arrayForth®
User's Manual

for G144A12 and EVB001

Rev 02b with polyFORTH®

Includes eForth 22a

Requires colorForth Kernel 4.2c

This manual is designed to prepare you for using arrayForth in designing, implementing and testing applications of our chips.

arrayForth is a complete, interactive software development and debugging environment for GreenArrays Chips. It includes assembler/compiler, example source code including all ROM on each chip, a full software-level simulator for each chip, an Interactive Development Environment for use with real chips, and utilities for creating boot streams and burning them into flash memory.

arrayForth runs on Windows®, Mac®/Parallels, and Linux/WINE platforms as well as selected native PC hardware. Although it is configured to support the GreenArrays EVB001 Evaluation Board, it may easily be used to program and debug our chips in your own designs.

Along with the above tools, including complete source code for the Virtual Machine environments, this release incorporates the source code for our Automated Testing systems as well as that which has been used in taking the characterization measurements reflected in the G144A12 Data Book.

Your satisfaction is very important to us! Please familiarize yourself with our Customer Support web page at http://www.greenarraychips.com/home/support. This will lead you to the latest software and documentation as well as resources for solving problems and contact information for obtaining help or information in real time.

Contents

1. Introduction to this Manual

This is the primary reference manual for the arrayForth programming environment. It should be read and understood in its entirety. In the interest of avoiding needless and often confusing redundancy, it is designed to be used in combination with other documents.

1.1 Related Documents

The general characteristics and programming details for the F18A computers and I/O used in the GA144 are described in a separate document; please refer to *F18A Technology Reference*. The boot protocols supported by the chip are detailed in *Boot Protocols for GreenArrays Chips*. The configuration and electrical characteristics of the chip are documented in *G144A12 Chip Reference.* The evaluation board has its own Data Book along with numerous Application Notes. eForth and polyFORTH are likewise documented separately. The current editions of these, along with many other relevant documents and application notes as well as the current edition of this document, may be found on our website at http://www.greenarraychips.com . It is always advisable to ensure that you are using the latest documents before starting work.

1.2 Status of Data Given

The data given herein are *released* and *supported*. The subject applications are under continual development; thus the software and its documentation may be revised at any time.

Supplemental information is available on our website at http://www.greenarraychips.com/home/support. This page is updated frequently and we recommend that you visit it regularly.

Much of the material in this manual has been compiled from contributions made by Chuck Moore and the late Jeff Fox. Originally in the form of HTML documents, many of which were linked on our website, experience has taught us that the material was difficult to access and study in that form. Therefore GreenArrays has replaced the HTML hierarchy with a single, comprehensive Guide.

1.3 Documentation Conventions

1.3.1 Numbers

Numbers are written in decimal unless otherwise indicated. Hexadecimal values are indicated by explicitly writing “hex” or by preceding the number with the lowercase letter “x”. In colorForth coding examples, hexadecimal values are italicized and darkened.

1.3.2 Node coordinates

Each GreenArrays chip is a rectangular array of ***nodes,*** each of which is an F18 computer. By convention these arrays are represented as seen from the top of the silicon die, which is normally the top of the chip package, oriented such that pin 1 is in the upper left corner. Within the array, each node is identified by a three or four digit number denoting its Cartesian coordinates within the array as *yxx* or *yyxx* with the lower left corner node always being designated as node 000. This convention is expanded to *cyyxx* on the EVB001, in which case *c* is chip number (0 for host, 1 for target). All functions herein accepting *yxx* notation also recognize *cyyxx* appropriately.

1.3.3 Register names

Register names in prose may be used with or without the word "register" and are usually shown in a bold font and capitalized where necessary to avoid ambiguity, such as for example the registers **T S R I A B** and **IO** or **io** .

1.3.4 Bit Numbering

Binary numbers are represented as a horizontal row of bits, numbered consecutively right to left in ascending significance with the least significant bit numbered zero. Thus bit *n* has the binary value 2^n. The notation P9 means bit 9 of register **P**, whose binary value is x200, and T17 means the sign (high order) bit of 18-bit register **T**.

2. Introduction to arrayForth

arrayForth is a system of software tools that may be used to develop, debug and install software for GreenArrays chips. This system runs on several platforms that provide the Win32 API: Microsoft Windows (XP, 2000 and later), as well as the Parallels environment on Macs and the WINE environment on Linux. Procedures and tips for installing and managing arrayForth on each of those platforms may be found in the Appendices of this document, supplemented by FAQ items on our website.

arrayForth is implemented as an application of the colorForth/386 system, which has a number of distinctive properties with which this manual will acquaint you. *To keep this manual simple, it is focused on working with F18 code for our chips. Therefore it touches only peripherally on the programming of the x86 host computer.*

2.1 What is colorForth?

Nearly forty years ago, Forth was developed as the world's first and, at that time, only practical, fully Integrated (and explicitly Interactive) software Development Environment (IDE). Decades later, the industry has made attempts to imitate such an environment, yet Forth remains the leader in both integration and interactivity.

Through a continual process of incremental change, Forth has evolved to meet new challenges in systems and applications programming. colorForth represents one evolutionary step, seeking to maximize speed of compilation and interpretation by minimizing the complexity of these processes. This has been accomplished by a novel approach to source language representation.

Every programming language devised in the past half century, including classical Forth, has defined its source language as a stream of characters. The syntactic elements of this source have been delimited by various punctuation characters. Processing the source requires parsing the stream, one character at a time.

colorForth represents the first known experiment in eliminating the task of parsing from the acts of program compilation and script interpretation. Instead of processing the source code one character at a time each time it is compiled or interpreted, the identification of syntactic elements is done once, by a cooperation between the programmer and the editor, when entering or changing the source.

Instead of storing the source as a stream of characters, the source is stored as a series of pre-parsed syntactic elements. Each pre-parsed word is stored, in binary, in the source file; part of this binary representation is a binary tag which indicates which of 16 syntactic elements the word represents. When source code is displayed, either on a screen or as HTML, each syntactic element is displayed in a characteristic color. Hence the name, colorForth.

The x86 Forth system underlying arrayForth was deliberately stripped down by Chuck Moore to suit his own purposes. It is not an ANS Forth, lacks many words and functions of classical Forth systems, and some words such as **-** *and* ***or*** *have unconventional functions. Focus on programming the F18 since the x86 system will be supplanted entirely later on.*

2.2 colorForth human interface

The above characteristics of colorForth imply a new human interface using a conventional keyboard and display.

2.2.1 The Interpreter

The interpreter is the default program you will be communicating with using the keyboard and display. It accepts words and numbers, one at a time, as you type them. Numbers are pushed onto the stack; the top few elements of the stack are shown at the bottom of the screen. Words are executed when you type them. If a word is not found in the dictionary, that word, followed by a question mark, is shown in the bottom right quadrant of the screen. This process is called interpretation.

The word you type might be a simple definition such as **+** which replaces the top two numbers on the stack with their sum. So for example if you had typed **5** and then **6** the stack display will show **5 6** and if you then type **+** the stack display will now show **11** .

The word may do a great deal more. It might compile and run an extensive utility or application, which might put up a customized graphic or text screen, and might give you a completely different keyboard interaction while it is running. The colorForth editor is such a program.

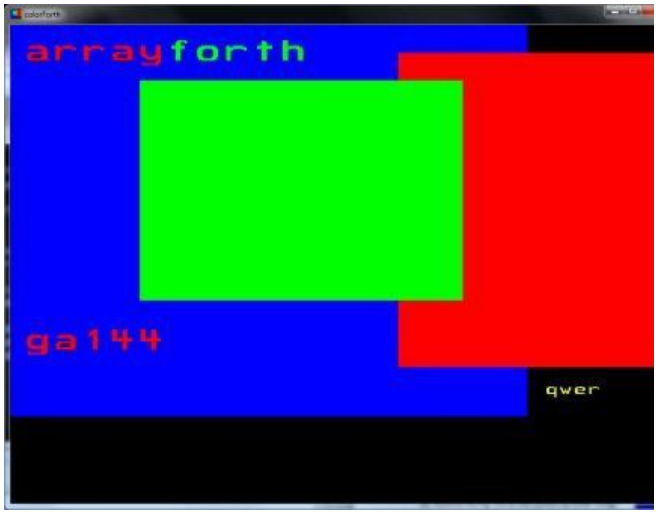
When any colorForth word or program you have invoked from the keyboard completes, control always returns to the keyboard interpreter.

2.2.2 Keyboard and display

Your interaction with colorForth is accomplished by using a PC keyboard and a graphic display. As you will see, colorForth has unique human interfaces and we are continually experimenting with improvements to them. In fact, each colorForth application may define its own customized human interface if desired.

Situational awareness is very important in colorForth! The meaning of pressing a given button on the keyboard varies as your actions change the system from one state to another. With this economy of motion comes the requirement that you maintain a heightened awareness of system state from keystroke to keystroke. With only a very few exceptions, the system state and the meanings of the keyboard buttons are apparent from a glance at the screen once you are familiar with colorForth. Until you are, however, use caution as you would when learning any other new psychomotor skill! For example, quickly drumming the keys in frustration would yield only **laksjdf** *on a plain old text editor which could easily be un-done with backspaces. However, in the colorForth editor such non-deliberate use of keys can have truly amazing, unintended consequences, and by the time the actions have been taken you may have to audit your whole disk to find out what you have wrought. We recommend that you keep cats and small children away from your keyboard when colorForth is running!*

Most people find that once they have mastered this new skill it works well for them, and that with the simple but powerful set of tools in colorForth it's a pleasingly productive environment. Take your time getting accustomed to it, and it should serve you very well.



We'll start with the Interpreter interface since it's the first thing you encounter and contains good examples of the common display elements. Here is what you see on booting arrayForth. The display is composed of two major elements: The logo, with the `arrayforth` label, and the interpreter's feedback which is shown in the black areas at the bottom of the screen. The annunciator reading **qwer** is part of this feedback. The feedback is comprised of several components, discussed below.

The first of the two major elements, the logo, may be replaced during use of the system by other things such as the listing of a block. The interpreter simply displays this element, whatever it is, with the interpreter's feedback superimposed over it. The entire screen is refreshed, from whatever raw data each part is based on, each time you strike a key; thus, the effects of interpreter interaction may be seen right away when they occur.

2.2.2.1 Interpreter Feedback Area

Here is an example of what you will see at the bottom of the screen when using the Interpreter:

The annunciators **qwer** and **text** are part of a keyboard / control panel hint rectangle at the lower right corner of the screen. The word **png** is feedback showing the word most recently typed; it changes as you key additional characters of a new word. The number **50389** shows the stack content; it is presently the only item on the stack. While you are typing a word or number, the binary value of that number or encoded values(s) of the word are shown at the top of the stack (top is on the right.)

Here is what you see if you have pushed three numbers, one through three, onto the stack and then typed **png** to capture the screen:

If there are more than five elements on the stack, only the top five are shown with an ellipsis (**...**) on the left side of the line. Here is what you see if you have pushed six numbers, one through six, onto the stack and then typed **png**:

When the stack is empty, the bottom line is simply blank. If items are removed from the stack when it is empty, this condition is indicated as follows. In this example, the stack was cleared, then the word **drop** was executed three times, after which the word **png** was typed to capture the screen:

You may clear the stack at any time by typing the word **c** .

If you type a word that the interpreter cannot find in the dictionary, a question mark is appended to the display of the most recently typed word. Here is an example resulting from trying to interpret an unknown word **poobah** :

The question mark is also inserted if an abort condition occurs while executing a word from the interpreter. When the word in question causes code to be interpreted or compiled, such as **load** , the system attempts to place the editor's cursor at the point of difficulty; in that case, typing e to enter the editor, as discussed later, will give you more information.

2.2.2.2 Keyboard / Control Panel Hint Area

What you see in this area depends on the application with which you are interacting. Some applications are operated by pushing buttons on a keyboard "control panel" rather than by typing text; some examples of this are the OKAD chip layout tools, softsim, and in fact even the Editor. In other contexts, the keyboard is being used for input of text (words, numbers); examples are the Interpreter, and the editor when you have selected a color for text entry. Such cases are called *text entry mode*.

In *text entry mode*, by default colorForth uses a "QWERTY" keyboard whose operation is as close as practical to the behavior of a conventional typewriter keyboard and will be most familiar to those who have been trained as touch typists in that system. Another, optional keyboard is available for text entry: The special "dvorak" keyboard developed by Chuck Moore to minimize the number of buttons and amount of hand movement required. Its use is described by an application note available from our website. During text entry mode, the annunciator **`qwer`** in the hint area shows that the QWERTY keyboard is in use.

2.2.3 Using the Keyboard

When you begin *text entry mode*, the hinting area displays the annunciator **`qwer`** and you may enter words or numbers, one at a time. The software is designed to behave as simply and naturally as feasible in the majority of cases.

After typing a word or number you may *enter* it using the **space bar**, or alternatively the **enter** key (some may know it as **carriage return**) . The keyboard normally continues in text entry mode, expecting you to enter another word or number. However, when in the Interpreter, the word you just entered may run another application which can redefine keyboard operation until you return to the Interpreter, as we'll see later.

To erase a word or number *before you have entered* it, use the **backspace** key. To exit *text entry mode*, use the **escape** key. This doesn't do anything in the Interpreter, but some applications, such as the Editor, can "call" the text entry mode and in those cases you need to indicate when you are through by using **escape**. Note that at present escape will not erase current input, and backspace will not exit the text entry word. This is easy to forget.

When you begin typing a word or number, the keyboard software needs to determine which you are entering. Like classical Forth, colorForth allows you to define words that start with numeric digits, or even words that consist entirely of numeric digits. The keyboard software makes its decision with the first key you strike:

- if the key is a decimal digit **`0..9`** then you are entering a number; the key is interpreted as a digit, that digit is displayed on top of the stack, and a **`num`** annunciator is displayed in the hint area. Subsequent keystrokes must be digits and will be "shifted" into the displayed number using the current radix. The **`-`** key negates the number being entered and may be used repeatedly to toggle its sign. All numeric input is restricted to 32-bit values. As you type more digits, the result will be clipped modulo 2^{32}.
- If the key is any of the other 37 colorForth characters **`a..z !'*+ ,-./ ;?@`** then you are entering a word; the character is displayed to the left of the hint area, a Shannon-coded value consisting of that character is displayed on the top of the stack, and a **`text`** annunciator is displayed in the hint area. Subsequent keystrokes may be any colorForth character and will be appended to the displayed word to the left of the hint area as well as being added to the Shannon-coded representation on the stack. If another number appears on the stack while you are typing, this informs you that the last character you typed caused the Shannon-coded value to exceed one 32-bit number. That's all right, but is important to know about when creating Forth definitions to keep them unique; see 3.3.1, Syntax of colorForth, below.

The behavior above allows you to just type words and numbers naturally in the great majority of cases. There are only two situations that require you to do anything more:

- **Negative Numbers:** The keyboard software considers the minus sign **-** to be an alphabetic character when it's the first keystroke seen. Thus, simply typing **-123** results in a word, not a number. To enter a negative number, the minus sign has to be entered sometime after the first digit. So you can enter the value that was desired above as **123-** .

  We could have made it go the other way, but there are too many Forth words that start with a minus, such as the one's complement operator **-** , to justify this.

- **Words that start with a digit:** You can force the keyboard software into text mode by using the grave accent **`** key. This is typically on a button immediately to the left of **1** . After pressing it, the **text** annunciator turns on in the hint area, and the next character entered will be taken to be the first character of a word.

Decimal and Hexadecimal

There is a persistent flag indicating whether the human interface is in decimal or hexadecimal mode.

- **Decimal Mode** By default the human interface is in decimal mode. The stack is displayed in decimal, each digit you key into a number is shifted into it using base 10, and the only keys accepted during number entry are **0** through **9** and the minus sign **-** .

- **Switching Modes** You may place the human interface in hexadecimal mode by pressing the **F1** key. Actually this key toggles between decimal and hexadecimal mode. The **F1** key is recognized any time the hint area shows just the **qwer** annunciator, or both **qwer** and **num** . It instantly sets the other mode, affecting the stack display and subsequent digit entry. When taking text input in hexadecimal mode, the hint area shows **hex** .

- **Hexadecimal Mode** When in hexadecimal mode, the stack is displayed in unsigned hex. Each digit you key into a number is shifted into it using base 16. *The first digit of a hex number must be one of the decimal digits* ***0..9*** , but once number entry has begun any of the hex digits **0..9 a..f** or the minus sign may be entered. Thus, to enter the hex equivalent of 255, type **0ff.**

2.2.4 Message Area

A program may display a message informing you of an error or prompting some action of you. Such messages may be displayed on the left side of the line on which the words you type are shown, as in this example:

Transitory messages disappear after you have typed a few keystrokes. Other messages may be more persistent, as desired by the software generating them. To manually kill a message being displayed, type **-msg** .

2.3 arrayForth User Vocabulary

This section lists resident words (those accessible after **empty**) that are relevant when operating arrayForth and when using it to program the F18. These are all x86 functions, not F18 functions; for F18 compiler syntax see section 5.3 below Unless otherwise noted, you will normally use these words at the keyboard or use them in yellow when edited into source blocks such as scripts for the x86 utilities. Do not assume you know what a Forth word does until you have read it in this Manual! *Words and conventions necessary for programming the x86 are not listed here. x86 colorForth programming involves unusual conventions, such as the way in which macros interact with compilation and interpretation, and the semantics of words like* **if** *and* **next** .

System Control

boot resets CPU sending it back to the BIOS. *Native only*.

warm restarts the kernel, emptying dictionary and interpreting block 18.

c clears the stack, also corrects stack underflow.

pause lets the background task run. Practical use is to update display.

abort terminates program execution. The last word interpreted from keyboard is displayed with a question mark. The editor is positioned if possible to indicate the source of the trouble. The top stack item is discarded.

qwerty selects standard keyboard layout and operation.

seeb toggles between visibility and invisibility of blue words.

r? (-n) returns the number of words on the return stack.

bye closes files and exits arrayForth. *Win32 only.*

a-com (-n) returns the COM port number for EVB001 USB port A.

a-bps (-n) returns the baud rate desired for USB port A.

c-com (-n) returns the COM port number for EVB001 USB port C.

c-bps (-n) returns the baud rate desired for USB port C.

-msg stops any active display in the message area.

named (_) sets an ASCII pathname in fnam for use by utilities. The pathname is a single word that may be up to 79 characters long. From the keyboard the word will be yellow; in source code it should be white. Character transformations are made from cF {**;** **'**+@?*} to ASCII {**:**"=<>} and space.

Dictionary Management

mark saves the present state of the dictionary for later restoration by **empty** .

empty restores the dictionary to the most recent **mark** .

remember a class definer. The words in its class save the present state of the dictionary following their definition and when executed restore the dictionary to that point. Use: **reclaim remember** .

here (-b) returns byte address of next available byte in dictionary.

h (-a) a variable whose value is returned by **here** .

, (n) appends the given 32-bit word to the dictionary.

' (_-b) tick. Returns byte address of the definition whose name follows. Use from keyboard or in a block.

fill (wan) fills memory for n words starting at a with the value w .

move (sdn) copies n consecutive words from word address s to word address d.

Words Usable in Blue

cr starts a new line in display.

br double spaced break in display.

-cr prevents new line on next red word.

indent starts a new line indented three spaces.

Interpreter Control

load (b) interprets block b , normally an even number.

loads (bn) interprets n consecutive source blocks starting with block b .

thru (f l) interprets consecutive source blocks f through and including l .

finish interprets the current editor block starting at the editor's cursor position.

fh (i-n) "from here" used to simplify relocation of chunks of code including their load block; when interpreted from a block, returns sum of that block's number and i . When interpreted from keyboard, returns sum of i and the current editor block number.

exit causes the interpreter to stop processing a block when it is encountered.

orgn (-a) a variable used to register utilities that should be reloaded after recompile has compiled F18 source code.

Editor - See 3 below

Mass Storage - See 4.2

Utility Block Names

floppy (-n) Floppy disk utility. *Native only.*

icons (-n) Character font editor.

audit (-n) Disk audit utility. See section 4.2.1 below.

index (-n) Index writer. See section 4.2.3 below.

html (-n) HTML writer. See section 4.2.2 below.

host (-n) IDE for host chip over port A. See 6 below.

target (-n) IDE for target chip over port C. See 6 below.

serial (-n) IDE for use by other applications. See 6 below.

streamer (-n) Boot stream utility. See 8.1 below.

softsim (-n) F18 code simulator. See 7 below.

so (-n) abbreviates `softsim` .

Utility Effectors

compile compiles all active F18 source code; see 5.2 below.

recompile uses compile to recompile all F18 source then reloads the utility registered in `orgn` .

dump (a) displays a specially formatted dump starting at the given word address.

png Writes a screen shot. See section 4.2.2 below.

selftest (n) runs IDE selftest on a chip over the given COM port number. SPI flash boot must not be enabled on that chip.

autotest (n) Given host chip's IDE port number, runs ATS tests of the target chip using sync boot and tests SERDES between the chips.

Stack and Arithmetic

@ (a-n) fetches a word from RAM at the given word address.

! (na) stores n to RAM at word address a.

+! (na) adds n to RAM at word address a.

dup (a-aa) duplicates top item of stack.

drop (a) discards top item of stack.

nip (ab-b) discards second item of stack.

over (ab-aba) pushes a copy of the second item onto the stack.

swap (ab-ba) interchanges the top two stack items.

and (nn-n) bitwise logical AND of two 32-bit values.

negate (n-n) returns twos complement of a 32-bit number.

2/ (n-n) arithmetic right shift of a 32-bit number by one bit.

+ (ab-c) returns the 32-bit sum of two 32-bit numbers.

*** (ab-c)** 32-bit product of a and b.

/ (ab-q) 32-bit signed quotient a/b.

***/ (nab-n)** multiplies a number n by the ratio a/b.

abs (n-n) takes absolute value of a 32-bit signed number.

min (ab-n) returns lesser of two 32-bit signed numbers.

max (ab-n) returns greater of two 32-bit signed numbers.

v+ (vv-v) sum of 2-vectors each consisting of 32-bit signed components.

Watch Out for These!

- (n-n) Not subtraction! unary ones complement, like ANS Forth INVERT .

or (nn-n) bitwise EXCLUSIVE OR of two 32-bit values. Same as ANS Forth XOR .

+or (nn-n) bitwise INCLUSIVE OR of two 32-bit values. Same as ANS Forth OR .

