

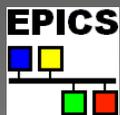
Embedding EPICS/RTEMS into Altera NIOS2 FPGA Softcore

Jeffrey O. Hill

Embedding EPICS/RTEMS into Altera NIOS2 FPGA Softcore

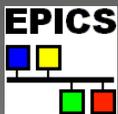
○ Overview

- > Requirements
- > Proof of Principal
- > Issues ...
- > First Step – Wrap Altera NIOS2 GNU Tools
- > Next Step – Build RTEMS/NIOS GNU Tools
- > Future Plans



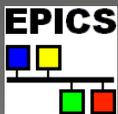
Requirements

- Requirements for EPICS IOCs, LANSCE RF system upgrade
 - > Must be deterministically synchronized with the timing system
 - Binding of captured waveforms with beam flavor attributes obtained from the timing system
 - Modal behavior changes of low level RF controls depending on the flavor of beam
 - > Must move captured waveforms from FPGA, into the IOC, and out to Ethernet



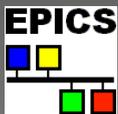
Proof of Principal

- Traditional VME/cPCI backplanes
 - > Now they are becoming a bottleneck
- There are Altera IP cores for
 - > System processor
 - > Ethernet interface
- Can we distribute the solution?
 - > One IOC on each cPCI RF board
 - > Stream data directly, FPGA to Ethernet
- A proof of principal is needed



Proof of Principal

- Third party FPGA intellectual property libraries for *ARM, MIPS*, etc
 - > Are well supported by the GNU tools
 - > However, use of these IP modules involves licensing expense
 - Which our RF group prefers to avoid



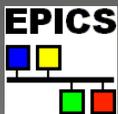
Proof of Principal

○ Hardware

- > Altera NIOS Embedded Evaluation Kit
 - NIOS II Soft-core Reference Platform on Cyclone III FPGA

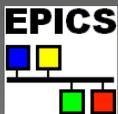
○ Software

- > Altera hardware and software design suite
- > GNU Cross Development Tools
- > RTEMS OS
- > EPICS IOC



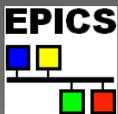
Issues...

- Altera *does*
 - > Provide source code for their `nios2` enhancements to `binutils/gcc/newlib`
 - > Modern version now available
 - FSF `binutils 2.20` for `nios2`
 - FSF `gcc 4.1` for `nios2`
 - FSF `newlib 1.16` for `nios2`
- Altera *doesn't* feedback their `nios2` enhancements into the asynchronous FSF releases of `binutils/gcc/newlib`



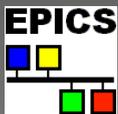
Issues...

- RTEMS *does* feed their enhancements back into the asynchronous FSF releases of `binutils/gcc/newlib`
- RTEMS does *depend* on these enhancements
 - > RTEMS 4.10 appears to require a recent release of `gnu gcc` and `newlib`
 - > Proper C++ runtime support on RTEMS requires RTEMS configured build of `gcc`



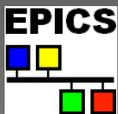
Issues...

- RTEMS **doesn't** supply it's nios2 support files in any production release, but
 - > These files **can** be obtained by fetching the main development trunk out of CVS
- Bringing all of the players together
 - > Is a learning experience...



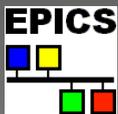
Roadmap

- Install Altera design tools into Linux
- Build and install `nios2-rtems-xxx` gnu cross development tools
- Build RTEMS for nios2
- Build EPICS for RTEMS and nios2



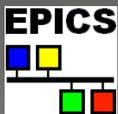
Installing Altera Design Tools into Linux

- Mostly routine, but some issues
- Difficulty getting the “usbblaster” device programmer to work on Ubuntu
 - > I eventually found a hint at the Altera wiki
 - The solutionn was to copy some Altera configuration files into Linux kernel areas for the benefit of the Altera JTag daemon



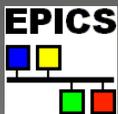
Building nios2-rtems GNU Cross Development Tools

