Advances in Developing Next-Generation Electronics Standards for Physics

IEEE Real Time Conference & xTCA Workshop
Institute of High Energy Physics, IHEP
Beijing China May 10-15, 2009

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Chair, PICMG xTCA for Physics Coordinating Committee
Outline

• Physics Interest in ATCA & MicroTCA (xTCA)
• xTCA Shortcomings for Physics
• PICMG xTCA for Physics Coordinating Committee
  – Major Goal: Specify Stable Platform Infrastructure
  – Defining Requirements via Survey
  – Progress to Date & Future Plans
  – How to Participate
• Acknowledgment
Physics Interest in xTCA

- PICMG ATCA, AMC standard specifications released June 2004
  - “The most ambitious development ever undertaken by the PICMG Consortium.”¹
  - Unique for Telecom industry to adopt common modular platform:
    - Up front R&D cost savings, quicker time-to-market for new technology products, interoperability gives customer more choices within market segments

- Major attractions for Physics:
  - High Performance BW, throughput, serial multi GbE backplane
  - High Availability design critical to next-generation very large machines
  - Readily adaptable to many data acquisition high speed processing applications
  - RTM solves ugly cable routing problems²

¹ PICMG press release, April 2009. PICMG currently ~400 corporate members worldwide
² First used in FASTBUS, later by VME and others
Physics Developments In Progress

• Growing evaluation projects at major labs
  – DESY, SLAC, IHEP, FNAL, ANL, BNL, KEK, CERN, FZJ, IN2P3, IPFN, JET, …

• Direct interest by funded and future projects
  – XFEL, ILC, ITER, JET, ATLAS Upgrade, Project X, FAIR, AGATA, …

• xTCA interest both accelerators and experiments

• Interest in options: ATCA+RTM,
  ATCA+AMC+RTM, AMC-μTCA (MTCA) + μRTM¹
  – ¹ New, under discussion by Physics Coordinating Committee
Non-Telecom Areas of Interest

• Medical physics company for new video-rate imaging platform
• μTCA strong interest for non-telecom industrial control, instrumentation markets
• AMC Mezzanine adapters for existing standards such as Industry Pack (IP)
• Analog AMC products beginning to emerge
xTCA Components for Evaluation (SLAC)

5-Slot Shelf w/Dual Processors & Hub Switcher

SLAC DAQ 0.5 TB/s DAQ

14-Slot Shelf

AMC Module

AMC 105 MS/s 14 bit 8 Ch ADC

μTCA 6 Slot 1U Shelf

SLAC HA Electronics R&D
Front Panel Entry Cable Transition Adapter

- Prototype demo for control system major upgrade
- Develop standard rear transition adapter with analog, RF, digital connector options
- Cable entry from rear top or bottom of racks

AMC Modules (6 max.)
Power Supply Module
Backplane
Rear Transition Cable Adapter
Integrated μTCA Carrier Chassis
Rear Transition Cable Adapter Chassis
Side View

SLAC HA Electronics R&D
Development of an 'universal' AMC module

- Hardware design with Virtex5 and 256MB DDR2 SRAM (1GB/s)
- FPGA code development with PCIe interface and DMA
  - 370 MB/s into user space (128byte payload size)
- DOOCS server and OS driver with hot-swap
- IPMI code for 'Module Management Controller' (Atmega-128)
- Piggyback with 2 ADC and 2 DAC channels, 100MHz
xTCA Shortcomings for Physics

- xTCA designed Telecom-centric, no analog
- Physics needs very high dynamic range, low noise and crosstalk to at least 100-200 MHz
- Virtually no analog products on market except AMC adapters for Industry Pack (IP) slow devices ADC-DAC (~100 KHz)
- New industry 100 MHZ ADC stimulated by DESY not fully tested (but appears very promising from system comparisons at DESY)
- DESY piggy-back board will give more information at 100 MHz; 500 MHz contemplated for next design
- One 500 MHz AMC design advertised but not delivered
Urgent Need for Addressing Analog

• Worries expressed at 051009 Workshop:
  – We don’t know we can build good enough designs because of proximity of switching power supply noise
  – There isn’t enough room on AMC to get good enough isolation between high BW ADC channels
  – Requirements are being pushed all the time and we can’t adopt xTCA without demonstrating real results in our applications
Analog Solutions

- Every new generation of instruments has this “chicken-and-egg” problem
  - Early CAMAC introduction was shunned by some on basis that could not support high performance analog (wrong)
  - VME was criticized for same reasons (wrong)
- Rapid demonstration of xTCA for high performance analog requires a strong lab-industry collaboration
  - Labs must take initiative to define critical requirements
  - Collaborate on joint plans with industry to verify designs, develop industrial suppliers
  - Cannot be accomplished by labs working in isolation from each other and industry
Short Wish-List for Physics

