

# **J1a**

## **SwapForth**

### **Reference**

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ANS Forth Compliance Label

J1a SwapForth is an ANS Forth System

Providing names from the **Core Extensions** word set

Providing names from the **Double-Number** word set

Providing names from the **Facility** word set

Providing names from the **Facility Extensions** word set

Providing names from the **String** word set

Providing names from the **Programming-Tools** word set

Providing names from the **Programming-Tools Extensions** word set

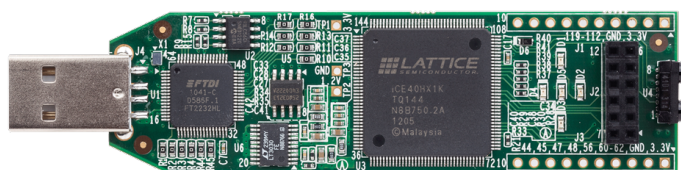
# Contents

|  |           |
|--|-----------|
| <b>1. Getting started</b>                                      | <b>5</b>  |
| 1.1. Some demos . . . . .                                      | 6         |
| 1.2. Building from Scratch . . . . .                           | 8         |
| <b>2. Available Words</b>                                      | <b>11</b> |
| 2.1. ANS Core Words . . . . .                                  | 11        |
| 2.2. Additional Words . . . . .                                | 12        |
| <b>3. Using SwapForth</b>                                      | <b>15</b> |
| 3.1. Raw UART access . . . . .                                 | 15        |
| 3.2. The SwapForth shell . . . . .                             | 15        |
| 3.2.1. Command reference . . . . .                             | 16        |
| 3.3. Tethered Mode . . . . .                                   | 16        |
| <b>4. Memory</b>   | <b>17</b> |
| 4.1. Memory map . . . . .                                      | 17        |
| 4.2. Dictionary Layout . . . . .                               | 18        |
| <b>5. iCEstick Hardware interface</b>                          | <b>19</b> |
| 5.1. Port Map . . . . .  | 21        |
| 5.1.1. \$0001: Digilent Pmod <sup>TM</sup> data . . . . .      | 21        |
| 5.1.2. \$0002: Digilent Pmod <sup>TM</sup> direction . . . . . | 21        |
| 5.1.3. \$0004: LEDs . . . . .                                  | 21        |
| 5.1.4. \$0008: PIO output . . . . .                            | 21        |
| 5.1.5. \$0800: SB_WARMBOOT control . . . . .                   | 22        |
| 5.1.6. \$1000: UART data . . . . .                             | 22        |
| 5.1.7. \$2000: IrDA, flash and UART inputs . . . . .           | 22        |
| <b>Index</b>   | <b>23</b> |



# Chapter 1

## Getting started



J1a SwapForth is a 16-bit version of SwapForth, intended as an interactive Forth system using very little logic and RAM. The system currently fits on a Lattice iCE40HX-1k FPGA. The J1a and peripherals use 1200 logic elements. SwapForth uses 4.7 Kbytes of RAM, leaving about 3.3 Kbytes for the application.

After installing the [icestorm](#) tools, you can run on a [Lattice iCEstick](#) like this

```
git clone git@github.com:jamesbowman/swapforth.git
cd swapforth/j1a
```

```
iceprog icestorm/j1a.bin
python shell.py -h /dev/ttyUSB0
```

(where `/dev/ttyUSB0` is the appropriate port your iCEstick was assigned). You should see something like

```
Contacting... established
Loaded 208 words
>
```

And you can now try the usual Forth things, e.g.

```
1 2 + .
3    ok
```

There is a fairly complete [core ANS-compatible Forth system](#) running on the board, including a compiler.

## 1.1 Some demos

You can control the five on-board LEDs

```
-1 leds
ok

0 leds
ok
```

and to make them blink

```
: blink
  32 0 do
    i leds
    100 ms
  loop
;
blink
```

There is an [Easter date calculator](#)

```
new
#include ../demos/easter.fs
```

Now you can do

```
>2015 .easter
2015 April 5   ok
```

Or even

```
>: 20easters
+ 2035 2015 do
+   cr i .easter
+ loop
+;
ok
>20easters

2015 April 5
2016 March 27
2017 April 16
```

```
2018 April 1
2019 April 21
2020 April 12
2021 April 4
2022 April 17
2023 April 9
2024 March 31
2025 April 20
2026 April 5
2027 March 28
2028 April 16
2029 April 1
2030 April 21
2031 April 13
2032 March 28
2033 April 17
2034 April 9    ok
```

