Embedding EPICS/RTEMs into Altera NIOS2 FPGA Softcore

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- 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
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
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**
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
RTEMS doesn’t supply its 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 solution 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 errors are eliminated
- Build the tool
- Install the tool
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.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
LANSCE 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

- Device Support
- Record Support
- DB Common
- CA Server

- Alarm State
- PV Value
- Signal Data
- Time Stamp
- Record Specific Values
- Device Specific Values
- Alarm State
- Record Specific Values
Multicast Enhancements

- Simplified configuration of EPICS Systems with
  - Multiple IOCs on one host
  - Installations with multiple subnets
Status – What is Implemented

- CA Server Event Queue Upgrade
- CA Server Event Filtering Upgrade
- CA Server Service Interface Upgrade

- Database CA Service
- Database Enhancements
- Device Support

- Implemented
- Under Design
- LANSCE Specific
## Status – What is Implemented

- Subscription update event filtering

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Status – What is Implemented

- CA Client, Protocol Upgrade
- CA Client, Interface Upgrade
- CA Server Protocol Upgrade
- In Progress
- Under Design

- Protocol design is out for review