ATCA developments for Control and Data Acquisition

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Mission

To contribute to the development of Nuclear Fusion as an energy source by:

• Carrying out Research, Development and Innovation activities in key international projects

• Fostering Excellency through high quality Education in the areas of Engineering, Science and Technology
Key areas

Experimental Physics

Plasma Engineering & Systems Integration

Theory & Modeling

Society
Key areas

- Theory & Modeling
- Experimental Physics
- Society

Control & Data Acquisition Systems
Internationalization

- Microwave diagnostics
- Experimental Physics
- Theory & Modelling
- Control & Data Acquisition

[Map of various plasma physics research facilities with connecting lines indicating international collaborations]
Control and Data Acquisition activities build upon Fusion specific needs
ATCA key advantages have been successfully demonstrated:
• **real-time data processing**, e.g. JET (UK), COMPASS (Czech. Rep.), TCA-Br (Brazil)
• **MIMO fast control applications**, e.g. JET

ATCA is being considered for critical fast plasma control systems, e.g. ITER, W7-X (Germany)
• **Modularity**
• **High availability**
• **Reliability**
• **Channel density per board**

Role of vendors critical to make it available to market
**ATCA-CONTROLLER-PCIe**
- twelve ATCA fabric channels (x4 full-duplex PCIe)
- multicore processor (currently over 40 GFLOPS)
- SIMD instructions plus signal processing libraries
- RTOS (RTAI for linux)
- one PCI legacy slot
- wide availability of components with low cost upgrades

**ATCA- MIMO-ISOL**
- 32 analog input channels (digitizer/transient recorder)
- 8 analog output channels (waveform generator).
- 8 digital input/output channels
- Customizable carrier boards and rear transition modules
- Both types of analog I/O can be present on the carrier board and on the RTM.

**ATCA-SR-TR**
- Data transfer rate of up to 800 Mbyte/s over x4 PCIe to the host processor.
- Choice of resolution
  - 250 MSPS @ 13-bit,
  - 400 MSPS @ 14-bit,
  - 500 MSPS @ 12-bit
- Maximum pulse rate of 5 Mpulse/s;
IPFN’s Atca® -MIMO-ISOL

“the star of the show”

ADC module

RTM
Leveraging on modularity
ATCA-32-Channel ADC Piggyback Module

Characteristics

- Input range: +/- 1 / 2.5 / 5 / 10 Volt, factory selectable
- Input impedance: Differential, 50Ω - 1M Ω, factory selectable
- Resolution: 12-18 bit, (current assembly is AD7641 / 2 MSPS/18-bit)
- Anti-aliasing filter: analog, 18 dB, 3 poles, 500KHz (100kHz)
- Voltage isolation: 1kV
Leveraging on modularity
Chopped integrator for long duration pulses

Characteristics

Module to ATCA - MIMO - ISOL data acquisition boards

Lower drift than normal analog integrators (suited for long pulse experiments)

Magnetics signals converted into AC signal by analog switch and numerical integration in PC or FPGA.

Conversion into AC signal cancels drift caused by operational amplifiers (present in normal integrators)

Since integration is numerical, module will additionally provide unintegrated signals (for fluctuation analysis)
General Purpose Board for CDAQ systems

- **32-Channel ADC Board** (ATCA_MIMO-ISOL) (Soft-X-Ray/Mirnov)
  - isolated (KVolts) 2 MSPS ADC Modules w/ high bandwidth/signal response and signal linearity

- **32 Channel Chopper Amp/Integrators Board** for Magnetic Diagnostics
  - 20 KSPS/12 bit, Switching time 1 ms, Switching transition time 40 us, Hi-pass filter 10 Hz (still under development)

- **8-Channel ADC Board** for very High-Speed Sampling (Thomson Scattering, etc.)
  - 400 MSPS/14 bit per channel, digital decimation filter, full mesh backplane interconnect
Case study
JET Vertical Stabilization system

Front view

Rear view

192 input signals
Case study
JET Vertical Stabilization system

- 192 signals acquired by ADCs and transferred at each cycle
- 50 µs control loop cycle time with jitter < 1 µs
- Always in real-time (24 hours per day)
  - 1.728 x 10⁹ 50 µs cycles/day
  - Crucial for ITER very long pulses

Front view
Case Study
ITER Fast Plant System Controller

CODAC
- HMI
- CODAC systems
- Central database

Self-description toolkit

1588 Master clock

Time Communication Network (TCN)

1588 switch

SDN

Scientific Data Archiving (SDA)

Synchronous Databus

Diagnostics

Actuators

CPU shelf

IO shelf

PCIe bus extension

IO Network cards

Fast Plant System Controller

High Performance Computers

Fusion Experiment

Plant Operational Network (PON)

PCIe/MXI board

CPU

U2 U

Network cards

Self description toolkit

CODAC systems

Central database

HMI
ATCA Alpha version demonstration
13 January 2011
FPSC | Crucial Requirements

- MIMO system (high channel density)
- Modularity / Expandability
- Safety: Galvanic Isolation
- Real-time complex algorithms
- Redundancy and high availability
- Serviceability (Remote hardware management, modularity, RTM)
- Timing and Event management
- Instrumentation for long discharge
- Integration into ITER CODAC (EPICS, HMI, PSH)
- COTS availability
ITER has a growing interest in several developments triggered by FPSC project.

ATCA HUB/Carrier board (PCIe on fabric) *

ATCA galvanic isolated digitizer node board *

* Under development
• Leverages on the existence of COTs AMC cards with PCIe interface

• AMC carrier with PCIe on fabric are not available from industry

Development ongoing
ATCA AMC Carrier / Hub

- **4 AMC slots** (PCIe x4, MGT x4, LVDS x4, GbE on AMC1, SATA AMC1 to 2)
- **Carrier**
  - PLX PEX PCIe Gen 2 switch (96 port)
  - PCIe x4 on backplane fabric (to 13 slots)
  - FPGA for timing and synchronization (from IEEE-1588 to IRIG on backplane + 1 MHz clock)
  - IPM controller module
  - No Ethernet on base fabric (PCB space constrain)
- **xTCA RTM connectivity**
- **Support for multiple processors on AMC slots or external through PCIe cable connection**
• PICMG 3.0/3.4 and AXIe compatible;
• Up to 24/48 analog inputs, outputs or a combination of both;
• Up to 8/16 digital inputs, outputs or a combination of both;
• All IO with galvanic isolation (1 kV)
• RTM version with 16 fiber optics interfaces for remote actuators/sensors.
ATCA I/O node card

- PCIe x4 connection to fabric channels 1 and 2
- No Ethernet on base (PCB space constrain)
- One FPGA (low-cost). Four FPGAs? (performance) each controls ¼ of the I/O modules
- IPM controller module
- SODIMM connector for DDR3 (2 GB per FPGA)
- Galvanic isolated analog and digital I/O support
• Data time stamping using IRIG time distributed by hub card
• Programmable timing unit for generating specific clock or trigger sequences for sampling
• All timing units will use a common synchronized clock
ATCA for

- Controllability
- “MIMO”ability
- Robustness
- Fault tolerance
- Reliability
- Maintainability
Is **ITER** (and fusion) a one-off case?
xTCA will be suitable for horizontal Control and Data Acquisition solutions
Fostering innovation on instrumentation technology

http://atca.ipfn.ist.utl.pt