- Typical steps when installing a GNU package from source
 - > Obtain source
 - > Patch source
 - > Run autoconf in the source
 - > Configure the source
 - > Build the package
 - > Install the package



Building nios2-rtems GNU Cross Development Tools

- Patch the source
 - > Obtain source code from Altera
 - > Obtain RTEMS patches for a similar version
 - > After patching...
 - Sometimes we have to fix by hand what is found in *.rej



Building nios2-rtems GNU Cross Development Tools

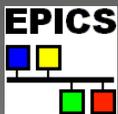
○ Patch the source

> FSF Newlib 1.18

- Applied RTEMS patch
- Forward annotated nios2 specific code from altera newlib 1.16

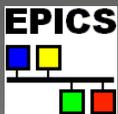
> Altera GCC 4.1

- Applied RTEMS patch
- Backward annotated rtems specific files for nios from more recent gcc



Building nios2-rtems GNU Cross Development Tools

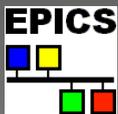
- Carefully run auto-tools against the source
 - > Must run exactly the right auto-tools version
 - Look in the auto-tool source file to determine the exact version number
 - Usually only autoconf needs to be run, but one has to look at which auto source files have been changed by a patch
 - Fix all warning messages
 - Invariably they occur because some auto-tool has the wrong version



Installing / Building nios2-rtems

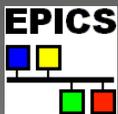
GNU Cross Development Tools

- Run gnu configure
 - > Look for errors in config.log, and keep installing missing packages until all error are eliminated
- Build the tool
- Install the tool



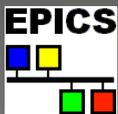
RTEMS Source Code

- The nios2 support isn't included in any production RTEMS release
 - > I obtained RTEMS 4.11- from anonymous CVS
 - In the cvs trunk, `nios2` support is included
 - > Eventually I will back-annotate the nios2 specific RTEMS code into a production release of RTEMS



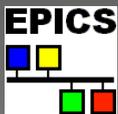
Specific Issues

- Undefined `_GLOBAL_OFFSET_TABLE_` symbol in `crti.o`
 - > Fixed by removing use of obsolete (in Altera gcc 4.1) `crti.o` from compiler driver and RTEMS
- Undefined networking code symbols
 - > Fixed by modifying the bsp's linker command file to properly map these FreeBSD `sysctl` symbols/sections



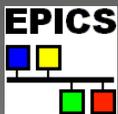
Specific Issues

- Initially the target produce no sign of life
 - > Fixed by carefully checking RTEMS hardware configuration against the hardware configuration produced by Altera design tools
 - Address in the target system of the JTAG UART was wrong



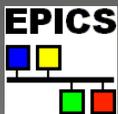
Status

- RTEMS appears to run on NIOS2, but more testing is required
- EPICS builds now against RTEMS and NIOS2 without problems, but I have to comment out initialization of the network
- Part of regression test complete but they are hanging up in the timer tests – possibly due to time failing to advance in the BSP



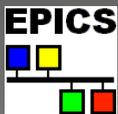
Future Plans

- Altera Triple-Speed-Ethernet
 - > Port Linux Ethernet driver to RTEMS
- Or, the open Ethernet driver
 - > RTEMS driver already exists
- Finish regression Tests
- Performance tests



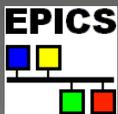
Open Questions

- Should the RTEMS BSP call the Altera HAL libraries so that we can adapt easily to FPGA changes made within the Altera design tools?



