gives a better program structure. A good habit is to use global labels to cut the program in subroutines, and to use local labels inside these subroutines.

  Note 2: The **Meta Kernel** command line is able to find labels in a source. Press blue shift `GOTO`.

2.6 Using constants

It is possible to define constants. It is useful to identify a memory address by a name, rather by the address itself.

For example, instead of typing `D1=80100` every time it is needed, it is better to declare `DC Result 80100` at the beginning of the project and then to type `D1=(5)Result` when needed.

Constant declaration:

`DCE` *`CstName Expression`* or

`EQUE` *`CstName Expression`* or

`DEFINE` *`CstName Expression`*

`DC` *`CstName CstValue`* or `EQU` *`CstName CstValue`*

CstValue is a hexadecimal number. A decimal number can be typed with a leading `#` character.

`DC Foo 10` is same as `DC Foo #16`

Note 1: A constant cannot be given the same name as a declared label.

Note 2: The name of a constant follows the same rules as the name of a label.

Note 3: A constant value is always stored on 5 nibbles.

Masd introduces a 'programming register' called CP (Constant Pointer) which helps to define constants. CP is defined by:

`CP=`*`Cst`* or `CPE=`*`Expression`*

CP is defined on 5 nibbles, its initial value is 80100.

`DCCP` *`Increment ConstantName`*

declares a constant with the current CP value and then increase CP by Increment.

Note: Increment is a hexadecimal value, to use a decimal value, put a leading `#`.

For example, if CP equals to $10

```
DCCP 5 Foo
```

defines a Foo constant with a value of $10 and then change the value of CP to $15.

Several constants can be defined, starting from CP.

`:` *`Inc CstName0 CstName1`* ... *`CstNameN-1`* `:`

defines *N* constants CstName*x* with a value of CP+*x*Inc* and then changes the CP value to CP+*N*Inc*.

By default, *Inc* is a decimal number. It can be typed in hexadecimal, with a leading `$`.

2.7 Expressions

An expression is a mathematical operation that is calculated while compiling.

Terms of this operation are hexadecimal or decimal values, constants or labels.

An expression stops on a separation character.

```
DCCP 5 @Data
...
D1=(5)@Data+$10/#2 D0=(5)$5+DUP LC(5)"DUP"+#5
```

are correct expressions.

Notes:

- A hexadecimal value must begin with a `$` and a decimal value must begin with a `#`.
- The `&` character equals to the address of the current instruction in absolute mode, or to the offset of the current instruction in standard mode (This value has no meaning in itself, but may be used to calculate the distance between a label and the current instruction).
- The value of a label is the address of the label in absolute mode, or the offset of the label in the program in normal mode (This value has no meaning in itself, but may be used to calculate the distance between a label and the current instruction).
- Entries from the STARTEXT table may be used. In an ambiguous case (`DUP+#5` may either be an addition `DUP` + 5, or an entry '`DUP+#5`'), add `""` around the word: `"DUP"+#5`.
- There are no priorities (precedences) in operations. $1+$2*$3=$9 instead of $7. Use parenthesis to set precedences.
- You can't use more than three level of parenthesis.
- Calculations are done on 64 bits.
- X divide by 0 = $FFFFFFFFFFFFFFFF.
- By default, expressions are calculated at the end of the compilation of the project.
- Masd can be forced to compile expressions using the `!COMPEXP` directive. But be careful, if an expression uses a label that is not already declared, this will cause an error on the expression and not on the !COMPEXP directive.
- Masd can be forced to compile the last expression using the `!COMPEX` directive with the same remarks than for !COMPEXP. This can be useful when local labs are used in an expression.

2.8 Skips

Skips are a first step from ML to a third generation language, even if they are only another way to write SATURN instructions.

The basement of Skips is the Block structure.

A block is enclosed in `{` and `}`, and can be inside another block.

The following instructions deal with blocks.

SKIPS instructions	Equivalents
`SKIP { ... }`	`GOTO .S ... *.S`
`SKIPL { ... }`	`GOTOL .S ... *.S`
`SKIPC { ... }`	`GOC .S ... *.S`
`SKC { ... }`	`GOC .S ... *.S`
`SKIPNC { ... }`	`GONC .S ... *.S`
`SKNC { ... }`	`GONC .S ... *.S`
Test `SKIPYES { ... }`	Test `GOYES .S ... *.S`
Test `{ ... }`	Test `GOYES .S ... *.S`
Test `→ { ... }`	/Test `GOYES .S ... *.S`
`SKUB { ... }`	`GOSUB .S ... *.S`
`SKUBL { ... }`	`GOSUBL .S ... *.S`
`{ ... }`	Defines a block (generates no code)

`STRING { ... }`	`$/02A2C GOIN5 *.S ... *.S` (to create a character string)
`CODE { ... }`	`$/02DCC GOIN5 *.S ... *.S` (to create a code object)
`STROBJ` *`PROLOG`* `{ ... }`	`$/`*`PROLOG`* `GOIN5 .S ... *.S` (to create a 'prolog – length' object)

/Test is the opposite of Test. For example if Test is `?A<C.A`, /Test is `?A>=C.A`. The test instructions dealing with the hardware register (`?HST=0`, `?MP=0`, `?SR=0`, `?XM=0` and `?SB=0`) cannot be inversed.

Once blocks are defined, special instructions can be used in them. These instructions called EXIT and UP allow to jump to the end or to the beginning of a block.

These instructions	are equivalent to

`{`
`  EXIT`
`  EXITC`
`  EXITNC`
`  ?A=0.A`
`EXIT`
`  UP`
`  UPC`
`  UPNC`
`  ?A=0.A UP`
`}`
	`*.Beginning`
	`  GOTO.End`
	`  GOC.End`
	`  GONC.End`
	`  ?A=0.A →.End`
	`  GOTO.Beginning`
	`  GOC.Beginning`
	`  GONC.Beginning`
	`  ?A=0.A`
	`→.Beginning`
	`*.End`

Note: do not make confusion between EXIT and UP instructions, which are GOTOs, and EXIT and UP after a test, which are GOYES's.

EXIT and UP can jump to the beginning or to the end of an upper-level block by specifying the number of blocks to exit, after the UP or EXIT instructions.

These instructions	Are equivalent to

`{`
`  {`
`  {`
`  UP2`
`  UP3`
`  EXIT1`
`  EXIT3`
`  }`
`  }`
`}`
	`*.Beg3`
	`  *.Beg2`
	`  *.Beg1`
	`  GOTO.Beg2`
	`  GOTO.Beg3`
	`  GOTO.End1`
	`  GOTO.End3`
	`  *.End1`
	`  *.End2`
	`*.End3`

Note: EXIT1 is equivalent to EXIT, and UP1 is equivalent to UP.

Using SKIPELSE, SKEC or SKENC instructions, two blocks create an IFNOT-THEN-ELSE structure.

These instructions	Are equivalent to	Or in high-level language

`?A=0.A`
`SKIPYES`
`{`
`  EXIT`
`  UP`
`}`
`SKELSE`
	`?A=0.A GOYES.Beg2`
	`*.Beg1`
	`  GOTO.End2  %` and not End1
	`  GOTO.Beg1`
	`*.End1`
	`GOTO.End2`
		`IF NOT A=0 THEN`
		`  BEGIN`
		`  ...`
		`  ...`
		`  END`
		`ELSE`
		`  BEGIN`

`{`
`  A+1.A`
`  EXIT`
`  UP`
`}`
	`*.Beg2`
	`  A+1.A`
	`  GOTO.End2`
	`  GOTO.Beg2`
	`*.End2`
		`  ...`
		`  ...`
		`  ...`
		`END`

2.9 Macros

If data are to be included in a project, they can be entered in a source file, using `$`.

But a simpler way is to include data from an external file, which is a macro. The macro file must be a character string, a graphic, a code object or a list.

In case of a string or a code, Masd includes only the data part (after the length)

In case of a graphic, only the graphic data will be included (no length, no dimensions).

In case of a list, only the first object of the list will be included following the previous rules.

The syntax is:

`/FileName`

Note: To know how Masd looks for the FileName file, see the following section.

2.10 Filename conventions

Masd sometimes needs to find a file in the HP 48 memory.

The file can be found either by specifying the complete file name and location, or only the file name to be search in the search path list.

The initial search path list contains the current directory, the upper directory and so on to the HOME directory.

Note: You can add a directory in the search path list using `!PATH+ RepName` where RepName identifies a directory name using the full pathname rules, explained below.

To specify a full path, use

`H/` to specify HOMEDIR as the root.

`x``/`, where *x* is a port number, to specify a port as root.

This root is followed by a list of directories, ending with the name of the file.

`4/TOTO/TITI/TUTU` specifies the TUTU file in the TITI directory, stored in the TOTO backup of the fourth port.

`H/ME/YOU` specifies the YOU file in the ME directory, in the HOMEDIR.

2.11 Units

A unit is a part of a project, which can be compiled separately and stored in a file. The generated unit code can then be included in the project final code, without recompiling it.

A unit can use labels and constants defined in the calling program, and the calling program can use labels and constants defined in the unit.

Any source can be changed into a unit by placing a `!UNIT` directive in the source.

In the calling source file, type `USES FileName` to include a unit.

Note 1: A unit is smaller in memory than the source file it comes from.

Note 2: Using a unit is a very fast operation, faster than compiling the source.

Note 3: Tools libraries can be created and distributed without sharing the source code.

2.12 Library creation

Libraries can be created with Masd using the following instructions:

LIB, MESSAGE, VISIBLE, HIDDEN and LCONFIG.

Here is a source producing a library:

```
!NO CODE          % no code prolog $02DCC
LIB               % beginning of lib
{ "library name"  % library title
  1234            % library romid in decimal
  MESSAGE         % message table
  { "Message 1"
    "Message 2"
  }
  VISIBLE         % $visible list
  { VisibleName1  % Name of File Names containing
    VisibleName2  % visible objects
  }
  HIDDEN          % $hidden list
  { HiddenName1   % Name of File Names containing
    HiddenName2   % hiddens objects
  }
  LCONFIG ConfigName    % Name of the file containing
                  % the Config Object
}                 % end of lib
@
```

2.13 SysRPL mode

Masd can switch to SysRPL mode (also called System RPL or External) using the **!RPL** directive. In RPL mode, lots of things are changing.

Separation characters don't change (Characters of ASCII number below 32).

Comments begin with * and end at the end of the line, or begin with '**(**' and end with '**)**'.

2.13.1 Instructions

In RPL mode, Masd interprets instructions in the following order.

a) Constants

If a constant exists with the same name, the constant value is used on 5 nibbles.

Example:

```
EQU TOTO 4E2CF
```

...

```
TOTO
```

will produce

```
FC2E4
```

b) External (in entry points table)

If an entry in the external table exists with the same name, the value associated with this entry is used.

```
BZUExt
```

will produce

```
DB10C
```

Note 1: Use the TableCreator program on your PC to create the table.

Note 2: This table can be stored anywhere in the HP 48 memory. Create a **STARTEXT** text file in the HOMEDIR with the file name of the External table on the first line and a **@** on the second line.

Example of a STARTEXT file for a table stored in the Table backup to the fourth port:

```
"4/Table
@"
```

Note 3: Using an external table is much faster than using constants. On the other hand, constants are project dependant, which is not the case of an external table.

c) Tokens

::	Program prolog $02D9D
;	List, Program or Algebraic end $0312B
{	List prolog $02A74
}	List end $0312B
SYMBOLIC	Algebraic prolog $02AB8
UNIT	Unit prolog $02ADA
# *cst*	System Binary of *cst* value, given in hexadecimal.
# #*cst*	System Binary of *cst* value, given in decimal.
#*cst*	System Binary (hexadecimal value). If the SB exists in ROM, its address is used.
##*cst*	System Binary (decimal value). If the SB exists in ROM, its address is used.
PTR *cst*	Address. **PTR 4E2CF** generates **FC2E4**.
ACPTR *cst1 cst2*	Extended pointer.
ROMPTR *LibN ObjN*	XLIB.
% *real*	Real number.
%% *real*	Long real number.
C% *real1 real2*	Complex number.
C%% *real1 real2*	Long complex number.
"..."	Character string. Special characters can be included by typing \ and the ascii value on two hexadecimal characters.
ID *name*	Global name.
LAM *name*	Local name.
TAG *chrs*	Tagged object.
X*xlibName*	XLIB identified by its name. If it is a standard HP48 command (like **xDUP**), the address is used instead of an XLIB object.
HXS *Size Data*	Binary integer ($02A4E), Size is in hexadecimal and Data is a set of hexadecimal characters. Example: **HXS 5 FFA21**
GROB *Size Data*	GROB ($02B1E).
LIBDAT *Size Data*	Library data ($02B88).
BAK *Size Data*	Backup ($02B62).
LIB *Size Data*	Library ($02B40).
EXT1 *Size Data*	Extended1 ($02BAA).
EXT2 *Size Data*	Extended2 ($02BCC).
EXT3 *Size Data*	Extended3 ($02BEE).
EXT4 *Size Data*	Extended4 ($02C01).
ARRAY *Size Data*	Array ($029E8).
LNKARRAY *Size Data*	Linked Array ($02A0A).

CODE *Size Data*	Code object ($02DCC).
NIBB *Size Data* or NIBHEX *Data* or CON(*Size*) *Expr*	Includes directly hexadecimal data (no prolog).
CHR x	Character object.
INCLOB *FileName*	Includes the content of the file *FileName*.
INCLUDE *FileName*	Includes the source of the file *FileName* to be compiled (Like ' in ASM mode).
LABEL *label*	Defines a label (like * in ASM mode).
EQU *CstName Cst* or EQUE *CstName Exp* or DEFINE *CstNam Exp*	Defines a constant (Like DC in ASM mode).
EQUCP *Interleave CstName*	Defines a constant (Like DCCP in ASM mode).

Note: A constant can be defined in ASM or RPL mode, and may be used in both modes.

d) Decimal value (System Binary)

If the instruction is not yet recognized, and if it is a decimal value, Masd generates a system binary.

e) Unnamed local variables

Then, Masd tries to match the instruction with declared local variables.

A local environment is set using:

`{{ var1 var2 ... varN }}` with *N*<23

These variables have names during compile time, but they are implemented as unnamed local variables, which are faster to access than named local variables.

A local variable is recalled by typing its name

Data can be stored in a local variable by typing its name, with a leading `!` or `=`.

Note 1: Local variable are available until the next local definition.

Note 2: The local environment is not closed automatically, use `ABND` or other provided words.

Example:

`{{ label1 label2 .. labelN }}` will become :

`' NULLLAM <#N> NDUPN DOBIND` (or `1LAMBIND` if there is only one variable)

And:

`label1 → 1GETLAM`

`=label1 → 1PUTLAM`

`!label1 → 1PUTLAM`

Program example

```
::
      {{ A B }}
      B A!
      ABND
;
```

```
::
' NULLLAM TWO NDUPN DOBIND
2GETLAM 1PUTLAM
ABND
;
```

Notes on RPL mode.

Masd switches back to ASM mode using the `!ASM` directive.

2.13.2 Special keystrokes in the command line

In the command line editor, some keystrokes help to enter characters that are specific to System RPL, and also to easily find a command (auto-completion).

[↶] followed by [' •] displays a comma `,`.

[↶] **maintained** and [' •] displays a semicolon `;`.

In alpha mode, [↷] followed by [VAR] displays a vertical bar `|`.

In alpha mode, [↷] **maintained** and [VAR] displays an anti-slash `\`.

Auto-completion works as follow:

Type the first characters of the command, for example `DU`.

Press [↷] and maintain it. Press [SPC] once. On the first screen line, appears the first available command that begins with `DU`: `DUMP`.

To see the next possibilities, press [SPC] (always with [↷] pressed): `DUP`, `DUP♦`, `DUP#<7`…

To go back, and see previous choices, press [•].

If you see the right command, simply release [↷], the command will be inserted in the text.

To cancel the search without inserting a command, press [+] once and then release [↷].

2.13.3 Program example

To find or understand the syntax of a particular object, use `→S2` to produces an Masd syntax-source

As in ASM mode, a RPL source must end with a `@`.

```
"!NO CODE
!RPL
::
ONE (My first program)
!ASM
% Turn into ASM mode
CODE ( SAVE LOADRPL )
!RPL (Turn into SysRPL mode)
TWO
;
@"
```

2.14 SATURN instructions syntax

In this section:

x is an integer number between 1 and 16.

h is a hexadecimal digit.

a is a 1 to 16 or a 0 to 15 number depending of the current mode (0-15 or 1-16)

f is a field A, B, X, XS, P, WP, M or S.

Reg is a working register A, B, C or D.

SReg is a save register R0, R1, R2, R3 or R4.

Exp is an expression.

Cst is a constant. The value is given in hexadecimal or decimal using a leading **$** or **#** respectively.

DReg is a pointer register D0 or D1.

Data is memory data pointed by D0 or D1. It means **DAT0** or **DAT1**.

Note: For instructions that use two working registers, only the pairs A-B, B-C, C-D and A-C are available.

For instructions like *Reg1=Reg1…* you can write only *Reg1…* Example: **A=A+C.A** is the same as **A+C.A**.

2.14.1 Assigning 0 to a register

Syntax: *Reg*=0.*f*

Example: **A=0.M**

2.14.2 Loading a value in A or C

LC and LA instructions allow to load a constant value into A or C register.

LC ***hhh...hh*** loads x nibbles into C.

LA ***hhh...hh*** loads x nibbles into A.

Example: **LC 80100**

Note: LC #12 allow to load 12 decimal into the 3 first nibbles of C. The number of nibbles used is the number of characters necessary to write the value (including the **#**). So #12 will take three nibbles.

LCASC(*x*) ***Characters*** loads the hexadecimal value of *x* characters into C. *x* must be between 1 and 8. **LAASC(*x*)** if the counterpart for A.

Example: **LCASC(7) HP_MASD**

LC(*x*) ***Exp*** or **LA(x) Exp** load the result of an expression into C or A, using x nibbles.

Example: **LC(5)@Buffer+DataOffset**

2.14.3 Loading a register value into another register

Syntax: *Reg1=Reg2.f*

Example: **A=B.X**

2.14.4 Exchange between two registers

Syntax: *Reg1Reg2*EX.*f*

Example: **CDEX.W**

2.14.5 Addition

Syntax: *Reg1=Reg1+Reg2.f* or *Reg1+Reg2.f*

Example: **C=C+A.A** or **C+A.A**

Note if *Reg1* and *Reg2* are same, this cause to multiply the register by two.

2.14.6 Subtraction

Syntax: *Reg1*=Reg1-Reg2.*f* or *Reg1-Reg2.f*

Example: **C=C-B.A** or **C-B.A**

Note: The following instructions are also available:

A=B-A.*f* **B=C-B.*f*** **C=A-C.*f*** **D=C-D.*f***

2.14.7 Increment and decrement

Syntax: *Reg=Reg+Cst.f* or *Reg+Cst.f* *Reg=Reg-Cst.f* or *Reg-Cst.f*

Example: **A=A+10.A** or **A+10.A** **A=A-10.A** or **A-10.A**

Note 1: The Saturn processor is not able to add a constant greater than 16 to a register but if *cst* is greater than 16, Masd will generate as many instructions as needed.

Note 2: Even if adding constants to a register is very useful, big constants should be avoided because this will slow down execution, and generate a big program.

Note 3: Adding a constant greater than 1 to a P, WP, XS or S field is a bugged SATURN instruction (problem with carry propagation). Use these instructions with care.

Note 4: After adding a constant greater than 16 to a register, the carry should not be tested.

2.14.8 Right nibbles shifting (divide by 16)

Syntax: *Reg*SR.*f*

Example: **ASR.W**

2.14.9 Left nibbles shifting (multiply by 16)

Syntax: *Reg*SL.*f*

Example: **ASL.W**

2.14.10 Right bit shifting (divide by 2)

Syntax: *Reg*SRB.*f*

Example: **ASRB.W**

2.14.11 Right circular nibble shifting

Syntax: *Reg*SRC.*f*

Example: **ASRC.W**

2.14.12 Left circular nibble shifting

Syntax: *Reg*SLC.*f*

Example: **ASLC.W**

2.14.13 Logical AND

Syntax: *Reg1=Reg1&Reg2.f* or *Reg1&Reg2.f*

Example: **C=C&B.A** or **C&B.A**

2.14.14 Logical OR

Syntax: *Reg1=Reg1* !*Reg2.f* or *Reg1* !*Reg2.f*

Example: **C=C!B.A** or **C!B.A**

2.14.15 Logical NOT

Syntax: *Reg1=-Reg1*-1.*f*

Example: `C=-C-1.A`

2.14.16 Mathematical NOT

Syntax: *Reg1=-Reg1.f*

Example: `C=-C.A`

2.14.17 Loading value into a R Register

Syntax: *RReg=Reg*.f

Example: `R0=A.W`

Note: *Reg* can only be A or C.

2.14.18 Loading value into A or C from a R register

Syntax: *Reg=RReg*.f

Example: `A=R1.X`

Note: *Reg* can only be A or C.

2.14.19 Exchange between A or C and a R register

Syntax: *RegRRegEX*.f

Example: `AR1EX.X`

Note: *Reg* can only be A or C.

2.14.20 Memory write (POKE)

Theses instructions write the value of A or C at the address pointed to by D0 or D1.

Syntax: *Data=Reg.f* or *Data=Reg.x*

Example: `DAT1=C.A` or `DAT0=A.10`

Note: *Reg* can only be A or C.

2.14.21 Memory read (PEEK)

Theses instructions load into A or C the data pointed to by D0 or D1.

Syntax: *Reg=Data.f* or *Reg=Data*.x

Example: `C=DAT1.A` or `A=DAT0.10`

Note: *Reg* can only be A or C.

2.14.22 D0 and D1 modifications

a) Loading D0 and D1

Syntax: *DReg=hh* or *DReg=hhhh* or *DReg=hhhhh* or *DReg*=(2)*Exp* or *DReg*=(4)*Exp* or *DReg*=(5)*Exp*

Example: `D0=FF` `D0=12345` `D1=(5)toto+$5`

b) Exchanges between A or C and D0 or D1

- Loading A or C, field A, into D0 or D1

Syntax: *DReg=Reg*

Example: `D0=A`

Note: *Reg* can only be A or C.

- Loading the four low nibbles of A or C into D0 or D1

Syntax: *DReg=Reg*S

Example: `D0=AS`

Note: *Reg* can only be A or C.

- Exchanging A or C, field A, and D0 or D1.

Syntax: *RegDRegEX*

Example: `AD1EX`

Note: *Reg* can only be A or C.

- Exchanging the 4 first nibbles of A or C and D0 or D1

Syntax: *RegDRegXS*

Example: `AD1XS`

Note: *Reg* can only be A or C.

c) Increment and decrement of D0 and D1

Syntax: *DReg=DReg+Cst* or *DReg+Cst*

Syntax: *DReg=DReg-Cst* or *DReg-Cst*

Example: `D0=D0+12` `D1-50`

Note 1: The Saturn processor is not able to add a constant greater than 16 to a register but if *cst* is greater than 16, Masd will generate as many instructions as needed.

Note 2: Even if adding constants to a register is very useful, big constants should be avoided because this will slow down execution, and generate a big program.

Note 3: After adding a constant greater than 16, the carry should not be tested.

2.14.23 Working registers tests

Notes:

- A test is always followed by `RTNYES`, `GOYES`, `SKIPYES`, `EXIT`, `UP`, `GOTO`, `GOTOL`, `GOVLNG`, `GOSUB`, `GOSUBL` or `GOSBVL`.
- `RTY` is the same as `RTNYES`.
- An arrow (`→`) may be followed by a label name, then replacing `GOYES`, or may be followed by a skip block, which is equivalent to the inverse of the test followed by SKIPYES, to reproduce a IF-THEN structure. Example: `?A=C.A → { }` is the same as `?A#C.A { }`.
- `SKIPYES` may be omitted if followed by a skip block (`{}`).
- If the test if followed by a `GOTO`, `GOTOL`, `GOVLNG`, `GOSUB`, `GOSUBL` or `GOSBVL`, Masd compiles the inverse of the test, to reproduce a GOYES with a larger range. Example: `?A=C.A GOTO B` is the same as `?A#C.A { GOTO B }`.
- `GOTO`, `GOTOL`, `GOVLNG`, `GOSUB`, `GOSUBL`, `GOSBVL` or `→ {` cannot be used after a HST test.
- A label name must follow a `GOYES`, `GOTO`, `GOTOL`, `GOVLNG`, `GOSUB`, `GOSUBL` or `GOSBVL`.

a) Equality and inequality tests

Syntax: ?*Reg1=Reg2.f* *?Reg1#Reg2.f*

Example: `?A=C.B` `?C#D.A`

Note: The HP inequality character may be used.

b) Lower and greater tests

Syntax: ?*Reg1<Reg2.f* ?*Reg1<=Reg2.f*

Example: `?A<C.B` `?C>=D.A`

Note: The HP lower or equal and greater or equal characters may be used.

c) Nullity tests

Syntax: ?*Reg=0.f* ?*Reg#0.f*

Example: `?A=0.B` `?C#0.XS`

Note: The HP inequality character may be used.

2.14.24 Working with some bits of A or C register

*Reg*BIT=*v.a* *?Reg*BIT=*v.a* where Reg is A or C, *v* is 0 or 1 (reset or set), and a is the bit number.

Examples: `ABIT=0.5`, `?CBIT=1.3 GOYES TOTO`

2.14.25 Operations on PC

`A=PC C=PC PC=A PC=C APCEX CPCEX PC=(A) PC=(C)`

2.14.26 Working with the Hardware Status Register

`SB=0 XM=0 SR=0 MP=0 HST=a`
`?SB=0 ?XM=0 ?SR=0 ?MP=0 ?HST=a`

2.14.27 Working with P

`P=a`
`P=P+1 P+1 P=P-1 P-1`
`?P=a ?P#a`
`P=C.a C=P.a CPEX.a`
`C=C+P+1 C+P+1`

2.14.28 Jump instructions

`GOTO label`
`GOTOL label` or `GOLONG label`
`GOVLNG Cst` *Cst* is an hexadecimal number.
`GOVLNG =label` *label* is a constant, or a label in absolute mode
`GOVLNG ="COMMAND"` *Command* is an entry in the STARTEXT table.
`GOSUB label`
`GOSUBL label`
`GOSBVL Cst` *Cst* is a hexadecimal number.
`GOSBVL =label` *label* is a constant, or a label in absolute mode.
`GOSBVL ="COMMAND"` *COMMAND* is an entry in the STARTEXT table.

