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

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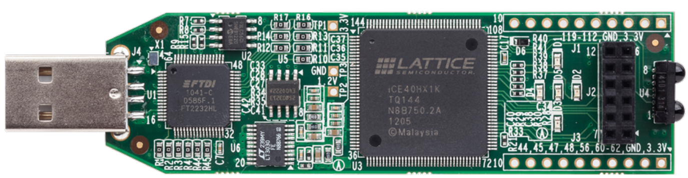
Chapter 1

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 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 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]]`

These core words **`abort"`** **`environment?`** are 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

`serialize`

`( -- )`

display all of current memory in base 36

`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 115200 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 115200
--- Miniterm on /dev/ttyUSB5: 115200,8,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 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

J1a 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

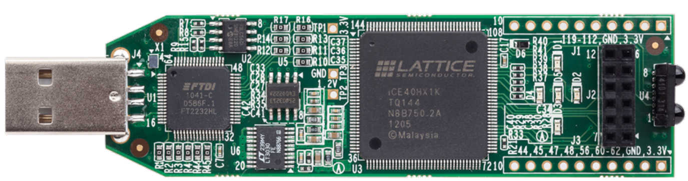
<table>
<tr><th>15</th><th>14</th><th>13</th><th>12</th><th>11</th><th>10</th><th>9</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td colspan="15">next pointer</td><td>imm</td></tr>
<tr><td colspan="8">name$_1$</td><td colspan="8">count</td></tr>
<tr><td colspan="16">...</td></tr>
<tr><td colspan="8">name$_n$</td><td colspan="8">name$_{n-1}$</td></tr>
<tr><td colspan="16">start of word's code
...</td></tr>
</table>

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$_1$ - name$_n$** - 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 tranceiver
- Digilent Pmod^{TM} 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^{TM} data

The read-write port at address \$0001 is for direct access to the Digilent Pmod^{TM} 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^{TM} direction

Each of the 8 bits controls the direction of the corresponding pin of the Digilent Pmod^{TM} 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.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
											IrDA SD	IrDA TXD	flash SCK	flash MOSI	flash CS

5.1.5 $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.

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

5.1.6 $2000: IrDA, flash and UART inputs

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

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
												IrDA RXD	flash MISO	UART key?	UART busy

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