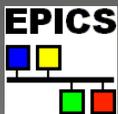
References

- <http://www.nios2rtems.com>
- <http://www.alterawiki.com/wiki/CrossGcc>
- <http://www.ifp.illinois.edu/~nakazato/tips/xgcc.html>



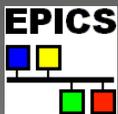
In Summary

- I have about 4 weeks invested so far into this project including 3 days lost to a hard drive failure
- However, already results are promising and perhaps this will prove to be a viable option



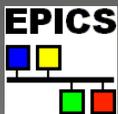
Switching Topics

- EPICS 3 Upgrades

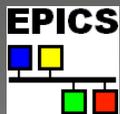
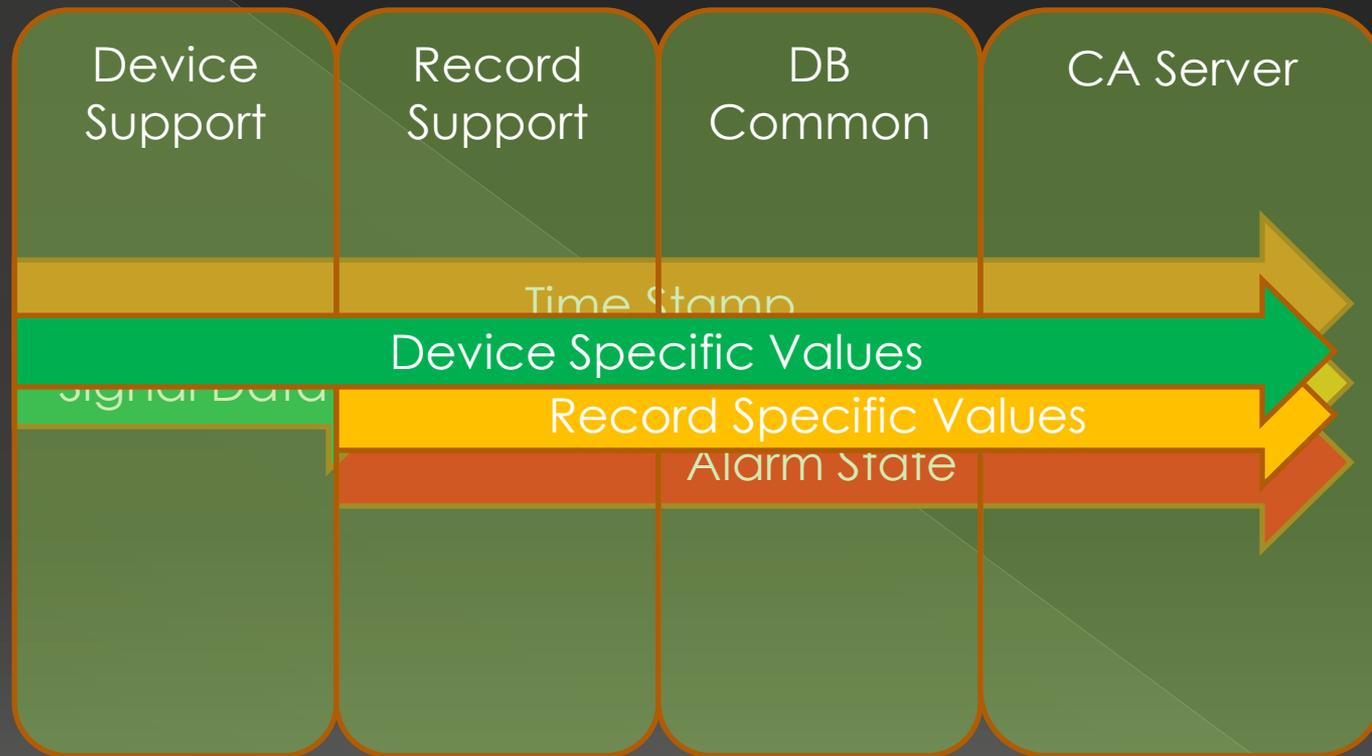


