Altera Lessons Learned

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Overview

Atomic Rules was subcontracted by MFS as part of OpenCPI Phase 2 to port specific functionality that was previously implemented with Xilinx FPGAs unto Altera FPGAs. Taken together, the Xilinx and Altera duopoly dominate the FPGA (PLD) market as shown below. By adapting key pieces of OpenCPI to work with Altera; OpenCPI is shown to be "vendor-agnostic", at least between Xilinx and Altera. This document captures the "lessons learned" in that process.

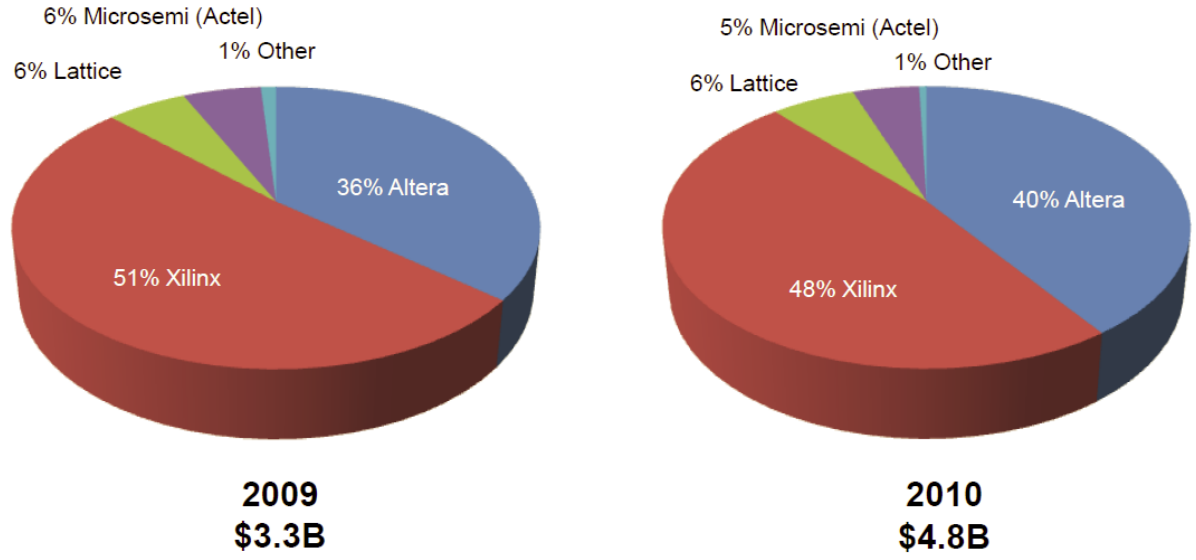


Figure 1 - PLD Market Share

Source: Altera

Tools

Xilinx and Altera offer a similar methodology to transform a circuit represented in RTL to a bitstream that can be run on their FPGA device. Both vendors have their strengths and weaknesses. The table below captures some of the similarities and differences in names and versions.

As of 2012-02-03

Attribute	Altera	Xilinx
Tool suite	Quartus	ISE
Version Used (2/2012)	11.1	13.4
Synthesis	Quartus	XST
Simulation	Modelsim “Altera Edition”	ISim
In-Circuit Debug	SignalTap	ChipScope

The Altera Build Process

To build Altera bitstreams, the following ten step process was used. There are most probably other ways to achieve the same result; but this process was use at the suggestion of the Altera FAEs.

Recompile BSV to Verilog if desired or required before beginning the RTL to bitstream process below.

Step	Action	Description
1	./cleanit	(script) Remove all prior artifacts from build directory.
2	./pullsrc	(script) Bring into the build directory the clean top-level .v and .qsf files
3	quartus &	(GUI) Launch Quartus GUI
4	Open .qpf	(GUI) Open the .qpf file associated with the project
5	Run Analysis & Synth	(GUI) Run Analysis and Synthesis on the design (button adjacent play)
6	Megafunction .qip	(GUI) Add to the project the .qip file associated with megafunction
7	Megafunction .tcl	(GUI) Add to the project the .tcl “pin assignment” script
8	Run .tcl	(GUI) Run the .tcl pin assignment script (note progress bar)
9	Run Full Compile	(GUI) Click the “play” button (typical 40~60 minute builds)
10	./sof2flash	(script) Convert the .sof bitstream to flash so it can be downloaded

General Observations

Documentation

There were a numerous defects that were either out and out defects in documentation, tacitly incorrect; or were errors of omission.