Chip Configuration Words

nnx (-n) number of node columns.

nny (-n) number of node rows.

nns (-n) number of nodes/chip.

nnc (-n) number of object bins.

nn-n (nn-n) convert cyyxx to linear node number on chip 0.

n-nn (n-nn) convert linear node number to yyxx notation.

@rom (nn-n) return ROM source load block for node given in cyyxx notation.

3. The Editor

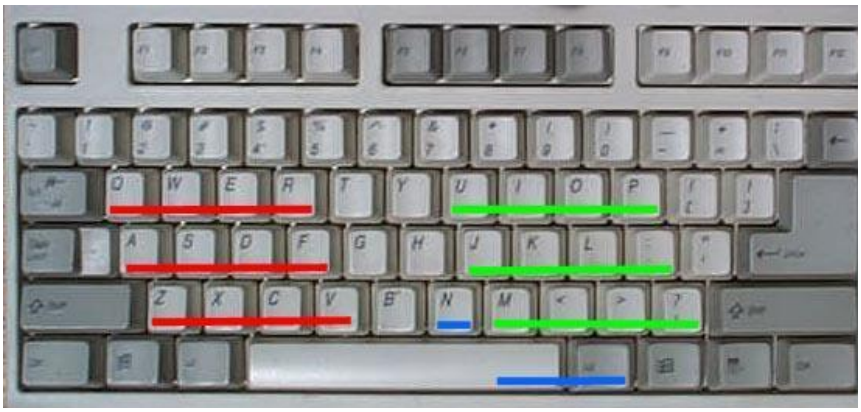
To invoke the editor from the interpreter, first enter a block number; let's say, 18. When you have done this, the number 18 will appear at the top of the Interpreter's stack display. *Do not attempt to edit blocks 0 through 17; these contain binaries and listing binaries can cause the windows version to trap.*

Now type `edit` .

You will see the source code in block 18 and the number 18 will be displayed above the editor control panel hint map (displayed in the lower right corner of the screen) indicating that the keyboard is now serving as a control panel. The block number is red when the editor is active, changing to grey when exiting the editor.

3.1 Control Panel

The editor is operated by pressing buttons on a control panel. All control panels in colorForth are built from the same set of 27 keys; only the assignments differ. These keys are as follow:



The hint map depicts the keyboard; the top three rows represent the red and green areas shown at left, while the bottom row represents the blue area.

When used as designed, left and right hands rest in the standard keyboard "home" positions with the left hand's four fingers on the center red row and the right on the center green row. Fingers of each hand are responsible for the red and green rows above and below the "home" positions. The thumb(s) (or right forefinger) press the qwerty keys "N", "Spacebar", and "Alt", marked blue. The key table below names the function of each control panel key, in colored functional groups, with hint character on top and QWERTY keycap labels in grey at the bottom of the key.

unused (Q)	unused (W)	unused (E)	w **White text** (R)		y **Yellow text** (U)	r **Red text** (I)	g **Green text** (O)	* **Show src or shadow** (P)
c **Change color** (A)	d **Find Defn or ref** (S)	f **Find next of same** (D)	j **Jump to prev block** (F)		l **Left cursor** (J)	u **Up cursor** (K)	d **Down cursor** (L)	r **Right cursor** (;)
a **Address in grey** (Z)	b **Blue text** (X)	unused (C)	k **Copy word** (V)		- **Back up 2 blocks** (m)	m **Magenta variable** (,)	c **Cyan text** (.)	+ **Forward 2 blocks** (/)
				x **Cut word** (N)	. **Exit editor** (space)	i **Insert word** (alt)		

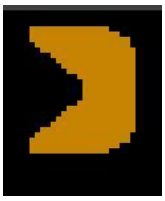
3.1.1 Exiting and re-entering the Editor

The key hinted as [.] (Exit editor) exits the Editor, returning control to the Interpreter and changing the red block number displayed above the hint area to grey. To return to the Editor, you may type `e` or enter a new block number and type `edit` . The editor may also be entered using the vocabulary for finding source, described later below, or by other utilities. You can always tell that the editor is active and that keystrokes will edit the current block when the number above the hint map is shown in red.

3.2 Navigation Commands

Navigation keys, highlighted in green in the keyboard table, move the editor from block to block and move the cursor within a block.

3.2.1 Cursor Control



When the editor is started for the first time the cursor appears in the upper left corner of a block. If there is text in that corner it will appear on top of the cursor. If the cursor is moved to the right it will be placed in the first space to the right of the first word.

The cursor resembles a "Pac-Man" character poised to "munch" the word to the left when the [x] (Cut word) key is pressed. Strings of text can be cut by repeatedly pressing or holding the [x] key

[l u d r] (Left, Up, Down, and Right cursor) keys under the fingers of the right hand move the cursor in units of words, not characters. The cursor cannot be moved above the top of the screen but it can be moved below the bottom of the screen. If the cursor is not visible, hold down the Up cursor key. It should always appear eventually.

Note that the Up and Down keys do not make precise up and down movements. Instead, they move eight words to the left or right respectively if possible.

3.2.2 Block Navigation

To begin editing some other arbitrary block, exit the editor and re-enter using `edit` as was described earlier. For local navigation the Editor supplies the following:

[j] (Jump to previous block) alternates between the last two blocks that you edited with the word `edit` . The traditional variable `blk` contains the number of the current block being edited, and is unchanged when you exit the editor. `blk 1 +` contains the number of the block that was current the last time `edit` was used. In addition to alternating the displayed block, the "j" key alternates these two values in `blk` .

[*] (Show source or shadow) toggles between even (source) and odd (shadow) blocks while editing. Each shadow block is intended for documentation of the source code in the corresponding even block. Since odd numbered blocks are not normally compiled, colored words on those blocks are intended to be comments only and may be used as desired to enhance readability.

[-] (Back up 2 blocks) and [+] (Forward 2 blocks) move the editor two blocks up or two blocks down. The editor will not decrement the block number to be edited below 18. More advanced navigation is supplied by the Search Utility; see below.

3.2.3 Copying Blocks

To copy an entire source block and its shadow, first display the source block that you want to copy using the editor, so that its number is in the variable `blk` . Then, exit the editor; put a destination source block number on the stack, and type `copy` . The first block, and its accompanying shadow, will be copied to the destination. If you want to edit the copied block just type `e` as `blk` will now be set to the number of the destination block.

3.3 Text Entry Modes

Text entry keys, highlighted in yellow in the keyboard table, select a color and put the editor and keyboard into text entry mode. In this mode, words and numbers you type are inserted into the current block at the cursor position and in the selected color. *To determine the current state of the keyboard, look in the hint area; if you see the editor control panel, buttons will be editor functions, whereas if you see text entry mode hints, you are entering text.* To return to the Editor from any text entry mode, use the **escape** key as described in section 2.2.3 above. The text entry keys are as follow:

[**w**] (White text) enters comments, which may be words or *small (27-bit signed) numbers* in decimal or hex. The Interpreter and Compilers ignore these words while the Editor simply displays them. Comments may contain any of the colorForth characters.

[**y**] (Yellow text) enters text that will be *interpreted* when blocks are loaded. Text may consist of words or numbers, and the numbers may be in decimal or hex. Words are executed, and numbers are placed on the stack.

[**g**] (Green text) enters text that will be *compiled* when blocks are loaded. Words are compiled in the form appropriate to the system for which compilation is being done; numbers are compiled as literals. Within F18 code, the distinction between green and yellow words becomes narrower than that.

[**c**] (Cyan text) enters words only. Not relevant for F18 code, but analogous to POSTPONE in ANS Forth when compiling x86 code.

[**r**] (Red text) enters a red word (labels a point in memory as a Forth definition) and switches to Green text entry to facilitate entering the body of the new definition.

[**m**] (Magenta variable) enters a magenta word that, when loaded, defines a variable whose value is actually stored in the source block itself and which is displayed in green, in decimal, when the source block is displayed. Not relevant for F18 code.

[**b**] (Blue text) enters words that are ignored by the Compilers and Interpreter, but which are *executed* by the source block display. Normally this is used for source code formatting but it may also be used to turn a source block into a sort of *data view*. Use care in entering blue words; unless you know what you are doing or are writing your own blue words, use only the following in blue: `cr br -cr` and `indent` as well as the new, preferred blue words introduced in Rev 01d: `,` (comma) `. .. ...` (one, two, and three dots), and `*` (star).

[**a**] (Address in grey) enters a special word that is *only* relevant in F18 code. Any short word (four characters or less) may be used; the word itself does not matter nor is it ever displayed in its own right; instead, it will be displayed as a faint grey, hex value in a special format. If the block is loaded by the F18 Compiler, the Compiler stores the value of its location counter at the point where the grey word occurs in the source into the text representation of the grey word in its source block for subsequent display by the Editor.

3.3.1 Syntax of colorForth

As stated in section 2.1 above, colorForth source is pre-parsed by cooperation between you and the editor. Your contribution to this process is selection of the appropriate color for each word and number you type, using the above text entry modes. In this way you will control what the Interpreter, Compilers, and Editor will do with each word when it is encountered.

When a block is loaded, red words are the names of new defined words, like the names that follow `:` (colon) in traditional Forth. Green words are words being compiled, like the traditional code between colon and semicolon. Yellow words are interpreted like code outside colon definitions and code within square brackets inside definitions. Magenta words are variables, and cyan words are like "postponed" words in ANS Forth (calls to macros).

Numbers can be entered in green (compiled), yellow (interpreted) or white (comments), and may be entered in hex or decimal. Hex numbers will appear in a darker green, darker yellow, or darker grey than decimal numbers, and may be italicized when the display medium permits.

If you intend to enter a number but enter a character string that resembles a number instead, it cannot be visually distinguished from a decimal number as it will be the same shade of yellow or green. But when you load the block unless you have actually defined a red word or magenta variable with a name that can be confused for a number, which is generally not a good idea in the first place, you will get a compiler error message that it did not recognize the string (that looked like a number) as a defined name.

x86 colorForth has two wordlists (forth and macro), where the macro words behave like IMMEDIATE words in classical Forth. It is an optimizing system so the Compiler and Interpreter make different uses of the two lists and there are rules about which has precedence; for example, *If the same word is both a macro and a forth word, the macro will always be found when compiling (green or cyan) and the forth word will always be found when interpreting (yellow).* Macros are only relevant in x86 code. In both F18 and x86 code, the dictionary records only the first 32 bits of identifiers (see 2.2.3, Using the Keyboard). Thus, the words **atlanta atlantis** and **atlantic** are all identical in colorForth.

A transition from green words to yellow words and back to green words causes a single word literal to be generated by the x86 compiler. This too is irrelevant in F18 code but is mentioned only to reduce confusion when reading x86 code.

Blue words are a new feature of colorForth. They are *interpreted while displaying a block*. They can format the display with `cr` `br` `indent` etc. or execute custom commands while viewing a screen. The word `seeb` in block 18 is "see blue" and when yellow will execute at boot time and make blue words visible in the editor. If `seeb` in block 18 is white then blue words will not be visible but will execute when a block is displayed. After the system has booted, you may execute `seeb` at any time to toggle the display of blue words on or off. In Rev 01d, new blue words that are not actually in the dictionary have been added for greater control over source formatting. The words `.` `..` and `...` take exactly one, two, or three spaces whether or not they are being displayed; leading and trailing spaces are suppressed. The word `,` takes exactly one space, suppressing leading spaces and starting a new line. The word `*` is intended for use immediately preceding a red word; it takes exactly one space, suppressing leading and trailing spaces, and suppresses the automatic new-line on the following red word. Because these new words suppress spaces, the cursor behaves differently when positioned to them. *As of Rev 01d, only authorized blue words are interpreted. Note that older systems may crash when trying to display code containing these new words because they lack that protection.*

3.4 Manipulating Text

The Editor has an *insert buffer* of finite size (18 Kbytes) for holding code that has been "cut" or "copied" for later "pasting". The buffer is cleared by `warm` and, on the native system, by floppy operations. The buffer works like a stack. The buttons that control this are:

[`x`] (Cut word) deletes the word to the left of the cursor and pushes it into the insert buffer stack. Successive depressions continue deleting toward the left.

[`k`] (Copy word) skips over the word to the left of the cursor and pushes it into the insert buffer stack. Successive depressions continue copying toward the left.

[`i`] (Insert word) pops a word from the insert buffer stack, inserting it at the cursor position and moving the cursor to the right. Successive depressions continue laying down code so that it will appear in the same order it had been in when cut or copied.

You may wish to change the color of a word without having to retype it, such as commenting a string of code by turning it white, or entering source code all in green as a single text entry session and then coming back to make comments white and things like variable references yellow. A special control panel button assists with this:

[`c`] (Change color) cycles the word to the left of the cursor through an appropriate cyclic sequence of colors, based on its present color. If the word in question is not a member of a reasonable sequence, its color is not affected by this button.

3.5 Search Utility

A resident set of utility functions, integrated with the Editor, facilitates searching the source in several practical and useful ways. When in the Interpreter, there are four words for starting a search, and one for continuing it. The words for starting the search are `find` `def` `from` and `literal`.

When a search is started, we begin at block 18 (except in the case of `from`) and scan forward looking for the particular target. If it is not found, we remain silently in the Interpreter. If it is found, we enter the Editor with the cursor set at (immediately to the right of) the target.

Once a search has been started, it may be continued from the point of the last target found by using the "f" control panel key, if in the Editor, or by typing `f` in the Interpreter. In either case, a successful find will display a block, while a failure to find will be as though you had done nothing at all.

When continuation is begun using the word `f` In the Interpreter, searching resumes at the point of last find in that same search. When continuing using the "f" control panel button in the Editor, the search resumes at the current cursor position in the current block, so you have more control in this case.

The searches continue up to the end of your disk image as defined by the three variables at the start of block 18. *Do not attempt to change these variables at this point in your study!*

The searches automatically consider only blocks of the same sort (source or shadow) as the block in which the search was started or continued. Thus, searches normally start with source only; they will never consider shadows unless you force them to using the word `from` with an odd block number, or by using the Editor's "f" key while looking at a shadow. To search all shadows, start a search normally, then edit block 19 and use the Editor's "f" key to continue.

3.5.1 Interpreter Search Words

`find` awaits a word from the keyboard and starts a new search for that word. It will find all instances of that word as a definition (red or magenta), reference (green, yellow, blue, or cyan), or any sort of comment.

`def` awaits a word from the keyboard and starts a new search for that word, as a definition (red or magenta) only.

`from` takes a number from the stack for use as starting block. It then awaits a word from the keyboard and starts a new search for that word, in any form as in `find` using this starting block.

`literal` takes a number from the stack and starts a new search for that value as a green or yellow number, matching its numerical value (regardless of whether displayed as decimal or as hex.)

`f` continues the most recently started search immediately after the point at which the last target was found in that search.

3.5.2 Editor Search Keys

"f" control panel key continues the most recently begun search, at the current editor cursor position. If the current block is source, only source will be searched; if it is a shadow, only shadows.

"d" control panel key starts a new search based on the word immediately preceding the cursor, as follows:

- If the word is a definition (red or magenta) then the new search will be for references (green, yellow, blue, or cyan) to that word.
- If the word is a reference or a white comment, then the new search will be for definitions of that word.
- If the word is a literal number, then we do not search as such but simply edit the block by that number. Handy for use in load blocks!

4. Mass Storage

arrayForth mass storage is organized in fixed length *blocks* of 1024 bytes (256 32-bit colorForth tokens.) By the classical Forth convention, blocks are addressed linearly starting with zero. x86 arrayForth block space is entirely implemented in RAM on the host system. Blocks 0 through 1439 are read from a disk or a file when the program loads, and are only written out as you instruct. Internal block address space continues beyond 1440 for various purposes; see section 10.4, Memory Map, for more information.

4.1 Disk Organization

The 1440 blocks of arrayForth are subdivided organizationally into twelve sections of 120 blocks each. Such a section is called an index page, so named because 60 lines fit well on a printed page. Each release of arrayForth includes an index listing showing the first line of each source block, delivered in a Word document named EVB001-rls-index.doc. For the purpose of this discussion, please refer to the reference copy of the index listing for this software release in section 10.4 below. The gross assignments for each index page are as follow:

Start Block	Purpose	Description
0	colorForth System	Host system words, utilities, load blocks
120		
240	Code Modules	SRAM cluster, Streamer. Also IDE scripts for setting DC test conditions
360	polyFORTH	Virtual machine for polyFORTH system.
480	ATS Chip tests	Production test modules packaged for self-test use.
600		
720	ATS plumbing	I/O support for Automated Testing Subsystem (production chip test)
840	User	Available for user code
960	User	Available for user code
1080	eForth	Virtual machine for eForth system.
1200	Modules, softsim	Softsim and some ROM code
1320	Compiler, ROM	F18 compiler and source code for chip ROM.

Since we are of the opinion that one of the fastest and best ways to learn a new machine or system is to study others' code, we have included a great deal of material here that you may delete if you need the space or find it of no interest. All of the code from 360 to 1200 is potentially of this sort..

The DC test condition scripts at 300 are for study only. polyFORTH and/or eForth may be deleted if you do not plan to use either. The ATS chip tests are provided to disclose exactly what we test in production chips; in addition tools are included to actually run these tests on either or both chips of the EVB001 insofar as is possible without the special I/O pin testing circuitry of the ATS test fixtures. The ATS plumbing, when complete, will be included for study as well.

We will now discuss several configuration blocks of particular interest.

`Blocks [0..12[` The first twelve blocks are reserved for the native system's colorForth kernel and boot.

`Blocks [12..18[` These six blocks hold the binaries for the fonts used on the colorForth display.

`Block 18` This load block defines the configuration of the colorForth system and application. It is loaded on cold or `warm` boot, compiling various extensions to colorForth, giving names to utilities, and loading blocks 144, 202 and 204 to complete the definition of the arrayForth environment. *The three magenta variables at the start of this block (**`ns nblk nc`**) must never be moved. Use great caution if altering block 18 or anything it loads since if this sequence is aborted early enough the editor is not available to fix the problem.* The yellow word `qwerty` in this block configures the system for standard keyboard layout and semantics; the yellow word `seeb` immediately following **`qwerty`** configures the system to display blue words. These are the recommended settings.

Block 144 This load block extends colorForth to support the arrayForth tools with global variables, extra functions, names of further utilities, resident capability to generate png files of screen graphics, and the principal chip configuration parameters from the three blocks 190, 192, and 194.

Block 202 This block defines application tools and is maintained by GreenArrays. When you have identified the COM port numbers corresponding to the three USB ports on the Eval Board, you will need to edit the values for **a-com** and **c-com** to be the COM port numbers for USB ports A and C, respectively. The baud rates for these ports are specified here as well.

Block 204 This block is yours, for any definitions you wish to make global so that they survive empty . Before adding a word to this block, make sure it does not redefine anything else that lies under the empty! Use **def** and **' (tick)** to verify no redefinitions.

Block 200 This is also yours, for compiling F18 code as described in section 5.2 below.

Block 148 is the load block for softsim. At present it's necessary to alter this block to control what code is loaded and executed in each node.

By reading the system load blocks starting with 18 in load order you will be able to follow the process of booting arrayForth and become familiar with its components.

To find the ROM code for SPI node 705 for example, type the phrase `705 @rom list` . **@rom** takes a node's cyyxx coordinates and returns the number of its ROM load block.

4.2 Tools for Managing Disk

Some classical Forth words are available:

block (n-a) returns the word address of block n in memory.
list (n) displays block n as source without entering the editor control panel.
l displays the current editor block as done by `list` .

qx (n) displays leading comments for the index page of 60 like blocks containing n . *When the audit utility is loaded, blocks differing between working and backup areas are shown in red.*
nx displays the index page following the current page.
bx displays the index page preceding the current page.
sx alternates between source and shadows for the current index page.
ox alternates between an index page based at 0 and corresponding page in backup area at **abuf** .
ax displays the index page in which the current editor block lies.

In addition, arrayForth provides these resident functions:

onamed (_) Sets an ASCII pathname for the working source file, by default named OkadWork.cf .
bnamed (_) Sets an ASCII pathname for the backup source file, by default named OkadBack.cf . Usage and character transformations are the same as for `named` .

save writes 1440 blocks from host RAM to the working source file in compressed format.
flush synonym for `save` to simplify concurrent use of arrayForth alongside polyFORTH.

@back (n) reads a colorForth compressed or uncompressed image, max 1440 blocks, from the backup source file to RAM disk at block n . On native system, reads from a floppy.
!back (n) writes 1440 blocks from host RAM block n to the backup source file with no compression. On native system, writes to an uncompressed floppy.
wrtboot writes 18 blocks of kernel and icons to the start of a floppy (Native only).
erase (bn) stores all zeroes into n consecutive blocks starting at block b .

4.2.1 Audit Utility

The auditing utility is a stand-alone set of tools that begins with `empty` and then compiles a temporary set of words. Portions of the utility are designed to integrate with features already in the resident editor. It is important to remember that the audit utility is not itself part of the editor's control panel mode, even though there are audit functions that will leave you in the editor. With one exception you must exit the editor in order to access any of the functions described below. How you use the utility will depend upon your needs at the time. It is appropriate for use when merging changes made by two people, for rolling back an accidental or ill-conceived change to your working file, or to confirm or document the complete set of changes incorporated into an internal release level.

The utility is compiled by typing `audit load` . To begin to examine all differences between working and backup source files, say `check all` . `check` will decompress the backup file if required and read it into the block space at abuf (10000). `all` sets up boundaries to limit your comparison to matching the 1422 blocks beginning with 18 to the 1422 blocks beginning with 10018. It begins searching from 18 stopping at the first differing block pair. It puts you in the editor for the different working block and makes the backup block selectable with the editor "jump" function. By holding down the jump key you can rapidly blink between the two blocks to identify the differences. To find the next difference you press space to exit the editor and enter the word `g` to continue searching forward from the currently displayed block. If there are no differing blocks remaining when typing `all` or `g` then there will be no change to the display or to the editor mode.

Depending upon your goal for matching the working and backup files, you may choose to make changes to one or the other image. You can use the editor's cut-copy-paste buffer to move code between the two blocks. Be careful to note that the high order digit of the block number is correct before making any changes and verify your result often with the jump function. If instead you are happy with the differences and simply want to overwrite one of the blocks with the other you can exit the editor and use either `take` or `give` . Regardless of which block you are currently looking at the word `take` replaces that one block (be it source or shadow) with the corresponding block that would be displayed next using the editor jump function. In contrast the word `give` replaces the block you do not see with the content of the one you are looking at. Human nature being what it is, in this case one can argue that it is safer to take than to give.