`GOC label`
`GONC label`
`GOTOC label` same as `SKIPNC { GOTO label }`
`GOTONC label` same as `SKIPC { GOTO label }`

`RTN RTNSXM RTNCC RTNSC RTI`
`RTNC RTNNC`
`RTNYES` or `RTY` after a test.

2.14.29 Exchanges between C and RSTK

`C=RSTK` and `RSTK=C` instructions allow to push to or pop data from the Saturn return stack.

2.14.30 Input / output instructions

`OUT=CS`, `OUT=C`, `A=IN` and `C=IN`

Note 1: `A=IN` and `C=IN` instructions are bugged (they only work on even addresses). So use `A=IN2` and `C=IN2`, which are ROM calls to `A=IN` and `C=IN` instructions.

Note 2: if the beginning of ROM is not usable (because it is recovered by RAM), use `A=IN3` and `C=IN3`, which are calls to `A=IN` and `C=IN` instructions in the **Meta Kernel** Card.

Note 3: `OUT=C=IN` is a ROM call that does `OUT=C C=IN`.

Note 4: `OUT=C=IN3` is the same, but in the **Meta Kernel** card (works even if lower ROM is recovered).

2.14.31 Processor control instructions

Working mode modification

`SETDEC SETHEX`

other instructions

`UNCNGF CONFIG RESET C=ID`
`SHUTDN INTON INTOFF RSI`
`SREQ?`
`BUSCB BUSCC BUSCD`

2.14.32 New instructions of Masd

`GOINC label`	Equivalent to `LC(5)label-&`. (& is the address of the instruction)
`GOINA label`	Equivalent to `LA(5)label-&`. (& is the address of the instruction)
« and »	Program prolog 02D9D and epilog 0312B.
~	Noeval
`Alabel`	In absolute mode, places the address of the label.
`Blabel`	In absolute mode, places the address of the label+5.
`$hhhh...hhh` or `NIBHEX hhhh...hhh`	Includes hexadecimal data.Example: `$12ACD545680B`.
`$/hhhh...hhh`	Includes hexadecimal data in reverse order. Example: `$/123ABC` is equivalent to `$CBA321`.
`$(x) Exp` or `CON(x) Exp` or `EXP(x) Exp`	Places the value of *Exp* in the code, on *x* nibbles.
`¢Ascii`	Includes ASCII data. The end of the string is the next ¢ or carriage return. Example: ¢Hello¢. To output a ¢ character, put it twice.
`INCLUDE FileName`	Includes directly the specified file as data.
`€Cst`	Includes the value of Cst on 5 nibbles. `€123` is equivalent to `$/00123`.
`¤cst`	Includes a system binary of value *Cst*.

`# cst`	Includes a system binary of value *Cst*. If this number already exists in ROM, its address is used instead.

`GOIN5 lab G5`
`lab`
`GOIN4 lab G4`
`lab`
`GOIN3 lab G3`
`lab`
`GOIN2 lab G2`
`lab`
	Same as `$(x)label-&` with *x*=5, 4, 3 or 2. Useful to create a jump table.

`SAVE`	Equivalent to `GOSBVL 0679B`
`LOAD`	Equivalent to `GOSBVL 067D2`
`RPL`	Equivalent to `A=DAT0.A D0+5 PC=(A)`
`LOADRPL`	Equivalent to `GOVLNG 138B9`
`INTOFF2`	Equivalent to `GOSBVL 01115`
`INTON2`	Equivalent to `GOSBVL 010E5`
`ERROR_C`	Equivalent to `GOSBVL 10F80`
`RES.STR`	Equivalent to `GOSBVL 05B7D`
`RES.ROOM`	Equivalent to `GOSBVL 039BE`
`[ ... ] Size`	Makes the code inside the brackets fit the given size, by adding zeros if necessary. Only three levels of brackets can be used.

2.15 Masd directives

`!PATH+ DirName`	Add the specified directory in the search path list.
`!LINK chr`	Change the char identifying link labs to *chr*.
`!OFF`	Shut down the screen. This speeds up the HP48 by 13%.
`!LOCAL chr`	Change the char identifying local labs to chr.
`!DISP message`	Display the message on the screen.
`!UNIT`	The output file will be a unit.
`!WAROFF`	Masd will not display ghost labels.
`!NO CODE`	Masd will not generate a $02DCC prolog but will directly output the data.
`!1-16`	Switch to 1-16 mode.
`!1-15`	Switch to 0-15 mode.
`!RPL`	Switch to RPL mode.
`!ASM`	Switch to ASM mode.
`!FL=0.a`	Clear the *a* compilation flag.
`!FL=1.a`	Set the *a* compilation flag.
`!?FL=0.a`	Compile the end of the line if flag *a* is set.
`!?FL=1.a`	Compile the end of the line if flag *a* is clear.
`!ABSOLUT Addr`	Switch to absolute mode. The program begins at the address *Addr*. Note: Masd always consider the prolog $02DCC and code length to be the beginning of the program even if !NO CODE is set.
`!ABSADR Addr`	If in absolute mode, add whites nibbles to continue at the specified address. If not possible, errors.
`!EVEN`	In absolute mode, cause an error if the directive is not on an even address.
`!ADR`	Masd will generate a source defining all constants and labels used in the program instead of the program.
`!COMPEXP`	Cause Masd to calculate all previous expressions.
`!COMPEX`	Cause Masd to calculate last expression.

2.16 Error messages

`Invalid File`	The file is not a source or a macro. (must end with a `@`)
`Too many links`	Only 256 links are supported. May be due to a recursion.
`Unknown Instr.`	Unknown instruction.
`Bad Field`	Incorrect field.
`0-15 Expected`	An integer between 0 and 15 is expected.
`1-16 Expected`	An integer between 1 and 16 is expected.
`Error Stack Size`	You use more than three brackets.
`Size Too Small`	Program between brackets is too big.
`Close Size`	There are more `]` than `[`.
`Label Expected`	A label name is expected.
`Const Expected`	A hexadecimal number is expected.
`Can't Find`	Can't find the label or the file.
`Lab. Already Dec.`	A label or a constant is already declared with the same name.
`Need {`	An opening `{` was expected.
`Need }`	A closing `}` was expected.
`Forbidden`	Operation not allowed.
`Bad Expression`	Error in expression.
`Jump too Long`	No comments.

3 Disassembler

The disassembler converts binary code into a source string. There are two ways to use it: with a Code on the stack level 1 or with two addresses (in binary) that point to the beginning and the end of the code to be disassembled.

The syntax used is Masd syntax, in mode 0-15.

Each line contains an address and an instruction.

If the **MK** system flag -7 is set (with `-7 SF2`), addresses are not shown, except for the destinations of jumps. In this case, the resulting source may be then reassembled if needed.

Example:

`-7 CF2` (default)	`-7 SF2`

`AE734 GOSBVL 0679B`
`AE73B LC 01000`
`AE742 C-A A`
`AE744 GONC AE742`
`AE747 GOVLNG 138B9`
	`GOSBVL 0679B`
	`LC 01000`
	`*AE742`
	`C-A A`
	`GONC AE742`
	`GOVLNG 138B9`
	`@`

4 Miscellaneous Utilities

These utilities are found in the MDGKER library.

Some of the following commands are marked **Dangerous!**, which means that incorrect use of them can corrupt memory. Use them at your own risk!

4.1 -→H →H

Returns a character string containing the hexadecimal numbers that form the object on stack level 1 in memory.

Example: `'A' →H` returns `"84E201014"`

4.2 H→ H→

Inverse of →H, it converts a hexadecimal character string to the objects coded in it. **Dangerous!**

Example: `"47A209C2A2B2130" H→` returns `« 1 »`

4.3 S→H S→H

Converts a character string into its hexadecimal form (every character is converted to two characters).

Example: `"HI" S→H` returns `"8494"`

4.4 H→S H→S

Inverse of S→H. Every couple of hexadecimal characters gives an ASCII character.

Example: `"8405" H→S` returns `"HP"`

4.5 CD→ CD→

Does a →H on the content of a Code object.

4.6 -→CD →CD

Inverse of CD→. A hexadecimal string is placed inside a Code object.

4.7 -→A →A

Returns the memory adress of the object on stack level 1.

Example: `1 →A` returns `#2A2C9h` (address of the real number 1)

4.8 A→ A→

Puts the object pointed to by the given address on stack. `Dangerous!`

Example: `#1B4Ach A→` returns `SIN`

4.9 PEEK PEEK

Reads memory. Level 2 contains the starting address (a binary number), level 1 gives the number of nibbles to be read (a binary number). A hexadecimal string is returned on the stack.

Example: `#0 #10d PEEK` returns `"2369B108DA"`

4.10 POKE POKE

Writes memory. Level 1 contains the hexadecimal string, level 1 the start address. `Dangerous!`

Example: `#101h "C" POKE` changes the contrast.

4.11 SREV SREV

Reverses the order of the characters in a string.

Example: `"HP 48" SREV` returns `"84 PH"`

4.12 PRG~LST PRG~L

Transforms a program to a list and vice-versa.

Example: `« SWAP DROP » PRG~LST` returns `PRG SWAP DROP END`.

4.13 -→RAM →RAM

Creates a new copy of the object in memory, equivalent to `NEWOB`, but it also works with ROM objects.

Example: `~ DUP →RAM` returns `PRG U 18AA5 U 03188 END` (the `DUP` program in ROM).

4.14 APEEK APEEK

Reads the address at a given address (binary number on stack level 1).

Example: `#3188h APEEK` returns `#318Dh`

4.15 R~SB R~SB

Transforms a real number to a system binary and vice-versa.

Example: `32 R~SB` returns `# 20h`

4.16 -→GROB2 →GROB

Transforms an object to its graphical representation.

The object is on stack level 2. A real number at level 1 gives the desired height:

- 1: Mini-font
- 2: Stack font
- 3: Big font

- 0: Big font, but if the object is an algebraic, the **MK** equation editor is used to draw it.

If the system flag2 -6 is set, the carriage returns in a string are used to draw multiple lines, otherwise if this flag -6 is cleared, the string will only be drawn on one line.

Example: `'SIN(X)' 0 →GROB2` returns `Graphic 31 × 9`

4.17 -→HEADER →HEAD

Defines the number of lines of the status area, 0, 1 or 2.

4.18 HEADER→ HEADE

Returns the current status area height.

4.19 INPUT2 INPUT

Works like `INPUT`, but uses the **Meta Kernel** environment.

4.20 DISP2 DISP2

Works like `DISP`, but uses the current system font (defined with `→FONT`), so that up to 9 lines can be written.

4.21 HALT2 HALT2

Works like `HALT`, but returns to the **Meta Kernel** stack (`HALT` returns to the standard HP stack).

Note: `DEBUG`, `SST` and `NEXT` in the PRG-RUN menu have been rewritten to work under the **Meta Kernel**.

4.22 -→S2 →S2

Converts an object into a character string in Masd format, in RPL mode.

4.23 -→S4 →S4

Converts an object into a character string, like the standard `→STR`. `EDIT` uses it.

4.24 CHOOSE2 CHOOS

Works like `CHOOSE`, but uses the current system font.

4.25 EDIT EDIT

Starts editing the object on stack level 1, with the command line editor.

4.26 VISIT VISIT

Starts editing the object stored in the given variable name, with the command line editor.

4.27 EDITB EDITB

Equivalent to `EDIT`, but uses the best adapted environment (command line, equation editor, graphic editor...), depending on the object type.

4.28 VISITB VISIT

Equivalent to `VISIT`, but uses the best adapted environment (command line, equation editor, graphic editor...), depending on the object type.

4.29 EQW EQW

Launches the equation editor with the expression given on stack level 1.

4.30 FILER FILER

Launches the filer.

4.31 ASM ASM

Launches the assembler with the source string on stack.

4.32 ER ER

Edits the error after assembling. There must be a string at level 2 and the errors list at level 1.

4.33 ASM→ ASM→

Starts the disassembler. Consult Page 44.

4.34 -→NDISP →NDIS

Defines the maximum number of lines taken by an object displayed on stack (including grobs and algebraics).

4.35 -→FONT →FONT

Sets the font object on stack level 1 as the system font.

4.36 FONT→ FONT→

Returns the current system font on the stack.

4.37 FONT8, FONT6 FONT8 FONT6

Returns the standard **Meta Kernel** fonts 6 and 8.

4.38 KERNEL? KERNE

Returns nothing. It is used to test if the **Meta Kernel** is present, if a program needs it.

4.39 SF2, CF2, FS?2, FC?2, FS?C2, FC?C2, STOF2, RCLF2 SF2 CF2 FS?2 FC?2 FS?C2 FC?C2 STOF2 RCLF2

Equivalent to `SF`, `CF`, `FS?`, `FC?`, `FS?C`, `FC?C`, `RCLF` and `STOF`, with the new **Meta Kernel** flags. Consult Page 14.

4.40 SREPL SREPL

Does a find/replace in a character string. The main string is at level 3, the find string at level 2 and the replace string at level 1. Every occurrence of the find string in the main string will be replaced by the replace string. The find and replace strings may have different lengths.

4.41 AR~LST AR~LS

Converts an array into a list of lists and vice-versa.

E.g. `[[ 1 2 ] [ 3 4 ]]` ← `AR~LST` → `{{ 1 2 } { 3 4 }}`.

Note: All the objects must be of the same type.

4.42 DIMS DIMS

Puts the size of the array contained in a list of lists on stack level 2 and 1 on stack level one. If it is **not** an array, returns 0.

```
{ 1 { 2 3 } } DIMS →0

{{ 1 'A' "ABC" }
 { 2 NOVAL 3 }} DIMS →{ 2 3 } 1
```

4.43 -→MINIFONT →MINI

Sets the mini-font object on stack level 1 as the system mini-font.

4.44 MINIFONT→ MINIF

Returns the current system mini-font on the stack.

4.45 FNT2GRB.PRG

Converts an **MK** font to a grob font (common 6,7 or 8 x 2048 grob).

This program is on the floppy disk.

4.46 GRB2FNT.PRG

Converts a grob font to an **MK** font. The grob in at level 3, the name is a character string at level 2 and the identifier a real number at level 1.

This program is on the floppy disk.

Appendixes

1 Introduction to assembly language

1.1 Introduction

Our purpose here is to help you translate an algorithm in Saturn assembly language, using Masd. You are supposed to already know the programming process, and RPL language.

If you want to learn how to program, there are several books to do it, like Wirst's 'The Art of Programming'.

We will try to give you the basis to build little programs. If you want to gain more experience, look at other people's programs, and read more advanced books on this subject.

Many informations here are taken from the excellent French book 'Voyage au Centre de la HP48' by Paul Courbis (Angkor).

1.2 What is assembly language (asm) ?

Asm is the only language directly readable by the microprocessor. Therefore, it is the fastest and the most powerful language. Each processor has its own asm. Asm is composed of binary numbers interpreted by the processor, each group of numbers giving instructions to be processed.

To make it easily readable by humans, each group of numbers is represented by a mnemonic. Assemblers (like Masd) translate these mnemonics to binary code, that the processor can execute. They sometimes add macro instructions or even structures to ease the programmer's work.

1.3 The Saturn processor

1.3.1 Generalities

SATURN is the name of a processor made by NEC. It is used in the HP48. It is a 4-bit processor (it can process 4 bits at each clock tick), with 4 64-bit working registers, 5 64-bit saving registers, 2 20-bit memory pointers, an internal 8-level return stack, 16 software flags, 4 hardware flags, 1 field register, 1 output register, 1 input register and 1 20-bit program counter.

A bit is a binary digit, it can takes only two values 0 or 1.

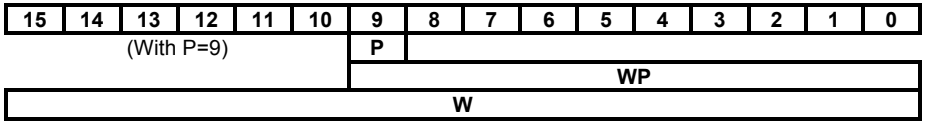
A nibble is a 4-bit value, from 0 to 15.

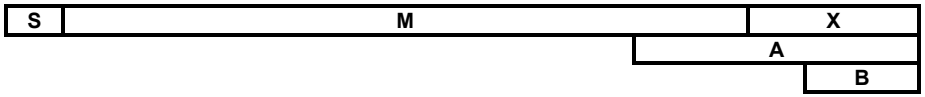
1.3.2 Working and saving registers

These registers are 64-bit (16-nibble) registers divided into fields.

A field is a part of a register; a group of nibbles. Two fields may overlap. They can have different lengths.

In a Saturn register, there are six fixed fields and two variable fields (depending on P register):





Example: Working with the A field only affects the 20 lowest bits of the register.

In this text, Cb means register C, field B.

1.3.3 P register

P is a 4-bit register which indicates the WP field length, the P field location, and the first modified nibble for the instructions LA and LC.

1.3.4 Flags register

The flags register is a 16-bit register, composed of 16 flags, which can be only 0 or 1. Their use is similar to RPL flags (CF, SF...).

1.3.5 Return stack

The return stack is a set of eight 20-bit registers. Only one of them is accessible directly (like the RPL stack).

When a subroutine is called (with `GOSUB`), the return address (just after the `GOSUB`) is pushed onto this stack. And when a `RTN` is encountered, the Saturn pops this address back from the stack and jumps to it.

Because there are only eight levels, building large programs with a lot of subroutine levels must not overload the return stack.

It is also possible to push a value with `RSTK=C` and to pop a value with `C=RSTK`.

1.3.6 Memory pointers

The three memory pointers D0, D1 and PC are 20-bit registers, which contains addresses.

D0 and D1 are used to access memory. You can load any address in them and then read memory.

PC is the Program Counter, it holds the address of the next instruction to be processed. It is modified at every jump (`GOTO`, `GOSUB`...), or directly with instructions such as `PC=C`.

a) Memory

Before examining pointers, let's see how memory is seen through HP asm.

HP memory can be compared to a ring of cells. Each cell contains one nibble. They are numbered from 0 to 524287 (20 bits). It is a ring, so the cell 524287 is followed by the cell 0. The number of a cell is called its address.

b) Pointers

A pointer is a register that contains an address. On HP48, a pointer is 20 bits (5 nibbles) long. Therefore we can access any memory cell with one pointer (Whereas on PC, we need two pointers).

c) Memory accesses

On the HP48, memory inputs and outputs are made through the A and C registers, D0 and D1 indicating which cell will be accessed.

It is possible to access more than one cell at one time, as up to an entire register (16 nibbles) can be loaded.

`A=DAT0 A` reads 5 nibbles at the address pointed by D0, then the data are put in the A field of A (Aa).

`DAT1=C 12` writes 12 nibbles at the address pointed by D1. The data written are the 12 lowest nibbles of C (nibbles 0 to 11).

Note that the Saturn processor inverses the order of the data read or written. E.g. if Ca contains 84571 and D1 contains 80200, `DAT1=C A` will fill memory as follow:

80200	80201	80202	80203	80204
1	7	5	4	8

The inversion is done at each read or write, so if you write and then read at the same address, using the same field, you will retrieve the same data.

1.4 Starting and stopping a Program

Starting to write an asm program looks difficult to beginners, because it requires comprehension of the RPL system, in order to avoid destroying other data.

To start a program, all the system data must be saved somewhere in memory, where they will be read back, after your program has finished, in order to continue normal operation. These data are contained in the registers Ba, Da, D0 and D1.

This saving is done with the Masd instruction `SAVE` (or the standard Saturn `GOSBVL 0679B`). Do it only one time, before doing any other processes.

At the end of your program, you have to restore the system data, with the instruction `LOAD` (or `GOSBVL 067D2`).

You can then exit to the RPL system with `RPL` (or `A=DAT0 A D0=D0+5 PC=(A)`).

These two instructions can be compacted into the single instruction `LOADRPL` (or `GOVLNG 138B9`).

The shortest program is:

```
"SAVE
% This program does nothing !
LOADRPL
@"
```

1.5 Working with the RPL stack

The RPL stack (the stack displayed on the screen) is stored in memory as a stack of addresses, each address points to an object in RAM or ROM. In order to reach an object, its address must be first read.

The stack pointer is in D1, pointing to the address of the first stack level. D1+5 points to the second level, and so on. A 00000 marks the end of the stack. The command `SAVE` saves D1 (and other RPL registers) in reserved RAM, so if you modify D1, and then need to read the RPL stack, do a `LOAD` before, which restores D1. And don't forget to do a `LOAD` before exiting from your program, otherwise D1 could point somewhere in memory, that may crash your HP.

Note: If a program needs to read the stack, it is recommended to do the argument tests in RPL before starting the asm code.

Example: To read the value of a system binary on the first stack level, do the following:

```
C=DAT1 A % Reads the address of the first level in Ca
CD1EX % D1 now points on the prolog of this object
      % Note that D1 is saved in Ca
D1=D1+5 % D1 points on the value of the SB
A=DAT1 A % Reads the value in Aa
CD1EX % Restores D1
```

To do a DROP, you just have to make the stack start 5 nibbles upper:

```
D1=D1+5 % The stack starts upper, so lower levels are dropped
D=D+1 A % Da contains the number of free 5 nibbles-blocks,
        % so you shall increment it
```

Da is also saved by `SAVE` and restored by `LOAD`.

If you do a `LOAD` after, the old value of D1 is retrieved. In order to effectively drop an element, do `LOAD D1+5 D+1.A` at the end of your program (before the `RPL` command), or do `LOAD D1+5 D+1.A SAVE` anywhere in your program.

To put an element on the stack, you just have to create a new stack level. E.g. if the object address is in Aa:

```
LOAD % loads the RPL registers
D=D-1.A SKIPNC % Tests free memory
{ C=0.A LC 1 ERREUR_C } % Insufficient mem
D1=D1-5 % Adds a stack level
DAT1=A A % Puts the object address
SAVE % Saves the RPL registers
```

1.6 Useful routines

Rf = field f of register R.

The functions ending with an EXIT (RPL return) shall be called with a GOVLNG, whereas the other function must be called with GOSBVL.

Note: you can replace `GOSBVL add RTN` by `GOVLNG add`, which is shorter and saves one RSTK level.

1.6.1 Stack exchanges

SB = System Binary (Prolog 02911).

Function	Address	Quick help	Modified registers
POP A	06641	Drops 1 SB, stores its value in Aa.	D1, Da, Ca, Aa
POP A C	03F5D	Drops 2 SB, stores their values in Aa and Ca.	D1, Da, Ca, Aa, 1 RSTK
PUSH R0	06537	Pushes R0a in a SB.	D0, D1, Aw, Ba, Ca, Da
PUSH R0, R1	06529	Pushes R0a and R1a in two SB.	D0, D1, Aw, Ba, Ca, Da, R0w
DROP EXIT	03249	Drops one object and exits.	
LOAD TRUE EXIT	25CE1	Loads RPL registers, pushes `TRUE` and exits.	
LOAD FALSE EXIT	26FAE	Loads RPL registers, pushes `FALSE` and exits.	
PUSH A EXIT	0357C	pushes Aa in a SB and exits.	
PUSH R0, R1 EXIT	03F14	pushes R0a and R1a in two SB and exits.	
PUSH TRUE EXIT	620C3	pushes `TRUE` and exits.	

PUSH FALSE EXIT	620DC	pushes FALSE and exits.	
PUSH CARRY EXIT	620D9	If carry is set, pushes a TRUE, else a FALSE; then EXITs.	

1.6.2 Calculations

Ba=Aa*Ca	03991		Aa, Ba, Ca
Cw,Aw=Aw*Cw	53EE4		Aw, Cw, Dw
Aw=Cw=Aw/Cw Bw=Remind.	65807		Aw, Bw, Cw, P
C=C/5	06A8E		A11, B11, C11, P
Aa=CRC(D0, Aa)	05981	Stores in Aa, the CRC of the memory area starting at D0, on Aa nibbles.	D1, D0, Aa, Ca, P

1.6.3 Miscellaneous

BEEP(Da,Ca)	017A6	Bips Ca ms, with a frequency of Da Hz.	D0, D1, P, Aw, Bw, Cw, Dw, R1w, R2w, R3w
EMPTYKBUF	00D57	Empties the keyboard buffer.	D1, Ca
BUSY ON	01BEB	Lights on the busy announciator.	D0, Cb
BUSY OFF	42359	Lights off the busy announciator.	D0, Cb
D0=@Screen	01C31	Stores the address of the first pixel of the screen in D0.	D0, Aa, Ca
D0=@Menu	01C58	stores the address of the first pixel of the menu in D0.	D0, Aa, Ca
DISP	11D8F	Displays Ca characters at D1 in a grob pointed by D0, which has a width of Da, starting at the Character number Ba.	XM, P, D0, D1, Aa, Ba, Cw, Da

1.6.4 Memory operations

DAT1=0 (Ca)	0675C	Resets to 0 a memory zone pointed by D1, on Ca nibbles.	D1, P, Aw, Ca
RES ROOM	039BE	Reserves Ca nibbles in temporary RAM. D0 indicates the starting.	ST0,1,10 D0, D1, P, Aw, Bw, Cw, Dw
RES STRING	05B7D	Reserves a character string of Ca nibbles in temporary RAM. R0a points on the prolog and D0 on the first character.	ST0,1,10 D0, D1, P, Aw, Bw, Cw, Dw
GARB COL	0313E	Does a garbage collect.	ST0,1,10, D0, D1, Aw, Bw, Cw, Dw
FREEROOM	16671	Resizes the object pointed by R0a (in temporary RAM), so that it ends at D0.	D0, D1, Aw, Ca, Ba, R1w
SKIP OBJ	03019	D0 pointing on an object, it is moved to the next object.	D0, ST1, Aa, Ca

1.7 Saturn instruction set

There are four columns in this table.

The first column may be empty, or contains a M or a star. M indicates that the calculation mode is used (SETDEC and SETHEX). A star indicates that the carry is modified by the instruction.

The second column contains the instruction mnemonic.

The third column indicates the fields which can be used with the instruction. f is any field, a or b is any field but A, d is a nibble value (0-15 or 1-16), x is a nibble value (0-15 only).