- MicroTCA package for Accelerator, Detector controls with analog space, connectors, rear I/O and RTM options
  - Current MTCA designs at “Wild West” stage
- Design approach for precise timing, synch and trigger distribution
  - Our systems must synch to machine RF, beams down to sub-picoseconds if needed
- Generic analog-digital-processing boards with infrastructure support of high level, real time, IPMI software, development tools that can be made widely available
  - Well defined “user payload design space” on generic AMCs with high quality interconnects, isolation, grounding and shielding for analog-digital applications
xTCA for Physics Coordinating Committee

• Why a Physics Subcommittee of PICMG?
  – Major Goals of a formal specifications, guidelines effort
    • Address expressed needs of current participants, seek out new requirements from broader physics community
    • Save engineering development effort for new designs, both hardware and software; concentrate on unique problems within stable platform
    • Share infrastructure designs, drivers, firmware, system software, IPMI among labs before embarking on major new system detailed applications designs
    • Plan to make all new generic and high volume applications products available through industry. Labs cannot compete with industry in efficient production if volumes are sufficient
    • *Fragmentation of the physics market will destroy chances for best commercial products at lowest cost!*
xTCA for Physics Technical Subcommittee
Organization & Proposed Scope

PICMG INDUSTRY STANDARDS ORGANIZATION
Technical Officer

TECHNICAL SUBCOMMITTEE
XTCA for Physics Coordinating Committee (CCTS)

Industry Standards Liaisons
SAF/SCOPE
VME/VSO
IEEE
Other

TECHNICAL SUBCOMMITTEE
Standards Working Groups (WGTS)

PHYSICS APPLICATIONS
Standards Interest Groups

PHYSICS APPLICATIONS PROFILE DEVELOPMENT INTEREST/WORKING GROUPS (E.G.)

Physics Profile Development
Requirements Documents for:
- Control Systems
- Machine Instrumentation
- Detector Instrumentation
- Timing and Synchronization
- Machine Safety Systems
- Personnel Safety Systems
- Intelligent Platform Management

STANDARD PLATFORM WORKING GROUP AREAS OF INTEREST

Hardware WGTS
- AdvancedTCA
- MicroTCA
- Networks
- Analog

Software WGTS
- Operating Systems
- Middleware
- Platform Real Time
- Shelf Management

Accelerators & Detectors
- Light Sources & Experiments
- Fusion Reactors/Experiments
- Astrophysics Instruments & Experiments
- Medical Scanners & Experiments
- Nuclear Instruments & Experiments

Rev 030409
PICMG xTCA for Physics Coordinating Committee Technical Subcommittee

- PICMG TC for Physics (CCTS)
  - Proposed at 2008 Nuclear Science Symposium, Dresden, in conjunction with 2-day xTCA Workshop
  - Organization of Coordinating Committee subsequently sponsored by PICMG Executive Members SLAC, DESY, IHEP and FNAL plus two Executive Member companies, Cypress Point Research & Performance Technologies
  - Approved by PICMG ExCom, organized March 10, 2009
    - Holds weekly web meetings
    - Current membership 44 companies, 5 labs, 65 individual members
Organization xTCA for Physics Technical Subcommittee

- Physics Coordinating Committee (CCTS) proposes WGTS’s
- All WGTS’s report to PICMG Technical Officer
- All WGTS standards documents reviewed/approved by CCTS before submittal to PICMG
- Call for Participation (CFP) for WGTS by PICMG standard procedure
- Specifications final approval by full PICMG membership
New Working Groups

• Two major Working Groups approved, about to be formalized with election of officers

• \textit{WG1: Physics xTCA I/O, Timing and Synchronization Working Group}

• \textit{WG2: Physics xTCA Software Architectures and Protocols Working Group}
Future Plans

• Conduct survey of requirements among labs actively engaged or planning on using xTCA
  – Find contact person in labs to help distribute survey
  – Small CCTS team correlates results, distributes report
  – Survey team led by Stefan Simrock, DESY, CCTS Assistant Chair
Future Plans 2

• Establish public web page for Physics on PICMG site
  – Background, goals of group
  – Reports, papers of current interest
  – xTCA Workshop presentations (FNAL ’07, Dresden ’08, IHEP ’09, …)
  – Current organization, information contacts, how to join CCTS and/or WG’s

• Operational before end 05/09
Future Plans 3

• Review WG Work Products
  – Some WG tasks urgent, driven by project needs at DESY, SLAC, etc.
  – Aiming for initial design, MTCA with μRTM by end 09 with prototype efforts underway
  – Down-select preferred first draft protocols on same timeframe.

