

J1a

SwapForth

Reference

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Adapted to Olimex ICE40 board by pbrier (pbrier@pbrier.nl)

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

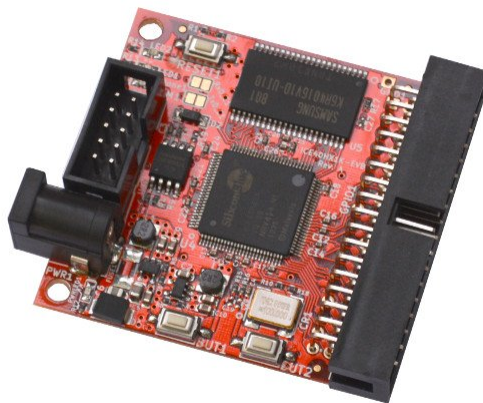
Providing names from the **Programming-Tools Extensions** word set

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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 [Olimex ICE40 board](#) like this

```
git clone https://github.com/pbrier/swapforth.git
cd swapforth/j1a
iceprogduino olimex-ice40/j1a.bin
python shell.py -h /dev/ttyUSB0
```

(where `/dev/ttyUSB0` is the appropriate port your serial adaptor 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

```
~/Documents/ice/swapforth/j1a $ make clean
~/Documents/ice/swapforth/j1a $ make j1a
```

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 (assuming your board's serial appears at `tttyUSB0`):

```
$ iceprogduino olimex-ice40/j1a.bin
$ python shell.py -h /dev/ttyUSB0 -p ../common/
Contacting... established
Loaded 143 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 olimex-ice40` again - this compiles an FPGA image with the complete code base built-in, which has the full set of words defined:

```
$ iceprogduino olimex-ice40/j1a.bin
$ python shell.py -h /dev/ttyUSB0 -p ../common/
Contacting... established
Loaded 207 words
-
```


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 (bit0=D1, bit1=D2)

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

buttons

```
( -- a )
```

Read current button state (bit0=BUTTON1, bit1=BUTTON2)

gpio!

```
( a -- )
```

Write GPIO value D0..D15 (set gpio_dir bits first if you want signal output)

gpio@

```
( -- a )
```

Read GPIO value D0..D15

gpio_dir

```
( a -- )
```

Set GPIO direction. 16bit direction (1=OUTPUT, 0=INPUT)

sramw

```
( d a -- )
```

Write data 'd' to SRAM address 'a'

sramr

```
( a -- d )
```

Read data from SRAM address 'a'

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 RTS as a reset signal, so you should make sure that it is set OFF by the terminal program:

```
$ miniterm.py --rts=0 --eol LF /dev/ttyUSB0 115200
--- Miniterm on /dev/ttyUSB5: 115200,8,N,1 ---
--- Quit: Ctrl+] | Menu: Ctrl+T | Help: Ctrl+T followed by Ctrl+H ---
--- forcing RTS 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.

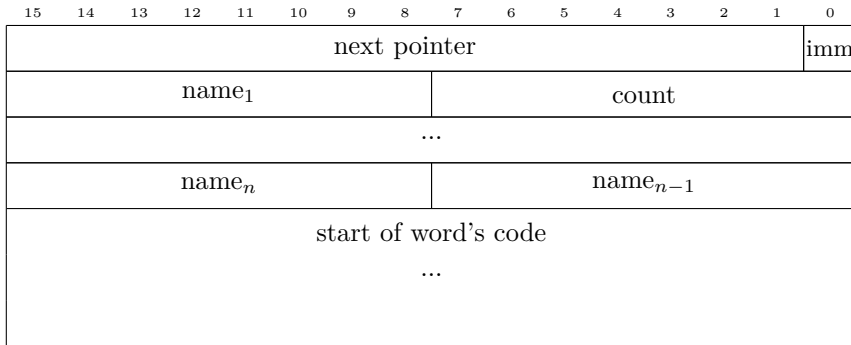
Chapter 4

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

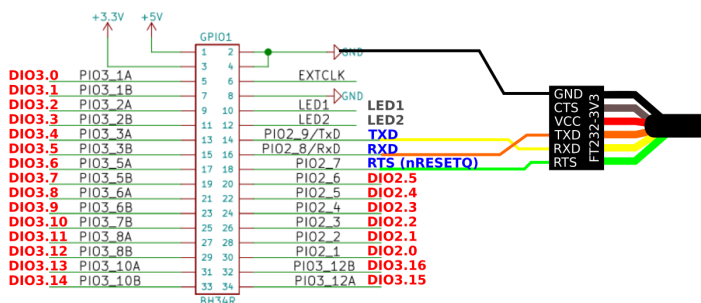


The SwapForth dictionary is a linked list; the variable `forth` holds the start of this list. Each dictionary entry has the following fields:

- **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
- **name₁ - name_n** - characters in name. If the length of the name is even, then a padding byte is appended

Chapter 5

Olimex ICE40 Hardware interface



The J1a for Olimex includes connections to the Olimex ICE40 peripherals:

- SPI flash
- 2x LEDs 2x Button
- GPIO connector
- UART
- SRAM (64k x 16bit accessible)

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 reads the buttons and sets the LEDs while also reporting the value to the serial console

```
\ output buttons to leds and terminal
: .bleds
begin
  $2000 io@
  2 rshift
  3 xor
  dup .x
  $0004 io!
again
;
```

```
\ display button io state as hex
: .buttons
begin
  $2000 io@ .x
again
;
```

```
\ test the digital outputs, generate square wave on each pin
\ D0=max freq, D1=Fmax/2 .. D15=Fmax/2^15
: testio
$ffff 2 io!
begin
  65535 0 do
    i 1 io!
```

```
    loop  
again  
;
```

5.1 Port Map

5.1.1 \$0001: data

The read-write port at address \$0001 is for direct access to the 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: direction

Each of the 8 bits controls the direction of the corresponding pin of the 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
														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 \$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!
```

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
													BOOT	S1	S0

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.

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

5.1.7 \$2000: IrDA, flash and UART inputs

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

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
											Button BUT2	Button BUT1	flash MISO	UART key?	UART busy