The last column is the execution length in Saturn cycles. n is the number of nibbles in the used field. If the time is not integer, take IP(time) if the instruction is on an even address or IP(time)+1 if the instruction is on an odd address. For tests instructions, there are two times separated by a slash, the first is for a true test, the second for a false test. For memory instructions, the two times indicate the instruction length and the memory operation length.

This list is taken from the book 'Voyage au centre de la HP48 GX' by Paul Courbis, Angkor Editions.

*	?A#0	A	21.5/13.5
*	?A#0	a	16.5/8.5+q
*	?A#C	A	21.5/13.5
*	?A#C	a	16.5/8.5+q
*	?A<=B	A	21.5/13.5
*	?A<=B	b	16.5/8.5+q
*	?A<B	A	21.5/13.5
*	?A<B	b	16.5/8.5+q
*	?A=0	A	21.5/13.5
*	?A=0	a	16.5/8.5+q
*	?A=C	A	21.5/13.5
*	?A=C	a	16.5/8.5+q
*	?A>=B	A	21.5/13.5
*	?A>=B	b	16.5/8.5+q
*	?A>B	A	21.5/13.5
*	?A>B	b	16.5/8.5+q
*	?ABIT=0	d	20.5/12.5
*	?ABIT=1	d	20.5/12.5
*	?B#0	A	21.5/13.5
*	?B#0	a	16.5/8.5+q
*	?B#A	A	21.5/13.5
*	?B#A	a	16.5/8.5+q
*	?B<=C	A	21.5/13.5
*	?B<=C	b	16.5/8.5+q
*	?B<C	A	21.5/13.5
*	?B<C	b	16.5/8.5+q
*	?B=0	A	21.5/13.5
*	?B=0	a	16.5/8.5+q
*	?B=A	A	21.5/13.5
*	?B=A	a	16.5/8.5+q
*	?B>=C	A	21.5/13.5
*	?B>=C	b	16.5/8.5+q
*	?B>C	A	21.5/13.5
*	?B>C	b	16.5/8.5+q
*	?C#0	A	21.5/13.5
*	?C#0	a	16.5/8.5+q
*	?C#B	A	21.5/13.5
*	?C#B	a	16.5/8.5+q
*	?C#D	A	21.5/13.5
*	?C#D	a	16.5/8.5+q
*	?C<=A	A	21.5/13.5
*	?C<=A	b	16.5/8.5+q
*	?C<A	A	21.5/13.5
*	?C<A	b	16.5/8.5+q
*	?C=0	A	21.5/13.5
*	?C=0	a	16.5/8.5+q
*	?C=B	A	21.5/13.5
*	?C=B	a	16.5/8.5+q
*	?C=D	A	21.5/13.5
*	?C=D	a	16.5/8.5+q
*	?C>=A	A	21.5/13.5
*	?C>=A	b	16.5/8.5+q
*	?C>A	A	21.5/13.5
*	?C>A	b	16.5/8.5+q
*	?CBIT=0	d	20.5/12.5
*	?CBIT=1	d	20.5/12.5
*	?D#0	A	21.5/13.5
*	?D#0	a	16.5/8.5+q
*	?D<=C	A	21.5/13.5
*	?D<=C	b	16.5/8.5+q
*	?D<C	A	21.5/13.5
*	?D<C	b	16.5/8.5+q
*	?D=0	A	21.5/13.5
*	?D=0	a	16.5/8.5+q
*	?D>=C	A	21.5/13.5
*	?D>=C	b	16.5/8.5+q
*	?D>C	A	21.5/13.5
*	?D>C	b	16.5/8.5+q
*	?HST=0	x	15.5/7.5
*	?MP=0		15.5/7.5
*	?P#	n	15.5/7.5
*	?P=	n	15.5/7.5
*	?SB=0		15.5/7.5
*	?SR=0		15.5/7.5
*	?ST=0	d	16.5/8.5
*	?ST=1	d	16.5/8.5
*	?XM=0		15.5/7.5
*M	A=-A	a	4.5+q
*M	A=-A	A	8
*M	A=-A-1	a	4.5+q
*M	A=-A-1	A	8
	A=0	a	4.5+q
	A=0	A	8
	A=A!B	f	6+q
	A=A!C	f	6+q
	A=A&B	f	6+q
	A=A&C	f	6+q
*M	A=A+1	a	4.5+q
*M	A=A+1	A	8
*M	A=A+A	a	4.5+q
*M	A=A+A	A	8
*M	A=A+B	a	4.5+q
*M	A=A+B	A	8
*M	A=A+C	a	4.5+q
*M	A=A+C	A	8
*	A=A+x+1	f	8+q
*M	A=A-1	a	4.5+q
*M	A=A-1	A	8
*M	A=A-B	a	4.5+q
*M	A=A-B	A	8
*M	A=A-C	a	4.5+q
*M	A=A-C	A	8
*	A=A-x-1	f	8+q
	A=B	a	4.5+q
	A=B	A	8
*M	A=B-A	a	4.5+q
*M	A=B-A	A	8
	A=C	a	4.5+q
	A=C	A	8
	A=DAT0	A	2.5,3.5
	A=DAT0	a	20+p,1+q/2
	A=DAT0	B	19.5
	A=DAT0	x+1	19+q,1+q/2
	A=DAT1	A	23.5,3.5
	A=DAT1	a	20+q,1+q/2
	A=DAT1	B	19.5
	A=DAT1	x+1	19+q,1+q/2
	A=IN		8.5
	A=PC		11
	A=R0	f	9+q
	A=R0	W	20.5
	A=R1	f	9+q
	A=R1	W	20.5
	A=R2	f	9+q
	A=R2	W	20.5
	A=R3	f	9+q
	A=R3	W	20.5
	A=R4	f	9+q
	A=R4	W	20.5
	ABEX	a	4.5+q

	ABEX	A	8
	ABIT=0	d	7.5
	ABIT=1	d	7.5
	ACEX	a	4.5+q
	ACEX	A	8
	AD0EX		9.5
	AD0XS		8.5
	AD1EX		9.5
	AD1XS		8.5
	APCEX		19
	AR0EX	f	9+q
	AR0EX	W	20.5
	AR1EX	f	9+q
	AR1EX	W	20.5
	AR2EX	f	9+q
	AR2EX	W	20.5
	AR3EX	f	9+q
	AR3EX	W	20.5
	AR4EX	f	9+q
	AR4EX	W	20.5
*	ASL	a	4.5+q
*	ASL	A	8
	ASLC		22.5
	ASR	a	4.5+q
	ASR	A	8
	ASRB	f	8.5+q
	ASRB	W	21.5
	ASRC		22.5
*M	B=-B	a	4.5+q
*M	B=-B	A	8
*M	B=-B-1	a	4.5+q
*M	B=-B-1	A	8
	B=0	a	4.5+q
	B=0	A	8
	B=A	a	4.5+q
	B=A	A	8
	B=B!A	f	6+q
	B=B!C	f	6+q
	B=B&A	f	6+q
	B=B&C	f	6+q
*M	B=B+1	a	4.5+q
*M	B=B+1	A	8
*M	B=B+A	a	4.5+q
*M	B=B+A	A	8
*M	B=B+B	a	4.5+q
*M	B=B+B	A	8
*M	B=B+C	a	4.5+q
*M	B=B+C	A	8
*	B=B+x+1	f	8+q
*M	B=B-1	a	4.5+q
*M	B=B-1	A	8
*M	B=B-A	a	4.5+q
*M	B=B-A	A	8
*M	B=B-C	a	4.5+q
*M	B=B-C	A	8
*	B=B-x-1	f	8+q
	B=C	a	4.5+q
	B=C	A	8
*M	B=C-B	a	4.5+q
*M	B=C-B	A	8
	BCEX	a	4.5+q
	BCEX	A	8
*	BSL	a	4.5+q
*	BSL	A	8
	BSLC		22.5
	BSR	a	4.5+q
	BSR	A	8
	BSRB	f	8.5+q
	BSRB	W	21.5
	BSRC		22.5
	BUSCB		10
	BUSCC		8.5
	BUSCD		10
*	C+P+1		9.5
	C=0	a	4.5+q
	C=0	A	8
	C=A	a	4.5+q
	C=A	A	8
*M	C=A-C	a	4.5+q
*M	C=A-C	A	8
*M	C=-C	a	4.5+q
*M	C=-C	A	8
*M	C=-C-1	a	4.5+q
*M	C=-C-1	A	8
	C=B	a	4.5+q
	C=B	A	8
	C=C!A	f	6+q
	C=C!A	f	6+q
	C=C!D	f	6+q
	C=C&A	f	6+q
	C=C&A	f	6+q
	C=C&D	f	6+q
*M	C=C+1	a	4.5+q
*M	C=C+1	A	8
*M	C=C+A	a	4.5+q
*M	C=C+A	A	8
*M	C=C+B	a	4.5+q
*M	C=C+B	A	8
*M	C=C+C	a	4.5+q
*M	C=C+C	A	8
*M	C=C+D	a	4.5+q
*M	C=C+D	A	8
*	C=C+x+1	f	8+q
*M	C=C-1	a	4.5+q
*M	C=C-1	A	8
*M	C=C-A	a	4.5+q
*M	C=C-A	A	8
*M	C=C-B	a	4.5+q
*M	C=C-B	A	8
*M	C=C-D	a	4.5+q
*M	C=C-D	A	8
*	C=C-x-1	f	8+q
	C=D	a	4.5+q
	C=D	A	8
	C=DAT0	A	23.5,3.5
	C=DAT0	a	20+q,1+q/2
	C=DAT0	B	19.5
	C=DAT0	x+1	19+q,1+q/2
	C=DAT1	A	23.5,3.5
	C=DAT1	a	20+q,1+q/2
	C=DAT1	B	19.5
	C=DAT1	x+1	19+q,1+q/2
	C=ID		13.5
	C=IN		8.5
	C=P	x	8
	C=PC		11
	C=R0	f	9+q
	C=R0	W	20.5
	C=R1	f	9+q
	C=R1	W	20.5
	C=R2	f	9+q
	C=R2	W	20.5

	C=R3	f	9+q
	C=R3	W	20.5
	C=R4	f	9+q
	C=R4	W	20.5
	C=RSTK		9
	C=ST		7
	CBIT=0	d	7.5
	CBIT=1	d	7.5
	CD0EX		9.5
	CD0XS		8.5
	CD1EX		9.5
	CD1XS		8.5
	CDEX	a	4.5+q
	CDEX	A	8
	CETDEC		4
	CETHEX		4
	CLRHST		4.5
	CLRST		7
	CONFIG		13.5
	CPCEX		19
	CPEX	x	8
	CR0EX	f	9+q
	CR0EX	W	20.5
	CR1EX	f	9+q
	CR1EX	W	20.5
	CR2EX	f	9+q
	CR2EX	W	20.5
	CR3EX	f	9+q
	CR3EX	W	20.5
	CR4EX	f	9+q
	CR4EX	W	20.5
*	CSL	a	4.5+q
*	CSL	A	8
	CSLC		22.5
	CSR	a	4.5+q
	CSR	A	8
	CSRB	f	8.5+q
	CSRB	W	21.5
	CSRC		22.5
	CSTEX		7
	D=0	a	4.5+q
	D=0	A	8
	D=C	a	4.5+q
	D=C	A	8
*M	D=C-A	a	4.5+q
*M	D=C-A	A	8
*M	D=-D	a	4.5+q
*M	D=-D	A	8
*M	D=-D-1	a	4.5+q
*M	D=-D-1	A	8
	D=D!C	f	6+q
	D=D&C	f	6+q
*M	D=D+1	a	4.5+q
*M	D=D+1	A	8
*M	D=D+C	a	4.5+q
*M	D=D+C	A	8
*M	D=D+D	a	4.5+q
*M	D=D+D	A	8
*	D=D+x+1	f	8+q
*M	D=D-1	a	4.5+q
*M	D=D-1	A	8
*M	D=D-C	a	4.5+q
*M	D=D-C	A	8
*	D=D-x-1	f	8+q
	D0=	pq	6
	D0=	pqrs	9
	D0=	pqrst	10.5
	D0=A		9.5
	D0=AS		8.5
	D0=C		9.5
	D0=CS		8.5
	D0=D0-	n+1	8.5
*	D0=D0+	n+1	8.5
	D1=	pq	6
	D1=	pqrs	9
	D1=	pqrst	10.5
	D1=A		9.5
	D1=AS		8.5
	D1=C		9.5
	D1=CS		8.5
	D1=D1-	n+1	8.8
*	D1=D1+	n+1	8.5
	DAT0=A	A	19.5
	DAT0=A	a	19+q
	DAT0=A	B	16.5
	DAT0=A	x+1	18+q
	DAT0=C	A	19.5
	DAT0=C	a	19.5
	DAT0=C	B	16.5
	DAT0=C	x+1	18+q
	DAT1=A	A	19.5
	DAT1=A	a	19+q
	DAT1=A	B	16.5
	DAT1=A	x+1	18+q
	DAT1=C	A	19.5
	DAT1=C	a	19.5
	DAT1=C	B	16.5
	DAT1=C	x+1	18+q
	DSL	a	4.5+q
	DSL	A	8
	DSLC		22.5
	DSR	a	4.5+q
	DSR	A	8
	DSRB	f	8.5+q
	DSRB	W	21.5
	DSRC		22.5
	GOC	xy	12.5/4.5
	GOLONG	pqrs	17
	GONC	xy	12.5/4.5
	GOSBVL	pqrst	19.5
	GOSUB	xyz	15
	GOSUBL	pqrs	18
	GOTO	xyz	14
	GOVLNG	pqrst	18.5
	HST=0	x	4.5
	INTOFF		7
	INTON		7
	LA	h0..hx	(15+3q)/2
	LC	h0..hx	3+3q/2
	MP=0		4.5
	OUT=C		7.5
	OUT=CS		5.5
	P=	n	3
	P=C	x	8
*	P=P+1		4
*	P=P-1		4
	PC=(A)		26,3.5
	PC=(C)		26,3.5
	PC=A		19
	PC=C		19
	R0=A	f	9+q
	R0=A	W	20.5

R0=C	f	9+q
R0=C	W	20.5
R1=A	f	9+q
R1=A	W	20.5
R1=C	f	9+q
R1=C	W	20.5
R2=A	f	9+q
R2=A	W	20.5
R2=C	f	9+q
R2=C	W	20.5
R3=A	f	9+q
R3=A	W	20.5
R3=C	f	9+q
R3=C	W	20.5
R4=A	f	9+q
R4=A	W	20.5
R4=C	f	9+q
R4=C	W	20.5
RESET		7.5

	RSI		8.5
	RSTK=C		9
	RTI		11
	RTN		11
	RTNC		12.5/4.5
*	RTNCC		11
	RTNNC		12.5/4.5
*	RTNSC		11
	RTNSXM		11
	SB=0		4.5
	SHUTDN		6.5
	SR=0		4.5
	SREQ?		9.5
	ST=0	d	5.5
	ST=1	d	5.5
	ST=C		7
	UNCNFG		14.5
	XM=0		4.5

2 Introduction to System RPL

2.1 Generalities

The System RPL integrated in the HP48, but which is not directly accessible by users. The SystemRPL has the same structure as RPL.

The RPL language and the standard environment are mainly programmed in SystemRPL, which shows its power and complexity.

So SystemRPL can do much more things than RPL and, like asm, can easily cause "Memory Lost".

In this section, `12345` represents an external. To use it, type `$ 12345h`, or `∈ 12345`.

2.2 External "Theory"

In the standard environment, external instructions (or simply 'externals') are displayed as `External` (that's why we call the language 'External'). Note that every RPL instruction can also be considered as an external (it has the same structure, only the display changes).

An external is the address of an object.

An object always begins with a prolog, and a prolog is in fact the address of the ML program that handles this object type.

So an external is the address of the address of an asm program.

E.g.: SIN is the external of address 1B4AC. At this address, we find the prolog 02D9D, and finally at the address 02D9D is the asm program which executes every program object.

Note: There are also many externals which are 'entry points'. Their prolog is simply the address of the asm program (In ROM, this program is just after its address). E.g.: The external DUP (`03188`) points directly onto 0318D, where the asm DUP is.

2.3 Writing a System RPL program

There is a list of entry points at the end of this section. When you know control structures and how to find the right instructions in this list, programming in SystemRPL is as simple as RPL.

With the **MK**, programs can be directly edited in command line, using the command library. Bu for real projects, it is better to work with the Masd in two times.

First write the program in a character string,

To compile this program, put the string on the stack and type `ASM`.

The program is put on the stack, where it can be saved, tested...

Here is a simple external program:

```
!NO CODE
!RPL
:: (Program prolog)
  500          (pushes the system binary <500d> on the stack)
  ZERO_DO          * FOR 0 to SB1-1
    INDEX@         * Recall the loop index
    #>$            * SB->S, convert the system binary into a string
    DISPROW1       * 1 DISP
  LOOP             * NEXT
;                  * End of the SysRpl program (colon)
@
```

Note that 'normal' RPL commands can be used in SystemRPL, but for all these commands, there an equivalent entry points.

In this program, there is a System Binary (or SB) which is an integer coded on five nibbles. It is the most used object, as lots of functions wait for them as arguments.

It is important to note that before the `DISPROW1`, there is a `#>$` which converts a SB into a character string. In RPL, DISP converts automatically every object into a string to display it. In SysRpl, most functions do NOT test the arguments, so the programmer has to do every conversion as needed. The external `DISP` supposes there is a character string on the stack; if there is no objects, or if there is another object type, be sure to see the well known question `Try To Recover Memory?`, whereas in RPL, the program would have ended with a `Too Few Arguments` or a `Bad Argument Type` error.

ALWAYS CHECK THE ARGUMENTS!

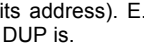
2.4 Instructions

The entry points list is very long, with more than 1700 entry points and 6000 externals. It is impossible to know all of them, but it is useful to learn some most used of them (mainly stack manipulations and structures).

Every RPL command has one or more external equivalent, because RPL which can handle multiple object types (e.g `DISP`, `+`) have an entry points equivalent for every object type (there are 27 external `+`!).

A good way to find an entry points is to decompile a RPL command.

For example, let's try to find the entry points `DUP`.

Put a RPL `DUP` on the stack by typing `~ DUP`. To type `~`, press  .

Copy the DUP program in temporary RAM with `→RAM`.

Now the DUP program is on the stack:

Transform it into SysRpl syntax using `→S2`

```
!NO CODE
!RPL
::
      CK1
      DUP
;
@"
```

Most RPL commands programs are made like this: a type control and the systemRpl command. So `CK1` controls there is at least one object on the stack.

Every RPL command can be decompiled like that, more or less simply depending on the number of arguments handled by the command, so it is important to know the control structures.

2.5 Control structures

2.5.1 Booleans

A boolean is a binary value (true or false). The **MK** defines two words for boolean values: **TRUE** and **FALSE**.

They are mainly used in control structures, because they are arguments of If-Then-Else, Do-Until and While-Repeat.

They are generated by typing their name, or as a result of a test function (equality, superiority...).

2.5.2 Tests

In SystemRpl, there are lots of control structures, but only the most used ones are detailed here: IF THEN, IF ELSE and IF THEN ELSE.

IF THEN: **IF**. Takes a boolean on the stack and evaluates the following object if the boolean is **TRUE**. Example:

```
:: IFT :: "True" DISPROW1 ; ;.
```

IF ELSE: **?SKIP**. Equivalent to a NOT IF THEN.

IF THEN ELSE: **ITE**. Takes a boolean on the stack, evaluates the following object if the boolean is **TRUE**, or the second following object if the boolean is **FALSE**.

```
::
     ITE
     "This is TRUE"
     :: "False !" 17 337 setbeep ;
     DISPROW1
;
```

2.5.3 Loops

There are two common loops: FOR NEXT, WHILE REPEAT END.

FOR NEXT:

```
#45
ZERO_DO      *FOR 0 to SB-1
...          *Your loop here
LOOP         *NEXT
```

WHILE REPEAT END :

```
BEGIN              *WHILE
...          * program which pushes a boolean on the stack
WHILE              *REPEAT
...          * your program here
REPEAT       *END
```

2.6 Unnamed local variables

There are two types of local variables: named and unnamed. Named variables are used like in RPL. Unnamed variables are faster.

They are indexed in the same order of their creation.

CACHE creates a local environment. The stack level 1 contains the character 0 (**K$ 0**), level 2 is a SB which is the number of variables to create, and level 3 to n+2 are initialization values.

More than one BIND environment can be stacked, but only the last created one is active.

ABND leaves the top-most environment. All BINDs must be UNBINDed before the program ends, otherwise the system will crash.

To ease the use of unnamed variables, the MASD provide a new mechanism (Check page 38)

Example:

```
{
LAM Variable1     * Name of the Variable
LAM Variable2
...
LAM Variablen
}
BIND  (Create the local variables)
LAM Variable1      (Recall the Variable1 content)
FALSE
' LAM Variable1 STOLAM
      (Stores the FALSE boolean into the variable Variable1)

ABND  (Purges the local variable)

{{ Nom1 Nom2 Nom3 }}
      (Creates 3 unnamed local variable)

Nom1  (Recalls the No1 variable's content)
TRUE !Nom1  (Stores the boolean TRUE into the No1 variable)

1GETLAM      (Recall the No1 variable's content)
FALSE
1PUTLAM      (Store the FALSE boolean into the No1 local variable)
ABND  (Purges the local variable)
```

2.7 Argument control

Every RPL program begins with the argument control. It is usually made in two steps: first check the number of arguments on stack, then branch in the program depending on the argument types.

Here are the externals which test that the required number of objects is on the stack (it also saves the program name, for error messages):

Checks 0 object (only saves the name)	**CK0**
Checks 1 object	**CK1**
Checks 2 objects	**CK2**
Checks 3 objects	**CK3**
Checks 4 objects	**CK4**
Checks 5 objects	**CK5**
Checks n objects (n is a SB on stack level 1)	**CKN**

Then, the following structure branches to different part of the program, depending on the object types.

```
::
      CKx&DISPATCH
      #SB_prg1
      :: program 1 ;
      #SB_prg2
      :: program 2 ;
      ...
```

Algebraic	#9
Array	#4
Backup	#9F
Binary integer	#B
Character	#6F
Code	#7F
Complex	#2
Directory	#2F
Extended pointer	#BF
Global name	#6
Graphic	#C
Library	#8F
Library data	#AF
Linked array	#5F
List	#5
Local name	#7

In order to test the stack for three character strings, do as follows:

```
::
 CK3 *check 3 objects
 CK&DISPATCH1  (dispatch)
  #333 (string, string, string)
  ::
     (Your program)
  ;
;
```

2.8 Entry points list

This list is not complete. Anyway, it may be sufficient to start programming, and to make good programs. If you don't find the entry points you need, remember that the best place to find it is in the HP48 ROM itself!

This list is extracted from the RPL Manual by Hewlett Packard, with their permission. The original RPL Manual, which contains much more explanations about SysRPL, can be found on the floppy disk (in different formats).

The following list is sorted by object types. The same list is also available, sorted by addresses and by function names, on the floppy disk.