Avalon

Altera has a proprietary signaling protocol called Avalon, of which there are streaming and memory-mapped variants. However, almost every IP used different variations on the interface. A comment in the Altera documentation paraphrased below, is typical of the variation among standard theme:

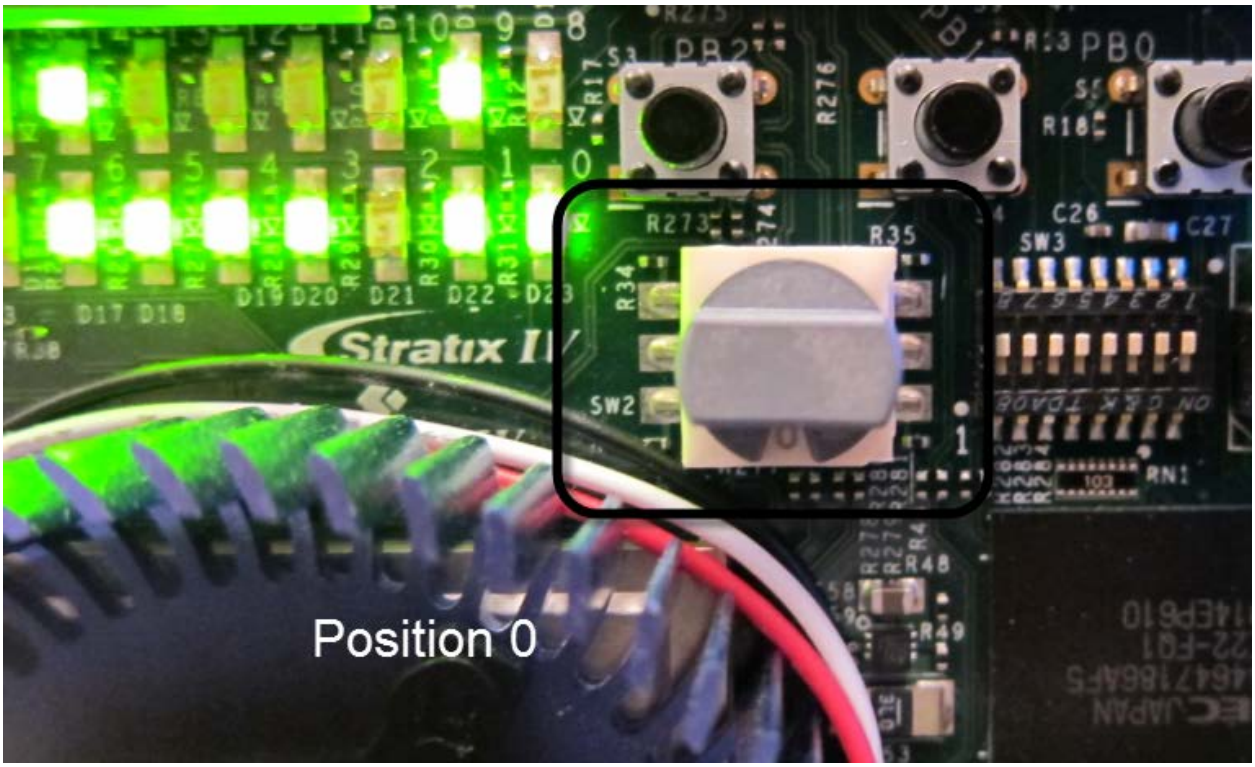
> "… *Unlike other Avalon-MM signals, this signal does not stay asserted if this other signal is de-asserted*."

This deviation from a standard, even a proprietary one such as Avalon, increases complexity and reduces interoperability.

