Parallax Propeller 2
Spin2 Language Documentation

2025-02-16

v50

Document Status

Version	Date	Progress
	2020_02_06	Started document.
v34t	2020_07_15	DEBUG added, documentation up-to-date.
v34u	2020_07_19	DEBUG improved, documentation up-to-date.
v35	2020_11_18	DEBUG improved with anti-aliasing throughout, QSIN / QCOS added.
v35e	2021_01_06	DEBUG_BAUD symbol added. Spin2 stack-locating bug fixed.
v35f	2021_01_29	DEBUG fixes. Was erring at 63 DEBUGs, now goes to 255. Was not always resetting the DEBUG.log file.
v35g	2021_02_13	DEBUG fixes. Line-clipping routine was causing floating-point exceptions and memory-access violations.
v35h	2021-02-15	• The first 16 LUT registers in the Spin2 interpreter were freed to allow for streamer 'imm-->LUT' usage. This is intended to support 1/2/4-bit video, via interrupt, within the same cog that the interpreter is running in. The inline-PASM limit went from $134 down to $124, in order to compensate. • A new DEBUG_WINDOWS_OFF symbol was added to inhibit any DEBUG windows from opening after a download. DEBUG_BAUD can now be set to alter the baud rate that DEBUG uses with PNut.exe.
v35i	2021-02-20	• Added command-line DEBUG-only mode for presenting flash-programmed DEBUG data and displays. • Fixed Floating-point error in SCOPE_XY.
v35j	2021-03-16	Fixed problem with DEBUG_BAUD <> 2_000_000 not working on some boards.
v35k	2021-03-19	Added DOWNLOAD_BAUD to existing DEBUG_BAUD for overriding default 2 Mbaud download and DEBUG.
v35L	2021-03-23	Added complete command-line interface to PNut.exe and included batch files for invoking PNut.exe and returning error status to STDOUT, STDERR, and ERRORLEVEL. See "Command Line options for PNut.exe".
v35m	2021-05-03	• Improved command-line interface of PNut.exe to support compiling with/without DEBUG and with/without flash loader, and saving .bin files without downloading. • Added axis inversion to the PLOT display in DEBUG.
v35n	2021-05-23	• Sprites added to DEBUG PLOT window. • REPEAT-var fixed so that var = final value after REPEAT (was final value +/- step).
v35o,p	2021-09-22	Floating-point math operators added to Spin2 with normal precedence rules. Fixed FSQRT bug in v35p.
v35q	2021-10-13	Main symbol table increased from 64KB to 256KB, others from 4KB to 32KB.
v35r	2021-12-22	PC_KEY and PC_MOUSE added for keyboard and mouse feedback from the host computer to the DEBUG Displays.
v35s	2022-02-05	• Negative floating-point constants can be preceded with a simple '-', so that '-.' is only needed for variables and expressions. • Fixed FSQRT() bugs in the compiler and the interpreter. Both were failing on FSQRT(-0.0) and the compiler was generating a wrong result for FSQRT(0.0). • Improved floating-point rounding operations in both the compiler and the interpreter, so that even mantissas with fractions of 0.500 will not have the usual 0.500 added to them before truncation. This eliminates rounding bias. • Added BYTEFIT, which is like BYTE for use in DAT sections, but verifies byte data are -$80 to $FF. • Added WORDFIT, which is like WORD for use in DAT sections, but verifies word data are -$8000 to $FFFF. • Added @"Text", which is a shorthand version of STRING() that only allows text between quotes.
v35t	2022-08-12	• New PASM-level debugger added for single-stepping and breakpoints, invoked by "DEBUG" in Spin2/PASM. • The DEBUG() command PC_MOUSE now reports a 7th long which contains the $00RRGGBB pixel color.
v35u	2022-08-26	Serial interface code now runs in a separate thread for better concurrency with the GUI. Should be more reliable.
v35v	2022-09-11	• The serial transmit pin (P62) is now held high before DEBUG, in case no pull-up resistor is present on P62. This enables the PASM-level debugger to work on early P2 Edge modules which don't have serial pull-ups. • PASM-only programs which use non-RCFAST clock modes now get prepended with a 16-long clock-setter program which sets the clock mode, moves the PASM program down into position, and then executes it. This means that the ASMCLK instruction is no longer needed at the start of PASM-only programs. This harmonizes with the PASM-level debugger's operation, where the clock is automatically set.
v36	2022-09-18	• DEBUG now adapts to run-time clock frequency changes. This is done by using the serial receive pin (P63) in long-repository mode to store the clock frequency outside of debug interrupts. The Spin2 CLKSET instruction now supports this feature.

<table>
<tr><td>v37</td><td>2022-11-19</td><td>● Parameterization added to child-object instantiations.
○ Up to 16 parameters are passable to each child object.
○ Parameters override CON symbols by the same name within the child object.
○ Useful for hard-coding child objects with buffer sizes, pin numbers, etc.
○ <code>ObjName : "ObjFile" | ParameterA = 1, ParameterB = 2, …</code>
● Spin2 local variables now get zeroed upon method entry.
● New ^@variable returns a field pointer for any hub byte/word/long OR registers, including any bitfield.
● New FIELD[ptr] variable alias uses ^@variable pointers, making all variables passable as parameters.
● New '...' can be used to ignore the rest of the line and continue parsing into the next line.
● New Spin2 'GETCRC(dataptr,crcpoly,bytecount) method computes a CRC of bytes using any polynomial.
● New Spin2 'STRCOPY(destination,source,maxsize)' method copies z-strings, including the zero.
● DEBUG display BITMAP now has 'SPARSE color' to plot large round pixels against a background color.
● GRAY, in addition to GREY, is now recognized as a color in DEBUG displays.
● Debugger's Go/Stop/Break button now temporarily inverses when clicked.</td></tr>
<tr><td>v38</td><td>2023-02-03</td><td>● Bug fixed from v37 that didn't allow parent-object CON blocks to use CON symbols from child objects.
● Bug fixed in interpreter which caused ROTXY()/POLXY()/XYPOL() to not work.
● REPEAT-var returned to original behavior where var = (final value +/- step) after REPEAT.
● All DEBUG displays now use gamma-corrected alpha blending for anti-aliasing.</td></tr>
<tr><td>v39</td><td>2023-03-05</td><td>● Bug fixed from v37 that caused uniquely-parameterized child objects of the same file to all be the same.
● No more ".obj" files generated automatically, as objects are now buffered in PC RAM to maintain uniqueness.
● No more ".lst" list files generated automatically, now only via Ctrl-L or Ctrl-I.
● No more ".txt" documentation files generated automatically, now only via Ctrl-D.
● No more ".bin" binary files generated automatically, now toggled via Ctrl-R.
● Bug fixed from v38 that caused the PASM debugger's REG/LUT/HUB maps to be low-contrast.
● PASM debugger now does more direct checksum on hub RAM, should improve visual change response.</td></tr>
<tr><td>v40</td><td>2023-09-21</td><td>● New smaller/faster REPEAT form added for iterating a variable from 0 to n-1, where n > 0.
○ <code>REPEAT n WITH i   'best way to iterate a variable from 0 to n - 1</code>
○ <code>REPEAT i from 0 to n - 1   'general equivalent, though WITH needs n > 0</code></td></tr>
<tr><td>v41</td><td>2023-09-24</td><td>Fixed a bug in the floating-point equality operators (<., >., <>., ==., <=., >=.).</td></tr>
<tr><td>v42</td><td>2023-11-11</td><td>● Added BYTES()/WORDS()/LONGS() methods to declare strings of sized values that return a pointer.
● Added LSTRING() method, similar to STRING(), but begins with a length byte and can contain zeros.</td></tr>
<tr><td>v43</td><td>2023-12-13</td><td>● Renamed BYTES()/WORDS()/LONGS() methods to BYTE()/WORD()/LONG() to conserve name space.
● New AUTO keyword added to DEBUG SCOPE Display to auto-scale trace data.
● New %"Text" added for expressing constants of up to four characters within a long, little-endian, zero-padded.
● implemented Spin2 keyword gating to inhibit namespace conflicts as new keywords are added in the future.
○ The comment {Spin2_v##} is sought before any Spin2 code, to enable new keywords.
○ {Spin2_v43}, for example, will enable the new LSTRING keyword (actually introduced in v42).
○ {Spin2_v41} is the default if no {Spin2_v##} comment was found.
○ As you enable newer keywords, you may need to change your symbol names to resolve conflicts.
○ This way, existing code is not automatically rendered uncompilable by Spin2 namespace growth.</td></tr>
<tr><td>v44</td><td>2024-03-13</td><td>● Data structures added to help simplify complex applications.
○ Structures can be defined within CON blocks using simple syntax.
○ Structures can be instantiated in VAR blocks and PUB/PRI headers.
○ Structures and structure pointers work the same way for accessing structure members.
○ FILL/COPY/SWAP/COMP methods added to perform bulk structure operations.
● Added BYTESWAP()/WORDSWAP()/LONGSWAP() methods to quickly swap ranges of hub memory.
● Added BYTECOMP()/WORDCOMP()/LONGCOMP() methods to quickly compare ranges of hub memory.
● Added "TRIGGER channel AUTO {offset}" to DEBUG SCOPE Display for auto-triggering.
● Added BOOL/BOOL_ to DEBUG output commands, outputs "TRUE" if non-0 or "FALSE" if 0.
● Added DEBUG backtick-mode output commands: `?(boolean) and `.(floating_point).
● On DEBUG download with no clock setup, 20 MHz crystal mode will be assumed to facilitate DEBUG.
● Fixed bug that caused DAT-block ORG sections to not pad zeroes to next long after FVAR/FVARS.</td></tr>
<tr><td>v45</td><td>2024-11-13</td><td>● Data structures have been revamped, backing out and replacing v44 functionality.
○ New keyword STRUCT is used to begin structure definitions in CON blocks.
■ <code>CON STRUCT point(x, y), STRUCT line(point a, point b)</code>
○ Structures are packed with no padding or alignment.
○ Structure variables can be declared in VAR blocks (example uses 'line' structure from above).
■ <code>VAR line a, b, c[8]</code>
○ Structure variables can be declared in PUB/PRI blocks as parameters, return values, and locals.
■ <code>PUB method(line a) : line b | line c[3]</code>
■ Structures of up to 15 longs can be passed as parameters and return values
○ Structures can be declared in DAT blocks and then filled in on trailing lines.
■ <code>DAT p point 'next line can define point p contents (LONG x,y)</code>
○ FILL/COPY/SWAP/COMP structure methods from v44 are removed, now handled by operators.
■ <code>structure~</code> 'fill structure with $00's
■ <code>structure~~</code> 'fill structure with $FF's
■ <code>structureA := structureB</code> 'copy structure's contents
■ <code>structureA :=: structureB</code> 'swap structures' contents
■ <code>structureA == structureB</code> 'check structures' equality and return TRUE/FALSE
■ <code>structureA <> structureB</code> 'check structures' inequality and return TRUE/FALSE
■ <code>structure := 1,2,3</code> 'write longs to a structure
○ New SIZEOF(structure) method returns the size of a structure in bytes.
■ accepts a STRUCT name, structure variable, or structure pointer variable.
● Pointer variables added for BYTE, WORD, LONG, and STRUCT variables.
○ Each pointer takes one LONG and holds the address of the variable being pointed to.
○ Pointers can be declared in VAR blocks.
■ <code>VAR ^BYTE a, b, c</code>
■ <code>VAR ^WORD d, e, f</code>
■ <code>VAR ^LONG g, h, i</code>
■ <code>VAR ^structname j, k, l</code>
○ Pointers can be declared as PUB/PRI parameters, return values, and local variables:
■ <code>PUB method(^BYTE a) : ^WORD b | ^LONG c, ^structname d</code>
○ Pointers have the same usage syntax as the variables they point to, but with extra functionality.
■ <code>ptrvar   'read/modify/write the pointed-to variable</code></td></tr>
</table>

		■ ptrvar[++] 'read/modify/write the pointed-to variable, post-inc pointer ■ ptrvar[--] 'read/modify/write the pointed-to variable, post-dec pointer ■ [++]ptrvar 'read/modify/write the pointed-to variable, pre-inc pointer ■ [--]ptrvar 'read/modify/write the pointed-to variable, pre-dec pointer ■ [ptrvar] 'read/modify/write the pointer variable, itself ○ All ++/-- operations on pointers will step by the BYTE/WORD/LONG/STRUCT size (1/2/4/?). **Note: There is a known bug in v45 which would crash the interpreter whenever FIELD was executed. This bug has been fixed in the latest PNut_v46.zip file.**
v46	2024-11-20	● DEBUG gating and disabling added. ○ Define constant DEBUG_MASK to establish 32 different permission bits for the file/object. ○ Use DEBUG[bitnumber]{(parameters…)} to gate the DEBUG via a bit within DEBUG_MASK. ○ Define constant DEBUG_DISABLE to a non-0 value to inhibit all DEBUGs in the file/object. ● Automatic prepending of the clock-setter program to PASM-only programs can now be inhibited. ○ Define constant _AUTOCLK = 0 to stop the clock-setter program from being prepended. ○ The ASMCLK pseudo-instruction can then be used to set the clock mode, if desired. ● VAR blocks can now switch type declarations on each line, instead of allowing only one type per line. ○ VAR BYTE a,b,c, WORD d,e,f, LONG g,h,i ● New DEBUG command C_Z will output the states of the C and Z flags, such as "C=0 Z=1". **Note: The PNut_v46.zip file has been updated on 2024.11.24 to fix a bug in the Spin2 interpreter which was introduced in v45. This bug would crash the interpreter whenever FIELD was executed.**
v47	2024-12-09	● Cooperative multitasking added, affords up to 32 tasks per cog. ○ `TASKSPIN(task,method({parameters}),stack_address)` ■ Initializes a Spin2 task, similarly to how COGSPIN initializes a Spin2 cog. ■ Task = 0..31 for a fixed task or -1 for the first free task. ■ If used as an expression term, it returns the task number or -1 if no tasks were free. ○ `TASKNEXT()` ■ Switches to the next unhalted task. ■ Eventually returns to the next instruction in the current task. ■ All tasks must periodically execute `TASKNEXT()` to maintain multitasking. ■ If `TASKNEXT()` executes in the only remaining task, it has no effect. ○ `TASKSTOP(task)` ■ Stops and frees a task. ■ Task = 0..31 for a fixed task or -1 for the current task. ■ Any remaining tasks keep running. ■ If there are no remaining tasks, the cog will be stopped and freed. ■ Top-level returns from methods and tasks effectively execute `TASKSTOP(-1)`. ○ `TASKHALT(task)` ■ Halts a task until `TASKCONT` allows it to continue. ■ Task = 0..31 for a fixed task or -1 for the current task. ■ If a task halts itself, a TASKNEXT() will automatically execute. ■ The register TASKHLT contains the halt bits for all tasks, in reverse order ● PASM interrupt routines can affect the TASKHLT bits to halt/un-halt tasks. ● If all tasks are halted, the switcher will wait for an interrupt to un-halt one. ○ `TASKCONT(task)` ■ Continues a task (0..31) that was halted by `TASKHALT`. ○ `TASKCHK(task)` ■ Checks the status of a task (0..31). ■ Returns 0 if the task is free, 1 if the task is running, or 2 if the task is halted. ○ `TASKID()` ■ Returns the ID of the current task (0..31). ○ Task pointers build downward in the last 32 free cog registers, from $11F..$100. ● Binary file downloading added to the command-line interface. ○ To compile and generate a .bin file: ■ `PNut_v47 filename -c` - compile source file ■ `PNut_v47 filename -cd` - compile with DEBUG enabled ■ `PNut_v47 filename -cf` - compile with flash loader attached ■ `PNut_v47 filename -cb` - compile with both DEBUG and flash loader ○ To download and run the .bin file: ■ `PNut_v47 filename -b` - download .bin file and run it ■ `PNut_v47 filename -bd` - download .bin file and run it with DEBUG ● In Spin2 expressions, #register now returns the register's address. ○ #pr0 now resolves to $1D8 ○ #inb now resolves to $1FF **Note: A bug causing SEND() and RECV() to not work was discovered in v47 and fixed in v48.**

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<tr>
<td>v48</td>
<td>2025-01-06</td>
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Pre-processor added which enables conditional compilation of source code.

Command line syntax can be used to define up to 16 preprocessor symbols which are checkable by all source files within the compilation.
<code>PNut_v48 filename -D egg -D bee</code>

Preprocessor commands can be used in source files to check, define, and undefine preprocessor symbols. Every file starts out with the preprocessor symbols defined on the command line.

<code>#DEFINE symbol</code>
Defines a preprocessor symbol for forward references within the file.
<code>#UNDEF symbol</code>
Undefines a preprocessor symbol for forward references within the file.
<code>#IFDEF symbol</code>
Starts a new conditional scope, true if the symbol is defined.
<code>#IFNDEF symbol</code>
Starts a new conditional scope, true if the symbol is undefined.
<code>#ELSEIFDEF symbol</code>
Adds an alternate condition to the current scope, true if the symbol is defined.
<code>#ELSEIFNDEF symbol</code>
Adds an alternate condition to the current scope, true if the symbol is undefined.
<code>#ELSE</code>
Adds a default condition to the current scope, true if nothing else was true.
<code>#ENDIF</code>
Ends the current conditional scope and reverts to any outer scope.
__DEBUG__
This preprocessor symbol is defined when DEBUG compilation is enabled.

Up to 8 levels of <code>#IFDEF/#IFNDEF</code> nesting are allowed.

Flash-image output added to the command-line interface.

The flash image:

Is useful for custom flash-update schemes.
Contains the loader and application code that are normally programmed into the flash.
Must be programmed into the flash, starting at $000000, to boot on power-up.

To compile and generate a flash image:
<code>PNut_v48 filename -ci</code> - compile and output filename.flash

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<td>v49</td>
<td>2025-02-02</td>
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CON STRUCT declarations are now exported to parent objects, just like CON integers and CON floats:

<code>CON STRUCT StructX(Object.StructA x[10]) 'StructX is ten StructA's, exported</code>
<code>CON STRUCT StructY = Object.StructA 'StructY is a copy of StructA, exported</code>
<code>VAR Object.StructA StructJ 'StructJ is an instance of StructA</code>
<code>VAR ^Object.StructA StructK 'StructK is a pointer to StructA</code>
<code>PUB Name(^Object.StructA StructL) 'StructL is a pointer to StructA</code>
<code>DAT StructM Object.StructA 'StructM is an instance of StructA</code>

DEBUG LOGIC display can now draw multi-bit groups as analog waveforms using the RANGE keyword.
DEBUG display line-rendering bug fixed which caused lines to have vertical and horizontal segments when slope was close to 1. This bug began in v44 due to an incomplete optimization of the SmoothLine procedure in DebugDisplayUnit.pas.

Note: A bug causing structure sizes to be wrong was discovered in v49 and fixed in v50.
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<td>v50</td>
<td>2025-02-16</td>
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Hidden bitmap layers are now loadable into DEBUG PLOT displays for whole or cropped presentation.

To load a layer ("layer_id" must be 1 to 8):
<code>DEBUG(`plotname LAYER layer_id 'filename.bmp')</code>
To copy a full layer to the display, top-left justified (useful for identically-sized backgrounds):
<code>DEBUG(`plotname CROP layer_id)</code>
To copy a full layer to the display at some position:
<code>DEBUG(`plotname CROP layer_id display_left display_top)</code>
To copy a portion of a layer to the display, from and to the same areas:
<code>DEBUG(`plotname CROP layer_id left top width height)</code>
To copy a portion of a layer to the display, from one area in the layer to another in the display:
<code>DEBUG(`plotname CROP layer_id layer_left layer_top width height plot_left plot_top)</code>

DAT blocks and inline PASM sections now support iterative code/data generation, which is especially useful for parameterized objects.

'DITTO count' is used to start a generative block.
All code within the block will be generated 'count' times.
Count can be a positive integer or zero (no code will be generated).
The block can contain any number of lines.
A special index variable '$$' is available within the block, which iterates from 0 to count - 1.
No symbols are allowed within the block, because symbols cannot be redefined.
To branch within the block, use $ (origin), i.e. '<code>TJZ reg,#$+5</code>'.
'DITTO END' terminates a generative block.

<pre>
{Spin2_v50}

This code...

symbol1 DITTO   8   'symbol allowed here
        wypin   pin_nco+$$,#pin_base+$$ 'no symbols allowed within, use #$+n
symbol2 DITTO   END   'symbol allowed here

Generates...

symbol1
        wypin   pin_nco+0,#pin_base+0   '$$ iterated from 0 to 7
        wypin   pin_nco+1,#pin_base+1
        wypin   pin_nco+2,#pin_base+2
</pre>
</td>
</tr>
</table>

```
        wypin   pin_nco+3,#pin_base+3
        wypin   pin_nco+4,#pin_base+4
        wypin   pin_nco+5,#pin_base+5
        wypin   pin_nco+6,#pin_base+6
        wypin   pin_nco+7,#pin_base+7
symbol2
```

- PUB/PRI methods now support ORGH (hub) inline PASM code, in addition to ORG (cog) inline PASM code.
    - Like ORG, ORGH loads the first 16 local long variables from hub RAM into cog registers, executes the inline code, and then updates the registers back to hub RAM.
    - Unlike ORG inline code, ORGH inline code does not load code into cog registers $000..$11F, but can be up to $FFFF instructions long, since it stays and executes in hub RAM.
    - ORGH allows inline PASM code without interfering with the $000..$11F cog register space, So, those cog registers can be used entirely for stay-resident code, like interrupt service routines or frequently-called fast PASM routines.

```
PUB go() | i

        ORGH                'execute PASM code from hub with local variable access
        sub  i,#1           'SUB, 1 long
        debug(uhex(i))      'DEBUG, 1 long
        long 0[$FFFB]       'lots of NOPs, $FFFB longs
        debug(sdec(i))      'DEBUG, 1 long, followed by RET, 1 long
        END                 'end of PASM hub code, at limit of $FFFF longs
```

- New `@\"string\n"` works like `@"string"`, but allows escape-character sequences.
    - `\a = 7, alarm bell`
    - `\b = 8, backspace`
    - `\t = 9, tab`
    - `\n = 10, new line`
    - `\f = 12, form feed`
    - `\r = 13, carriage return`
    - `\\ = 92, "\"`
    - `\x01 to \xFF = $01 to $FF`
    - Unknown sequences are just passed verbatim (i.e. `\d = "\d"`).

- Predefined registers, like PR0, IJMP1, DIRA, OUTA, and INA, are now allowed in CON block expressions.

- PASM DEBUG instructions can be now preceded by a condition, not just a _RET_.
    - Because the BRK instruction used for DEBUG is handled early in the pipeline, a condition has no effect, though an _RET_ will execute normally.
    - In order to make the BRK instruction conditional, an opposite-condition SKIP instruction is placed before it, causing the BRK to execute on the desired condition. Note this adds 1 instruction.

```
This code...

  IF_C  DEBUG   ("Hello")       'only execute DEBUG on condition

Generates...

  IF_NC SKIP    #1              'on opposite condition, skip next instruction
        DEBUG   ("Hello")       'BRK instruction used for DEBUG
```

v51 | Coming Soon

- Long variables within structures can now be used as method pointers.
- Method pointer instances can now use CON STRUCT names to define return-value counts.
    - `CON STRUCT sABC(Method, Time)`
    - `VAR sABC ABC`
    - `PUB/PRI… ABC := ABC.Method(ABC.Time) : sABC`

- New floating-point logarithmic and exponential operators added.
    - `fpx POW fpy  'returns fpx to the power of fpy, 3.0 POW 4.0 = 81.0`
    - `LOG2 fp      'returns the base-2 log of fp, LOG2 257.0 = 8.005625`
    - `EXP2 fp      'returns 2 to the power of fp, EXP2 8.005625 = 257.0`
    - `LOG10 fp     'returns the base-10 log of fp, LOG10 150.0 = 2.176091`
    - `EXP10 fp     'returns 10 to the power of fp, EXP10 2.176091 = 150.0`
    - `LOG fp       'returns the natural log of fp, LOG 0.0001 = -9.210340`
    - `EXP fp       'returns e to the power of fp, EXP -9.210340 = 0.0001`

New Keywords Introduced by New Versions

Version	New Keywords	Type	Description	Minimum to Enable
v43	**LSTRING**	Method	Declares a constant string preceded by a length byte.	{Spin2_v43}
v44	**BYTESWAP** **WORDSWAP** **LONGSWAP** **BYTECOMP** **WORDCOMP** **LONGCOMP** **BOOL, BOOL_** ~~FILL~~ ~~COPY~~ ~~SWAP~~ ~~COMP~~	Method Method Method Method Method Method DEBUG ~~Method~~ ~~Method~~ ~~Method~~ ~~Method~~	Swap two ranges of bytes. Swap two ranges of words. Swap two ranges of longs. Compare two ranges of bytes. Compare two ranges of words. Compare two ranges of longs. Output a boolean, "TRUE" if non-0 or "FALSE" if 0. ~~Fill a structure with a byte value.~~ ~~Copy one structure to another.~~ ~~Swap contents of structures.~~ ~~Compare contents of structures.~~	{Spin2_v44}

v45	**STRUCT** **SIZEOF**	Keyword Method	In a CON block, precedes a structure definition. Returns the size of a structure in bytes.	{Spin2_v45}
v46	**C_Z**	DEBUG	Output the C and Z flag states	{Spin2_v46}
v47	**TASKSPIN** **TASKNEXT** **TASKSTOP** **TASKHALT** **TASKCONT** **TASKCHK** **TASKID** **NEWTASK** **THISTASK** **TASKHLT**	Method Method Method Method Method Method Method Constant Constant Register	Initialize a new task. Switch to the next unhalted task. Stop and free a task. Halt a task. Continue a task. Check the status of a task. Unused/running/halted = 0/1/2. Get the ID of the current task. (-1) For use in TASKSPIN. (-1) For use in TASKSTOP and TASKHALT. Register which holds the HALT bits (in reverse order)	{Spin2_v47}
v50	**DITTO**	Directive	In a DAT block, begin/end an iterative generation section.	{Spin2_v50}
v51	**POW** **LOG2** **EXP2** **LOG10** **EXP10** **LOG** **EXP**	Operator Operator Operator Operator Operator Operator Operator	Floating-point x-to-power-of-y function Floating-point base-2 logarithm function Floating-point 2-to-power-of-x function Floating-point base-10 logarithm function Floating-point 10-to-power-of-x function Floating-point natural logarithm function Floating-point e-to-power-of-x function	{Spin2_v51}

Spin2 Overview

The Spin2 language is designed to be very simple and highly capable. Spin2 does not hide the underlying binary phenomena that make computers work, but allows you to exploit it for effective programming. Propeller 2 assembly language (PASM) is also supported in Spin2 as in-line sequences, callable routines, and stand-alone programs.

A person with programming experience will be able to get a solid understanding of Spin2 in a very short amount of time. Learning Spin2 will pay dividends by allowing you to focus on your ideas, without having to navigate a myriad of typecasts and usage rules. Your brain will delight in staying busy, with compile+download+execute times of under 1 second.

In Spin2:

- Code is composed in callable methods which can accept up to 127 parameters, return up to 15 values, and contain up 64KB of local variables.
- There are four base variable types: BYTE (8-bit), WORD (16-bit), LONG (32-bit), and STRUCTs containing BYTEs, WORDs, LONGs, and other nested STRUCTs. Arrays and bitfields are supported for each.
- There are four pointer variable types which provide dynamic BYTE, WORD, LONG, and STRUCT accesses.
- All math operations are performed at 32 bits and there are both signed/unsigned-integer and IEEE-754 floating-point operators.
- Programs, called objects, can easily incorporate other objects written by other authors.
- Objects compile to compact, hardware-accelerated bytecode blocks which invoke short sequences of cog-resident PASM code.
- Source code is case-insensitive
- Symbolic names can be up to 32 characters in length.

In this documentation, all keywords are in UPPERCASE for clarity and anything in lowercase represents a user-defined symbolic name.

There are two other core documents of interest to Propeller 2 programmers.

- Parallax Propeller 2 Documentation v35 - Rev B/C Silicon
- Parallax Propeller 2 Instructions v35 - Rev B/C Silicon

Here is the latest zip file which contains PNut_v48.exe and example files:

- https://obex.parallax.com/obex/pnut-spin2-latest-version/

Spin2 Program Structure

Spin2 programs are built from one or more objects. Objects are files which contain at least one public method, along with optional constants, data structures, child objects, variables, additional methods, and data. Objects are assembled together into a top-level object with an internal hierarchy of sub-objects. Each object instance, at run-time, gets its own set of variables, as defined by the object, to maintain its unique operating state.

Different parts of an object are declared within blocks, which all begin with 3-letter block identifiers.

The compiler can actually generate PASM-only programs, as well as Spin2+PASM programs, depending upon which blocks are present in the .spin2 file.

Note: Ensure the file is saved as a ".spin2" file, otherwise the example programs will not work. If you receive an error code of "expected unique parameter name", this could be your problem.

Block Identifier	Block Contents	Spin2+PASM Programs	PASM-only Programs
CON	Constant and data-structure declarations (CON is the initial/default block type)	Permitted	Permitted
OBJ	Child-object instantiations	Permitted	Not Allowed
VAR	Variable declarations - each instance of this object will have its own VAR memory	Permitted	Not Allowed
PUB	Public method for use by the parent object and within this object	Required	Not Allowed
PRI	Private method for use within this object	Permitted	Not Allowed

DAT	Data declarations, including PASM code	Permitted	Required

Here are some minimal Spin2 and PASM-only programs. If you copy and paste these into PNut.exe, you can hit F10 to run them.

Minimal Spin2 Program	<pre>PUB MinimalSpin2Program() 'first PUB method executes
	
	  REPEAT
	    PINWRITE(7..0, GETRND()) 'write a random pattern to P7..P0
	    WAITMS(100) 'wait 1/10th of a second, loop</pre>

Minimal PASM Program	<pre>DAT ORG 'start PASM at hub $00000 for cog $000
	
	loop DRVRND #0 ADDPINS 7 'write a random pattern to P7..P0
	        WAITX ##clkfreq_/10 'wait 1/10th of a second, loop
	        JMP #loop</pre>

Here is a Spin2 program which contains every block type.

All-Block Spin2 Program

```
CON _clkfreq = 297_000_000                      'set clock frequency

OBJ vga : "VGA_640x480_text_80x40"              'instantiate vga object

VAR time, i                                     'declare object-wide variables


PUB go()                                        'this first public method executes, cog stops after

  vga.start(8)                                  'start vga on base pin 8

  SEND := @vga.print                            'establish SEND pointer

  SEND(4, $004040, 5, $00FFFF)                  'set light cyan on dark cyan

  time := GETCT()                               'capture time

  i := @text                                    'print file to vga screen
  REPEAT @textend-i
    SEND(byte[i++])

  time := GETCT() - time                        'capture time delta in clock cycles

  time := MULDIV64(time, 1_000_000, clkfreq)    'get time delta in microseconds

  SEND(12, "Time elapsed during printing was ", dec(time), " microseconds.")  'print time delta


PRI dec(value) | flag, place, digit             'private method prints decimals, three local variables

  flag~                                         'reset digit-printed flag
  place := 1_000_000_000                        'start at the one-billion's place and work downward
  REPEAT
    IF flag ||= (digit := value / place // 10) || place == 1      'print a digit?
      SEND("0" + digit)                                           'yes
      IF LOOKDOWN(place : 1_000_000_000, 1_000_000, 1_000)        'also print a comma?
        SEND(",")                                                 'yes
  WHILE place /= 10                             'next place, done?


DAT

text   FILE   "VGA_640x480_text_80x40.txt"       'include raw file data for printing
textend
```

A breakdown of each block type follows.

CON Blocks

CON blocks are used to declare symbolic constants and data structures which can be used throughout the object.

Symbolic constants:

- Symbolic constants resolve to 32-bit values.
- Symbolic constants can be assigned using '=' or by just expressing their names in an enumeration list.
- Symbolic constants can be referenced by every block within the file, including CON blocks.
- Symbolic constants can be referenced by the parent object's methods via 'objectname.constantname' syntax.
- If a "." or "e" is present among decimal digits, the value is encoded in IEEE-754 single-precision format.