2.8.1 Notations

Ob	Any object
Id	Identifier Object

Addr	Word	Stack diagram
64E0A	2EXT	→ #EE
64DE2	2GROB	→ #CC
64C66	2LIST	→ #55
04099	2REAL	→ #11


```
      #SB_prgn
      :: program n ;
;
```

Each SB describes the object types found on stack, which are accepted by the program, with the following code:

Long complex	#4F
Long real	#3F
Program	#8
Real	#1
Reserved 1	#CF
Reserved 2	#DF
Reserved 3	#EF
String	#3
System binary	#1F
Tagged	#D
Unit	#E
Xlib name	#0F
Any type	#0

Lam	Temporary Identifier Object
romptr	ROM Pointer Object
#	Binary Integer Object
%	Real Object
%%	Extended Real Object
C%	Complex Object
C%%	Extended Complex Object
arry	Array Object
lnkarry	Linked Array Object
$	Character String Object
hxs	Hex String Object
chr	Character Object
ext	External Object
code	Code Object
primcode	Primitive Code Object
::	Secondary Object
{}	List Object
symb	Symbolic Object
comp	Any Composite Object (list, secondary, symbolic)
rrp	Directory Object
tagged	Tagged Object
flag	TRUE/FALSE

2.8.2 Binary Integers

a) Built-in Binary Integers

64E64	3REAL	→ #111
34301	Attn#	→ #A03
64CE8	BINT_115d	→ #73
64CF2	BINT_116d	→ #74

64D06	**BINT_122d**	→ #7A
64D1A	**BINT_130d**	→ #82
64D24	**BINT_131d**	→ #83
64BE4	**BINT_65d**	→ #41
64C84	**BINT_91d**	→ #5B
64C8E	**BINT_96d**	→ #60
64E1E	**BINT253**	→ #
64E28	**BINT255d**	→ #FF
64BDA	**BINT40h**	→ #40
64D10	**BINT80h**	→ #80
64DD8	**BINTC0h**	→ #C0
64CC0	**char**	→ #6F
6506C	**Connecting**	→ #C0A
0403F	**EIGHT**	→ #8
040A3	**EIGHTEEN**	→ #12
64C34	**EIGHTY**	→ #50
64C3E	**EIGHTYONE**	→ #51
0405D	**ELEVEN**	→ #B
0407B	**EXT**	→ #E
6508A	**EXTOBOB**	→ #E00
64DF6	**EXTREAL**	→ #E1
64E00	**EXTSYM**	→ #EA
04085	**FIFTEEN**	→ #F
64B4E	**FIFTY**	→ #32
64B9E	**FIFTYEIGHT**	→ #3A
64B80	**FIFTYFIVE**	→ #37
64B76	**FIFTYFOUR**	→ #36
64BA8	**FIFTYNINE**	→ #3B
64B58	**FIFTYONE**	→ #33
64B94	**FIFTYSEVEN**	→ #39
64B8A	**FIFTYSIX**	→ #38
64B6C	**FIFTYTHREE**	→ #35
64B62	**FIFTYTWO**	→ #34
642E3	**FIVE**	→ #5
64C5C	**FIVEFOUR**	→ #54
64C70	**FIVESIX**	→ #56
64C52	**FIVETHREE**	→ #53
0417F	**FORTY**	→ #28
64B3A	**FORTYEIGHT**	→ #30
64B1C	**FORTYFIVE**	→ #2D
64B44	**FORTYNINE**	→ #31
04189	**FORTYONE**	→ #29
64B30	**FORTYSEVEN**	→ #2F
64B26	**FORTYSIX**	→ #2E
0419D	**FORTYTHREE**	→ #2B
04193	**FORTYTWO**	→ #2A
642E3	**FOUR**	→ #4
64C0C	**FOURFIVE**	→ #45
0407B	**FOURTEEN**	→ #E
64BF8	**FOURTHREE**	→ #43
64BEE	**FOURTWO**	→ #42
0417F	**FOURTY**	→ #28
0402B	**id**	→ #6
0402B	**idnt**	→ #6
64C98	**IDREAL**	→ #61
00305	**infreserr**	→ #305
64F04	**INTEGER337**	→ #
00A03	**intrptderr**	→ #a03
04021	**list**	→ #5
64C48	**LISTCMP**	→ #52
64C7A	**LISTLAM**	→ #57
64C3E	**LISTREAL**	→ #51
6509E	**MINUSONE**	→ #FFFFF
04049	**NINE**	→ #9
040AD	**NINETEEN**	→ #13
00303	**ofloerr**	→ #303
073DB	**ONE**	→ #1
64CAC	**ONEHUNDRED**	→ #64
63AC4	**ONEONE**	→ #1 #1
03FF9	**real**	→ #1
0411B	**REALEXT**	→ #1E
0408F	**REALOB**	→ #10
64E32	**REALOBOB**	→ #100
04099	**REALREAL**	→ #11
040F3	**REALSYM**	→ #1A
64E14	**ROMPANY**	→ #F0
0403F	**seco**	→ #8
6427A	**SEVEN**	→ #7
04099	**SEVENTEEN**	→ #11
64C16	**SEVENTY**	→ #46
64C20	**SEVENTYFOUR**	→ #4A
64C2A	**SEVENTYNINE**	→ #4F
0402B	**SIX**	→ #6
0408F	**SIXTEEN**	→ #10
64BB2	**SIXTY**	→ #3C
64C02	**SIXTYEIGHT**	→ #44
64BDA	**SIXTYFOUR**	→ #40
64BBC	**SIXTYONE**	→ #3D
64BD0	**SIXTYTHREE**	→ #3F
64BC6	**SIXTYTWO**	→ #3E
0400D	**str**	→ #3
04053	**sym**	→ #A
04049	**symb**	→ #9
64D56	**SYMBUNIT**	→ #9E
64DBA	**SYMEXT**	→ #AE
64D92	**SYMID**	→ #A6
64D9C	**SYMLAM**	→ #A7
64D6A	**SYMOB**	→ #A0
64D74	**SYMREAL**	→ #A1
64DB0	**SYMSYM**	→ #AA
64DEC	**TAGGEDANY**	→ #D0
04053	**TEN**	→ #A
04071	**THIRTEEN**	→ #D
0411B	**THIRTY**	→ #1E
0416B	**THIRTYEIGHT**	→ #26
0414D	**THIRTYFIVE**	→ #23
04143	**THIRTYFOUR**	→ #22
04175	**THIRTYNINE**	→ #27
04125	**THIRTYONE**	→ #1F
04161	**THIRTYSEVEN**	→ #25
04157	**THIRTYSIX**	→ #24
04139	**THIRTYTHREE**	→ #21
0412F	**THIRTYTWO**	→ #20
642D1	**THREE**	→ #3
04067	**TWELVE**	→ #C
040B7	**TWENTY**	→ #14
04107	**TWENTYEIGHT**	→ #1C
040E9	**TWENTYFIVE**	→ #19
040DF	**TWENTYFOUR**	→ #18
04111	**TWENTYNINE**	→ #1D
040C1	**TWENTYONE**	→ #15
040FD	**TWENTYSEVEN**	→ #1B

040F3	**TWENTYSIX**	→ #1A
040D5	**TWENTYTHREE**	→ #17
040CB	**TWENTYTWO**	→ #16
642BF	**TWO**	→ #2
64D24	**XHI**	→ #83
64D1A	**XHI-1**	→ #82

b) Binary Integer Manipulation

- Arithmetic Functions

Addr	Word	Stack diagram
03EC2	**#***	#2 #1 → #2*#1
03DBC	**#+**	#2 #1 → #2+#1
63808	**#+-1**	#2 #1 → #2+#1-1
03DE0	**#-**	#2 #1 → #2-#1
624FB	**#-#2/**	#2 #1 → (#2-#1)/2
637CC	**#-+1**	#2 #1 → (#2-#1)+1
03EF7	**#/**	#2 #1 → #remainder #quotient
03DEF	**#1+**	# → #+1
639CA	**#1+'**	# → #+1 (and quotes next runstream object)
62809	**#1+DUP**	# → #+1 #+1
03E0E	**#1-**	# → #-1
6264E	**#10***	# → #*10
625DA	**#10+**	# → #+10
625EA	**#12+**	# → #+12
03E6F	**#2***	# → #*2
03E2D	**#2+**	# → #+2
03E4E	**#2-**	# → #-2
03E8E	**#2/**	# → FLOOR(#/2)
6256A	**#3+**	# → #+3
625FA	**#3-**	# → #-3
6257A	**#4+**	# → #+4
6260A	**#4-**	# → #-4
6258A	**#5+**	# → #+5
6261A	**#5-**	# → #-5
62691	**#6***	# → #*6
6259A	**#6+**	# → #+6
625AA	**#7+**	# → #+7
62674	**#8***	# → #*8

- Conversion Functions

Addr	Word	Stack diagram	Explanation
18CEA	**COERCE**	% → #	If %<0 then # is 0, If %>FFFFF then #=FFFFF
194F7	**COERCE2**	%2 %1 → #2 #1	If %<0 then # is 0, If %>FFFFF then #=FFFFF
62CE1	**COERCEDUP**	% → # #	If %<0 then # is 0, If %>FFFFF then #=FFFFF
62E7B	**COERCESWAP**	ob % → # ob	If %<0 then # is 0, If %>FFFFF then #=FFFFF
18DBF	**UNCOERCE**	# → %	
63B96	**UNCOERCE%%**	# → %%	
1950B	**UNCOERCE2**	#2 #1 → %2 %1	

Addr	Word
65433	**CHR_#**
6544F	**CHR_-**
6546B	**CHR_1**
65487	**CHR_5**
654A3	**CHR_9**
654BF	**CHR_=**
654DB	**CHR_C**
654F7	**CHR_G**
65513	**CHR_K**
6552F	**CHR_O**
6554B	**CHR_S**

64209	**ZERO**	→ #0
641FC	**ZEROZERO**	→ #0 #0
6431D	**ZEROZEROONE**	→ #0 #0 #1
64331	**ZEROZEROTWO**	→ #0 #0 #2
64309	**ZEROZEROZERO**	→ #0 #0 #0

625BA	**#8+**	# → #+8
625CA	**#9+**	# → #+9
624C6	**#MAX**	#2 #1 → MAX(#2,#1)
624BA	**#MIN**	#2 #1 → MIN(#2,#1)
63704	**2DUP#+**	#2 #1 → #2 #1 #1+#2
637F4	**DROP#1-**	# ob → #-1
628EB	**DUP#1+**	# → # #+1
6292F	**DUP#1-**	# → # #-1
63704	**DUP3PICK#+**	#2 #1 → #2 #1 #1+#2
6372C	**OVER#+**	#2 #1 → #2 #1+#2
6377C	**OVER#-**	#2 #1 → #2 #1-#2
63718	**ROT#+**	#2 ob #1 → ob #1+#2
62DCC	**ROT#+SWAP**	#2 ob #1 → #1+#2 ob
63768	**ROT#-**	#2 ob #1 → ob #1-#2
637B8	**ROT#1+**	# ob ob' → ob ob' #+1
62DCC	**ROT+SWAP**	#2 ob #1 → #1+#2 ob
62794	**SWAP#-**	#2 #1 → #1-#2
62904	**SWAP#1+**	# ob → ob #+1
51843	**SWAP#1+SWAP**	# ob → #+1 ob
637E0	**SWAP#1-**	# ob → ob #-1
51857	**SWAP#1-SWAP**	# ob → #-1 ob
637A4	**SWAPOVER#-**	#2 #1 → #1 #2-#1

2.8.3 Character Constants

Addr	Word	Stack diagram	Explanation
05A51	**CHR>#**	chr → #	
05A75	**#>CHR**	# → chr	
6475C	**CHR>$**	chr → $	

65567	**CHR_W**
65583	**CHR_a**
6559F	**CHR_e**
655BB	**CHR_i**
655D7	**CHR_m**
655F3	**CHR_q**
6560F	**CHR_u**
6562B	**CHR_y**
6542C	**CHR_DblQuote**
6564E	**CHR_Angle**
6566A	**CHR_Newline**
65686	**CHR_Space**

656A2	**CHR_{**
656BE	**CHR_<>**
6543A	**CHR_***
65456	**CHR_.**
65472	**CHR_2**
6548E	**CHR_6**
654AA	**CHR_:**
654C6	**CHR_>**
654E2	**CHR_D**
654FE	**CHR_H**
6551A	**CHR_L**
65536	**CHR_P**
65552	**CHR_T**
6556E	**CHR_X**
6558A	**CHR_b**
655A6	**CHR_f**
655C2	**CHR_j**
655DE	**CHR_n**
655FA	**CHR_r**
65616	**CHR_v**
65632	**CHR_z**
65639	**CHR_->**
65655	**CHR_Deriv**
65671	**CHR_Pi**
6568D	**CHR_UndScore**
656A9	**CHR_}**
65441	**CHR_+**
6545D	**CHR_/**
65479	**CHR_3**
65495	**CHR_7**
654B1	**CHR_;**
654CD	**CHR_A**
654E9	**CHR_E**
65505	**CHR_I**
65521	**CHR_M**
6553D	**CHR_Q**
65559	**CHR_U**
65575	**CHR_Y**
65591	**CHR_c**
655AD	**CHR_g**
655C9	**CHR_k**
655E5	**CHR_o**
65601	**CHR_s**
6561D	**CHR_w**

Addr	Word	Stack diagram	Explanation
656C5	**$_R<<**		$ "R\80\80" "R<angle><angle>"
656D5	**$_R<Z**		$ "R\80Z" "R<angle>Z"
656E5	**$_XYZ**		$ "XYZ"
656F5	**$_<<>>**		$ "ABBB"
65703	**$_{}**		$ "{}"
65711	**$_[]**		$ "[]"
6571F	**$_''**		$ """
6572D	**$_::**		$ "::"
6573B	**$_LRParens**		$ "()"
65749	**$_2DQ**		$ """"""
65757	**$_ECHO**		$ "ECHO"
65769	**$_EXIT**		$ "EXIT"
6577B	**$_Undefined**		$ "Undefined"
65797	**$_RAD**		$ "RAD"
657A7	**$_GRAD**		$ "GRAD"
65238	**NEWLINE$**		$ "\0a"
65254	**SPACE$**		$ " "

6541E	**CHR_00 (hex0)**
65640	**CHR_<<**
6565C	**CHR_Integral**
65678	**CHR_RightPar**
65694	**CHR_[**
656B0	**CHR_<=**
65448	**CHR_,**
65464	**CHR_0**
65480	**CHR_4**
6549C	**CHR_8**
654B8	**CHR_<**
654D4	**CHR_B**
654F0	**CHR_F**
6550C	**CHR_J**
65528	**CHR_N**
65544	**CHR_R**
65560	**CHR_V**
6557C	**CHR_Z**
65598	**CHR_d**
655B4	**CHR_h**
655D0	**CHR_l**
655EC	**CHR_p**
65608	**CHR_t**
65624	**CHR_x**
65425	**CHR_...**
65647	**CHR_>>**
65663	**CHR_LeftPar**
6567F	**CHR_Sigma**
6569B	**CHR_]**
656B7	**CHR_>=**

2.8.4 Hex & Character Strings

a) Character Strings

Addr	Word	Stack diagram	Explanation
623A0	**!append$**	$1 $2 → $3	Same as &$, except that it will attempt the concatenation "in place," if there is not enough memory for the new string, and the target is in tempob.
05B15	**$>ID**	$name → Id	Converts string object to name object
05193	**&$**	$1 $2 → $3	Appends $2 to $1
63F6A	**&$SWAP**	ob $1 $2 → $3 ob	Appends $2 to $1, then swaps result with ob
0525B	**>H$**	$ chr → $'	Prepends chr to $
052EE	**>T$**	$ chr → $'	Appends chr to $
63259	**1_#1-SUB$**	$ # → $'	Where $' = chars 1 thru #-1 of $
162B8	**a%>$**	% → $	Converts % to $ using current display mode
162AC	**a%>$,**	% → $	Converts % to $ using current display mode. Same as a%>$, but with no commas
18873	**AND$**	$1 $2 → $1 AND $2	Bitwise logical AND of two strings
62BB0	**APPEND_SPACE**	$ → $'	Appends space to $
45676	**Blank$**	# → $	Creates a string of # spaces
050ED	**CAR$**	$ → chr | $	Returns 1st chr of $ or NULL$ if $ is null

0516C	**CDR$**	$ → $'	$' is $ minus first character. Returns NULL$ if $ is null
12770	**COERCE$22**	$ → $'	If $ longer than 22 chars., truncates to 21 chars & appends "..."
15B13	**DECOMP$**	ob → $	Decompiles object for stack display
14088	**DO>STR**	ob → $	Internal version of **OSTR**
04D3E	**DROPNULL$**	ob → NULL$	Drops object, returns zero-length string
63295	**DUP$>ID**	$name → $name Id	Dups, converts string object to name object
627BB	**DUPLEN$**	$ → $ #length	Returns $ and its length
63209	**DUPNULL$?**	$ → $ flag	Returns TRUE if $ is zero-length
15A0E	**EDITDECOMP$**	ob → $	Decompile object for editing
05BE9	**ID>$**	ID → $name	Converts name object to a string
04D87	**JstGETTHEMSG**	# → $	Fetches message from message table
63281	**LAST$**	$ # → $'	Returns last # chrs of $
627BB	**LEN$**	$ → #length	Returns length of $
63191	**NEWLINE$&$**	$ → $'	Appends "\0a" to $
04D3E	**NULL$**	→ $	Returns empty string
0556F	**NULL$?**	$ → flag	Returns TRUE if $ is zero-length
62D59	**NULL$SWAP**	ob → $ ob	Swaps empty string into level 2
1613F	**NULL$TEMP**	→ $	Creates empty string in TEMPOB
18887	**OR$**	$1 $2 → $3	Bitwise logical OR of two strings
05622	**OVERLEN$**	$ ob → $ ob #length	Returns length of $ in level 2
238A4	**palparse**	$ → ob TRUE $ → $ #pos $' FALSE	Parse a string into an object and TRUE, or returns position of error and FALSE
645B1	**POS$**	$search $find #start → #pos	Returns #pos (#0 if not found) of $find within $search starting at head of $search
645BD	**POS$REV**	$search $find #start → #pos	Returns #pos (#0 if not found) of $find within $search starting at tail of $search
49709	**PromptIdUtil**	id ob → $	Returns string in the form **"id: ob"**
127A7	**SEP$NL**	$ → $2 $1	Separate $ at newline character
63245	**SUB$**	$ #start #end → $'	Returns substring of $
30805	**SUB$1#**	$ #pos → #	Returns bint with value of character in $ at position #pos
62D6D	**SUB$SWAP**	ob $ #start #end → $' ob	Returns substring of $ and swaps with ob
622EF	**SWAP&$**	$1 $2 → "$2$1"	Appends $1 to $2
0D304	**TIMESTR**	%date %time → "WED 03/30/90 11:30:15A"	Returns string time and date (equivalent to the user word **TSTR**)
1889B	**XOR$**	$1 $2 → $3	Bitwise logical XOR of two strings

b) Hex Strings

Addr	Word	Stack diagram	Explanation
5435D	**#>%**	hxs → %	Converts hxs to real
543F9	**%>#**	% → hxs	Converts real to hxs
0518A	**&HXS**	hxs1 hxs2 → hxs3	Appends hxs2 to hxs1
51532	**2HXSLIST?**	{ hxs1 hxs2 } → #1 #2	Converts list of two hxs into two bints. Generates Bad Argument Value error for invalid input
544EC	**HXS#HXS**	hxs1 hxs2 → %flag	Returns %1 if hxs1 <> hxs2, otherwise %0
05A03	**HXS>#**	hxs → #	Converts lower 20 bits of hxs into a bint
54061	**HXS>$**	hxs → $	Does hxs>$, then appends base character
5435D	**HXS>%**	hxs → %	Converts hex string to real number
54552	**HXS<HXS**	hxs1 hxs2 → %flag	Returns %1 if hxs1<hxs2, otherwise %0
54500	**HXS>HXS**	hxs1 hxs2 → %flag	Returns %1 if hxs1>hxs2, otherwise %0
5452C	**HXS>=HXS**	hxs1 hxs2 → %flag	Returns %1 if hxs1>=hxs2, otherwise %0
5453F	**HXS<=HXS**	hxs1 hxs2 → %flag	Returns %1 if hxs1<=hxs2, otherwise %0
05616	**LENHXS**	hxs → #length	Returns # of nibbles in hxs
055D5	**NULLHXS**	→ hxs	Returns zero-length hex string
05815	**SUBHXS**	hxs #m #n → hxs'	Returns substring

Addr	Word
2A562	**%%.1**
2B3DD	**%%.4**
2A57C	**%%.5**
2A4C6	**%%0**
2A4E0	**%%1**
2A596	**%%10**
2B2DC	**%%12**

User RPL binary integers are actually hex strings. The following words assume 64-bit or shorter hex strings, and return results according to the current wordsize:

Addr	Word	Stack diagram	Explanation
53F05	**bit/**	hxs1 hxs2 → hxs3	Divides hxs1 by hxs2
5429F	**bit%#/**	% hxs → hxs'	Divides % by hxs, returns hxs
542BD	**bit#%/**	hxs % → hxs'	Divides hxs by %, returns hxs
53ED3	**bit***	hxs1 hxs2 → hxs3	Multiplies hxs1 by hxs2
542D1	**bit%#***	% hxs → hxs'	Multiplies % by hxs, returns hxs
542EA	**bit#%***	hxs % → hxs'	Multiplies hxs by %, returns hxs
53EA0	**bit+**	hxs1 hxs2 → hxs3	Adds hxs1 to hxs2
54330	**bit%#+**	% hxs → hxs'	Adds % to hxs, returns hxs
54349	**bit#%+**	hxs % → hxs'	Adds hxs to %, returns hxs
53EB0	**bit-**	hxs1 hxs2 → hxs3	Subtracts hxs2 from hxs1
542FE	**bit%#-**	% hxs → hxs'	Suptracts % from hxs, returns hxs
5431C	**bit#%-**	hxs % → hxs'	Suptracts hxs from %, returns hxs
53D04	**bitAND**	hxs1 hxs2 → hxs3	Bitwise logical AND
53E65	**bitASR**	hxs → hxs'	Arithmetic shift right one bit
53D15	**bitOR**	hxs1 hxs2 → hxs3	Bitwise logical OR
53D4E	**bitNOT**	hxs1 hxs2 → hxs3	Bitwise logical NOT
53E0C	**bitRL**	hxs → hxs'	Circular left shift by 1 bit
53E3B	**bitRLB**	hxs → hxs'	Circular left shift by 1 byte
53DA4	**bitRR**	hxs → hxs'	Circular right shift by 1 bit
53DE1	**bitRRB**	hxs → hxs'	Circular right shift by 1 byte
53D5E	**bitSL**	hxs → hxs'	Shift left by 1 bit
53D6E	**bitSLB**	hxs → hxs'	Shift left by 1 byte
53D81	**bitSR**	hxs → hxs'	Shift right by 1 bit
53D91	**bitSRB**	hxs → hxs'	Shift right by 1 byte
53D26	**bitXOR**	hxs1 hxs2 → hxs3	Bitwise logical XOR

Wordsize control:

Addr	Word	Stack diagram	Explanation
54039	**WORDSIZE**	→ #	Returns user binary integer wordsize
53CAA	**dostws**	# →	Stores binary wordsize
540BB	**hxs>$**	hxs → $	Converts hex string to chr string using the current display mode and wordsize

2.8.5 Real Numbers

a) Built-in Reals

2A4FA	**%%2**
0F688	**%%2PI**
2A514	**%%3**
2A52E	**%%4**
2A548	**%%5**
2B300	**%%60**
2B1FF	**%%7**
2A562	**%.1**

2A57C	**%.5**
2A386	**%-1**
2A4C6	**%0**
2A4E0	**%1**
2A596	**%10**
415F1	**%100**
1CC03	**%11**
2B2DC	**%12**
1CC37	**%13**
1CC51	**%14**
1CC85	**%15**
1CD3A	**%16**
1CD54	**%17**
650FC	**%180**
2A39B	**%-2**
1CC6B	**%20**
1CCA4	**%21**
1CCC3	**%22**
1CCE2	**%23**
1CD01	**%24**
1CD20	**%25**
1CD73	**%26**
1CD8D	**%27**
2A3B0	**%-3**
65126	**%360**
2A3C5	**%-4**

b) Real Number Functions

Addr	Word	Stack diagram	Explanation
2A99A	**%%***	%%1 %%2 → %%3	Multiplies two extended reals
62FED	**%%*ROT**	ob1 ob2 %%1 %%2 → ob2 %%3 ob1	Multiplies two extended reals, then does a ROT
62EA3	**%%*SWAP**	ob %%1 %%2 → %%3 ob	Multiplies two extended reals, then does a SWAP
63C18	**%%*UNROT**	ob1 ob2 %%1 %%2 → %%3 ob1 ob2	Multiplies two extended reals, then does an UNROT
2A943	**%%+**	%%1 %%2 → %%3	Adds two extended reals
2A94F	**%%-**	%%1 %%2 → %%3	Subtraction
2A8F0	**%%ABS**	%% → %%'	Absolute value
2AD08	**%%ACOSRAD**	%% → %%'	Arc-cosine using radians
2AD4F	**%%ANGLE**	%%x %%y → %%angle	Angle using current angle mode from %%x %%y
2AD6C	**%%ANGLEDEG**	%%x %%y → %%angle	Angle using degrees from %%x %%y
2AD7C	**%%ANGLERAD**	%%x %%y → %%angle	Angle using radians from %%x %%y
2ACD8	**%%ASINRAD**	%% → %%'	Arc-sine using radians
2A910	**%%CHS**	%% → %%'	Change sign
2AC57	**%%COS**	%% → %%'	Cosine
2AC68	**%%COSDEG**	%% → %%'	Cosine using degrees
2ADC7	**%%COSH**	%% → %%'	Hyperbolic cosine
2AC78	**%%COSRAD**	%% → %%'	Cosine using radians
2AB1C	**%%EXP**	%% → %%'	e^x
2AF99	**%%FLOOR**	%% → %%'	Greatest integer <= x
2AF27	**%%H>HMS**	%% → %%'	Decimal hours to hh.mmss
2AF99	**%%INT**	%% → %%'	Integer part
2AB5B	**%%LN**	%% → %%'	ln(x)
2AB94	**%%LNP1**	%% → %%'	ln(x+1)
2A6DC	**%%MAX**	%%1 %%2 → %%3	Returns greater of two %%s
2B4C5	**%%P>R**	%%radius %%angle → %%x %%y	Polar to rectangular conversion
2B498	**%%R>P**	%%x %%y → %%radius %%angle	Rectangular to polar conversion
2AC06	**%%SIN**	%% → %%'	Sine
2AC17	**%%SINDEG**	%% → %%'	Sine using degrees
2AD95	**%%SINH**	%% → %%'	Hyperbolic sine
2AAEA	**%%SQRT**	%% → %%'	Square root
2ACA8	**%%TANRAD**	%% → %%'	Tangent using radians

2A3DA	**%-5**
2A3EF	**%-6**
2A404	**%-7**
2A419	**%-8**
2A42E	**%-9**
2A487	**%-MAXREAL**
2A4B1	**%-MINREAL**
2A4FA	**%2**
2A514	**%3**
2A52E	**%4**
2A548	**%5**
2B300	**%6**
2B1FF	**%7**
2A35C	**%8**
650A8	**%e**
2A472	**%MAXREAL**
2A49C	**%MINREAL**
2A443	**%PI**

2AA5F	**%%^**	%%1 %%2 → %%3	Exponential
2A943	**%+**	%1 %2 → %3	Addition
51BE4	**%+SWAP**	ob %1 %2 → %3 ob	Addition, then SWAP
2A94F	**%-**	%1 %2 → %3	Subtraction
50262	**%1+**	% → %+1	Adds one
50276	**%1-**	% → %-1	Subtracts one
543F9	**%>#**	% → hxs	Converts real to binary integer
2A5C1	**%>%%**	% → %%	Converts real to extended real
2A95B	**%>%%-**	%1 %2 → %%3	Converts 2 % to %%, then subtracts
2AA9E	**%>%%1**	%x → %%	Converts % to %%, then does 1/x
2AD5B	**%>%%ANGLE**	%x %y → %%angle	Angle in current angle mode
2AAF6	**%>%%SQRT**	% → %%	Converts % to %%, then sqrt(x)
62E8F	**%>%%SWAP**	ob % → %% ob	Converts % to %%, then SWAP
51A07	**%>C%**	%real %imag → C%	Real to complex conversion
2A673	**%>HMS**	% → %hh.mmss	Decimal hours to hh.mmss
2A8F0	**%ABS**	% → %'	Absolute value
18CD7	**%ABSCOERCE**	% → #	Absolute value, convert to bint
2AD08	**%ACOS**	% → %'	Arc cosine
2AE13	**%ACOSH**	% → %'	Hyperbolic arc cosine
2ABBA	**%ALOG**	% → %'	10^x
2AD4F	**%ANGLE**	%x %y → %angle	Angle using current angle mode from %x %y
2ACD8	**%ASIN**	% → %'	Arc sine
2AE00	**%ASINH**	% → %'	Hyperbolic arc sine
2AD21	**%ATAN**	% → %'	Arc tangent
2AE26	**%ATANH**	% → %'	Hyperbolic arc tangent
2AF73	**%CEIL**	% → %'	Next greatest integer
2A910	**%CH**	%1 %2 → %3	Percent change
2A910	**%CHS**	% → %'	Change sign
2AE62	**%COMB**	%m %n → %COMB(m,n)	Combinations of m items taken n at a time
2AC57	**%COS**	% → %'	Cosine
2ADC7	**%COSH**	% → %'	Hyperbolic cosine
2A622	**%D>R**	% → %'	Degrees to radians
2AB1C	**%EXP**	% → %'	e^x
2AB42	**%EXPM1**	% → %'	e^x-1
2AE39	**%EXPONENT**	% → %'	Returns exponent
2B0C4	**%FACT**	% → %!	Factorial
2AF99	**%FLOOR**	% → %'	Greatest integer <= x