Downloading a Bitstream to Altera Flash

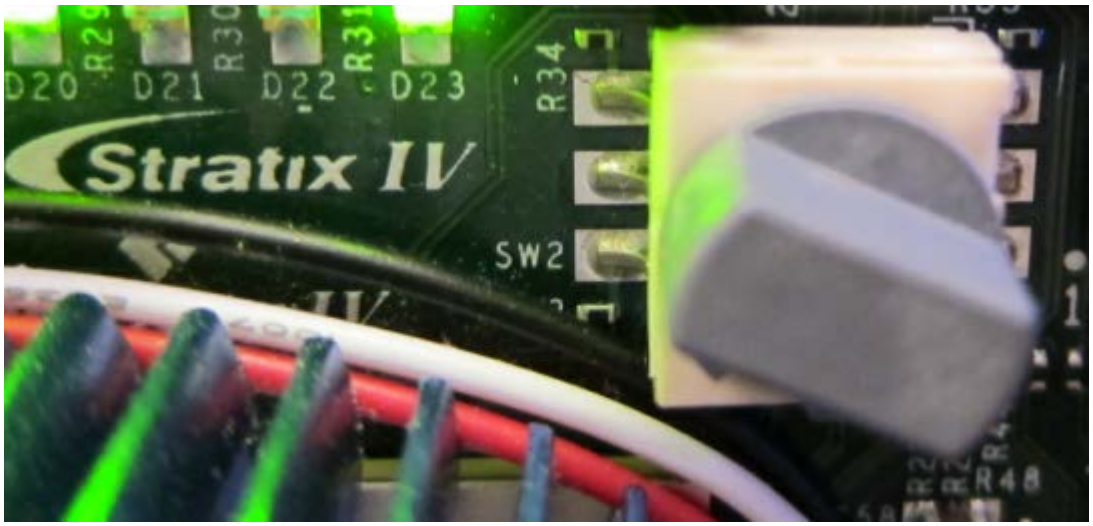
The following process is used to download a .flash file to the “alst4” platform.