There should not be any changes to the binaries located below block 18 unless you have made edits to the character font table in blocks 12 to 17. To verify these binaries use the word `?bin` . It will place on the stack the numbers of any differing blocks in this range. To compress and write all of blocks 0 to 1439 out as the working source file simply type `save` . This can be done at any time, not just when audit is loaded, because it is a resident definition. You can write the image from 10000 to 11439 back to the backup source file using `!back` but be aware that `!back` does not compress the image. colorForth does not care when booting or when using `check` whether an image is initially compressed or not. Only the size of the external file is affected. In addition an uncompressed source file is easier to export and decode using other software.

Frequently your requirements for block maintenance will be less comprehensive than when dealing with entire source images. You might need to move a small range of blocks from one place to another, or to copy a set of blocks to be changed or reconfigured. In the latter case you may want to audit your changes against the original block range as a confirmation. To copy a range of blocks and shadows to another place type `s d n +blocks` where **s** is the starting block number, **d** is the destination number and **n** is the number of source/shadow pairs to move. Do not copy overlapping ranges from low to higher numbered blocks; you'd have better luck running with scissors.

You can use the word `wipe` to blank the current block or `first last+1 obliterate` to blank an entire range. Obliterate is intentionally made hard to type. Exercise care in its use. Wipe and obliterate do not come with an undo function.

You can set up a small range of blocks to run across with the audit's `g` word by using `matching` and `to` . Type `s d matching` where **s** and **d** are the starting blocks of the two ranges you want to match, then type `n to` where **n** is the last block number in the lower range. Typing `n list v` will get the compare started by examining block **n** for differences. Afterward use `g` just as with the full range compare.

4.2.2 HTML Listings

Load the HTML utility with `html load`. The default output filename is `cf.html`. You can change this name from the command prompt if you like by typing, for example, `named my.html`. Then type `first last+2 run`, where `first` and `last+2` are block numbers. The result is an html file with shadow blocks on the left side and code blocks on the right. For example, to produce a listing of an entire colorForth floppy image, type `18 1440 run`. The colors have been altered only so that the background can be white and comments black. This saves black toner or ink when printing the listings.

4.2.3 Index Listing

Load the indexing utility with `index load`. The default output filename is `index.txt`. You can change this name from the command prompt if you like by typing, for example, `named my.txt`. Then type `first last+2 run`, where `first` and `last+2` are block numbers. An index is the top line (approximately) of each block in the range specified. No colors are indicated, just text.

4.2.4 PNG Screen Captures

The PNG utility is resident in colorForth. You can capture the screen as a `.png` file at any time by typing `png` at the command prompt. A png file will be created with the default name of `OkadOut.gds`. You will probably want to rename this to something more appropriate, with a `.png` extension.

PNG is appropriate when the screen contains graphics other than a source block. The HTML utility is more suitable for source code.

4.3 The Bonus Materials

Some of the "study material" supplied on this disk image may be executed to do useful things, as follow:

`selftest (n)` If the ATS materials supplied in 480 to 720 are still intact, this phrase will run all relevant ATS tests on the chip whose IDE COM port number is given. Note that in order to test the Host chip in this way, its no-boot jumper J26 must be installed before running **`selftest`** or the IDE will hang.

`autotest (n)` Again if the ATS materials are intact, this will cause the Host chip to run ATS tests on the Target chip using the same general procedure as does the factory chip tester, by running tests through the synchronous connection between each chip's node 300. In addition, it runs SERDES test between Host node 701 and Target node 001, transferring a quarter million words of known unique values each way and verifying correct receipt with line turn-arounds.

`450 load` Host polyFORTH IDE boot procedure. Install no boot jumper before loading this.

`460 load` Burns polyFORTH into flash.

`1140 load` Host eForth IDE boot procedure. Install no-boot jumper before loading this.

`1190 load` Burns eForth into flash, for example when updating eForth.

5. Programming the F18

In classical Forth systems, incremental compilation is a normal mode of operation. One can load (compile) an application, and then load another block (or body) of code that uses what had previously been compiled. That works out fine for a single task in a single computer, but things can get trickier when programming an array of computers each of which may have different ROM and each of which may need to get its hands upon the addresses of things in another node. To address this set of complications while preserving effective interactivity, we have made compilation a single monolithic operation covering all the source code currently of interest to you, and made this operation fast and unobtrusive enough that changes may be made and immediately tested, as follows.

5.1 Source and Object Code

The F18 compiler processes a simplified language, encoded in colorForth, producing object code in a binary image of both ROM and RAM for each node. This binary image resides in host computer memory starting at block 32768 where there is a *bin* of 2048 bytes belonging to each physical node, followed by some number of virtual bins. The constant **nnc** gives the number of bins for which space is allocated. By typing **nnc** you will see on the stack the value 432 which is 144*3; the area is sized for programs using up to two chips, with an extra 144 nodes' worth of virtual bins into which object (for library code distributed by GreenArrays) may be stashed as noted later.

5.2 Compiling F18 Code

The word **compile** loads the compiler and performs a complete compilation, leaving the dictionary empty and the object code available for further actions such as loading into nodes with the IDE or generating boot streams. When integrated with higher level tools such as the IDE, `compile` is extended to reload the higher level tool after recompiling the F18 code, with little or no disturbance in the context of your work.

Block 146 is interpreted by `compile` to perform this operation in several steps:

1. ROM is compiled for every node of chip 0 so that the object area has correct data for all ROM even if you are not compiling anything in a given node yourself.

2. Block 150 is loaded to compile RAM code for any desired nodes. By convention, block 150 is used to load system code provided with the software distribution, after which it loads block 200, a block reserved for your own application code. In the distributed base, block 200 is delivered with examples for convenience, but unlike the code loaded in block 150 this may be discarded if you don't need it.

5.3 Compiler Syntax and Semantics

If you have not read DB001, the F18A Technology Reference, please do so to familiarize yourself with the computers and their instruction sets before reading this section. To compile code for some node, the minimum you have to write is `<cyyxx> node` to select that node and, as recommended practice, `<n> org` to set the location counter, followed by F18 code for that node. The full set of directives for code management is as follows:

`node (nn)` Given a node number in cyyxx notation, starts compilation of code tailored for that particular node. The bin "belonging" to that node is cleared, the ROM code for that node is compiled so that its symbols are available and correct. The location counter is set to begin compilation at location zero.

`bin (nn)` is used after code has been compiled for a node to stash the object code just created in some other bin (*bin number nn*) than the one "belonging" to that node. Bin assignments are currently controlled by GreenArrays; at this time we recommend you compile directly for the intended nodes and not use `bin` yourself.

`reclaim` empties the compiler's dictionary of F18 red word definitions. Used to keep the dictionary from overflowing and to control the scope of red F18 identifiers. It's a good idea to use `reclaim` before selecting a `node` .

Later on, when loading code into nodes with the IDE "by hand" or when specifying boot conditions for tools such as the automated IDE loader or the stream generator, object code is identified by its *bin number*. By default that is simply the node number unless you have used `bin` to stash the code elsewhere.

The F18 Compiler is simpler than is that of the x86; please refer to section 3.3.1 above for comparison. There are no macros / IMMEDIATE words, there is no extensive optimizer as is present in the x86 compiler, and nothing special happens on a yellow to green transition. Neither magenta nor cyan words are meaningful. Here is what the F18 compiler does with each color tagged word:

Yellow numbers are placed on the compiler's stack. Green numbers are compiled as 18-bit F18 literals. Both green and yellow words are executed; the words generating F18 instructions compile opcodes into F18 memory when the compiler encounters them. White comments are ignored. Red words fill any partial F18 instruction word with nops to align on a word boundary and create the red word in the dictionary as a definition beginning at the current position in F18 memory.

Although yellow words are executed when encountered, the dictionary structure of the x86 colorForth system precludes access to host system words that are "buried" by F18 definitions. Thus the common practice of using such words interpretively to manipulate the compiler's stack during compilation is generally not possible. For example, words like { `dup drop over + - and or 2* 2/ push pop` } may not be used for this purpose because those words generate F18 opcodes. *Do not code yellow usage in F18 source other than as you find discussed here.*

Due to the dictionary structure of the x86 colorForth system, many of the host computer's garden-variety Forth words may not be used. Now, let's clarify some of the concepts referenced so far.

5.3.1 Location Counter

This is an incremental compiler. Opcodes and literals are written into an image of target node memory as they are encountered; the only retroactive action it performs is to store into the destination fields of words containing forward referencing jumps (such as `if`) or calls (`leap`) when those forward references are resolved. The compiler keeps track of the current position in target F18 memory with three variables:

`ip (-a)` address of instruction word being built
`h (-a)` address of the next word to store into target memory
`slot (-a)` next available slot number. 4 means slot 0 of a new word that has not been stored yet.

As opcodes are compiled, they are added to the instruction word being built and `slot` is maintained until the word is full or until compiling an opcode that will not fit into the word. At that time the word being built is padded with `.` (nop) opcodes if necessary, and a new instruction word is started at the address in `h` . This leaves `ip` pointing at the new instruction word and `h` pointing at the next location in memory. The duality of `ip` and `slot` is necessary to support multiple instructions per word; the duality of `ip` and `h` is necessary to support literals.

When literals are compiled, a `@p` opcode is compiled and then the literal value is stored at `h` , advancing `h` . Alternatively you may write `@p` yourself and lay the following words down using yellow `,` (comma) or using the compiler itself to generate an instruction word.

Jumping, calling, and memory operations address a word, not an opcode. When encountering a red word, or any other compiler directive defining a place that may be addressed in memory, any code under construction is padded with `.` (nop) opcodes if necessary to align the location counter on a word boundary. This means that in absence of explicit control transfer opcodes, execution continues across alignment boundaries including the start of a red definition, a technique we have learned to use often.

Location counters are incremented in the same way the hardware increments them: The low order seven bits increment without changing the remaining bits of **`P`** . If you are generating code in RAM you will stay in RAM, wrapping its address space at x80 in terms of the value of `P` and also at x40 in the sense that the hardware ignores bit 6 of the address. The compiler will also generate code for ROM, in which case the wrapping points are at x100 and xC0. The P9 bit (x200) may be set as you wish to specify addressable destinations which will run in Extended Arithmetic Mode.

The location counter is managed using these words (all but the grey words should be written in yellow):

`org (n)` sets the compiler's location counter to a given address at which following code will be compiled into the current node's bin. `h` and `ip` are initially equal but will separate after the first opcode has been compiled.

`here (-n)` forces word alignment as described above and returns the current aligned location.

any grey word signals the compiler to save its location counter in the grey word's representation in the source code. When a block containing a grey word is displayed, the location counter `h` at that point in the program is shown as a two or three digit hex number; if the location counter is not word aligned at that point, the representation `xx/n` indicates that slot `n` will be compiled next.

`+cy` forces word alignment then turns P9 on in the location counter. Places in memory subsequently defined will be run in Extended Arithmetic Mode if reached by jump, call, execute or return to those places.

`-cy` forces word alignment then turns P9 off in the location counter.

Slot assignment is a microscopic aspect of location counter management but is important to an F18 programmer for reasons such as optimizing forward references, aligning code on word boundaries for generation of literal instruction words to send another node through a com port, and the like; use grey words to help you learn about this. There are many directives that force word alignment. For slot control within a word, the following two are useful:

`.` compiles a nop into the next available slot, effectively skipping it.

`..` forces word alignment.

5.3.2 Control Structure Directives

These are used like those in classical Forth, and should be written in green. The stack effects shown in green reflect the host compiler's stack; those shown in prose reflect the F18 stack.

5.3.2.1 Simple Forward Transfers

Forward transfer opcodes are compiled into the next available slot and may, unless you are controlling slot allocation yourself, be compiled into slots 0, 1 or 2 with 10, 8 or 3-bit destination fields. The stack "handle" for the unresolved forward transfer identifies both the location and the slot of the transfer opcode. When `then` resolves a forward transfer, it will abort with error message "out of range" if the transfer is unable to reach the position at which `then` occurs without a larger destination field; when this occurs you must alter the code to resolve the problem.

`if (-r)` If **`T`** is nonzero, program flow continues; otherwise jumps to matching `then` .

`-if (-r)` If **`T`** is negative, program flow continues; otherwise jumps to matching `then` .

`zif (-r)` If **`R`** is zero, pops the return stack and program flow continues; otherwise decrements **`R`** and jumps to matching `then` .

`ahead (-r)` jumps to matching `then` .

`leap (-r)` compiles a call to matching `then` .

`then (r)` forces word alignment and resolves a forward transfer.

5.3.2.2 Count-controlled Looping

The F18 hardware supports looping under control of a count in **`R`** . The number in `R` is zero-based so the number of iterations such a loop makes is one greater than the value in `R` and that value will be zero during the last iteration of a loop. No forward transfers are used by these words and there are no issues with slots; all directives that generate backward transfers will pad the code if needed so that an opcode with the necessary size destination field may be compiled. The directives are as follow:

for (-a) (n) pushes n onto the return stack, forces word alignment and saves **here** to be used as a transfer destination by the directive that ends the loop. There are times when it is useful to decompose this directive's actions so that the pushing of the loop count and the start of the loop itself may be separated by such things as initialization code or a red word. In this case you may write **push** <other things> **begin**.

next (a) ends a loop with conditional transfer to the address **a**. If **R** is zero when next is executed, the return stack is popped and program flow continues. Otherwise **R** is decremented by one and control is transferred to **a**.

unext (a) ends a micronext loop. Since the loop occurs entirely within a single instruction word, the address is superfluous; it is present only so that the form **<n> for … unext** may be written. The micronext opcode may be compiled into any of the four slots.

5.3.2.3 Arbitrary Control Structures

As with ANS Forth, any desired control structure may be generated based on a few simple directives and flexible semantics; see the ANS Forth standard, or more to the point see the F18 code supplied with arrayForth, for many examples of composite control structures. The following directives are provided; the same stack notation (**a** for destinations and **r** for handles to forward references) is employed here. If necessary you may code **swap** in yellow to affect the compiler's stack.

begin (-a) forces word alignment and saves **here** to be used as a transfer destination.

while (x-rx) equivalent to **if swap**. Typically used as a conditional exit from within a loop.

-while (x-rx) equivalent to **-if swap**. Typically used as a conditional exit from within a loop.

until (a) If **T** is nonzero, program flow continues; otherwise jumps to **a**. Typically used as a conditional exit at the end of a loop.

-until (a) If **T** is negative, program flow continues; otherwise jumps to **a**. Used like **until**.

end (a) unconditionally jumps to **a**.

***next (ax-x)** equivalent to **swap next** .

5.3.3 F18 Opcodes

The preferred opcode names, as shown in the *F18A Technology Reference,* each compile an opcode into a slot:

```
ex  @p @+ @b @  !p !+ !b !
+* 2* 2/ -  + and or drop  dup pop over a  . push b! a!
```

The **call** opcode is compiled when a red F18 definition is used in green.

Tail optimization is performed by **;** if immediately preceded by a **call**. In this case, the **call** is converted into a **jump**, conserving return stack space and leading to other useful techniques.

5.3.4 Other Useful Words

io right down left up data ldata register names, equivalent to writing address in green.

---u --l- --lu -d-- -d-u -dl- -dlu r--- r--u r-l- r-lu rd-- rd-u rdl- rdlu red definitions for single com ports and all combinations; use in green to generate calls and jumps.

await generates a call to the default multiport execute for a node based on its position in the array.

' (-a) (tick) places the address of an F18 red word on the compiler's stack.

5.4 Module Organization

A preliminary convention has been adopted for organizing and packaging code in a modular way, from a single node to a cluster. This convention allows use of a single block number or name as a "handle" for the module. The first two or more blocks of the module have fixed functions at fixed offsets. We recommend that you apply these principles in packaging your own code. The SRAM Control Cluster Mark 1 may be studied as an example while reading the following sections; the constant **sram** is the number of the first block of that module.

5.4.1 Load Block

The first block in a module is a single block which when loaded will cause all of the source code needed by a module to be compiled. There may be arguments to this block. When completed the necessary object code will be stored in appropriate bins (which may simply be those belonging to the nodes programmed.) If by its design a module needs to export addresses or other identifiers, these will be available in the dictionary after it has been compiled for use in code compiled later. *In a degenerate case this block may actually contain all of the module's source code.* See block **sram** for an example.

5.4.1.1 Identifier Scope Control

F18 compilation is done incrementally, which means that identifiers may not be "forward referenced" symbolically. Any identifier of any sort must be defined earlier in the compilation sequence than its references.

The scope of identifiers, including intentional or inadvertent overloading of system or compiler vocabulary, is controlled using the **remember** word **reclaim**. In the normal case, identifiers are not exported at all, and if they are it is usually not far in the compilation sequence. As a general practice, we recommend starting each node's code with **reclaim** unless you are forced to do otherwise. Elaborate scope management structures may be implemented by defining and using your own **remember** words within the scope of **reclaim**.

5.4.2 Boot Descriptors

The second block in a module (load block number plus two) defines the loading requirements for the module, using the high-level language described in section 5.5.1 below. This language lists the nodes that have to be loaded, indicates what code to load into their RAM, provides for initialization of registers and/or stacks, and provides a starting execution address for each node. The data are recorded in tables so that the order of declaration does not need to match the actual order in which the nodes are loaded. See block **sram 2 +** for an example.

5.4.3 Residual Paths

In rare cases there may be modules that need to be loaded, activated, and used during a boot sequence; SRAM and SDRAM control clusters are examples of these. Once started it may be difficult or impossible to stop them without resetting the chip and, in the case of SDRAM, perhaps losing the data in the device. If an application's boot process has this sort of complication then the module in question should provide a new path for use by stream or IDE loaders that can reach and boot all nodes remaining in the chip that are not part of the module which is running and hence now "in the way." See block **sram 4 +** for an example, showing suitable paths for boot nodes 708 (async serial) and 705 (SPI flash.)

5.4.4 Organization of Larger Projects

The appropriate structure for a larger program depends on its size and intended use. The load block should still be first. Boot descriptors should start in the second block but may require several. If IDE operation is appropriate after the program has been loaded, an IDE personalization with path(s) adjusted to access the remainder of the chip may be useful. Scripts may be necessary to specify boot stream generation, IDE loading, and/or **softsim** setup as appropriate. You might wish to include a script to produce HTML listings. Not all of these elements are appropriate for every application, but if they are small you might wish to place them in this area before the actual source code. These are merely suggestions and the recommendations may change as the system evolves.

5.5 Methods of Loading Code

After code has been compiled by reference from blocks 150 or 200, it may be loaded for execution or simulation. There are presently four basic ways in which this may be done:

Manual, interactive loading into the real chip: Use **hook** to build a wire to the desired node and use **boot** to insert code into its RAM .

Manual, interactive loading into softsim: Use **node** to select a node and **boot** to insert code.

Automated loading into the real chip using IDE: Use the IDE **loader** utility to load code as directed by interpreting Boot Descriptors.

Automated loading into the real chip using boot streams: Use the **streamer** utility to construct a boot stream as directed by Boot Descriptors, then present the resulting stream to a boot node.

Automated loading into softsim: Initialize nodes as directed by Boot Descriptors.

Each of the automated methods uses the common Boot Descriptor Syntax to define what code, if any, shall be loaded and what other initialization shall be performed before starting each node.

5.5.1 Boot Descriptor Syntax

Automated IDE and stream loading *touch* all nodes in a defined path starting at the relevant boot node. Automated softsim loading touches all nodes in a chip. There is a single default treatment applying to each node touched, regardless of which of the three methods is used. Boot Descriptors are used to specify non-default treatments using statements that start with the word **+node** and continue with phrases describing the needed initialization of memory and/or registers in the node. Nodes may appear in any order since these statements are simply filling tables for later use. For the same reason, **+node** statements are cumulative in that one **100 +node** phrase may set the memory loading and starting address for node 100 while another **100 +node** phrase interpreted later may override the starting address specified earlier. The following words are used in Boot Descriptors. Their use in context is described in following chapters on IDE, Streamer and Softsim; examples may be found by searching the distributed source code.

+node (nn) Selects table entries for node number nn, in cyyxx notation. The values in the table entries are not changed by **+node** and so their values will be default unless a previous **+node** phrase has been interpreted for the same node.

/ram (bin) Loads all of RAM from the given bin in cyyxx notation. By default nothing is loaded.

/part (a n bin) Loads part of RAM, n words from the given bin, starting at address a in both the bin and the node's RAM. This completely overrides any earlier **/ram** or **/part** phrases. It is not possible to specify loading of various parts of RAM from various places in Rev 01e, but we plan to permit this in a later revision.

/b (a) Specifies an initial value for register **B** . Default value is the address of the **IO** register, as at reset.

/a (n) Specifies an initial value for register **A** . Default value is unspecified, as at reset.

/io (n) Specifies a value to be loaded into the **IO** register.

/stack (<n values> n) Specifies up to ten values to be pushed onto the data stack, with the rightmost value on top. For example `30 20 10 3 /stack` produces the same effect as though a program had executed code `30 20 10` .

/p (a) Specifies an initial value for register P . Default value is xA9 which is the routine warm in every node's ROM. When the node is started, warm jumps to the appropriate multiport execute for the node's position in the array. If you wish to leave the boot routine enabled in a boot node that is touched by an automated loading procedure, specify its P value as xAA as is done by reset for such nodes.

6. Interactive Testing

Interactivity is a critical, cardinal virtue of Forth as a programming system. Turning Forth into a batch mode programming system would be a travesty, sacrificing one of its most potent properties and setting the clock back nearly forty years. When using Forth, a programmer becomes accustomed to having her fingers literally on the fabric of the computer, directly manipulating its memory, registers, and other resources; exercising hardware and software without necessarily having to write (and debug) software simply to exercise those things.

The IDE was implemented as a natural and obvious extension of the umbilical methods used with embedded Forth systems for many decades. The method used is as non-invasive of hardware and software as is practical in this architecture, requiring no RAM or ROM in a node being tested and touching its registers as lightly as feasible.

6.1 Terminology

Debugging is done on one or more *target nodes*, using an umbilical connection which will involve one or more intermediate nodes of one to three kinds (*root*, *wire*, and *end*), depending on the physical location of the target node within the chip and on the *path* taken to reach it. For IDE over the asynchronous interfaces of the Evaluation Board, the root node for either chip will always be 708. The IDE may thus be used to debug code in any node *except* 708.