2AF4D	**%FP**	% → %'	Fractional part
2A6A0	**%HMS+**	%1 %2 → %3	HH.MMSS addition
2A6C8	**%HMS-**	%1 %2 → %3	HH.MMSS subtraction
2A68C	**%HMS>**	% → %'	Convert hh.mmss to decimal hours
2AF60	**%IP**	% → %'	Integer part
2EC11	**%IP>#**	% → #	IP(ABS(x) converted to binary integer
2AB5B	**%LN**	% → %'	ln(x)
2AB94	**%LNP1**	% → %'	ln(x+1)
2AB81	**%LOG**	% → %'	Common log
2A930	**%MANTISSA**	% → %'	Returns mantissa
2A6DC	**%MAX**	%1 %2 → %	Returns larger of two reals
62D81	**%MAXorder**	%1 %2 → %larger %smaller	Orders two numbers
2A70E	**%MIN**	%1 %2 → %	Returns smaller of two reals
2ABDC	**%MOD**	%1 %2 → %3	Returns %1 MOD %2
2AE4C	**%NFACT**	% → %'	Factorial
2AA81	**%NROOT**	%1 %2 → %3	Nth root
2A9C9	**%OF**	%1 %2 → %3	Returns percantage of %1 that is %2
2AE75	**%PERM**	%m %n → %PERM(%m,%n)	Returns permutations of %m items taken %n at a time
2B4BB	**%POL>%REC**	%x %y → %radius %angle	Rectangular to polar conversion
2A655	**%R>D**	%radians → %degrees	Radians to degrees
2AFC2	**%RAN**	→ %random	Random number
2B044	**%RANDOMIZE**	%seed →	Updates random number seed, uses the system clock if %=0
2B48E	**%REC>%POL**	%radius %angle → %x %y	Polar to rectangular conversion
2A8D7	**%SGN**	% → %'	Sign: -1, 0 or 1 returned depending on the sign of the argument
2AC06	**%SIN**	% → %'	Sine
2AD95	**%SINH**	% → %'	Hyperbolic sine
2B4F2	**%SPH>%REC**	%r %th %ph → %x %y %z	Spherical to rectangular conversion
2AAEA	**%SQRT**	% → %'	Square root
2ACA8	**%T**	%1 %2 → %3	Percent total
2ACA8	**%TAN**	% → %'	Tangent

Addr	Word	Stack diagram
51A07	**%>C%**	%real %imag → C%
?	**%%>C%%**	%%real %%imag → C%%
51A07	**%%>C%**	%%real %%imag → C%
05D2C	**C%>%**	C% → %real %imag
05DBC	**C%%>%%**	C%% → %%real %%imag

c) Complex Functions

Addr	Word	Stack diagram	Explanation
51EFA	**C%1/**	C% → C%'	Inverse
52062	**C%ABS**	C% → %	Returns SQRT(x^2+y^2) from (x,y)
52863	**C%ACOS**	C% → C%'	Arc cosine
52305	**C%ALOG**	C% → C%'	Common antilog
52099	**C%ARG**	C% →	Returns ANGLE(x,y) from (x,y)
52804	**C%ASIN**	C% → C%'	Arc sine
52675	**C%ATAN**	C% → C%'	Arc tangent
52374	**C%C^C**	C%1 C%2 → C%3	Power
51B70	**C%CHS**	C% → C%'	Change sign
51B91	**C%%CHS**	C%% → C%%'	Change sign
51BB2	**C%CONJ**	C% → C%'	Conjugate
51BC1	**C%%CONJ**	C%% → C%%'	Conjugate
52571	**C%COS**	C% → C%'	Cosine
52648	**C%COSH**	C% → C%'	Hyperbolic cosine
52193	**C%EXP**	C% → C%'	e^z
521E3	**C%LN**	C% → C%'	Natural logarithm
522BF	**C%LOG**	C% → C%'	Common logarithm
520CB	**C%SGN**	C% → C%'	Returns (x/SQRT(x^2+y^2),y/SQRT(x^2+y^2))
52530	**C%SIN**	C% → C%'	Sine
5262F	**C%SINH**	C% → C%'	Hyperbolic sine
52107	**C%SQRT**	C% → C%'	Square root
525B7	**C%TAN**	C% → C%'	Tangent

2ADED	**%TANH**	% → %'	Hyperbolic tangent
2AA5F	**%^**	%1 %2 → %3	Exponential
2B470	**2%>%**	%%1 %%2 → %1 %2	Extended real to real conversion
2B45C	**2%>%%**	%1 %2 → %%1 %%2	Real to extended real conversion
05D2C	**C%>%**	C% → %real %imag	Complex to real conversion
0CC39	**DDAYS**	%date1 %date2 → %diff	Days between dates in DMY format
2B07B	**DORANDOMIZE**	% →	Updates random number seed
2B529	**RNDXY**	%number %places → %number'	Rounds %number to %places
2B53D	**TRCXY**	%number %places → %number'	Truncates %number to %places
632A9	**SWAP%>C%**	%imag %real → C%	Real to complex conversion

2.8.6 Complex Numbers

a) Built-in Complex Numbers

Addr	Word	Stack diagram
524AF	**C%0**	→ (0,0)
524F7	**C%1**	→ (1,0)
5196A	**C%-1**	→ (-1,0)
5193B	**C%%1**	→ (%%1,%%0)

b) Conversion Words

519F8	**C%%>C%**	C%% → C%
519CB	**C%>%%**	C% → %%real %%imag
519DF	**C%>%%SWAP**	C% → %%imag %%real
519B7	**C>Im%**	C% → %imag
519A3	**C>Re%**	C% → %real

5265C	**C%TANH**	C% → C%'	Hyperbolic tangent

2.8.7 Arrays

Addr	Word	Stack diagram	Explanation
03562	**ARSIZE**	[array] → #elements [array] → {dims}	
0371D	**GETATELN**	# [array] → ob `TRUE` # [array] → `FALSE`	`FALSE` if no such element.
03442	**MAKEARRY**	{dims} ob → [array]	Creates an unlinked array having the same element type as ob. All elements are initialized to ob.
35CAE	**MATCON**	[arry%] % → [arry%]' [arryC%] C% → [arryC%]'	Sets all elements in array to % or C%.
37E0F	**MATREDIM**	[array] {dims} → [array]'	
3811F	**MATTRN**	[array] → [array]'	
357A8	**MDIMS**	[1-D array] → #m `FALSE` [2-D array] → #m #n `TRUE`	
62F9D	**MDIMSDROP**	[2-D array] → #m #n	Don't use `MDIMSDROP` on a vector!
63141	**OVERARSIZE**	[array] ob → [array] ob #elements	
355B8	**PULLREALEL**	[arry%] # → [arry%] %	
355C8	**PULLCMPEL**	[arryC%] # → [arryC%] C%	
35628	**PUTEL**	[arry%] % # → [arry%]' [arryC%] C% # → [arryC%]	
3566F	**PUTREALEL**	[arry%] % # → [arry%]'	
356F3	**PUTCMPEL**	[arryC%] C% # → [arryC%]'	

2.8.8 Composite Objects

In the notation below, the term "comp" refers to either any composite object. The term "#n" refers to the number of objects in a composite object, and the term "#i" refers to the index of an object within a composite.

Addr	Word	Stack diagram	Explanation
0521F	**&COMP**	comp comp' → comp''	comp is concatenated to comp'
63FFB	**2Ob>Seco**	ob1 ob2 → :: ob1 ob2 ;	
05445	**::N**	obn ... ob1 #n → :: obn ... ob1 ;	
632D1	**::NEVAL**	obn ... ob1 #n → ?	Does ::N, then evaluates secondary
052FA	**>TCOMP**	comp ob → comp'	ob is added to the tail of comp
6317D	**CARCOMP**	comp → ob comp → comp	Returns first object in the core of the composite. Returns an null comp if the supplied composite is null.
05153	**CDRCOMP**	comp → comp' comp → comp	Returns the core of the composite minus the first object. Returns null comp if if the supplied composite is null.
631E1	**DUPINCOMP**	comp → comp obn ... ob1 #n	
63231	**DUPLENCOMP**	comp → comp #n	
6321D	**DUPNULLCOMP?**	comp → comp flag	TRUE if comp is null.
63A6F	**DUPNULL{}?**	{list} → {list} flag	TRUE if {list} is null.
644A3	**EQUALPOSCOMP**	comp ob → #pos | #0	Returns the index of the first object in comp matching (EQUAL) ob (see NTHOF also)
64127	**Embedded?**	ob1 ob2 → flag	Returns TRUE if ob2 is embedded in, or the same as, ob1; otherwise returns FALSE.
62B88	**INCOMPDROP**	comp → obn ... ob1	
054AF	**INNERCOMP**	comp → obn ... ob1 #n	
62C41	**INNERDUP**	comp → obn ... ob1 #n #n	
0567B	**LENCOMP**	comp → #n	
6480B	**NEXTCOMPOB**	comp #offset → comp #offset' ob TRUE comp #offset → comp FALSE	#offset is the nibble offset from the start of the list to the Nth object in the list. Returns a new #offset and the next object if the next object is not SEMI, otherwise returns the list and FALSE. Use #5 at the start of the list.
62D1D	**NTHCOMDDUP**	comp #i → ob ob	
62B9C	**NTHCOMPDROP**	comp #i → ob	
056B6	**NTHELCOMP**	comp #i → ob TRUE comp #i → FALSE	Returns FALSE if #i is out of range
644BC	**NTHOF**	ob comp → #i | #0	Same as SWAP EQUALPOSCOMP.
055FD	**NULL::**	→ :: ;	(Returns null secondary)
63A6F	**NULL{}**	→ { }	(Returns null list)
23EED	**ONE{}N**	ob → { ob }	
63FFB	**Ob>Seco**	ob → :: ob ;	
6448A	**POSCOMP**	comp ob pred → #i | #0	If the specified object "matches" an element of the specified composite, where "match" is defined as the specified predicate returning TRUE when applied to an element of the comp and the object, then POSCOMP returns the left- to- right index of the element within the composite, or zero. For instance, to find the first real less than 5 in a list of reals: :: {list} 5 ' %< POSCOMP ;
1DC00	**PUTLIST**	ob #i {list} → {list}'	Assumes 0<#i<=#n
05821	**SUBCOMP**	comp #m #n → comp' (Returns subcomposite)	IF #m > #n THEN comp' is null IF #m=0 THEN #m is set to 1 IF #n=0 THEN #n is set to 1 IF #m > LEN(comp) THEN comp' is null IF #n > LEN(comp) THEN #n is set to LEN(comp)
631F5	**SWAPINCOMP**	comp obj → obj obn ... ob1 #n	
631CD	**THREE{}N**	ob1 ob2 ob3 → { ob1 ob2 ob3 }	
631B9	**TWO{}N**	ob1 ob2 → { ob1 ob2 }	
631A5	**{}N**	obn ... ob1 #n → {list}	
35491	**apndvarlst**	{list} ob → {list}'	Adds ob to the list if ob is not found within the list
643EF	**matchob?**	ob comp → ob TRUE ob comp → FALSE	Determines if ob is equal (EQUAL) to any element of comp

2.8.9 Tagged Objects

Addr	Word	Stack diagram	Explanation
22618	**%>TAG**	ob % → tagged	Tags ob with %
22618	**>TAG**	ob $ → tagged	Tags ob with $
05F2E	**ID>TAG**	ob id/lam → tagged	Tags ob with id
64775	**STRIPTAGS**	tagged → ob	Removes all tags
647A2	**STRIPTAGS12**	tagged ob' → ob ob'	Strips tags from level 2 object
647BB	**TAGOBS**	ob $ → tagged ob1 ... obn { $1 ... $n } → tagged1 ... taggedn	Tags one object, or several objects if a list of tags is in level 1
225F5	**USER$>TAG**	ob $ → tagged	Tags ob with $ (up to 255 chrs valid)

2.8.10 Unit Objects

Addr	Word	Stack diagram	Explanation
0FE44	**U>NCQ**	unit → n%% cf%% qhxs	Returns number, conversion factor, and hex quantity string
0F584	**UM=?**	unit1 unit2 → %flag	Returns %1 if two unit obs are equal
0F598	**UM#?**	unit1 unit2 → %flag	Returns %1 if unit1 <> unit2
0F5AC	**UM<?**	unit1 unit2 → %flag	Returns %1 if unit1 < unit2
0F5C0	**UM>?**	unit1 unit2 → %flag	Returns %1 if unit1 > unit2
0F5D4	**UM<=?**	unit1 unit2 → %flag	Returns %1 if unit1 <= unit2
0F5E8	**UM>=?**	unit1 unit2 → %flag	Returns %1 if unit1 >= unit2
0F33A	**UM>U**	% unit → unit'	Replaces the number part of a unit object
0FBAB	**UM%**	unit %percentage → unit'	Returns a percentage of a unit object
0FC3C	**UM%CH**	unit1 unit2 → %	Returns percent difference
0FCCD	**UM%T**	unit1 unit2 → %	Returns percentage fraction
0F6A2	**UM+**	unit1 unit2 → unit3	Addition
0F774	**UM-**	unit1 unit2 → unit3	Subtraction
F792	**UM***	unit1 unit2 → unit3	Multiply
0F823	**UM/**	unit1 unit2 → unit3	Divide
10B72	**UM^**	unit1 unit2 → unit3	Power
?	**UM1/**	unit → unit'	Inverse
0F5FC	**UMABS**	unit → unit'	Absolute value
0F615	**UMCHS**	unit → unit'	Change sign
0F371	**UMCONV**	unit1 unit2 → unit1'	Converts unit1 to units of unit2
0F660	**UMCOS**	unit → unit'	Cosine
0FB6F	**UMMAX**	unit1 unit2 → unit?	Returns larger of unit1 and unit2
0FB8D	**UMMIN**	unit1 unit2 → unit?	Returns smaller of unit1 and unit2
0F945	**UMSI**	unit → unit'	Convert to SI base units
0F62E	**UMSIN**	unit → unit'	Sine
F913	**UMSQ**	unit → unit'	Square
F92C	**UMSQRT**	unit → unit'	Square root
0F674	**UMTAN**	unit → unit'	Tangent
0F34E	**UMU>**	unit → % unit'	Returns number and normalized unit parts of a unit object
0F8FA	**UMXROOT**	unit1 unit2 → unit3	unit1^1/unit2
0F218	**UNIT>$**	unit → $	Decompiles a unit object with tics

2.8.11 Temporary Variables and Temporary Environments

Addr	Word	Stack diagram	Explanation
62DB3	**1ABNDSWAP**	ob → lamob ob	Does :: 1GETLAM ABND SWAP ;
634B6	**1GETABND**	→ lamob	Does :: 1GETLAM ABND ;
613B6	**1GETLAM**	→ ob	Returns contents of 1st lam
613E7	**2GETLAM**	→ ob	Returns contents of 2nd lam
6140E	**3GETLAM**	→ ob	Returns contents of 3rd lam
61438	**4GETLAM**	→ ob	Returns contents of 4th lam
6145C	**5GETLAM**	→ ob	Returns contents of 5th lam
6146C	**6GETLAM**	→ ob	Returns contents of 6th lam
6147C	**7GETLAM**	→ ob	Returns contents of 7th lam
6148C	**8GETLAM**	→ ob	Returns contents of 8th lam
6149C	**9GETLAM**	→ ob	Returns contents of 9th lam
614AC	**10GETLAM**	→ ob	Returns contents of 10th lam

614BC	**11GETLAM**	→ ob	Returns contents of 11th lam
614CC	**12GETLAM**	→ ob	Returns contents of 12th lam
614DC	**13GETLAM**	→ ob	Returns contents of 13th lam
614EC	**14GETLAM**	→ ob	Returns contents of 14th lam
614FC	**15GETLAM**	→ ob	Returns contents of 15th lam
6150C	**16GETLAM**	→ ob	Returns contents of 16th lam
6151C	**17GETLAM**	→ ob	Returns contents of 17th lam
6152C	**18GETLAM**	→ ob	Returns contents of 18th lam
6153C	**19GETLAM**	→ ob	Returns contents of 19th lam
6154C	**20GETLAM**	→ ob	Returns contents of 20th lam
6155C	**21GETLAM**	→ ob	Returns contents of 21st lam
6156C	**22GETLAM**	→ ob	Returns contents of 22nd lam
62F07	**1GETSWAP**	ob → lamob ob	Does `:: 1GETLAM SWAP ;`
634CF	**1LAMBIND**	ob →	Does `:: 1NULLLAM{} BIND ;`
34D2B	**1NULLLAM{}**	→ { NULLLAM }	Returns list with one null lam
615E0	**1PUTLAM**	ob →	Stores ob into 1st lam
615F0	**2PUTLAM**	ob →	Stores ob into 2nd lam
61600	**3PUTLAM**	ob →	Stores ob into 3rd lam
61615	**4PUTLAM**	ob →	Stores ob into 4th lam
61625	**5PUTLAM**	ob →	Stores ob into 5th lam
61635	**6PUTLAM**	ob →	Stores ob into 6th lam
61645	**7PUTLAM**	ob →	Stores ob into 7th lam
61655	**8PUTLAM**	ob →	Stores ob into 8th lam
61665	**9PUTLAM**	ob →	Stores ob into 9th lam
61675	**10PUTLAM**	ob →	Stores ob into 10th lam
61685	**11PUTLAM**	ob →	Stores ob into 11th lam
61695	**12PUTLAM**	ob →	Stores ob into 12th lam
616A5	**13PUTLAM**	ob →	Stores ob into 13th lam
616B5	**14PUTLAM**	ob →	Stores ob into 14th lam
616C5	**15PUTLAM**	ob →	Stores ob into 15th lam
616D5	**16PUTLAM**	ob →	Stores ob into 16th lam
616E5	**17PUTLAM**	ob →	Stores ob into 17th lam
616F5	**18PUTLAM**	ob →	Stores ob into 18th lam
61705	**19PUTLAM**	ob →	Stores ob into 19th lam
61715	**20PUTLAM**	ob →	Stores ob into 20th lam
61725	**21PUTLAM**	ob →	Stores ob into 21st lam
61735	**22PUTLAM**	ob →	Stores ob into 22nd lam
632E5	**2GETEVAL**	→ ?	Recalls & evaluates ob in 2nd lam
07943	**@LAM**	id → ob `TRUE` id → `FALSE`	Recalls lam by name, returns ob and `TRUE` if id exists; `FALSE` otherwise
07497	**ABND**	→	Abandons topmost temp var env.
074D0	**BIND**	ob ... { id ... } →	Creates new temp var env.
61CE9	**CACHE**	obn ... ob1 n lam →	Saves away n objects plus the count n in a temporary environment, each object being bound to the same identifier lam. The last pair has the count.)
61EA7	**DUMP**	NULLLAM → ob1..obn n	`DUMP` is essentially the inverse of `CACHE`, BUT: it ONLY works with NULLLAM as the cached name, and it ALWAYS does a garbage collect.
634CA	**DUP1LAMBIND**	ob → ob	Does `DUP`, then `1LAMBIND`
61610	**DUP4PUTLAM**	ob → ob	Does `DUP`, then `4PUTLAM`
61745	**DUPTEMPENV**	→	Duplicates topmost temporary env., clearing the protection word.
075A5	**GETLAM**	#n → ob	Returns object in #nth temp var
34D30	**NULLLAM**	→ NULLLAM	Null temporary variable name
075E9	**PUTLAM**	ob #n →	Stores ob in #nth temp var
18513	**STO**	ob id →	Stores ob in named global/temp var
07D1B	**STOLAM**	ob id →	Stores ob in named temp var

2.8.12 Checking Arguments

a) Number of Arguments

The following words verify that required number of arguments are on the stack, and issue the "Too Few Arguments" error otherwise.

Addr	Word	Stack diagram	Explanation
18A1E	**CK0**	→	No arguments required. Should be the 1st object of a command.
18A15	**CK0NOLASTWD**	→	No arguments required. Doesn't record the command.
18AA5	**CK1**	ob → ob	One argument required. Should be the 1st object of a command.
18AB2	**CK1NOLASTWD**	ob → ob	One argument required. Doesn't record the command.
18A80	**CK2**	ob2 ob1 → ob2 ob1	Two arguments required. Should be the 1st object of a command.
18A8D	**CK2NOLASTWD**	ob2 ob1 → ob2 ob1	Two arguments required. Doesn't record the command.
18A5B	**CK3**	ob3 ob2 ob1 → ob3 ob2 ob1	Three arguments required. Should be the 1st object of a command.
18A68	**CK3NOLASTWD**	ob3 ob2 ob1 → ob3 ob2 ob1	Three arguments required. Doesn't record the command.
18B92	**CK4**	ob4 ob3 ob2 ob1 → ob4 ob3 ob2 ob1	Four arguments required. Should be the 1st object of a command.
18B9F	**CK4NOLASTWD**	ob4 ob3 ob2 ob1 → ob4 ob3 ob2 ob1	Four arguments required. Doesn't record the command.
18B6D	**CK5**	ob5 ob4 ob3 ob2 ob1 → ob5 ob4 ob3 ob2 ob1	Five arguments required. Should be the 1st object of a command.
18B7A	**CK5NOLASTWD**	ob5 ob4 ob3 ob2 ob1 → ob5 ob4 ob3 ob2 ob1	Five arguments required. Doesn't record the command.
40BC9	**AtUserStack**	→	`:: CK0NOLASTWD 0LASTOWDOB! ;`
1592D	**CK1NoBlame**	ob → ob	`:: 0LASTOWDOB! CK1NOLASTWD ;`
18C34	**CKN**	obn ... ob1 #n → obn ... ob1	n arguments required. Should be the 1st object of a command.
18C4A	**CKNNOLASTWD**	obn ... ob1 #n → obn ... ob1	n arguments required. Doesn't record the command.

b) Dispatching on Argument Type

Addr	Word	Stack diagram	Explanation
18A1E	**CK&DISPATCH0**	... →	Dispatches upon the next pairs of objects (#type action).
18B7A	**CK&DISPATCH1**	... →	Dispatches upon the next pairs of objects (#type action). If no match found, does a second pass, stripping any tags from stack objects.
18ECE	**CK1&Dispatch**	ob →	One argument required, then dispatches upon the next pairs of objects (#type action).
18EDF	**CK2&Dispatch**	ob1 ob2 →	Two arguments required, then dispatches upon the next pairs of objects (#type action).
18EF0	**CK3&Dispatch**	ob1 ob2 ob3 →	Three arguments required, then dispatches upon the next pairs of objects (#type action).
18F01	**CK4&Dispatch**	ob1 ob2 ob3 ob4 →	Four arguments required, then dispatches upon the next pairs of objects (#type action).
18F12	**CK5&Dispatch**	ob1 ob2 ob3 ob4 ob5 →	Five arguments required, then dispatches upon the next pairs of objects (#type action).

```
CK&DISPATCH1
  #type1 action1
  #type2 action2
  ...
  #typen action3
;
```

The object-pair sequence must be terminated by a `SEMI` (`;`).

A binary integer typei is nominally encoded as follows:

```
#nnnnn
 |||||
 ||||+-- Level 1 argument type
 |||+--- Level 2 argument type
 ||+---- Level 3 argument type
 |+----- Level 4 argument type
 +------ Level 5 argument type
```

Each "n" is a hexadecimal digit representing an object type, as shown in the table below. Thus #00011 represents two real numbers; #000A0 indicates a symbolic class object (symb, id, or lam) in level 2 and any type of object in level 1. There are also two-digit object type numbers, ending in F; use of any of these consequently reduces the total number of arguments that can be encoded in a single typei integer. For example, #13F4F represents a real number in level 3, an extended real in level 2, and an extended complex in level 1.

The following table shows the hex digit values for each argument type. The column "# name" shows the object pointer name for the corresponding binary integer that may be used for a single argument function. The "Binary Integers" chapter contains a list of built-in binary integers that may be used for various common two-argument combinations.