## 1.2 Building from Scratch

After installing the icestorm tools, run

```
rm build/*
make -C icestorm
```

This will produce `j1a.bin` - but it only contains the very bare-bones system; the rest of SwapForth still needs to be compiled. To do this, load `j1a.bin` and start the shell:

```
$ iceprog icestorm/j1a.bin
$ python shell.py -h /dev/ttyUSB0 -p ../common/
Contacting... established
Loaded 127 words
>
```



Then compile the rest of SwapForth and write the finished executable with these commands:

```
#include swapforth.fs
#flash build/nuc.hex
#bye
```

Now run `make -C icestorm` again - this compiles an FPGA image with the complete code base built-in.



# Chapter 2

## Available Words

### 2.1 ANS Core Words

J1a SwapForth implements most of the core ANS 94 Forth standard. Implemented words are:

```
! # #> #s ' ( * */ */mod + +! +loop , - . ." / /mod 0< 0=
1+ 1- 2! 2* 2/ 2@ 2drop 2dup 2over 2swap : ; < <# = > >body
>in >number >r ?dup @ abort abort" abs accept align aligned
allot and base begin bl c! c, c@ cell+ cells char char+ chars
constant count cr create decimal depth do does> drop dup else
emit environment? evaluate execute exit fill find fm/mod here
hold i if immediate invert j key leave literal loop lshift m*
max min mod move negate or over postpone quit r> r@ recurse
repeat rot rshift s" s>d sign sm/rem source space spaces state
swap then type u. u< um* um/mod unloop until variable while
word xor [ ' ] [char] ]
```

The core word `environment?` is not implemented. J1a SwapForth also implements the following standard words:

```
.( .r .s /string 0<> 0> :noname <> ?do again ahead case
cmove cmove> compile, d+ d. d.r d0= d2* dabs dnegate dump
endcase endof erase false hex key? m+ marker ms nip of pad
parse refill restore-input save-input sliteral throw true tuck
u.r u> unused within words [compile] \
```

Double numbers are supported using the standard `.` suffix. The Forth 200x number prefixes are supported: `$` for hex, `#` for decimal, `%` for binary, and `'c'` for character literals. `parse-name` is also implemented.

## 2.2 Additional Words

The following words are not standard. Some are traditional Forth words, others are specific to the J1a SwapForth implementation.

**.x**

( n -- )

display n as a 4-digit hex number

---

**-rot**

( x1 x2 x3 -- x3 x1 x2 )

rotate the top three stack entries

---

**bounds**

( start cnt -- start+cnt start )

prepare to loop on a range

---

**forth**

( -- a )

variable: most recent dictionary entry

---

**io!**

( x a -- )

store x to IO port a

---

**io@**

( a -- x )

fetch from IO port a

---

**leds**

( x -- )

write **x** to the onboard LEDs

---

**new**

( -- )

restore code and data pointers to the power-up state

---

**s,**

( a u -- )

add the **u**-character string **a** to the data space

---

**tth**

( -- a )

variable: tethered mode

---



## Chapter 3

# Using SwapForth

### 3.1 Raw UART access

At boot, SwapForth listens for a command on the UART. Connection parameters are 460800 8N1, and any terminal program should be able to connect. Note that the hardware board uses DTR as a reset signal, so you should make sure that it is set OFF by the terminal program:

```
$ miniterm.py --dtr=0 /dev/ttyUSB5 460800
--- Miniterm on /dev/ttyUSB5: 460800,8,N,1 ---
--- Quit: Ctrl+] | Menu: Ctrl+T | Help: Ctrl+T followed by Ctrl+H ---
--- forcing DTR inactive

ok
ok
ok
```

### 3.2 The SwapForth shell

The SwapForth shell is a Python program that runs on the host PC. It has a number of advantages over raw UART access:

- command-line editing
- command history
- word completion on TAB

- local file `include`
- `^C` for interrupt

### 3.2.1 Invocation

The shell is a Python program. To run it, go to the appropriate directory and type:

```
python shell.py -h /dev/ttyUSB0
```

### 3.2.2 Command reference

**#bye** - quit SwapForth shell

**#flash** - copy the target state to a local file

**#include** - send local source file

**#noverbose** - turn off include echo

**#time** - measure execution time

## 3.3 Tethered Mode

J1b SwapForth supports *tethered mode*, which makes the UART protocol easier to use for host programs. The SwapForth shell uses tethered mode. To enter tethered mode, write one to the variable **tth** :

```
1 tth !
```

In tethered mode, **accept** transmits byte value 30 (hex **1e**, ASCII code RS). This allows the listening program to know that the target machine is ready to accept a line of input. In addition, **accept** does not echo characters as they are typed.