The inner load block for the asynchronous IDE is serial but this is intended to be used as a factor of other utilities. To work with the host chip, say `host load` and to work with the target chip say `target load` after remembering to edit `a-com` and `c-com` to identify the correct COM ports.

6.2 Using the IDE

1. To prepare for debugging, prepare the desired source code to be compiled for RAM under control of the main load block at 200. Initially use bins with numbers in [000..717].
2. Examine and, if necessary, change the path lists as appropriate to make sure you can reach all the places you need to. See examples in the code, or advanced application notes.
3. Plug the IDE connection(s) into your host computer if you have not done so already. Make sure nothing else in the windows environment (like dialog boxes) has any open handles for the device(s).
4. To work with the host chip, say `host load` and to work with the target chip say `target load` after remembering to edit `a-com` and `c-com` to identify the correct COM ports.
5. Say `talk` to find and open the port, reset the chip, and download root node talker code into the chip.
6. Display the indicator panel (say `panel`) if you wish to view it (recommended!)
7. As the indicator panel will show, you should at this point have three defined paths, one to each of the nodes immediately adjacent to the root node.
8. Define, tear down, and select paths as you wish, and operate on the nodes in question using the words described below. *Note: If you wish to ensure that all other bootable nodes are completely idle, begin your activities by saying* `2 <root> hook` *and then* `2 -hook` *to tear that path down. The default path 2 can reach all 143 nodes accessible to the IDE.*
9. If you wish to change the code you are downloading into any node(s), change the F18 source and say `compile` which recompiles that source to binary and then re-enters the interactive environment, displaying the block you have most recently displayed. Any paths you had wired up, and whichever you had most recently selected, will still be in effect as you can see by displaying `panel` again. *Recompilation does not communicate with the chip under test.*

When you are finished, you can say empty and do other things; as long as you do not say bye to your arrayForth session, you may later load the IDE again and resume communicating with whichever paths you had left connected.

6.3 Vocabulary

Words come in two classes: Those which wire, rip and select paths, and those that operate on the target node.

6.3.1 Path Routing Control

The simplest way to visualize and check the current routing situation is to simply display the **panel** . Node numbers used with these words are always in the cyyxx form.

path (i) Selects path *i* (0, 1, or 2) so that all subsequent target operations will apply to the target node for that path. *This is necessary when more than one path leads to the same target node.*

node (nn) Selects whichever path presently has node *n* as its target, if any. Note that it is possible to set up more than one path to different ports of the same node; if you have done this, *path* will permit you to select the desired port. Leaves a default path selected if none of them targets the node given.

hook (i nn) Wires path *i* to target node *n* after ripping out any existing wiring for that path, leaving path *i* selected. If the node in question is not accessible in the route list for that path, leaves the path set for the appropriate adjacent node as target.

-hook (i) Forces ripping out of any wiring for path *i* . Each node that had previously been part of this path is left in its default warm state (multiport execute); the target node *is not affected*.

6.3.2 Target Operations

Each of these operations applies to the target node of the currently selected path. To help in orientation, it is good to display the panel unless there's something better for you to be looking at while working.

compile Recompiles both the F18 source and the arrayForth IDE source, allowing changes in the binary images that may be loaded into nodes, or aspects of the IDE such as automated test functions (see below). Connection to the chip is maintained, and any wiring context presently in place is preserved.

panel displays the indicator panel block.

upd retrieves all ten words of the data stack into the local array **stak** which is indexed (T, S, and the eight elements in the F18 stack, first element being the one that would next be popped into S). panel displays the contents of stak in two rows. First row is the deepest four elements of the F18 stack, followed by the shallower four elements, then S and T. The shallowest element is immediately left of S; "deeper" moves to the left on that row, then to the right on the row above, with the deepest element on the right side of the top row. This is isomorphic with the stack array and makes its behavior clearer.

?ram retrieves all of RAM from the selected node, updating the panel display.

?rom retrieves all of ROM from the selected node, updating the panel display.

lit (n) removes a number from the host computer's colorForth stack, pushing it onto the data stack of the target node and updating the stack display on the panel .

r@ (a-n) reads RAM, ROM, register or port *a* in the target node, pushing the data read, *n* onto the colorForth stack of the host computer. *Not to be confused with the F18 @/@a function. In this release, uses and does not restore register a in the target node.*

r! (n a) writes a number from colorForth data stack of the host computer into target memory (RAM, register, port) address *a* . *Not to be confused with the F18 !/!a function. In this release, uses and does not restore register a in the target node.*

call (a) calls, from the port, the code at address *a* in the target. If that code returns to the port or re-establishes the normal rest state of the target node, interactive use may continue once the code completes. No interlocking is done so this method may also be used to start application processing which will not admit to further port execution access. Interaction with a node actively running an application may also be arranged but at the cost of periodically polling, as described below.

boot (a n bin) loads code into the target node, starting at address *a* in both target and bin for *n* words, from the current binary output area identified by *bin*. This need not be the same node as the target.

focus forces the target to call only the port on which the current IDE path is talking to it. This remains in effect until the target is directed to execute elsewhere.

virgin forces the target to call its default multiport execution address to un-do the effects of `focus`.

io data up down ldata left right place chip port addresses on the colorForth stack.

rb! @b !b ra@ ra! @a !a @+ !+ r+ r+* r2* r2/ r- rand ror rdrop rdup rover Execute single F18 instructions in target, using target's stack, and update stack display in panel.

6.3.3 Advanced Uses

When ripping a path out, all wire and end nodes (if any) are left in their default multiport executes. This is necessary so that, for example, paths may be crossed so long as they are not used concurrently to cause conflicts. There are occasions, such as when starting nodes that send unsolicited code or data to other nodes, when this is not appropriate. In those cases the following two functions are useful:

unfoc Conditions -hook to work as stated above..

foc Conditions -hook to leave every wire and end node focused back toward the root. This leaves the path completely impenetrable to anyone other than the root node, and further hooking and starting of nodes will be necessary if that path is ever to be permeable again.

The IDE is factored such that it may become a tool of other utilities. Examples are the selftest and autotest routines, the IDE boot and flash burning tools used for eForth and polyFORTH, and even the host and target load blocks. Until these conventions are documented here, please read the code just identified to see how it is done.

6.3.4 Working with Two Chips

The IDE may be used to interactively debug software on both chips of the Evaluation Board as though they were a single chip with 288 nodes, using just the serial interface for the host chip.

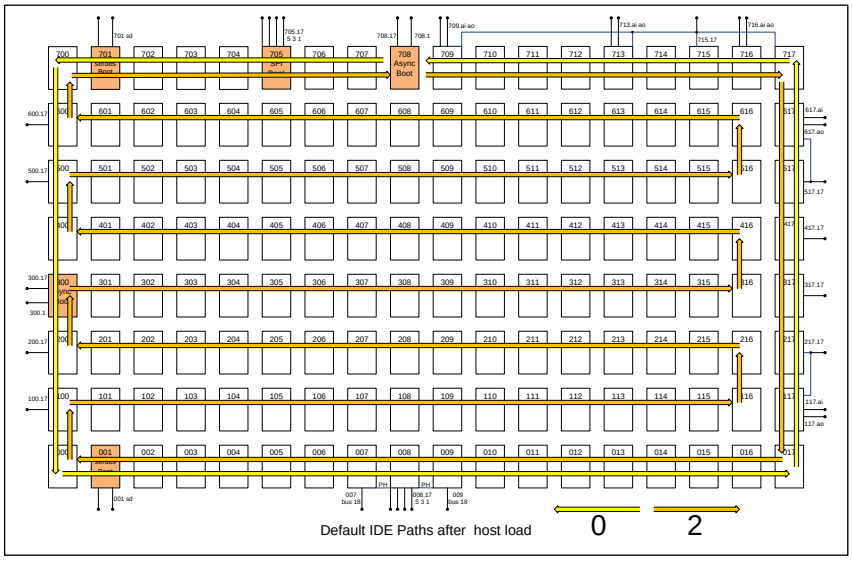
bridge load compiles a host IDE version capable of operating on both chips. Initially it is identical with `host`.

span extends the bridge IDE to encompass both chips. In order to successfully invoke `span` the edge nodes of the host chip starting with 707, proceeding to the left to 700, and downward to and including 300 must be accessible for programming; it is typically used immediately after loading `bridge` unless something such as polyFORTH needs to be set up on the host chip first.. `span` resets the Target chip and programs node 300 on each chip as a transparent bridge for carrying port communications between them, using 2-wire synchronous communications. New default paths 0 and 2 are set up to cover both chips. Thereafter, nodes 300 are dedicated to this purpose until the chips are reset.

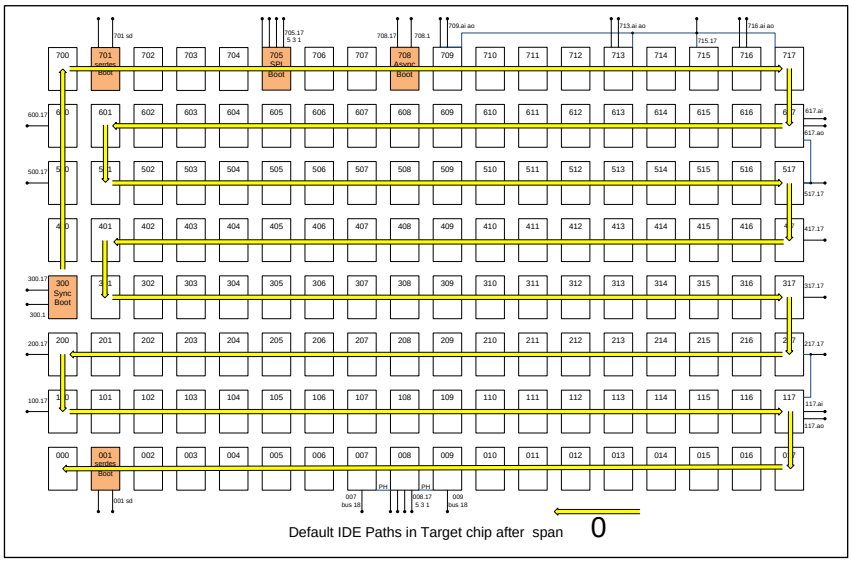
With the port bridge built, the **up** ports of node 400 on each chip are logically connected as though they were a simple COM port. Port read/write communications, such as IDE, are basically transparent across this connection except that data transfers take 100 or more times longer, no flow control is supported, and polling of **io** by node 400 has limited usefulness. Node 300 will seem to be writing when a word sent by the other chip is waiting to be read, it will seem to be neither reading nor writing during serial data transmission in either direction, and it will seem to be reading at all other times regardless of the state of node 400 in the other chip.

The default paths after `span`, shown below, facilitate full access to the Target chip with or without the polyFORTH virtual machine present on the Host chip. Extended node numbering is supported in the form cyyxx where c is zero-relative chip number; thus nodes 000 through 717 are on the Host chip, while nodes 10000 through 10717 are on the Target chip.

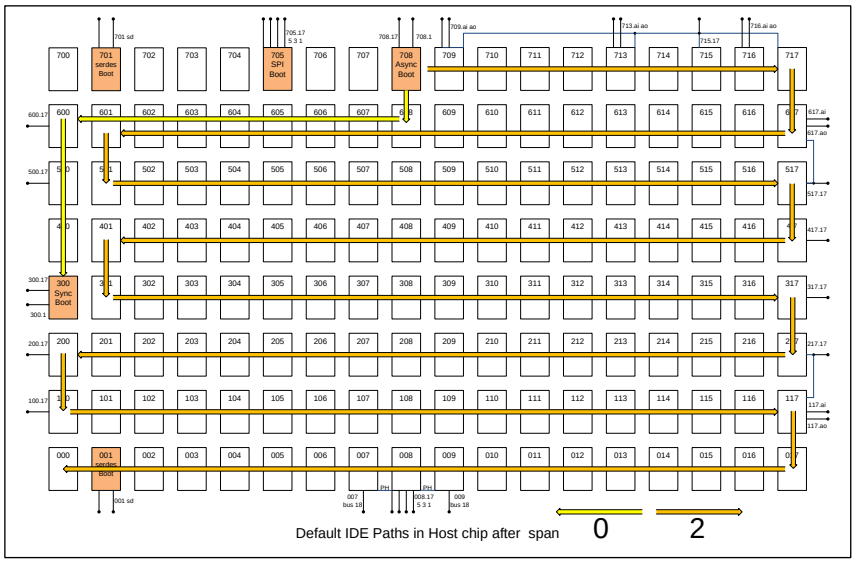
6.3.5 Default IDE Paths



Path 1 is available for general use after host load or bridge load .



After span path 0 is generally used for target chip...



... and path 2 is generally used for the host chip. Path 1 is available for general use. The port bridge only requires special code in nodes 300 and 10300.

6.3.6 Automated Loading with the IDE

Block 846 in the distributed source code is a simple template for automated loading of a trivial program using the IDE. It consists of the following elements:

```
host load  loader load
```

This phrase establishes context of a particular IDE configuration, that of the host chip on the evaluation board, and attaches to it the `loader` utility. `loader` uses `talk` to reset the chip and load IDE support code into the boot node.

```
0 708 hook  0 -hook
```

This phrase uses the default IDE path 0 to quickly force all I/O nodes to `warm`, thus ensuring that no boot node is paying attention to its pins any longer.

```
600 +node  600 /ram  0 1 /stack  12 /p
```

This phrase specifies that node 600 should be loaded from its own default bin, that 0 should be pushed onto the stack, and that the node will be started executing at location x12.

```
2 ship
```

This phrase actually loads the chip using the given IDE path. Every node in that path is touched except the boot node itself. If `+node` phrases specify nodes that are not present on the given path, they are simply ignored.

The default IDE path 2 may be used to load every node in the chip except node 708 itself.

6.3.7 Asynchronous Boot Streams

The IDE may be used to sending an arbitrary bootstream through the asynchronous serial port. Instead of using the loader as above, the framer is invoked and a stream is created as if to be burned into flash. The only differences are that `frame` is redefined to use the concatenation address of the serial boot node instead of the SPI boot node, and a different path rooted at node 708 instead of 705 is used. Once the stream is created via boot descriptors followed by `frame`, the IDE is loaded and the stream is sent to the serial boot node via `send`. This method is much faster than the IDE loader.

`send (a n)` Transmits a stream of *n* words starting at word address *a* from x86 memory.

For examples of use, either polyFORTH or eForth can be quickly loaded this way by typing **`430 load`** or **`1152 load`** respectively.

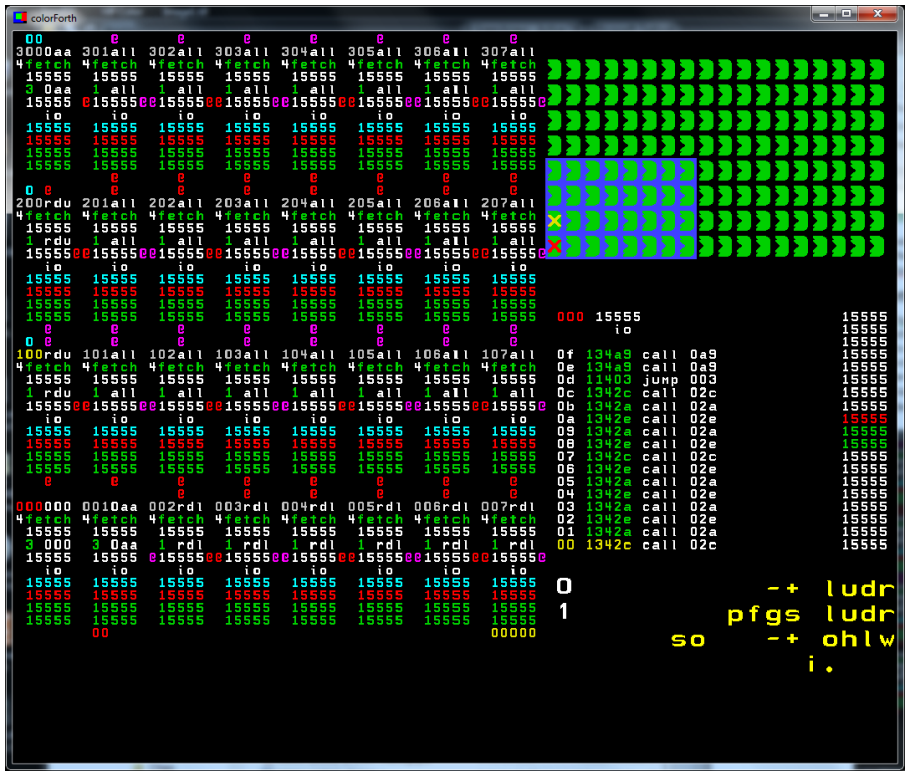
The async boot stream can also span both host and target. Block 424 is an example of loading both chips with polyFORTH and any other desired code. Invoking the word **`2chip`** extends the node numbering in the same way that `span` does for the IDE loader. The bridge needs to be installed explicitly though. See the code section labeled "bridge to target" in block 426 for an example.

7. Simulation Testing with Softsim

Softsim (the Software Simulator) is a program that simulates the actions of Green Arrays computers, ***in a single GA144 chip***, at a pretty high level. It takes short cuts that allow it to run much faster than a full hardware simulation. The following is a quick tutorial in how to use softsim.

7.1 Getting Started

After starting arrayForth, type **so** at the command line. You should see a colorful display. In the default layout shown below, there are three sections which help you "drill down" into the chip. In the upper right corner is a *full chip view* showing its 144 computers as an 8x18 array. On the left is an *overview* showing the major status and registers of a rectangular section of the chip's nodes. This can be up to a 4x8 array as shown. The overview section is highlighted in the full chip display. In the lower right part of the display you'll see two white numbers in the larger font which represent "time" (the current step number) and "gap" (the number of steps between display updates). Further to the right you'll see yellow keyboard hints.



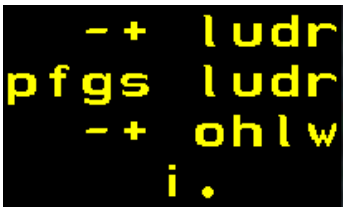
Immediately below the full chip view there is a *detailed view* of a single node, called the *focus node*. Its node number, 000, is shown in red at the top left of this view. This node's position is shown in the full chip view with a red "X". In the overview, the focus node's three-digit number, normally shown in grey at the upper left of each node's rectangle, is changed to red for the *focus* node.

In addition to the focus node, a second node, called the *other node*, may be selected as well. Its detailed view may replace the full chip view using the **w** key on the control panel, and the *focus* and *other* node numbers may be exchanged with the **o** key on the control panel. The other node, if visible on the chip, is marked with a yellow "X" in the full chip display, and with yellow node numbers in the overview and detailed view.

All sections of the display are animated during simulation. In the full chip view, each node is green when active and grey when suspended.

7.2 Navigating

Your right hand is the main control for what you are seeing on the display.



Now look at the keyboard hints in the lower right corner. The **ludr** hints mean left, up, down, and right. The middle row's **ludr** keys change the current focus node, changing the red node number in the lower right detailed view, and moving the red markers in overview and full chip view. It's possible to move the red marker off the screen, but you will still know where it has gone by looking at the detailed view on the lower right. Try it and see.

Now try pressing the **ludr** keys in the upper row of the hints. This will move your overview window around inside the chip. You'll see the grey node numbers change as you press these keys, and the highlighted rectangle in the full chip view moves correspondingly. The focus and other nodes do not change when the overview is moved.

Suppose you want to watch two nodes interacting in more detail. That's why the *other* node exists. The middle row **ludr** keys only affect the focus node in the lower right, but you can swap the focus and other nodes by pressing the **o** key on the control panel. Try it. You'll see the red and yellow nodes changing roles. Now you can choose two nodes to watch closely (use the **w** key to replace the full chip view with the *other* node's detailed view.)

In addition to the full stack display (deepest item of return stack on top, , each detailed view shows a sixteen-word memory dump. You can navigate through the memory dump of the focus node by pressing the **h** (higher) and **l** (lower) keys on the control panel. These move through RAM and ROM in 8-word steps.

7.3 Making it Go

Let's call the two large, white numbers in the larger font in the lower right *time* and *gap*. *time* is the number of steps that have occurred since the start of the simulation. *gap* is the number of steps that will occur between display updates. *gap* starts as 1, so the display is updated after each single step. There is another variable named *fast* which can be swapped with *gap* if you want the display to run faster and show fewer updates. This variable can be increased or decreased by 1 using the **+** or **-** control panel keys in the bottom row, or by 100 using the **+** or **-** keys in the top row. The **f** key toggles the value of *gap* between *fast* and 1. The simulation runs very much faster when it's not updating the display.

The **g** and **s** keys in the left hand control the progress of the simulation. Press and release the **s** (step) key. You should see time change from 0 to 1 and some changes will occur in the overview as well.

When you press the **g** (go) key, the simulation will go on running and updating the display until you press another key. Be careful because whatever key you press will also be take its own effect. If you just want to stop running the simulation press the **s** key. The simulation will stop after one more step and nothing else will happen after that until you press another key.

The **p** key is for power. It simulates a power on reset, starting the simulation over from the beginning and setting time back to 1.

The **i** key runs the current instruction in the focus node to completion rather than just a single time step. It also initiates *instruction word tracking* in the memory display. When tracking is active, the currently executing instruction word is always visible in the lower 8 words of memory display. Pressing **g** for go will not change the state of tracking. Pressing **s** for step turns tracking off, as does navigating the memory display.

When you're done with softsim or need to use the interpreter, press the **.** key (space bar). That returns you to the colorforth interpreter.

7.4 The Memory Dump and Decompilation

Each detailed view shows a combination memory dump and decompilation/disassembly of the code for a node, along with a dump of both stacks. The A and B registers appear at the top next to the node number. The stacks are shown as a single array with the return stack growing upward from R (in red) and the data stack growing downward from T and S (in green). The memory dump shows the addresses of memory words in the left column. The instruction word or 18 bit data word follows in green. The instructions for each slot appear next, sometimes followed by the value of an address field. While a node with detailed view is executing, the line where the current instruction word was read appears in red. The instruction in the current slot is also in red. The other instructions remain white. The line that the P register points to is shown in yellow. If the instruction word has been fetched from a com port the disassembly and instruction word are shown in red above the memory dump, below the B register.

7.5 The left side display

In the array of nodes on the left each rectangle contains a list of the values of registers and opcode names representing the current state of that node. Most of the numbers have identifying colors which turn to grey when the node is suspended. You'd probably like to know which registers the numbers represent. Each node has twelve lines.