LANSCCE Requirements

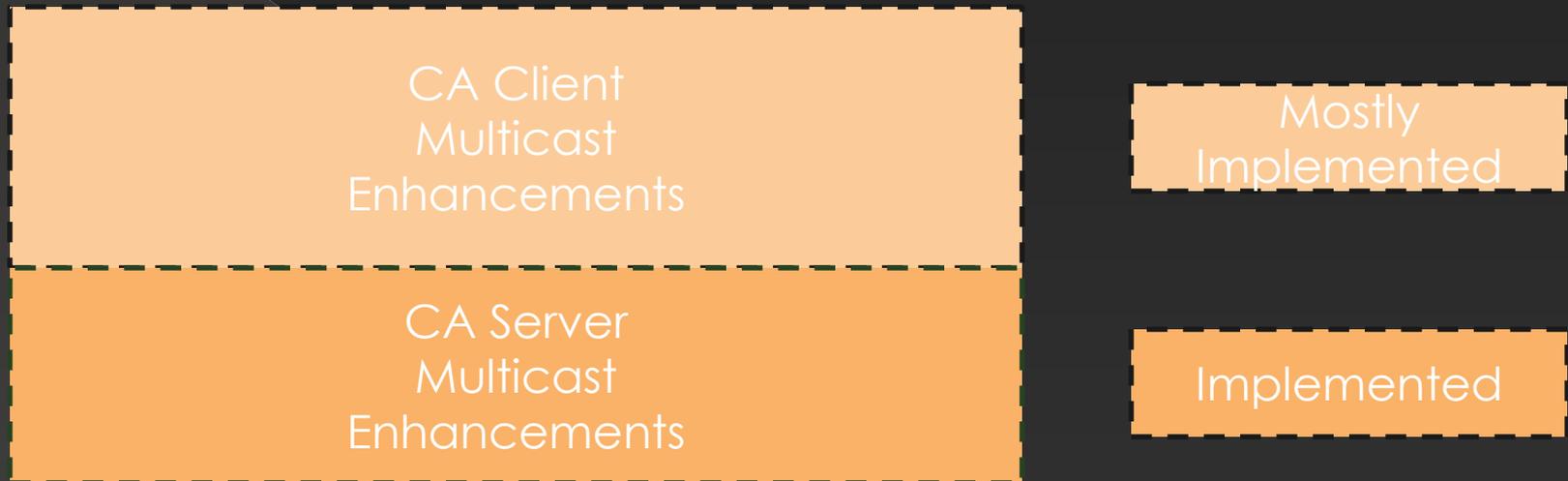
- LANSCE, a versatile machine
 - Originally producing H⁺, H⁻, and polarized H⁻
 - Each with different intensities, duty factors, and even energies
 - depending on experimental and medical isotope production needs
- LANSCE timing and flavoring of data
 - Flavoring
 - Selection based on - logical combinatorial of beam gates
 - Timing
 - Selection based on - time window sampling
- Many permutations
 - Too many to, a-priori, install records for all of them
 - Subscription update filtering is needed