Value	Argument	# name	User TYPE

0	Any Object	any	
1	Real Number	real	0
2	Complex Number	cmp	1
3	Character String	str	2
4	Array	arry	3,4
5	List	list	5
6	Global Name	idnt	6
7	Local Name	lam	7
8	Secondary	seco	8
9	Symbolic	symb	9
A	Symbolic Class	sym	6,7,9
B	Hex String	hxs	10
C	Graphics Object	grob	11
D	Tagged Object	TAGGED	12
E	Unit Object	unitob	13
0F	ROM Pointer		14
1F	Binary Integer		20
2F	Directory		15
3F	Extended Real		21
4F	Extended Complex		22
5F	Linked Array		23
6F	Character		24
7F	Code Object		25
8F	Library		16
9F	Backup		17
AF	Library Data		26
BF	External object1		27
CF	External object2		28
DF	External object3		29
EF	External object4		30

2.8.13 Loop Control Structures

a) Indefinite Loops

Addr	Word	Stack diagram	Explanation
071A2	**BEGIN**	→	Copies the interpreter pointer (RPL variable I) onto the return stack. Also called IDUP.
62B6F	**UNTIL**	flag →	If flag is TRUE, drops the top pointer on the return stack, otherwise copies that pointer to the interpreter pointer.
633F8	**WHILE**	flag →	If the flag is TRUE, then does nothing. Else drops the first pointer from the return stack, and skips the interpreter pointer past the next two objects.
071E5	**REPEAT**	→	Copies the first pointer on the return stack to the interpreter pointer.
071AB	**AGAIN**	→	Copies the first pointer on the return stack to the interpreter pointer.

```
BEGIN
  <test clause>
WHILE
  <loop object>
REPEAT
```

```
BEGIN
  <loop clause>
UNTIL
```

```
BEGIN
  <loop clause>
AGAIN
```
Terminating this loop requires an error event, or a direct manipulation of the return stack.

b) Definite Loops

Addr	Word	Stack diagram	Explanation
073DB	**#1+_ONE_DO**	#finish →	Equivalent to #1+ ONE DO; commonly used to execute a loop #finish times.
073DB	**DO**	#finish #start →	Begins DO loop
63466	**DROPLOOP**	ob →	Performs DROP, then LOOP
6347F	**DUP#0_DO**	# → #	Begins # ... #0 DO loop
63411	**DUPINDEX@**	ob → ob ob #index	Does DUP, then returns value of index in topmost DoLoop env.
6400F	**ExitAtLOOP**	→	Stores zero in stopping value of topmost DoLoop environment
63411	**INDEX@**	→ #index	Returns index of topmost DoLoop environment
63790	**INDEX@#-**	# → #'	Subtracts index value of topmost DoLoop environment from #
07270	**INDEXSTO**	# →	Stores # as index of top DoLoop environment
07249	**ISTOP@**	→ #stop	Returns stop value of the topmost DoLoop environment
07295	**ISTOPSTO**	# →	Stores new stop value in the topmost DoLoop environment
07258	**JINDEX@**	→ #index	Returns index of second DoLoop environment
073A5	**LOOP**	→	End of loop structure
633C6	**NOT_UNTIL**	flag →	End of loop structure
073DB	**ONE_DO**	#finish →	Begins #1...#finish DO loop
63439	**OVERINDEX@**	ob1 ob2 → ob1 ob2 ob1 #index	Does OVER, then returns value of index in topmost DoLoop environment
63425	**SWAPINDEX@**	ob1 ob2 → ob2 ob1 #index	Does SWAP, then returns value of index in topmost DoLoop environment
6344D	**SWAPLOOP**	ob1 ob2 → ob2 ob1	Does SWAP, then LOOP
6400F	**ZEROISTOPSTO**	→	Stores zero as the stop value in the topmost DoLoop environment
073C3	**ZERO_DO**	#finish →	Begins DO loop from #0 to #finish
63498	**toLEN_DO**	{list} → {list}	Begins DO loop from #1 of elements in list to stop value #number-of-elements+1.

2.8.14 Error Generation & Trapping

Addr	Word	Stack diagram	Explanation
04EA4	**ABORT**	→	Does ERRORCLR and ERRJMP
1502F	**DO#EXIT**	msg# →	Stores a new error number and executes ERRJMP; also executes AtUserStack. Puts the object ERRJMP on the stack
141E5	**ERRBEEP**	→	Generates an error beep
63155	**ERRJMP**	→	Invokes error handling subsystem
04CE6	**ERROR@**	→ #	Returns the current error number
04D33	**ERRORCLR**	→	Stores zero as the error number
6383A	**ERROROUT**	# →	Stores a new error number and does ERRJMP
04D0E	**ERRORSTO**	# →	Stores new error number
04E5E	**ERRSET**	→	used in ERRSET <suspect ob> ERRTRAP <if-error action>
04EB8	**ERRTRAP**	→	Skips next object in runstream.

2.8.15 Test and Control

a) Flags and Tests

Addr	Word	Stack diagram	Explanation
03EB1	**AND**	flag1 flag2 → flag	If flag1 and flag2 are both TRUE then TRUE else FALSE.
03AC0	**FALSE**	→ FALSE	Puts the FALSE flag on the stack.
6350B	**FALSETRUE**	→ FALSE TRUE	
2F934	**FalseFalse**	→ FALSE FALSE	
6362D	**OR**	flag1 flag2 → flag	If either flag1 or flag2 is TRUE then TRUE else FALSE.
635B0	**ORNOT**	flag1 flag2 → flag3	Logical OR followed by logical NOT.
03AF2	**NOT**	flag → flag'	If flag is TRUE then FALSE else TRUE.
62C55	**NOTAND**	flag1 flag2 → flag3	Logical NOT, then logical AND.
62C91	**ROTAND**	flag1 ob flag2 → ob flag3	Does ROT, then logical AND.
03A81	**TRUE**	→ TRUE	Puts the TRUE flag on the stack.
634F7	**TrueFalse**	→ TRUE FALSE	
0BBED	**TrueTrue**	→ TRUE TRUE	
03ADA	**XOR**	flag1 flag2 → flag	If both flag1 and flag2 are either TRUE or FALSE then FALSE, else TRUE.
5380E	**COERCEFLAG**	TRUE → %1 FALSE → %0	Converts a system flag to a real number flag.

♦ General Object Tests

Addr	Word	Stack diagram	Explanation
03B2E	**EQ**	ob1 ob2 → flag	If objects ob1 and ob2 are the same object, i.e. occupy the same physical space in memory, then TRUE else FALSE.
03B97	**EQUAL**	ob1 ob2 → flag	where ob1 and ob2 are not primitive code objects. If objects ob1 and ob2 are the same then TRUE else FALSE (this word is the system equivalent of the user RPL command **SAME**)
635D8	**2DUPEQ**	ob1 ob2 → ob1 ob2 flag	Returns TRUE if ob1 and ob2 have the same physical address.
63605	**EQOR**	flag1 ob1 ob2 → flag2	Does EQ, then logical OR.

63619	**EQUALOR**	flag1 ob1 ob2 → flag2	Does EQUAL, the logical OR.
6303D	**EQOVER**	ob1 ob2 ob3 → ob1 flag ob1	Does EQ, then OVER.
635C4	**EQUALNOT**	ob1 ob2 → flag	Returns FALSE if ob1 is equal to ob2.
62198	**TYPEARRY?**	ob → flag	TRUE if the object is an array
62193	**DTYPEARRY?** **DUPTYPEARRY?**	ob → ob flag	Dups and TRUE if the object is an array
6212F	**TYPEBINT?**	ob → flag	TRUE if the object is a binary integer
6212A	**DUPTYPEBINT?**	ob → ob flag	Dups and TRUE if the object is a binary integer
62256	**TYPECARRY?**	ob → flag	TRUE if the object is a complex array
62025	**TYPECHAR?**	ob → flag	TRUE if the object is a character
62020	**DUPTYPECHAR?**	ob → ob flag	Dups and TRUE if the object is a character
62183	**TYPECMP?**	ob → flag	TRUE if the object is a complex number
6217E	**DUPTYPECMP?**	ob → ob flag	Dups and TRUE if the object is a complex number
621EC	**TYPECOL?**	ob → flag	TRUE if the object is a program
621E7	**DTYPECOL?** **DUPTYPECOL?**	ob → ob flag	Dups and TRUE if the object is a program
62159	**TYPECSTR?**	ob → flag	TRUE if the object is a character string
62154	**DTYPECSTR?** **DUPTYPECSTR?**	ob → ob flag	Dups and TRUE if the object is a character string
6204F	**TYPEEXT?**	ob → flag	TRUE if the object is an unit
6204A	**DUPTYPEEXT?**	ob → ob flag	Dups and TRUE if the object is an unit
62201	**TYPEGROB?**	ob → flag	TRUE if the object is a graphics object
621FC	**DUPTYPEGROB?**	ob → ob flag	Dups and TRUE if the object is a graphics object
62144	**TYPEHSTR?**	ob → flag	TRUE if the object is a hex string
6213F	**DUPTYPEHSTR?**	ob → ob flag	Dups and TRUE if the object is a hex string
6203A	**TYPEIDNT?**	ob → flag	TRUE if the object is an identifier (global name)
62035	**DUPTYPEIDNT?**	ob → ob flag	Dups and TRUE if the object is an identifier (global name)
6211A	**TYPELAM?**	ob → flag	TRUE if the object is a temporary identifier (local name)
62115	**DUPTYPELAM?**	ob → ob flag	Dups and TRUE if the object is a temporary identifier (local name)
62216	**TYPELIST?**	ob → flag	TRUE if the object is a list
62211	**DTYPELIST?** **DUPTYPELIST?**	ob → ob flag	Dups and TRUE if the object is a list
6223B	**TYPERARRY?**	ob → flag	TRUE if the object is a real array
6216E	**TYPEREAL?**	ob → flag	TRUE if the object is a real number
62169	**DTYPEREAL?** **DUPTYPEREAL?**	ob → ob flag	Dups and TRUE if the object is a real number
621AD	**TYPEROMP?**	ob → flag	TRUE if the object is a ROM pointer (XLIB name)
621A8	**DUPTYPEROMP?**	ob → ob flag	Dups and TRUE if the object is a ROM pointer (XLIB name)
621C2	**TYPERRP?**	ob → flag	TRUE if the object is a directory
621BD	**DUPTYPERRP?**	ob → ob flag	Dups and TRUE if the object is a directory
621D7	**TYPESYMB?**	ob → flag	TRUE if the object is a directory
621D2	**DUPTYPESYMB?**	ob → ob flag	Dups and TRUE if the object is a directory
6222B	**TYPETAGGED?**	ob → flag	TRUE if the object is a tagged
62226	**DUPTYPETAG?**	ob → ob flag	Dups and TRUE if the object is a tagged

♦ Binary Integer Comparisons

Equality is tested in the sense of EQUAL (not EQ). Ordering treats all binary integers as unsigned.

Addr	Word	Stack diagram	Explanation
03D19	**#=**	# #' → flag	TRUE if # = #'.
03D4E	**#<>**	# #' → flag	TRUE if # <> #' (not equal).
03CA6	**#0=**	# → flag	TRUE if # = 0
03CC7	**#0<>**	# → flag	TRUE if # <> 0
03CE4	**#<**	# #' → flag	TRUE if # < #'
03D83	**#>**	# #' → flag	TRUE if # > #'
6289B	**2DUP#<**	# #' → # #' flag	TRUE if # < #'
628B5	**2DUP#=**	# #' → # #' flag	TRUE if # = #'
62266	**DUP#0=**	# → # flag	TRUE if # = #0
622C5	**DUP#1=**	# → # flag	TRUE if # = #1
622D4	**DUP#0<>**	# → # flag	TRUE if # <> #0
622C5	**DUP#1=**	# → # flag	TRUE if # = #1
63687	**DUP#<7**	# → # flag	TRUE if # < #7
63BAA	**DUP%0=**	% → % flag	TRUE if % = %0
636F0	**ONE#>**	# → flag	TRUE if # > #1
63385	**ONE_EQ**	# → flag	TRUE if # is ONE
636DC	**OVER#>**	# #' → # flag	TRUE if # > #'
6364B	**OVER#0=**	# ob → # ob flag	TRUE if # is #0
6365F	**OVER#<**	# #' → # flag	TRUE if # > #'
620EB	**OVER#=**	# #' → # flag	TRUE if # = #'
636DC	**OVER#>**	# #' → # flag	TRUE if # < #'

♦ Decimal Number Tests

Addr	Word	Stack diagram	Explanation
2A81F	**%<**	% %' → flag	TRUE if % < %'
2A8AB	**%<=**	% %' → flag	TRUE if % <= %'
2A8CC	**%<>**	% %' → flag	TRUE if % <> %'
2A8C1	**%=**	% %' → flag	TRUE if % = %'
2A87F	**%>**	% %' → flag	TRUE if % > %'
2A895	**%>=**	% %' → flag	TRUE if % >= %'
2A80B	**%0<**	% → flag	TRUE if % < 0
2A7BB	**%0<>**	% → flag	TRUE if % <> 0
2A75A	**%0=**	% → flag	TRUE if % = 0
2A788	**%0>**	% → flag	TRUE if % > 0
2A7E3	**%0>=**	% → flag	TRUE if % >= 0
2A80B	**%%0<=**	%% %%' → flag	TRUE if %% <= %%'
2A7BB	**%%0<>**	%% → flag	TRUE if %% <> 0
2A75A	**%%0=**	%% → flag	TRUE if %% = 0
2A788	**%%0>**	%% → flag	TRUE if %% > 0
2A7E3	**%%0>=**	%% → flag	TRUE if %% >= 0
2A87F	**%%>**	%% %%' → flag	TRUE if %% > %%'
2A895	**%%>=**	%% %%' → flag	TRUE if %% >= %%'
2A8AB	**%%<=**	%% %%' → flag	TRUE if %% <= %%'
51B2A	**C%%0=**	C%% → flag	TRUE if C%% = (%%0,%%0)
51B43	**C%0=**	C% → flag	TRUE if C% = (0,0)

b) Words that Operate on the Runstream

Addr	Word	Stack diagram	Explanation
06E97	**' [MK: ~]**	→ ob	Pushes the next object in the runstream on the stack (does not EVALuate it).
06EEB	**'R**	→ ob	Pushes the next object in the return stack on the stack (does not EVALuate it). If `func` contains `:: 'R STO ;`, then `func ob1 ob2` will evaluate as `ob1 STO ob2`.
639DE	**'R'R**	→ ob ob	Pushes the next two objects in the return stack on the stack.
61B89	**ticR**	→ ob TRUE FALSE	This word works similarly to 'R, except that it returns a flag to indicate whether the end of the top return stack composite has been reached. That is, if the top return stack pointer points to an object pointer to SEMI, then ticR pops the return stack and returns only FALSE. Otherwise return the next object from the composite and TRUE, while advancing the return stack pointer to the next object.
07E50	**>R**	:: →	Inserts the body of :: into the runstream, just below the top one. (That is, pushes a pointer to the body of :: onto the return stack). An example of its use is `:: ' :: <foo> ; >R <bar> ;` which will, when executed, cause <bar> to be executed before <foo>.
2B498	**R>**	→ ::	Creates a program object from the composite body pointed to by the top return stack pointer, and pushes the program on the data stack and pops the return stack. Example: `:: :: R> EVAL <foo> ; <bar> ;` which, when executed, will cause <bar> to be executed before <foo>.
62C19	**R@**	→ ::	Same as R> except that the return stack is not popped.
06FB7	**RDROP**	→	Pops the return stack.
?	**IDUP**	→	Duplicates the top body in the runstream. (That is, pushes the RPL variable I onto the return stack).

06FD1	**COLA**	→	Drops the remainder past the next object in the runstream and executes this object.
61A3B	**?SEMI**	flag →	Exits the current program if flag is TRUE.
638E4	**?SEMIDROP**	ob TRUE → FALSE →	Drops ob if flag is TRUE; exits the current program if flag is FALSE.
0712A	**?SKIP**	flag →	If flag is TRUE, skips the next object following ?SKIP.
61A2C	**NOT?SEMI**	flag →	Exits the current program if flag is FALSE.

c) If/Then/Else

Addr	Word	Stack diagram	Explanation
070C3	**RPITE**	flag ob1 ob2 → ?	If flag is TRUE then drop flag and ob2 and EVALuate ob1, else drop flag and ob1 and EVALuate ob2.
070FD	**RPIT**	flag ob → ?	If flag is TRUE then drop flag and EVALuate ob, else just drop flag and ob.
63E48	**IT**	flag →	If flag is TRUE then execute the next object in the runstream; otherwise skip that object.
63E89	**ITE**	flag →	If flag is TRUE the execute the next object in the runstream, and skip the second object; otherwise skip the next object and execute the second.
0712A	**?SKIP**	flag →	If flag is TRUE, skip the next object in the runstream; otherwise, execute it.
0714D	**SKIP**	→	Skips over the next object in the runstream and continues execution beyond it. The sequence SKIP ; is a NOP.
63E89	**#0=ITE**	# →	#0= ITE
63E9D	**#<ITE**	# →	#0< ITE
62C2D	**#=ITE**	# →	#= ITE
63EB1	**#>ITE**	# →	#> ITE
63E61	**ANDITE**	flag flag' →	AND ITE
63EC5	**DUP#0=ITE**	# → #	DUP #0= ITE
63E2F	**EQIT**	ob1 ob2 →	EQ IT
63E75	**EQITE**	ob ob' →	EQ ITE
63E48	**DUP#0=IT**	# → #	DUP #0= IT
63EED	**SysITE**	# →	
63ED9	**UserITE**	# →	

d) CASE words

Addr	Word	Stack diagram	Explanation
61993	**case**	flag →	if TRUE, executes the next object in the runstream and skips the remaining program; if FALSE, skips the next object in the runstream.
618D3	**#=casedrop**	# # → # #' → #	Should be named OVER#=casedrop.
5F181	**%1=case**	% →	
5F127	**%0=case**	% → flag	
63DDF	**ANDNOTcase**	flag1 flag2 →	
63CEA	**ANDcase**	flag1 flag2 →	
6191F	**case2drop**	ob1 ob2 TRUE →	

Addr	Word	Stack diagram
03258	**2DROP**	ob1 ob2 →
6254E	**2DROP00**	ob1 ob2 → #0 #0
62B0B	**2DROPFALSE**	ob1 ob2 → FALSE
031AC	**2DUP**	ob1 ob2 → ob1 ob2 ob1 ob2
63C40	**2DUP5ROLL**	ob1 ob2 ob3 → ob2 ob3 ob2 ob3 ob1
611F9	**2DUPSWAP**	ob1 ob2 → ob1 ob2 ob2 ob1
63FBA	**2OVER**	ob1 ob2 ob3 ob4 → ob1 ob2 ob3 ob4 ob1 ob2
62001	**2SWAP**	ob1 ob2 ob3 ob4 → ob3 ob4 ob1 ob2
60F4B	**3DROP**	ob1 ob2 ob3 →
611FE	**3PICK**	ob1 ob2 ob3 → ob1 ob2 ob3 ob1
63C68	**3PICK3PICK**	ob1 ob2 ob3 → ob1 ob2 ob3

		FALSE →	
618D3	**casedrop**	ob TRUE → FALSE →	
61891	**DUP#0=case**	# → #	
618A8	**DUP#0=csedrp**	# → # # →	If # <> #0 If # = #0
63DF3	**EQUALNOTcase**	ob ob' →	
63CFE	**EQUALcase**	ob ob' →	
63CA4	**EQUALcasedrp**	ob ob' ob' → ob ob' ob" → ob	
61933	**EQcase**	ob1 ob2 →	
619AD	**NOTcase**	flag →	
618E8	**NOTcasedrop**	ob FALSE → TRUE →	
629BC	**ORcase**	flag1 flag2 →	
6187C	**OVER#=case**	# #' → #	
63BEB	**caseDoBadKey**	flag →	Exit via DoBadKey
63BD2	**caseDrpBadKey**	ob TRUE → FALSE →	Exit via DoBadKey
61970	**case2DROP**	ob1 ob2 TRUE → FALSE →	
6194B	**caseDROP**	ob TRUE → FALSE →	
6359C	**caseFALSE**	TRUE → FALSE FALSE →	
634E3	**caseTRUE**	TRUE → TRUE FALSE →	
63547	**casedrpfls**	ob TRUE → FALSE FALSE →	
63583	**case2drpfls**	ob1 ob2 TRUE → FALSE FALSE →	
638B2	**casedrptru**	ob TRUE → TRUE FALSE →	
63CBD	**DUP#0=csDROP**	#0 → # → #	If # <> 0.
638CB	**NOTcaseTRUE**	FALSE → TRUE TRUE →	

2.8.16 Stack Operations

		ob1 ob2
630B5	**3PICKOVER**	ob1 ob2 ob3 → ob1 ob2 ob3 ob1 ob3
62EDF	**3PICKSWAP**	ob1 ob2 ob3 → ob1 ob2 ob1 ob3
60FAC	**3UNROLL**	ob1 ob2 ob3 → ob3 ob1 ob2
60F7E	**4DROP**	ob1 ob2 ob3 ob4 →
6121C	**4PICK**	ob1 ob2 ob3 ob4 → ob1 ... ob4 ob1
630C9	**4PICKOVER**	ob1 ob2 ob3 ob4 → ob1 ob2 ob3 ob4 ob1 ob4
62EF3	**4PICKSWAP**	ob1 ob2 ob3 ob4 → ob1 ob2 ob3 ob1 ob4
60FBB	**4ROLL**	ob1 ob2 ob3 ob4 → ob2 ob3 ob4 ob1
6109E	**4UNROLL**	ob1 ob2 ob3 ob4 → ob4 ob1 ob2 ob3

6113C	**4UNROLL3DROP**	ob1 ob2 ob3 ob4 → ob4
62D09	**4UNROLLDUP**	ob1 ob2 ob3 ob4 → ob4 ob1 ob2 ob3 ob3
63015	**4UNROLLROT**	ob1 ob2 ob3 ob4 → ob4 ob3 ob2 ob1
60F72	**5DROP**	ob1 ... ob5 →
6123A	**5PICK**	ob1 ... ob5 → ob1 ... ob5 ob1
60FD8	**5ROLL**	ob1 ... ob5 → ob2 ... ob5 ob1
62880	**5ROLLDROP**	ob1 ... ob5 → ob2 ... ob5
610C4	**5UNROLL**	ob1 ... ob5 → ob5 ob1 ... ob4
60F66	**6DROP**	ob1 ... ob6 →
6125E	**6PICK**	ob1 ... ob6 → ob1 ... ob6 ob1
61002	**6ROLL**	ob1 ... ob6 → ob2 ... ob6 ob1
60F54	**7DROP**	ob1 ... ob7 →
61282	**7PICK**	ob1 ... ob7 → ob1 ... ob7 ob1
6106B	**7ROLL**	ob1 ... ob7 → ob2 ... ob7 ob1
612A9	**8PICK**	ob1 ... ob8 → ob1 ... ob8 ob1
6103C	**8ROLL**	ob1 ... ob8 → ob2 ... ob8 ob1
63119	**8UNROLL**	ob1 ... ob8 → ob8 ob1 ... ob7
0314C	**DEPTH**	ob1 ... obn → ob1 ... obn #n
03244	**DROP**	ob →
627A7	**DROPDUP**	ob1 ob2 → ob1 ob1
6210C	**DROPFALSE**	ob → FALSE
63FA6	**DROPNDROP**	ob1 ... obn # ob →
62946	**DROPONE**	ob → #1
63029	**DROPOVER**	ob1 ob2 ob3 → ob1 ob2 ob1
632F9	**DROPRDROP**	ob → (and pops 1 return stk level)
62FC5	**DROPROT**	ob1 ob2 ob3 ob4 → ob2 ob3 ob1
6270C	**DROPSWAP**	ob1 ob2 ob3 → ob2 ob1
62726	**DROPSWAPDROP**	ob1 ob2 ob3 → ob2
62103	**DROPTRUE**	ob → TRUE
62535	**DROPZERO**	ob → #0
627D5	**DUP**	ob → ob ob
6119E	**DUP#1+PICK**	... #n → ... #n obn
611F9	**DUP3PICK**	ob1 ob2 → ob1 ob2 ob2 ob1
61099	**DUP4UNROLL**	ob1 ob2 ob3 → ob3 ob1 ob2 ob3
62CB9	**DUPDUP**	ob → ob ob ob
63A9C	**DUPONE**	ob → ob ob #1
630DD	**DUPPICK**	... #n → ... #n obn-1
630F1	**DUPROLL**	... #n → ... #n obn-1
62FB1	**DUPROT**	ob1 ob2 → ob2 ob2 ob1
63AD8	**DUPTWO**	ob → ob ob #2
61380	**DUPUNROT**	ob1 ob2 → ob2 ob1 ob2
63A88	**DUPZERO**	ob → ob ob #2
62F75	**N+1DROP**	ob ob1 ... obn #n →
62F75	**NDROP**	ob1 ... obn #n →
031D9	**NDUP**	ob1 ... obn #n → ob1 ... obn ob1 ... obn
5E370	**NDUPN**	ob #n → ob ... ob
63533	**ONEFALSE**	→ #1 FALSE
62E67	**ONESWAP**	ob → #1 ob
63051	**OVER**	ob1 ob2 → ob1 ob2 ob1
63C90	**OVER5PICK**	v w x y z → v w x y z y v
62CCD	**OVERDUP**	ob1 ob2 → ob1 ob2 ob1 ob1
62D31	**OVERSWAP**	ob1 ob2 → ob2 ob1 ob1
62D31	**OVERUNROT**	ob1 ob2 → ob1 ob1 ob2
61184	**PICK**	obn ... #n → ... obn
612DE	**ROLL**	obn ... #n → ... obn
62F89	**ROLLDROP**	obn ... #n → ...
62D45	**ROLLSWAP**	obn ... ob #n → ... obn ob
1DABB	**ROT**	ob1 ob2 ob3 → ob2 ob3 ob1
62726	**ROT2DROP**	ob1 ob2 ob3 → ob2
62C7D	**ROT2DUP**	ob1 ob2 ob3 → ob2 ob3 ob1 ob3 ob1
60F21	**ROTDROP**	ob1 ob2 ob3 → ob2 ob3
60F0E	**ROTDROPSWAP**	ob1 ob2 ob3 → ob3 ob2
62775	**ROTDUP**	ob1 ob2 ob3 → ob2 ob3 ob1 ob1
62CA5	**ROTOVER**	ob1 ob2 ob3 → ob2 ob3 ob1 ob3
6112A	**ROTROT2DROP**	ob1 ob2 ob3 → ob3
60EE7	**ROTSWAP**	ob1 ob2 ob3 → ob2 ob1 ob3
62F2F	**SWAP**	ob1 ob2 → ob2 ob1
6386C	**SWAP2DUP**	ob1 ob2 → ob2 ob1 ob2 ob1
63C54	**SWAP3PICK**	ob1 ob2 ob3 → ob1 ob3 ob2 ob1
63C7C	**SWAP4PICK**	ob1 ob2 ob3 ob4 → ob1 ob2 ob4 ob3 ob4
62F5C	**SWAPDROP**	ob1 ob2 → ob2
62830	**SWAPDROPDUP**	ob1 ob2 → ob2 ob2
6284B	**SWAPDROPSWAP**	ob1 ob2 ob3 → ob3 ob1
21660	**SWAPDROPTRUE**	ob1 ob2 → ob2 TRUE
62747	**SWAPDUP**	ob1 ob2 → ob2 ob1 ob1
63AB0	**SWAPONE**	ob1 ob2 → ob2 ob1 #1
61380	**SWAPOVER**	ob1 ob2 → ob2 ob1 ob2
60F33	**SWAPROT**	ob1 ob2 ob3 → ob3 ob2 ob1
4F1D8	**SWAPTRUE**	ob1 ob2 → ob2 ob1 TRUE
6133E	**UNROLL**	... ob #n → ob ...
28558	**UNROT**	ob1 ob2 ob3 → ob3 ob1 ob2
6112A	**UNROT2DROP**	ob1 ob2 ob3 → ob3
6284B	**UNROTDROP**	ob1 ob2 ob3 → ob3 ob1
62CF5	**UNROTDUP**	ob1 ob2 ob3 → ob3 ob1 ob2 ob2
6308D	**UNROTOVER**	ob1 ob2 ob3 → ob3 ob1 ob2 ob1
60F33	**UNROTSWAP**	ob1 ob2 ob3 → ob3 ob2 ob1
63079	**ZEROOVER**	ob → ob #0 ob
5DE7D	**reversym**	ob1 ... obn #n → obn ... ob1 #n