From top to bottom, using node 100 from the above display as an example, they are:

Row	Example	Name	Description
1	0 @	Pins and/or ports	States of the pins are represented by 0 or 1 for low or high, yellow for output and cyan for input. Blank when the node has no external pins. Analog and Serdes pins are red. Pins are on the top for top nodes, bottom for bottom nodes, and on the outside for side nodes. If the node has a port on this side, see row 12 for its representation
2	100rdu	NODE/Abus	The grey node number followed by the white address bus. Com port addresses appear as three characters including r, d, l, u, or 'all' if it's a four port address.
3	4fetch	SLOT/OPCODE	The white slot number is followed by the green opcode name.
4	15555	I	White, the instruction register
5	1 rdu	M/P	The memory timer counts down in green. '-' indicates that the node is suspended. The value of P, the program counter, follows in white.
6	15555	A	White, 18 bit pointer register A.
7	io	B	White, 10 bit pointer register B.
8	15555	IO	Cyan, the write-only part of the IO register.
9	15555	R	Red, top of return stack.
10	15555	T	Green, top of data stack. Carry latch shown as high order .
11	15555	S	Green, second on data stack.
12	@	Pins and/or ports	When a com port is being read from or written to it is represented on the appropriate side of the node with a "@" for reading and a "!" for writing. The Right and Down ports are in red while the Up and Left ports are in Magenta. Pins appear here for top and bottom edge nodes.

7.6 Getting your Code to Run

By default when softsim is loaded each node's memory (RAM and ROM) is initialized with the code most recently compiled into the bin whose number is the same as that of the node. Again by default, register **B** is initialized with the address of **io** and register **P** is initialized the same as the hardware does after reset (see chip data book.) Thus, without any further arrangements on your part (and without the SMTM demonstration program that's started in block 1234 as delivered), the simulated chip will only run boot nodes' initialization code and soon all nodes will be suspended. There are several general ways in which to get the chip started.

The first method is closest to the actual operation of the chip. This is done by building a testbed that directly simulates one of the four possible boot sources for the chip (SPI flash, async serial, sync serial, or SERDES) and allows the simulator to boot a complete application just as the chip does. This can take a very long time and you will probably prefer to use a more direct, if slightly less realistic, method.

The second method is to force one or more nodes to execute code from RAM. As indicated above, if you simply compile code for node 105 that code will appear in node 105's simulated RAM unless you have indicated otherwise. To run this code simply specify any desired starting address for the node. By using the boot descriptor syntax you may fully control what code is loaded into each node, what if any register and/or stack initialization is done, and what starting address is loaded into **P** . As of rev 1g, softsim will process standard Boot Descriptors (see 5.5.1 above) and may therefore be used to simulate an application of any size using the same initial conditions as the IDE or stream loaders create in the real chip, using the same specifications.

A third method may be used by compiling your own ROM code (simply compile code with location counter in ROM). This method is useful for testing proposed new ROM code, including application specific ROM.

7.6.1 Softsim Example Program

For demonstration purposes block 200 compiles a short program into node 0 that will copy itself into neighbor nodes along a predetermined path. As delivered, block 216 has a line reading **0 +node 0 /ram 0 /p** . This tells softsim that when it starts node 0 should begin executing at address 0. Softsim already has the code for bin 0 in node 0, so **0 /ram** serves only as documentation. Type **so** to start softsim. When softsim starts for the first time node 0 will be the focus node. It should be marked with a red X in the lower left corner of the full chip view. Notice that address 0 in the memory dump is yellow. That means the **P** register contains a 0 and the program will fetch its first instruction from there. Press the **i** key repeatedly and watch the program as it makes a call to address x02c. Note that pressing the **i** causes the memory display to track the instruction word, so it automatically navigates to address x02c. Pressing **s** instead would leave the memory display at address 0. Press the **f** (fast) key. The "gap" should show as 100. Press the **g** (go) key and watch the module migrate from node to node.

7.6.2 Breakpoints

Each node may have one and only one breakpoint set using the word <slot> <addr> <node> **break** . When that node is about to execute the instruction from addr/slot softsim will stop and paint a colored box around that node to identify the reason for stopping. A cyan colored X will appear on the same node in the full chip view as well. Those markers will disappear as soon as another step is taken by pressing **s g** or **i** .

The breakpoint may be removed via the command <node> **-break** . Breakpoints may be set or cleared at any time interactively.

7.7 Testbeds

In order to test your simulated program's interaction with the outside world you will need to make a testbed to simulate inputs and outputs. There are two example testbeds in softsim as released, namely the SPI and Sync boot testbeds on blocks 1230 and 1244-1246. We'll start with a simpler example to build up to what you'll need to know in order to understand these testbeds and to create your own.

Unfortunately, testbeds are written and execute in x86 colorForth. Everywhere else in this manual we have been able to avoid discussing the peculiarities of the x86 system's vocabulary, but here you will be using it. Follow examples and contact customer support for assistance if needed.

The softsim engine uses vectored execution to run testbed code. An execution vector is just a variable that contains the address of some code to be executed. If you've stored the address of a code snippet into a variable, say `this` for example, then you execute the snippet with the phrase `this xqt` . The softsim engine has a couple of node variables, local to a particular node, which are meant to contain the addresses of testbed code. The first is called **`softbed`** and holds the behavior of the testbed after reset. The second is **`'bed`** which holds the behavior to be executed in the next time epoch. The address in `softbed` is copied to `'bed` when softsim is initialized or restarted. If your testbed is best defined as a state machine, you may assign the code for each major state to `'bed` in each step (a vastly superior way to mechanize state machines than case statements).

It's simple to do this. Use the arrayForth word **`assign`** to store the address of the code following `assign` into the vector. Here's an example of its use. Suppose you want to simulate a fast square wave on pin 17 of node 600:

```
/wave softbed assign  time @ 10 / 1 and ?v p17v ! ;

600 !node /wave
```

Add this code to block 216 where testbeds are compiled. Run softsim and watch the pin in node 600 toggle every 10 steps. The first line defines the testbed. The second line attaches that testbed to node 600 interpretively. `600 !node` makes node 600 the current node with regard to node variables. When `/wave` is executed in that interpretive phrase, the address of the code following `assign` is stored into softbed. When softsim is initialized (by **`/softsim`**) that address is copied from `softbed` to `'bed` for node 600. Then for each step of softsim that code is executed for node 600.

The assigned code begins with a yellow **`time`** . `time` is a global variable which starts at 0 and is incremented for every step of softsim. *`time` is literally the very rough timebase for softsim (note that it does not correspond directly to any particular unit of time but is a necessary evil in order to simulate the chip's operations in an orderly way. Each step is on the order of T_{SLOT} (1300 to 1650 nS at 1.8v and 22°C, see G144A12 Chip Reference "Typical Instruction Timings.") The softsim engine allocates more than one step for longer instructions but only in integer multiples. Coupled with the fact that each node may have a different T_{SLOT} than its neighbors due to variations in silicon process, temperature due to its duty cycle of operation, and accumulated aging of each node which varies by lifespan duty cycles, timing in steps must be taken with a grain of salt. In future versions of softsim we might make a wall-clock time base for testbeds to use and allow the step time to be specified for a given run, allowing for boundary condition testing; if you wish to do this yourself now, do arithmetic on `time` before using it in the testbed.* For node 600 at each step the value of `time` is fetched and divided by 10. If the result is odd the pin goes high; if even the pin goes low. The word **`?v`** is part of softsim and turns a truth value into a voltage. If the input is 0 it remains 0; If it's non-zero (true), the value of the global variable **`vdd`** is returned. This is 1800 by default, in units of millivolts. **`p17v`** is a node variable. It contains the voltage on pin 17 for the current node. Since `/wave` is only executed for node 600 this code will set the voltage on 600.17 as a function of time; nominally a square wave whose period is roughly 28 nanoseconds. Node variables **`p1v`** **`p3v`** and **`p5v`** also exist for nodes with two or four pins.

In the Sync boot testbed on block 1230 `time` is not used as the timebase. Instead a global variable named **`dly`** was created to keep time. Also note that instead of using `?v` to get a voltage value `vdd @` is used in yellow. Global variables in x86 colorForth need to be yellow but are usually followed by a green `@` or `!` . In this case we use a yellow `@` to fetch the value from `vdd` at compile time. The constant value is then compiled as a literal by the yellow to green color transition. This is a feature of the x86 colorForth which doesn't apply to F18A code.

Another example might simulate a wire connecting two pins, 600.17 and 500.17. We will assume 600.17 is an output and 500.17 is an input.

```
/follower softbed assign  600 !node p17v @ 500 !node p17v ! ;

500 !node /follower
```

This testbed will cause 500.17 to have the same state as 600.17. Your program can set or clear 600.17 and code in node 500 can read 500.17 from the io register and act accordingly, as if a real wire connected the two pins. A fine point from this example is that for consistent timing this sort of testbed should usually be attached to the receiving node.

The SPI testbed in blocks 1244 and 1246 doesn't need a timebase. The testbed can simply react to changes in pin voltage set by the F18A program. It does this by reading the voltage on a pin via, for example, `p17v @` and interpreting the state of the pin as high when V_{IH} or V_{IL} thresholds are crossed. In fact it will be either 1800 mv or 0 mv for a GPIO pin in the present simulator. The situation is a bit more complicated because the testbed must pretend to be a device which responds to the SPI protocol. For example, the SPI device must wait until the enable pin goes low before paying attention to the clock pin. You can make such testbeds as simple or as elaborate as you require.

Here's a simple state machine that waits on a pin before taking some action.

Suppose you have a circuit that reads the signal on pin 708.17 and puts the inverted value on 708.1. Softsim already has the word **`low?`** which sets the x86 minus flag if its input is less that 900 mv. It's used as in `p17v @ low? -if ...`. Note that `-if` is used, rather than `if`. The word **`high?`** below can be used as `p17v @ high? -if ...` similarly.

```
high? v negate vdd @ + low? ;

/waiter softbed assign begin

begin 'bed assign 0 p1v ! p17v @ low? until

begin 'bed assign vdd @ p1v ! p17v @ high? until end

708 !node /waiter
```

In this case we change the execution vector `'bed` to reflect changing conditions. The third line is a `begin until` loop. It first assigns the following code to `'bed` and exits. Next time this node's `'bed` executes pin 1 is set to 0 millivolts and pin 17 in read. If pin 17 is not low the `until` returns to `begin` and reassigns `'bed` to the same address, ending execution for this step. If pin 17 is low the code falls through to the next line where the values are reversed. Finally when pin 17 goes high again `end` jumps back to the first `begin` and the cycle starts over. Note that `assign` not only makes the assignment but also terminates execution with a return.

With these simple building blocks more complicated devices can be simulated by custom testbeds.

7.8 Interactive Testing with Softsim

Interactive softsim is intended to work very much like the interactive IDE. Skills learned in one should apply to the other, except that this mechanism can interact with a node to which no path could be built in IDE. The *remote opcodes* listed below have the same names as the words in the IDE and have the same results once you realize that they always work on the softsim's focus node. The command **node** will make any node become the focus node without having to navigate to it. Similarly the command **other** will make any node directly become the *other* node without having to navigate to it. These words may of course be used in scripting to automate test set-up.

Note that most of the remote opcodes names start with "r" for remote, to distiguish them from the PC colorForth words with the same names. Some of the opcodes have no PC equivalents and dispense with the "r" prefix.

The commonly used ports have names to make them easy to use. For example you can say **io r@** to read the **io** register of the focus node. You can also say (hex) **30000 io r!** for example in a node with an io pin and see the pin change state to a yellow 1. **0 right r!** writes a 0 to the node sharing its right port with the focus node. **0 call** starts the focus node executing code at address 0 in its RAM. It runs for three steps in order to fetch the instruction into the instruction register then leaves you in the softsim keyboard handler so you can single step or go to finish executing that code. The word **lit** takes the number on top of the host stack and pushes it onto the top of the focus node stack, just as it would in the IDE. To manually resume control panel operation, say **ok h** .

7.8.1 Vocabulary Reference

Host Commands

node (nn) sets node nn (yyxx form) as the *focus* node.

other (nn) sets node nn as *other*.

call (a) makes a call to address a in focus node and starts softsim control panel.

boot (acn) moves c words from address a of bin n into focus node RAM.

lit (n) pushes n from host stack onto focus node's data stack.

r@ (a-n) fetches a word from focus node address a onto host stack..

r! (na) stores n from host stack to focus node address a .

break (slot addr node) sets breakpoint for given node to stop before executing the opcode in the given 0-relative slot of the instruction word at the given address.

-break (node) clears breakpoint for the given node.

F18 Opcodes

rdup (n-nn) *all of these*
rdrop (n) *use node's own*
rover (ab-aba) *stack.*
rpop (-n) from return stack
rpush (n) onto return stack
r- (n-n) bitwise invert
rand (nn-n) bitwise AND
ror (nn-n) bitwise exclusive OR
r+ (nn-n) 18-bit add, *not in EAM*
r+* (st-st) multiply step uses **A**
r2* (n-m) left shift
r2/ (n-n) arith right shift
ra! (n) to register **A**
ra@ (-n) from register **A**
rb! (n) to register **B**
!b (n)
!a (n)
!+ (n)
@b (-n)
@a (-n)
@+ (-n)

Convenient Constants

io (-a) pushes address of io register onto host stack.
data (-a) up data register.
ldata (-a) left data register.
right (-a) right port.
down (-a) down port.
left (-a) left port.
up (-a) up port.

8. Preparing Boot Streams

Unless equipped with special ROM or booted using SERDES, our chips must be booted after reset by having a suitable *boot stream* made available to one of its *boot nodes* (such as async serial, 2-wire synchronous serial, or SPI flash nodes that are enabled for boot after reset.) A boot stream consists of one or more *boot frames*, which are data structures defined and processed by the boot nodes of our chips. Each boot frame contains zero or more words of data, a starting memory or port address at which the data are consecutively written, and a jump address to which control is transferred by the boot node after the frame has been processed. Every boot node defines a *concatenation address* to which a boot frame may jump to process another frame. After reset, a chip may boot itself from a slave device such as SPI flash memory, or it may wait to receive boot stream(s) on one or more of its enabled interfaces. For example, a daisy chain of subsidiary chips may be booted by a master chip using frames stored in the master's mass storage or read from its boot device (such as an SPI flash). As another example, the serial IDE works by transmitting boot frames into the chip under test.

8.1 The Streamer Utility

This section introduces the arrayForth tools for building boot streams from compiled source code. For more details about boot stream composition and boot protocols, see the library of Application Notes.

Block 848 in the distributed source code is a simple template for generating a boot stream to load a trivial program and burning that stream to SPI flash. It consists of the following elements:

```
empty  compile  streamer load  framer load
```

This phrase compiles all relevant source code and loads the environment and vocabulary for composing SPI flash boot streams.

```
entire course
```

This phrase specifies the path to be used by the stream. **`entire`** is a default path covering the entire GA144 from SPI boot node 705, and may be used to program any or all of the 144 nodes in the chip, including node 705 itself. Node 705 is the last node loaded in an SPI boot stream.

```
600 +node  600 /ram  0 1 /stack  12 /p
```

This phrase specifies that node 600 should be loaded from its own default bin, that 0 should be pushed onto the stack, and that the node will be started executing at location x12.

```
frame
```

This word builds the complete boot stream in a memory buffer. It's factorable into **`exec fram`** where `exec` is the concatenation address for the SPI boot node. To make a frame for another boot node, use the concatenation address for that node. For example, x0ae is the address for the async serial boot node. This is the only change needed, other than the path, in order to make a boot stream rooted in any boot node.

```
0 fh loaded !  nores  strlen leng !
```

This phrase sets up feedback to be displayed during flash burning. The current block's number is shown, the result is set to blank, and the display is set to show the stream's length.

```
stream ers
```

This phrase erases enough flash to contain the stream. Some versions may simply erase the first 32k bytes of flash regardless of stream length. Others may erase the entire chip, see following section.

```
stream 0 swap 18burn
```

This phrase burns the generated stream into flash starting at byte address zero so that it may be booted automatically by node 705 on chip reset.

8.2 Burning Flash

By loading the streamer utility you gain a vocabulary for erasing, burning and verifying SPI flash connected to boot node 705 as it is connected on the Evaluation Board.

8.2.1 Erasing Flash

Flash needs to be erased before being written. This is done with the word `ers` which expects two parameters: A starting address and a number of *bytes* to be erased.

Example: **`0 8092 ers`**

The smallest unit of flash that can be erased on the Evaluation Board is 4K bytes, so the starting address should be on a 4K byte boundary and that's where the erasing will start. The number of bytes erased will be rounded up to the nearest 4K as well. *Note: Currently the whole flash is always erased. However,* `ers` *should be called with correct arguments for upward compatibility.*

8.2.2 Writing Flash

There are two streamer commands for writing flash: `burn` and `18burn` .

`burn (s d n)` writes flash in 16 bit units. `s` is the *word* address of a buffer of 16-bit words in host memory, `d` is byte address of destination in flash, and `n` is number of 16-bit words to write.

`18burn (s d n)` writes flash in 18-bit units. `s` is the word address of a buffer in host memory with a sequence of 18-bit values stored in consecutive 32-bit words, `d` is byte address of destination in flash, and `n` is the number of 18-bit words to write.

`burn` is used for 16 bit data such as the polyFORTH nucleus or the eForth kernel. Both are virtual code for virtual machines that run out of 16-bit SRAM.

Example: **`<filebuf> x8000 <filelen/2> burn`**

This example burns <filelen/2> words to flash at byte address x8000 from the given buffer.

`18burn` is used to write 18-bit data such as boot streams. The word `stream` returns the beginning address in host memory and the length in 18-bit words describing the output of the `framer` utility. Having built a boot stream, burn it into flash at address 0 as follows:

Example: **`stream 0 swap 18burn`**

8.3 Serial Boot Streams

By specifying a different path, rooted at a different boot node such as 708 for async serial or 300 for synchronous serial, the `framer` can build streams suitable for presentation to those nodes. See the discussion of the word `frame` above to create such frames; see the discussion at the end of the Interactive Testing section, above, for examples of one way to use such streams.

9. Practical Example

We have chosen a simple application to act as a practical example of how to develop and test an arrayForth program. The only parts we will need are those included in your EVB001 evaluation kit so you should be able to reproduce our results exactly. Our application is a simple PWM algorithm generating output to an LED.

Although simple, the PWM we will demonstrate uses a nontrivial approach. Many PWMs divide a fixed interval into a low period and a high period such that their sum is a constant period. The output value is the ratio of high to low time. The fixed maximum update rate derives from the period chosen. The resolution derives from the number time units the period is divided up into, usually a power of two.

PWMs have the benefit of generating an analog value from a digital output which is linear, assuming you can feed a perfect integrator. All PWMs force a trade-off between resolution and update rate. Usually this trade-off is fixed by the designer for any given application by choosing an inner loop timing interval and a number of intervals in the major period.

The algorithm we will demonstrate has several benefits over the classical design. The value presented for output is represented as a binary fraction between 0 and 1. The precision of the output is not affected by the inner loop update frequency which should always run as rapidly as attainable by the selected hardware. The higher the inner loop frequency the faster any given output will reach its desired average value. The maximum output rate is determined by period of the inner loop times the power of two represented by the least significant bit you have decided is important.

9.1 Selecting resources

For our example we will be using node 600 from the host chip because its output is easily accessible. We must move the jumper on J39 from 1-2 to 2-3 to expose host 600.17 output. This would affect automatic MMC access but will not interfere with access to the boot flash.

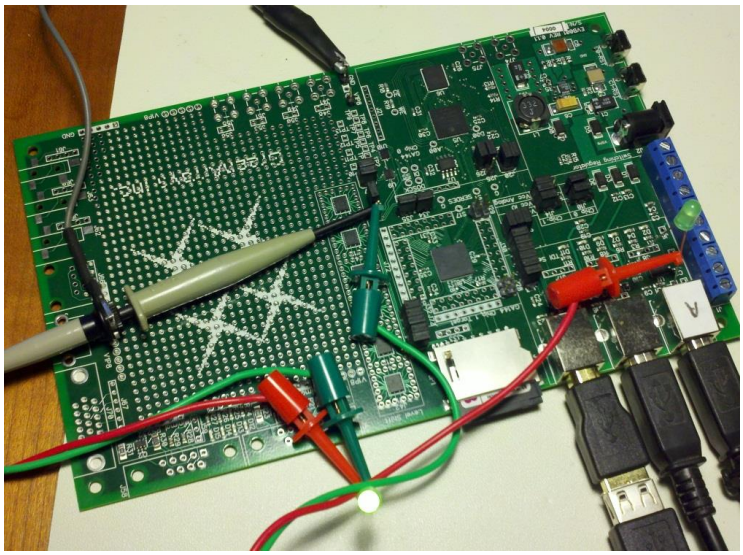
For brightness we will use 3.3v provided by one of the FTDI chips. Pin J7 is from the USB chip we will be using so it makes a good choice. We have chosen to solder one of our LEDs between J7 and J8-3 as a com input activity light. By connecting one of our clip leads to the anode of this LED we can pick up the 3.3v safely.

To minimize measurement interference we placed our scope between ground and J39-1. We have soldered stake pins to one of the ground areas near the prototyping region on our EVB001 and connected scope ground there.

We will use the default IDE hook path 0 which runs the perimeter counter clockwise. To make sure that node 705 is available right after reset be sure to keep J26 1-2 jumpered (for SPI no-boot select) whenever testing.

9.2 Wiring

See the adjacent image for a wiring example. We twisted the clip leads together loosely and connected one lead from the J7 USB LED anode to the anode of our free standing test LED. The other color clip lead runs from J39-1 to the test LED cathode. You may choose to place one of the resistors supplied between 3.3v and the LED to limit current when the LED is powered. We have chosen to leave it out in this demo as the measured voltage is just below spec and it simplifies the setup.



We can verify our wiring and check our assumptions by simple interactive use of the IDE.

1. Make sure the No-Boot jumper J26 is installed to avoid conflicts which might cause hangs.
2. Simply type **`host load panel`** to load the IDE.
3. Then type **`talk 0 600 hook upd`** to gain access to node 600 and display its stack.
4. Switch to hex input (see 2.2.3 above) and type **`20000 io r!`** to place the pin in strong pull down and the LED should illuminate. A glance at the scope should show the pin to be near 0.5v due to maximum current draw through the LED.