Set the board SW2 rotary switch to the horizontal position 0

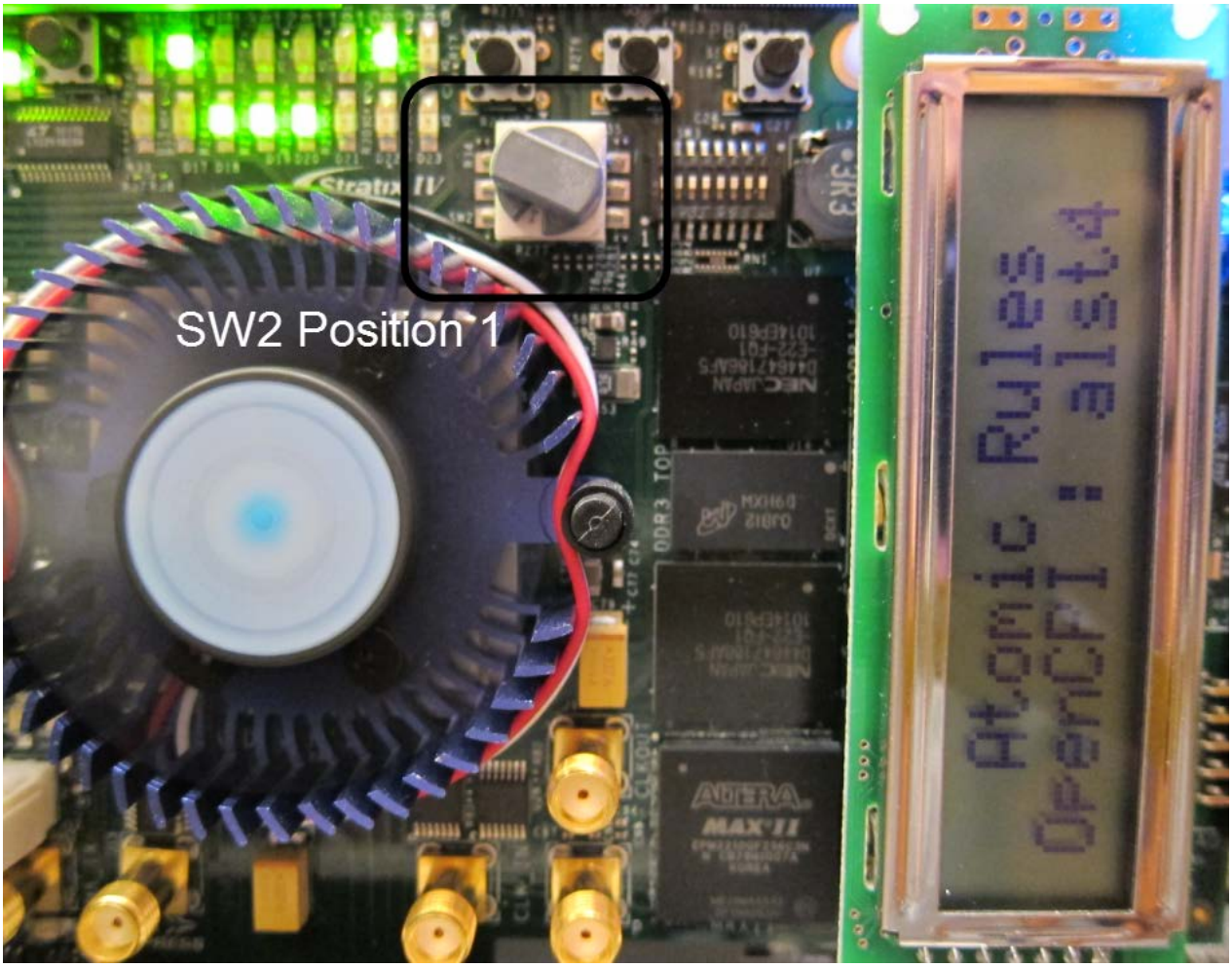


Use a web browser to connect to the board and download the .flash image

Set the board SW2 to position 1 and reboot. (Position 1 is one click clockwise from horizontal)



Note the LCD will refresh.



Transcript and Reproduction of Altera Function

With a bitstream rebuilt from source on 2012-02-03, the following objective evidence of performance is captured.