2.8.17 Memory Operations

a) Temporary Memory

Addr	Word	Stack diagram	Explanation
37B44	**CKREF**	ob → ob'	If ob is in TEMPOB, is not embedded in a composite object, and is not referenced, then does nothing. Otherwise copies ob to TEMPOB and returns the copy.
06B4E	**INTEMNOTREF?**	ob → ob flag	If the input object is in TEMPOB area, is not embedded in a composite object, and is not referenced, returns ob and TRUE, otherwise returns ob and FALSE.
06657	**TOTEMPOB**	ob → ob'	Copies ob into TEMPOB and returns pointer to the new ob.

b) Variables

Addr	Word	Stack diagram	Explanation
08696	**CREATE**	ob id →	Creates a RAM-WORD with ob as its object part and the NAME FORM from id as its name part, in the current directory. An error occurs if ob is or contains the current directory ("Directory Recursion"). Assumes that ob is not a primitive code object.
18513	**STO**	ob id → ob lam →	In the lam case, the temporary identifier lam is re-bound to ob. The binding is to the first such temporary identifier object matching lam in the Temporary Environment area (searching from the first temporary environment to the last). An error is returned if lam is unbound. In the id case, STO attempts to match id to the name part of a global variable. If resolution is unsuccessful, STO creates a variable with ob as its object part and the name form from id as its name part, in the current directory. If resolution is successful, then ob replaces the object part of the resolved variable. If any updatable system object pointers reference the object part of the resolved variable, then the object part is placed into the temporary object area prior to the replacement and all affected updatable system object pointers are adjusted to reference the copy of the object part in the temporary object area. For the id case, STO assumes that ob is not a primitive code object.
61B45	**@**	id → ob TRUE id → FALSE lam → ob TRUE lam → FALSE	In the lam case, @ attempts to match lam to the temporary identifier object part of a binding in the Temporary Environment area (searching from the first temporary environment to the last). If successful, then the object bound to lam is returned along with a TRUE flag; else, a FALSE flag is returned. In the id case, @ attempts to match id to the name part of a global variable, starting in the current directory, and working up through parent directories if necessary. If the resolution is unsuccessful, then a FALSE flag is returned. Otherwise, the object part of the resolved variable is returned with a TRUE flag.
18513	**?STO_HERE**	ob id → ob lam →	This is the system version of user **STO**. It is the same as SAFESTO, except that for global variables, it a) stores only in the current directory; and b) will not overwrite a stored directory.
1853B	**SAFE@_HERE**	id → ob TRUE id → FALSE lam → ob TRUE lam → FALSE	Same as SAFE@, except for global variables the search is restricted to the current directory.
1854F	**PURGE**	id →	Purges variable specified by id; does no type check on stored object.
20B81	**XEQRCL**	id → ob	Same as SAFE@ for global variables, but errors if variable is nonexistent
18513	**XEQSTOID**	ob id →	Alternate name for ?STO_HERE

c) Directories

Addr	Word	Stack diagram	Explanation
08D08	**CONTEXT!**	rrp →	Stores a pointer to a rooted directory as the current directory
08D5A	**CONTEXT@**	→ rrp	Recalls the current context directory.
184E1	**CREATEDIR**	id →	Creates a directory object in the current directory.
18779	**DOVARS**	→ { id1 id2 ... }	Returns list of variable names from the current directory.
08D92	**HOMEDIR**	→	Makes HOME the current directory.
1848C	**PATHDIR**	→ { HOME dir dir ... }	Returns the current path.
1A16F	**UPDIR**	→	Switches context to the parent of the current directory.
20FF2	**XEQORDER**	{ id1 id2 ... } →	ORDERs current directory.
18595	**XEQPGDIR**	id →	Purges a directory while respecting reference/garbage collection conventions.

d) The Hidden Directory

Addr	Word	Stack diagram	Explanation
6408C	**PuHiddenVar**	id →	Purges the hidden variable named id.
64023	**RclHiddenVar**	id → ob TRUE id → FALSE	Recalls (@) a hidden variable.
64078	**StoHiddenVar**	ob id →	Stores ob in hidden variable

e) Additional Memory Utilities

Addr	Word	Stack diagram	Explanation
05F42	**GARBAGE**	→	Forces garbage collection.
05F61	**MEM**	→ #	Returns the amount of free memory (a garbage collection is not forced)

05944	**OCRC**	ob → #nibbles
		checksum(hxs)
			Returns size of object in nibbles and a hex string checksum

6595A	**getnibs**	hxsDATA hxsADDR → hxsDATA'	Internal RPL version of PEEK
6594E	**putnibs**	hxsDATA hxsADDR →	Internal RPL version of POKE

2.8.18 Display Management & Graphics

a) Display Organization

Addr	Word	Stack diagram	Explanation
12655	**ABUFF**	→ textgrob	
12665	**GBUFF**	→ graphgrob	
12635	**HARDBUFF**	→ Hbgrob	Returns whichever of the text or graph grob is currently displayed.
12645	**HARDBUFF2**	→ menugrob	
0E128	**HBUFF_X_Y**	→ HBgrob #x1 #y1	

b) Preparing the Display

Addr	Word	Stack diagram	Explanation
130AC	**RECLAIMDISP**	→	Makes the text grob the current display, clears it and resizes it to the standard size (131x56) if necessary.
39531	**ClrDA1IsStat**	→	Suspends the ticking clock display.
4E2CF	**TURNMENUOFF**	→	Removes the menu from the display and resizes the text grob to 131x64.
4E347	**TURNMENUON**	→	Restores the menu display.

c) Controlling Display Refresh

Addr	Word	Stack diagram	Explanation
3902C	**SetDA1Temp**	→	Freezes display area 1
?	**SetDA2aTemp**	→	Freezes display area 2a
?	**SetDA2bTemp**	→	Freezes display area 2b
?	**SetDA3Temp**	→	Freezes display area 3
3922F	**SetDAsTemp**	→	Freezes all display areas
39144	**ClrDAsOK**	→	Redraws the entire lcd when program ends

d) Clearing the Display

Addr	Word	Stack diagram	Explanation
126DF	**BLANKIT**	#startrow #rows →	Clears #rows starting at #startrow
3A578	**BlankDA12**	→	Clears rows 0 through 56
3A55F	**BlankDA2**	→	Clears rows 16 through 56
134AE	**CLEARVDISP**	→	Zeros out all of HARDBUFF
0E06F	**Clr16**	→	Clears top 16 pixel rows
0E083	**Clr8**	→	Clears top 8 pixel rows
0E097	**Clr8-15**	→	Clears pixel rows 8-15

e) Annunciator Control

Addr	Word	Stack diagram	Explanation

1133A	**ClrAlphaAnn**	→	Clears the alpha annunciator
1136E	**ClrLeftAnn**	→	Clears the left-shift annunciator
11354	**ClrRightAnn**	→	Clears the right-shift annunciator
1132D	**SetAlphaAnn**	→	Sets the alpha annunciator
11361	**SetLeftAnn**	→	Sets the left-shift annunciator
11347	**SetRightAnn**	→	Sets the right-shift annunciator

f) Display Coordinates

Addr	Word	Stack diagram	Explanation
0E0FB	**Rows8-15**	→ HBgrob #x1 #y1+8 #x1+131 #y1+16	
0E0AB	**TOP16**	→ HBgrob #x1 #y1 #x1+131 #y1+16	
0E0D3	**TOP8**	→ HBgrob #x1 #y1 #x1+131 #y1+8	
137B6	**WINDOWCORNER**	→ #x #y	Returns pixel numbers of upperleft corner of the window
?	**Save16**	→ grob	Calls TOP16 and SUBGROB to produce a grob consisting of the top 16 rows of the current display

g) Displaying Text

When the text grob is the current display AND has not been scrolled (except for DISPROWn*), the following words may be used to display text. Long strings are truncated to 22 characters with a trailing ellipsis (...), and strings shorter than 22 characters are blank filled.

Addr	Word	Stack diagram	Explanation
1245B	**DISPROW1**	$ →	Displays text in row 1 with the medium (5x7) font.
12725	**DISPROW1***	$ →	Displays text in row 1 with the medium (5x7) font, even if the display has been scrolled.
1246B	**DISPROW2**	$ →	Displays text in row 2 with the medium (5x7) font.
12748	**DISPROW2***	$ →	Displays text in row 2 with the medium (5x7) font, even if the display has been scrolled.
1247B	**DISPROW3**	$ →	Displays text in row 3 with the medium (5x7) font.
1248B	**DISPROW4**	$ →	Displays text in row 4 with the medium (5x7) font.
1249B	**DISPROW5**	$ →	Displays text in row 5 with the medium (5x7) font.
124AB	**DISPROW6**	$ →	Displays text in row 6 with the medium (5x7) font.
124BB	**DISPROW7**	$ →	Displays text in row 7 with the medium (5x7) font.
12429	**DISPN**	$ #row →	Displays text in row #row with the medium (5x7) font.
3A4CE	**Disp5x7**	$ #start #max →	Displays text starting at row #start with the medium (5x7) font, for a maximum of #max rows.
12415	**BIGDISPROW1**	$ →	Displays text in row 1 with the big (5x9) font.
12405	**BIGDISPROW2**	$ →	Displays text in row 2 with the big (5x9) font.
123F5	**BIGDISPROW3**	$ →	Displays text in row 3 with the big (5x9) font.
123E5	**BIGDISPROW4**	$ →	Displays text in row 4 with the big (5x9) font.
123C8	**BIGDISPN**	$ #row →	Displays text in row #row with the big (5x9) font.
38926	**FlashWarning**	$ →	Displays a warning message during 3 seconds.

h) Graphics Objects

♦ Graphics Tools

Addr	Word	Stack diagram	Explanation
11CF3	**$>BIGGROB**	$ → grob	5x9 font
11D00	**$>GROB**	$ → grob	5x7 font
11F80	**$>grob**	$ → grob	3x7 font
503D4	**DOLCD>**	→ 64x131grob	LCD
11679	**GROB!**	grob1 grob2 #col #row →	Stores grob1 into grob2. This is a bang-type word with no error checks!
11A6D	**GROB!ZERO**	grob #x1 #y1 #x2 #y2 → grob'	Zeros out a rectangular section of a grob. NOTE: Bang-type operation.
6389E	**GROB!ZERODRP**	grob #x1 #y1 #x2 #y2 →	Zeros out a rectangular section of a grob. NOTE: Bang-type operation!
12F94	**GROB>GDISP**	grob →	Stores graph grob with new grob.
12635	**HARDBUFF**	→ Hbgrob	The current display grob
12DD1	**HEIGHTENGROB**	grob #rows →	Adds #rows to grob, unless grob is null. NOTE: Assumes text grob or graph grob!
122FF	**INVGROB**	grob → grob'	Invert grob data bits - bang-type.

50B08	**LINEOFF**	#x1 #y1 #x2 #y2 →	Clears pixels in a line in text grob. Note: #x2 must be > #x1 (use ORDERXY#)
50ACC	**LINEOFF3**	#x1 #y1 #x2 #y2 →	Clears pixels in a line in graph grob. Note: #x2 must be > #x1 (use ORDERXY#)
50B17	**LINEON**	#x1 #y1 #x2 #y2 →	Sets pixels in a line in text grob. Note: #x2 must be > #x1 (use ORDERXY#)
50AEA	**LINEON3**	#x1 #y1 #x2 #y2 →	Sets pixels in a line in graph grob. Note: #x2 must be > #x1 (use ORDERXY#)
1158F	**MAKEGROB**	#height #width → grob	
51893	**ORDERXY#**	#x1 #y1 #x2 #y2 → #x1 #y1 #x2 #y2	Orders two points for line drawing
1383B	**PIXOFF**	#x #y →	Clears a pixel in the text grob
1380F	**PIXOFF3**	#x #y →	Clears a pixel in the graph grob
1384A	**PIXON**	#x #y →	Sets a pixel in the text grob
13992	**PIXON?**	#x #y → flag	Returns TRUE if text grob pixel is set
13986	**PIXON?3**	#x #y → flag	Returns TRUE if graph grob pixel is set
13825	**PIXON3**	#x #y →	Sets a pixel in the graph grob
1192F	**SUBGROB**	grob #x1 #y1 #x2 #y2 → subgrob	
659DE	**Symb>HBuff**	symb →	Displays symb in HARDBUFF in Equation-Writer form. May enlarge HARDBUFF, so do RECLAIMDISP afterwards.
50AF9	**TOGLINE**	#x1 #y1 #x2 #y2 →	Toggles pixels in a line in text grob. Note: #x2 must be > #x1 (use ORDERXY#)
50ADB	**TOGLINE3**	#x1 #y1 #x2 #y2 →	Toggles pixels in a line in graph grob. Note: #x2 must be > #x1 (use ORDERXY#)

♦ Grob Dimensions

Addr	Word	Stack diagram	Explanation
4F7E6	**CKGROBFITS**	grob1 grob2 #n #m → grob1 grob2' #n #m	Truncates grob2 if it doesn't fit in grob1
5179E	**DUPGROBDIM**	grob → grob #height #width	
5187F	**GBUFFGROBDIM**	→ #height #width	Returns dimensions of graph grob
50578	**GROBDIM**	grob → #height #width	
63C04	**GROBDIMw**	grob → #width	

♦ Built-in Grobs

Addr	Word	Stack diagram	Explanation
66EA5	**BigCursor**	→ grob	5x9 Cursor (outline box)
5053C	**CROSSGROB**	→ grob	5x5 "+" symbol
13D8C	**CURSOR1**	→ grob	5x9 Insert Cursor (arrow)
13DB4	**CURSOR2**	→ grob	5x9 Replace Cursor (solid box)
5055A	**MARKGROB**	→ grob	5x5 "X" symbol
66ECD	**MediumCursor**	→ grob	5x7 Cursor (outline box)
66EF1	**SmallCursor**	→ grob	3x5 Cursor (outline box)

♦ Menu Display Utilities

Addr	Word	Stack diagram	Explanation
3A297	**Grob>Menu**	#col 8x21grob →	Displays an 8x21 (only!) grob
3A2DD	**Id>Menu**	#col Id →	Recalls Id and displays standard label or directory label, depending on the contents of Id.
3A2C9	**Seco>Menu**	#col seco →	Evaluates secondary and uses result to produce and display appropriate menu label
3A2B5	**Str>Menu**	#col $ →	Makes and displays standard menu label
3A38A	**MakeBoxLabel**	$ → grob	Box with bullet in it
3A3EC	**MakeDirLabel**	$ → grob	Box with directory bar
3A44E	**MakeInvLabel**	$ → grob	White label (solver)
3A328	**MakeStdLabel**	$ → grob	Black label (standard)

i) Scrolling the Display

Addr	Word	Stack diagram	Explanation
4D16E	**SCROLLDOWN**	→	Scroll down one pixel with repeat
4D150	**SCROLLLEFT**	→	Scroll left one pixel with repeat
4D18C	**SCROLLRIGHT**	→	Scroll right one pixel with repeat

4D132	**SCROLLUP**	→	Scroll up one pixel with repeat
516AE	**JUMPBOT**	→	Move window to bottom edge of grob
516E5	**JUMPLEFT**	→	Move window to left edge of grob
51703	**JUMPRIGHT**	→	Move window to right edge of grob
51690	**JUMPTOP**	→	Move window to bottom edge of grob

2.8.19 Keyboard Control

a) Key Locations

Addr	Word	Stack diagram	Explanation
41CA2	**Ck&DecKeyLoc**	%rc.p → #KeyCode #Plane	**WAIT** returns %rc.p
41D92	**CodePl>%rc.p**	#KeyCode #Plane → %rc.p	

b) Waiting for a Key

Addr	Word	Stack diagram	Explanation
04708	**CHECKKEY**	→ #KeyCode TRUE → FALSE	Returns, but does not pop, the next key in the buffer.
00D71	**FLUSHKEYS**	→	Flushes the key buffer.
04714	**GETTOUCH**	→ #KeyCode TRUE → FALSE	Pops next key from buffer.
42402	**KEYINBUFFER?**	→ flag	Returns TRUE if a key is in the buffer, otherwise returns FALSE.
42262	**ATTN?**	→ flag	Returns TRUE if [ATTN] has been pressed
05068	**ATTNFLGCLR**	→	Clears the attn key flag (does not flush attn key from buffer)
41F65	**WaitForKey**	→ #KeyCode #Plane	Returns next fully formed keystroke.

c) InputLine

Addr	Word	Stack diagram	Explanation
42F44	**InputLine**	$prompt $editline #cursorpos #insrep #entry #alphalock ILMENU #ilmenurow flagattnabort? #parse → ? flag	Internal INPUT. Displays the prompt in display are 2a, sets the keyboard entry modes, initializes the edit line, accepts user input, parses, evaluates or returns the user-input edit line, returns TRUE if exited by Enter or FALSE if aborted by Attn.

The stack on entry must contain the following: (from level 9 to level 1)

$Prompt	The prompt to be displayed during user input
$EditLine	The initial edit line
CursorPos	The initial edit line cursor position, specified as a binary integer character number or a two-element list of binary integer row and column numbers. For all numbers, #0 indicates the end of the edit line, row, or column.
#Ins/Rep	The initial insert/replace mode: #0 current insert/replace mode #1 insert mode #2 replace mode
#Entry	The initial entry mode: #0 current entry mode plus program entry #1 program/immediate entry #2 program/algebraic entry
#AlphaLock	The initial alpha-lock mode: #0 current alpha lock mode #1 alpha lock enabled #2 alpha lock disabled
ILMenu	The initial InputLine menu in the format specified by ParOuterLoop
#ILMenuRow	The initial InputLine menu row number in the format specified by ParOuterLoop
AttnAbort?	A flag specifying whether pressing Attn while a non-null edit line exists should abort InputLine (TRUE) or just clear the edit line (FALSE)
#Parse	How to process the resulting edit line: #0 Return the edit line as a string #1 Return the edit line as a string AND as a parsed object #2 Parse and evaluate the edit line

InputLine returns different results, depending on the initial value of #Parse:

#0	→ $EditLine TRUE	Edit line
#1	→ $EditLine ob TRUE	Edit line and parsed edit line
#2	→ Ob1 ... Obn TRUE	Resulting object or objects
any	→ FALSE	Attn pressed to abort edit

d) The Parameterized Outer Loop

Addr	Word	Stack diagram	Explanation
38985	**ParOuterLoop**	AppDisplay AppKeys NonAppKeyOK? DoStdKeys? AppMenu #AppMenuRow SuspendOK? ExitCond AppError →	Parameterized outer loop.

The parameterized outer loop, ParOuterLoop, takes nine arguments, in order:

AppDisplay	The display update object to be evaluated before each key evaluation. "AppDisplay" should handle display updating not handled by the keys themselves, and should also perform special handling of errors.
AppKeys	The hard key assignments, a secondary object in the format described below.
NonAppKeyOK?	A flag specifying whether the hard keys not assigned by the application should perform their default actions or be canceled.
DoStdKeys?	A flag used in conjunction with "NonAppKeyOK?" specifying whether standard key definitions are to be used for non-application keys instead of default key processing.
AppMenu	The menu key specification, a secondary or list in the format specified in the menu key assignments document, or FALSE.
#AppMenuRow	The initial application menu row number. For most applications, this should be binary integer one.
SuspendOK?	A flag specifying whether or not any user command that would create a suspended environment and restart the system outer loop should instead generate an error.
ExitCond	An object that evaluates to TRUE when the outer loop is to be exited, or FALSE otherwise. "ExitCond" is evaluated before each application display update and key evaluation.
AppError	The error-handling object to be evaluated if an error occurs during the key evaluation part of the parameterized outer loop.

2.8.20 System Commands

Addr	Word	Stack diagram	Explanation
422A1	**ALARM?**	→ flag	Returns TRUE if an alarm is due
40BC9	**AtUserStack**	→	Declares user ownership of all objects on the stack.
0EB81	**CLKTICKS**	→ hxs	Returns 13 nibble hex string reflecting the number of ticks since 01/01/0000. There are 8192 ticks per second.
53761	**ClrSysFlag**	# →	Clears system flag from #1 to #64
53755	**ClrUserFlag**	# →	Clears user flag from #1 to #64
0CC0E	**DATE**	→ %date	Returns real number date
1415A	**DOBEEP**	%freq %duration →	BEEP command
53C43	**DOBIN**	→	Set base mode to BINary
53C5B	**DODEC**	→	Set base mode to DECimal
166FB	**DOENG**	# →	Set ENG display with # (0-11) digits
166E3	**DOFIX**	# →	Set FIX display with # (0-11) digits
53C37	**DOHEX**	→	Set base mode to HEXadecimal
53C4F	**DOOCT**	→	Set base mode to OCTal
166EF	**DOSCI**	# →	Set SCI display with # (0-11) digits
16707	**DOSTD**	→	Set STD display mode
167BF	**DPRADIX?**	→ flag	Returns TRUE if current radix is . Returns FALSE if current radix is ,
2A5D2	**SETDEG**	→	Set DEGREES angle mode
2A604	**SETGRAD**	→	Set GRADS angle mode
2A5F0	**SETRAD**	→	Set RADIANS angle mode
40EE7	**SLOW**	→	15msec delay
0CBFA	**TOD**	→ %time	Returns time of day in h.ms form

53784	**TestSysFlag**	# → flag	Returns TRUE if system flag # is set
53778	**TestUserFlag**	# → flag	Returns TRUE if user flag # is set
40F02	**VERYSLOW**	→	300 msec delay
40F12	**VERYVERYSLOW**	→	3 sec delay
54039	**WORDSIZE**	→ #	Returns binary wordsize
53CAA	**Dostws**	# →	Stores binary wordsize
1A7C9	**Dowait**	%seconds →	Waits for %seconds in light sleep

3 Tips and tricks

3.1 Meta Kernel and UFL

UFL (Universal Font Library) is an attempt to normalize the use of fonts in HP48 programs. The idea is too allow all programs to share the same fonts, instead of having as many fonts as software. UFL is a standard library. It provides two differents fonts, the normal font or the mini-font. The **Meta Kernel** is able to work only with the last one, since the **MK** provides many more powerful features in font management, such as more than 240 different fonts at the same time, while UFL can manage only one. Also, you can change the system font, without restarting your HP48 with an ON-C.

You will find more informations about the UFL at this URL:

http://www.engr.uvic.ca/~aschoorl/ufl/

The **Meta Kernel** uses its own mini-font, but may use the UFL mini-font. Just execute these few lines, or add them in the STARTUP file:

```
1 FNT →MINIFONT
```

3.2 STARTED and EXITED examples

3.2.1 Remove the header display

When you edit files, it may be useful to have the whole screen available. Using the STARTED and EXITED capabilities, it is very easy to remove the header while editing, and restore it after.

```
STARTED:
«
     0  →HEADER
»

EXITED:
«
     2  →HEADER
»
```

3.2.2 Edit compressed files

When you are short in memory, it may be useful to compress some files. BZ was writter by Mika Heiskanen (http://www.hut.fi/~mheiskan/) it is a very efficient and very fast compressor.

You will find the BZPlus package on http://hp48.ml.org/utils/compress/

The problem with the compressor, is that if you want to edit the file, you must uncompress the file manually, edit it, compress it again, then store it.

With STARTED and EXITED, you won't have to do that anymore. The idea is to check if a file is a compressed file with STARTED, if yes uncompress it, and when leaving the command line, compress it with EXITED.

The main difficulty is that the **Meta Kernel** can edit more than one text at the same time. Then you must save the history of the edited files, in order to know if the file was compressed or not. The history will be saved in the HOME directory with the name CHECK.BZ

STARTED is called by the **Meta Kernel** just before editing an object, and finds the object on the first stack level. Sometimes the **MK** calls STARTED without any valid object, in this case, you find the object NULL$ on the stack.

EXITED is called by the **Meta Kernel** just after exiting the command line by pressing ENTER or ON. When the user press ENTER, the **MK** pushes two objects on the stacks as follow:

2: Object

1: TRUE

If the user has pressed ON, only FALSE is pushed on the first stack level.

The following STARTED and EXITED use both SytemRPL and UserRPL, they may be enhanced very easily by using only SystemRPL. Anyway, it is a good example of how to use the MASD in RPL mode.

```
"!NO CODE
!RPL
::
     xDUP NULL$ EQ                    (Check if it's the NULL$ object)
     ?SKIP                            (If yes do nothing)
     ::
          xPATH xHOME xSWAP           (Save the working directory)
          xIF xBZ?                    (Is it a compressed file?)
          xTHEN
          :: xBZU %1 ;                (If yes, uncompress it)
          xELSE %0
          xIFEND
          xIFERR                      (Check if the history file exists)
          :: ' ID CHECK.BZ xRCL ;
          xERRTHEN
          ::                          (If not, create it with a null list)
               xDROP {}
               ' ID CHECK.BZ xSTO
               %1
          ;
          xIFEND
          xDROP                       (Save the history entry)
          ' ID CHECK.BZ xSTO+
          xSWAP xEVAL                 (Go to the previous directory)
     ;
;
@"

EXITED:
"!NO CODE
!RPL
::
     xPATH xSWAP xHOME                (Save the working directory)
     ITE                              (If the user pressed ENTER)
     ::
          xSWAP                       (Get the entry in the history file)
          ID CHECK.BZ
          xIF xHEAD
          xTHEN                       (If it was a compressed file)
          ::                          (Compress it again)
               xIFERR xBZC xERRTHEN xIFEND
          ;
          xIFEND
          xSWAP TRUE
     ;
     FALSE
     ID CHECK.BZ                      (Remove the entry in the history)
```

```
    xTAIL
    ' ID CHECK.BZ xSTO
    xSWAP xEVAL                    (Go to the previous directory)
;
@"
```

3.3 Meta Kernel and Erable

Erable is a very powerful Algebra system for the HP48GX. Combined with the **Meta Kernel**, you will get one of the best handheld computer algebra system (far better than the TI-92). Here is an example of an STARTEQW file, which allow to use all Erable's functions from the Equation Writer, by pressing CST.