Data structures:

- A data structure declaration defines a packed group of bytes, words, longs, and substructures.
- A structure definition begins with STRUCT, then a name, followed by a list of members enclosed in parentheses:
  - `STRUCT structname(BYTE|WORD|LONG|substructname membername{[arraysize]}, …)`
- Each member of a structure is a BYTE/WORD/LONG/STRUCT with a name. LONG is the default if just a name is given.
- Each member of a structure can be declared as an array by adding [arraysize] after the member name.
- Structure declarations can contain unlimited levels of nesting.
- Structure member names are scoped to the structure itself, so there are no namespace conflicts.
- Data structures are limited to $FFFF bytes, though arrays of up to $FFFF structures can be instantiated.
- No storage space is allocated until a structure is instantiated as a variable within a VAR block or a PUB/PRI header.
- Structure variables and structure pointer variables are accessed in Spin2 using the following syntax:

- ```
  structvar{[index]}{.substructure_name{[index]}...}{.byte_word_long_name{[index]}}
  ```

- Structures can also be accessed by using the STRUCT name and an address:
  - ```
    structname[address]{[index]}{.substructure_name{[index]}...}{.byte_word_long_name{[index]}}
    ```

CON — Direct Constant Assignments

```
CON  EnableFlow = 8                'single assignments
     DisableFlow = 4
     ColorBurstFreq = 3_579_545
     UpperNibs = $F0F0F0F0

     PWM_base = 8
     PWM_pins = PWM_base ADDPINS 7

     x = 5, y = -5, z = 1          'comma-separated assignments

     HalfPi = 1.5707963268         'IEEE-754 single-precision float values
     QuarPi = HalfPi / 2.0
     NegG   = -1e9
     Micro  = 1e-6

     j = ROUND(4000.0 / QuarPi)    'float to integer
```

CON — Enumerated Constant Assignments

```
CON  #0,a,b,c,d           'a=0, b=1, c=2, d=3    (start=0, step=1)
     #1,e,f,g,h           'e=1, f=2, g=3, h=4    (start=1, step=1)

     #4[2],i,j,k,l        'i=4, j=6, k=8, l=10   (start=4, step=2)
     #-1[-1],m,n,p        'm=-1, n=-2, p=-3      (start=-1, step=-1)

     #16                  'start=16, step=1
     q                    'q=16
     r[0]                 'r=17   ([0] is a step multiplier)
     s                    's=17
     t                    't=18
     u[2]                 'u=19   ([2] is a step multiplier)
     v                    'v=21
     w                    'w=22

CON  e0,e1,e2             'e0=0, e1=1, e2=2      (start=0, step=1)
                          '..enumeration is reset at each CON
```

CON — Data Structure Definitions

```
CON

  STRUCT sPoint(x, y)
  'sPoint contains long x and long y.
  'sPoint would generate this in memory if instantiated as "VAR sPoint point":
  '
  ' +00: long point.x
  ' +04: long point.y


  STRUCT sLine(sPoint a, sPoint b, BYTE color)
  'sLine contains sPoint a, sPoint b, and byte color.
  'sLine would allocate this in memory if instantiated as "VAR sLine line":
  '
  ' +00: long line.a.x
  ' +04: long line.a.y
  ' +08: long line.b.x
  ' +0C: long line.b.y
  ' +10: byte line.color
  '
  'sLine would allocate this in memory if instantiated as "VAR sLine line[2]":
  '
  ' +00: long line[0].a.x
  ' +04: long line[0].a.y
  ' +08: long line[0].b.x
  ' +0C: long line[0].b.y
  ' +10: byte line[0].color
  ' +11: long line[1].a.x
  ' +15: long line[1].a.y
  ' +19: long line[1].b.x
  ' +1D: long line[1].b.y
  ' +21: byte line[1].color

  STRUCT sCopyA = sLine
  'sCopyA is a copy of the sLine structure

  STRUCT sCopyB = object.structure
  'sCopyB is a copy of a child object's structure
```

OBJ Blocks

OBJ blocks are used to instantiate child objects into the current (parent) object.

Child objects can be instantiated with parameters which override CON symbols of the same name within the child object.

- Up to 16 parameters are allowed.
- Useful for hard-coding buffer sizes, pins, etc.

Child objects' methods can be executed and their constants can be referenced by the parent object at run time.

- Up to 32 different child objects can be incorporated into a parent object.
- Child objects can be instantiated singularly or in arrays of up to 255.
- Up to 1024 child objects are allowed per parent object.

OBJ syntax is as follows:

```
OBJ objectname{[instances]} : "objectfilename{.spin2}" {| parameter = value{, ...}}
```

OBJ
 	
Child-Object Instantiations
	`OBJ  vga       : "VGA_Driver"                'instantiate "VGA_Driver.spin2" as "vga"`
	`     mouse     : "USB_Mouse"                 'instantiate "USB_Mouse.spin2" as "mouse"`
	`     pwm       : "PWM_Driver" | p = 8, w = 4  'instantiate "PWM_Driver.spin2" as "pwm" with parameters`
	`     v[16]     : "VocalSynth"                'instantiate an array of 16 objects, v[0] through v[15]`

From within a parent-object method, a child-object method can be called by using the syntax:

```
object_name.method_name({any_parameters})
```

From within a parent-object method, a child-object constant can be referenced by using the syntax:

```
object_name.constant_name
```

VAR Blocks

VAR blocks are used to declare symbolic variables which can be utilized by all methods within the object. Each instance of an object gets its own set of variables.

- Variables can be the following types:
  - BYTE (8 bits), can be declared as a single or array
  - WORD (16 bits), can be declared as a single or array
  - LONG (32 bits, default type), can be declared as a single or array
  - STRUCT (contains BYTE, WORD, LONG, and nested STRUCT types), can be declared as a single or array
  - ^BYTE pointer (32 bits), can be stepped by +/-1 when referenced.
  - ^WORD pointer (32 bits), can be stepped by +/-2 when referenced.
  - ^LONG pointer (32 bits), can be stepped by +/-4 when referenced.
  - ^STRUCT pointer (32 bits), can be stepped by +/-STRUCT size when referenced.
- Pointer variables are used with the same syntax as regular variables, including size overrides, indexes, and bitfields, but with some additional features.
  - `ptrvar` 'read/modify/write the pointed-to-variable, same usage syntax as a regular variable
  - `ptrvar[++]` 'read/modify/write the pointed-to-variable, post-inc the pointer by BYTE/WORD/LONG/STRUCT (1/2/4/?)
  - `ptrvar[--]` 'read/modify/write the pointed-to-variable, post-dec the pointer by BYTE/WORD/LONG/STRUCT (1/2/4/?)
  - `[++]ptrvar` 'read/modify/write the pointed-to-variable, pre-inc the pointer by BYTE/WORD/LONG/STRUCT (1/2/4/?)
  - `[--]ptrvar` 'read/modify/write the pointed-to-variable, pre-dec the pointer by BYTE/WORD/LONG/STRUCT (1/2/4/?)
  - `[ptrvar]` 'read/modify/write the pointer, itself
    - `[ptrvar] := @regvar     'point the pointer to a BYTE/WORD/LONG/STRUCT`
    - `[ptrvar]++              'post-inc the pointer by BYTE/WORD/LONG/STRUCT (1/2/4/?)`
  - Pointers, from outside to inside:
    - `ptrvar                  'the pointed-to variable, has same usage syntax as a regular variable`
    - `@ptrvar                 'the address of the pointed-to variable, equals the pointer variable`
    - `[ptrvar]                'the pointer variable, equals the address of the pointed-to variable`
    - `@[ptrvar]               'the address of the pointer variable`
- Variables are packed in memory in the order they are declared, beginning at a long-aligned address.
- Each object's first 15 longs of variable memory are accessed via special bytecodes for improved efficiency.
- Each instance of an object will require one long, plus its amount of declared VAR space, plus 0..3 bytes to long-align to the next object's VAR space.
- Variables are initialized to zero at run time.

VAR syntax is as follows:

```
VAR {{^}BYTE|{^}WORD|{^}LONG|{^}StructName} VarName{[ArraySize]} {, VarName{[ArraySize]} {, ...}
```

VAR — Variable Declarations

```
VAR  CogNum                     'The default variable size is LONG (32 bits).
     CursorMode
     PosX                       'The first 15 longs have special bytecodes for faster/smaller code.
     Posy
     SendPtr                    'So, declare your most common variables first, as longs.

     BYTE StringChr             'byte variable (8 bits)
     BYTE StringBuff[64]        'byte variable array (64 bytes)
     BYTE a,b,c[1000],d         'comma-separated declarations

     WORD CurrentCycle          'word variable (16 bits)
     WORD Cycles[200]           'word variable array (200 words)
     WORD e,f[5],g,h[10]        'comma-separated declarations

     LONG Value                 'long variable
     LONG Values[15]            'long variable array (15 longs)
     LONG i[100],j,k,l          'comma-separated declarations

     StructTypeA sRecord        'structure variable of StructTypeA
     StructTypeB sRecord[20]    'structure variable array of StructTypeB

     ^BYTE bytePtr              'byte pointer variable (long)
```

```
^WORD wordPtr              'word pointer variable (long)
^LONG longPtr              'long pointer variable (long)
^StructTypeC StructPtr     'structure pointer variable of StructTypeC (long)

BYTE a,b,c, WORD d, LONG e 'Multiple types can be declared on the same line.

ALIGNW                     'word-align to hub memory, advances variable pointer as necessary

ALIGNL                     'long-align to hub memory, advances variable pointer as necessary
BYTE Bitmap[640*480]       '..useful for making long-aligned buffers for FIFO-wrapping
```

PUB and PRI Blocks

PUB and PRI blocks are used to define public and private executable Spin2 methods.

- PUB methods are available to the parent object, as well as to the object they are defined in.
- PRI methods are available only to the object they are defined in.
- The first PUB method in an object is what executes when that object is run as the top-level object.
- Methods can have from 0 to 127 input parameter longs, made up of individual longs and of structures up to 15 longs.
    - ^BYTE, ^WORD, ^LONG, and ^StructName overrides will cause parameters to become pointers, instead of longs.
- Methods can have from 0 to 15 output result longs, made up of individual longs and of structures up to 15 longs.
    - ^BYTE, ^WORD, ^LONG, and ^StructName overrides will cause results to become pointers, instead of longs.
- Methods can have up to 64KB of local variables.
    - BYTE, WORD, LONG, and StructName overrides can instantiate singular or array variables.
    - ^BYTE, ^WORD, ^LONG, and ^StructName overrides will instantiate pointer variables.
    - No override will result in a long variable.
- Overrides apply only to the variable being declared, not subsequent variables.
- Parameters, then results, and then local variables are packed into stack memory in the order they are declared.
- In-line PASM code can access the first 16 longs of parameters/results/locals via registers with the same symbolic names.
- Results and local variables are initialized to zero on method entry.

PUB/PRI syntax is as follows:

```
PUB|PRI MethodName({{^BYTE|^WORD|^LONG|^StructName} Parameter{, ...}}) {: {^BYTE|^WORD|^LONG|^StructName} Result{, ...}} {|
{ALIGNW|ALIGNL} {{^}BYTE|{^}WORD|{^}LONG|{^}StructName} LocalVar{[ArraySize]}{, ...}}
```

PUB / PRI Declarations (method code would go below each declaration)	Input Parameters (longs)	Output Results (longs)	Local Variables (longs, words, bytes, structures, structure pointers)
`PUB go()`	0	0	0
`PUB SetupADC(pins)`	1	0	0
`PUB StartTx(pin, baud) : Okay`	2	1	0
`PRI RotateXY(X, Y, Angle) : NewX, NewY | p,q,r`	3	2	3 longs
`PRI Shuffle() | i, j`	0	0	2 longs
`PRI FFT1024(^LONG DataPtr) | a, b, x[1024], y[1024]`	1	0	1+1+1024+1024 longs
`PRI ReMix() : Length, SampleRate | WORD Buff[20000], k`	0	2	20000 words + 1 long
`PRI StrCheck(StrPtrA, StrPtrB) : Pass | i, BYTE Str[64]`	2	1	1 long + 64 bytes
`PRI Analyze(^StructTypeX pX) | StructTypeX sX[10]`	1	0	sizeof(StructTypeX) x 10

DAT Blocks

DAT blocks are used to express data and PASM code.

- Data is packed in memory in the order they are declared, beginning at a long-aligned address.
- Data is expressed using the following syntax: {symbolname} **`BYTE/WORD/LONG data{[count]} {,data...}`**
- Symbols that precede data and PASM instructions resolve to addresses
    - In Spin2+PASM programs, hub addresses are relative to the start of the object and can be referenced as follows:
        - 'SymbolName' will return the data at the symbol, in accordance with its size (byte/word/long).
        - '@SymbolName' will return the address of the data.
        - '@@SymbolName' will convert an '@Symbol' in the data to an absolute address (see "DAT Data Pointers")
    - In PASM-only programs, hub addresses are absolute.

DAT
Symbols and Data

```
DAT                                               'symbols without data take the size of the previous declaration

HexChrs       BYTE    "0123456789ABCDEF"          'HexChrs is a byte symbol that points to the "0"
symbol0                                           'symbol0 is a byte symbol that points after the "F"

Pattern       WORD    $CCCC,$3333,$AAAA,$5555     'Pattern is word symbol that points to $CCCC
symbol1                                           'symbol1 is a word symbol that points after $5555

Billion       LONG    1_000_000_000               'Billion is a long symbol that points to 1_000_000_000
symbol2                                           'symbol2 is a long symbol that points after 1_000_000_000

DoNothing     NOP                                 'DoNothing is a long symbol that points to a NOP instruction
symbol3                                           'symbol3 is a long symbol that points after the NOP instruction

symbol4       BYTE                                'symbol4 is a byte symbol that points to $78
symbol5       WORD                                'symbol5 is a word symbol that points to $5678
symbol6       LONG                                'symbol6 is a long symbol that points to $12345678
```

```
                LONG    $12345678               'long value $12345678

                LONG    1.0                     'IEEE-754 1.0 is long value $3F800000

                BYTE    100[64]                 '64 bytes of value 100

                BYTE    10, WORD 500, LONG $FC000 'BYTE/WORD/LONG overrides allowed for single values
                BYTE    FVAR 99, FVARS -99      'FVAR/FVARS overrides allowed, can be read via RFVAR/RFVARS

                BYTEFIT -$80,$FF                'size-check data, overrides allowed for single values
                WORDFIT -$8000,$FFFF            'size-check data, overrides allowed for single values

BaseLine        line                            'BaseLine is a symbol marking the start of a 'line' structure
                LONG    0,0,1919,1079           'define the contents of the 'line' structure
```

```
FileDat         FILE    "Filename"              'include binary file, FileDat is a byte symbol that points to file
```

```
                ALIGNW                          'word-align to hub by emitting a zero byte, if necessary
                ALIGNL                          'long-align to hub by emitting 1 to 3 zero bytes, if necessary
```

DAT
Data Pointers

```
DAT

Str0            BYTE    "Monkeys",0     'strings with symbols
Str1            BYTE    "Gorillas",0
Str2            BYTE    "Chimpanzees",0
Str3            BYTE    "Humanzees",0

StrList         WORD    @Str0           'in Spin2, these are offsets of strings relative to start of object
                WORD    @Str1           'in Spin2, @@StrList[i] will return address of Str0..Str3 for i = 0..3
                WORD    @Str2           'in PASM-only programs, these are absolute addresses of strings
                WORD    @Str3           '(use of WORD supposes offsets/addresses are under 64KB)
```

DAT
Cog-exec

```
DAT             ORG                     'begin a cog-exec program (no symbol allowed before ORG)
                                        'COGINIT(16, @IncPins, 0) will launch this program in a free cog
IncPins         MOV     DIRA,#$FF       'to Spin2 code, IncPins is the 'MOV' instruction (long)
Loop            ADD     OUTA,#$01       'to Spin2 code, @IncPins is the hub address of the 'MOV' instruction
                AND     OUTA,#$FF       'to Spin2 code, #IncPins is the cog address of the 'MOV' instruction
                JMP     #Loop           'to PASM code, #Loop is the cog address ($001) of the 'ADD' instruction
```

```
                JMP     #$              '$ is the current origin, which steps by 1 with each cog-exec instruction
```

```
                ORG                     'set cog-exec mode, cog address = $000, cog limit = $1F8 (reg, both defaults)
                ORG     $100            'set cog-exec mode, cog address = $100, cog limit = $1F8 (reg, default limit)
                ORG     $100,$120       'set cog-exec mode, cog address = $100, cog limit = $120 (reg)
                ORG     $200            'set cog-exec mode, cog address = $200, cog limit = $400 (LUT, default limit)
                ORG     $300,$380       'set cog-exec mode, cog address = $300, cog limit = $380 (LUT)
```

```
                ADD     register,#1     'in cog-exec mode, instructions force alignment to cog/LUT registers
```

```
                ORGF    $040            'fill to cog address $040 with zeros (no symbol allowed before ORGF)
```

```
                FIT     $020            'test to make sure cog address has not exceeded $020
```

```
x               RES     1               'reserve 1 register, advance cog address by 1, don't advance hub address
y               RES     1               'reserve 1 register, advance cog address by 1, don't advance hub address
z               RES     1               'reserve 1 register, advance cog address by 1, don't advance hub address
buff            RES     16              'reserve 16 registers, advance cog address by 16, don't advance hub address
```

DAT
Hub-exec

```
DAT             ORGH    $400            'begin a hub-exec program at $400 (no symbol allowed before ORGH)
                                        'COGINIT(32+16, @IncPins, 0) will launch this program in a free cog
IncPins         MOV     DIRA,#$FF       'In Spin2, IncPins is the 'MOV' instruction (long)
Loop            ADD     OUTA,#1         'In Spin2, @IncPins is the hub address of the 'MOV' instruction
                JMP     #Loop           'In PASM, Loop is the hub address ($00404) of the 'ADD' instruction
```

```
                JMP     #$              '$ is the current origin, which steps by 4 with each hub-exec instruction
```

```
                ORGH                    'set hub-exec mode, hub origin = $00400, origin limit = $100000 (both defaults)
                ORGH    $1000           'set hub-exec mode, hub origin = $01000, origin limit = $100000 (default limit)
                ORGH    $FC000,$FC800   'set hub-exec mode, hub origin = $FC000, origin limit = $FC800
```

```
                FIT     $2000           'test to make sure hub address has not exceeded $2000
```

There are some differences between Spin2+PASM programs and PASM-only programs, when it comes to hub-exec code:

Spin2+PASM Programs

- Hub-exec code must use relative addressing, since it is not located at its place of origin.
- The LOC instruction can be used to get addresses of data assets within relative hub-exec code.
- ORGH must specify at least $400, so that pure hub-exec code will be assembled.
- The default ORGH address of $400 is always appropriate, unless you are writing code which will be moved to its actual ORGH address at runtime, so that it can use absolute addressing.

```
DAT     ORGH            'set hub-exec mode and set origin to $400
        ORGH    $FC000  'set hub-exec mode and set origin to $FC000
```

PASM-Only Programs	• Hub-exec code may use absolute and relative addressing, since origin always matches hub address.
	• ORGH fills hub memory with zeros, up to the specified address.
	
	`DAT     ORGH            'set hub-exec mode at current hub address`
	`        ORGH    $400    'set hub-exec mode and fill hub memory with zeros to $400`

Spin2 Language

Comments

Comments can occur anywhere in Spin2 or PASM code and take several forms:

Comment	Examples	Descriptions
To end of line	`a := 0   'comment here`	• initiated by apostrophe, rest of line is ignored
To end of line (documentation)	`b := 1   ''comment here`	• initiated by two apostrophes, rest of line is ignored • Comment text goes into the documentation file

Intra-line or multi-line	`x := 4, {comment here} y := 5`
	
	`{comment here`
	`comment here}`
		• Everything within braces is ignored, including end-of-lines

Intra-line or multi-line (documentation)	`x := 4, {{comment here}} y := 5`
	
	`{{comment here`
	`comment here}}`
		• Everything within double braces is ignored, including end-of-lines
		• Comment text goes into the documentation file

Continue code on next line	`z := 100   ...  comment here`
	`     * x   ...  comment here`
	`     - w`
		• Initiated by three periods, rest of line is ignored
		• parsing continues on next line, as if no end-of-line was encountered

Constants

Constants resolve to 32-bit values and can be expressed as follows:

Constants	Examples	Descriptions

Decimal	`1`
	`-150`
	`3_000_000`
		• Decimal values use digits '0'..'9'
		• Underscores '_' are allowed after the first digit for placeholding

Hexadecimal	`$1B`
	`$AA55`
	`$FFFF_FFFF`
		• Hex values start with '$' and use digits '0'..'9' and 'A'..'F'
		• Underscores '_' are allowed after the first digit for placeholding

Double Binary	`%%21`
	`%%01_23`
	`%%3333_2222_1111_0000`
		• Double binary values start with '%%' and use digits '0'..'3'
		• Underscores '_' are allowed after the first digit for placeholding

Binary	`%0110`
	`%1_1111_1000`
	`%0001_0010_0011_0100`
		• Binary values start with '%' and use digits '0' and '1'
		• Underscores '_' are allowed after the first digit for placeholding

Float	`-1.0`
	`1_250_000.0`
	`1e9`
	`5e+6`
	`-1.23456e-7`
		• Float values use digits '0'..'9' and have a '.' and/or 'e' in them
		• Floats are encoded in IEEE-754 single-precision 32-bit format
		• Underscores '_' are allowed after the first digit for placeholding
		• Special floating-point operators (+. -. *. /.) treat long values as floats

Character	`"H"`	• A single character in quotes resolves to an 8-bit ASCII value • `"A"` → `$41`
String	`"Hello"`	• Multiple characters in quotes resolve to 8-bit ASCII values separated by commas • `"Hello"` → `$48, $65, $6C, $6C, $6F`
Packed Characters	`%"ABCD"` `%"123"`	• Up to four 8-bit ASCII values packed into a long, little-endian, zero-padded • `%"ABCD"` → `$44_43_42_41` • `%"123"` → `$00_33_32_31`

Variables

In Spin2, there are both user-defined and permanent variables. The user-defined variable sources are listed below and the permanent variables are shown in the table.

- VAR variables (hub)
- PUB/PRI parameters, return values, and local variables (hub)
- DAT symbols (hub)
- Cog registers

Variables (all LONG)	Variable Name	Address or Offset	Description	Useful in Spin2	Useful in Spin2-PASM	Useful in PASM-Only
Hub Locations	`CLKMODE`	`$00040`	Clock mode value	Yes	Yes	No

	CLKFREQ	$00044	Clock frequency value	Yes	Yes	No
Hub VAR	VARBASE	+0	Object base pointer, @VARBASE is VAR base, used by method-pointer calls	Maybe	No	No
Cog Registers	PR0	$1D8	Spin2 <-> PASM communication	Yes	Yes	No
	PR1	$1D9		Yes	Yes	No
	PR2	$1DA		Yes	Yes	No
	PR3	$1DB		Yes	Yes	No
	PR4	$1DC		Yes	Yes	No
	PR5	$1DD		Yes	Yes	No
	PR6	$1DE		Yes	Yes	No
	PR7	$1DF		Yes	Yes	No
	IJMP3	$1F0	Interrupt JMP's and RET's	No	Yes	Yes
	IRET3	$1F1		No	Yes	Yes
	IJMP2	$1F2		No	Yes	Yes
	IRET2	$1F3		No	Yes	Yes
	IJMP1	$1F4		No	Yes	Yes
	IRET1	$1F5		No	Yes	Yes
	PA	$1F6	Pointer registers	No	Yes	Yes
	PB	$1F7		No	Yes	Yes
	PTRA	$1F8	Data pointer passed from COGINIT	No	Yes	Yes
	PTRB	$1F9	Code pointer passed from COGINIT	No	Yes	Yes
	DIRA	$1FA	Output enables for P31..P0	Yes	Yes	Yes
	DIRB	$1FB	Output enables for P63..P32	Yes	Yes	Yes
	OUTA	$1FC	Output states for P31..P0	Yes	Yes	Yes
	OUTB	$1FD	Output states for P63..P32	Yes	Yes	Yes
	INA	$1FE	Input states from P31..P0	Yes	Yes	Yes
	INB	$1FF	Input states from P63..P32	Yes	Yes	Yes

In Spin2, all variables can be indexed and accessed as bitfields. Additionally, symbolic hub variables can have BYTE/WORD/LONG size overrides:

Variable Usage	Example	Description
Plain	AnyVar HubVar.WORD BYTE[address] REG[register]	Hub or permanent register variable Hub variable with BYTE/WORD/LONG size override Hub BYTE/WORD/LONG by address Register, 'register' may be symbol declared in ORG section
With Index	AnyVar[index] HubVar.BYTE[index] LONG[address][index] REG[register][index]	Hub or permanent register variable with index Hub variable with size override and index Hub BYTE/WORD/LONG by address with index Register with index
With Bitfield	AnyVar.[bitfield] HubVar.LONG.[bitfield] WORD[address].[bitfield] REG[register].[bitfield]	Hub or permanent register variable with bitfield Hub variable with size override and bitfield Hub BYTE/WORD/LONG by address with bitfield Register with bitfield
With Index and Bitfield	AnyVar[index].[bitfield] HubVar.BYTE[index].[bitfield] LONG[address][index].[bitfield] REG[register][index].[bitfield]	Hub or permanent register variable with index and bitfield Hub variable with size override, index, and bitfield Hub BYTE/WORD/LONG by address with index and bitfield Register with index and bitfield

A bitfield is a 10-bit value which contains a base-bit number in bits 4..0 and an additional-bits number in bits 9..5. Bitfields can be defined in a few different ways:

Bitfield	Bit Range	Details
.[%00000_00000]	0	0 additional bits above the base bit 0, a single-bit bitfield
.[%00000_11111]	31	0 additional bits above the base bit 31, a single-bit bitfield
.[%00010_01111]	17..15	2 additional bits above the base bit 15, a three-bit bitfield
.[%11110_00000]	30..0	30 additional bits above the base bit 0, a 31-bit bitfield
.[%11111_10000]	15..0, 31..16	31 additional bits above the base bit 16, wraps around, a 32-bit bitfield
.[%00001_11111]	0, 31	1 additional bit above the base bit 31, wraps around, a 2-bit bitfield
.[23]	23	Just the base bit, adds no extra bits
.[31..20]	31..20	'Top..Bottom' syntax allowed within '.[]', wraps if Top < Bottom
.[5 ADDBITS 7]	12..5	ADDBITS can be used to compute the bitfield
.[BitfieldCon]	13..9	CON BitfieldCon = 9 ADDBITS 4 'BitfieldCon useful in PASM, too
.[BitfieldVar]	?	BitfieldVar := BaseBit ADDBITS ExtraBits 'wraps if BaseBit + ExtraBits > 31

In addition to bitfields, there are also pinfields, which are used to select a range of I/O pins within the same 32-pin block (P63..P32 or P31..P0). Pinfields are 11-bit values which contain a base-pin number in bits 5..0 and an additional-pins number in bits 10..6. Pinfields are used by instructions which interface to pins.

Pinfield	Pin Range	Details
PINLOW(%00000_000000)	0	0 additional pins above the base pin 0, a single-pin pinfield
PINLOW(%00000_111111)	63	0 additional pins above the base pin 63, a single-pin pinfield

`PINLOW(%00011_100000)`	`35..32`	3 additional pins above the base pin 32, a four-pin pinfield
`PINLOW(%11111_001000)`	`7..0, 31..8`	31 additional pins above the base pin 8, wraps around, a 32-pin pinfield
`PINLOW(19)`	`19`	Just the base pin, adds no extra pins
`PINLOW(49..40)`	`49..40`	'Top..Bottom' syntax allowed within '`.[]`', wraps if Top < Bottom
`PINLOW(11 ADDPINS 4)`	`15..11`	ADDPINS can be used to compute the pinfield
`PINLOW(PinfieldCon)`	`53..50`	`CON PinfieldCon = 50 ADDPINS 3           'PinfieldCon useful in PASM, too`
`PINLOW(PinfieldVar)`	`?`	`PinfieldVar := BasePin ADDPINS ExtraPins  'wraps if BasePin + ExtraPins > 31`

Expressions

- Run-time expressions can incorporate constants, variables, and methods' return values
- Compile-time expressions can use only constants.
- All expressions can use operators.

Here are some examples of expressions:

Expression	Details
`BYTE[i++]`	Byte pointed to by 'i', post-increment 'i'
`(digit := value / place // 10) OR place == 1`	Boolean with buried 'digit' assignment
`place /= 10`	Divide 'place' by 10
`"0" + digit`	Get 'digit' character
`PINREAD(17..12)`	Read pins 17..12

Operators

Below is a table of all the operators available for use in Spin2. Compile-time expressions can use the unary, binary, ternary, and float operators.

Var-Prefix Operators	Term (PUB/PRI only)	Term Priority	Assign (PUB/PRI only)	Assign Priority	Description	
`++ (pre)`	`++var`	1	`++var`	1	Pre-increment var, return var	
`-- (pre)`	`--var`	1	`--var`	1	Pre-decrement var, return var	
`?? (pre)`	`??var`	1	`??var`	1	Iterate long var per XORO32, return pseudo-random value	
Var-Postfix Operators	**Term (PUB/PRI only)**	**Term Priority**	**Assign (PUB/PRI only)**	**Assign Priority**	**Description**	
`(post) ++`	`var++`	1	`var++`	1	Return var, post-increment var	
`(post) --`	`var--`	1	`var--`	1	Return var, post-decrement var	
`(post) !!`	`var!!`	1	`var!!`	1	Return var, post-logical-NOT var (0 → -1, non-0 → 0)	
`(post) !`	`var!`	1	`var!`	1	Return var, post-bitwise-NOT var	
`(post) \`	`var\x`	1	`var\x`	1	Return var, post-assign x to var	
`(post) ~`	`var~`	1	`var~`	1	Return var, post-clear all bits in var	
`(post) ~~`	`var~~`	1	`var~~`	1	Return var, post-set all bits in var	
Address Operators	**Term (PUB/PRI only)**	**Term Priority**			**Description**	
`^@`	`^@anyvar`	1			Field pointer to any hub or register variable, including bitfield	
`@`	`@hubvar`	1			Hub address of VAR/PUB/PRI/DAT variable	
`@`	`@method`	1			Pointer to method, may be @object{[i]}.method	
`@@`	`@@x`	1			Hub address of this object + x, 'DAT x long @dat_symbol'	
`#`	`#reg_symbol`	1			Register address of cog/LUT symbol	
Unary Operators	**Term (All blocks)**	**Term Priority**	**Assign (PUB/PRI only)**	**Assign Priority**	**Description**	**Floating-Point Operator**
`!!, NOT`	`!!x`	12	`!!= var`	1	Logical NOT (0 → -1, non-0 → 0)	
`!`	`!x`	2	`!= var`	1	Bitwise NOT (1's complement)	
`-`	`-x`	2	`-= var`	1	Negate (2's complement)	CON only *
`-.`	`-.x`	2			Floating-point negate (toggles MSB)	All blocks
`ABS`	`ABS x`	2	`ABS= var`	1	Absolute value	CON only *
`FABS`	`FABS x`	2			Floating-point absolute value (clears MSB)	All blocks
`ENCOD`	`ENCOD x`	2	`ENCOD= var`	1	Encode MSB, 0..31	
`DECOD`	`DECOD x`	2	`DECOD= var`	1	Decode, 1 << (x & $1F)	
`BMASK`	`BMASK x`	2	`BMASK= var`	1	Bitmask, (2 << (x & $1F)) - 1	
`ONES`	`ONES x`	2	`ONES= var`	1	Sum all '1' bits, 0..32	
`SQRT`	`SQRT x`	2	`SQRT= var`	1	Square root of unsigned value	
`FSQRT`	`FSQRT x`	2			Floating-point square root	
`QLOG`	`QLOG x`	2	`QLOG= var`	1	Unsigned value to logarithm {5'whole, 27'fraction}	

`QEXP`	`QEXP x`	2	`QEXP= var`	1	Logarithm to unsigned value	
Binary Operators	Term (All blocks)	Term Priority	Assign (PUB/PRI only)	Assign Priority	Description	Floating-Point Operator
`>>`	`x >> y`	3	`var >>= y`	17	Shift x right by y bits, insert 0's	
`<<`	`x << y`	3	`var <<= y`	17	Shift x left by y bits, insert 0's	
`SAR`	`x SAR y`	3	`var SAR= y`	17	Shift x right by y bits, insert MSB's	
`ROR`	`x ROR y`	3	`var ROR= y`	17	Rotate x right by y bits	
`ROL`	`x ROL y`	3	`var ROL= y`	17	Rotate x left by y bits	
`REV`	`x REV y`	3	`var REV= y`	17	Reverse order of bits 0..y of x and zero-extend	
`ZEROX`	`x ZEROX y`	3	`var ZEROX= y`	17	Zero-extend above bit y	
`SIGNX`	`x SIGNX y`	3	`var SIGNX= y`	17	Sign-extend from bit y	
`&`	`x & y`	4	`var &= y`	17	Bitwise AND	
`^`	`x ^ y`	5	`var ^= y`	17	Bitwise XOR	
`|`	`x | y`	6	`var |= y`	17	Bitwise OR	
`*`	`x * y`	7	`var *= y`	17	Signed multiply	CON only *
`*.`	`x *. y`	7			Floating-point multiply	All blocks
`/`	`x / y`	7	`var /= y`	17	Signed divide, return quotient	CON only *
`/.`	`x /. y`	7			Floating-point divide	All blocks
`+/`	`x +/ y`	7	`var +/= y`	17	Unsigned divide, return quotient	
`//`	`x // 7`	7	`var //= y`	17	Signed divide, return remainder	
`+//`	`x +// y`	7	`var +//= y`	17	Unsigned divide, return remainder	
`SCA`	`x SCA y`	7	`var SCA= y`	17	Unsigned scale, (x * y) >> 32	
`SCAS`	`x SCAS y`	7	`var SCAS= y`	17	Signed scale, (x * y) >> 30	
`FRAC`	`x FRAC y`	7	`var FRAC= y`	17	Unsigned fraction, (x << 32) / y	
`+`	`x + y`	8	`VAR += y`	17	Add	CON only *
`+.`	`x +. y`	8			Floating-point add	All blocks
`-`	`x - y`	8	`var -= y`	17	Subtract	CON only *
`-.`	`x -. y`	8			Floating-point subtract	All blocks
`#>`	`x #> y`	9	`var #>= y`	17	Force x => y, signed	CON only *
`<#`	`x <# y`	9	`var <#= y`	17	Force x <= y, signed	CON only *
`ADDBITS`	`x ADDBITS y`	10	`var ADDBITS= y`	17	Make bitfield, (x & $1F) | (y & $1F) << 5	
`ADDPINS`	`x ADDPINS y`	10	`var ADDPINS= y`	17	Make pinfield, (x & $3F) | (y & $1F) << 6	
`<`	`x < y`	11			Signed less than (returns 0 or -1)	CON only **
`+<`	`x +< y`	11			Unsigned less than (returns 0 or -1)	
`<.`	`x <. y`	11			Floating-point less than (returns 0 or -1)	All blocks
`<=`	`x <= y`	11			Signed less than or equal (returns 0 or -1)	CON only **
`+<=`	`x +<= y`	11			Unsigned less than or equal (returns 0 or -1)	
`<=.`	`x <=. y`	11			Floating-point less than or equal (returns 0 or -1)	All blocks
`==`	`x == y`	11			Equal (returns 0 or -1)	CON only **
`==.`	`x ==. y`	11			Floating-point equal (returns 0 or -1)	All blocks
`<>`	`x <> y`	11			Not equal (returns 0 or -1)	CON only **
`<>.`	`x <>. y`	11			Floating-point not equal (returns 0 or -1)	All blocks
`>=`	`x >= y`	11			Signed greater than or equal (returns 0 or -1)	CON only **
`+>=`	`x +>= y`	11			Unsigned greater than or equal (returns 0 or -1)	
`>=.`	`x >=. y`	11			Floating-point greater than or equal (returns 0 or -1)	All blocks
`>`	`x > y`	11			Signed greater than (returns 0 or -1)	CON only **
`+>`	`x +> y`	11			Unsigned greater than (returns 0 or -1)	
`>.`	`x >. y`	11			Floating-point greater than (returns 0 or -1)	All blocks
`<=>`	`x <=> y`	11			Signed comparison (<,=,> returns -1,0,1)	CON only ***
`&&, AND`	`x && y`	13	`var &&= y`	17	Logical AND (x <> 0 AND y <> 0, returns 0 or -1)	
`^^, XOR`	`x ^^ y`	14	`var ^^= y`	17	Logical XOR (x <> 0 XOR y <> 0, returns 0 or -1)	
`||, OR`	`x || y`	15	`var ||= y`	17	Logical OR (x <> 0 OR y <> 0, returns 0 or -1)	
Ternary Operator	Term (All blocks)	Priority (term)			Description	
`? :`	`x ? y : z`	16			If x <> 0 then return y, else return z	
Assign Operator			Assign (PUB/PRI only)	Priority	Description	
`:=`			`var := x` `v1,v2 := x,y`	17	Set var to x Set v1 to x, set v2 to y, etc. ('_' on left = ignore)	
Equate Operator			Assign (CON only)	Priority	Description	
`=`			`symbol = x`	17	Set symbol to x in CON block	
Float Conversions	Term (All blocks)				Description	Floating-Point Operator
`FLOAT()`	`FLOAT(x)`				Convert integer x to float	All blocks
`ROUND()`	`ROUND(x)`				Convert float x to rounded integer	All blocks
`TRUNC()`	`TRUNC(x)`				Convert float x to truncated integer	All blocks

*,**,*** In CON blocks, this operator will take on floating-point functionality when applied to floating-point constants and symbols.
** In CON blocks, relational operators (<, <=, ==, <>, >=, >) will return 1.0 or 0.0, instead of integer -1 or 0, when applied to floating-point constants and symbols.
*** In CON blocks, the <=> operator will return -1.0, 0.0, or 1.0, instead of integer -1, 0, or 1, when applied to floating-point constants and symbols.

Spin2 Version Selection

To avoid namespace conflicts between future Spin2 keyword additions and user symbols, a means of gating new keywords was implemented starting in v43.

The compiler searches for a "{Spin2_v##}" comment before any code is expressed in the .spin2 file. ## is a two-digit number which selects the version of Spin2 for which its and all subsequent versions' keywords will be enabled. If no {Spin2_v##} is found, the compiler will default to enabling all keywords used in v41.

For example, to select v43, which would enable use of the LSTRING() method, you could place this comment at the top of your file:

```
{Spin2_v43}
```

Version numbers below 43 will be ignored, causing v41 to be used. If a version number found in code exceeds the current compiler's version, it will generate an error. Not every future version of Spin2 will constitute a meaningful version number for version selection, since it might not contain any new keywords which need gating, but it might be helpful to the person working with the code to know what the author's expectation might have been regarding other aspects of the compiler.

Built-In Methods

Hub Methods	Details
`HUBSET(Value)`	Execute HUBSET instruction using Value.
`CLKSET(NewCLKMODE, NewCLKFREQ)`	Safely establish new clock settings and update CLKMODE and CLKFREQ.
`COGSPIN(CogNum, Method({Pars}), StkAddr)`	Start Spin2 method in a cog, returns cog's ID if used as an expression element, -1 = no cog free.
`COGINIT(CogNum, PASMaddr, PTRAvalue)`	Start PASM code in a cog, returns cog's ID if used as an expression element, -1 = no cog free.
`COGSTOP(CogNum)`	Stop cog CogNum.
`COGID() : CogNum`	Get this cog's ID.
`COGCHK(CogNum) : Running`	Check if cog CogNum is running, returns -1 if running or 0 if not.
`LOCKNEW() : LockNum`	Check out a new LOCK from inventory, LockNum = 0..15 if successful or < 0 if no LOCK available.
`LOCKRET(LockNum)`	Return a certain LOCK to inventory.
`LOCKTRY(LockNum) : LockState`	Try to capture a certain LOCK, LockState = -1 if successful or 0 if another cog has captured the LOCK.
`LOCKREL(LockNum)`	Release a certain LOCK.
`LOCKCHK(LockNum) : LockState`	Check a certain LOCK's state, LockState[31] = captured, LockState[3:0] = current or last owner cog.
`COGATN(CogMask)`	Strobe ATN input(s) of cog(s) according to 16-bit CogMask.
`POLLATN() : AtnFlag`	Check if this cog has received an ATN strobe, AtnFlag = -1 if ATN strobed or 0 if not strobed.
`WAITATN()`	Wait for this cog to receive an ATN strobe.

Pin Methods	Details
`PINW | PINWRITE(PinField, Data)`	Drive PinField pin(s) with Data.
`PINL | PINLOW(PinField)`	Drive PinField pin(s) low.
`PINH | PINHIGH(PinField)`	Drive PinField pin(s) high.
`PINT | PINTOGGLE(PinField)`	Drive and toggle PinField pin(s).
`PINF | PINFLOAT(PinField)`	Float PinField pin(s).
`PINR | PINREAD(PinField) : PinStates`	Read PinField pin(s).
`PINSTART(PinField, Mode, Xval, Yval)`	Start PinField smart pin(s): DIR=0, then WRPIN=Mode, WXPIN=Xval, WYPIN=Yval, then DIR=1.
`PINCLEAR(PinField)`	Clear PinField smart pin(s): DIR=0, then WRPIN=0.
`WRPIN(PinField, Data)`	Write 'mode' register(s) of PinField smart pin(s) with Data.
`WXPIN(PinField, Data)`	Write 'X' register(s) of PinField smart pin(s) with Data.
`WYPIN(PinField, Data)`	Write 'Y' register(s) of PinField smart pin(s) with Data.
`AKPIN(PinField)`	Acknowledge PinField smart pin(s).
`RDPIN(Pin) : Zval`	Read Pin smart pin and acknowledge, Zval[31] = C flag from RDPIN, other bits are RDPIN data.
`RQPIN(Pin) : Zval`	Read Pin smart pin without acknowledge, Zval[31] = C flag from RQPIN, other bits are RQPIN data.

Timing Methods	Details
`GETCT() : Count`	Get 32-bit system counter.
`POLLCT(Tick) : Past`	Check if system counter has gone past 'Tick', returns -1 if past or 0 if not past.
`WAITCT(Tick)`	Wait for system counter to get past 'Tick'.
`WAITUS(Microseconds)`	Wait Microseconds, uses CLKFREQ, duration must not exceed $8000_0000 clocks.

`WAITMS(Milliseconds)`	Wait Milliseconds, uses CLKFREQ, duration must not exceed $8000_0000 clocks.
`GETSEC() : Seconds`	Get seconds since booting, uses 64-bit system counter and CLKFREQ, rolls over every 136 years.
`GETMS() : Milliseconds`	Get milliseconds since booting, uses 64-bit system counter and CLKFREQ, rolls over every 49.7 days.

PASM interfacing	Details
`CALL(RegisterOrHubAddr)`	CALL PASM code at Addr, PASM code should avoid registers $120..$1D7 and LUT $010..$1FF.
`REGEXEC(HubAddr)`	Load a self-defined chunk of PASM code at HubAddr into registers and CALL it. See REGEXEC description.
`REGLOAD(HubAddr)`	Load a self-defined chunk of PASM code or data at HubAddr into registers. See REGLOAD description.

Math Methods	Details
`ROTXY(x, y, angle32bit) : rotx, roty`	Rotate (x,y) by angle32bit and return rotated (x,y).
`POLXY(length, angle32bit) : x, y`	Convert (length,angle32bit) to (x,y).
`XYPOL(x, y) : length, angle32bit`	Convert (x,y) to (length,angle32bit).
`QSIN(length, step, stepsInCircle) : y`	Rotate (length,0) by (step / stepsInCircle) * 2Pi and return y. Use 0 for stepsInCircle = $1_0000_0000. stepsInCircle is unsigned.
`QCOS(length, step, stepsInCircle) : x`	Rotate (length,0) by (step / stepsInCircle) * 2Pi and return x. Use 0 for stepsInCircle = $1_0000_0000. stepsInCircle is unsigned.
`MULDIV64(mult1,mult2,divisor) : quotient`	Divide the 64-bit product of 'mult1' and 'mult2' by 'divisor', return quotient (unsigned operation).
`GETRND() : rnd`	Get random long (from xoroshiro128** PRNG, seeded on boot with thermal noise from ADC).
`NAN(float) : NotANumber`	Determine if a floating-point value is not a number, return true (-1) or false (0).

Memory Methods	Details
`GETREGS(HubAddr, CogAddr, Count)`	Move Count registers at CogAddr to longs at HubAddr.
`SETREGS(HubAddr, CogAddr, Count)`	Move Count longs at HubAddr to registers at CogAddr.
`BYTEFILL(Destination, Value, Count)`	Fill Count bytes starting at Destination with Value.
`WORDFILL(Destination, Value, Count)`	Fill Count words starting at Destination with Value.
`LONGFILL(Destination, Value, Count)`	Fill Count longs starting at Destination with Value.
`BYTEMOVE(Destination, Source, Count)`	Move Count bytes from Source to Destination.
`WORDMOVE(Destination, Source, Count)`	Move Count words from Source to Destination.
`LONGMOVE(Destination, Source, Count)`	Move Count longs from Source to Destination.
`BYTESWAP(AddrA, AddrB, Count)`	Swap Count bytes of data starting at AddrA and AddrB.
`WORDSWAP(AddrA, AddrB, Count)`	Swap Count words of data starting at AddrA and AddrB.
`LONGSWAP(AddrA, AddrB, Count)`	Swap Count longs of data starting at AddrA and AddrB.
`BYTECOMP(AddrA, AddrB, Count) : Match`	Compare Count bytes of data starting at AddrA and AddrB, return -1 if match or 0 if mismatch.
`WORDCOMP(AddrA, AddrB, Count) : Match`	Compare Count words of data starting at AddrA and AddrB, return -1 if match or 0 if mismatch.
`LONGCOMP(AddrA, AddrB, Count) : Match`	Compare Count longs of data starting at AddrA and AddrB, return -1 if match or 0 if mismatch.
`SIZEOF(Structure) : ByteCount`	Get the size of a Structure in bytes. Structure can be a structure variable, a structure pointer variable, or a STRUCT name.

String Methods	Details
`STRSIZE(Addr) : Size`	Count bytes in zero-terminated string at Addr and return string size, not including the zero.
`STRCOMP(AddrA, AddrB) : Match`	Compare zero-terminated strings at AddrA and AddrB, return -1 if match or 0 if mismatch.
`STRCOPY(Destination, Source, Max)`	Copy a zero-terminated string of up to Max characters from Source to Destination. The copied string will occupy up to Max+1 bytes, including the zero terminator.
`@"Text" : StringAddress`	Compose a zero-terminated string from text within quotes, return address of string.
`STRING("Text",13) : StringAddress`	Compose a zero-terminated string (quoted characters and values 1..255), return address of string.
`LSTRING("Hello",0,"Terve",0)`	Compose a length-headed string (quoted characters and values 0..255), return address of string.
`BYTE($80,$09,$77,WORD $1234,LONG -1)`	Compose a string of bytes, return address of string. WORD/LONG size overrides allowed.
`WORD(1_000,10_000,50_000,LONG $12345678)`	Compose a string of words, return address of string. BYTE/LONG size overrides allowed.
`LONG(1e-6,1e-3,1.0,1e3,1e6,-50,BYTE $FF)`	Compose a string of longs, return address of string. BYTE/WORD size overrides allowed.
`GETCRC(BytePtr, Poly, Count) : CRC`	Compute a CRC of Count bytes starting at BytePtr using a custom polynomial of up to 32 bits.

Index ↔ Value Methods	Details
`LOOKUP(Index: v1, v2..v3, etc) : Value`	Lookup value (values and ranges allowed) using 1-based index, return value (0 if index out of range).
`LOOKUPZ(Index: v1, v2..v3, etc) : Value`	Lookup value (values and ranges allowed) using 0-based index, return value (0 if index out of range).

`LOOKDOWN(Value: v1, v2..v3, etc) : Index`	Determine 1-based index of matching value (values and ranges allowed), return index (0 if no match).
`LOOKDOWNZ(Value: v1, v2..v3, etc) : Index`	Determine 0-based index of matching value (values and ranges allowed), return index (0 if no match).

USING METHODS

Methods that return single results can be used as terms in expressions:

```
  x := GETRND() +// 100    'Get a random number between 0 and 99

  BYTEMOVE(ToStr, FromStr, STRSIZE(FromStr) + 1)
```

Methods which return multiple results (like POLXY) can be used to supply multiple parameters to other methods:

```
  x,y := SumPoints(POLXY(rho1,theta1), POLXY(rho2,theta2))
```

…**where**…

```
PRI SumPoints(x1, y1, x2, y2) : x, y
  RETURN x1+x2, y1+y2
```

Multiple method results can be assigned to variables or ignored by using an underscore in lieu of a variable name::

```
  x,y := ROTXY(xin,yin,theta)     'use both the x and y results
  _,y := ROTXY(xin,yin,theta)     'use only the y result
  x,_ := ROTXY(xin,yin,theta)     'use only the x result
```

Assignments are very flexible. Assume these structures each have 5 longs in them:

```
  DataStruct1,  DataStruct2 := 5,4,1,7,3,8,2,0,6,9      'load DataStruct1 and DataStruct2
_(DataStruct1), DataStruct2 := 5,4,1,7,3,8,2,0,6,9      'only load DataStruct2
          _(5), DataStruct2 := 5,4,1,7,3,8,2,0,6,9      'only load DataStruct2
```

To ignore multiple values on the right-hand side of an assignment, you can use '_(?)' syntax on the left-hand side, where '?' is a constant, a STRUCT name, or a structure variable/pointer.

User-defined methods which return one or more results can also be used as instructions, where the return values are ignored. However, built-in methods such as STRSIZE, which return results, can only be used as expression terms.

ABORT

Spin2 has an "abort" mechanism for instantly returning, from any depth of nested method calls, back to a base caller which used '\' before the method name. A single return value can be conveyed from the abort point back to the base caller:

```
PRI Sub1() : Error      'Sub1 calls Sub2 with an ABORT trap
  Error := \Sub2()      '\ means call method and trap any ABORT
  \Sub2()               'in this case, the ABORT value is ignored

PRI Sub2()              'Sub2 calls Sub3
  Sub3()                'Sub3 never returns here due to the ABORT
  PINHIGH(0)            'PINHIGH never executes

PRI Sub3()              'Sub3 ABORTs, returning to Sub1 with ErrorCode
  ABORT ErrorCode       'ABORT and return ErrorCode
  PINLOW(0)             'PINLOW never executes
```

Regardless of how many return values a particular method may have, when that method is called with a preceding "\", there will be only one return value, which may be ignored.

If no value is specified after ABORT, then zero will be returned.

If a method is called with a preceding "\", but no ABORT occurs, then zero will be returned.

If an ABORT executes without a "\" trap somewhere in the call chain, the cog returns past the top-level method and executes COGSTOP(COGID), shutting itself down.

The abort mechanism is intended as a means to return from a deeply nested subroutine where some error situation has developed, but it can be used for any purpose. Basically, it's a way to return to a base caller without having to check for a condition to do so at every level of the call chain. It returns all the way back to the caller with the "\" abort trap, carrying the ABORT value. You can compose hierarchical levels of "\" abort traps and ABORT points.

METHOD POINTERS

Method pointers are LONG values which point to a method and are then used to call that method indirectly.

To establish a method pointer, you can assign a long variable using "@" before the method name. Note that there are no parentheses after the method name:

```
LongVar := @SomeMethod                          'a method within the current object
LongVar := @SomeObject.SomeMethod               'a method within a child object
LongVar := @SomeObject[index].SomeMethod        'a method within an indexed child object
```

Method pointers can be generated on-the-fly and passed as parameters:

```
SetUpIO(@InMethod,@OutMethod)
```

Method pointers are then used in the following ways to call methods:

```
LongVar()                                      'no parameters and no return values
LongVar(Par1, Par2)                            'two parameters and no return values
Var := LongVar():1                             'no parameters and one return value
Var1,Var2 := LongVar(Par1):2                   'one parameters and two return values
Var1,Var2 := POLXY(LongVar(Par1,Par2,Par3):2)  'three parameters and two return values
```

There is no compile-time awareness of how many parameters the method pointed to actually has. You need to code your method pointer usage such that you supply the proper number of parameters and specify the proper number of return values after a colon ":", so that there is agreement with the method pointed to.

Method pointers can be passed through object hierarchies to enable direct calling of any method from anywhere. They can also be used to dynamically point to different methods which have the same numbers of parameters and return values.

How Method Pointers Work

An @method expression generates a 32-bit value which has two bitfields:

[31..20] = Index of the method, relative to the method's object base. The index of the first method will be twice the number of objects instantiated

[19..0] = Address of the method's VAR base. The method's VAR base, in turn, contains the address of the method's object base.

By putting the method's index and VAR base address together into the 32-bit value, and having the VAR base contain the method's object base address, a complete method pointer is established in a single long, which can be treated as any other variable.

To accommodate method pointers, each object instance reserves the first long of its VAR space for the object base address. When an @method expression executes, that first long is written with the object's base address.

SEND

SEND is a special method pointer which is inherited from the calling method and, in turn, conveyed to all called methods. Its purpose is to provide an efficient output mechanism for data.

SEND can be assigned like a method pointer, but it must point to a method which takes one parameter and has no return values:

```
SEND := @OutMethod
```

When used as a method, SEND will pass all parameters, including any return values from called methods, to the method SEND points to:

```
SEND("Hello! ", GetDigit()+"0", 13)
```

Any methods called within the SEND parameters will inherit the SEND pointer, so that they can do SEND methods, too:

```
PUB Go()
  SEND := @SetLED
  REPEAT
    SEND(Flash(),$01,$02,$04,$08,$10,$20,$40,$80)

PRI Flash() : x
  REPEAT 2
    SEND($00,$FF,$00)
  RETURN $AA

PRI SetLED(x)
  PINWRITE(56 ADDPINS 7, !x)
  WAITMS(125)
```

In the above example, the following values are output in repeating sequence: $00, $FF, $00, $00, $FF, $00, $AA, $01, $02, $04, $08, $10, $20, $40, $80 (but inverted for LEDs)

Though a called method inherits the current SEND pointer, it may change it for its own purposes. Upon return from that method, the SEND pointer will be back to what it was before the method was called. So, the SEND pointer value is propagated in method calls, but not in method returns.

RECV

RECV, like SEND, is a special method pointer which is inherited from the calling method and, in turn, conveyed to all called methods. Its purpose is to provide an efficient input mechanism for data.

RECV can be assigned like a method pointer, but it must point to a method which takes no parameters and returns a single value:

```
RECV := @InMethod
```

An example of using RECV:

```
VAR i

PUB Go()
```

```
  RECV := @GetPattern
  REPEAT
    PINWRITE(56 ADDPINS 7, !RECV())
    WAITMS(125)

PRI GetPattern() : Pattern
  RETURN DECOD(i++ & 7)
```

In the above example, the following values are output in repeating sequence: $01, $02, $04, $08, $10, $20, $40, $80 (but inverted for LEDs)

Though a called method inherits the current RECV pointer, it may change it for its own purposes. Upon return from that method, the RECV pointer will be back to what it was before the method was called. So, the RECV pointer value is propagated in method calls, but not in method returns.

FLOW CONTROL

Spin2 has three basic flow-control constructs:

IF / IFNOT + ELSEIF / ELSEIFNOT + ELSE	- Conditional execution with random decision logic
CASE / CASE_FAST	- Conditional execution with single target and multiple match tests
REPEAT	- Looped execution with various modes

All these constructs use relative indentation to determine which code falls under their control:

```
  IF cog                                'if cog <> 0
    COGSTOP(cog-1)                      '..then stop cog
    PINCLEAR(av_base_pin_ ADDPINS 4)    '..then clear pin mode(s)
```

The flow-control constructs can be nested in any order:

```
  CASE flag
    0: CASE_FAST chr
         0:     BYTEFILL(@screen, " ", screen_size)
                col := row := 0
         1:     col := row := 0
         2..7:  flag := chr
                RETURN
         8:     IF col
                  col--
         9:     REPEAT
                  out(" ")
                WHILE col & 7
         10:    RETURN
         11:    color := $00
         12:    color := $80
         13:    newline()
         OTHER: out(chr)

    2:    col := chr // cols
    3:    row := chr // rows
    4..7: background0_[flag-$04] := chr << 8
  flag := 0
```

IF / IFNOT + ELSEIF / ELSEIFNOT + ELSE

The IF construct begins with IF or IFNOT and optionally employs ELSEIF, ELSEIFNOT, and ELSE. To all be part of the same decision tree, these keywords must have the same level of indentation.

The indented code under IF or ELSEIF executes if <condition> is not zero. The code under IFNOT or ELSEIFNOT executes if <condition> is zero. The code under ELSE executes if no other indented code executed:

`IF / IFNOT <condition>`	- Initial IF or IFNOT
`  <indented code>`	
`ELSEIF / ELSEIFNOT <condition>`	- Optional ELSEIF or ELSEIFNOT
`  <indented code>`	
`ELSE`	- Optional final ELSE
`  <indented code>`	

CASE / CASE_FAST

The CASE construct sequentially compares a target value to a list of possible matches. When a match is found, the related code executes.

Match values/ranges must be indented past the CASE keyword. Multiple match values/ranges can be expressed with comma separators. Any additional lines of code related to the match value/range must be indented past the match value/range:

```
CASE target                           - CASE with target value
  <match> : <code>                    - match value and code
    <indented code>
  <match..match> : <code>             - match range and code
    <indented code>
  <match>,<match..match> : <code>     - match value, range, and code
    <indented code>
  OTHER : <code>                      - optional OTHER case, in case no match found
    <indented code>
```

CASE_FAST is like CASE, but rather than sequentially comparing the target to a list of possible matches, it uses an indexed jump table of up to 256 entries to immediately branch to the appropriate code, saving time at a possible cost of larger compiled code. If there are only contiguous match values and no match ranges, the resulting code will actually be smaller than a normal CASE construct with more than several match values.

For CASE_FAST to compile, the match values/ranges must be unique constants which are all within 255 of each other.

See CASE_FAST example under "FLOW CONTROL" above.

REPEAT

All looping is achieved through REPEAT constructs, which have several forms:

```
REPEAT                                  - Repeat forever (useful for putting at end of program if you don't want the cog to stop and cease driving its I/O's)
  <indented code>

REPEAT <count>                          - Repeat <count> times, if <count> is zero then <indented code> is skipped
  <indented code>

REPEAT <positive_count> WITH <variable> - Repeat <positive_count> times while iterating <variable> from 0 to <positive_count> - 1
  <indented code>                       - After completion, <variable> = <positive_count>

REPEAT <variable> FROM <first> TO <last>              - Repeat while iterating <variable> from <first> to <last>, stepping by +/-1
  <indented code>                                     - After completion, <variable> = <last> +/- 1

REPEAT <variable> FROM <first> TO <last> STEP <delta> - Repeat while iterating <variable> from <first> to <last>, stepping by +/-<delta>
  <indented code>                                     - After completion, <variable> = <last> +/- <delta>

REPEAT WHILE <condition>                - Repeat while <condition> is not zero, <condition> is evaluated before <indented code> executes
  <indented code>

REPEAT UNTIL <condition>                - Repeat until <condition> is not zero, <condition> is evaluated before <indented code> executes
  <indented code>

REPEAT                                  - Repeat while <condition> is not zero, <condition> is evaluated after <indented code> executes
  <indented code>
WHILE <condition>                       - WHILE must have same indentation as REPEAT

REPEAT                                  - Repeat until <condition> is not zero, <condition> is evaluated after <indented code> executes
  <indented code>
UNTIL <condition>                       - UNTIL must have same indentation as REPEAT
```

Within REPEAT constructs, there are two special instructions which can be used to change the course of execution: NEXT and QUIT. NEXT will immediately branch to the point in the REPEAT construct where the decision to loop again is made, while QUIT will exit the REPEAT construct and continue after it. These instructions are usually used conditionally:

```
REPEAT
  <indented code>
  IF <condition>                        - Optionally force the next iteration of the REPEAT
    NEXT
  <indented code>
  IF <condition>                        - Optionally quit the REPEAT
    QUIT
  <indented code>
```

IN-LINE PASM CODE

Spin2 methods can execute in-line PASM code by preceding the PASM code with an **'ORG {start{, limit}'** and terminating it with an **END**. 'Start' is the first register into which your PASM code will be assembled and 'limit' is the upper register which must not be encroached upon. Defaults for 'start' and 'limit' are $000 and $120, respectively.

```
PUB go() | x

  REPEAT

    ORG
        GETRND  WC      'rotate a random bit into x
        RCL     x,#1
    END

    PINWRITE(56 ADDPINS 7, x)     'output x to the P2 Eval board's LEDs
    WAITMS(100)
```

Your PASM code will be assembled with a RET instruction added at the end to ensure that it returns to Spin2, in case no early _RET_ or RET executes.

Here's the internal Spin2 procedure for executing in-line PASM code:

- Save the current streamer bytecode address for restoration after the PASM code executes.
- Copy the method's first 16 long variables, including any parameters, return values, and local variables, from hub RAM to cog registers $1E0..$1EF.
- Copy the in-line PASM-code longs from hub RAM into cog registers, starting at the register address specified after the ORG (default is $000).
- CALL the PASM code. The PASM code returns when an intervening _RET_ or RET executes, or the appended RET executes.
- Restore the 16 longs in cog registers $1E0..$1EF back to hub RAM, in order to update any modified method variables.
- Restore the streamer address and resume Spin2 bytecode execution.

Within your in-line PASM code, you can do all these things:

- Read and write the following register areas:
    - $000..$11F, which your PASM code loads into. You can even load different PASM programs at different addresses within this range and CALL them from Spin2.
    - $1D8..$1DF, which are general-purpose registers, named PR0..PR7, available to both PASM and Spin2 code.
    - $1E0..$1EF, which contain the method's first 16 long hub RAM variables and are assigned the same symbolic names, for use in your PASM code.
    - $1F0..$1FF, which include IJMP3, IRET3, IJMP2, IRET2, IJMP1, IRET1, PA, PB, PTRA, PTRB, DIRA, DIRB, OUTA, OUTB, INA, and INB.
    - LUT $000..$00F, which are available for any use and ideal for streamer modes which use the LUT.
    - Avoid writing to $120..$1D7 and LUT RAM $010..$1FF, since the Spin2 interpreter occupies these areas. You can look in "Spin2_interpreter.spin2" to see the interpreter code.
- Use the FIFO temporarily by executing RDFAST/WRFAST and RFxxxx/WFxxxx instructions.
- Use the streamer, including LUT modes which utilize LUT $000..$00F.
- Use up to 5 levels of the hardware stack for nested CALLs, including CALLs to hub RAM.
- Declare and reference regular and local symbols. These symbols will not be accessible outside of your PASM code.
- Declare BYTE, WORD, and LONG data. BYTEFIT and WORDFIT are also allowed.
- Use the RES, ORGF, and FIT directives. The directives ORG, ORGH, ALIGNW, ALIGNL, and FILE are not allowed within in-line PASM code.
- Establish an interrupt which executes your code remaining in cog registers $000..$11F. Spin2 accommodates interrupts and only stalls them briefly.
- Return to Spin2, at any point, by executing an _RET_ or RET instruction.

CALLING PASM FROM SPIN2

You can do a **CALL(address)** in Spin2 to execute PASM code in either cog register space or hub RAM.

```
PUB go()

  REPEAT
    CALL(@random)
    PINWRITE(56 ADDPINS 7, pr0)
    WAITMS(100)


DAT     ORGH    'hub PASM program to rotate a random bit into x

random  GETRND  WC
 _RET_  RCL     pr0,#1
```

Here's the internal Spin2 procedure for executing a CALL:

- Save the current streamer bytecode address for restoration after the PASM code executes.
- CALL the PASM code.
- Restore the streamer address and resume Spin2 bytecode execution.

Within code which you CALL, you can do all these things:

- Read and write the following cog register and LUT areas:
    - $000..$11F, which may contain PASM code and/or data which you previously loaded.
    - $1D8..$1DF, which are general-purpose registers, named PR0..PR7, available to both PASM and Spin2 code.
    - $1E0..$1EF, which are available for scratchpad use, but will likely be rewritten when Spin2 resumes.
    - $1F0..$1FF, which include IJMP3, IRET3, IJMP2, IRET2, IJMP1, IRET1, PA, PB, PTRA, PTRB, DIRA, DIRB, OUTA, OUTB, INA, and INB.
    - LUT $000..$00F, which are available for any use and ideal for streamer modes which use the LUT.
    - Avoid writing to registers $120..$1D7 and LUT RAM $010..$1FF, since the Spin2 interpreter occupies these areas. You can look in "Spin2_interpreter.spin2" to see the interpreter code.
- Use the FIFO temporarily by executing RDFAST/WRFAST and RFxxxx/WFxxxx instructions.
- Use the streamer, including LUT modes which utilize LUT $000..$00F.
- Use up to 5 levels of the hardware stack for nested CALLs, including CALLs to hub RAM.
- Establish an interrupt which executes your code remaining in cog registers $000..$11F. Spin2 accommodates interrupts and only stalls them briefly.

- Return to Spin2, at any point, by executing an _RET_ or RET instruction.

REGLOAD and REGEXEC

The Spin2 instructions **REGLOAD(HubAddress)** and **REGEXEC(HubAddress)** are used to load or load-and-execute PASM code and/or data chunks from hub RAM into cog registers.

The chunk of PASM code and/or data must be preceded with two words which provide the starting register and the number of registers (longs) to load, minus 1.

```
PUB go()

  REGLOAD(@chunk)    'load self-defined chunk from hub into registers

  REPEAT
    CALL(#start)     'call program within chunk at register address
    WAITMS(100)

DAT

chunk   WORD    start,finish-start-1  'define chunk start and size-1

        ORG     $100                  'org can be $000..$120-size

start   DRVRND  #0 ADDPINS 7          'some code
 _RET_  DRVNOT  #8                    'more code + return
finish
```

REGEXEC works like REGLOAD, but it also CALLs to the start register of the chunk after loading it.

In the example below, REGEXEC launches a chunk of code in upper register memory which sets up a timer interrupt and then returns to Spin2. Meanwhile, as the Spin2 method repeatedly randomizes pins 60..63 every 100ms, the chunk of code loaded into upper register memory perpetuates the timer interrupt and toggles pins 56..59 every 500ms. Note that registers $000..$117 are still free for other code chunks and interrupts 2 and 3 are still unused.