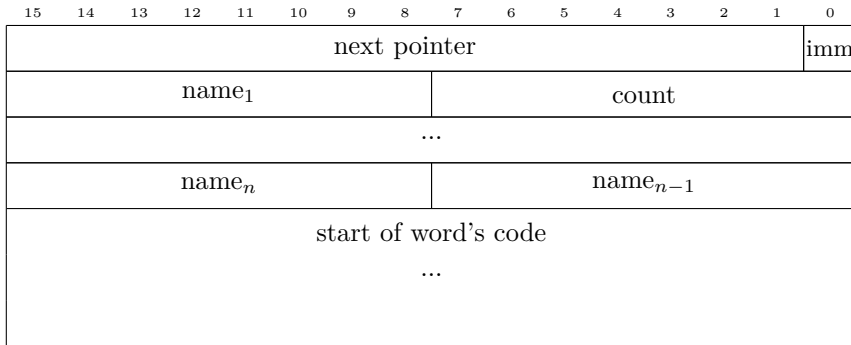
# Chapter 4

## Memory

### 4.1 Memory map

The J1a SwapForth implementation uses 8Kbytes of RAM for code and data. The standard Forth words access this RAM. Cells are 16-bits, and must be aligned to a 16-bit boundary.

## 4.2 Dictionary Layout

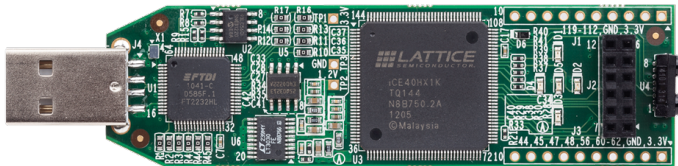


The SwapForth dictionary is a linked list; the variable `forth` holds the start of this list. Each dictionary entry has the following fields:

- **next pointer** - address of the next dictionary entry, or zero for the last dictionary entry
- **imm** - immediate bit, set if the word is immediate
- **count** - length of the name, in characters, 1-31
- **name<sub>1</sub> - name<sub>n</sub>** - characters in name. If the length of the name is even, then a padding byte is appended

## Chapter 5

# iCEstick Hardware interface



The J1a for iCEstick includes connections to the iCEstick peripherals:

- SPI flash
- LEDs
- IrDA transceiver
- Digilent Pmod<sup>TM</sup> connector
- UART

Access to peripherals is via the `io@` and `io!` words. Peripherals are port-mapped into a 16-bit IO address space. Most ports are either read-only or write-only. For read-only ports, writing to the port has no effect. For write-only ports, reading from the port gives zero.

As an example of direct port access, this word blinks the on-board LEDs when a signal on IrDA is detected.

```
: x
  begin
    $2000 io@      \ read from input port
    8 and 0=       \ true if bit 3 (IrDA RXD) is 0
    $0004 io!      \ write to LEDS
  again
;
```

## 5.1 Port Map

### 5.1.1 \$0001: Digilent Pmod™ data

The read-write port at address \$0001 is for direct access to the Digilent Pmod™ connector. The port pins are assigned:

| connection | Left row pins | right row pins | connection |
|------------|---------------|----------------|------------|
| bit 0      | 1             | 7              | bit 4      |
| bit 1      | 2             | 8              | bit 5      |
| bit 2      | 3             | 9              | bit 6      |
| bit 3      | 4             | 10             | bit 7      |
| ground     | 5             | 11             | ground     |
| 3.3v       | 6             | 12             | 3.3v       |

Correspondingly the port bits are assigned to pins as follows:

|    |    |    |    |    |    |   |   |    |   |   |   |   |   |   |   |
|----|----|----|----|----|----|---|---|----|---|---|---|---|---|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7  | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|    |    |    |    |    |    |   |   | 10 | 9 | 8 | 7 | 4 | 3 | 2 | 1 |

Note that pin direction is controlled by the corresponding bit the port at address \$0002.