This STARTEQW was written by Erable's author: Bernard Parisse

You will find more information about Erable at:

http://www-fourier.ujf-grenoble.fr/pp/parisse/english.html

```
STARTEQW:
« "ERABLE"
{ "1.SIMP" "2.TRIG" "3.INTDER" "4.EXEC"
  "5.PLOT" "6.CFG" "7.ARIT" }
1 CHOOSE2
IF THEN
  DUP
  {
  { EXPA COLC EXPLIN SINCOS TEXPA LNCOLC TSIMP
    { "0.BACK" STARTEQW } }
  { TRIGLIN TRIGCOS TRIGSIN TAN2SC TAN2SC2 HALFTAN
  { "0.BACK" STARTEQW }
  }
  { der1 RISCH PF LAP ILAP { "0.BACK" STARTEQW }}
  {
  { "1.NEW VX" « DUP 'VX' STO » }
  { 2 "REPLACE" « "REPLACE" { "'X='" 4 ALG V }
    INPUT2 STR→ EXEC » }
  { "3.COMMAND" « "COMMAND" { "" 4 ALG V }
    INPUT2 STR→ EVAL » }
  { "4.ISOL VX" « VX EXEC » }
  { "0.BACK" STARTEQW }
  }
  {
  { "1.ERASE AND PLOT" « ERASE DUP STEQ
    # B4045h LIBEVAL » }
  { "2.ADD TO PLOT" « EQ DUP TYPE 5 ==
    IF THEN OVER + ELSE OVER 2 →LIST END
    STEQ # B4045h LIBEVAL » }
  { "3.PLOT MENU" « # B4045h LIBEVAL » }
  { "0.BACK" STARTEQW }
  }
  {
  { "1.COMPLEX MODE" « 13 SF » }
  { "2.REAL MODE" « 13 CF » }
  { "3.INTEGER ARIT" « 10 SF » }
  { "4.POLYN. ARIT" « 10 CF » }
  { "0.BACK" STARTEQW }
  }
  { CHS re im conj { "BACK" STARTEQW } }
  }
  SWAP
  1 1 SUB STR→ GET 1 CHOOSE2
    IF THEN EVAL END
  END
  »
```

3.3.1 STARTOFF and TOFF example

Here is a completely useless program. But like all completely useless programs, it is completely essential.

This is a screen saver program, it will displays points in the screen until you press a key.

If you want the **Meta Kernel** to run this program after two minutes of idle time, put **#983040d** in the 'TOFF' file.

```
STARTOFF:
«
PICT→ LCD→ →PICT { #0 #0 } PVIEW
DO
RAND 131 * R→B
RAND 64 * R→B
2 →LIST PIXON
UNTIL KEY END DROP
TEXT →PICT
»
```

4 The MK for Programmers

4.1 Customizing the Filer

4.1.1 Overview

The filer is completely customizable. You can run your own programs from inside the filer. These programs can utilize all of the functionality of the filer, which the internal functions use. You can also access all internal functions. This customization is accomplished using a custom menu that displays labels for each of your custom programs. In the filer, if you press CST or CUSTOM in the built-in menu, the filer will try to find the file 'FILER.CUSTOM'. This file is used to create your custom menu.

4.1.2 FILER.CUSTOM Format

FILER.CUSTOM is a list with the following arguments :

```
{
GROB 131*n                  This is the GROB that will be displayed in the menu
                            area when you press CST. You can also use a
                            program that gives a GROB as a result.
System Binary 1             Number of pages for the menu
{
      System binary 2       Execution Type
      System binary 3       Exit type
      [Program]             Program which will be run by the filer
      [System binary 4]     Shortcut-key for the program
}
{
      ....An entry just as above for each custom program
}
}
```

4.1.3 Explanation of each component

a) System Binary 1 and GROB

This is an integer that tells the FILER how many pages the menu will use. For example, if you want two pages (12 labels) then *GROB 131*n* would be a 131*16 GROB and SB1 would be 2.

b) System binary 2

This integer allows you to control when the program will be started.

There are 5 possibilities:

SB	Program Control
0	You can run the program everywhere (VAR,PORT,BACKUP,LIB)
1	Only when you are in VAR
2	Won't run if you are in a library
3	Won't run if you are in a backup
4	Will run only in port (home of the port)

c) System binary 3

This integer tells the filer how the associated program will be runned. This also allows you to access all the filer's internal subroutines. There are two categories of custom programs: internal calls, and custom calls.

NOTE: You can use a Binary integer instead of System Binary (it is easier to manage with the User-RPL compiler).

d) Internal calls

The internal calls are included so that you can access the built-in functionalities of the filer from inside your custom menu. For these calls, you don't need to put a program in the file unless you want to allow a shortkey (Ex Left-Shift 2). If you use a shortkey then add any program you want because it won't be runned at all. You should use the smallest possible program (ex: TakeOver $40788) internal empty program).

SB	Operation
0	Bip
1	Info
2	Hexa
3	View
4	Arbo
5	Up
6	MaxUp
7	Down
8	Maxdown
9	Select (same as ENTER)
A	Updir
B	Downdir
C	Previous menu
D	Next menu
E	EVAL
F	Swap header
18	Display or remove file's details (Type& size)
19	EDIT
1A	COPY
1B	MOVE
1C	RCL
1D	PURGE
1E	RENAME
1F	CRDIR
20	ORDER
21	SEND
22	HALT2
23	EDITB

e) Custom program

If you are going to run a custom program there are 7 ways to call the program. Every time, the filer will place the working path on the stack.

Examples:

```
{}                  for HOME
:nb:{}              for a port
:02: { FOO.DIR }    if you are working in port 2 in the backup FOO.DIR
```

If you launch the program in the VAR, then your program will start in the current directory. The possible calls are: (1: ect is the resulting stack that will appear just before your program is run)

SB	Type of call

10	Recalls only the path: 1: Path
11	Recalls the name and the object for the currently selected object: 3: Path 2: Object 1: Name
12	Multiple objects selected n: Path ... 5: Object 2 4: Name 2 3: Object 1 2: Name 1 1: Number of objects (System Binary)
13	The FILER will call your program after each object. The FILER will place the following on the stack each time and call your program for each object selected. 3: Path 2: Object 1 1: Name 1
14	Recalls the name of the current object only 2: Path 1: Name
15	Recalls all the names selected n: path ... 3: Name2 2: Name1 1: Number of names selected (System Binary)
16	Recalls the current object only in a string of addresses 2: Path 1: String
17	Recalls the selected objects in a string of addresses 2: Path 1: String

f) Explanation for the string of addresses

This string recalled by the filer is a list of addresses. You can use it only in ML or with FILER_FRCL, FILER_FNAME and FILER_NXTADR, for SysRPL use:

FILER_FRCL (C030F): Takes a String of addresses, and recalls the first object. FILER_FNAME (C030A): Same thing but recalls the first name object, FILER_NXTADR (C0314): Takes a string of addresses, and removes the first addresses. And FALSE if there are some addresses left. TRUE if not.

The string format is:

Prolog (02A2C) Size AdrName1 AdrObject1 AdrName2 AdrObject2 ...

Each address is on 5 nibbles.

g) Explanations about the name

For all calls except 14 and 15, the name is the real filename. If you call the program from a library, then the name will be the name of the library itself (Like '`Strwrt: v4.31 (c)`'). However, for 14 and 15, if you have selected a library, the name will be a real number that is the library number. For 13, if the object is a library, then the name will be a 'L' plus the Id number.

Example: For Library 1303, the name will be: 'L1303'

NOTE: You can browse every library, but can only run your programs from an attached library.

h) Warning and very important points

In order to save room, we used list of addresses. So, if you modify the directory structural in your programs (using STO, PURGE, etc.), then NEVER USE CALL 13. And if you are a very experienced programmer, you can use calls 16 and 17.

4.2 Machine Language entry points list

Here is a list of entry points inside the **Meta Kernel**. They can be used by experienced programmers for programs to take advantage of the **MK**. Of course, if these entry points are used, the program won't run without the **MK**.

Call a routine with `GOSBVL C0xxx`.

Rf means the R register with the field f. Example: Ca describes the register C, field A.

Input and output registers are described in the 'In' and 'out' sections.

4.2.1 MINI_DISP

Address `C0040`
Description Displays a Mini-font character string
In
Ca = number of characters
D1 = string address
D0 = display starting address (in a 131*x grob)
ST11 = inversion (white on black)

4.2.2 MINI_FONT_ADDRESS

Address `C0047`
Description Mini-font address in the card
E.g `D0=C0047 A=DAT0.A`

4.2.3 DISPLAY_SBR

Address `C004C`
Description Main display routine
Call INIT_DISPLAY_LINE before using this routine.
In
R0b = font identifier
R1s = (font height) * 2 - 1
D0 = starting display address in a grob
D1 = string address
Da = number of characters
R2a = display grob width in nibbles
Ba = left margin in characters
Ca = right margin in characters
ST4 = display left shift
ST5 = display right shift
ST0,1,2,3 = text attributes (bold, italic, underlined, inversed)
ST8 = display carriage returns as characters if set
ST9 = mini-font display
Out
D0 = next line address in the grob
Aa = last written character address
Da = number of remaining characters

ST8 = set if a CR has been read
D1 = end of displayed text in the grob

4.2.4 EDIT_SBR

Address C0053
Description Mini-edit (used by FIND in the command line)
Call INIT_DISPLAY_LINE before using this routine.
In
R4a = screen address
Ca = maximum number of characters
D1 = buffer address
ST9 = mini-font display
Out
Carry = set if ENTER has been pressed, clear exit by ON

4.2.5 FILER.ADR

Address C0319
Description Address of the main FILER program

4.2.6 SCAN_FONT

Address C009A
Description Rebuild the font table
This function forces the **MK** to search through all ports to build the font table.

4.2.7 RECONFIG

Address C00A1
Description Reconfigures the second card
After a DECONFIG, this routine reconfigures the second port card at C0000 (hidden by the **MK** card), and the bank switcher at 7F000.

4.2.8 DECONFIG

Address C00A8
Description Deconfigures the second card
This routine is used to gain direct access to the second card, without deconfiguring the **MK**.
The second port card is moved from C0000 (where it is hidden by the **MK** card) to 40000. The bank switcher is moved from 7F000 to 3F000.

4.2.9 CMD_SIZE

Address C00BE
Description Computes the command line size
Out
Aa = number of characters.

4.2.10 GET_PATH

Address C00C5
Description Finds the relative path of a directory
In
D1 = buffer address
Ca = maximum length
If ST2 = 0, the path is taken from the HOME directory to the current directory
if ST2 = 1, D0 = starting directory address, Da = ending directory address

4.2.11 DECONFIG_RAM

Address C00CC
Description Moves the RAM from 80000 to 00000
Useful if you plan to make your own interrupt handler. If your RAM based program call this entry point, the return address (RTN) will be recalculated

4.2.12 RECONFIG_RAM

Address C00D3
Description Moves the RAM from 00000 back to 80000

4.2.13 GET_FONT

Address C00DA
Description Returns the address of a given font
Call SCAN_FONT once before using this routine.
In
Ab = font id
Out
R0a = font address

4.2.14 INIT_DISPLAY_LINE

Address C00E1
Description Initializes the display routines
This routine initializes the registers necessary for the **MK** display routines.
In
Ca = screen width in nibbles

4.2.15 CHANGE_FLAG

Address C00E8
Description Updates the ST flags 0 to 3 and R0 for the display routine
Computes some parameters for the display routines, when special characters are encountered (font control characters...)

4.2.16 GET_ASCII_KEY

Address C00F6
Description Keyboard handler
Gets an ASCII character or a key number if not in ALPHA mode. This routine handles the shifts and alpha displays.
Out
ST0 = 0 if ASCII
ST0 = 1 if key number.

4.2.17 GET_KEY

Address C00FD
Description Keyboard handler
Out
Carry = set if no character in the keyboard buffer.
Aa = key code (if carry cleared)

4.2.18 RUN_KEY

Address C0104
Description Key assignment
This routine associates an assembly code with a key.
Syntax:

```
GOSBVL =RUN_KEY
GOIN4 NO_KEY_ROUTINE
$/01 GOIN4 KEY_A % 01 is the A key code
$/xx GOIN4 KEY_x % xx key code (same as in External)
...
$00 GOIN4 NOT_HANDLED_KEY % a bip routine for example
```

4.2.19 MINI_DISP_VAL

Address C010B
Description Displays a hexa value in mini-font
In
D0 = screen address
Bw = number to be displayed
Ca = number of digits to be displayed
ST11 = inverse (white on black)
ST10 = 1 to display leading zeros

4.2.20 MINI_DISP_AWP

Address C0112
Description Displays a hexadecimal value in mini-font
In
D0 = screen address
Awp = number to be displayed
P = (number of digits) - 1
ST11 = inverse (white on black)
ST10 = 1 to display leading zeros

4.2.21 TRUP

Address C0119
Description Copy up
Equivalent to 066B9, but works even after a DECONFIG_RAM (when RAM is at 00000)

4.2.22 TRDN

Address C0120
Description Copy down
Equivalent to 0670C, but works even after a DECONFIG_RAM (when RAM is at 00000)

4.2.23 ZEROM

Address C0127
Description Resets a memory zone to 0
In
D1 = zone starting address
Ca = number of nibbles to blank

4.2.24 SCAN_KEY

Address C012E
Description Keyboard handler
Does a keyboard scan, updates the keyboard buffer and the keystate. Use it when interrupts are disabled.

4.2.25 NEW_ADR

Address C0135
Description Moves an object at the end of the temporary zone
Moves an object in the temporary RAM at the end of this zone, so that 16671 (object resize) and RESIZE_PLUS can be used on it.

4.2.26 RESIZE_PLUS

Address C013C
Description Resize up a character string
Resize up the last character string in the temporary RAM.
In
R0a = string address
D0 = new end of the character string

4.2.27 C=IN3

Address C02F2
Description Equivalent to C=IN2, but in the **MK** card

4.2.28 A=IN3

Address C02FA
Description Equivalent to A=IN2, but in the **MK** card

4.2.29 OUT=C=IN3

Address C02EF
Description Equivalent to OUT=C=IN, but in the **MK** card

4.2.30 OUT=CA=IN3

Address C02F7
Description Equivalent OUT=C A=IN, but in the **MK** card

4.2.31 DISP_DEC

Address C0143
Description Displays a decimal number
In
D0 = screen address
Ca = number to be displayed
ST11 = inverse (white on black)
ST10 = 1 to display leading zeros

4.2.32 MULT_BAC

Address C014A
Description Ba = Ca * Aa

4.2.33 GREY?

Address C0151
Description Tests if a grob is in grayscale
In
D1 = grob address
Out
Carry = set if grob is in grayscale

4.2.34 BEEP

Address C0158
Description Do a beep if the system flag –56 is clear

4.2.35 KEY_REPEAT

Address C015C
Description Keyboard handler routine
Repeats a routine associated with a key.
Syntax:
```
GOSBVL =KEY_REPEAT
$/keymask % in/out mask  e.g $/02040 for Q (OUT=040, IN=02)
GOTO KEY_REPEAT_ROUTINE
GOTO END_KEY_REPEAT
```

4.2.36 KEY_NO

Address C0160
Description Waits for all keys to be released

4.2.37 HEX_DEC

Address C0164
Description Hexa to decimal conversion
In
Ca = hexa to be converted
Out
Aa = decimal result

4.2.38 A_DIV_C

Address C0168
Description Ba = Aa / Ca

4.2.39 SET_BIT

Address C016C
Description Sets a bit in a bit field
In
D1 = bit field address
Aa = bit number (to be set to 1)

4.2.40 CLEAR_BIT

Adresse FEC3F
Description Clears a bit in a bit field
In
D1 = bit field address
Aa = bit number (to be clear)

4.2.41 BIT?

Address C0173
Description Tests a bit in a bit field
In
D1 = bit field address
Aa = bit number (to be tested)
Out
Carry = set to the value of the tested bit

4.2.42 BZU.SBR

Addresse C017A
Description Décompression BZU
Uncompress data using Mika Heiskanen algorithm in his program BZ.
In
D0 = Address of the object to decompress (strings without the B prolog BZ).
D1 = Address where you want to uncompress.

4.2.43 INV.ZONE

Address C0186
Description Inverse a memory zone
In
D0 = Address zone.
Ca = Size in nibbles to inverse

4.2.44 OFF.SBR

Address C0192
Description Turns off the machine (real Off)
OFF in ML, doesn't reboot if libraries have changed.

4.2.45 InitTable

Adresse FECA0
Description Initializes memory zones for SysRPL-table routines
Initializes pointers used by the following routines, which deal with the System RPL entry point table.
There are examples on the floppy disk, in the file EXAMPLES2.DIR.
Warning: Port 2 must be at address 40000. Use the DECONFIG and RECONFIG routines.
Out
Carry set if no table has been found.
Uses RSTK(5) Aw Cw Ba D0 D1 Da, plus the following memory zones:
(b=bytes, n=nibbles)

DC	@ResZone	BE4A5	% on 256b, table name
DC	NbExternals	BE422	% on 5n, number of entries
DC	@TableText	BE427	% on 5n, address of the first entry
DC	@TableHash	BE42C	% on 5n, address of the hash table
DC	@Table→@	BE431	% on 5n, address of the pointers table, sorted by addresses
DC	TablePort	BE436	% on 2n, port number of the table
DC	RclPort	BE3AF	% on 2n, port number of the table

4.2.46 GetAdr

Adresse FECAC
Description Returns the address associated with a name
Warning: Port 2 must be at address 40000. Use the DECONFIG and RECONFIG routines.
In
DO = Address of the text to find, followed by a separation character
Out
Carry = Set if name not found
Ca = Address
Uses Aw, Cw, Ba, Da, D0, D1, RSTK(5).
DC @ResZone BE4A5 % on 256b, name saved

4.2.47 GetText

Adresse FECA6
Description Returns a pointer to the name associated to an address
Warning: Port 2 must be at address 40000. Use the DECONFIG and RECONFIG routines.

In
Ca = Address
Out
Carry = Set if address not found
D1 = Address of the text (2n for the length, followed by the characters)
Uses Aa, Ba, Ca, Da, D0, D1, RSTK(2).

4.2.48 GetFirst

Adresse FECB2
Description Finds the first name beginning with the given text
Warning: Port 2 must be at address 40000. Use the DECONFIG and RECONFIG routines.
In
DO = Address of the text to find, followed by a separation character
Out
Carry = Set if no name found
D1 = Address of the text (2n for the length, followed by the characters)
Uses Aw, Ba, Cw, RSTK(4), D0, D1, Da
DC `@ResZone BE4A5` % sur 256o sauvegarde du nom à rechercher

4.2.49 GetNext

Adresse FECB8
Description Finds the next name beginning with the given text
Use GetFirst first, values of Bb, Da and D1 must be preserved.
Warning: Port 2 must be at address 40000. Use the DECONFIG and RECONFIG routines.
In
DO = Address of the text to find, followed by a separation character
Out
Carry = Set if no name found
D1 = Address of the text (2n for the length, followed by the characters)
Uses Aw, Ba, Cw, RSTK4, D0, D1, Da
DC `@ResZone BE4A5` % sur 256o sauvegarde du nom à rechercher

4.2.50 GetFirstAdr

Adresse FECBE
Description Returns a pointer to the first table entry
Warning: Port 2 must be at address 40000. Use the DECONFIG and RECONFIG routines.
Out
D0 = Address of an entry structure:
Address (5n), name length (2n), name.
Uses D0, D1, Aa, Da, Ca, RSTK(2).

4.2.51 GetNextAdr

Adresse FECC4
Description Returns a pointer to the next table entry
Use GetFirstAdr first, values of Da, et D1 must be preserved.
The table is sorted by addresses.
Warning: Port 2 must be at address 40000. Use the DECONFIG and RECONFIG routines.
Out
Carry = Set if no more entries
D0 = Address of an entry structure (see GetFirstAdr)
Uses D0, D1, Aa, Da, Ca, RSTK(2).

4.2.52 RclPath

Adresse FEC39
Description Finds the address of a file
Warning: Port 2 must be at address 40000. Use the DECONFIG and RECONFIG routines.
In
DC `@ResZone BE4A5` % on 256b, filename (Masd syntax, ends with an ASCII 0)
Out
Carry = Set if no file found
D1 = Address of the file
Uses Aw, Ba, Cw, RSTK4, D0, D1

4.3 SysRPL entry points

Here is a list of entry points inside the **Meta Kernel**. They can be used by programmers for programs to take advantage of the **MK**. Of course, if these entry points are used, the program won't run without the **MK**.

Call a routine with `PTR xxxxx` in MASD, or with `e xxxxx`

4.3.1 GET.INDEX

Address FEC96
Description Create an index for a fast access
In
1 : Matrix (List of list)
Out
2 : Matrix (list of list)
1 : Index (Strings)

4.3.2 GET .Y.I

Address C006A
Description Recall a row from a matrix
In
3 : Matrix (List of list)
2 : Index (String)
1 : Row nb (System Binary)
Out
3 : Matrix (List of list)
2 : Index (String)
1 : List

4.3.3 GET .X.Y.I

Address C0305
Description Recall a cell
In
4 : Matrix (List of list)
3 : Index (String)
2 : X (System Binary)
1 : Y (System Binary)
Out
3 : Matrix (List of list)

2 : Index (String)
1 : Object

4.3.4 PUT.X.Y

Address FEC64
Description Put an object into a cell
The matrix has to be splited using INNERCOMP ($ 54AF) ex :
{ { 1 2 3 } { 4 5 6 } } INNERCOMP :
3 : { 1 2 3 }
2 : { 4 5 6 }
1 : <2>

In
N : First row
...
5 : Row n
4 : Number of rows (System Binary)
3 : X (System Binary)
2 : Y (System Binary)
1 : Object
Out
N : First row
...
2 : Row n
1 : Number of rows (System Binary)

4.3.5 DIMS

Address FEC9B
Description Give the dimension of a matrix
In
1 : Matrix (list of list)
Out
If it's a matrix
4 : Matrix
3 : X (System Binary)
2 : Y (System Binary)
1 : TRUE
or
1 : FALSE

4.3.6 FILER_FNAME

Address C030A
Description Voir la page 79

4.3.7 FILER_FRCL

Address C030F
Description Voir la page 79

4.3.8 FILER_NEXTADR

Address C0314
Description Voir la page 79

4.3.9 SURPRISE

Address C031E
Description Just try

4.3.10 INPUT

Address C0080
Description SysRPL INPUT, works like `InputLine (42F44)`
This INPUT command takes 10 arguments. Consult page 74.

4.3.11 CTRL_LOOP

Address C0085
Description Parameterized outer loop, like `ParOuterLoop (38985)`
Takes 9 arguments. Consult page 74.

4.3.12 INIT_CMD

Address C008A
Description Initializes the command line

4.3.13 CMP_PLUS

Address C0090
Description Adds a character to the command line string

4.3.14 DISP_CALL

Address C0095
Description Text display
In
2: Character string
1: `TRUE` if carriage returns are to be interpreted

4.3.15 BZU

Address C018D
Description Uncompress with BZU
Uncompress the compressed strings using Mika Heiskanen algorithm in his program BZ.
In
1 : Strings (without its BZ prolog).
Out
1 : Object

4.3.16 KER_PARAM

Address C0181
Description OuterLoop
Internal version of the ParOuterLoop. This program doesn't create a local environment to save the menus, therefore you can use unnamed local variables.

4.3.17 MINI_EDITOR

Address C0199
Description Mini editor on one screen line
In
3: String (if boolean on level 2 is TRUE)
2: Boolean
1: Line number, where the command line has to be put.
Out
2: String
1: Boolean (TRUE if line validated by ENTER, else FALSE)
If the boolean is TRUE, the editor is initialised with the character string on level 2.

4.3.18 KEY_PARAM

Address FEC82
Description Recall a program associated to a key
Assigns a program to key. Recalls the corresponding program.
In
3: Key code
2: Shift code
1: program list (string)
The list is as follow in MASD format :

```
STRING (
$/axx ∈ xxxxx
% a is 1 if in alpha mode, else 0. xx is the code of the key, plus the ML shift code:
%RightShift=C0 ; LeftShift=40. For example for the LeftShift+ENTER, run the %internal
command                    DUP :
$/059 EXP(5)DUP
$00 %at the end
)
```

Out
If the key is in the list :
2: program
1: TRUE
Otherwise
1: FALSE

4.3.19 UPSTACK.ADR

Address FEC69
Description Internal programs list
Recalls the programs list used by the Interactive Stack. See KEY_PARAM.
Out
1: String

4.3.20 WAITKEY.ADR

Address FEC6E
Description Internal programs list
Recalls the programs list used by the Kernel. See KEY_PARAM.
Out
1 : String

4.3.21 COMMANDLINE.ADR

Address FEC73
Description Internal programs list
Recalls the programs list used by the command line editor. See KEY_PARAM.
Out
1 : String

4.3.22 MATRIX.ADR

Address FEC87
Description Internal programs list
Recalls the programs list used by the Matrix Writer. See KEY_PARAM.
Out
1 : String

4.3.23 SAVE.ARG

Address FEC78
Description Save the LASTARG
This program is very useful, while you want to run a User RPL command, and you don't want this program to save the last arg. See LOAD.ARG too
Ex :

```
"!NO CODE
!RPL
EQU  SAVE.ARG FEC78
EQU  LOAD.ARG FEC7D
::
     SAVE.ARG
     xDUP
     LOAD.ARG
;
@"
```

In case of errors, the program will restore the good stack.

4.3.24 LOAD.ARG

Address FEC7D
Description Restore the LASTARG saved by SAVE.ARG
See above

Index

—!—

—#—

—;—

—1—

—A—

—B—

—C—

—D—

—E—

—F—

—G—

—H—

—I—

—K—

—L—

—M—

—N—

—O—

—P—

—R—

—S—

—T—

—U—

—V—

—W—

—X—

–Z–