• Further Information
  – www.picmg.com (“coming soon”)
Acknowledgments

• The ongoing work described is a collaboration of several labs and industry partners.
• Thanks to the PICMG organization, members and officers for encouragement and generous help, and to the key people at the founding labs.
• Special thanks to PICMG Physics Committee officers Augustus Lowell and Zhen-An Liu; to Assistant Officers Stefan Simrock and Robert Downing; to Kay Rehlich and Stefan Simrock and their teams for generous sharing of xTCA R&D for the new XFEL accelerator control systems; and again to Robert Downing for leading the Profile for Physics concepts development and documentation and many fruitful discussions.
Backup Slides
## xTCA for Physics CC Membership

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SLAC HA Electronics R&D
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Technical Challenges 2

• Auto-failover software for HA
• Low latency software & firmware protocols for fast feedback systems
• IPMI subsystem
  – Out-Of-Band vs. In-Band systems, HA implications of choices
  – Extension of IPMI to “non-managed-platform” chassis as currently found throughout accelerator systems
WG1 Preliminary SOW Tasks

• Specify AMC’s with Rear I/O (AMC-IO) and an associated µRTM

• Consider potential needs for Mezzanine Cards.

• Specify ATCA carrier for the AMC-IO.

• Specify ATCA RTM module to accommodate AMC-IO along with support features such as power, management, JTAG, etc.
WG1 SOW Tasks -2

• Specify e-keying code extensions to the Shelf Management Section to accommodate the additions to the AMC, RTM, μRTM and the μTCA shelf specifications.

• Specify lines, both bussed and radial, that are in both ATCA and μTCA backplanes that could be used for Physics clocks, gates and triggers. If necessary, specify lines that are not in the ATCA and μTCA backplanes but could be added to the RTM and/or μRTM for such use.
WG2 Preliminary SOW Tasks

• Define protocols and APIs for management and control of real-time data acquisition and machine-control components, to include calibration, synchronization, and triggering mechanisms.

• Define protocols and APIs for high-rate and low-latenacy distribution of data among the various data acquisition, machine-control, data processing, data storage, and data transmission components, including use of the backplane fabrics within shelves and use of external links between shelves.

• Define the mechanisms and techniques within the ATCA/µTCA infrastructure to manage component-, shelf-, subsystem-, experiment-, and facility-level redundancy and automated failover.
WG2 SOW Tasks -2

• Define protocols and APIs for management of resources within an xTCA network, including identification and allocation of common functional modules among subsystems and experiments, management of active module disposition and status, and auditing of component usage and maintenance.

• Define a common set of APIs and functional blocks at the software and FPGA firmware levels to be provided as a standard development library for xTCA application development, including standard operating system and thread management functions, module identification and data routing functions, standard I/O management functions, and standard data processing blocks.
Technical Challenges 1
Single & Double Wide on μTCA

- Options
  - I/O “Stolen lines” vs. separate connectors
  - Timing & I/O backplane
  - Double wide
  - Stacked boards
  - Panel width

Courtesy R. Downing
Single & Double Wide on ATCA Carrier

- All I/O, special timing connections via Zone 3
- All serial data connections via Zone 2
- All Power Zone 1

Courtesy R. Downing
"Stolen Lines" Initial Concept for μRTM

- Appropriated unused Telco Lines for Physics I/O, clocks-sync-triggers
- Note: Precision clocks best on star configuration, not bussed
- Could use extraneous 10GbE lanes
MicroTCA Shelf Concept (Kay Rehlich, DESY)

• Features
  – 12-Double high payload slots
  – RTM powered
  – Dual bulk power
  – Dual MCH-Shelf Manager
  – Accommodates standard AMC’s in half height
  – Scalable number of payloads
  – Scalable redundancy
IPMI in ATCA (Chris Engels, 2008 Tutorial)

IPMI is the main Protocol of System Management
IPMI Concepts for Managed, Non-Managed Platform Extensions

A. Managed System with Shelf IPMI

B. Managed System with Shelf IPMI Extended to Remote FRUs
IPMI Example – DESY (Kay Rehlich)
IPMI Developments – DESY (Kay Rehlich)

- **IPMI code on Atmel-128**
  - Implements version 1.5 functions
  - FPGA code loading in preparation
- **IPMI control system integration**
  - Control System server for ATCA, μTCA and computers
  - IPMI communication via Ethernet to the crates
  - Extracts from IPMI the available information
  - Creates a dynamic list of AMC modules
  - Creates a dynamic list of sensors
  - Archives values and provides reset/boot commands to FPGAs or CPUs
  - Required configuration: one entry per crate (IP name)