

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

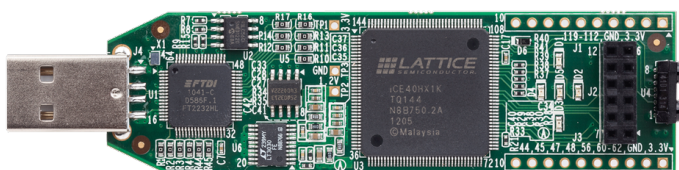
Providing names from the **Programming-Tools Extensions** word set

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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 uses 1100 logic elements. SwapForth uses 5 Kbytes of RAM, leaving about 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 196 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 are not implemented: **abort" environment?**

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

The SwapForth Shell

3.1 Command reference

3.2 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 can access this RAM.

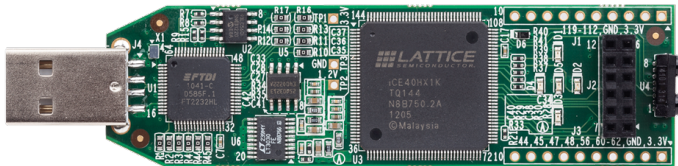
4.2 Dictionary Layout

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

- **next pointer** - address of the next dictionary entry, or zero for the last dictionary entry
- **imm** - immediate bit
- **count** - length of the name, in characters, 1-31
- **name₁ - 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 transceiver
- Digilent PmodTM 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

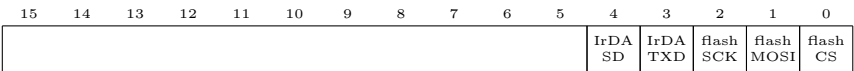
The five on-board LEDS are controlled by write-only port at address \$0004. Setting a bit to 1 lights the corresponding LED.

| | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|---|---|---|---|---|------|------|------|------|------|
| 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

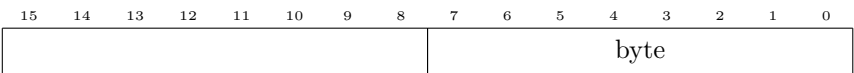
Write-only port \$0008 controls the flash and IrDA outputs.



5.1.5 \$1000: UART data

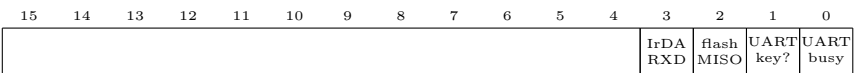
The read-write port at address \$1000 is for UART transmission or reception. Writing to the port starts transmission of a byte, reading the port returns the incoming byte.

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



5.1.6 \$2000: IrDA, flash and UART inputs

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



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