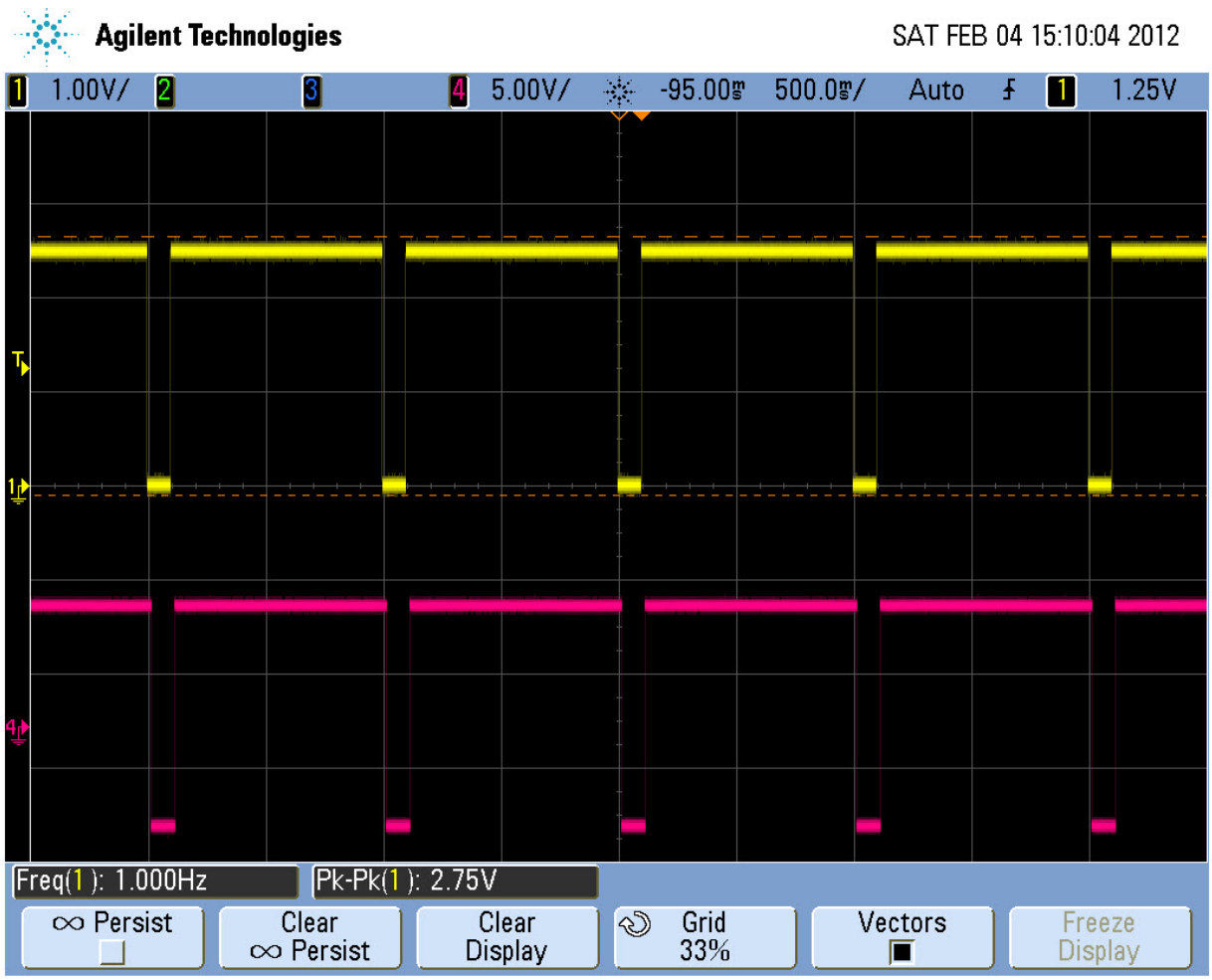
OCFRP

```
[shep@core920 projects]$ cd ocpi
[shep@core920 ocpi]$ date
Sat Feb  4 15:05:06 EST 2012
[shep@core920 ocpi]$ git pull
Already up-to-date.
[shep@core920 ocpi]$ cd bin
[shep@core920 bin]$ sudo -E ./ocfrp_check
Found OpenCPI FPGA reference platform "0000:04:00.0" with bitstream birthday:
Thu Feb  2 12:50:26 2012
Found OpenCPI FPGA reference platform "0000:03:00.0" with bitstream birthday:
Wed Jan 19 14:55:44 2011
```