EPICS Paradigm Shift

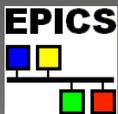


Status – What is Implemented

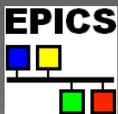
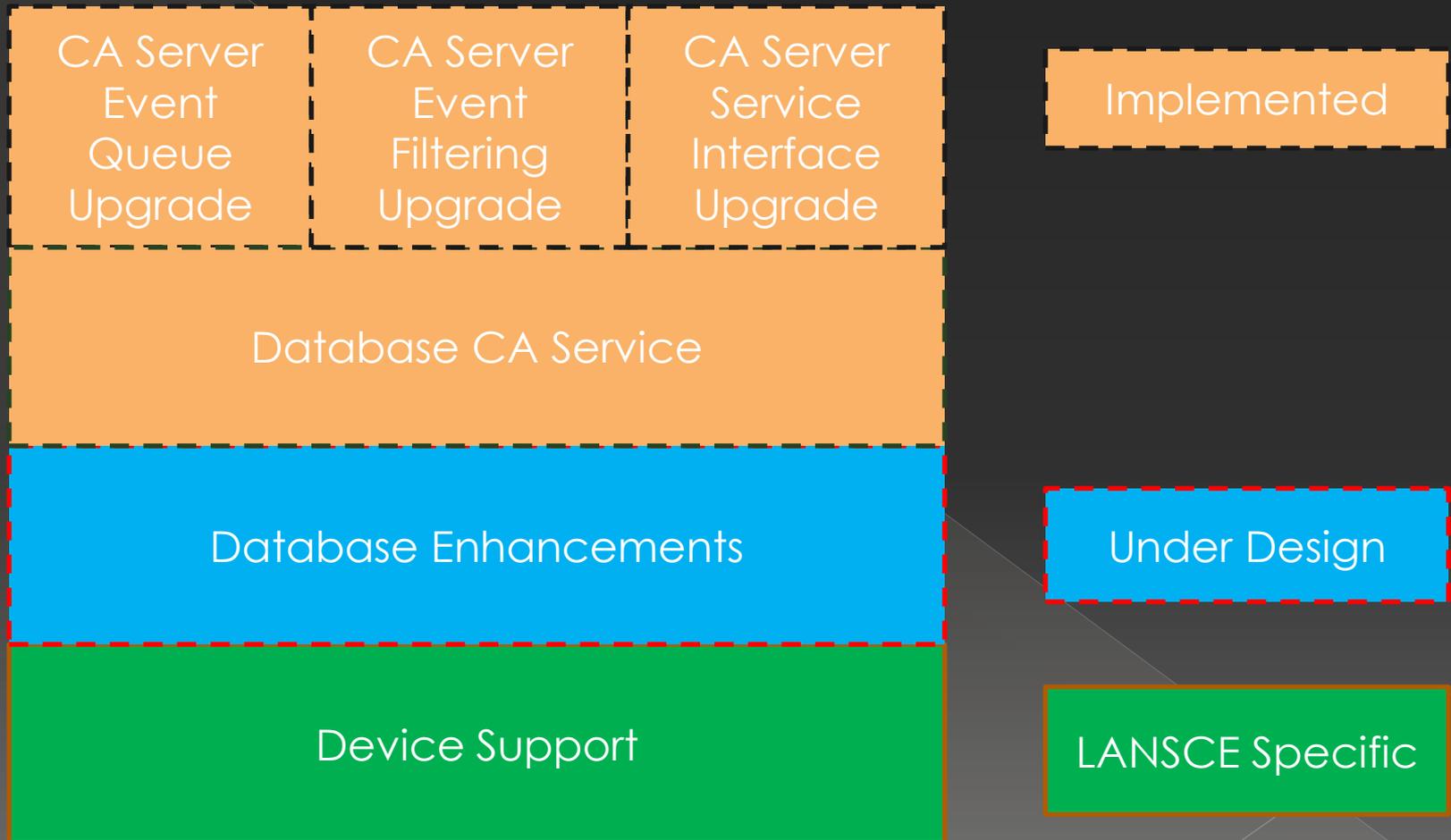


○ Multicast Enhancements

- > Simplified configuration of EPICS Systems with
 - Multiple IOCs on one host
 - Installations with multiple subnets



Status – What is Implemented



Status – What is Implemented

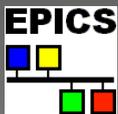
- Subscription update event filtering

```
>camonitor "fred$F $(PV:)>30 && $(PV)<40"
```

fred\$F \$(PV:)>30 && \$(PV)<40	2010-06-03 07:58:47.224969	36.6466
fred\$F \$(PV:)>30 && \$(PV)<40	2010-06-03 07:58:47.227964	37.1654
fred\$F \$(PV:)>30 && \$(PV)<40	2010-06-03 07:58:47.267460	33.9427
fred\$F \$(PV:)>30 && \$(PV)<40	2010-06-03 07:58:47.276013	33.9976
fred\$F \$(PV:)>30 && \$(PV)<40	2010-06-03 07:58:47.299041	37.8033
fred\$F \$(PV:)>30 && \$(PV)<40	2010-06-03 07:58:47.319065	33.549

```
>camonitor "fred$F $(PV:flavor)==30 "
```

fred\$F \$(PV:flavor)==30	2010-06-03 07:58:18.906049	44.1145
fred\$F \$(PV:flavor)==30	2010-06-03 07:58:21.899019	39.2743
fred\$F \$(PV:flavor)==30	2010-06-03 07:58:24.885000	54.3352
fred\$F \$(PV:flavor)==30	2010-06-03 07:58:27.855063	93.9634
fred\$F \$(PV:flavor)==30	2010-06-03 07:58:30.811997	97.7081



Status – What is Implemented



- Protocol design is out for review