```
PUB go()

  REGEXEC(@chunk)                       'load self-defined chunk and execute it
                                        'chunk starts timer interrupt and returns
  REPEAT
    PINWRITE(60 ADDPINS 3, GETRND())    'randomize pins 60..63
    WAITMS(100)                         'pins 56..59 toggle via interrupt

DAT

chunk   WORD    start,finish-start-1    'define chunk start and size-1
        ORG     $118                    'org can be $000..$120-size

start   MOV     IJMP1,#isr              'set int1 vector
        SETINT1 #1                      'set int1 to ct-passed-ct1 event
        GETCT   PR0                     'get ct
 _ret_  ADDCT1  PR0,bigwait             'set initial ct1 target, return to Spin2

isr     DRVNOT  #56 ADDPINS 3           'interrupt service routine, toggle 56..59
        ADDCT1  PR0,bigwait             'set next ct1 target
        RETI1                           'return from interrupt

bigwait LONG    20_000_000 / 2          '500ms second on RCFAST
finish
```

DATA STRUCTURES

Data structures make it easy to organize variables via encapsulation. A whole set of related variables can be declared and passed as a single parameter, either by value or pointer.

In the example below, drawLines is passed '@Lines' which is the base address of an array of line structures. The address is received by drawLines as a structure pointer 'pLine', where it gets used.

```
{Spin2_v46}

CON  STRUCT sPoint(byte x, byte y)
     STRUCT sLine(sPoint a, sPoint b, byte color)

     LineCount = 100

VAR  sLine Line[LineCount]              'Line is an array of sLine structures


PUB go() | i

  debug(`plot myplot size 256 256 hsv8x update)

  repeat
    repeat LineCount with i             'set up random lines
      Line[i].a.x := getrnd()
      Line[i].a.y := getrnd()
      Line[i].b.x := getrnd()
      Line[i].b.y := getrnd()
      Line[i].color := getrnd()

    drawLines(@Line, LineCount)         'draw them by passing Line base-structure address
```

```
PRI drawLines(^sLine pLine, count) | i  'pLine is a structure pointer of type sLine

  debug(`myplot clear linesize 2)

  repeat count with i
    debug(`myplot color `(pLine[i].color))
    debug(`myplot set  `(pLine[i].a.x, pLine[i].a.y))
    debug(`myplot line `(pLine[i].b.x, pLine[i].b.y))

  debug(`myplot update)
```

Small structures can be passed by value, as well as by address:

- Structures that do not exceed 15 longs…
    - can be passed by value as multi-long parameters and return values
    - will have any unused upper bytes zero-padded within the last long
    - can be used in multi-long assignments (structure := 1,2,3)
- Structures that do not exceed 1 long…
    - can be passed by value as a single-long parameters and return values
    - will have any unused upper bytes zero-padded within the long

There are four special structure-assignment operations that work on structures of any size, aside from general arbitrary assignments for small structures:

- `structure~                 'fill structure with $00's`
- `structure~~                'fill structure with $FF's`
- `structureA := structureB   'copy structure's contents`
- `structureA :=: structureB  'swap structures' contents`

- `structure := 1,2,3         'write arbitrary longs to a structure (15 longs, max)`

There are two structure-comparison operations which resolve to single expression terms:

- `structureA == structureB   'check structures' equality and return TRUE/FALSE`
- `structureA <> structureB   'check structures' inequality and return TRUE/FALSE`

FIELD POINTERS

Field pointers allow you to point to any hub byte/word/long location OR cog register, without making distinction as the field pointer is passed and used.

A field pointer can be obtained for any hub or register variable. By specifying an optional bit range in the field pointer declaration, the field pointer can then be used to index into an array of sub-variables of non-standard bit width.

The ^@variable operator will return a 32-bit value which will fully define where the variable is located and what range of bits comprise it.

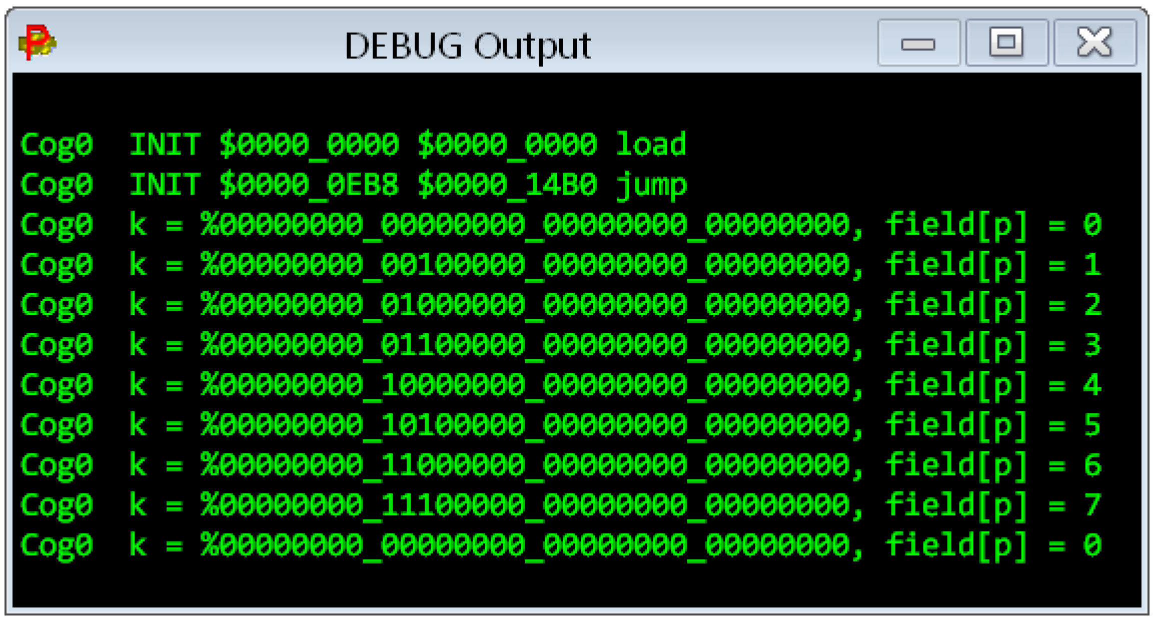
Once this field pointer is obtained, it can be passed among methods and used to access the variable that it points to using FIELD[fieldpointer].

Indexing is also supported via FIELD[fieldpointer][index]. If the variable pointed to is two bits long, then the indexing will step by units of two bits. Non-power-of-two bitfield sizes also work, but you must be pointing to a WORD or LONG in hub memory, so that the base read/write address can move in byte increments, allowing upper bits to be read or written in the upper byte(s) of the WORD or LONG.

When planning to index into an array of n-bitfields, make sure that you pick an adequately-large (BYTE/WORD/LONG) variable size for the array, so that indexed accesses will always be within the BYTE/WORD/LONG boundary. For example, single-bitfields will always work within BYTE arrays, but three-bitfields can span two bytes, so they would require a WORD array. Anything ten bits or larger would require a LONG array, since they may span three bytes.

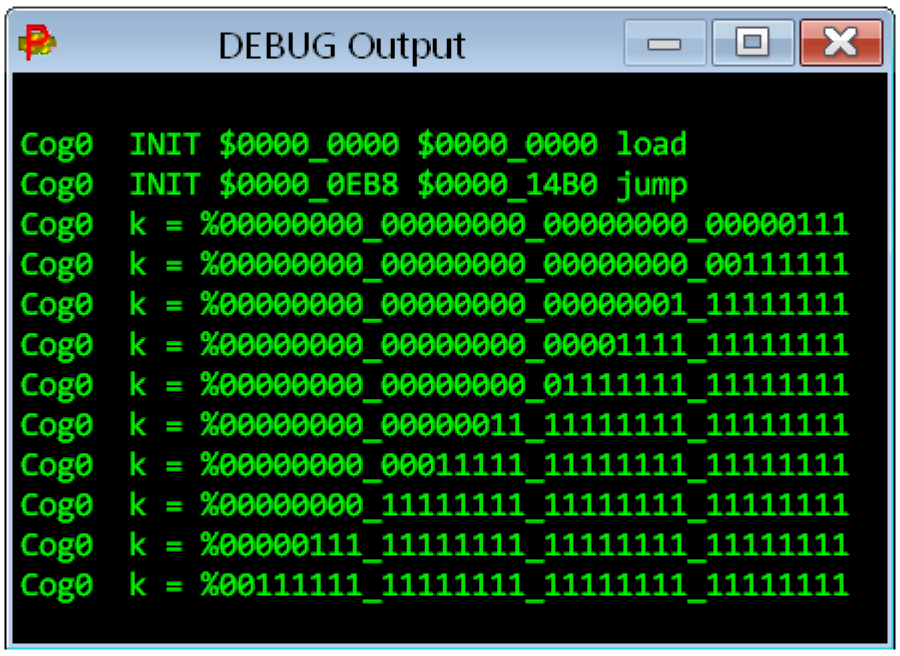
Here is an example program which uses a field pointer to access three bits within a long variable. Note that the pointer 'p' can be passed around in code and then used with FIELD to read, write, or modify the data it points to.

```
CON _clkfreq = 10_000_000

PUB go() | p, k

  p := ^@k.[23..21]   'get a pointer to three bits within k

  repeat 9
    debug(ubin_long(k), udec(field[p]++))   'show k and three bits via p
```



Here is an example using indexing to affect successive bitfields.

```
CON _clkfreq = 10_000_000

PUB go() | p, k, i

  p := ^@k.[2..0]        'get a pointer to the three lowest bits of k

  repeat 10
    field[p][i++]~~      'set three bits at a time, progressing upwards
    debug(ubin_long(k))
```



Aside from supporting optional bitfields, field pointers also differentiate between hub memory and registers. So, field pointers can reference both types of memory without any special syntax.

Here is how field pointers are encoded into 32-bit values:

Variable Syntaxes	Field Pointer Declarations	Field Pointer Encodings

`register_name`
 	
`REG[address]`
	`^@register`
	`^@register.[bbbbb addbits sssss]`
	`^@register.[msbit..lsbit]`
	`^@register.[bit]`
		`00_11111_00000_00000000000rrrrrrrrr`
		`00_sssss_bbbbb_00000000000rrrrrrrrr`

`byte_name`
 	
`BYTE[address]`
	`^@byte`
	`^@byte.[bbbbb addbits sssss]`
	`^@byte.[msbit..lsbit]`
	`^@byte.[bit]`
		`01_00111_00000_aaaaaaaaaaaaaaaaaaaa`
		`01_sssss_bbbbb_aaaaaaaaaaaaaaaaaaaa`

`word_name`
 	
`WORD[address]`
	`^@word`
	`^@word.[bbbbb addbits sssss]`
	`^@word.[msbit..lsbit]`
	`^@word.[bit]`
		`10_01111_00000_aaaaaaaaaaaaaaaaaaaa`
		`10_sssss_bbbbb_aaaaaaaaaaaaaaaaaaaa`

`long_name`
 	
`LONG[address]`
	`^@long`
	`^@long.[bbbbb addbits sssss]`
	`^@long.[msbit..lsbit]`
	`^@long.[bit]`
		`11_11111_00000_aaaaaaaaaaaaaaaaaaaa`
		`11_sssss_bbbbb_aaaaaaaaaaaaaaaaaaaa`

Note that since the bottom 20 bits of field pointers are base addresses, their values can be conveniently added to or subtracted from when used:

```
FIELD[fieldpointer + @record].
FIELD[fieldpointer + SectorBase(x)].
FIELD[fieldpointer - 4].
```

DEBUG

The Spin2 compiler contains a stealthy debugging program that can be automatically downloaded with your application. It uses the last 16 KB of RAM plus a few bytes for each Spin2 DEBUG statement and one instruction for each PASM DEBUG statement. You can place DEBUG() statements in your application which contain output commands that will serially transmit the state of variables and equations as your application runs. Each time a DEBUG statement is encountered during execution, the debugging program is invoked and it outputs the message for that statement. There is also a single-stepping PASM debugger which can be invoked via plain DEBUG statements which do not contain any parameters within parentheses. Debugging is initiated in PNut by adding the Ctrl key to the usual F10 to 'run' or F11 to 'program', or in PropellerTool by enabling Debug Mode with Ctrl+D then using F10 or F11 as is normal. This compiles your application with all the DEBUG statements, adds the debugging program to the download, and then brings up the DEBUG Output window which begins receiving messages at the start of your application.

Things to know about the DEBUG system

- To use the debugger, you must configure at least a 10 MHz clock derived from a crystal or external input. You cannot use RCFAST or RCSLOW.
- The debugging program occupies the top 16 KB of hub RAM, remapped to $FC000..$FFFFF and write-protected. The hub RAM at $7C000..$7FFFF will no longer be available.
- Data defining each DEBUG() statement is stored within the debugger image in the top 16 KB of RAM, minimizing impact on your application code.
- In Spin2, each DEBUG statement adds three bytes, plus any code needed to reference variables and resolve run-time expressions used in the DEBUG() statement.
- In PASM, each DEBUG statement adds one instruction (long).
- DEBUG statements are ignored by the compiler when not compiling for DEBUG mode, so you don't need to comment them out when debugging is not in use.
- If no DEBUG statements exist in your application, you will still get notification messages when cogs are started, if you are running the debugging program.
- Debugging is invoked by holding CTRL (in PNut), or enabling debug with CTRL+D (in Propeller Tool), before the usual F9..F11 keys, to compile, download, and program to flash.
- During execution, as DEBUG() statements are encountered, text messages are sent out serially on P62 at 2 Mbaud in 8-N-1 format.
- DEBUG() messages always start with "CogN ", where N is the cog number, followed by two spaces, and they always end with CR+LF (new line).
- Up to 255 DEBUG() statements can exist within your application, since the BRK instruction is used to interrupt and select the particular DEBUG() statement definition.
- You can define several symbols to modify debugger behavior: DEBUG_COGS, DEBUG_DELAY, DEBUG_BAUD, DEBUG_PIN, DEBUG_TIMESTAMP, etc. See table.
- Each time a debug-enabled cog is started, a debug message is output to indicate the cog number, code address (PTRB), parameter (PTRA), and 'load' or 'jump' mode.
- For Spin2, DEBUG() statements can output expression and variable values, hub byte/word/long arrays, and register arrays.
- For PASM, DEBUG() statements can output register values/arrays, hub byte/word/long arrays, C/Z flags, and constants. PASM syntax is used: implied register or #immediate.
- DEBUG() output data can be displayed as floating-point, decimal, hex, or binary, and sized to byte, word, long, or auto. Hub character strings are also supported.
- DEBUG() output commands show both the source and value: "DEBUG(UHEX(x))" might output "x = $ABC".
- DEBUG() commands which output data can have multiple sets of parameters, separated by commas: SDEC(x,y,z) and LSTR(ptr1,size1,ptr2,size2)
- Commas are automatically output between data: "DEBUG(UHEX_BYTE(d,e,f), SDEC(g))" might output "d = $45, e = $67, f = $89, g = -1_024".
- All DEBUG() output commands have alternate versions, ending in "_" which output only the value: DEBUG(UHEX_BYTE_(d,e,f)) might output "$45, $67, $89".
- DEBUG() statements can contain comma-separated strings and characters, aside from commands: DEBUG(`"We got here! Oh, Nooooo...", 13, 13)`
- DEBUG() statements may contain IF() and IFNOT() commands to gate further output within the statement. An initial IF/IFNOT will gate the entire message.
- DEBUG() statements may contain a final DLY(milliseconds) command to slow down a cog's messaging, since messages may stream at the rate of ~10,000 per second.
- DEBUG() statements may contain PC_KEY() and PC_MOUSE() commands to get the state of the host's keyboard and mouse into DEBUG() Displays.
- DEBUG() serial output can be redirected to a different pin, at a different baud rate, for displaying/logging elsewhere.
- DEBUG without parentheses will invoke that cog's PASM-level debugger, from either Spin2 or PASM. There is no limit on the number of plain DEBUG commands.
- By defining either the DEBUG_COGINIT or DEBUG_MAIN symbol, the PASM-level debugger will be started automatically for each cog upon its COGINIT.
- LOCK[15] is allocated by the debugger and used among all cogs during their debug interrupts to time-share the DEBUG serial TX and RX pins, as well as some RAM.
- P63 is configured in long-repository mode and holds the clock frequency value between debug interrupts. It must be updated when the clock frequency is altered.
- Command-line supports DEBUG-only mode: PNut -debug {CommPort if not 1} {BaudRate if not 2_000_000}

Commands for use within DEBUG() statements

Conditionals	Details
`IF(condition)`	If condition <> 0 then continue at the next command within the DEBUG() statement, else skip all remaining commands and output CR+LF. If used as the first command in the DEBUG() statement, IF will gate ALL output for the statement, including the "CogN "+CR+LF. This way, DEBUG() messages can be entirely suppressed, so that you can filter what is important.
`IFNOT(condition)`	If condition = 0 then continue at the next command within the DEBUG() statement, else skip all remaining commands and output CR+LF. If used as the first command in the DEBUG() statement, IFNOT will gate ALL output for the statement, including the "CogN "+CR+LF. This way, DEBUG() messages can be entirely suppressed, so that you can filter what is important.

Boolean Output *	Details	Output
`BOOL(value)`	Output "TRUE" if value is not 0 or "FALSE" if 0.	`TRUE / FALSE`

String Output *	Details	Output
`ZSTR(hub_pointer)`	Output zero-terminated string at hub_pointer.	`"Hello!"`
`LSTR(hub_pointer,size)`	Output 'size' characters of string at hub_pointer.	`"Goodbye."`

Floating-Point Output *	Details	Min Output	Max Output
`FDEC(value)`	Output floating-point value.	`-3.4e+38`	`3.4e+38`
`FDEC_REG_ARRAY(reg_pointer,size)`	Output register array as floating-point values.	`-3.4e+38`	`3.4e+38`
`FDEC_ARRAY(hub_pointer,size)`	Output hub long array as floating-point values.	`-3.4e+38`	`3.4e+38`

Decimal Output, unsigned *	Details	Min Output	Max Output
`UDEC(value)`	Output unsigned decimal value.	`0`	`4_294_967_295`
`UDEC_BYTE(value)`	Output byte-size unsigned decimal value.	`0`	`255`
`UDEC_WORD(value)`	Output word-size unsigned decimal value.	`0`	`65_535`
`UDEC_LONG(value)`	Output long-size unsigned decimal value.	`0`	`4_294_967_295`
`UDEC_REG_ARRAY(reg_pointer,size)`	Output register array as unsigned decimal values.	`0`	`4_294_967_295`
`UDEC_BYTE_ARRAY(hub_pointer,size)`	Output hub byte array as unsigned decimal values.	`0`	`255`
`UDEC_WORD_ARRAY(hub_pointer,size)`	Output hub word array as unsigned decimal values.	`0`	`65_535`
`UDEC_LONG_ARRAY(hub_pointer,size)`	Output hub long array as unsigned decimal values.	`0`	`4_294_967_295`
Decimal Output, signed *	**Details**	**Min Output**	**Max Output**
`SDEC(value)`	Output signed decimal value.	`-2_147_483_648`	`2_147_483_647`
`SDEC_BYTE(value)`	Output byte-size signed decimal value.	`-128`	`127`
`SDEC_WORD(value)`	Output word-size signed decimal value.	`-32_768`	`32_767`
`SDEC_LONG(value)`	Output long-size signed decimal value.	`-2_147_483_648`	`2_147_483_647`
`SDEC_REG_ARRAY(reg_pointer,size)`	Output register array as signed decimal values.	`-2_147_483_648`	`2_147_483_647`
`SDEC_BYTE_ARRAY(hub_pointer,size)`	Output hub byte array as signed decimal values.	`-128`	`127`
`SDEC_WORD_ARRAY(hub_pointer,size)`	Output hub word array as signed decimal values.	`-32_768`	`32_767`
`SDEC_LONG_ARRAY(hub_pointer,size)`	Output hub long array as signed decimal values.	`-2_147_483_648`	`2_147_483_647`
Hexadecimal Output, unsigned *	**Details**	**Min Output**	**Max Output**
`UHEX(value)`	Output auto-size unsigned hex value.	`$0`	`$FFFF_FFFF`
`UHEX_BYTE(value)`	Output byte-size unsigned hex value.	`$00`	`$FF`
`UHEX_WORD(value)`	Output word-size unsigned hex value.	`$0000`	`$FFFF`
`UHEX_LONG(value)`	Output long-size unsigned hex value.	`$0000_0000`	`$FFFF_FFFF`
`UHEX_REG_ARRAY(reg_pointer,size)`	Output register array as unsigned hex values.	`$0000_0000`	`$FFFF_FFFF`
`UHEX_BYTE_ARRAY(hub_pointer,size)`	Output hub byte array as unsigned hex values.	`$00`	`$FF`
`UHEX_WORD_ARRAY(hub_pointer,size)`	Output hub word array as unsigned hex values.	`$0000`	`$FFFF`
`UHEX_LONG_ARRAY(hub_pointer,size)`	Output hub long array as unsigned hex values.	`$0000_0000`	`$FFFF_FFFF`
Hexadecimal Output, signed *	**Details**	**Min Output**	**Max Output**
`SHEX(value)`	Output auto-size signed hex value.	`-$8000_0000`	`$7FFF_FFFF`
`SHEX_BYTE(value)`	Output byte-size signed hex value.	`-$80`	`$7F`
`SHEX_WORD(value)`	Output word-size signed hex value.	`-$8000`	`$7FFF`
`SHEX_LONG(value)`	Output long-size signed hex value.	`-$8000_0000`	`$7FFF_FFFF`
`SHEX_REG_ARRAY(reg_pointer,size)`	Output register array as signed hex values.	`-$8000_0000`	`$7FFF_FFFF`
`SHEX_BYTE_ARRAY(hub_pointer,size)`	Output hub byte array as signed hex values.	`-$80`	`$7F`
`SHEX_WORD_ARRAY(hub_pointer,size)`	Output hub word array as signed hex values.	`-$8000`	`$7FFF`
`SHEX_LONG_ARRAY(hub_pointer,size)`	Output hub long array as signed hex values.	`-$8000_0000`	`$7FFF_FFFF`
Binary Output, unsigned *	**Details**	**Min Output**	**Max Output**
`UBIN(value)`	Output auto-size unsigned binary value.	`%0`	`%11111111_11111111_11111111_11111111`
`UBIN_BYTE(value)`	Output byte-size unsigned binary value.	`%00000000`	`%11111111`
`UBIN_WORD(value)`	Output word-size unsigned binary value.	`%00000000_00000000`	`%11111111_11111111`
`UBIN_LONG(value)`	Output long-size unsigned binary value.	`%00000000_00000000_00000000_00000000`	`%11111111_11111111_11111111_11111111`
`UBIN_REG_ARRAY(reg_pointer,size)`	Output register array as unsigned binary values.	`%00000000_00000000_00000000_00000000`	`%11111111_11111111_11111111_11111111`
`UBIN_BYTE_ARRAY(hub_pointer,size)`	Output hub byte array as unsigned binary values.	`%00000000`	`%11111111`
`UBIN_WORD_ARRAY(hub_pointer,size)`	Output hub word array as unsigned binary values.	`%00000000_00000000`	`%11111111_11111111`
`UBIN_LONG_ARRAY(hub_pointer,size)`	Output hub long array as unsigned binary values.	`%00000000_00000000_00000000_00000000`	`%11111111_11111111_11111111_11111111`

Binary Output, signed *	Details	Min Output	Max Output
`SBIN(value)`	Output auto-size signed binary value.	`-%10000000_00000000_00000000_00000000`	`%01111111_11111111_11111111_11111111`
`SBIN_BYTE(value)`	Output byte-size signed binary value.	`-%10000000`	`%01111111`
`SBIN_WORD(value)`	Output word-size signed binary value.	`-%10000000_00000000`	`%01111111_11111111`
`SBIN_LONG(value)`	Output long-size signed binary value.	`-%10000000_00000000_00000000_00000000`	`%01111111_11111111_11111111_11111111`
`SBIN_REG_ARRAY(reg_pointer,size)`	Output register array as signed binary values.	`-%10000000_00000000_00000000_00000000`	`%01111111_11111111_11111111_11111111`
`SBIN_BYTE_ARRAY(hub_pointer,size)`	Output hub byte array as signed binary values.	`-%10000000`	`%01111111`
`SBIN_WORD_ARRAY(hub_pointer,size)`	Output hub word array as signed binary values.	`-%10000000_00000000`	`%01111111_11111111`
`SBIN_LONG_ARRAY(hub_pointer,size)`	Output hub long array as signed binary values.	`-%10000000_00000000_00000000_00000000`	`%01111111_11111111_11111111_11111111`

* These commands accept multiple parameters, or multiple sets of parameters. Alternate commands with the same names, but ending in "_", are also available for value-only output (i.e. BOOL_, ZSTR_, LSTR_, UDEC_).

Miscellaneous	Details
`DLY(milliseconds)`	Delay for some milliseconds to slow down continuous message outputs for this cog. DLY is only allowed as the last command in a DEBUG() statement, since it releases LOCK[15] before the delay, permitting other cogs to capture LOCK[15] so that they may take control of the DEBUG() serial-transmit pin and output their own DEBUG() messages.
`PC_KEY(pointer_to_long)`	FOR USE IN GRAPHICAL DEBUG() DISPLAYS - Must be the last command in a DEBUG() statement. Returns any new host-PC keypress that occurred within the last 100ms into a long inside the chip. The DEBUG() Display must have focus for keypresses to be noticed. `LONG key            'Key long which receives keypresses (0 if no keypress)` 0 = <no keypress> 1 = Left Arrow 2 = Right Arrow 3 = Up Arrow 4 = Down Arrow 5 = Home 6 = End 7 = Delete 8 = Backspace 9 = Tab 10 = Insert 11 = Page Up 12 = Page Down 13 = Enter 27 = Esc 32..126 = Space to "~", including all symbols, digits, and letters If used in Spin2 code, the long must be in the hub (use @key as the pointer). If used in PASM code, the long must be a cog register (use #key as the pointer).

`PC_MOUSE(pointer_to_7_longs)`	FOR USE IN GRAPHICAL DEBUG() DISPLAYS - Must be the last command in a DEBUG() statement.
	
	Returns the current host-PC mouse status into a 7-long structure inside the chip, arranged as follows:
	
	`LONG xpos           'X position within the DEBUG Display (xpos<0 and ypos<0 if mouse is outside)`
	`LONG ypos           'Y position within the DEBUG Display`
	`LONG wheeldelta     'Scroll-wheel delta, 0 or +/-1 if changed (the DEBUG Display must have focus)`
	`LONG lbutton        'Left-button state, 0 or -1 if pressed`
	`LONG mbutton        'Middle-button state, 0 or -1 if pressed`
	`LONG rbutton        'Right-button state, 0 or -1 if pressed`
	`LONG pixel          'Pixel color at mouse position, $00_RR_GG_BB or -1 if outside the DEBUG Display`
	
	If used in Spin2 code, the seven longs must be in the hub (use @xpos as the pointer).
	If used in PASM code, the seven longs must be cog registers (use #xpos as the pointer).

`C_Z`	Output the C and Z flags as "C=? Z=?". Useful in PASM code.

Symbols you can define to modify DEBUG behavior

CON Symbol	Default	Purpose
`DOWNLOAD_BAUD`	`2_000_000`	Sets the download baud rate.
`DEBUG_COGS`	`%11111111`	Selects which cogs have debug interrupts enabled. Bits 7..0 enable debugging interrupts in cogs 7..0.
`DEBUG_COGINIT`	`undefined`	By declaring this symbol, each cog's PASM-level debugger will initially be invoked when a COGINIT occurs.
`DEBUG_MAIN`	`undefined`	By declaring this symbol, each cog's PASM-level debugger will initially be invoked when a COGINIT occurs, and it will be ready to single-step through main (non-interrupt) code. In this case, DEBUG commands will be ignored, until you select "DEBUG" sensitivity in the debugger.
`DEBUG_DELAY`	`0`	Sets a delay in milliseconds before your application runs and begins transmitting DEBUG messages.
`DEBUG_PIN_TX`	`62`	Sets the DEBUG serial output pin. For DEBUG windows to open, DEBUG_PIN must be 62.
`DEBUG_PIN_RX`	`63`	Sets the DEBUG serial input pin for interactivity with the host PC.
`DEBUG_BAUD`	`DOWNLOAD_BAUD`	Sets the DEBUG baud rate. May be necessary to add DEBUG_DELAY if DEBUG_BAUD is less than DOWNLOAD_BAUD.
`DEBUG_TIMESTAMP`	`undefined`	By declaring this symbol, each DEBUG message will be time-stamped with the 64-bit CT value.
`DEBUG_LOG_SIZE`	`0`	Sets the maximum size in bytes of the 'DEBUG.log' file which will collect DEBUG messages. A value of 0 will inhibit log file

		generation.
DEBUG_LEFT	(dynamic)	Sets the left screen coordinate where the DEBUG message window will appear.
DEBUG_TOP	(dynamic)	Sets the top screen coordinate where the DEBUG message window will appear.
DEBUG_WIDTH	(dynamic)	Sets the width of the DEBUG message window.
DEBUG_HEIGHT	(dynamic)	Sets the height of the DEBUG message window.
DEBUG_DISPLAY_LEFT	0	Sets the overall left screen offset where any DEBUG displays will appear (adds to 'POS' x coordinate in each DEBUG display).
DEBUG_DISPLAY_TOP	0	Sets the overall top screen offset where any DEBUG displays will appear (adds to 'POS' y coordinate in each DEBUG display).
DEBUG_WINDOWS_OFF	0	Disables any DEBUG windows from opening after downloading, if set to a non-zero value.
DEBUG_MASK	undefined	Assigning a 32-bit mask value to this symbol allows individual DEBUG statements to be gated according to the state of a particular mask bit. This is done by placing a mask bit number (0..31) in brackets, immediately after the DEBUG keyword and before any parameters: `DEBUG[MaskBitNumber]{(parameters…)}`. If the particular mask bit is high, the DEBUG will be compiled, otherwise it will be ignored.
DEBUG_DISABLE	undefined	Assigning a non-0 value to this symbol will disable all DEBUG statements in the file/object.

Simple DEBUG example in Spin2

```
CON _clkfreq = 10_000_000      'set 10 MHz clock (assumes 20 MHz crystal)

PUB go() | i
  REPEAT i FROM 0 TO 9         'count from 0 to 9
    DEBUG(UDEC(i))             'debug, output i
```

When run with Ctrl-F10, the Debug window opens and this is what appears:

```
Cog0  INIT $0000_0000 $0000_0000 load
Cog0  INIT $0000_0D6C $0000_10BC jump
Cog0  i = 0
Cog0  i = 1
Cog0  i = 2
Cog0  i = 3
Cog0  i = 4
Cog0  i = 5
Cog0  i = 6
Cog0  i = 7
Cog0  i = 8
Cog0  i = 9
```

In the first line of the report, you see Cog0 loading the Spin2 set-up code from $00000. In the second line, the Spin2 interpreter is launched from $00D6C with its stack space starting at $010BC. After that, the Spin2 program is running and you see 'i' iterating from 0 to 9.

If you change the "9" to "99" in the REPEAT, data will scroll too fast to read, but by adding a DLY command at the end of the DEBUG statement, you can slow down the output:

```
debug(udec(i), dly(250))     'debug, output i with a 250ms delay after each report
```

Let's say you want to limit the messages being output, so that only odd values of 'i' are shown. You could use an IF at the start of your DEBUG statement to check the least-significant bit of 'i'. When the IF is false, no message will be output, causing only the odd values of i to be shown:

```
debug(if(i & 1), udec(i), dly(250))     'debug, output only odd i values with a 250ms delay after each report
```

Simple DEBUG example in PASM

```
CON _clkfreq = 10_000_000       'set 10 MHz clock (assumes 20 MHz crystal)

DAT     ORG

        MOV     i,#9            'set i to 9
loop    DEBUG   (UHEX_LONG(i))  'debug, output i in hex
        DJNF    i,#loop         'decrement i and loop if not -1
        JMP     #$              'don't go wandering off, stay here

i       RES     1               'reserve one register as 'i'
```

When run with Ctrl-F10, the Debug window opens and this is what appears:

```
Cog0  INIT $0000_0000 $0000_0000 load
Cog0  i = $0000_0009
Cog0  i = $0000_0008
Cog0  i = $0000_0007
Cog0  i = $0000_0006
Cog0  i = $0000_0005
Cog0  i = $0000_0004
Cog0  i = $0000_0003
Cog0  i = $0000_0002
Cog0  i = $0000_0001
Cog0  i = $0000_0000
```

In the first line of the report, you see Cog0 loading our PASM program from $00000. After that, the program runs and you see 'i' iterating from 9 down to 0.

If you change the "9" to "99" in the MOV instruction and you'd like to slow things down, add a DLY command to the DEBUG statement and be sure to express the milliseconds as #250, since a plain 250 would be understood as register 250:

```
debug   (uhex_long(i), dly(#250))      'debug, output i in hex and delay for 250ms after each report
```

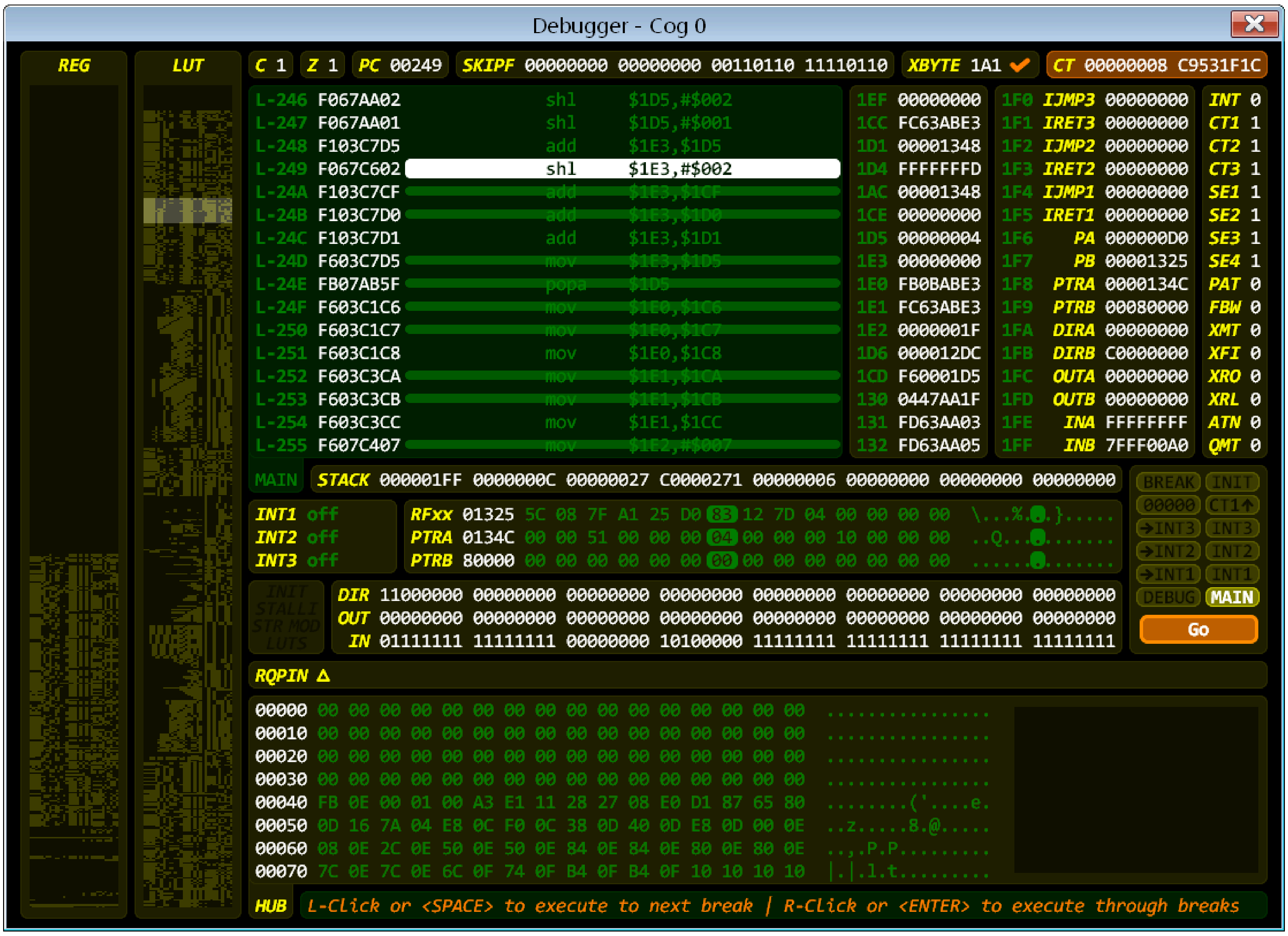
PASM-Level Debugger

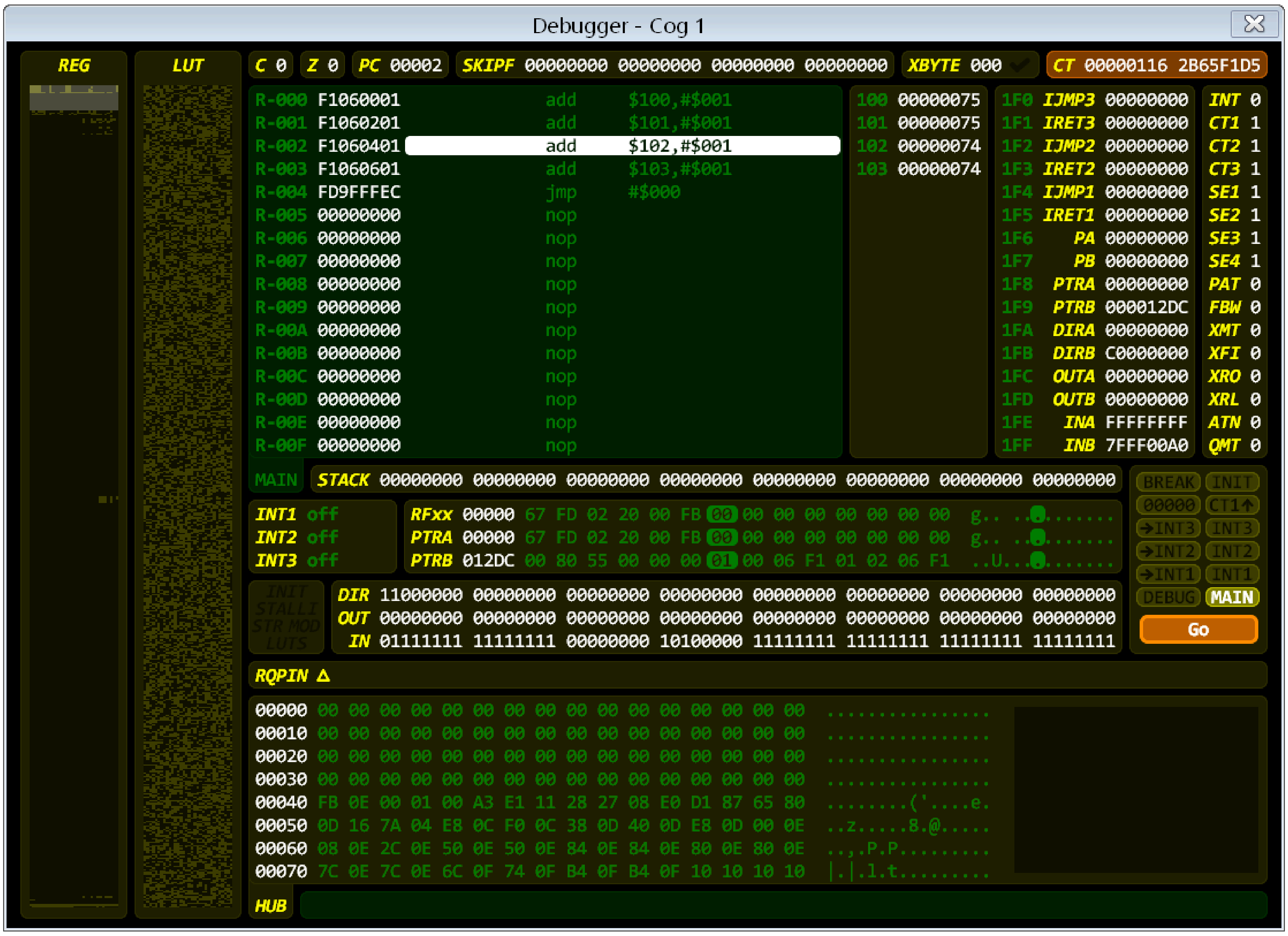
```
CON _clkfreq = 200_000_000
    debug_main                  'run debugger(s) for all main code

PUB go() | i

  coginit(newcog, @pasm, 0)     'start another cog with a pasm program

  repeat                        'increment i
    i++

DAT     org

pasm    add     $100,#1         'increment some registers
        add     $101,#1
        add     $102,#1
        add     $103,#1
        jmp     #pasm           'loop

        long    0[11]           'clear space after code for clarity
```

In the example above, the DEBUG_MAIN symbol causes a debugger window to open for each cog when it is initially launched via COGINIT. The above example will launch TWO cogs and debuggers. Cog 0 will be running a Spin2 program that just increments the variable 'i' in a REPEAT loop, and Cog 1 will be running a PASM program that repeatedly adds one to registers $100 to $103.

Once inside the debugger, you must confirm which break condition(s) you'd like and then click the 'Go' button to execute code to the next break. As you move the mouse around within the debugger window, hints are given on the bottom line which alert you of your options. The debugger is designed to be self-explanatory.

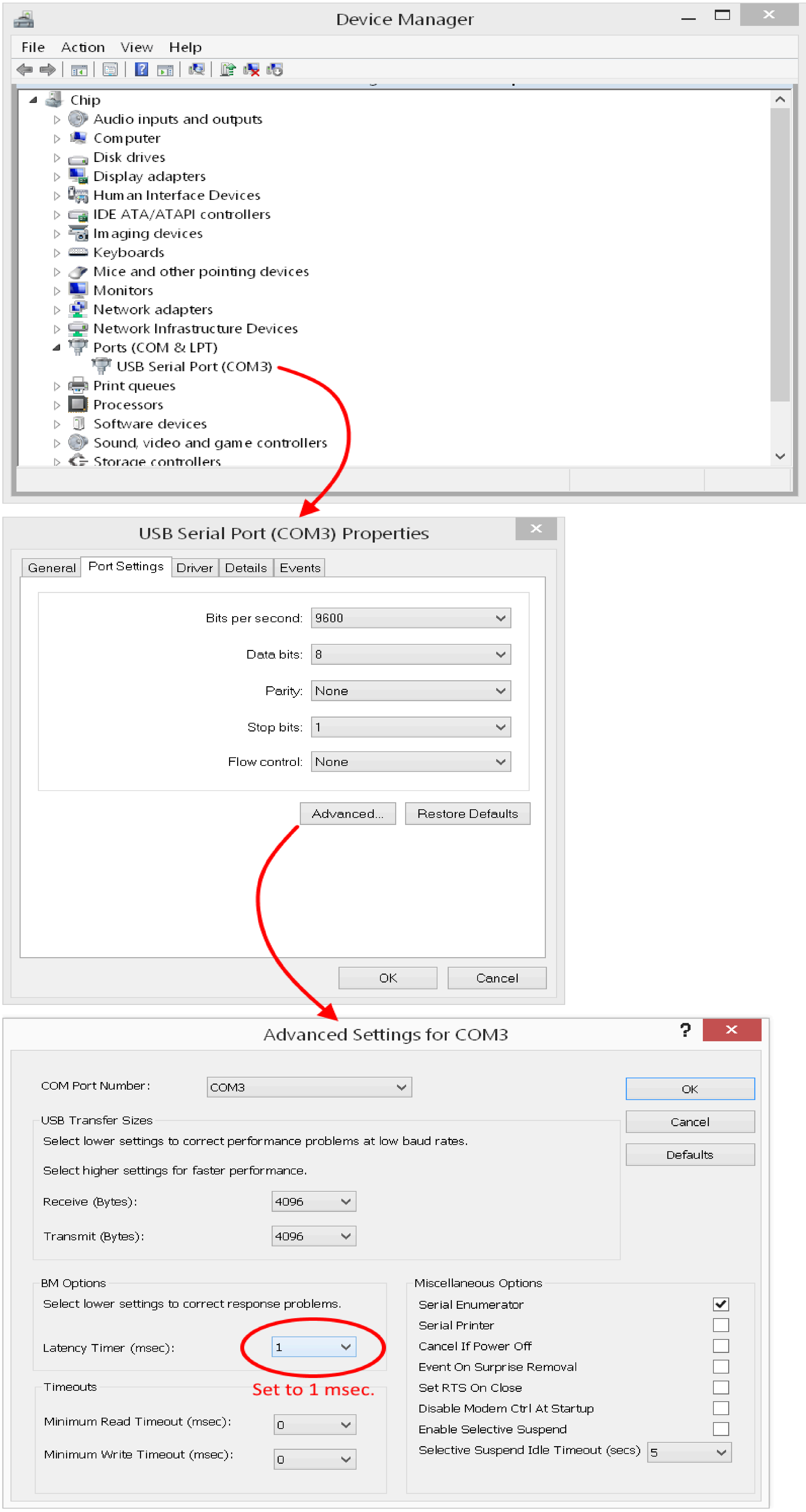
Note that 'DEBUG' break sensitivity is exclusive to all but 'INIT' (COGINIT) sensitivity. This is because plain DEBUG commands can only be differentiated from DEBUG() commands if no other debug interrupt sources are enabled. The asynchronous 'BREAK', which is actually always enabled, is visually indicated by the absence of all other sensitivities, excepting 'INIT'. Because COGINITs can always be detected within debug interrupts, 'INIT' sensitivity is independent of all the others. To use the asynchronous break capability, you must have another cog that is frequently updating its own debugger, so that it can serve as the messenger to generate the asynchronous break for the cog of interest.





To launch a debugger or force an update to an already-open debugger, you can insert a plain DEBUG command into your Spin2 or PASM code where you would like the update to occur. You can place any number of plain DEBUG commands throughout your application, since they all resolve to a 'BRK #0' instruction, whereas DEBUG() commands resolve to unique 'BRK #1..255' instructions. For plain DEBUG commands to be subsequently registered by the debugger after pressing the 'Go' button, the 'DEBUG' sensitivity button must be set. This will be the default sensitivity, unless either DEBUG_COGINIT or DEBUG_MAIN symbols were defined, which set the initial sensitivity to either 'INIT' or 'MAIN'.

For decent debugger performance, it is necessary to go into the Windows Device Manager and set the USB Serial Port's Latency Timer to 1 ms, instead of the default 16 ms. Here are the windows you need to navigate through to change the Latency Timer setting. Also be sure that the "USB Transfer Sizes" are both set to 4096:


Device Manager
File Action View Help
Chip
Audio inputs and outputs
Computer
Disk drives
Display adapters
Human Interface Devices
IDE ATA/ATAPI controllers
Imaging devices
Keyboards
Mice and other pointing devices
Monitors
Network adapters
Network Infrastructure Devices
Ports (COM & LPT)
USB Serial Port (COM3)
Print queues
Processors
Software devices
Sound, video and game controllers
Storage controllers
USB Serial Port (COM3) Properties
General
Port Settings
Driver
Details
Events
Bits per second: 9600
Data bits: 8
Parity: None
Stop bits: 1
Flow control: None
Advanced...
Restore Defaults
OK
Cancel
Advanced Settings for COM3
COM Port Number: COM3
OK
Cancel
Defaults
USB Transfer Sizes
Select lower settings to correct performance problems at low baud rates.
Select higher settings for faster performance.
Receive (Bytes): 4096
Transmit (Bytes): 4096
BM Options
Select lower settings to correct response problems.
Latency Timer (msec): 1
Set to 1 msec.
Timeouts
Minimum Read Timeout (msec): 0
Minimum Write Timeout (msec): 0
Miscellaneous Options
Serial Enumerator
Serial Printer
Cancel If Power Off
Event On Surprise Removal
Set RTS On Close
Disable Modem Ctrl At Startup
Enable Selective Suspend
Selective Suspend Idle Timeout (secs) 5

DEBUG dynamic clock frequency adaptation

When DEBUG is enabled, the serial receive pin (P63) is configured as a long repository to hold the clock frequency value, so that the debugger can compute the proper baud rate during debug interrupts. This long-repository value must be updated whenever the clock frequency is changed, in order to keep the debugger communicating properly.

Below is a code snippet which demonstrates how to do this.

```
DAT             org

clock_change    rep     #99,#1                  'use REP to stall all interrupts (including debug)

                andn    old_mode,#%11           'switch to 20 MHz while maintaining old pll/xtal settings
                hubset  old_mode

                mov     old_mode,new_mode       'establish new pll/xtal settings while staying at 20 MHz
                andn    old_mode,#%11
                hubset  old_mode

                waitx   ##20_000_000/100        'allow 10ms for new settings to stabilize

                mov     old_mode,new_mode       'switch to new settings
                hubset  old_mode

                dirh    #63                     'must enable smart pin to update long repository
                wxpin   new_freq,#63            'write new_freq to rx pin long repository
        _ret_   dirl    #63                     'put smart pin back to sleep, REP cancels upon _ret_


old_mode        res     1
new_mode        res     1
new_freq        res     1
```

DEBUG() memory utilization

Here is what the memory utilization looks like for a Spin2 DEBUG() command. You can see, on the Spin2 side, that a bytecode is needed to read the variable 'i', and then three obligatory bytecodes make up the actual DEBUG() command.

The 'stack adjustment' byte tells the interpreter how far to drop the stack to effectively 'pop' all the expressions that were pushed in preparation for the DEBUG() event. In this case of 'i', only, the stack needs to drop by four bytes (one long). When the debugging program is invoked, the values it needs will be ordered right above the current Spin2 stack pointer.

```
debug("What? ", udec(i))

Spin2 bytecodes            DEBUG database in
in application             top 16KB of RAM

$E0 - read 'i'             $04 - output "CogN  "
$44 - DEBUG bytecode       $06 - output string
$04 - stack adjustment     $57 - "W"
$01 - unique BRK code      $68 - "h"
                           $61 - "a"
                           $74 - "t"
                           $3F - "?"
                           $20 - " "
                           $00 - end of string
                           $41 - UDEC + output string
                           $69 - "i"
                           $00 - end of string
                           $00 - end of DEBUG statement
```

The 'unique BRK code' byte (1..255) is used as an index to look up the specific record in the DEBUG() database at the top of memory, from which the debugging program reads its commands.

In the case where debugging is active, but a cog has had its debug interrupt disabled via the DEBUG_COGS symbol, Spin2 DEBUG commands will not trigger a debug interrupt, but they do still pop any DEBUG-intended values from the stack, so these are harmless events.

For PASM DEBUG commands, a 'BRK #code' instruction is inserted where the DEBUG command was placed, and all related data resides in the DEBUG database. If a cog's debug interrupt is disabled, the 'BRK #code' instruction does nothing, taking two clocks.

DEBUG and interrupts

Interrupt requests received during a DEBUG command will execute after the DEBUG completes, but the response time may be so skewed that the retrigger setup for the interrupt won't happen properly. High-frequency cyclical smart pin interrupts are especially prone to this problem. Imagine you do an AKPIN instruction within your normal ISR (interrupt service routine) to drop the INA/INB signal so that the smart pin can make it go high again, triggering a new interrupt. Meanwhile, after the AKPIN and before the RETIx, the smart pin triggers, raising INA/INB high. This is only happening because your cycle-frame timing has become skewed from the DEBUG command. This interrupt won't be seen since it happened when the ISR was busy. This will cause the interrupt to cease cycling. CT interrupts are not prone to this problem, though, since they have $8000_0000 clock cycles in which to be recognized. To remedy the smart-pin retrigger problem, you could trigger on INA/INB-high, as opposed to INA/INB-rise, but this could cause performance problems with your smart pin configurations.

One fail-safe way to get around this DEBUG/interrupt dilemma is to only do DEBUG commands from cogs that are not executing ISRs in the background. If the ISRs can tolerate timing skew and there is no risk of hanging interrupt cycling, you can do DEBUG commands with some understood interrupt timing degradations.

Graphical DEBUG Displays

DEBUG() commands can invoke special graphical DEBUG displays which are built into the tool. These graphical displays each take the form of a unique window. Once instantiated, displays can be continuously fed data to generate animated visualizations. These displays are very handy for development and debugging, as various data types can be viewed in their proper contexts. Up to 32 graphical displays can be running simultaneously.

When a DEBUG message contains a backtick (`) character (ASCII $60), a string, containing everything from the backtick to the end of the message, is sent to the graphical DEBUG display parser. The parser looks for several different element types, treating any commas as whitespace:

Element Type	Example	Description
`display_type`	`LOGIC, SCOPE, PLOT, BITMAP`	This is the formal name of the graphical DEBUG display type you wish to instantiate.
`unknown_symbol`	`MyLogicDisplay`	Each graphical DEBUG display Instance must be given a unique symbolic name.
`instance_name`	`MyLogicDisplay`	Once instantiated, a graphical DEBUG display instance is referenced by its symbolic name.
`keyword`	`TITLE, POS, SIZE, SAMPLES`	Keywords are used to configure displays. They might be followed by numbers, strings, and other keywords.
`number`	`1024, $FF, %1010`	Numbers can be expressed in decimal, hex ($), and binary (%).
`string`	`'Here is a string'`	Strings are expressed within single-quotes.

Before getting into how all this fits together, we need to go over some special DEBUG()-display syntax that can be used for displays. This syntax is invoked when the first character in the DEBUG() command is the backtick. This causes everything in the DEBUG() command to be viewed as a string, except when subsequent backticks act as 'escape' characters to allow normal or shorthand DEBUG() commands.

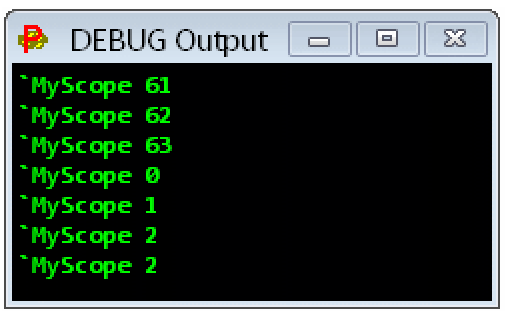
DEBUG Statement (v = 100, w = 1.0, bytes[a] = 1,2,3,4,5)	DEBUG Message Output	Note
``DEBUG("`LOGIC MyLog SAMPLES ", SDEC_(v))``	``Cog0  `LOGIC MyLog SAMPLES 100``	Regular DEBUG() syntax can drive DEBUG() displays, but it's verbose.
``DEBUG(`LOGIC MyLog SAMPLES 100)``	`` `LOGIC MyLog SAMPLES 100``	DEBUG()-display syntax is simpler and 'CogN' is omitted in the output.
``DEBUG(`LOGIC MyLog SAMPLES `?(v))``	`` `LOGIC MyLog SAMPLES TRUE``	Booleans are output using `?(value) notation. Short for BOOL_.
``DEBUG(`LOGIC MyLog SAMPLES `.(w))``	`` `LOGIC MyLog SAMPLES 1.000000e+00``	Floating-point values are output using `.(value) notation. Short for FDEC_.
``DEBUG(`LOGIC MyLog SAMPLES `(v))``	`` `LOGIC MyLog SAMPLES 100``	Decimal numbers are output using `(value) notation. Short for SDEC_.
``DEBUG(`LOGIC MyLog SAMPLES `$(v))``	`` `LOGIC MyLog SAMPLES $64``	Hex numbers are output using `$(value) notation. Short for UHEX_.
``DEBUG(`LOGIC MyLog SAMPLES `%(v))``	`` `LOGIC MyLog SAMPLES %1100100``	Binary numbers are output using `%(value) notation. Short for UBIN_.
``DEBUG(`LOGIC MyLog TITLE '`#(v)')``	`` `LOGIC MyLog TITLE 'd'``	Characters are output using `#(value) notation.
``DEBUG(`MyLog `UDEC_BYTE_ARRAY_(@a,5))``	`` `MyLog 1, 2, 3, 4, 5``	Regular DEBUG() commands can follow the backtick, as well.

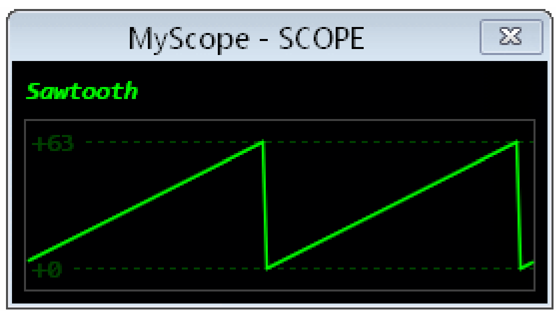
There are two steps to using graphical DEBUG() displays. First, they must be instantiated and, second, they must be fed:

To Use a Display:	1st	2nd	3rd	4th	Note
First, instantiate it.	`	display_type	unknown_symbol	keyword(s), number(s), string(s)	Unknown_symbol becomes instance_name.
Then, feed it.	`	instance_name(s)	keyword(s), number(s), string(s)		Multiple displays can be fed the same data.

To bring this all together, let's show a sawtooth wave on a SCOPE display:

```
CON _clkfreq = 10_000_000

PUB go() | i

  debug(`SCOPE MyScope SIZE 254 84 SAMPLES 128)
  debug(`MyScope 'Sawtooth' 0 63 64 10 %1111)

  repeat
    debug(`MyScope `(i & 63))
    i++
    waitms(50)
```





In the example above, a SCOPE is instantiated called MyScope that is 254 x 84 pixels and shows 128 samples. A width of 254 was chosen since samples are numbered 0..127 and I wanted them to be spaced at a constant two-pixel pitch (127 * 2 = 254). A height of 84 was chosen so that there would be 10 pixels above and below the waveform, which will have a height of 64 pixels. A channel called "Sawtooth" is defined which, for the purpose of display, has a bottom value of 0 and a top value of 63, is 64 pixels tall within that range, and is elevated 10 pixels off the bottom of the scope window. The %1111 enables top and bottom legend values and top and bottom lines. Within the REPEAT block, the SCOPE is fed a repeating pattern of 0..63 which forms the sawtooth wave. The SCOPE updates its display each time it receives a value. If there were eight channels defined, instead of just one, it would update the display on every eighth value received, drawing all eight channels.

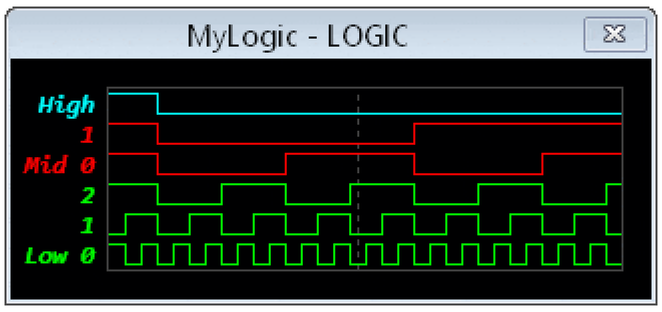
Currently, the following graphical DEBUG() displays are implemented, but more will be added in the future:

Display Types	Descriptions
`LOGIC`	Logic analyzer with single and multi-bit labels, 1..32 channels, can trigger on pattern
`SCOPE`	Oscilloscope with 1..8 channels, can trigger on level with hysteresis
`SCOPE_XY`	XY oscilloscope with 1..8 channels, persistence of 0..512 samples, polar mode, log scale mode
`FFT`	Fast Fourier Transform with 1..8 channels, 4..2048 points, windowed results, log scale mode
`SPECTRO`	Spectrograph with 4..2048-point FFT, windowed results, phase-coloring, and log scale mode
`PLOT`	General-purpose plotter with cartesian and polar modes
`TERM`	Text terminal with up to 300 x 200 characters, 6..200 point font size, 4 simultaneous color schemes
`BITMAP`	Bitmap, 1..2048 x 1..2048 pixels, 1/2/4/8/16/32-bit pixels with 19 color systems, 15 direction/autoscroll modes, independent X and Y pixel size of 1..256
`MIDI`	Piano keyboard with 1..128 keys, velocity depiction, variable screen scale

Following are elaborations of each DEBUG() display type.

LOGIC Display   Logic analyzer with single and multi-bit labels, 1..32 channels, can trigger on pattern

```
CON _clkfreq  = 10_000_000

PUB go() | i

  debug(`LOGIC MyLogic SAMPLES 32 'Low' 3 'Mid' 2 'High')
  debug(`MyLogic TRIGGER $07 $04 HOLDOFF 2)

  repeat
    debug(`MyLogic `(i & 63))
    i++
    waitms(25)
```



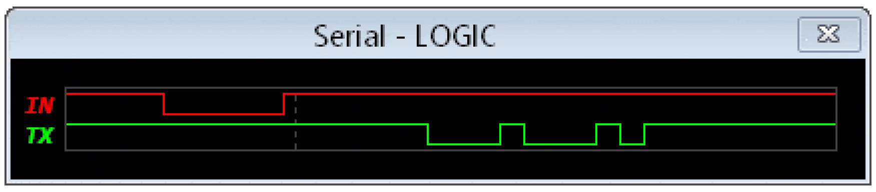
LOGIC Instantiation	Description	Default
`TITLE 'string'`	Set the window caption to 'string'.	<none>
`POS left top`	Set the window position.	0, 0
`SAMPLES 4_to_2048`	Set the number of samples to track and display.	32
`SPACING 2_to_32`	Set the sample spacing. The width of the display will be SAMPLES * SPACING.	8
`RATE 1_to_2048`	Set the number of samples (or triggers, if enabled) before each display update.	1
`LINESIZE 1_to_7`	Set the line size.	1
`TEXTSIZE 6_to_200`	Set the legend text size. Height of text determines height of logic levels.	editor text size
`COLOR back_color {grid_color}`	Set the background and grid colors *.	BLACK, GRAY 4
`'name' {1_to_32 {color}}`	Set the next channel or channel-group name, optional group bit count, optional color *. If no names are given, a single group of 32 channels will be established.	1, default color
`'name' 2_to_32 RANGE {color}`	Set the next channel-group name, to be drawn as a waveform, with optional color *.	default color
`packed_data_mode`	Enable packed-data mode. See description at end of this section.	<none>
`HIDEXY`	Hide the X,Y mouse coordinates from being displayed at the mouse pointer.	not hidden
LOGIC Feeding	**Description**	**Default**
`TRIGGER mask match sample_offset`	Trigger on (data & mask) = match. If mask = 0, trigger is disabled.	0, 1, SAMPLES / 2
`HOLDOFF 2_to_2048`	Set the minimum number of samples required from trigger to trigger.	SAMPLES
`data`	Numerical data is applied LSB-first to the channels.	
`CLEAR`	Clear the sample buffer and display, wait for new data.	
`SAVE {WINDOW} 'filename'`	Save a bitmap file (.bmp) of either the entire window or just the display area.	

CLOSE	Close the window.	

* Color is rgb24 value, else BLACK / WHITE or ORANGE / BLUE / GREEN / CYAN / RED / MAGENTA / YELLOW / GRAY followed by an optional 0..15 for brightness (default is 8).

The LOGIC display can be used to display data that was captured at high speed. In the example below, the P2 is generating 8-N-1 serial at 333 Mbaud using a smart pin. This bit stream can be captured by the streamer. On every clock, the streamer will record the smart pin's IN signal and its output state, as read from an adjacent pin. Every time it gets four two-bit sample sets, it does an RFBYTE to save them to hub RAM, forming contiguous bytes, words, and longs. By invoking the LONGS_2BIT packed-data mode, we can have the LOGIC display unpack the two-bit sample sets from longs, yielding 16 sets per long.

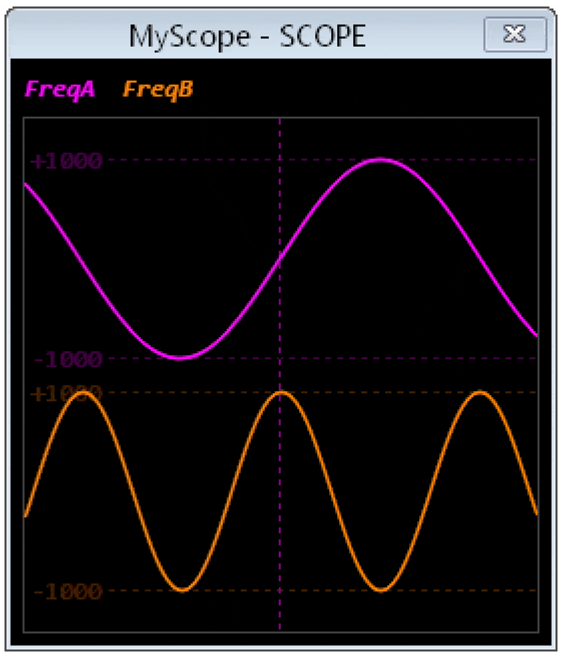
```
CON _clkfreq  = 333_333_333  'go really fast, 3ns clock period
    rxpin     = 24           'even pin
    txpin     = rxpin+1      'odd pin
    samps     = 32           'multiple of 16 samples
    bufflongs = samps / 16   'each long holds 16 2-bit samples
    xmode     = $D0800000 + rxpin << 17 + samps   'streamer mode

VAR buff[bufflongs]