SWCTL and GPS Time

```
[shep@core920 bin]$ sudo -E ./swctl 0xDE000000 0xDFFF0000 settime
[shep@core920 bin]$ sudo -E ./swctl 0xDE000000 0xDFFF0000 admin
OCCP Admin Space
 Open:         0x4f70656e "nepO"
 CPI:          0x43504900 ""
 revision:     0x00000001
 birthday:     0x4f2acce2 Thu Feb  2 17:50:26 2012
 workerMask:   0x0000721c workers 2 3 4 9 12 13 14 exist
 pci_dev_id:   0x00000400
 attention:    0x00000000
 cpStatus:     0x00000000
 scratch20:    0x00000000
 scratch24:    0x00000000
 cpControl:    0x00000000
 timeStatus:   0x3800002c ppsInSticky timeSetSticky ppsOK
 timeControl:  0x00000000
 gpsTimeMS:    0x4f2d8ffc (1328386044) Sat Feb  4 20:07:24 2012
 gpsTimeLS:    0x59c69b4c (1506185015)
 deltaTimeMS:  0x00000000
 deltaTimeLS:  0x00000000
 refPerPPS:    0x05f5e066 (99999846)
 dnaLS:        0x0badc0de
 dnaMS:        0x0badc0de
 numDPMemReg:  0x00000002 (2)
 DP 0:      0x10000008
 DP 1:      0x10020008
 UUID[ 3: 0]: 0xc0000000 0xd0000000 0xe0000000 0xf0000000
 UUID[ 7: 4]: 0x80000000 0x90000000 0xa0000000 0xb0000000
 UUID[11: 8]: 0x40000000 0x50000000 0x60000000 0x70000000
 UUID[15:12]: 0x00000000 0x10000000 0x20000000 0x30000000
```