### 5.1.2 \$0002: Digilent Pmod™ direction

Each of the 8 bits controls the direction of the corresponding pin of the Digilent Pmod™ connector. 0 sets the pin to input, 1 means sets the pin to output. The bit-to-pin mapping is the same as for port \$0001.

### 5.1.3 \$0004: LEDs

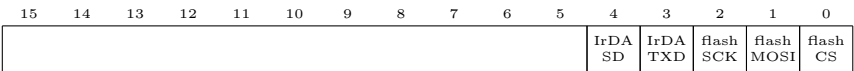
The five on-board LEDS are controlled by write-only port at address \$0004. Setting a bit to 1 lights the corresponding LED.

|    |    |    |    |    |    |   |   |   |   |   |      |      |      |      |      |
|----|----|----|----|----|----|---|---|---|---|---|------|------|------|------|------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4    | 3    | 2    | 1    | 0    |
|    |    |    |    |    |    |   |   |   |   |   | LED5 | LED4 | LED3 | LED2 | LED1 |

Built-in word `leds` writes to this port.

### 5.1.4 \$0008: PIO output

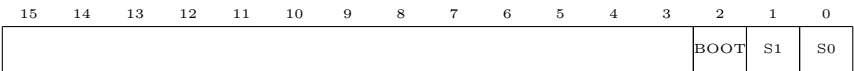
Write-only port \$0008 controls the flash and IrDA outputs.



5.1.5 \$0800: SB\_WARMBOOT control

Write-only port \$0800 is an interface to the SB\_WARMBOOT module. When activated, the FPGA loads a new configuration from external flash. There can be up to four external configurations; configuration 0 is the base SwapForth, and configurations 1-3 are available for other uses. So to reload the base system:

```
4 $800 io!
```



5.1.6 \$1000: UART data

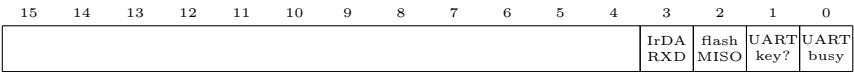
The read-write port at address \$1000 is for UART transmission or reception. Writing to the port starts transmission of a byte, reading the port returns the incoming byte.

Standard words **key** , **key?** and **emit** can be used to access this port.



5.1.7 \$2000: IrDA, flash and UART inputs

Read-only port \$2000 contains the input signals from the IrDA receiver, SPI flash, and UART.



# Index

-rot, 12  
.(, 11  
.r, 11  
.s, 11  
.x, 12  
/string, 11  
:noname, 11  
<>, 11  
?do, 11  
[compile], 11  
#bye, 16  
#flash, 16  
#include, 16  
#noverbose, 16  
#time, 16  
\\, 11  
0<>, 11  
0>, 11  
  
again, 11  
ahead, 11  
ANS, 11  
  
blink, 20  
bounds, 12  
#bye, 16  
  
case, 11  
cmove, 11  
cmove>, 11  
compile,, 11  
*computus*, 7  
  
d+, 11  
d., 11  
d.r, 11  
d0=, 11  
d2\*, 11  
dabs, 11  
demos, 6  
dictionary, 18  
dnegate, 11  
DTR, 15  
dump, 11  
  
easter, 7  
emit, 22  
endcase, 11  
endof, 11  
erase, 11  
  
false, 11  
#flash, 16  
forth, 12  
Forth 200x, 11  
FPGA, 5  
  
git, 5  
  
hex, 11  
  
iceprog, 5  
icestorm, 5  
#include, 16  
IrDA, 19

key, 22  
key?, 11, 22  
  
LEDs, 6, 19  
leds, 12, 21  
  
m+, 11  
marker, 11  
ms, 11  
  
new, 13  
nip, 11  
#noverbose, 16  
  
of, 11  
  
pad, 11  
parse, 11  
parse-name, 11  
Pmod, 19  
  
RAM, 5, 17  
reconfigure, 22  
refill, 11  
reset, 15  
restore-input, 11  
  
s,, 13  
save-input, 11  
SB\_WARMBOOT, 22  
shell, 15  
sliteral, 11  
SPI flash, 19  
  
tethered mode, 16  
throw, 11  
#time, 16  
true, 11  
tth, 13, 16  
tuck, 11  
  
u.r, 11  
  
u>, 11  
UART, 15, 19  
unused, 11  
  
within, 11  
words, 11