Try typing the following in succession and observe the voltage on your scope:

- **`10000 io r!`** (weak pull-down)
- **`30000 io r!`** (drive pin high)
- **`0 io r!`** (high impedance)

9.3 Writing the code

The sample code we will show you has been placed in block 842. This is part of an open range of blocks that you may use freely. To make sure that our work is automatically run through the F18 compiler we have also placed a load for it into block 200. (You should follow the same pattern when you begin your own projects. If your project spans many blocks it's a good practice to use the first block to load all the others and load only this first block from 200.) Blocks 200 and 842 in the arrayForth distribution contain these things to facilitate your walking through this exercise.

When picking a sequence for loading your blocks the safest one is to load each server node sometime before their respective clients. As a matter of definition a pair of nodes have a server/client relationship if the server trusts jumping or calling the shared port and the client feeds instructions to the same port. In practice this relationship does not change dynamically. By loading the servers first then names defined in them are available for making instruction words that the client can feed back to them.

Our sample is only one block and one node long. It begins with an identifying comment and then shows that it is F18 code for node 600 beginning from location zero. If this code were node-independent, you might want to leave out the **`600 node`** phrase and specify that from the block loading this one. The code is divided into three sections, each one in turn more aware of the others. We will describe the code in the order of its writing, as if wrapping the onion.

```
                                                 842 list
pwm demo for host node 600                       pwm demo 600 node 0 org

pol checks for ide inputs and calls down         pol 000 @b 2000 dw and if
when noticed.                                    ... 003 ... down b! @b push ex
rtn is the return point from a down call         rtn 006 ... io b! then 008 drop
and is used by upd as an re-entry point.
cyc begins the actual pwm code.                  cyc ie- 1FFFF and over . + -if
upd is the ide entry point for initial           ... 00C ... 20000 !b pol ;
start or output update.                          ... 00F then 10000 0 !b pol ;

                                                 upd 012 xex- drop push drop 100
                                                 ... 014 pop pop iex- rtn ; 016
```

The core function is the three lines beginning with the comment "cyc". This code expects two stack items: an increment value and an error accumulator. It implements the inner loop of the PWM algorithm by calculating and sending a new value to the output pin. The hex number 20000 sets the output to strong pull down which will turn on the LED. All other output values will not cause significant current flow. A hex value of 30000 would select strong pull up and is not useful for this application. The hex value 10000 sets weak pull down and turns the LED off. The commented 0 would select tristate output which also turns off the LED but permits the pad to float higher. By toggling which of these values is commented one can rapidly compare the consequences. We will discuss how this is done in the next section.

The algorithm used is essentially an adaptation of the classical Bresenham line interpolation algorithm (or at least one understanding of it). PWMs are good at adjusting average power by controlling the duty cycle of a current source or sink. Power sinks such as LEDs or motors are examples of good candidates for PWM control. Because the switch to the energy source is either full on or off they are more efficient than typical analog control methods. The following analogy should help us to visualize this use of the algorithm.

Think of a pixel as being the smallest unit of energy that we can control; full power times the shortest time period we can cycle the algorithm. We can map the set of all positive slopes onto the set of binary fractions between 0 and 1 by thinking of the slope as the ratio of power on to power off time. A vertical slope is full power and a flat slope is zero power. An infinitely thin line leaving the origin with rational ratio will pass between many pixels without striking them dead center. There is an error term that maintains the amount by which each ideal point is missed as the line goes by. The slope, as a binary fraction, is added to this error term. Each time there is an overflow a one is output. Each time there is no overflow a zero is output. The remainder less than one left in the error term is always carried forward to the next interval.

At 0.5 duty cycle there is a perfect square wave at maximum frequency. Above 0.5 the high pulses begin to concatenate, separated by low pulses of the minimum width. Below 0.5 the low pulses concatenate between lone high pulses. At 0.25 there is a pulse train at half the maximum frequency. At 0.125 the frequency is a quarter of maximum. Above 0.5 for complementary slopes (where complementary is defined as 1-x and x is 0.5 to a positive power), the signal frequency changes just as it does for those x below 0.5, except that the output signal is inverted. For slopes below 0.5 represented by more than one 1 bit in their binary fractional forms, the output is made up from all contributing frequencies interspersed. Because only a single overflow is possible in each cycle, each frequency is magically merged at its own unique phase. At slopes of either 1.0 or 0.0 the error term never changes and the output either saturates or stops.

In our implementation the hex number 20000 represents 1. The number 10000 is a half and so on. At the beginning of "cyc" the **`1ffff and`** removes any present overflow bits from the error term so that the next new one can be detected. The phrase **`over . + -if`** adds the slope in S to the error term in T and tests the overflow bit. In the case of overflow **`20000 !b`** maximizes the output current. For the non-overflow case **`10000 !b`** minimizes the current flow. If our algorithm never had to represent but a single slope then at this point each of the two output phrases would simply jump back to the **`cyc`** point. We want our code to entertain new inputs as well as to accept debugging illumination requests so instead we jump to the command monitoring function called **`pol`** above.

When the code is running in diagnostic mode it will be loaded from an IDE "wire" coming from node 700. Examination of the G144 quick reference poster shows that 600 and 700 are connected by their **`down`** ports. When an IDE command is issued across the wire the first instruction is a focusing call that limits the target's program counter to only a single port decode (in case the target had been executing a multiport fetch before). At the completion of an IDE command, other than the call command, a return instruction completes the command and returns the target to its original task. For an idle target node this will be a multiport execute. In our case we will be executing the PWM rather than a port fetch. The three lines of code starting with **`pol`** serve to poll for IDE commands and if one is detected then we turn control over to the port completely.

The first line of code fetches the IO port value, masks out the down write bit and if the result is zero (no write pending) it jumps to the **`drop`** which restores the stack to the values expected by "cyc". If a write is pending we need to give up control to the port but need to leave a return path to the PWM in case the intentions of the IDE are temporary. We assume there is a focusing call to **`down`** sitting in the port and this instruction needs to be removed by reading. We also must emulate executing this call but with a return address back to ourselves. The phrase **`@b push ex`** pulls the call from the port, pushes it to the return stack where **`ex`** (execute) performs a co-routine jump to the address pushed as part of the call. The new return address replaces the call address on the return stack. In this way when the IDE completes it will return us to the **`io b!`** phrase on the last of these three lines, restoring B.

The final requirement that must be met for this demonstration code is to help the IDE in setting up and changing the operating conditions. The IDE provides for pushing a literal item onto the target data stack but it does not support insertion of an item to replace S in a single operation. The two lines of code called **`upd`** provide this function. The hex literal 100 at the end of the first line is known to occupy location 13 in ram. We will code an IDE script word in the next

block called **seed** which will store a value from the arrayForth stack at location 13 and then call **upd** to inject that value into the PWM as a new slope.

As soon as the code is written we add the phrase **842 load** into block 200 so that the next time we type **compile** this block will be included in the compilation. Once we do so we will observe that all our grey numbers which were initially 001 have all been modified by the F18 compile to reflect the program counter at that point in the program. If you mistyped any names or used a name before defining it the compiler will abort with question mark appended to the word you typed (such as **compile**) to perform the compilation. If you respond with **e** the editor will take you to the point in the block where the error was first detected. If all compiles well the next step is to generate some IDE script to help us install and test the code.

9.4 The IDE script

We believe that interactive development is not merely the responsibility of some esoteric, third-party, software development platform. We believe it is primarily a mindset. The choices and tools presented by the development platform must simply not conflict with the proper mindset. The mindset cannot be enforced by the tools. The following precepts can be considered to be part of the mindset.

- Make small changes.
- Save often.
- Test every change.
- Make sure all steps are repeatable (such as rebuilding everything before each test).
- Choose development paths that do not preclude testing for significant intervals.
- Shun tools which delay your feedback because they serve to distract you.

The reason colorForth keeps all source code memory-resident and compiles all code from pre-parsed tokens is to encourage recompiling often. The use of scripts encourages repeatability and in colorForth you cannot even make a definition without first committing it into a block. The arrayForth word **compile** supports these precepts by quickly rebuilding all F18 object code and also by reloading whatever test environment you have configured for the current stage in your development. To support the latter function, whenever you load testing tools they should begin with the phrase **0 fh orgn !** which directs compile to reload that test environment as part of its job.

In block 844 you will find the test script we have built for exercising the PWM demo. The template for this script was copied from the **host** block that you loaded earlier when we typed **host load** as part of assumption checking for node 600 and our wiring. We encourage you to read the shadow for the **host** block. In our present case we have deleted the sample definition and the **canon load** and added two script definitions on top the standard serial IDE functions. We could also, if we had wanted, defined here a custom wiring path to replace the standard one but the defaults will be adequate for such a simple program.

```
                                                  844 list
configure ide for demo testing.                   demo ide boot empty compile serial load

***no canonical opcodes***                        customize -canon 0 fh orgn !
use the 'remote' ones                             a-com sport ! !nam

seed loads pwm 'rate' and re-/runs cycle.         seed n 13 r! 12 call upd ;
run selects node 600 target, loads the pwm
into it and starts it with a default value.       run talk 0 600 hook 0 64 600 boot
                                                  upd ?ram panel 0 lit 18000 seed ;
```

The word **seed** uses IDE remote commands to place its argument on top of the template literal in node 600 **upd** and to restart the PWM at the **upd** entry point. The panel stack display is also updated so that, if you are viewing the panel, you will see your new argument there. It is helpful when outputting a sequence to see what you put out last. On the other hand outputting a new seed does not force panel display as this would be presumptuous and could easily be considered a distraction.

The word **`run`** forces a reset to the host chip and reloads node 600 via path 0. It displays the panel and starts the PWM with an initial seed value of 0.75 duty cycle. Note that you would not need to use this word after a **`compile`** if you had not made changes to the F18 code. If you had only added or changed some script function you would be good to go.

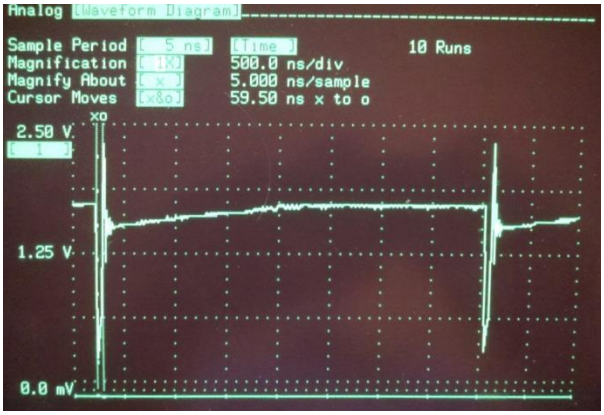
To compile this script code for the first time and get it hooked in you type **`844 load`** this time only. In the future simply use **`compile`** and you will also load these definitions.

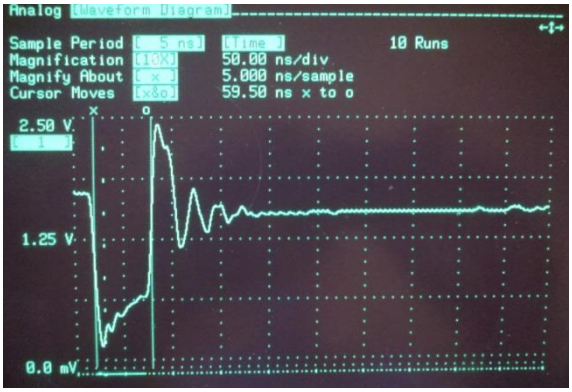
So now that your PWM and test code is loaded, it is time to power up the scope, type **`run`** and use **`seed`** to observe the effects of different values upon the waveform and the LED. Note that although the waveform energy is a linear function of duty cycle, your eyes do not perceive the LED intensity as linear. In a dark room you can observe the smallest value of 1 as well as increments of 1 but as soon as it becomes significantly bright you can no longer resolve such small differences. Your eye has some kind of a logarithmic response and responds better to powers of two or less. Perhaps a Fibonacci ramp would be more pleasing.

9.5 Output Observations

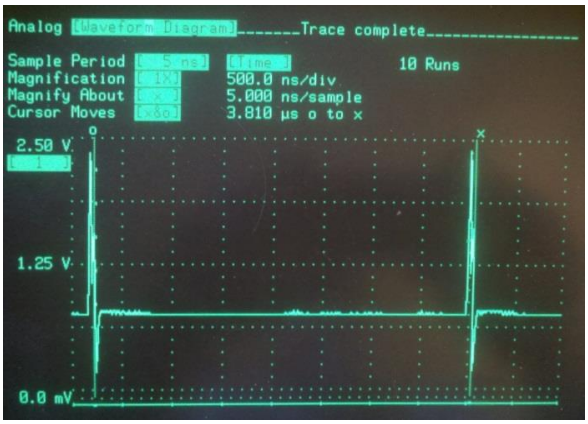
The output waveforms shown in this section demonstrate the behavior of the PWM. We will use the term *bit cell* when referring to the smallest unit of output and the word *frame* to refer to the period determined by the frequency contribution of the least significant one bit in the slope value. For consistency all the waveforms shown have a frame size of 64 bit cells. The size of our bit cell is determined by the both the algorithm and the particular speed of the node and chip under test. For our case the bit cell time is approximately 59.5ns and the frame time comes out to approximately 3.81us. The output values of 1/64 and 63/64 have been chosen because they are easy to sync a scope to, because they are complementary, and because they highlight the effect and shape of a single bit cell. The last value of 33/64 demonstrates how two frequency components merge.

The first image shows a frame of mostly zero (higher voltage). You can see how the output rings and then floats up gradually.

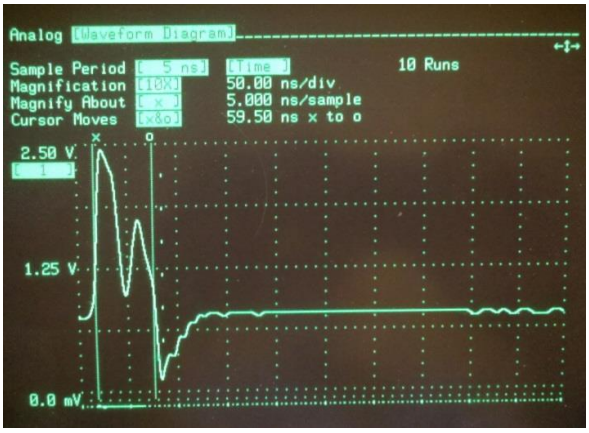




The second image zooms in on the one bit at the perimeter of the frame. We see a strong negative going pulse that arcs back up to a stable voltage just before releasing.

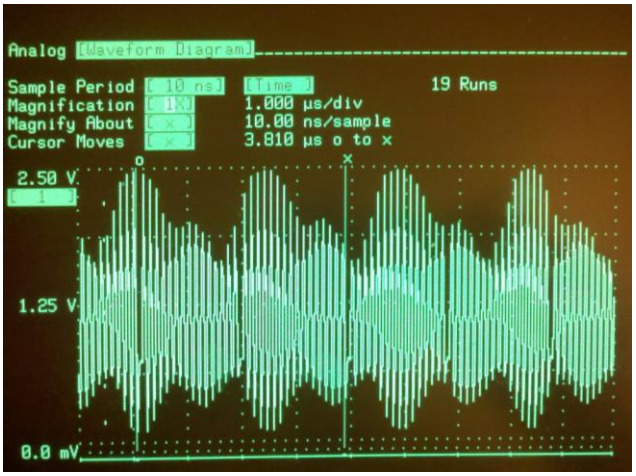


The third image is of a frame of 63 one bit cells and a single zero bit cell. You can see how the frame begins with a strong low going pulse that quickly stabilizes to a firm value and ends with a short ring as it is released for one bit cell.



The fourth image is a zoom into the frame transition of the previous capture and shows the single zero bit cell being replaced by the long string of ones.

The last image is of the value 33/64. It contains two complete frames. In each frame you may count 33 one bit cells and 31 zero bit cells. Observe that this packing is accomplished by joining two one bit cells in each of two locations. There is also a change of phase in the second half of each frame.



9.6 Further Study

Please see the hybrid DAC function **-dac** described in the *G144A12 Chip Reference*. That algorithm, present in ROM of the Analog nodes, uses duty cycle variation to enhance the resolution of the 9-bit current sourcing DACs.

10. Appendix: Reference Material

10.1 Glossary of Terms

This section contains concise definitions of key elements, terms, and concepts of colorForth.

Character A member of the colorForth character set.

Compilation The process of interpreting a stream of color tagged words and numbers from a source block in RAM. White (comment) and Blue (display functions) are ignored as are word extensions. Yellow words and numbers are interpreted immediately when encountered; for words, only the `forth` word list is searched. When a magenta word is encountered, a variable is added to the word list (`forth` must be selected) and its value is stored in the source code where the variable's definition appears; the current value of any active variable is visible when displaying its source. When a red word is encountered, that word is added to the `forth` or `macro` word list depending on which was selected most recently, and associated with the next location in the dictionary (this is done in such a way that preceding code may continue executing across the boundary identified by the red word). When a green word is encountered, the `macro` word list is searched and if found that word is executed immediately. If not found a green word is next searched in the `forth` word list and if found a call to that word is compiled into the dictionary. Cyan is used to compile a call to a macro rather than to execute it. Grey words are ignored by the PC compiler but are updated by the F18 compiler to hold F18 memory addresses. Every colorForth program, except the kernel, is compiled from source when needed. No "object code" or other binary image format is saved or manipulated except that F18 binaries reside temporarily in mass storage blocks for use by softsim, the IDE, or stream building.

Editor The program which displays a block of colorForth source code along with a control panel for a custom keyboard interaction, and which is the main tool for maintaining the content of source code.

Interpretation The process of acting immediately by direction of words and numbers. When a number is encountered it is pushed onto the stack. When a word is encountered it is executed. This is what the Interpreter does with all input received from the keyboard. When loading a block, the interpreter processes yellow words and numbers in the same way. When other colors are encountered, they are handled as described above in Compilation.

Number An integer in 32-bit, twos complement form. When used in the context of code or communications with F18 processors, only the low order 18 bits of a number are sent to the F18, and only 18 bits are received back.

Tag A number which is combined with the internal binary representation of a word to identify it syntactically.

Text Entry Mode A state of the system during which the keyboard is being used for entry of text, meaning words or numbers. When in this mode, one of two possible keyboard behaviors is active: QWERTY, or dvorak. Anything colorForth understands may be typed using either keyboard, but each has its own meanings for the keyboard buttons, each has a different protocol for indicating whether a word or a number is being entered, and each makes different use of the keyboard hint area of the display.

Word When referring to memory, a word is either 32 bits (on the PC platforms) or 18 bits (on the F18 computers.) When referring to colorForth words, a word is a string of one or more characters that are Shannon coded and tagged.

10.2 colorForth Tag Reference

Tag	Syntax Element	Color
15	Commented Number	White
14	Display Macro	Blue
13	Compiler Feedback	Grey
12	Variable	Magenta
11	*Obsolete comment form*	(White)
10	*Obsolete comment form*	(White)
9	Comment	White
8	Interpreted Number	Yellow
7	Compiled Macro Call	Cyan
6	Compiled Number	Green
5	Compiled Big Number	Green
4	Compiled Forth Word	Green
3	Define a Forth Word	Red
2	Interpreted Big Number	Yellow
1	Interpreted Forth Word	Yellow
0	Word Extension	(color of preceding word)

10.3 colorForth Characters and Binary Representation

The following table shows three values for each of the 48 colorForth characters. Character value zero (space) is not an actual character; instead it denotes the end of a word.

The first column is the Shannon-coded binary value for the character. The second column shows the graphic for the character, and the third column is its internal numerical value when not Shannon-coded. *ASCII character codes are not used within colorForth;* they are only used for communication with external systems.

Shannon	chr	cF	Shannon	chr	cF	Shannon	chr	cF
0 000		0	10 000	s	8	1100 000	d	16
0 001	r	1	10 001	m	9	1100 001	v	17
0 010	t	2	10 010	c	10	1100 010	p	18
0 011	o	3	10 011	y	11	1100 011	b	19
0 100	e	4	10 100	l	12	1100 100	h	20
0 101	a	5	10 101	g	13	1100 101	x	21
0 110	n	6	10 110	f	14	1100 110	u	22
0 111	i	7	10 111	w	15	1100 111	q	23
1101 000	0	24	1110 000	8	32	1111 000	;	40
1101 001	1	25	1110 001	9	33	1111 001	'	41
1101 010	2	26	1110 010	j	34	1111 010	!	42
1101 011	3	27	1110 011	-	35	1111 011	+	43
1101 100	4	28	1110 100	k	36	1111 100	@	44
1101 101	5	29	1110 101	.	37	1111 101	*	45
1101 110	6	30	1110 110	z	38	1111 110	.	46
1101 111	7	31	1110 111	/	39	1111 111	?	47

10.4 Memory Map

arrayForth mass storage block address space maps directly onto the active memory available for use by the system. Its absolute memory origin varies between the Native and Win32 systems, but block 0 is always the beginning of this area regardless of what absolute address it corresponds with. In the table below, the block numbers are absolute but the memory addresses are all relative to the origin of block 0.

Block number	Relative byte addr	Size in bytes	Usage
32768	x2000000	864k	Object code area, two blocks per bin. 144 bins (0000..0717) for host chip; 144 bins (0800..1517) for target chip; 144 bins (1600..2317) for GreenArrays tools and utilities.
29000	x1C52000	3,768k	Buffer for source compression/decompression functions.
10000	x9C4000	19,000k	Compare area for audit utility, otherwise available.
2900	x2D5000	7,100k	Initial value of here after boot. Program text and data.
2880	x2D0000	20k	List of forth words, 8 bytes per word, limit of 2560
1440	x168000	1440k	Extended source code area, unused at present
18	x4800	1440-18k	Source code (from OkadWork.cf on Win32 systems)
12	x3000	6k	Icons table for character set.
0	0	12k	Native system kernel.