PPS Output locked to GPS PPS Input



Top trace: FET Probe on PPS out signal from HSMC riser card

Bottom trace: PPS signal from GPS uBlox EVK-5T

Flash Access

Read Flash device with FlashWorker (Worker 9) using $OCPI/bin/testSeq12 and verify that indirect I/O and flat map return the same results:

```
Worker 9 control op: initialize(0)
Result: 0xc0de4201
Worker 9 control op: start(4)
Result: 0xc0de4201
Worker 9, offset:0x00000000(4), hexVal:0x00000003 decVal:3, 8
Worker 9, offset:0x00000004(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000008(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x0000000c(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000010(4), hexVal:0x00000000 decVal:0, 8

read addr 0
Worker 9, offset 0x8, writing value: 0x0
Worker 9, offset 0x18, writing value: 0x0
Worker 9, offset:0x00000000(4), hexVal:0x00000003 decVal:3, 8
Worker 9, offset:0x00000004(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000008(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x0000000c(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000010(4), hexVal:0x0000703a decVal:28730, 8

read addr 1
Worker 9, offset 0x8, writing value: 0x1
Worker 9, offset 0x18, writing value: 0x0
Worker 9, offset:0x00000000(4), hexVal:0x00000003 decVal:3, 8
Worker 9, offset:0x00000004(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000008(4), hexVal:0x00000001 decVal:1, 8
Worker 9, offset:0x0000000c(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000010(4), hexVal:0x0000703a decVal:28730, 8

read addr 2
Worker 9, offset 0x8, writing value: 0x2
Worker 9, offset 0x18, writing value: 0x0
Worker 9, offset:0x00000000(4), hexVal:0x00000003 decVal:3, 8
Worker 9, offset:0x00000004(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000008(4), hexVal:0x00000002 decVal:2, 8
Worker 9, offset:0x0000000c(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000010(4), hexVal:0x00000001 decVal:1, 8

read addr 4
Worker 9, offset 0x8, writing value: 0x4
Worker 9, offset 0x18, writing value: 0x0
Worker 9, offset:0x00000000(4), hexVal:0x00000003 decVal:3, 8
Worker 9, offset:0x00000004(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000008(4), hexVal:0x00000004 decVal:4, 8
Worker 9, offset:0x0000000c(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000010(4), hexVal:0x00000074 decVal:116, 8
```

```
read addr 8
Worker 9, offset 0x8, writing value: 0x8
Worker 9, offset 0x18, writing value: 0x0
Worker 9, offset:0x00000000(4), hexVal:0x00000003 decVal:3, 8
Worker 9, offset:0x00000004(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000008(4), hexVal:0x00000008 decVal:8, 8
Worker 9, offset:0x0000000c(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000010(4), hexVal:0x0000483a decVal:18490, 8

read addr 0x100
Worker 9, offset 0x8, writing value: 0x100
Worker 9, offset 0x18, writing value: 0x0
Worker 9, offset:0x00000000(4), hexVal:0x00000003 decVal:3, 8
Worker 9, offset:0x00000004(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000008(4), hexVal:0x00000100 decVal:256, 8
Worker 9, offset:0x0000000c(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000010(4), hexVal:0x0000ffff decVal:65535, 8

read addr 0x1000
Worker 9, offset 0x8, writing value: 0x1000
Worker 9, offset 0x18, writing value: 0x0
Worker 9, offset:0x00000000(4), hexVal:0x00000003 decVal:3, 8
Worker 9, offset:0x00000004(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000008(4), hexVal:0x00001000 decVal:4096, 8
Worker 9, offset:0x0000000c(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000010(4), hexVal:0x0000ffff decVal:65535, 8

read addr 0x100000
Worker 9, offset 0x8, writing value: 0x10000
Worker 9, offset 0x18, writing value: 0x0
Worker 9, offset:0x00000000(4), hexVal:0x00000003 decVal:3, 8
Worker 9, offset:0x00000004(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000008(4), hexVal:0x00010000 decVal:65536, 8
Worker 9, offset:0x0000000c(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000010(4), hexVal:0x00002020 decVal:8224, 8

read addr 0x10000
Worker 9, offset 0x8, writing value: 0x100000
Worker 9, offset 0x18, writing value: 0x0
Worker 9, offset:0x00000000(4), hexVal:0x00000003 decVal:3, 8
Worker 9, offset:0x00000004(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000008(4), hexVal:0x00100000 decVal:1048576, 8
Worker 9, offset:0x0000000c(4), hexVal:0x00000000 decVal:0, 8
Worker 9, offset:0x00000010(4), hexVal:0x00005454 decVal:21588, 8
```

```
read using flatmap
Worker 9, offset:0x00080000(4), hexVal:0x0000703a decVal:28730, 8
Worker 9, offset:0x00080004(4), hexVal:0x00000074 decVal:116, 8
Worker 9, offset:0x00080008(4), hexVal:0x0000483a decVal:18490, 8
Worker 9, offset:0x0008000c(4), hexVal:0x0000f804 decVal:63492, 8
Worker 9, offset:0x00080010(4), hexVal:0x0000fd1e decVal:64798, 8
Worker 9, offset:0x00080014(4), hexVal:0x0000203a decVal:8250, 8
Worker 9, offset:0x00080018(4), hexVal:0x0000e03a decVal:57402, 8
Worker 9, offset:0x0008001c(4), hexVal:0x00000034 decVal:52, 8
Worker 9, offset:0x00080020(4), hexVal:0x00000704 decVal:1796, 8
Worker 9, offset:0x00080024(4), hexVal:0x0000c83a decVal:51258, 8
```