PUB go() | i, buffaddr

  debug(`logic Serial samples `(samps) spacing 12 'TX' 'IN' longs_2bit)
  debug(`Serial trigger %10 %10 22)
  buffaddr := @buff

  repeat
    org
    wrpin     ##+1<<28,#rxpin       'rxpin inputs txpin at rxpin+1

    wrpin     #%01_11110_0,#txpin   'set async tx mode for txpin
    wxpin     ##1<<16+8-1,#txpin    'set baud=sysclock/1 and size=8
    dirh      #txpin                'enable smart pin

    wrfast    #0,buffaddr           'set write-fast at buff
    xinit     ##xmode,#0            'start capturing 2-bit samples

    wypin     i,#txpin              'transmit serial byte

    waitxfi                          'wait for streamer capture done
    end

    debug(`Serial `uhex_long_array_(@buff, bufflongs))
    i++
    waitms(20)
```



SCOPE Display

Oscilloscope with 1..8 channels, can trigger on level with hysteresis

```
CON _clkfreq   = 100_000_000

PUB go() | a, af, b, bf

  debug(`SCOPE MyScope)
  debug(`MyScope 'FreqA' -1000 1000 100 136 15 MAGENTA)
  debug(`MyScope 'FreqB' -1000 1000 100 20 15 ORANGE)
  debug(`MyScope TRIGGER 0 HOLDOFF 2)

  repeat
    a := qsin(1000, af++, 200)
    b := qsin(1000, bf++, 99)
    debug(`MyScope `(a,b))
    waitus(200)
```



SCOPE Instantiation	Description	Default
TITLE 'string'	Set the window caption to 'string'.	<none>
POS left top	Set the window position.	0, 0
SIZE width height	Set the display size (32..2048 x 32..2048)	255, 256
SAMPLES 16_to_2048	Set the number of samples to track and display.	256
RATE 1_to_2048	Set the number of samples (or triggers, if enabled) before each display update.	1
DOTSIZE 0_to_32	Set the dot size in pixels for showing exact sample points.	0
LINESIZE 0_to_32	Set the line size in half-pixels for connecting sample points.	3
TEXTSIZE 6_to_200	Set the legend text size.	editor text size
COLOR back_color {grid_color}	Set the background and grid colors *.	BLACK, GRAY 4

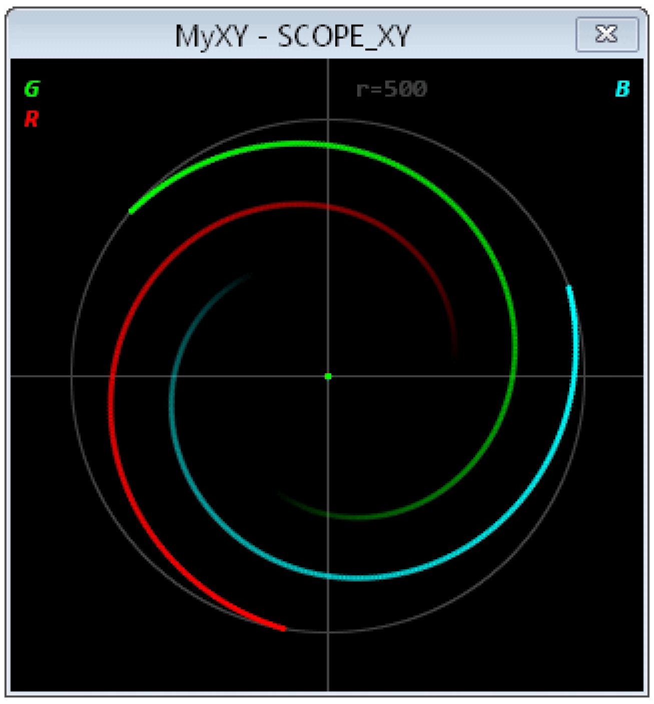
`packed_data_mode`	Enable packed-data mode. See description at end of this section.	<none>
`HIDEXY`	Hide the X,Y mouse coordinates from being displayed at the mouse pointer.	not hidden
SCOPE Feeding	**Description**	**Default**
`'name' {min {max {y_size {y_base {legend} {color}}}}}`	Set first/next channel name, min value, max value, y size, y base, legend, and color *. Legend is %abcd, where %a to %d enable max legend, min legend, max line, min line.	full, no legend, default color
`'name' AUTO {y_size {y_base {legend} {color}}}`	Set first/next channel name, auto-scale, y size, y base, legend, and color *. Legend is %abcd, where %a to %d enable max legend, min legend, max line, min line.	auto, no legend, default color
`TRIGGER channel {arm_level {trigger_level {offset}}}`	Set the trigger channel, arm level, trigger level, and right offset. If channel=-1, disabled.	-1, -1, 0, width / 2
`TRIGGER channel AUTO {offset}`	Set the trigger channel, 33% arm level, 50% trigger level, and right offset. If channel=-1, disabled.	-1, width / 2
`HOLDOFF 2_to_2048`	Set the minimum number of samples required from trigger to trigger.	SAMPLES
`data`	Numerical data is applied to the channels in ascending order.	
`CLEAR`	Clear the sample buffer and display, wait for new data.	
`SAVE {WINDOW} 'filename'`	Save a bitmap file (.bmp) of either the entire window or just the display area.	
`CLOSE`	Close the window.	

* Color is rgb24 value, else BLACK / WHITE or ORANGE / BLUE / GREEN / CYAN / RED / MAGENTA / YELLOW / GRAY followed by an optional 0..15 for brightness (default is 8).

SCOPE_XY Display

XY oscilloscope with 1..8 channels, persistence of 1..512 samples, polar mode, log scale mode

```
CON _clkfreq = 100_000_000

PUB go() | i

  debug(`SCOPE_XY MyXY RANGE 500 POLAR 360 'G' 'R' 'B')

  repeat
    repeat i from 0 to 500
      debug(`MyXY `(i, i, i, i+120, i, i+240))
      waitms(5)
```



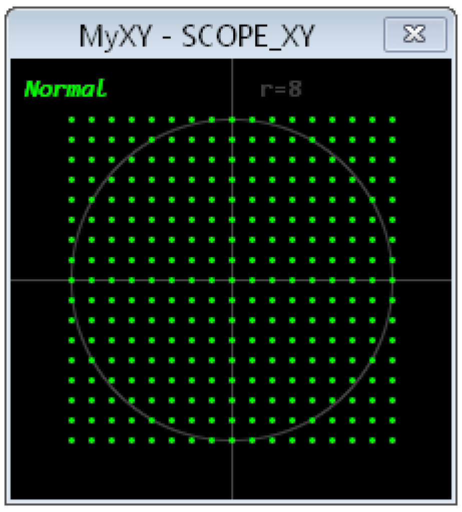
SCOPE_XY Instantiation	**Description**	**Default**
`TITLE 'string'`	Set the window caption to 'string'.	<none>
`POS left top`	Set the window position.	0, 0
`SIZE radius`	Set the display radius in pixels.	128
`RANGE 1_to_7FFFFFFF`	Set the unit circle radius for incoming data	$7FFFFFFF
`SAMPLES 0_to_512`	Set the number of samples to track and display with persistence. Use 0 for infinite persistence.	256
`RATE 1_to_512`	Set the number of samples before each display update.	1
`DOTSIZE 2_to_20`	Set the dot size in half-pixels for showing sample points.	6
`TEXTSIZE 6_to_200`	Set the legend text size.	editor text size
`COLOR back_color {grid_color}`	Set the background and grid colors *.	BLACK, GRAY 4
`POLAR {twopi {offset}}`	Set polar mode, twopi value, and offset. For a twopi value of $100000000 or -$100000000, use 0 or -1.	$100000000, 0
`LOGSCALE`	Set log-scale mode to magnify points within the unit circle.	<off>
`'name' {color}`	Set the first/next channel name and optionally assign it a color *.	default color
`packed_data_mode`	Enable packed-data mode. See description at end of this section.	<none>
`HIDEXY`	Hide the X,Y mouse coordinates from being displayed at the mouse pointer.	not hidden
SCOPE_XY Feeding	**Description**	**Default**
`x y`	X-Y data pairs are applied to the channels in ascending order. In polar mode, x=length and y=angle.	

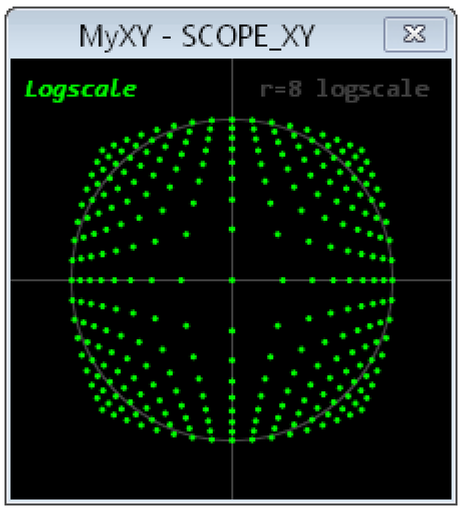
`CLEAR`	Clear the sample buffer and display, wait for new data.	
`SAVE {WINDOW} 'filename'`	Save a bitmap file (.bmp) of either the entire window or just the display area.	
`CLOSE`	Close the window.	

* Color is rgb24 value, else BLACK / WHITE or ORANGE / BLUE / GREEN / CYAN / RED / MAGENTA / YELLOW / GRAY followed by an optional 0..15 for brightness (default is 8).

```
CON _clkfreq = 10_000_000     'Normal mode

PUB go() | x, y
  debug(`SCOPE_XY MyXY SIZE 80 RANGE 8 SAMPLES 0 'Normal')
  repeat x from -8 to 8
    repeat y from -8 to 8
      debug(`MyXY `(x,y))
```

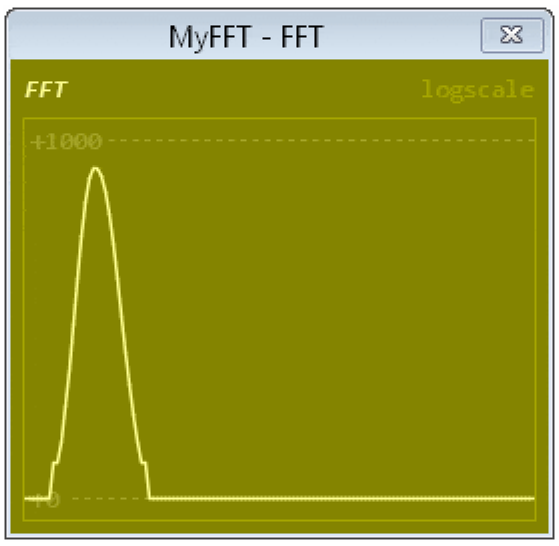
```
CON _clkfreq = 10_000_000     'LOGSCALE mode magnifies low-level details

PUB go() | x, y
  debug(`SCOPE_XY MyXY SIZE 80 RANGE 8 SAMPLES 0 LOGSCALE 'Logscale')
  repeat x from -8 to 8
    repeat y from -8 to 8
      debug(`MyXY `(x,y))
```

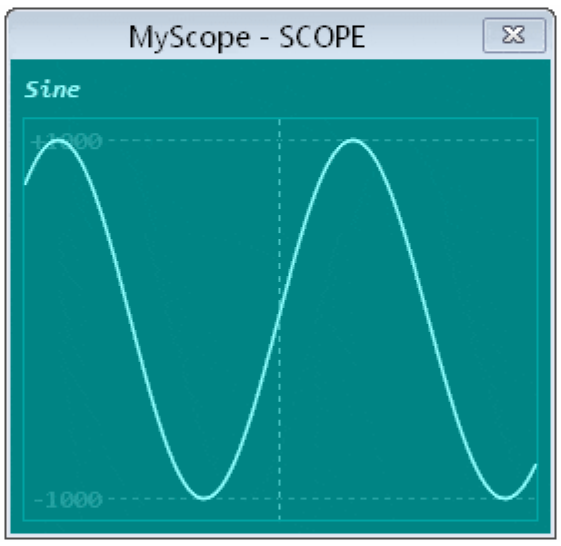




FFT Display Fast Fourier Transform with 1..8 channels, 4..2048 points, windowed results, log scale mode

```
CON _clkfreq = 100_000_000

PUB go() | i, j, k

  ' Set up FFT
  debug(`FFT MyFFT SIZE 250 200 SAMPLES 2048 0 127 RATE 256 LOGSCALE COLOR YELLOW 4 YELLOW 5)
  debug(`MyFFT 'FFT' 0 1000 180 10 15 YELLOW 12)

  ' Set up SCOPE
  debug(`scope MyScope POS 300 0 SIZE 255 200 COLOR CYAN 4 CYAN 5)
  debug(`MyScope 'Sine' -1000 1000 180 10 15 CYAN 12)
  debug(`MyScope TRIGGER 0)

  repeat
    j += 1550 + qsin(1300, i++, 31_000)
    k := qsin(1000, j, 50_000)
    debug(`MyFFT MyScope `(k))
    waitus(100)
```





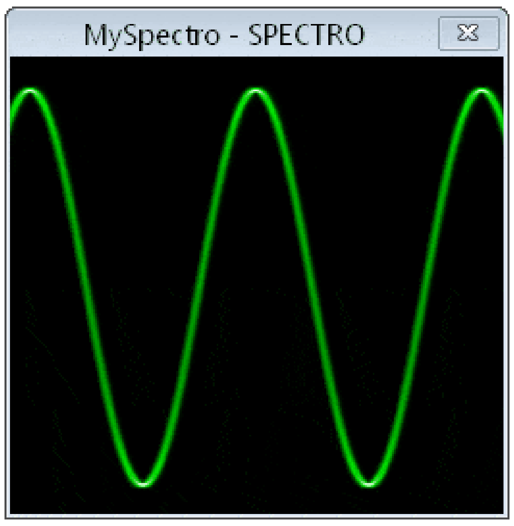
FFT Instantiation	Description	Default
`TITLE 'string'`	Set the window caption to 'string'.	<none>
`POS left top`	Set the window position.	0, 0
`SIZE width height`	Set the display size (32..2048 x 32..2048)	256, 256
`SAMPLES 4_to_2048 {first {last}}`	Set the 2^n number of FFT inputs points, plus the first and last result values to display.	512, 0, 255
`RATE 1_to_2048`	Set the number of samples before each display update.	SAMPLES

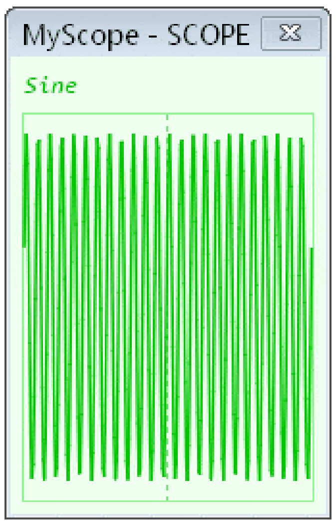
`DOTSIZE 0_to_32`	Set the dot size in pixels for showing exact sample points.	0
`LINESIZE neg32_to_32`	Set the line size in half-pixels for connecting sample points. A negative line size will make isolated vertical lines.	3
`TEXTSIZE 6_to_200`	Set the legend text size.	editor text size
`COLOR back_color {grid_color}`	Set the background and grid colors *.	BLACK, GRAY 4
`LOGSCALE`	Set log-scale mode to magnify low-level results.	<off>
`packed_data_mode`	Enable packed-data mode. See description at end of this section.	<none>
`HIDEXY`	Hide the X,Y mouse coordinates from being displayed at the mouse pointer.	not hidden
FFT Feeding	**Description**	**Default**
`'name' {mag {max {y_size {y_base {legend {color}}}}}}`	Set the first/next channel name, magnification factor (2^n, n = 0..11), max amplitude, y size, y base, legend, and color *. Legend is %abcd, where %a to %d enable max legend, min legend, max line, min line.	full, no legend, default color
`data`	Numerical data is fed into the channels' sliding Hanning windows from which the FFT computes power levels.	
`CLEAR`	Clear the sample buffer and display, wait for new data.	
`SAVE {WINDOW} 'filename'`	Save a bitmap file (.bmp) of either the entire window or just the display area.	
`CLOSE`	Close the window.	

* Color is rgb24 value, else BLACK / WHITE or ORANGE / BLUE / GREEN / CYAN / RED / MAGENTA / YELLOW / GRAY followed by an optional 0..15 for brightness (default is 8).

SPECTRO Display — Spectrograph with 4..2048-point FFT, phase-coloring, and log scale mode

```
CON _clkfreq = 100_000_000

PUB go() | i, j, k

  ' Set up SPECTRO
  debug(`SPECTRO MySpectro SAMPLES 2048 0 236 RANGE 1000 LUMA8X GREEN)

  ' Set up SCOPE
  debug(`SCOPE MyScope POS 280 SIZE 150 200 COLOR GREEN 15 GREEN 12)
  debug(`MyScope 'Sine' -1000 1000 180 10 0 GREEN 6)
  debug(`MyScope TRIGGER 0)

  repeat
    j += 2850 + qsin(2500, i++, 30_000)
    k := qsin(1000, j, 50_000)
    debug(`MySpectro MyScope `(k))
    waitus(100)
```

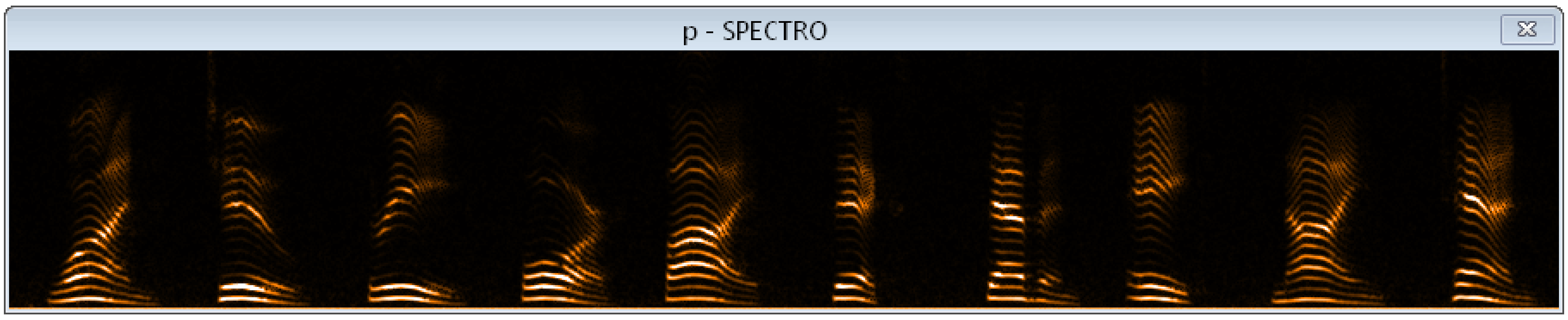




SPECTRO Instantiation	Description	Default
`TITLE 'string'`	Set the window caption to 'string'.	<none>
`POS left top`	Set the window position.	0, 0
`SAMPLES 4_to_2048 {first {last}}`	Set the 2^n number of FFT input points, plus the first and last result values to display (defines display height).	512, 0, 255
`DEPTH 1_to_2048`	Set the number of vertical-line FFT results to display (defines the display width).	256
`MAG 0_to_11`	Set the magnification factor (2^n, n = 0..11).	0
`RANGE saturation_power`	Set the power level at which pixel brightness saturates.	$7FFFFFFF
`RATE 1_to_2048`	Set the number of samples before each display update.	SAMPLES / 8
`TRACE 0_to_15`	Set the trace pattern (see TRACE animation in BITMAP Display).	15 (right, up, scroll)
`DOTSIZE width_and_height {height}`	Set the spectrograph pixel-width and pixel-height (1..16) together, or set them independently.	1, 1
`luma_or_hsv {color_or_phase}`	Set the color scheme to LUMA8(W)(X) with color *, or HSV16(W)(X) with 0..255 phase-coloring offset.	LUMA8X ORANGE
`LOGSCALE`	Set log-scale mode to magnify low-level results.	<off>
`packed_data_mode`	Enable packed-data mode. See description at end of this section.	<none>
`HIDEXY`	Hide the X,Y mouse coordinates from being displayed at the mouse pointer.	not hidden
SPECTRO Feeding	**Description**	**Default**
`data`	Numerical data is fed into a sliding Hanning window from which the FFT computes power and phase.	
`CLEAR`	Clear the sample buffer and display, wait for new data.	
`SAVE {WINDOW} 'filename'`	Save a bitmap file (.bmp) of either the entire window or just the display area.	
`CLOSE`	Close the window.	

* Color is ORANGE / BLUE / GREEN / CYAN / RED / MAGENTA / YELLOW / GRAY.

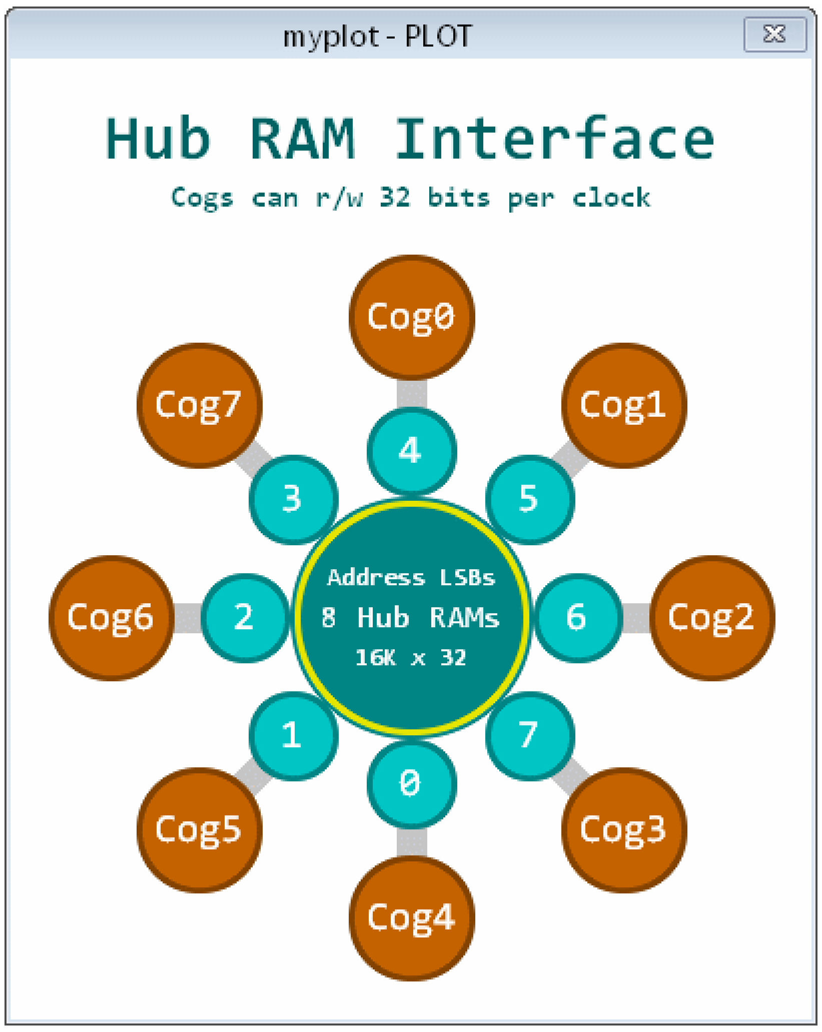
Below, a SPECTRO display was fed ADC samples from a pin attached to a microphone. This is what verbally counting from "1" to "10" looks like, spectrally. The "1" is on the left and the "10" is on the right. The vertical distance between horizontal trend lines is glottal pitch. The larger brightness trends are vocal formants. This gives some idea of how our ears perceive speech:



PLOT Display

General-purpose plotter with cartesian and polar modes

```
CON _clkfreq = 10_000_000

PUB go(): i, j, k

  debug(`plot myplot size 400 480 backcolor white update)
  debug(`myplot origin 200 200 polar -64 -16)
  k~
  repeat
    debug(`myplot clear)
    debug(`myplot set 240 0 cyan 3 text 24 3 'Hub RAM Interface')
    debug(`myplot set 210 0 text 11 3 'Cogs can r/w 32 bits per clock')

    if k & 8    'move RAMs or draw spokes?
      j++
    else
      repeat i from 0 to 7
        debug(`myplot gray 12 set 83 `(i*8) line 150 `(i*8) 15)

    debug(`myplot set 0 0 cyan 4 circle 121 yellow 7 circle 117 3)
    debug(`myplot set 20 0 white text 9 'Address LSBs')
    debug(`myplot set 0 0 text 11 1 '8 Hub RAMs')
    debug(`myplot set 20 32 text 9 '16K x 32' )

    repeat i from 0 to 7    'draw RAMs and cogs
      debug(`myplot cyan 6 set 83 `(i*8-j) circle 43 text 14 '`(i)')
      debug(`myplot cyan 4 set 83 `(i*8-j) circle 45 3)
      debug(`myplot orange 6 set 150 `(i*8) circle 61 text 13 'Cog`(i)')
      debug(`myplot orange 4 set 150 `(i*8) circle 63 3)

    debug(`myplot update `dly(30))
    k++
```



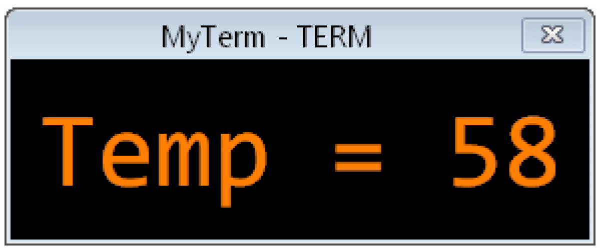
PLOT Instantiation	Description	Default
`TITLE 'string'`	Set the window caption to 'string'.	<none>
`POS left top`	Set the window position.	0, 0
`SIZE width height`	Set the display width (32..2048) and height (32..2048).	256, 256
`DOTSIZE width_and_height {height}`	Set the display pixel-width and pixel-height (1..256) together, or set them independently.	1, 1
`lut1_to_rgb24`	Set the color mode.	RGB24
`LUTCOLORS rgb24 rgb24 ...`	For LUT1..LUT8 color modes, load the LUT with rgb24 colors. Use HEX_LONG_ARRAY_ to load colors.	default colors 0..7
`BACKCOLOR color`	Set the background color according to the current color mode. *	BLACK
`UPDATE`	Set UPDATE mode. The display will only be updated when fed an 'UPDATE' command.	automatic update
`HIDEXY`	Hide the X,Y mouse coordinates from being displayed at the mouse pointer.	not hidden
PLOT Feeding	**Description**	**Default**
`lut1_to_rgb24`	Set color mode.	rgb24
`LUTCOLORS rgb24 rgb24 ...`	For LUT1..LUT8 color modes, load the LUT with rgb24 colors. Use HEX_LONG_ARRAY_ to load values.	default colors 0..7
`BACKCOLOR color`	Set the background color according to the current color mode. *	BLACK
`COLOR color`	Set the drawing color according to the current color mode. Use just before TEXT to change text color. *	CYAN
`BLACK/WHITE or ORANGE/BLUE/GREEN/CYAN/ RED/MAGENTA/YELLOW/GRAY {brightness}`	Set the drawing color and optional 0..15 brightness for ORANGE..GRAY colors (default is 8).	CYAN

`OPACITY level`	Set the opacity level for DOT, LINE, CIRCLE, OVAL, BOX, and OBOX drawing. 0..255 = clear..opaque.	255
`PRECISE`	Toggle precise mode, where line size and (x,y) for DOT and LINE are expressed in 256ths of a pixel.	disabled
`LINESIZE size`	Set the line size in pixels for DOT and LINE drawing.	1
`ORIGIN {x_pos y_pos}`	Set the origin point to cartesian (x_pos, y_pos) or to the current (x, y) if no values are specified.	0, 0
`SET x y`	Set the drawing position to (x, y). After LINE, the endpoint becomes the new drawing position.	
`DOT {linesize {opacity}}`	Draw a dot at the current position with optional LINESIZE and OPACITY overrides.	
`LINE x y {linesize {opacity}}`	Draw a line from the current position to (x,y) with optional LINESIZE and OPACITY overrides.	
`CIRCLE diameter {linesize {opacity}}`	Draw a circle around the current position with optional line size (none/0 = solid) and OPACITY override.	
`OVAL width height {linesize {opacity}}`	Draw an oval around the current position with optional line size (none/0 = solid) and OPACITY override.	
`BOX width height {linesize {opacity}}`	Draw a box around the current position with optional line size (none/0 = solid) and OPACITY override..	
`OBOX width height x_radius y_radius {linesize {opacity}}`	Draw a rounded box around the current position with width, height, x and y radii, and optional line size (none/0 = solid) and OPACITY override.	
`TEXTSIZE size`	Set the text size (6..200).	10
`TEXTSTYLE style_YYXXUIWW`	Set the text style to %YYXXUIWW: %YY is vertical justification: %00 = middle, %10 = bottom, %11 = top. %XX is horizontal justification: %00 = middle, %10 = right, %11 = left. %U is underline: %1 = underline. %I is italic: %1 = italic. %WW is weight: %00 = light, %01 = normal, %10 = bold, and %11 = heavy.	%00000001
`TEXTANGLE angle`	Set the text angle. In cartesian mode, the angle is in degrees.	0
`TEXT {size {style {angle}}} 'text'`	Draw text with overrides for size, style, and angle. To change text color, declare a color just before TEXT.	
`LAYER layer 'filename.bmp'`	Load a bitmap image file into layer (1..8) for later copying into the plot via CROP.	
`CROP layer {left_layer top_layer width height {left_plot top_plot}}`	Copy a layer image into the plot. If no coordinates are given, the whole layer image will be copied to the upper left corner of the plot (useful for backgrounds). If the first four coordinates are specified, that area of the layer image will be copied to the same area of the plot (useful for static overlays). If the last two coordinates are also specified, they will alter where in the plot the layer image area gets copied to (useful for dynamic overlays). The coordinates for this command are always (left-to-right, top-to-bottom).	
`CROP layer AUTO left_plot top_plot`	Copy a whole layer image into the plot at specified coordinates (left-to-right, top-to-bottom).	
`SPRITEDEF id x_dim y_dim pixels… colors…`	Define a sprite. Unique ID must be 0..255. Dimensions must each be 1..32. Pixels are bytes which select palette colors, ordered left-to-right, then top-to-bottom. Colors are longs which define the palette referenced by the pixel bytes; $AARRGGBB values specify alpha-blend, red, green, and blue.	
`SPRITE id {orient {scale {opacity}}}`	Render a sprite at the current position with orientation, scale, and OPACITY override. Orientation is 0..7, per the first eight TRACE modes. Scale is 1..64. See the DEBUG_PLOT_Sprites.spin2 file.	<id>, 0, 1, 255
`POLAR {twopi {offset}}`	Set polar mode, twopi value, and offset. For example, POLAR -12 -3 would be like a clock face. For a twopi value of $100000000 or -$100000000, use 0 or -1. In polar mode, (x, y) coordinates are interpreted as (length, angle).	$100000000, 0
`CARTESIAN {ydir {xdir}}`	Set cartesian mode and optionally set Y and X axis polarity. Cartesian mode is the default. If ydir is 0, the Y axis points up. If ydir is non-0, the Y axis points down. If xdir is 0, the X axis points right. If xdir is non-0, the X axis points left.	0, 0
`CLEAR`	Clear the plot to the background color.	
`UPDATE`	Update the window with the current plot. Used in UPDATE mode.	
`SAVE {WINDOW} 'filename'`	Save a bitmap file (.bmp) of either the entire window or just the display area.	
`CLOSE`	Close the window.	

* Color is a modal value, else BLACK / WHITE or ORANGE / BLUE / GREEN / CYAN / RED / MAGENTA / YELLOW / GRAY followed by an optional 0..15 for brightness (default is 8).

TERM Display — Terminal for displaying text