10.5 Index Listing for Rev 02a


```
240 framer overlay
242 - framer com 131
244 - framer "pth 67898173 "wall 271590019
246 - framer
248 - framer
250 ers flash erase function overlay
252 flash writer 18 bit overlay
254 - code for flash writer
256 exercising flash 20 org
258 writing flash 8 bits overlay
260 code for reading and writing flash 8 bits
262 default flash path for whole chip
264 sram cluster mk1
266 - load descriptor
268 - residual paths
270 sram.16 address-bus 9 node
272 - control-pins 8 node host
274 - data-bus 7 node host
276 - interface 107 node 0 org
278 - user node 106, 108, or 207.
280 - degenerate sram 107 node 0 org
282 streamer
284 flash utilties feedback
286 - flash utilities feedback
288 pf to flash
290 speedup spi boot 705 node 0 org
292
294 stream to file named stream.bin
296
298
300 dc characterization code added march 2011.
302 custom test code 609 node 0 org
304 set all high z for leakage test talk
306 set all weak pd for wpd test talk
308 set all high for several tests talk
310 set all low for several tests talk
312 t04 all node access talk
314 vt=- node 217 compile talk 2 217 hook upd
316 vt=- node 517 compile talk 0 517 hook upd
318 vt n7/8 compile talk
320 vt n9/8 compile talk
322 t10 schmitt power talk
324 t11 suspended power talk
326 study single node = boot power talk
328 t12a boot power talk
330 t12b boot pwr = drop same talk
332 t12c boot pwr = drop alternating talk
334 t12d boot pwr = greg test talk
336 t12e boot pwr = unext talk
338 sram test bd quiet i/o talk
340 study single node w/boot suspended talk
342 705 unext w/boot suspended talk
344 instr timing code 610 node 0 org
346 study instr timing talk
348
350
352
354
356 mark mem test all nodes
358 mark burn on one weak node
360 polyforth virtual machine reclaim
362 - load descriptors
364 -- virtual machine
366 -- serial terminal
368 -- additional i/o
370 - host ide with pf running empty compile
372 -- residual paths
374 pf.16 stack 0 org
376 - stack cont"d
378 pf.16 bitsy 0 org
380 - bitsy cont"d
382 stack down bxxx 6 node 0 org
384
386 stack up axxx 206 node 0 org
388
390 bitsy down fxxx 5 node 0 org
392
394 bitsy up exxx 205 node 0 org
396
398 serial transmit 100 node 0 org
400 - receive 200 node 28 org
402 - interface 104 node 20 org
404 generate ganglia
406 - ganglion template
408 - snorkel reclaim 207 node 0 org
410 spi flash sst25wf080 reclaim 705 node 0 org
412 minimal spi reclaim 705 node 0 org
414
416
418
420 2 chip async bootstream demo
422 - generate stream
424 async pf bootstream with bridge
426 - generate pf stream
428 -- path both chips
430 install pf via async bootstream
432 - generate pf stream
434 -- read pf nucleus ft 0 chr 9216 0 chr !
436 -- load polyforth nucleus
438
440
442
444
446 - sram loader nodes
448 - spi flash 8 bits 705 node 0 org host
450 polyforth ide boot host bridge load
452 - custom ide paths
454 - sram user code from nodes 106, 108, 207
456 - ph0 sram setup
458
460 install pf in flash
462 - burn pf nucleus
464 -- read pf nucleus ft 0 chr 9216
466 - generate pf stream
468 -- load polyforth nucleus
470
472
474
476
478
```

```
480 g144a12 ats test components
482 2000 port tests
484 2001 port tests with 2
486 2002 extensive ram test jeff
488 2003 testing t and s
490 2004 testing t and r
492 2005 testing stack registers
494 2006 testing return stack registers
496 2007 mark ram test 200 node
498 2008 mark r d stack test
500 2009 =  a shift test
502 2010 t s a and r data path tests
504 2011 gpio pin test
506 2012 mark d stack test
508 2013 io data path tests
510 2014 set/clear carry test
512 2015 mark <p test
514 2016 test i-ad and r-ad data paths
516 2017 rom checksum
518 2100 parallel port pin test
520 2101 mark <b !b test
522 2102 mark t to b reg test
524 2103 mark port to i-reg test
526 2104 mark port to i-reg-bit-short test
528 2105 mark port to i-reg-bit-short test
530 2106 mark port to i-reg-bit-short test
532 2107 mark port to i-reg-bit-short test
534 2108 mark port to i-reg-bit-short test
536 2109 mark port to i-reg-bit-short test
538 2110 mark prp-call test
540 2111 mark prp-ex test
542 2112 serdes 001 slave test
544 2113 serdes 701 master test
546 2114 basic analog checks
548 2115 mark 2  test
550 2116 mark 2/ test
552 2117 mark 2/ test
554 2200 tst= mark testing =
556 2201 mark r d stack test v2
558 2202 mark d stack test v2
560 2203 mark test = v2
562 2204 mark testing and
564 2205 mark test and
566 2206 mark testing or
568 2207 mark test or v2
570 2208 mark test -
572
574
576
578
580
582
584
586
588
590
592
594
596
598
600 res for more ats test pkgs ---
602
604
606
608
610
612
614
616
618
620
622
624
626
628
630 1900 ats analog
632 1901 ats sync boot master
634 1902 boot frame for master testing
636 1903 boot frame for master testing
638 1904 ats sync bridge
640 1905 uut bridge debug
642 1906 tester bridge debug
644 bridge loader
646
648 1400 ats cs master0 n108
650 1401 ats cs wire
652 1402 ats cs digital
654 1403 ats cs analog
656
658 xxxx smtm mem-random converted
660 tb001 ide pretest empty compile serial load
662 - pre powerup tests 662 list
664 - power opens and shorts
666 - results
668 - port bridge
670 tb001 ide creepers empty serial load
672 - all tests
674 - multichip ide
676 -- paths 0,1
678 -- paths 1
680 -- paths 1a
682 - control lines
684 - all-nodes runner
686 - incremental runner
688 - build table of valid io w/r bits
690 - build table of rom checksums
692 - results
694 - runner for 911 pin test
696 - runner for 917 rom checksum
698 - runner for 2113 serdes test
700 - runner for 2114 analog test
702
704
706
708 selftest a chip, port on stack empty stp !
710 - paths
712 ats target test given host port empty stp !
714 - paths
716 - build port bridge
718 - runner for 2113 serdes test
```

```
720 10baset ethernet cluster mk1
722 - load descriptor
724 - residual paths exit
726 - tx load descriptor
728 417 tx osc 788 load exit 417 node 0 org
730 317/316 tx pin 317 node 0 org
732 315 tx mux 315 node
734 115/215 autonegot 215 node 0 org
736 314 tx framing 314 node 0 org
738 214 tx delay 214 node 0 org reclaim
740 114 tx crc reclaim 114 node 0 org =cy
742 113 tx unpack 113 node 0 org reclaim
744 112 tx wire 112 node 0 org reclaim
746 108 sram master reclaim host host"s memory...
748 109 dma nexus slave 109 node 0 org
750 110 dma nexus 110 node 0 org
752 110 continued
754 111 tx ctl 111 node 0 org
756 010 rx ctl 10 node 0 org
758 011 rx byteswap 11 node 0 org reclaim
760 012 rx pack 12 node 0 org reclaim
762 013 rx crc reclaim 13 node 0 org =cy
764 014 rx frame 14 node 0 org reclaim
766 015 rx parse 15 node 0 org reclaim
768 016 rx timing 16 node 0 org
770 217/216/116 rx active pull-down
772 117/017 rx pin 117 node 0 org reclaim
774 517 tx osc monitor 517 node reclaim
776 516 tx osc agent 516 node 0 org =cy
778
780 ether test ide empty compile
782 flakey 517 tx osc monitor 517 node reclaim
784 flakey 516 tx osc agent 516 node 0 org =cy
786
788 417 tx osc 417 node 2 org
790
792
794
796
798
800
802
804
806
808
810
812
814
816
818
820
822
824
826
828
830
832
834
836
838
```

```
840 uncommitted/user code
842 pwm demo 600 node 0 org
844 demo ide boot empty compile serial load
846 loader template host load loader load
848 framer template empty
850 framer host flash to target boot
852 framer bridge paths
854 - app boot descriptors
856
858
860
862
864
866
868
870
872
874
876
878
880
882
884
886
888
890 carry time 308 node reclaim 0 org
892
894
896 0xx-108 rx sram logging
898 gpio rx pin 217 node 0 org
900 sha-256 scheduler 101 node 0 org =cy
902 sha-256 scheduler 102 node 0 org =cy
904 data source 100 node 0 org
906 data sink 201 node 0 org
908 data sink 1 node 0 org
910
912
914 softsim setup
916
918
920
922
924 sha-256 scheduler 101 node 0 org =cy
926
928
930 ethernet calibration code
932 ether calib ide boot host load loader load
934 - residual paths
936 417 send link pulses 417 node 0 org
938 217/317 rx pin 217 node 0 org
940 117/217/317 rx pin 117 node 0 org
942 117/217/317 rx timing 117 node 0 org
944
946 - testloop load descriptor
948 015..517 rx display
950 rx timing 217 node 0 org
952 test rx in 300 400 node 0 org
954 rx timing 2 217 node 0 org
956 417 orig tx osc 417 node 0 org
958
```

```
 960 an012 ti sensortag reclaim
 962 - load descriptors
 964 -- code
 966
 968
 970 an012 ide boot bridge load loader load
 972 - custom ide paths
 974 install pf in flash
 976 - generate pf stream
 978 -- load polyforth nucleus
 980 715 xtal osc reclaim 10715 node 0 org
 982 717 hub timing reclaim 10717 node 0 org
 984 713 light sensor reclaim 10713 node 0 org
 986
 988 709 i2c timing reclaim 10709 node 0 org
 990 708 slow i2c reclaim 10708 node 0 org
 992
 994
 996
 998
1000 705 spi boot reclaim 10705 node 0 org
1002 617 fake hub reclaim 10617 node 0 org
1004
1006
1008
1010
1012
1014
1016
1018
1020
1022
1024
1026
1028
1030
1032
1034
1036
1038
1040
1042
1044
1046
1048
1050
1052
1054
1056
1058
1060 more tests
1062
1064
1066
1068
1070
1072
1074
1076
1078
```

```
1080 compile 16-bit eforth virtual machine
1082 - e4vm16 stack 8xxx-9xxx
1084 --- more stack
1086 -- stack up bud axxx 206 node 20 org
1088
1090 -- stack down bud bxxx 6 node 20 org
1092
1094 - e4vm16 bitsy cxxx 105 node 0 org
1096 --- more bitsy
1098 -- bitsy right bud dxxx 104 node host
1100
1102 -- bitsy up bud exxx 205 node 20 org
1104
1106 -- bitsy down bud fxxx 5 node 20 org
1108
1110 - flash to sram pipe host
1112 -- head/pipe nodes take two parameters!
1114 -- tail / starter node takes three parameters!
1116 -- eforth flash interface 0 org
1118
1120 - siobus16 wire nodes host
1122 -- generic siobus wire 30 org
1124 -- tx plug node host
1126 -- rx plug node 0 org
1128 --- more rx
1130 -- 1-pin plug node 20 org
1132 -- dummy flash controller plug 0 org
1134
1136
1138
1140 eforth ide host load
1142 - ide build paths
1144 - read 16-bit eforth.bin file
1146 - ide access sram16 from nodes 108 and 207
1148 - ide access term16 from 104 , flash from 706
1150
1152 install eforth via async bootstream
1154 - generate eforth stream
1156 -- read eforth kernel ft 0
1158 -- load eforth kernel
1160 eforth chip builder
1162 - build sram16 using srampath
1164 - build siobus wires and plugs using e4path
1166 - build e4vm16 nodes using e4path
1168
1170 - sram loader nodes
1172 - spi flash 8 bits 705 node 0 org host
1174 load eforth kernel
1176
1178
1180 build eforth bootstream
1182 - build siobus and virtual machine bootstream
1184 - build flash-sram pipe bootstream
1186
1188
1190 burn 18-bit eforth bootstream into flash
1192
1194 burn 16-bit eforth.bin file into flash
1196
1198 eforth index and listing
```

```
1200
1202
1204
1206
1208
1210
1212
1214
1216
1218
1220
1222
1224
1226
1228
1230 sync boot testbed
1232
1234
1236 configuration tables com 0
1238 - initial values
1240 interactive
1242 build boot stream for softsim testbeds
1244 spi testbed clk 1 btcnt 33
1246 spi testbed
1248 show directions arrow 92 92 arrow !
1250 prelude comb 75530240
1252 softsim node variables
1254 softsim node variables and shared code
1256 softsim all tiks
1258 softsim all toks
1260 softsim suspended tiks and toks
1262 softsim tik/tok and power op 271568644
1264 softsim read/write access
1266 softsim port, register, and memory access
1268 softsim ops common code
1270 softsim ops control
1272 softsim ops read/write and alu.1
1274 softsim ops alu.2 and jump table
1276 softsim display ops >op 271571672
1278 softsim display numbers base 16
1280 softsim display directions
1282 softsim display registers
1284 softsim display pins
1286 softsim display big nodes nod 0 nod2 18
1288 softsim display small nodes
1290 softsim display map and screen
1292 softsim keyboard handler
1294 softsim keyboard handler
1296 softsim connect node ports
1298 softsim assign node pins and wake-up
1300 unused
1302 unused
1304 eforth rom code
1306 e4 bitsy 1of2
1308 e4 bitsy 2of2
1310 e4 stack 1of2
1312 e4 stack 2of2
1314 e4th bitsy
1316 e4 terminal 1of2 - serial i/o
1318 e4 terminal 2of2 - bitsy commands
1320 sdram address-bus
1322 sdram control-pins
1324 sdram data-bus
1326 sdram idle-loop
1328 sdram user interface
1330 async ats interface 0 org
1332
1334
1336
1338
1340
1342 smtm test 32 org
1344 14 word ga144 creeper test frame 3/25/11
1346 fill neighbor"s memory fake test
1348 extensive neighbor"s memory test 005-035
1350 1604 all nodes template 15 node 0 org
1352 erase flash 0 org
1354 hardware multiply test 0 org =cy
1356 soft multiply test 0 org =cy
1358 multiply exerciser 0 org
1360 serdes test AA org data a! 3FFFE dup ! up a! b
1362 serdes test 2 AA org data a! 33333 dup ! up a!
1364 spi flash writer michael = greg 2.1 0 org
1366 take adc data 0 org
1368 generate dac waves 0 org
1370 spi flash 8 bits 0 org
1372 1600 ide via async boot 708 node 0 org
1374 1601 ide via sync boot 300 node 0 org
1376 1602 ide wire node 17 node 0 org
1378 1603 ide last guy 16 node 1E org
1380 common
1382 polynomial approximation
1384 interpolate
1386 fir or iir filter
1388 routing: called with "a relay"
1390 multiply
1392 lshift rshift
1394 triangle
1396 fractional multiply
1398 divide
1400 f18 compiler h 22 ip 21 slot 4 call> 24576 cal
1402 target
1404 f18 jump instructions
1406 complex instructions
1408 instructions
1410 port literals and constants
1412 more instructions
1414
1416
1418 math rom anywhere 0 kind
1420 serdes boot top/bot 6 kind AA reset
1422 sync serial boot side 2 kind AA reset
1424 async serial boot top/bot 1 kind AA reset
1426 more async serial
1428 spi boot top/bot 4 kind AA reset host
1430 more spi
1432 analog 0 kind
1434 dac
1436 1-wire 3 kind AA org
1438 null rom anywhere 0 kind
```

10.6 Bin Assignments for Rev 02a

"Bins" are receptacles for object code and are numbered like nodes in the chips. Bins 000 through 717 contain code that is by default destined for the nodes on the host chip. Bins 800 through 1517 map onto the target chip. Bins 1600 through 2317 are reserved for utility and tool code, and are managed by GreenArrays. Their purpose is to allow this code to be compiled and available for use at any time without interfering with application code. This table documents the assignments in effect as of the release identified above.

```
1600  ide async node
1601  ide sync node
1602  ide wire
1603  ide last-guy
1604  ide all nodes template
1605  Snorkel
1606  SST25WFxxx Flash node 705
1607
1608  spi speedup function
1609  18-bit flash r/w for 705
1610  18-bit flash helper for 706
1611  8-bit flash r/w
1612
1613  flash erase
1614  SRAM Node 107 interface (std)
1615  - Node 007 Data bus
1616  - Node 008 Control
1617  - Node 009 Address bus

1700  polyFORTH Stack (106)
1701  - Stack down (006)
1702  - Stack up (206)
1703  Bitsy (105)
1704  - Bitsy down (005)
1705  - Bitsy up (205)
1706  Serial tx (100)
1707  - Rx (200)
1708  - Interface (104)
1709  - Wire (102 and others)
1710  Flash to sram for 705
1711  - Wire for 605 etc
1712  - <unused>
1713  - Temp SRAM code for 108
1714  Ganglion nodes eee
1715  - nodes eoo
1716  - nodes oee
1717  - nodes ooo

1800  <reserved for eForth/pF>
1801  Ethernet DMA
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813  Node 600 code (temporary)
1814  Flash to sram for 705
1815  - Wire for 605 etc
1816  - SRAM interface for 208
1817  - Temp SRAM code for 108
```

```
1900  ats/ide analog
1901  ats/ide sync boot master
1902  ats/ide test frame
1903  ats/ide test frame
1904  ats/ide sync bridge
1905  ats/ide uut bridge debug
1906  ats/ide tester bridge debug
1907  framer bridge builder
1908  <free>
1909
1910
1911
1912
1913
1914
1915
1916
1917

2000  Creeper test modules 1 (full)
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

2100  Creeper test modules 2 (full)
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
```

```
2200  Creeper test modules 3 (half
full)
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211
2212
2213
2214
2215
2216
2217

2300  <reserved creeper tests 4>
2301
2302
2303
2304
2305
2306
2307
2308
2309
2310
2311
2312
2313
2314
2315
2316
2317
```

11. Appendix: Microsoft Windows® Platform

11.1 Windows arrayForth Requirements

The host system requirements are as follow:

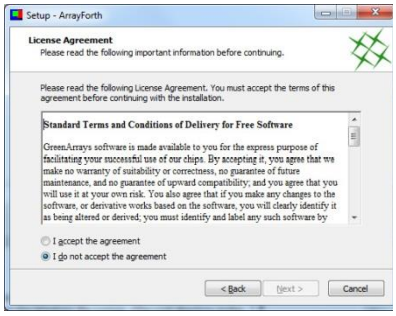
- Microsoft Windows with Win32 environment. We have tested this system on Windows 2000 Professional, Windows XP Professional, Windows Vista and Windows 7 and 8. See below for Windows 8 issues.
- Sufficient physical memory and swap file to run at least one instance of a program that is capable of requiring commitment of 768 megabytes of virtual memory. Actual requirements depend on how much memory you actually access, which should be considerably less than this.
- Display capable of at least 1024x768x24 bit graphics. The display may be resized after the program is started.
- Standard PC keyboard.
- At least one RS232 interface with COM port drivers if you wish to use the Interactive Development Environment to communicate with GreenArrays chips. For the EVB001 Evaluation Board, this is done with direct USB cables to the FTDI chips on the board, allowing much faster communications than are reliable with RS232 electrical interfaces.

11.2 Installation

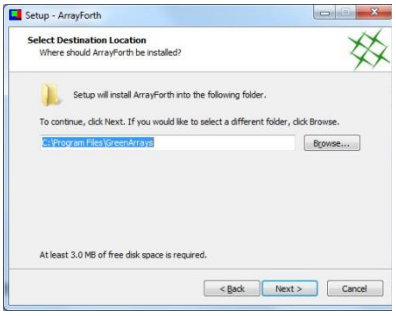
Starting with release 01b, arrayForth is distributed as a conventional, executable Windows installer. Use it as follows:

1. Download and run the installer, or run it directly from your browser if the browser supports that operation. You will see a greeting diaglog that looks like this. Click the "next" button.

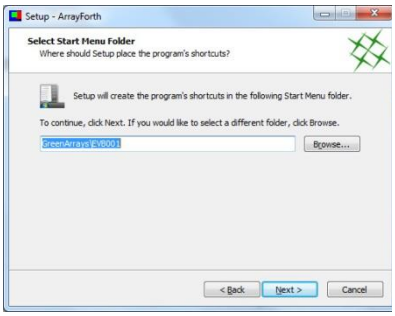
2. You will now be asked to read and accept our Standard Terms and Conditions for Delilvery of Free Software. If you click the "I accept the agreement" item, the "next" button will be enabled and you may proceed.



3. The installer asks you to select a location at which arrayForth should be installed. By default this is a directory ("folder") that will be called c:\ Program Files\GreenArrays. If you don't want it to be there, please change the destination in this dialog; the shortcuts made by the installer will be configured for this directory and it will be simpler for you to place it where you like initially rather than to move it after installation. You may install multiple instances as you wish. Hit next when done.

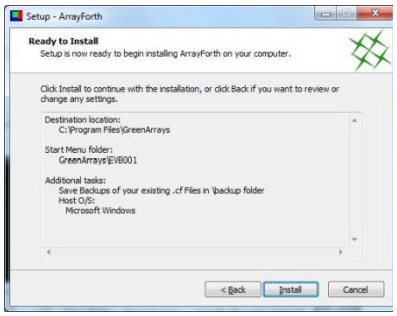


4. Next, the installer asks where it should place the program's shortcuts. By default there will be a new Start menu group called GreenArrays with a subgroup EVB001 in which shortcuts will be generated for this instance of arrayForth and for a file explorer view of the entire GreenArrays directory structure, facilitating your finding of your files. You will need to get at them later. Specify where you want them and hit next.

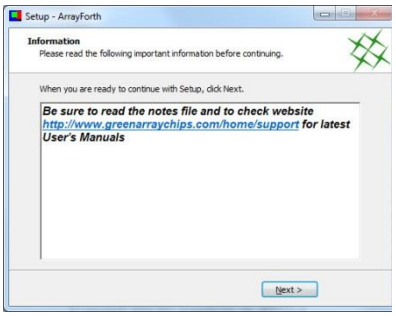


5. The next dialog is important. It begins with a check box which, if checked, will instruct the installer to save backups of your existing source files (.cf for arrayForth and .blk for polyFORTH) in a \backup folder. This will be a subdirectory inside the arrayForth directory structure. It is advisable that you check this box if you are installing an update on top of an existing installation; you may then, later on, use a copy of your previous working .cf file as the backup source file in order to merge your work with the updated system. The second area asks you to select one of a set of buttons to indicate which supported platform you are using. This will affect mainly what shortcuts the Installer will generate. For Windows and Mac Parallels platforms, the shortcuts will be in the Start menu and will assume a Windows compatible environment. For Wine environments, the shortcuts will be on the desktop and will use different scripting files to start the arrayForth program. Select the appropriate items and hit next.