DRAM Test

Use the dram test feature of swctl to fully test the FPGA attached DRAM by writing DRAM then reading back the pattern; then writing a permuted pattern, and reading, etc. Use $ocpi/bin/testSeq9a

```
[shep@core920 bin]$ sudo -E ./testSeq9a
admin probe
OCCP Admin Space
 Open:         0x4f70656e "nepO"
 CPI:          0x43504900 ""
 revision:     0x00000001
 birthday:     0x4f2acce2 Thu Feb  2 17:50:26 2012
 workerMask:   0x0000721c workers 2 3 4 9 12 13 14 exist
 pci_dev_id:   0x00000400
 attention:    0x00000000
 cpStatus:     0x00000000
 scratch20:    0x00000000
 scratch24:    0x00000000
 cpControl:    0x00000000
 timeStatus:   0x300000e1 ppsInSticky timeSetSticky
 timeControl:  0x00000000
 gpsTimeMS:    0x4f2d9649 (1328387657) Sat Feb  4 20:34:17 2012
 gpsTimeLS:    0xf84009e4 (4164943139)
 deltaTimeMS:  0x00000000
 deltaTimeLS:  0x00000000
 refPerPPS:    0x05f5e488 (100000904)
 dnaLS:        0x0badc0de
 dnaMS:        0x0badc0de
 numDPMemReg:  0x00000002 (2)
 DP 0:      0x10000008
 DP 1:      0x10020008
 UUID[ 3: 0]: 0xc0000000 0xd0000000 0xe0000000 0xf0000000
 UUID[ 7: 4]: 0x80000000 0x90000000 0xa0000000 0xb0000000
 UUID[11: 8]: 0x40000000 0x50000000 0x60000000 0x70000000
 UUID[15:12]: 0x00000000 0x10000000 0x20000000 0x30000000
reset workers
Worker 4, writing control register value: 0x4
Worker 3, writing control register value: 0x4
Worker 2, writing control register value: 0x4
Worker 10, writing control register value: 0xf
Worker 11, writing control register value: 0xf
Worker 12, writing control register value: 0xf
unreset workers
Worker 4, writing control register value: 0x80000004
Worker 3, writing control register value: 0x80000004
Worker 2, writing control register value: 0x80000004
Worker 10, writing control register value: 0x8000000f
Worker 11, writing control register value: 0x8000000f
Worker 12, writing control register value: 0x8000000f
initialize workers
```

```
Worker 4 control op: initialize(0)
Result: 0xc0de4201
Worker 3 control op: initialize(0)
Result: 0xc0de4201
Worker 2 control op: initialize(0)
Result: 0xc0de4201
Worker 10 control op: initialize(0)
Result: 0xc0de4203
Worker 11 control op: initialize(0)
Result: 0xc0de4203
Worker 12 control op: initialize(0)
Result: 0xc0de4201
start workers
Worker 12 control op: start(4)
Result: 0xc0de4201
Worker 11 control op: start(4)
Result: 0xc0de4203
Worker 10 control op: start(4)
Result: 0xc0de4203
Worker 4 control op: start(4)
Result: 0xc0de4201
Worker 3 control op: start(4)
Result: 0xc0de4201
Worker 2 control op: start(4)
Result: 0xc0de4201
Read Memory Controler Status
Worker 12, offset:0x00000000(4), hexVal:0x00000073 decVal:115, 8
Worker 12, offset:0x00000004(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000008(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x0000000c(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000010(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000014(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000018(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x0000001c(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000020(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000024(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000028(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x0000002c(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000030(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000034(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000038(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x0000003c(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000040(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000044(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset:0x00000048(4), hexVal:0x00000000 decVal:0, 8
Worker 12, offset 0x80000, writing value: 0x3020100
Worker 12, offset 0x80004, writing value: 0x7060504
Worker 12, offset 0x80008, writing value: 0xb0a0908
Worker 12, offset 0x8000c, writing value: 0xf0e0d0c
Worker 12, offset 0x80010, writing value: 0x13121110
Worker 12, offset 0x80014, writing value: 0x17161514
Worker 12, offset 0x80018, writing value: 0x1b1a1918
Worker 12, offset 0x8001c, writing value: 0x1f1e1d1c
Worker 12, offset 0x80020, writing value: 0x23222120
```

```
Worker 12, offset 0x80024, writing value: 0x27262524
Worker 12, offset 0x80028, writing value: 0x2b2a2928
Worker 12, offset 0x8002c, writing value: 0x2f2e2d2c
Worker 12, offset 0x80030, writing value: 0x33323130
Worker 12, offset 0x80034, writing value: 0x37363534
Worker 12, offset 0x80038, writing value: 0x3b3a3938
Worker 12, offset 0x8003c, writing value: 0x3f3e3d3c
Worker 12, offset:0x00080000(4), hexVal:0x03020100 decVal:50462976, 8
Worker 12, offset:0x00080004(4), hexVal:0x07060504 decVal:117835012, 8
Worker 12, offset:0x00080008(4), hexVal:0x0b0a0908 decVal:185207048, 8
Worker 12, offset:0x0008000c(4), hexVal:0x0f0e0d0c decVal:252579084, 8
Worker 12, offset:0x00080010(4), hexVal:0x13121110 decVal:319951120, 8
Worker 12, offset:0x00080014(4), hexVal:0x17161514 decVal:387323156, 8
Worker 12, offset:0x00080018(4), hexVal:0x1b1a1918 decVal:454695192, 8
Worker 12, offset:0x0008001c(4), hexVal:0x1f1e1d1c decVal:522067228, 8
Worker 12, offset:0x00080020(4), hexVal:0x23222120 decVal:589439264, 8
Worker 12, offset:0x00080024(4), hexVal:0x27262524 decVal:656811300, 8
Worker 12, offset:0x00080028(4), hexVal:0x2b2a2928 decVal:724183336, 8
Worker 12, offset:0x0008002c(4), hexVal:0x2f2e2d2c decVal:791555372, 8
Worker 12, offset:0x00080030(4), hexVal:0x33323130 decVal:858927408, 8
Worker 12, offset:0x00080034(4), hexVal:0x37363534 decVal:926299444, 8
Worker 12, offset:0x00080038(4), hexVal:0x3b3a3938 decVal:993671480, 8
Worker 12, offset:0x0008003c(4), hexVal:0x3f3e3d3c decVal:1061043516, 8
Read
Worker 12, offset 0x58, writing value: 0x0
Worker 12, offset:0x00000080(4), hexVal:0x03020100 decVal:50462976, 8
Worker 12, offset:0x00000084(4), hexVal:0x07060504 decVal:117835012, 8
Worker 12, offset:0x00000088(4), hexVal:0x0b0a0908 decVal:185207048, 8
Worker 12, offset:0x0000008c(4), hexVal:0x0f0e0d0c decVal:252579084, 8
Worker 12, offset 0x58, writing value: 0x10
Worker 12, offset:0x00000080(4), hexVal:0x13121110 decVal:319951120, 8
Worker 12, offset:0x00000084(4), hexVal:0x17161514 decVal:387323156, 8
Worker 12, offset:0x00000088(4), hexVal:0x1b1a1918 decVal:454695192, 8
Worker 12, offset:0x0000008c(4), hexVal:0x1f1e1d1c decVal:522067228, 8
Worker 12, offset 0x58, writing value: 0x20
Worker 12, offset:0x00000080(4), hexVal:0x23222120 decVal:589439264, 8
Worker 12, offset:0x00000084(4), hexVal:0x27262524 decVal:656811300, 8
Worker 12, offset:0x00000088(4), hexVal:0x2b2a2928 decVal:724183336, 8
Worker 12, offset:0x0000008c(4), hexVal:0x2f2e2d2c decVal:791555372, 8
Worker 12, offset 0x58, writing value: 0x30
Worker 12, offset:0x00000080(4), hexVal:0x33323130 decVal:858927408, 8
Worker 12, offset:0x00000084(4), hexVal:0x37363534 decVal:926299444, 8
Worker 12, offset:0x00000088(4), hexVal:0x3b3a3938 decVal:993671480, 8
Worker 12, offset:0x0000008c(4), hexVal:0x3f3e3d3c decVal:1061043516, 8
Dtest

npages:2^8  pagesz(4B words):2^17  memoryBytes:2^27
Worker 12, memory test offset 0x80000, test loop count: 4

k:02 Rd:09d
```

<Stopped after 2 successful passes>