```
CON _clkfreq = 10_000_000

PUB go() | i

  debug(`TERM MyTerm SIZE 9 1 TEXTSIZE 40)
  repeat
    repeat i from 50 to 60
      debug(`MyTerm 1 'Temp = `(i)')
      waitms(500)
```



TERM Instantiation	Description	Default
`TITLE 'string'`	Set the window caption to 'string'.	<none>
`POS left top`	Set the window position.	0, 0
`SIZE columns rows`	Set the number of terminal columns (1..256) and terminal rows (1..256).	40, 20

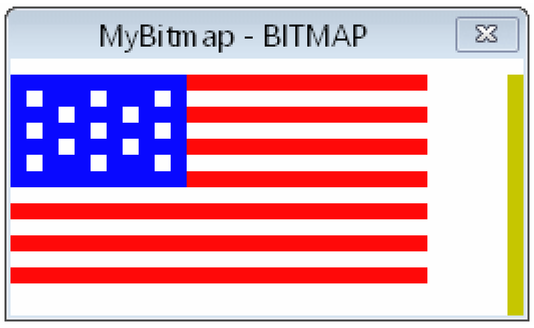
`TEXTSIZE size`	Set the terminal text size (6..200).	editor text size
`COLOR text_color back_color ...`	Set text-color and background-color combos #0..#3. *	default colors
`BACKCOLOR color`	Set the display background color. *	BLACK
`UPDATE`	Set UPDATE mode. The display will only be updated when fed an 'UPDATE' command.	automatic update
`HIDEXY`	Hide the X,Y mouse coordinates from being displayed at the mouse pointer.	not hidden

TERM Feeding	Description	Default
`character`	0 = Clear terminal display and home cursor. 1 = Home cursor. 2 = Set column to next character value. 3 = Set row to next character value. 4 = Select color combo #0. 5 = Select color combo #1. 6 = Select color combo #2. 7 = Select color combo #3. 8 = Backspace. 9 = Tab to next 8th column. 13+10 or 13 or 10 = New line. 32..255 = Printable character.	
`'string'`	Print string.	
`CLEAR`	Clear the display to the background color.	
`UPDATE`	Update the window with the current text screen. Used in UPDATE mode.	
`SAVE {WINDOW} 'filename'`	Save a bitmap file (.bmp) of either the entire window or just the display area.	
`CLOSE`	Close the window.	

* Color is a modal value, else BLACK / WHITE or ORANGE / BLUE / GREEN / CYAN / RED / MAGENTA / YELLOW / GRAY followed by an optional 0..15 for brightness (default is 8).

BITMAP Display   Pixel-driven bitmap

```
CON _clkfreq = 10_000_000

PUB go() | i

  debug(`bitmap MyBitmap SIZE 32 16 DOTSIZE 8 LUT2 LONGS_2BIT)
  debug(`MyBitmap TRACE 14 LUTCOLORS WHITE RED BLUE YELLOW 6)
  repeat
    debug(`MyBitmap `uhex_(flag[i++ & $1F]) `dly(100))

DAT

flag    long    %%3333333333333330
        long    %%0010101022222220
        long    %%0010101020202020
        long    %%0010101022222220
        long    %%0010101022020220
        long    %%0010101022222220
        long    %%0010101020202020
        long    %%0010101022222220
        long    %%0010101022020220
        long    %%0010101022222220
        long    %%0010101020202020
        long    %%0010101022222220
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0010101010101010
        long    %%0000000000000000
        long    %%0000000000000000
        long    %%0000000000000000
        long    %%0000000000000000
        long    %%0000000000000000
```



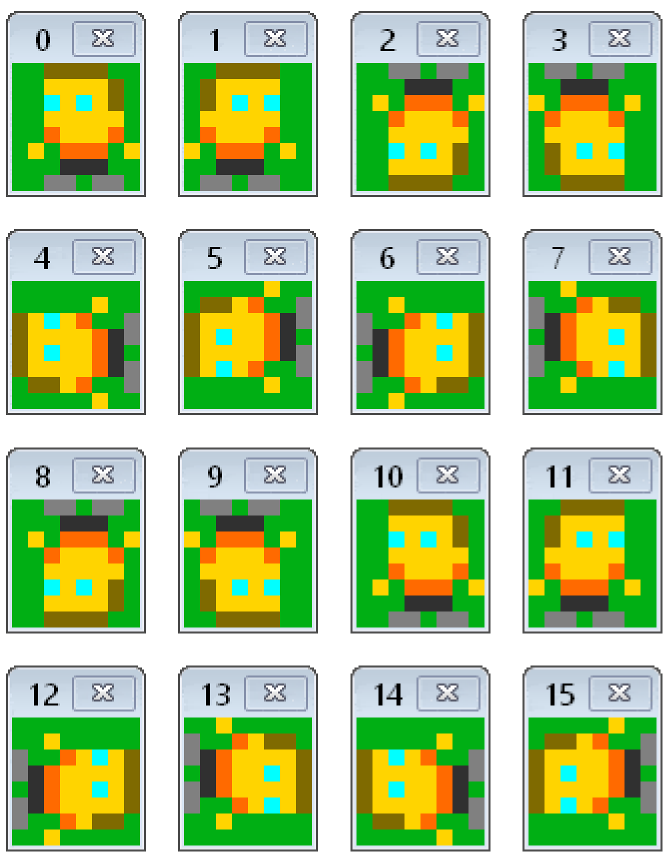
BITMAP Instantiation	Description	Default
`TITLE 'string'`	Set the window caption to 'string'.	<none>
`POS left top`	Set the window position.	0, 0
`SIZE x_pixels y_pixels`	Set the number of pixels in the bitmap (1..2048 for both x and y).	256, 256

`DOTSIZE width_and_height {height}`	Set the bitmap pixel-width and pixel-height (1..256) together, or set them independently.	1, 1
`SPARSE color`	Show large round pixels against a colored background. DOTSIZE must be at least 4. *	<off>
`lut1_to_rgb24`	Set the color mode. See images below.	RGB24
`LUTCOLORS rgb24 rgb24 ...`	For LUT1..LUT8 color modes, load the LUT with RGB24 colors. Use HEX_LONG_ARRAY_ to load.	default colors 0..7
`TRACE 0_to_15`	Set the pixel loading direction and whether to scroll after each line is filled. See animation below.	0
`RATE pixels_per_update`	Set the number of pixels before each display update. 'RATE -1' sets the rate to the bitmap size.	line size
`packed_data_mode`	Enable packed-data mode. See description at end of this section.	<none>
`UPDATE`	Set UPDATE mode. The display will only be updated when fed an 'UPDATE' command.	automatic update
`HIDEXY`	Hide the X,Y mouse coordinates from being displayed at the mouse pointer.	not hidden
BITMAP Feeding	**Description**	**Default**
`pixel`	Numerical pixel data that is fed into the bitmap.	
`lut1_to_rgb24`	Change the color mode.	RGB24
`LUTCOLORS rgb24 rgb24 ...`	For LUT1..LUT8 color modes, load the LUT with rgb24 colors. Use HEX_LONG_ARRAY_ to load colors.	default colors 0..7
`TRACE 0_to_15`	Change the direction in which pixels are loaded into the bitmap. Sets the rate to the line size.	0
`RATE pixels_per_update`	Set the number of pixels before each display update. 'RATE -1' sets the rate to the bitmap size.	
`SET x_position {y_position}`	Set the current pixel-loading position. Cancels scroll mode by clearing bit 3 of TRACE.	
`SCROLL x_scroll y_scroll`	Scroll the bitmap by some number of pixels. Negative/positive values determine the direction, 0 = none.	
`CLEAR`	Clear the bitmap to zero-value pixels.	
`UPDATE`	Update the window with the current bitmap. Used in UPDATE mode.	
`SAVE {WINDOW} 'filename'`	Save a bitmap file (.bmp) of either the entire window or just the bitmap at 1x scale.	
`CLOSE`	Close the window.	

* Color is ORANGE / BLUE / GREEN / CYAN / RED / MAGENTA / YELLOW / GRAY.

TRACE modes

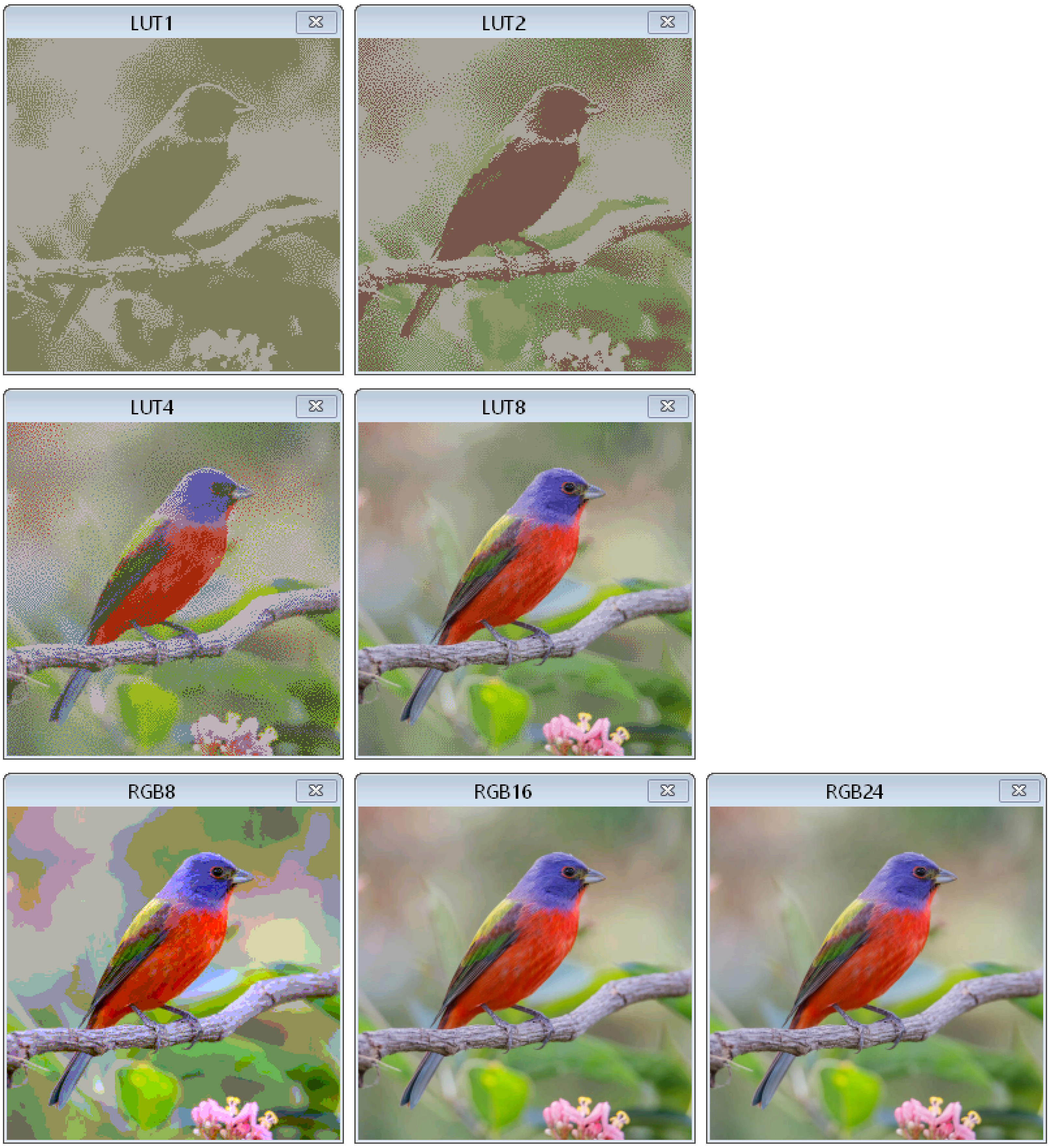
Rate is set to 1 so that each pixel can be seen as it's loaded.



Color Mode	Bits/ Pixel	Description	Intention
`LUT1`	1	Pixel indexes LUT colors 0..1	Memory-efficient 2-color-palette graphics
`LUT2`	2	Pixel indexes LUT colors 0..3	Memory-efficient 4-color-palette graphics
`LUT4`	4	Pixel indexes LUT colors 0..15	Memory-efficient 16-color-palette graphics
`LUT8`	8	Pixel indexes LUT colors 0..255	Memory-efficient 256-color-palette graphics.
`LUMA8`	8	From black to color *	Instrumentation where luminance indicates level
`LUMA8W`	8	From white to color *	Instrumentation where saturation indicates level

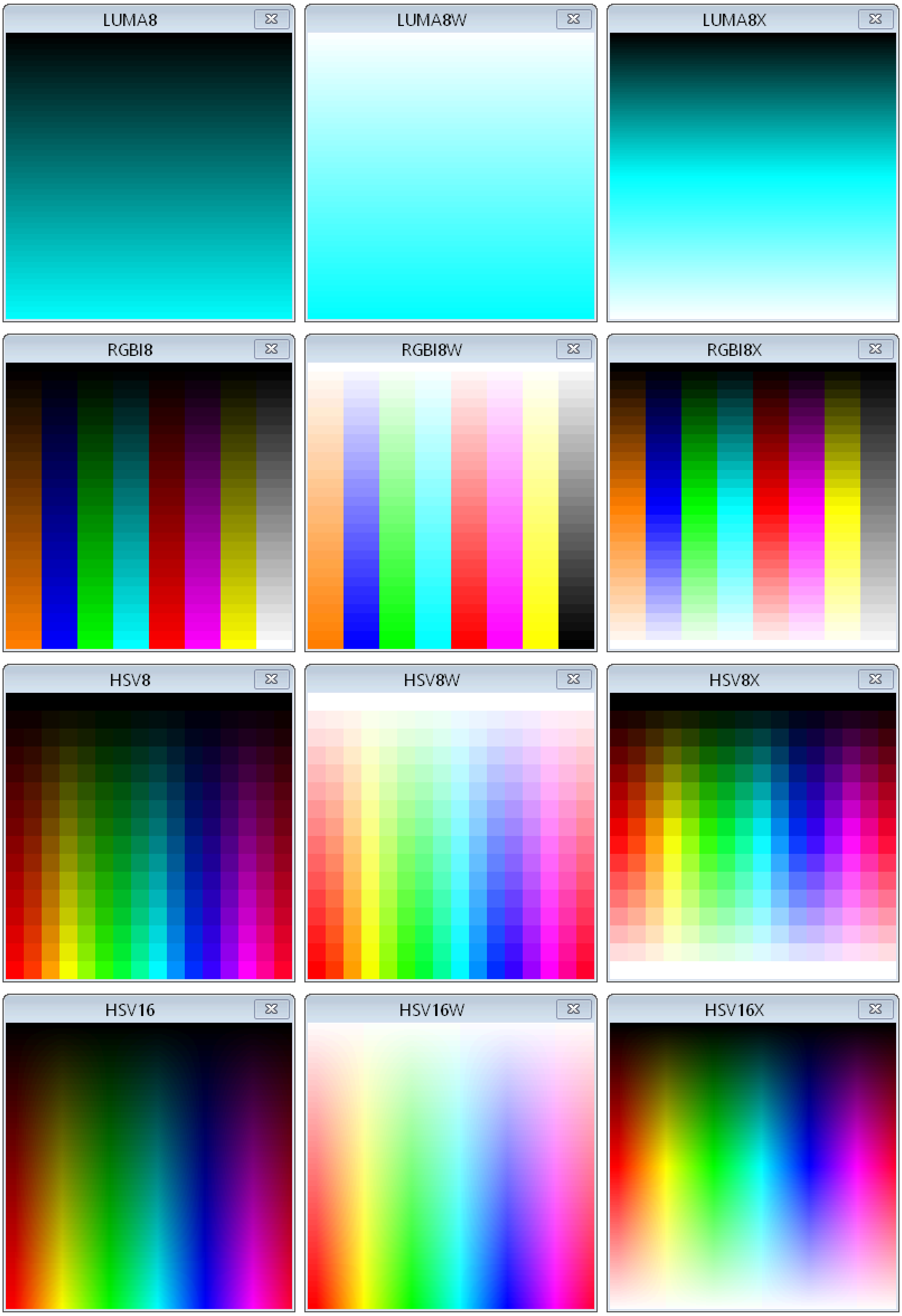
LUMA8X	8	From black to color * to white	Instrumentation where luminance indicates level, peaking in white
HSV8	8	From black to color: %HHHHSSSS	16 hues with 16 luminance levels
HSV8W	8	From white to color: %HHHHSSSS	16 hues with 16 saturation levels, coming from white
HSV8X	8	From black to color to white: %HHHHSSSS	16 hues with 16 luminance levels, peaking in white
RGBI8	8	From black to color: %RGBIIIII	8 basic colors with 32 luminance levels
RGBI8W	8	From white to color: %RGBIIIII	8 basic colors with 32 saturation levels, coming from white
RGBI8X	8	From black to color to white: %RGBIIIII	8 basic colors with 32 luminance levels, peaking in white
RGB8	8	%RRRGGGBB	Byte-level RGB with 8 red, 8 green, and 4 blue levels
HSV16	16	From black to color: %HHHHHHHH_SSSSSSSS	256 hues with 256 luminance levels
HSV16W	16	From white to color: %HHHHHHHH_SSSSSSSS	256 hues with 256 saturation levels, coming from white
HSV16X	16	From black to color to white: %HHHHHHHH_SSSSSSSS	256 hues with 256 luminance levels, peaking in white
RGB16	16	%RRRRRGGG_GGGBBBBB	Word-level RGB with 32 red levels, 64 green levels, and 32 blue levels
RGB24	24	%RRRRRRRR_GGGGGGGG_BBBBBBBB	Full RGB with 256 levels for red, green, and blue

* Color is ORANGE / BLUE / GREEN / CYAN / RED / MAGENTA / YELLOW / GRAY.




```
CON _clkfreq = 100_000_000

PUB go() | i
  debug(`bitmap a title 'LUT1'  pos 100 100 trace 2 lut1 longs_1bit alt)
  debug(`bitmap b title 'LUT2'  pos 370 100 trace 2 lut2 longs_2bit alt)
  debug(`bitmap c title 'LUT4'  pos 100 395 trace 2 lut4 longs_4bit alt)
  debug(`bitmap d title 'LUT8'  pos 370 395 trace 2 lut8 longs_8bit)
  debug(`bitmap e title 'RGB8'  pos 100 690 trace 2 rgb8)
  debug(`bitmap f title 'RGB16' pos 370 690 trace 2 rgb16)
  debug(`bitmap g title 'RGB24' pos 640 690 trace 2 rgb24)
```

```
  waitms(1000)

  showbmp("a", @image1, $8A,   2,  $800)    'send LUT1 image
  showbmp("b", @image2, $36,   4, $1000)    'send LUT2 image
  showbmp("c", @image3, $8A,  16, $2000)    'send LUT4 image
  showbmp("d", @image4, $36, 256, $4000)    'send LUT8 image

  i := @image5 + $36  'send RGB8/RGB16/RGB24 images from the same 24-bpp file
  repeat $10000
    debug(`e `uhex_(byte[i+0] >> 6 + byte[i+1] >> 5 << 2 + byte[i+2] >> 5 << 5 ))
    debug(`f `uhex_(byte[i+0] >> 3 + byte[i+1] >> 2 << 5 + byte[i+2] >> 3 << 11))
    debug(`g `uhex_(byte[i+0]      + byte[i+1] << 8      + byte[i+2] << 16     ))
    i += 3

PRI showbmp(letter, image_address, lut_offset, lut_size, image_longs) | i
  image_address += lut_offset
  debug(``#(letter) lutcolors `uhex_long_array_(image_address, lut_size))
  image_address += lut_size << 2 - 4
  repeat image_longs
    debug(``#(letter) `uhex_(long[image_address += 4]))

DAT
image1  file "bird_lut1.bmp"
image2  file "bird_lut2.bmp"
image3  file "bird_lut4.bmp"
image4  file "bird_lut8.bmp"
image5  file "bird_rgb24.bmp"
```

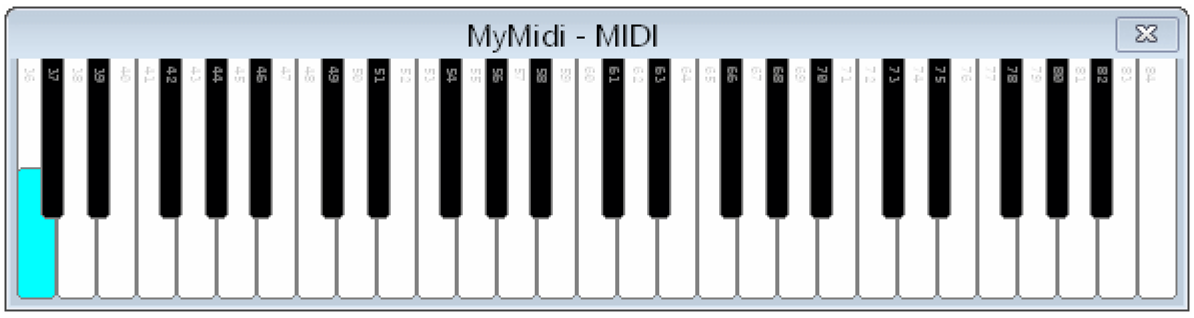



```
CON _clkfreq = 100_000_000

PUB go() | i
  debug(`bitmap a title 'LUMA8'  pos 100 100 size 1 256 dotsize 256 1 luma8  cyan)
  debug(`bitmap b title 'LUMA8W' pos 370 100 size 1 256 dotsize 256 1 luma8w cyan)
  debug(`bitmap c title 'LUMA8X' pos 640 100 size 1 256 dotsize 256 1 luma8x cyan)
  debug(`bitmap d title 'RGBI8'  pos 100 395 size 8 32 dotsize 32 8 trace 4 rgbi8)
  debug(`bitmap e title 'RGBI8W' pos 370 395 size 8 32 dotsize 32 8 trace 4 rgbi8w)
  debug(`bitmap f title 'RGBI8X' pos 640 395 size 8 32 dotsize 32 8 trace 4 rgbi8x)
  debug(`bitmap g title 'HSV8'   pos 100 690 size 16 16 trace 4 dotsize 16 hsv8)
  debug(`bitmap h title 'HSV8W'  pos 370 690 size 16 16 trace 4 dotsize 16 hsv8w)
  debug(`bitmap i title 'HSV8X'  pos 640 690 size 16 16 trace 4 dotsize 16 hsv8x)
  debug(`bitmap j title 'HSV16'  pos 100 985 size 256 256 trace 4 hsv16)
  debug(`bitmap k title 'HSV16W' pos 370 985 size 256 256 trace 4 hsv16w)
  debug(`bitmap l title 'HSV16X' pos 640 985 size 256 256 trace 4 hsv16x)
  waitms(1000)
  repeat i from 0 to 255                   'feed 8-bit displays
    debug(`a b c d e f g h i `uhex_(i))
  repeat i from 0 to 65535                 'feed 16-bit displays
    debug(`j k l `uhex_(i))
```

MIDI Display

MIDI keyboard for viewing note-on/off status with velocity

```
CON _clkfreq = 10_000_000

PUB go() | i

  debug(`midi MyMidi size 3 range 36 84)
  repeat
    repeat i from 36 to 84
      debug(`MyMidi $90 `(i, getrnd() & $7F))
      waitms(150)
      debug(`MyMidi $80 `(i, 0))
```

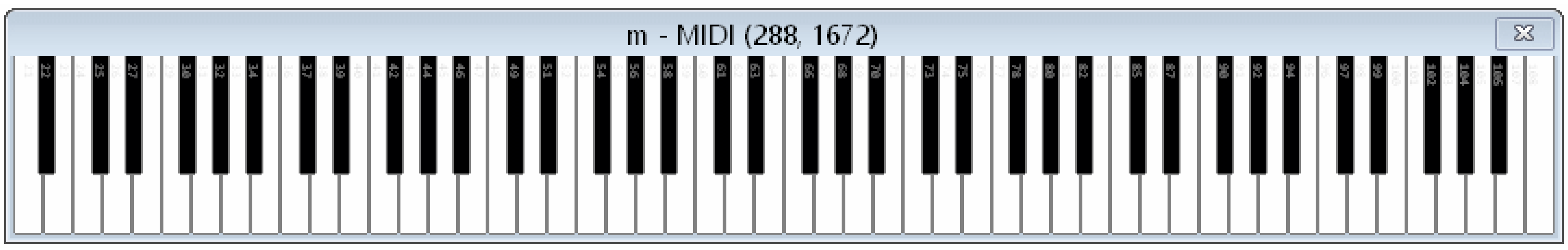


MIDI Instantiation	Description	Default
TITLE 'string'	Set the window caption to 'string'.	<none>
POS left top	Set the window position.	0, 0
SIZE keyboard_size	Set the size of the MIDI keyboard display (1..50).	4
RANGE first_key last_key	Set the first and last MIDI key numbers (0..127).	21, 108 (88 keys)
CHANNEL channel_number	Set the MIDI channel number to observe (0..15).	0
COLOR white_key black_key	Set the 'ON' colors for white and black keys. *	CYAN, MAGENTA
MIDI Feeding	**Description**	**Default**
byte	If ($90 + channel) then NOTE_ON mode, else if ($80 + channel) then NOTE_OFF mode. If NOTE_ON mode then receive a key ($00..$7F) and then its velocity ($00..$7F), update display. If NOTE_OFF mode then receive a key ($00..$7F) and then its velocity ($00..$7F), update display.	
CLEAR	Clear all notes.	
SAVE {WINDOW} 'filename'	Save a bitmap file (.bmp) of either the entire window or just the display area.	
CLOSE	Close the window.	

* Color is BLACK / WHITE or ORANGE / BLUE / GREEN / CYAN / RED / MAGENTA / YELLOW / GRAY followed by an optional 0..15 for brightness (default is 8).

Here is a PASM program which receives MIDI serial on P16 and sends it to the MIDI display:

```
CON     _clkfreq        = 10_000_000
        rxpin           = 16

DAT     org

        debug   (`midi m size 2)

        wrpin   #%11111_0,#rxpin
        wxpin   ##(clkfreq_/31250) << 16 + 8-1, #rxpin
        drvl    #rxpin

.wait   testp   #rxpin  wc
 if_nc  jmp     #.wait

        rdpin   x,#rxpin
        shr     x,#32-8

        debug   ("`m ", uhex_byte_(x))

        jmp     #.wait

x       res     1
```



Packed-Data Modes

Packed-data modes are used to efficiently convey sub-byte data types, by having the host side unpack them from bytes, words, or longs it receives. As well, bytes can be sent within words and longs, and words can be sent within longs for some efficiency improvement.

To establish packed-data operation, you must specify one of the modes listed below, followed by optional 'ALT' and 'SIGNED' keywords:

```
packed_data_mode {ALT} {SIGNED}
```

The **ALT** keyword will cause bits, double-bits, or nibbles, within each byte sent, to be reordered end-to-end on the host side, within each byte. This simplifies cases where the raw data you are sending has its bitfields out-of-order with respect to the DEBUG display you are using. This is most-likely to be needed for bitmap data that was composed in standard formats.

The **SIGNED** keyword will cause all unpacked data values to be sign-extended on the host side.

Packed-Data Modes	Descriptions	Final Values	Final Values if SIGNED
`LONGS_1BIT`	Each value received is translated into 32 separate 1-bit values, starting from the LSB of the received value.	0..1	-1..0
`LONGS_2BIT`	Each value received is translated into 16 separate 2-bit values, starting from the LSBs of the received value.	0..3	-2..1
`LONGS_4BIT`	Each value received is translated into 8 separate 4-bit values, starting from the LSBs of the received value.	0..15	-8..7
`LONGS_8BIT`	Each value received is translated into 4 separate 8-bit values, starting from the LSBs of the received value.	0..255	-128..127
`LONGS_16BIT`	Each value received is translated into 2 separate 16-bit values, starting from the LSBs of the received value.	0..65,535	-32,768..32,767
`WORDS_1BIT`	Each value received is translated into 16 separate 1-bit values, starting from the LSB of the received value.	0..1	-1..0
`WORDS_2BIT`	Each value received is translated into 8 separate 2-bit values, starting from the LSBs of the received value.	0..3	-2..1
`WORDS_4BIT`	Each value received is translated into 4 separate 4-bit values, starting from the LSBs of the received value.	0..15	-8..7
`WORDS_8BIT`	Each value received is translated into 2 separate 8-bit values, starting from the LSBs of the received value.	0..255	-128..127
`BYTES_1BIT`	Each value received is translated into 8 separate 1-bit values, starting from the LSB of the received value.	0..1	-1..0
`BYTES_2BIT`	Each value received is translated into 4 separate 2-bit values, starting from the LSBs of the received value.	0..3	-2..1
`BYTES_4BIT`	Each value received is translated into 2 separate 4-bit values, starting from the LSBs of the received value.	0..15	-8..7

Built-In Symbols for Smart Pin Configuration

Smart Pin Symbol Value	Symbol Name	Details
A Input Polarity	**(pick one)**	
`%0000_0000_000_0000000000000_00_00000_0`	`P_TRUE_A (default)`	True A input
`%1000_0000_000_0000000000000_00_00000_0`	`P_INVERT_A`	Invert A input
A Input Selection	**(pick one)**	
`%0000_0000_000_0000000000000_00_00000_0`	`P_LOCAL_A (default)`	Select local pin for A input
`%0001_0000_000_0000000000000_00_00000_0`	`P_PLUS1_A`	Select pin+1 for A input
`%0010_0000_000_0000000000000_00_00000_0`	`P_PLUS2_A`	Select pin+2 for A input
`%0011_0000_000_0000000000000_00_00000_0`	`P_PLUS3_A`	Select pin+3 for A input
`%0100_0000_000_0000000000000_00_00000_0`	`P_OUTBIT_A`	Select OUT bit for A input
`%0101_0000_000_0000000000000_00_00000_0`	`P_MINUS3_A`	Select pin-3 for A input
`%0110_0000_000_0000000000000_00_00000_0`	`P_MINUS2_A`	Select pin-2 for A input
`%0111_0000_000_0000000000000_00_00000_0`	`P_MINUS1_A`	Select pin-1 for A input
B Input Polarity	**(pick one)**	
`%0000_0000_000_0000000000000_00_00000_0`	`P_TRUE_B (default)`	True B input
`%0000_1000_000_0000000000000_00_00000_0`	`P_INVERT_B`	Invert B input
B Input Selection	**(pick one)**	
`%0000_0000_000_0000000000000_00_00000_0`	`P_LOCAL_B (default)`	Select local pin for B input
`%0000_0001_000_0000000000000_00_00000_0`	`P_PLUS1_B`	Select pin+1 for B input
`%0000_0010_000_0000000000000_00_00000_0`	`P_PLUS2_B`	Select pin+2 for B input
`%0000_0011_000_0000000000000_00_00000_0`	`P_PLUS3_B`	Select pin+3 for B input
`%0000_0100_000_0000000000000_00_00000_0`	`P_OUTBIT_B`	Select OUT bit for B input
`%0000_0101_000_0000000000000_00_00000_0`	`P_MINUS3_B`	Select pin-3 for B input
`%0000_0110_000_0000000000000_00_00000_0`	`P_MINUS2_B`	Select pin-2 for B input
`%0000_0111_000_0000000000000_00_00000_0`	`P_MINUS1_B`	Select pin-1 for B input
A, B Input Logic	**(pick one)**	

%0000_0000_000_0000000000000_00_00000_0	P_PASS_AB (default)	Select A, B
%0000_0000_001_0000000000000_00_00000_0	P_AND_AB	Select A & B, B
%0000_0000_010_0000000000000_00_00000_0	P_OR_AB	Select A | B, B
%0000_0000_011_0000000000000_00_00000_0	P_XOR_AB	Select A ^ B, B
%0000_0000_100_0000000000000_00_00000_0	P_FILT0_AB	Select FILT0 settings for A, B
%0000_0000_101_0000000000000_00_00000_0	P_FILT1_AB	Select FILT1 settings for A, B
%0000_0000_110_0000000000000_00_00000_0	P_FILT2_AB	Select FILT2 settings for A, B
%0000_0000_111_0000000000000_00_00000_0	P_FILT3_AB	Select FILT3 settings for A, B
Low-Level Pin Modes	**(pick one)**	
Logic/Schmitt/Comparator Input Modes		
%0000_0000_000_0000000000000_00_00000_0	P_LOGIC_A (default)	Logic level A → IN, output OUT
%0000_0000_000_0001000000000_00_00000_0	P_LOGIC_A_FB	Logic level A → IN, output feedback
%0000_0000_000_0010000000000_00_00000_0	P_LOGIC_B_FB	Logic level B → IN, output feedback
%0000_0000_000_0011000000000_00_00000_0	P_SCHMITT_A	Schmitt trigger A → IN, output OUT
%0000_0000_000_0100000000000_00_00000_0	P_SCHMITT_A_FB	Schmitt trigger A → IN, output feedback
%0000_0000_000_0101000000000_00_00000_0	P_SCHMITT_B_FB	Schmitt trigger B → IN, output feedback
%0000_0000_000_0110000000000_00_00000_0	P_COMPARE_AB	A > B → IN, output OUT
%0000_0000_000_0111000000000_00_00000_0	P_COMPARE_AB_FB	A > B → IN, output feedback
%xxxx_xxxx_xxx_xxxxSIOHHHLLL_xx_xxxxx_x		Sync mode, IN/output polarity, high/low drive
ADC Input Modes		
%0000_0000_000_1000000000000_00_00000_0	P_ADC_GIO	ADC GIO → IN, output OUT
%0000_0000_000_1000010000000_00_00000_0	P_ADC_VIO	ADC VIO → IN, output OUT
%0000_0000_000_1000100000000_00_00000_0	P_ADC_FLOAT	ADC FLOAT → IN, output OUT
%0000_0000_000_1000110000000_00_00000_0	P_ADC_1X	ADC 1x → IN, output OUT
%0000_0000_000_1001000000000_00_00000_0	P_ADC_3X	ADC 3.16x → IN, output OUT
%0000_0000_000_1001010000000_00_00000_0	P_ADC_10X	ADC 10x → IN, output OUT
%0000_0000_000_1001100000000_00_00000_0	P_ADC_30X	ADC 31.6x → IN, output OUT
%0000_0000_000_1001110000000_00_00000_0	P_ADC_100X	ADC 100x → IN, output OUT
%xxxx_xxxx_xxx_xxxxxxOHHHLLL_xx_xxxxx_x		O = output polarity, HHH/LLL = high/low drive
DAC Output Modes		**DIR enables output, OUT enables ADC**
%0000_0000_000_1010000000000_00_00000_0	P_DAC_990R_3V	DAC 990Ω, 3.3V peak, ADC 1x → IN
%0000_0000_000_1010100000000_00_00000_0	P_DAC_600R_2V	DAC 600Ω, 2.0V peak, ADC 1x → IN
%0000_0000_000_1011000000000_00_00000_0	P_DAC_124R_3V	DAC 123.75Ω, 3.3V peak, ADC 1x → IN
%0000_0000_000_1011100000000_00_00000_0	P_DAC_75R_2V	DAC 75Ω, 2.0V peak, ADC 1x → IN
%xxxx_xxxx_xxx_xxxxxDDDDDDDD_xx_xxxxx_x		DDDDDDDD = 8-bit DAC value
Level-Comparison Modes		**DIR enables output (1.5kΩ drive)**
%0000_0000_000_1100000000000_00_00000_0	P_LEVEL_A	A > Level → IN, output OUT
%0000_0000_000_1101000000000_00_00000_0	P_LEVEL_A_FBN	A > Level → IN, output negative feedback
%0000_0000_000_1110000000000_00_00000_0	P_LEVEL_B_FBP	B > Level → IN, output positive feedback
%0000_0000_000_1111000000000_00_00000_0	P_LEVEL_B_FBN	B > Level → IN, output negative feedback
%xxxx_xxxx_xxx_xxxxSLLLLLLLL_xx_xxxxx_x		S = Synchronous, LLLLLLLL = 8-bit Level
Low-Level Pin Sub-Modes		
Sync Mode	(pick one)	(for Logic/Schmitt/Comparator/Level modes)
%xxxx_xxxx_xxx_xxxxSxxxxxxxx_xx_xxxxx_x		Sync mode bit
%0000_0000_000_0000000000000_00_00000_0	P_ASYNC_IO (default)	Select asynchronous I/O
%0000_0000_000_0000100000000_00_00000_0	P_SYNC_IO	Select synchronous I/O
IN Polarity	(pick one)	(for Logic/Schmitt/Comparator modes)
%xxxx_xxxx_xxx_xxxxxIxxxxxxx_xx_xxxxx_x		IN polarity bit
%0000_0000_000_0000000000000_00_00000_0	P_TRUE_IN (default)	True IN bit
%0000_0000_000_0000010000000_00_00000_0	P_INVERT_IN	Invert IN bit
Output Polarity	(pick one)	(for Logic/Schmitt/Comparator/ADC modes)

%xxxx_xxxx_xxx_xxxxxxOxxxxxx_xx_xxxxx_x		Output polarity bit
%0000_0000_000_0000000000000_00_00000_0	P_TRUE_OUTPUT (default) P_TRUE_OUT (for brevity)	Select true output
%0000_0000_000_0000001000000_00_00000_0	P_INVERT_OUTPUT P_INVERT_OUT (for brevity)	Select inverted output
Drive-High Strength	(pick one)	(for Logic/Schmitt/Comparator/ADC modes)
%xxxx_xxxx_xxx_xxxxxxxHHHxxx_xx_xxxxx_x		Drive-high selector bits
%0000_0000_000_0000000000000_00_00000_0	P_HIGH_FAST (default)	Drive high fast (30mA)
%0000_0000_000_0000000001000_00_00000_0	P_HIGH_1K5	Drive high 1.5kΩ
%0000_0000_000_0000000010000_00_00000_0	P_HIGH_15K	Drive high 15kΩ
%0000_0000_000_0000000011000_00_00000_0	P_HIGH_150K	Drive high 150kΩ
%0000_0000_000_0000000100000_00_00000_0	P_HIGH_1MA	Drive high 1mA
%0000_0000_000_0000000101000_00_00000_0	P_HIGH_100UA	Drive high 100µA
%0000_0000_000_0000000110000_00_00000_0	P_HIGH_10UA	Drive high 10µA
%0000_0000_000_0000000111000_00_00000_0	P_HIGH_FLOAT	Float high
Drive-Low Strength	(pick one)	(for Logic/Schmitt/Comparator/ADC modes)
%xxxx_xxxx_xxx_xxxxxxxxxxLLL_xx_xxxxx_x		Drive-low selector bits
%0000_0000_000_0000000000000_00_00000_0	P_LOW_FAST (default)	Drive low fast (30mA)
%0000_0000_000_0000000000001_00_00000_0	P_LOW_1K5	Drive low 1.5kΩ
%0000_0000_000_0000000000010_00_00000_0	P_LOW_15K	Drive low 15kΩ
%0000_0000_000_0000000000011_00_00000_0	P_LOW_150K	Drive low 150kΩ
%0000_0000_000_0000000000100_00_00000_0	P_LOW_1MA	Drive low 1mA
%0000_0000_000_0000000000101_00_00000_0	P_LOW_100UA	Drive low 100µA
%0000_0000_000_0000000000110_00_00000_0	P_LOW_10UA	Drive low 10µA
%0000_0000_000_0000000000111_00_00000_0	P_LOW_FLOAT	Float low
DIR/OUT Control	**(pick one)**	
%0000_0000_000_0000000000000_00_00000_0	P_TT_00 (default)	TT = %00
%0000_0000_000_0000000000000_01_00000_0	P_TT_01	TT = %01
%0000_0000_000_0000000000000_10_00000_0	P_TT_10	TT = %10
%0000_0000_000_0000000000000_11_00000_0	P_TT_11	TT = %11
%0000_0000_000_0000000000000_01_00000_0	P_OE	Enable output in smart pin mode, regardless of DIR
%0000_0000_000_0000000000000_01_00000_0	P_CHANNEL	Enable DAC channel in non-smart pin DAC mode
%0000_0000_000_0000000000000_10_00000_0	P_BITDAC	Enable BITDAC for non-smart pin DAC mode
Smart Pin Modes	**(pick one)**	
%0000_0000_000_0000000000000_00_00000_0	P_NORMAL (default)	Normal mode (not smart pin mode)
%0000_0000_000_0000000000000_00_00001_0	P_REPOSITORY	Long repository (non-DAC mode)
%0000_0000_000_0000000000000_00_00001_0	P_DAC_NOISE	DAC Noise (DAC mode)
%0000_0000_000_0000000000000_00_00010_0	P_DAC_DITHER_RND	DAC 16-bit random dither (DAC mode)
%0000_0000_000_0000000000000_00_00011_0	P_DAC_DITHER_PWM	DAC 16-bit PWM dither (DAC mode)
%0000_0000_000_0000000000000_00_00100_0	P_PULSE	Pulse/cycle output
%0000_0000_000_0000000000000_00_00101_0	P_TRANSITION	Transition output
%0000_0000_000_0000000000000_00_00110_0	P_NCO_FREQ	NCO frequency output
%0000_0000_000_0000000000000_00_00111_0	P_NCO_DUTY	NCO duty output
%0000_0000_000_0000000000000_00_01000_0	P_PWM_TRIANGLE	PWM triangle output
%0000_0000_000_0000000000000_00_01001_0	P_PWM_SAWTOOTH	PWM sawtooth output
%0000_0000_000_0000000000000_00_01010_0	P_PWM_SMPS	PWM switch-mode power supply I/O
%0000_0000_000_0000000000000_00_01011_0	P_QUADRATURE	A-B quadrature encoder input
%0000_0000_000_0000000000000_00_01100_0	P_REG_UP	Inc on A-rise when B-high
%0000_0000_000_0000000000000_00_01101_0	P_REG_UP_DOWN	Inc on A-rise when B-high, dec on A-rise when B-low
%0000_0000_000_0000000000000_00_01110_0	P_COUNT_RISES	Inc on A-rise, optionally dec on B-rise
%0000_0000_000_0000000000000_00_01111_0	P_COUNT_HIGHS	Inc on A-high, optionally dec on B-high
%0000_0000_000_0000000000000_00_10000_0	P_STATE_TICKS	For A-low and A-high states, count ticks

%0000_0000_000_0000000000000_00_10001_0	P_HIGH_TICKS	For A-high states, count ticks
%0000_0000_000_0000000000000_00_10010_0	P_EVENTS_TICKS	For X A-highs/rises/edges, count ticks / Timeout on X ticks of no A-high/rise/edge
%0000_0000_000_0000000000000_00_10011_0	P_PERIODS_TICKS	For X periods of A, count ticks
%0000_0000_000_0000000000000_00_10100_0	P_PERIODS_HIGHS	For X periods of A, count highs
%0000_0000_000_0000000000000_00_10101_0	P_COUNTER_TICKS	For periods of A in X+ ticks, count ticks
%0000_0000_000_0000000000000_00_10110_0	P_COUNTER_HIGHS	For periods of A in X+ ticks, count highs
%0000_0000_000_0000000000000_00_10111_0	P_COUNTER_PERIODS	For periods of A in X+ ticks, count periods
%0000_0000_000_0000000000000_00_11000_0	P_ADC	ADC sample/filter/capture, internally clocked
%0000_0000_000_0000000000000_00_11001_0	P_ADC_EXT	ADC sample/filter/capture, externally clocked
%0000_0000_000_0000000000000_00_11010_0	P_ADC_SCOPE	ADC scope with trigger
%0000_0000_000_0000000000000_00_11011_0	P_USB_PAIR	USB pin pair
%0000_0000_000_0000000000000_00_11100_0	P_SYNC_TX	Synchronous serial transmit
%0000_0000_000_0000000000000_00_11101_0	P_SYNC_RX	Synchronous serial receive
%0000_0000_000_0000000000000_00_11110_0	P_ASYNC_TX	Asynchronous serial transmit
%0000_0000_000_0000000000000_00_11111_0	P_ASYNC_RX	Asynchronous serial receive

Built-In Symbols for Streamer Modes

Streamer Symbol Value	Symbol Name
Immediate → LUT → Pins / DACs	
%0000_0000_0000_0000 << 16 %0000_DDDD_EPPP_BBBB << 16	X_IMM_32X1_LUT
%0001_0000_0000_0000 << 16 %0001_DDDD_EPPP_BBBB << 16	X_IMM_16X2_LUT
%0010_0000_0000_0000 << 16 %0010_DDDD_EPPP_BBBB << 16	X_IMM_8X4_LUT
%0011_0000_0000_0000 << 16 %0011_DDDD_EPPP_BBBB << 16	X_IMM_4X8_LUT
Immediate → Pins / DACs	
%0100_0000_0000_0000 << 16 %0100_DDDD_EPPP_PPPA << 16	X_IMM_32X1_1DAC1
%0101_0000_0000_0000 << 16 %0101_DDDD_EPPP_PP0A << 16	X_IMM_16X2_2DAC1
%0101_0000_0000_0010 << 16 %0101_DDDD_EPPP_PP1A << 16	X_IMM_16X2_1DAC2
%0110_0000_0000_0000 << 16 %0110_DDDD_EPPP_P00A << 16	X_IMM_8X4_4DAC1
%0110_0000_0000_0010 << 16 %0110_DDDD_EPPP_P01A << 16	X_IMM_8X4_2DAC2
%0110_0000_0000_0100 << 16 %0110_DDDD_EPPP_P10A << 16	X_IMM_8X4_1DAC4
%0110_0000_0000_0110 << 16 %0110_DDDD_EPPP_0110 << 16	X_IMM_4X8_4DAC2
%0110_0000_0000_0111 << 16 %0110_DDDD_EPPP_0111 << 16	X_IMM_4X8_2DAC4
%0110_0000_0000_1110 << 16 %0110_DDDD_EPPP_1110 << 16	X_IMM_4X8_1DAC8
%0110_0000_0000_1111 << 16 %0110_DDDD_EPPP_1111 << 16	X_IMM_2X16_4DAC4
%0111_0000_0000_0000 << 16 %0111_DDDD_EPPP_0000 << 16	X_IMM_2X16_2DAC8
%0111_0000_0000_0001 << 16 %0111_DDDD_EPPP_0001 << 16	X_IMM_1X32_4DAC8
RDFAST → LUT → Pins / DACs	
%0111_0000_0000_0010 << 16 %0111_DDDD_EPPP_001A << 16	X_RFLONG_32X1_LUT
%0111_0000_0000_0100 << 16 %0111_DDDD_EPPP_010A << 16	X_RFLONG_16X2_LUT
%0111_0000_0000_0110 << 16 %0111_DDDD_EPPP_011A << 16	X_RFLONG_8X4_LUT

%0111_0000_0000_1000 << 16 %0111_DDDD_EPPP_1000 << 16	X_RFLONG_4X8_LUT
RDFAST → Pins / DACs	
%1000_0000_0000_0000 << 16 %1000_DDDD_EPPP_PPPA << 16	X_RFBYTE_1P_1DAC1
%1001_0000_0000_0000 << 16 %1001_DDDD_EPPP_PP0A << 16	X_RFBYTE_2P_2DAC1
%1001_0000_0000_0010 << 16 %1001_DDDD_EPPP_PP1A << 16	X_RFBYTE_2P_1DAC2
%1010_0000_0000_0000 << 16 %1010_DDDD_EPPP_P00A << 16	X_RFBYTE_4P_4DAC1
%1010_0000_0000_0010 << 16 %1010_DDDD_EPPP_P01A << 16	X_RFBYTE_4P_2DAC2
%1010_0000_0000_0100 << 16 %1010_DDDD_EPPP_P10A << 16	X_RFBYTE_4P_1DAC4
%1010_0000_0000_0110 << 16 %1010_DDDD_EPPP_0110 << 16	X_RFBYTE_8P_4DAC2
%1010_0000_0000_0111 << 16 %1010_DDDD_EPPP_0111 << 16	X_RFBYTE_8P_2DAC4
%1010_0000_0000_1110 << 16 %1010_DDDD_EPPP_1110 << 16	X_RFBYTE_8P_1DAC8
%1010_0000_0000_1111 << 16 %1010_DDDD_EPPP_1111 << 16	X_RFWORD_16P_4DAC4
%1011_0000_0000_0000 << 16 %1011_DDDD_EPPP_0000 << 16	X_RFWORD_16P_2DAC8
%1011_0000_0000_0001 << 16 %1011_DDDD_EPPP_0001 << 16	X_RFLONG_32P_4DAC8
RDFAST → RGB → Pins / DACs	
%1011_0000_0000_0010 << 16 %1011_DDDD_EPPP_0010 << 16	X_RFBYTE_LUMA8
%1011_0000_0000_0011 << 16 %1011_DDDD_EPPP_0011 << 16	X_RFBYTE_RGBI8
%1011_0000_0000_0100 << 16 %1011_DDDD_EPPP_0100 << 16	X_RFBYTE_RGB8
%1011_0000_0000_0101 << 16 %1011_DDDD_EPPP_0101 << 16	X_RFWORD_RGB16
%1011_0000_0000_0110 << 16 %1011_DDDD_EPPP_0110 << 16	X_RFLONG_RGB24
Pins → DACs / WRFAST	
%1100_0000_0000_0000 << 16 %1100_DDDD_WPPP_PPPA << 16	X_1P_1DAC1_WFBYTE
%1101_0000_0000_0000 << 16 %1101_DDDD_WPPP_PP0A << 16	X_2P_2DAC1_WFBYTE
%1101_0000_0000_0010 << 16 %1101_DDDD_WPPP_PP1A << 16	X_2P_1DAC2_WFBYTE
%1110_0000_0000_0000 << 16 %1110_DDDD_WPPP_P00A << 16	X_4P_4DAC1_WFBYTE
%1110_0000_0000_0010 << 16 %1110_DDDD_WPPP_P01A << 16	X_4P_2DAC2_WFBYTE
%1110_0000_0000_0100 << 16 %1110_DDDD_WPPP_P10A << 16	X_4P_1DAC4_WFBYTE
%1110_0000_0000_0110 << 16 %1110_DDDD_WPPP_0110 << 16	X_8P_4DAC2_WFBYTE
%1110_0000_0000_0111 << 16 %1110_DDDD_WPPP_0111 << 16	X_8P_2DAC4_WFBYTE
%1110_0000_0000_1110 << 16 %1110_DDDD_WPPP_1110 << 16	X_8P_1DAC8_WFBYTE
%1110_0000_0000_1111 << 16 %1110_DDDD_WPPP_1111 << 16	X_16P_4DAC4_WFWORD
%1111_0000_0000_0000 << 16 %1111_DDDD_WPPP_0000 << 16	X_16P_2DAC8_WFWORD
%1111_0000_0000_0001 << 16 %1111_DDDD_WPPP_0001 << 16	X_32P_4DAC8_WFLONG
ADCs / Pins → DACs / WRFAST	
%1111_0000_0000_0010 << 16 %1111_DDDD_W000_0010 << 16	X_1ADC8_0P_1DAC8_WFBYTE
%1111_0000_0000_0011 << 16	X_1ADC8_8P_2DAC8_WFWORD

%1111_DDDD_WPPP_0011 << 16	
%1111_0000_0000_0100 << 16 %1111_DDDD_W000_0100 << 16	X_2ADC8_0P_2DAC8_WFWORD
%1111_0000_0000_0101 << 16 %1111_DDDD_WPPP_0101 << 16	X_2ADC8_16P_4DAC8_WFLONG
%1111_0000_0000_0110 << 16 %1111_DDDD_W000_0110 << 16	X_4ADC8_0P_4DAC8_WFLONG
DDS / Goertzel	
%1111_0000_0000_0111 << 16 %1111_DDDD_0PPP_P111 << 16	X_DDS_GOERTZEL_SINC1
%1111_0000_1000_0111 << 16 %1111_DDDD_1PPP_P111 << 16	X_DDS_GOERTZEL_SINC2
Sub-Fields	
DAC Channel Outputs	
%xxxx_DDDD_xxxx_xxxx << 16 %0000_0000_0000_0000 << 16 %0000_0001_0000_0000 << 16 %0000_0010_0000_0000 << 16 %0000_0011_0000_0000 << 16 %0000_0100_0000_0000 << 16 %0000_0101_0000_0000 << 16 %0000_0110_0000_0000 << 16 %0000_0111_0000_0000 << 16 %0000_1000_0000_0000 << 16 %0000_1001_0000_0000 << 16 %0000_1010_0000_0000 << 16 %0000_1011_0000_0000 << 16 %0000_1100_0000_0000 << 16 %0000_1101_0000_0000 << 16 %0000_1110_0000_0000 << 16 %0000_1111_0000_0000 << 16	 X_DACS_OFF (default) X_DACS_0_0_0_0 X_DACS_X_X_0_0 X_DACS_0_0_X_X X_DACS_X_X_X_0 X_DACS_X_X_0_X X_DACS_X_0_X_X X_DACS_0_X_X_X X_DACS_0N0_0N0 X_DACS_X_X_0N0 X_DACS_0N0_X_X X_DACS_1_0_1_0 X_DACS_X_X_1_0 X_DACS_1_0_X_X X_DACS_1N1_0N0 X_DACS_3_2_1_0
Pin Output Control	
%xxxx_xxxx_Exxx_xxxx << 16 %0000_0000_0000_0000 << 16 %0000_0000_1000_0000 << 16	 X_PINS_OFF (default) X_PINS_ON
Write Control	
%xxxx_xxxx_Wxxx_xxxx << 16 %0000_0000_0000_0000 << 16 %0000_0000_1000_0000 << 16	 X_WRITE_OFF (default) X_WRITE_ON
Alternate Order for 1/2/4 bits	
%xxxx_xxxx_xxxx_xxxA << 16 %0000_0000_0000_0000 << 16 %0000_0000_0000_0001 << 16	 X_ALT_OFF (default) X_ALT_ON

Built-In Symbols for Events and Interrupt Sources (PASM only, see silicon doc)

Symbol Value	Symbol Name	Details
0	EVENT_INT / INT_OFF	Interrupt-occurred event or interrupts off
1	EVENT_CT1	CT-passed-CT1 event
2	EVENT_CT2	CT-passed-CT2 event
3	EVENT_CT3	CT-passed-CT3 event
4	EVENT_SE1	Selectable event 1
5	EVENT_SE2	Selectable event 2
6	EVENT_SE3	Selectable event 3
7	EVENT_SE4	Selectable event 4
8	EVENT_PAT	INA/INB pattern match/mismatch event
9	EVENT_FBW	Hub FIFO block-wrap event
10	EVENT_XMT	Streamer command-empty event
11	EVENT_XFI	Streamer command-finished event
12	EVENT_XRO	Streamer NCO-rollover event
13	EVENT_XRL	Streamer-read-last-LUT-location event
14	EVENT_ATN	Attention-requested event
15	EVENT_QMT	GETQX/GETQY-on-empty event

Built-In Symbols for COGINIT() Usage

COGINIT Symbol Value	Symbol Name	Details
`%00_0000`	`COGEXEC (default)`	Use "COGEXEC + CogNumber" to start a cog in cogexec mode
`%10_0000`	`HUBEXEC`	Use "HUBEXEC + CogNumber" to start a cog in hubexec mode
`%01_0000`	`COGEXEC_NEW`	Starts an available cog in cogexec mode
`%11_0000`	`HUBEXEC_NEW`	Starts an available cog in hubexec mode
`%01_0001`	`COGEXEC_NEW_PAIR`	Starts an available eve/odd pair of cogs in cogexec mode, useful for LUT sharing
`%11_0001`	`HUBEXEC_NEW_PAIR`	Starts an available eve/odd pair of cogs in hubexec mode, useful for LUT sharing

Built-In Symbol for COGSPIN() Usage

COGSPIN Symbol Value	Symbol Name	Details
`%01_0000`	`NEWCOG`	Starts an available cog

Built-In Symbol for TASKSPIN() Usage

TASKSPIN Symbol Value	Symbol Name	Details
`-1`	`NEWTASK`	Starts an available task

Built-In Symbol for TASKSTOP() and TASKHALT() Usage

TASKSPIN Symbol Value	Symbol Name	Details
`-1`	`THISTASK`	Stops or halts this task

Built-In Numeric Symbols

Symbol Value	Symbol Name	Details
`$0000_0000`	`FALSE`	Same as 0
`$FFFF_FFFF`	`TRUE`	Same as -1
`$8000_0000`	`NEGX`	Negative-extreme integer, -2_147_483_648 ($8000_0000)
`$7FFF_FFFF`	`POSX`	Positive-extreme integer, +2_147_483_647 ($7FFF_FFFF)
`$4049_0FDB`	`PI`	Single-precision floating-point value of Pi, 3.14159265

Command Line options for PNut.exe

Command	Compile with DEBUG	Compile with Flash	Compile and save OBJ & BIN	Download	Start DEBUG	Action	ERROR.TXT file afterwards (file will contain one of these lines)
`pnut`						Start PNut.exe.	**`okay`**
`pnut filename`						Load source *filename* (.spin2 extension is assumed, but not enforced).	**`okay`**
`pnut filename -c`			✔			Load source *filename* and compile, then exit.	**`okay`** <filename_path>**`:`**<line_number>**`:error:`**<error_message>
`pnut filename -cd`	✔		✔			Load source *filename* and compile with DEBUG, then exit.	**`okay`** <filename_path>**`:`**<line_number>**`:error:`**<error_message>
`pnut filename -cf`		✔	✔			Load source *filename* and compile with flash loader, then exit.	**`okay`** <filename_path>**`:`**<line_number>**`:error:`**<error_message>
`pnut filename -cb`	✔	✔	✔			Load source *filename* and compile with both DEBUG and flash loader, then exit.	**`okay`** <filename_path>**`:`**<line_number>**`:error:`**<error_message>
`pnut filename -r`			✔	✔		Load source *filename,* compile, download, then exit.	okay <filename_path>**`:`**<line_number>**`:error:`**<error_message> **`serial_error`**

`pnut filename -rd`	✔		✔	✔	✔	Load source *filename*, compile with DEBUG, download, start DEBUG, then exit when the DEBUG window is closed.	`okay`
							<filename_path>`:`<line_number>`:error:`<error_message>
							`serial_error`

`pnut filename -f`		✔	✔	✔		Load source *filename*, compile with flash loader, download, then exit.	`okay`
							<filename_path>`:`<line_number>`:error:`<error_message>
							`serial_error`

`pnut filename -fd`	✔	✔	✔	✔	✔	Load source *filename*, compile with both DEBUG and flash loader, download, start DEBUG, then exit when the DEBUG window is closed.	`okay`
							<filename_path>`:`<line_number>`:error:`<error_message>
							`serial_error`

`pnut filename -b`				✔		Load binary *filename.bin* and download.	`okay` `serial_error`
`pnut filename -bd`				✔	✔	Load binary *filename.bin,* download, start DEBUG, then exit when the DEBUG window is closed.	`okay` `serial_error`
`pnut -debug {CommPort} {BaudRate}`					✔	Open CommPort (default = 1) at BaudRate (default = 2_000_000), start DEBUG, then exit when the DEBUG window is closed.	`okay` `serial_error`

Included Batch File to invoke PNut.exe and return status to STDOUT, STDERR, and ERRORLEVEL

PNUT_SHELL.BAT File	Batch File Line Descriptions
`@echo off`	Cancel echo to console.
`set ERROR_FILE=error.txt`	Set ERROR.TXT filename.
`if exist %ERROR_FILE% del /q /f %ERROR_FILE%`	If ERROR.TXT exists, delete it.
`if exist %1 set GOOD_SRC=1`	Check first parameter for a valid source file.
`if exist %1.spin2 set GOOD_SRC=1`	Check first parameter for a valid .spin2 source file.
`if defined GOOD_SRC (`	IF source file exists
`    pnut_v48 %1 %2 %3`	...Invoke PNut with passed parameters. Example: pnut_shell filename -r
`    set pnuterror = %ERRORLEVEL%`	...Capture ERRORLEVEL from PNut (0 = okay, 1 = error).
`    for /f "tokens=*" %%i in (%ERROR_FILE%) do echo %%i 1>&2`	...Copy ERROR.TXT file to STDOUT and STDERR.
`) else (`	ELSE
`    set pnuterror=-1`	...Set file-not-found error.
`    echo "Error: File NOT found - %1" 1>&2`	...Return file-not-found error message to STDOUT and STDERR.
`)`	
`exit %pnuterror%`	Return ERRORLEVEL. Change to 'exit /b %pnuterror%' to maintain the console window.

Clock Setup

To establish the initial clock setup for your program, you can declare certain symbols which the compiler will look for to determine your setup. These symbols must be defined in one of the following combinations:

CON symbol declarations (numbers are for example, can vary)	Effect	HUBSET %CC_SS **
`CON _clkfreq = 250_000_000` `_errfreq = 0`	Selects XI/XO-crystal-plus-PLL mode, assumes 20 MHz crystal. The optimal PLL setting will be computed to achieve _clkfreq. Compilation fails if _clkfreq ± _errfreq is unachievable. *	`10_11`

`CON _xtlfreq = 12_000_000`
`_clkfreq = 148_500_000`
`_errfreq = 150_000`
	Selects XI/XO-crystal-plus-PLL mode, along with frequencies.
	The optimal PLL setting will be computed to achieve _clkfreq.
	Compilation fails if _clkfreq ± _errfreq is unachievable. *
		`1x_11`

`CON _xinfreq = 32_000_000`
`_clkfreq = 297_500_000`
`_errfreq = 100_000`
	Selects XI-input-plus-PLL mode, along with frequencies.
	The optimal PLL setting will be computed to achieve _clkfreq.
	Compilation fails if _clkfreq ± _errfreq is unachievable. *
		`01_11`

`CON _xtlfreq = 16_000_000`	Selects XI/XO-crystal mode and frequency.	`1x_10`
`CON _xinfreq = 100_000_000`	Selects XI-input mode and frequency.	`01_10`
`CON _rcslow`	Selects internal RCSLOW oscillator which runs at ~20 KHz.	`00_01`
`CON _rcfast`	Selects internal RCFAST oscillator which runs at 20 MHz+.	`00_00`
`No symbol and not DEBUG mode`	Selects internal RCFAST oscillator which runs at 20 MHz+.	`00_00`
`No symbol and DEBUG mode`	Selects XI/XO-crystal mode and 20 MHz to facilitate DEBUG.	`10_10`

*	The _errfreq declaration is optional, since _errfreq defaults to 1_000_000.
**	If _xtlfreq >= 16_000_000 then x=0 for 15pF per XI/XO, else x=1 for 30pF per XI/XO.

During compilation, two constant symbols are defined by the compiler, whose values reflect the compiled clock setup:

Symbol	Description
`clkmode_`	The compiled clock mode, settable via HUBSET. ● For Spin2 programs, HUBSET will be invoked with 'clkmode_' before your program starts, in order to set the compiled clock mode. The 'clkmode_' value will also be stored in the hub variable 'clkmode'. ● For pure PASM programs, 'clkmode_' can be used to set the clock mode away from its initial

	RCFAST setting to any crystal/PLL compiled setting, as follows:
	
	`HUBSET  ##clkmode_ & !3    'start crystal/PLL, stay in RCFAST`
	`WAITX   ##20_000_000/100   'wait 10ms`
	`HUBSET  ##clkmode_         'switch to crystal/PLL`
	
	● The 'clkmode_' value may differ in each file of the application hierarchy. Files below the top-level file do not inherit the top-level file's value.

`clkfreq_`	The compiled clock frequency. ● For Spin2 programs, the 'clkfreq_' value will be stored in the hub variable 'clkfreq'. ● For pure PASM programs, 'clkfreq_' may be referenced only as a constant. ● The 'clkfreq_' value may differ in each file of the application hierarchy. Files below the top-level file do not inherit the top-level file's value.

For Spin2 programs, two hub variables are maintained which reflect the current clock setup:

Spin2 Variables	Description
`clkmode`	The current clock mode, located at LONG[$40]. Initialized with the 'clkmode_' value.
`clkfreq`	The current clock frequency, located at LONG[$44]. Initialized with the 'clkfreq_' value.

	● For Spin2 methods, these variables can be read and written as 'clkmode' and 'clkfreq'.
	
	Rather than write these variables directly, it's much safer to use:
	
	`CLKSET(new_clkmode, new_clkfreq)`
	
	This way, all other code sees a quick, parallel update to both 'clkmode' and 'clkfreq', and the clock mode transition is done safely, employing the prior values, in order to avoid a potential clock glitch.
	
	● For PASM code running under Spin2, these variables can be read and written as follows:
	
	`RDLONG  x,#@clkmode       'read clkmode into x`
	`WRLONG  x,#@clkmode       'write x to clkmode`
	
	`RDLONG  x,#@clkfreq       'read clkfreq into x`
	`WRLONG  x,#@clkfreq       'write x to clkfreq`
	
	`SETQ    #2-1              'read clkmode and clkfreq into x and x+1`
	`RDLONG  x,#@clkmode`
	
	`SETQ    #2-1              'write x and x+1 to clkmode and clkfreq`
	`WRLONG  x,#@clkmode`

For PASM-only programs, there is a special instruction named ASMCLK which will set the clock mode specified by the clock setup symbols. ASMCLK has no operands, but may be used with a conditional prefix. ASMCLK will assemble to one or six PASM instructions, depending upon the clock mode.

As of v35v, ASMCLK is no longer needed at the start of PASM-only programs, since a 16-long clock-setter program is automatically prepended to PASM-only programs which use any non-RCFAST (default) clock mode. This clock-setter program sets the clock mode, moves your PASM program down by 16 longs, then executes it by doing a COGINIT #0,#0, to effect a normal start.

If you'd rather not have the clock-setter program prepended to your PASM-only program, you can inhibit it by declaring constant _AUTOCLK = 0. Then, your code will begin executing with the default RCFAST mode. If you want to switch to another clock mode, you will need to configure the clock manually in your code, perhaps opting to use the ASMCLK instruction.

CON declarations (numbers are for example, can vary)	HUBSET %CC_SS	ASMCLK assembles to:

`CON  _clkfreq = 250_000_000`
`     _errfreq = 0`
	10_11	`HUBSET  ##clkmode_ & !%11    'start external clock, stay in RCFAST mode`
		`WAITX   ##20_000_000/100     'allow 10ms for external clock to stabilize`
		`HUBSET  ##clkmode_           'switch to external clock mode`

`CON  _xtlfreq =  12_000_000`
`     _clkfreq = 148_500_000`
`     _errfreq =     150_000`
	1x_11	

`CON  _xinfreq =  32_000_000`
`     _clkfreq = 297_500_000`
`     _errfreq =     100_000`
	01_11	

`CON  _xtlfreq =  16_000_000`	1x_10	
`CON  _xinfreq = 100_000_000`	01_10	
`CON  _rcslow`	00_01	`HUBSET  #1                   'switch to RCSLOW mode`
`CON  _rcfast`	00_00	`HUBSET  #0                   'stay in RCFAST mode`