6. The next dialog is the familiar "Ready to Install" summary of what the Installer proposes to do based on your input in the preceding dialogs. If there are unpleasant surprises, use the back button and correct your input as needed. When you are satisfied with what you see here, hit Install. You will then see a progress meter dialog that should complete very quickly.



7. You will then see a dialog which purports to convey Important Information… and indeed it might. Should any given release require that you take any special actions or be aware of any changes in procedure or usage that might be at odds with the current editions of manuals like this one, this may be your only chance to learn of such before encountering it. Please take the time to read what is written here so you will not later regret having failed to do so!



8. Finally you will see a dialog about Completing the Setup Wizard, which will by default offer you the opportunity to read our standard text file that documents changes in this version. Again this is highly recommended reading; if you must forego it at this time, the file is present in the arrayForth directory structure for future reading.

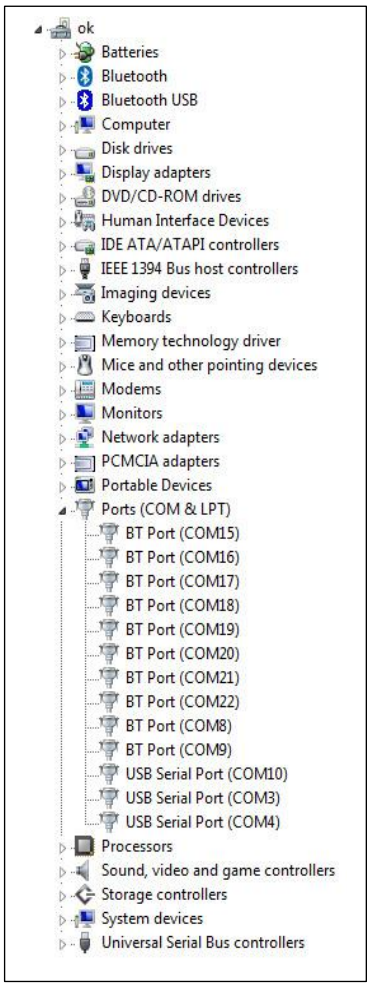
This concludes the initial phase of installing arrayForth. You should be able to run arrayForth using the installed shortcut and will only need to take further steps if you intend to communicate with real GA144 chips, such as those on the Evaluation Board.

11.2.1 Identifying and Configuring COM Ports

Until release 01c, COM port baud rates, framing, and so on were set using **`mode`** commands in the `okad.bat` script file on Windows systems, or **`stty`** commands in the `linuxwine.bat` script for Wine systems. Starting in 01c, arrayForth sets these parameters itself. The script files are still used, in case you encounter a system in which they turn out to be necessary, but the `mode` and `stty` commands are commented in the released files. If you find a situation in which arrayForth is unable to set the COM port up properly, please inform Customer Support right away.

If you plan to use COM port(s) to communicate with a GreenArrays chip or with the Eval Board, you will need to identify the COM port(s) in question. This procedure is designed for use with the Evaluation Board; to use arrayForth to interact with our chips on other boards, you will most likely be using some single USB to RS232 adaptor and so some of the steps may be omitted. *We recommend FTDI based communication devices for all communications with our chips, whether they be RS232 adaptors or embedded chips such as those used in our Eval Boards. This is because the FTDI drivers appear to be free of some common bugs in FIFO management that can create havoc with automated communications.*

1. The EVB001 board has three USB connectors identified as A, B and C reading left to right along the top left corner of the board. Port A is by default used for IDE on the Host chip, port B is used for a serial terminal on eForth or polyFORTH, and port C is used for IDE on the Target chip. The following steps should be taken for each of these three independent USB to serial adaptors. If instead you are configuring your installation for use with one or more actual USB to RS232 adaptors, perhaps for use with other boards than the EVB001, you will need to take these steps for each of those adaptors and should do them completely with one adaptor at a time. If you intend to be using several adaptors it is a good idea to leave the ones you have already configured plugged in while configuring the next, so that the system does not try assigning all of them the same COM port number!



   a. Obtain Windows drivers for each USB serial adaptor you intend to use and appropriate to the version of Windows you are running. Although it is generally recommended to install drivers before first mating the device with the computer, Windows 7 seems to have relaxed this requirement. Nevertheless even on Windows 7 you may have to connect to Windows Update or to go to the manufacturer of your adaptor for drivers.

   b. Plug in the USB to serial adaptor (or Eval board port) and go through the procedure for installing a new Windows USB device. This can vary from trivial to a grueling hassle. Eventually your device will be "ready to use."

   c. Find the Windows Device Manager. The exact procedure varies between versions of Windows but in general you can get there by right clicking "My Computer" desktop icon (or corresponding clickable area of Start menu) and selecting "Properties". This should take you to a display on which you may select "Device Manager", or perhaps "Hardware" and then "Device Manager". You may also find it in the "Control Panel." Persist until you are looking at a tree view, like this one, listing various classes of devices. Open the tree view for "Ports" which include COM and LPT port names. Your USB port should be listed here. If there are more than one and you are uncertain which is your new port, unplug the device while watching this display. It should update and the device in question should have

disappeared. Now plug it back in and record its COM port number and which of your interfaces (such as Eval Board port A/B/C) it represents.

Regarding this relationship: Some USB devices have internal unique serial numbers and some do not. The default behavior of later Windows systems is to make a permanent association between a given vendor/device/serial number and a given COM port, regardless of which USB connection it is plugged into. This is a *good thing*. For devices lacking a serial number, Windows tends to assign the COM port to that vendor/device on a particular USB socket. Thus the COM port number can be expected to change if you move the same USB to RS232 adaptor from a direct USB socket on the computer to one on, say, a docking station. This is the stuff of madness but you will need to cope with it if you use such interfaces.

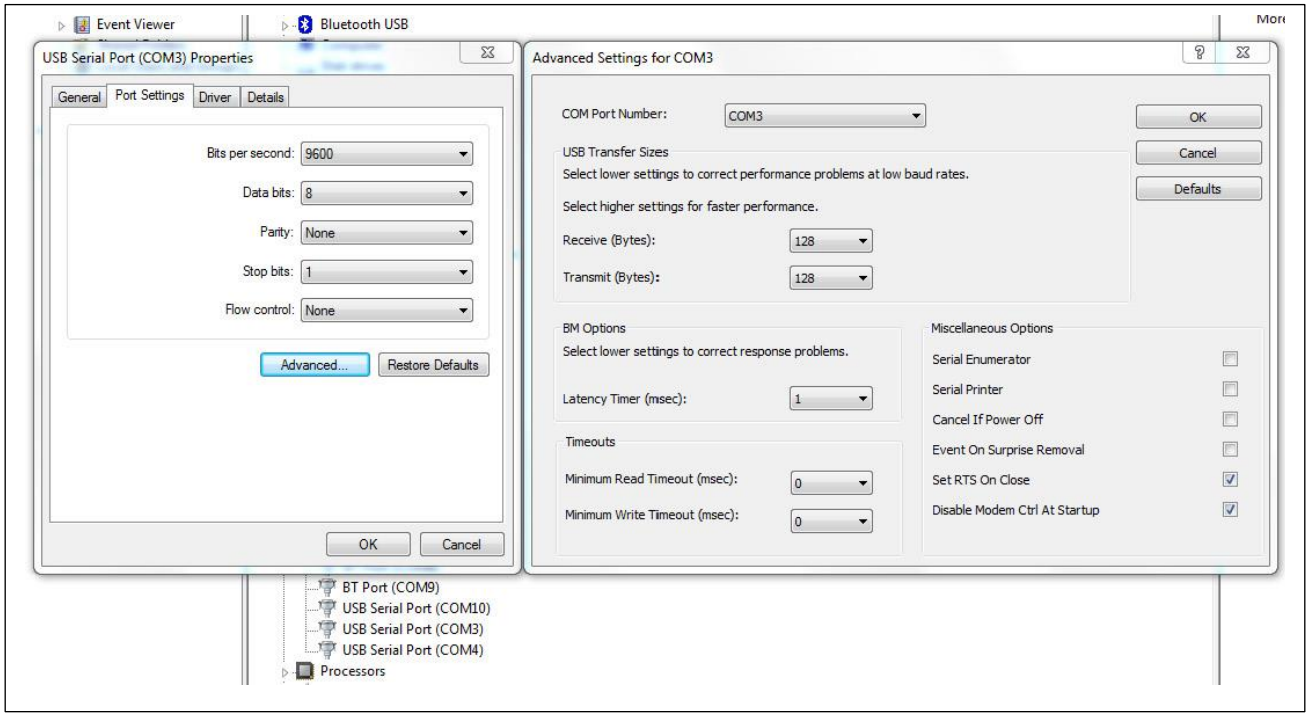
d. Having identified the new port, double click it in the Device Manager and you should get a USB Serial Port Properties dialog box. On the front page / first tab you will see the manufacturer ID.

e. If the manufacturer is FTDI, you have some things to do in order to optimize this port. On the Port Settings tab you should find an "Advanced" button and on pressing it should get a separate dialog box entitled something like "Advanced Settings for COMxx". If this is the case, please refer to the screen image below and do the following:

   i. In the "USB Transfer Sizes" section, the default settings for Receive and Transmit are 4096 bytes. Reducing these to 128 bytes seems to improve performance in our uses.

   ii. The next item called "Latency Timer (msec)" which defaults to 16. We get the best results in IDE and serial terminal performance with this value reduced to 1 ms.

   iii. Please see "Miscellaneous Options." We get the best results from setting these as shown. Instructions in app notes relative to the EVB001 will assume you have made these same settings.



2. Decide what baud rate(s) you will employ (but do not enter it in the above property sheets). What is feasible depends on the electrical characteristics of the PC serial interface in use. Our default baud rate, 921600, is correct for the EVB001 USB ports (all factory testing of each Eval Board is done at this speed.) If you are using an actual RS232 interface then the maximum usable rate will depend on the quality of its

chipset including its line transceivers. We have on rare occasion found RS232 interfaces that we could use at 460,800 baud, but more commonly the limit will be 115,200 or if you are lucky 230,400. Don't go any lower than 19,200 baud because our async nodes only have 18 bit time delay counters…

3. Start arrayForth using the shortcut made by the installer, or by double-clicking Okad.bat. Say `202 edit` and edit the port number for `a-com` (IDE for host or only chip) or `c-com` (target chip on Eval Board) as appropriate to reflect the ports(s) you have identified. Make sure the new port number is in yellow. Similarly, edit desired baud rates for these ports `a-bps` and `c-bps` if necessary; see above regarding appropriate baud rates to be used. Say `save` .
4. Shut down arrayForth by saying `bye` and restart the program.
5. Check the command window (see below) which should give feedback of success in configuring the serial port(s). You are now ready to begin IDE operations.

You may install multiple copies or versions of arrayForth on the same machine; just make a separate directory for each, and name your shortcuts to avoid confusion. This may be useful if you are working with multiple chips, or even multiple projects.

11.2.2 Windows 8 Installation

Our software is designed to run on a desktop computer, not on a telephone. It is assumed that you will be using the desktop interface to Windows 8, and that you will have installed one of the after-market programs such as StartIsBack that restores easy access to the start menu directories that are maintained in Windows 8 but are hidden by the asinine configuration in which that system is shipped. Contact our customer support hotline if you need advice on how to go about this.

11.3 Running arrayForth

Once you have taken care of the above chores, running arrayForth is simple:

1. Click the shortcut for the desired copy of the software.
2. When the arrayForth logo screen appears, the system is ready to use. The graphic window may be resized, minimized, dragged to other display screens, and so forth.
3. In addition to the arrayForth graphic window, you will also see a simple console window. Diagnostic messages may appear here. This console window is actually the primary window for arrayForth; if you wish to kill arrayForth by closing a window, closing the console window will accomplish this in one step. Note: It is normal to see a message `FFFFFFFE Error in system operation` immediately following the line that starts with `Reading file OkadWork.cf` . This simply means that the file was compressed and all 1440 blocks could not be read.
4. To exit arrayForth normally, simply say `bye` to the interpreter.

You may run multiple copies of arrayForth so long as you don't exceed the virtual memory capacity of the operating system you are using. This can be convenient when talking to more than one chip. For example, in one step of our factory testing we run `selftest` on both host and target chips simultaneously using two arrayForth sessions. Be careful to only edit your source base in one instance if they both use the same directory, otherwise `save` operations will overwrite one another.

12. Appendix: Apple Mac® Platform with Windows

12.1 Mac Requirements

arrayForth can be run on Apple computers that are built from Intel x86 processors, by using Parallels, a product of Elements5, hosting a Microsoft Windows® operating system (XP or later). The following procedures have been tested on a MacBook running OS X version 10.6, Parallels 5.09, and Windows XP Professional. We also believe they should work using Windows installed on a Mac system using VirtualBox; if you install our software on this configuration, please let us know how it went.

Note: If you are new to Windows, be aware that you will need to change some of the default settings in Windows before it is practical to do some of these things. For example, by default the Windows file explorer hides file extensions lilke .bat and .exe … and even hides whole files. If you are in this situation and have no idea how to do those things, contact our support hotline and we may be able to supply a "script" describing how to do it on the version of Windows you have installed.

12.2 Installation

Because Parallels (and VirtualBox) are Virtual Machine environments running actual Windows software, the procedures are almost identical with those on a Windows system. The differences we know of are as follow:

1. You should download the installer executable into some path actually rooted in `C:` in the windows environment's file system. Working directories are not correct when Windows programs are executed from places that are not, such as `\\.psf\Home\Documents` as one example.
2. When first plugging an adaptor or Eval Board port, go through the procedure for installing Windows drivers, associating the device with Virtual Machine rather than Mac OS when you are given that choice.

12.3 Running arrayForth

Again, running arrayForth is the same as on the Windows platform with these exceptions:

1. Be prepared for keyboard surprises and check the Parallels documentation to explain anomalies. For example, to use the F1 key you may have to hold down the Fn key as a shift.

13. Appendix: unix Platform including Mac OS X

If you have an Intel x86-based unix system, you may be able to run arrayForth using the Wine subsystem. Wine is an open source implementation of the Windows API that runs on BSD Unix, Linux, Mac OS X and Solaris systems. Its home page is at WineHQ.org. The following has been tested in a freshly installed Ubuntu Linux version 11.04 with a freshly installed Wine obtained from the "Ubuntu software center" as "Microsoft Windows Compatibility Layer (meta package)."

13.1 Installation

Although Wine is not a Virtual Machine environment, most steps are the same as with the Windows platform. The differences are as follow:

1. Download the Windows Installer from our website. Save it in your Downloads directory.
2. Start Nautilus, the GUI file manager program, and navigate to your Downloads directory.
3. Right click on the icon for the setup program, select "Properties", select the "Permissions" tab on the resulting dialog, and check the box to "Allow executing file as program." (equivalent to `chmod u+x`)
4. Right click again and choose the menu item "Open with Wine Windows Program Loader." The installer should run as described above.

5. In the "Select Additional Tasks" window, check the box "Linux with Wine." When you finish the process, there should be two new icons on your desktop. The first is the arrayForth icon named "arrayForth EVB001 <vers>" that starts arrayForth, and the other is a folder icon named "GreenArrays" which opens the install directory using a GUI program called "Wine File".
6. What Wine calls drive C: in this window can be found in the Ubuntu file system as `/home/<yourlogin>/.wine/drive_c` .

13.1.1 Identifying and Configuring COM Ports

1. The procedure for identifying COM ports in unix is quite different than in Windows; contact Customer Support for assistance or suggestions. If you plug USB serial devices in one at a time they will by default be assigned consecutive unix device names of the form `/dev/ttyUSBn` where `n` starts at zero. The capability of Windows to identify a particular USB device by serial number does not seem to exist. Not only does the order in which currently inserted USB devices matter, but also the amount of time a device was unplugged before it is plugged back in seems to matter as well. You will probably be best served by plugging cables into your machine in a fixed sequence and following that sequence, without skipping cables, every time. We recommend that EVB001 users make a habit of plugging the three cables for USB ports A, B, and C into the computer in that same sequence every time; if port C is to be plugged in, make sure A and B have been plugged in or C will be assigned to one of the ports normally used by A or B. Follow this procedure for each of the three USB ports A, B, and C in order:
   a. Plug in the first USB to serial adaptor and run `dmesg` at the `bash` command line. You will see the name of the device listed near the end of the report, most likely `/dev/ttyUSB0`. If you do not see such a line, unplug the adaptor and plug it back in, waiting several seconds between steps; log writing seems to be out of phase some times.
   b. When this has been done, do the same for adaptors or cables B and C in order, one at a time.
   c. In the shell, navigate via `cd ~/.wine/dosdevices` . Typing `ls` there should show you `c:` and `z:` . If you have a real serial port its device name will be `/dev/ttyS0` . You will need to create a link for each of the USB ports you have identified; we recommend you use the following pattern for the commands that do this:

      ```
      ln -s /dev/ttyUSB0 com1
      ln -s /dev/ttyUSB1 com2
      ln -s /dev/ttyUSB2 com3
      ```

      You can use whatever COM port numbers you like, but 1, 2, 3 are sensible for A, B and C. The script files supplied assume you have done so. After you have done this, in future you may check which devices are currently plugged in using the command `ls -l ~/.wine/dosdevices` where color coding of device names will indicate their status.
2. Now, explore the install directory using the desktop icon. You will see a file called `linuxwine.bat` which is the script normally used by the installer in making the arrayForth icon. Open this file with a text editor. You will see the following:

   ```
   rem used ONLY for Linux/wine desktop shortcut.

   z:\\bin\\stty -F /dev/ttyUSB0 921600 -parenb cs8 -cstopb -crtscts raw -echo
   z:\\bin\\stty -F /dev/ttyUSB2 921600 -parenb cs8 -cstopb -crtscts raw -echo

   Okad2-41b-pd.exe
   rem howdy
   ```

   The purpose of these lines is to set the baud rate and other parameters for the IDE connection(s) to USB ports A and C on the eval board. If you have had to use some other ports than USB0 and USB2 for these purposes, edit this file accordingly You should now be ready to restart arrayForth and communicate with your chips.

The `linuxwine.bat` file may need editing for other configurations. In addition you may need to employ other scripting options we have worked out; contact customer support for advice if necessary.

13.2 Running arrayForth

Preferably you will use the desktop shortcuts. You may choose to create scripts to run arrayForth from the BASH or other shell:

1. Navigate to the directory containing the `.exe` file, `OkadWork.cf`, and `Okad.sh`.
2. Type `./Okad.sh` after editing it to do the stty commands for your ports.

14. Appendix: Native PC Platform

14.1 Native arrayForth Requirements

For Native systems, arrayForth normally boots from a 3.5" floppy. Actually, it can boot from any BIOS compatible boot medium that looks like a straight disk with 512 byte sectors, so the same image should boot if copied to absolute zero (no partitions) on ATA hard disks, USB floppies or flash, or SATA disks.

Other requirements are:

- 3.5" Floppy with ISA compatible Floppy Disk Controller (no USB) is necessary in order to read or write blocks for any other purpose than booting.
- Standard PC (XT or AT) keyboard with ISA compatible keyboard processor, or with USB keyboard using System Management Mode "legacy keyboard" emulation.
- One of a relatively limited set of ATI or NVidia PCI/AGP graphic interfaces. We cannot tell you which ones, because ATI and NVidia have refused to inform us of which boards support which BIOS mode codes for what display configurations.
- One gigabyte of RAM for the standard system as distributed. This is not all needed simply to develop code for our chips, but the system comes configured that way because we do need the space for CAD operations.
- At least one 16450 compatible UART and RS232 interface (real, not USB) if you wish to use the Interactive Development Environment to communicate with GreenArrays chips.

14.2 Running arrayForth Natively

Assuming that you have a compatible hardware platform, and have made any needed BIOS settings (to boot first from floppy, to enable emulation of keyboard processor on USB systems, and so on), it is very simple to start arrayForth running:

1. Insert arrayForth floppy in drive.
2. Power up or reset the PC.
3. Wait for the floppy to be read in its entirety.
4. When the arrayForth logo screen appears, the system is ready to use.
5. Plug serial cable into COM1 if you intend to communicate with GreenArrays chips.

You can use the floppy drive to save your work as a bootable system. You can also read other floppies for comparison and reconciliation using the audit utility.

To access an Evaluation Board from a native PC, you will need to configure the board for true RS232 interfaces. Please refer to the relevant Application Note on our website.

15. Data Book Revision History

REVISION	DESCRIPTION
110912	Preliminary Release for Rev 01a software
110915	Correct order of images in Practical Example. Reorganize and clarify Editor description. Update index listing. Fix numerous typographical errors.
110918	Add 2.3 arrayForth User Vocabulary. Expand upon 5.3 F18 Compiler Syntax. Update installation instructions to reflect 01b installer. Add new disk management words. Fix typos. Remove inaccurate statements from Practical Example.
111004	Fix typos. Deprecate obsolete colorForth comment types in 01c editor. Clarify functions of talk in the IDE. Clarify softsim section and document new interactive vocabulary. Emphasize use of recaim to control identifier scope. Add a-com and c-com used by internal baud rate setting functions. Document new onamed and bnamed functions to rename the working and backup source files. Show the new installation instructions which no longer require editing of .bat files, and include screenshots for readers unfamiliar with the Windows Device Manager.
111016	Update to correspond with software release 01d. Add sections for memory map and bin assignment tables. Describe new blue words. Remove mention of watermarked block number in editor and replace with image and prose describing the block number over hint area with color annunciating editor status. Update audit utility backup image area. Fix typos and make minor improvements in clarity.
111103	Update to correspond with software release 01e. Document preliminary module structure. Add description of new common load descriptor syntax and describe its use with automated IDE loading and boot stream generation.
111223	Update to correspond with software release 01g. Document improvements in keyboard feedback area, new grey word behavior, and refinements in the interactions between node and org in the F18 compiler. Document improvements in softsim (testbed mechanism, human interface, boot descriptor processing, breakpoint mechanism).
120923	Updated to correspond with software release 02a. More F18 code released including fully supported polyFORTH Virtual Machine.. thru is now available to make load blocks more readable. IDE and SPI loading paths made as complete as possible. Interval timer nodes added for polyFORTH. arrayForth and polyFORTH version numbers will now be identical in each release.
131030	Updated to correspond with software release 02b. IDE and framer support programming both chips on an EVB. A new booting option loads one or both chips using a minimal boot stream through serial port, considerably faster than the IDE method, without altering flash. polyFORTH F18 code now supports Ethernet daughter board.

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Product Data Book DB004 *Revised 10/30/13*

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