USING THE ADVANCED TELECOM COMPUTING ARCHITECTURE xTCA AS CRATE STANDARD FOR XFEL

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Abstract

At XFEL it is planned to install most electronic components and computers for LLRF, diagnostics and controls inside the tunnel. Access to these devices during the XFEL operation will not be possible. Remote control and monitoring of all relevant parameters of the shelfs/crates and the computers must be ensured and should be done in a standardised way. In addition software downloads and debugging up to the FPGA level should be provided, even if an operating system crashes e.g. due to radiation, maintenance functionality must be available.

An introduction to xTCA will be given, the reasons to change the crate standard from a VME to a xTCA based system and the experience with this new electronics standard will be described.

MOTIVATION

At FLASH [1], the test facility for the XFEL[2] and ILC[3] project all beam based related controls is using the VME standard. This about 30 year old standard serves very well for a fast ADC system with more then 150 pieces of 8 channel VME boards distributed in about 40 VME crates and synchronized by a central timing system. In addition, the Low Level Radio Frequency LLRF system to control the High Power klystrons and many other special diagnostic is based on this crate standard.

But VME has some drawback like :

- no standardized monitoring of crates and boards
- the parallel bus, which comes to its throughput limits
- moves to high priced systems
- a single module can harm the full crate

This leads to the question, if there is a new industrial crate standard to overcome these drawbacks and full fill the additional requirements for XFEL. The new Advanced Telecom Computer Architecture ATCA was identified as a possible option.

XFEL LAYOUT

The XFEL facility will have a 100m long injector section with 4 acceleration modules and then the main Linac section with 96 modules. Always 4 modules are connected to one high power klystron station as one accelerator section and is controlled independently. After this the beam is spilt up into several undulator lines to create the photon beam.

REQUIREMENTS

It is planned to install most of the electronics for LLRF, klystron control and beam diagnostic inside the main tunnel, because short cable length are required. These electronic racks will be placed along the tunnel inside concrete housings. The expected radiation level should be low enough that high integrated electronics can survive, but still single upsets events have to be expected.

The requirements for the XFEL crate standard are :

- long term industrial standard
- high data throughput
- independent from a particular operating system
- remote management of the crate and the inserted boards
- remote software download and debugging of FPGA code
- self configurable
- scaleable
- highly reliable => redundancy, if required
- hot swap of modules desirable
- wide range of different, but compatible crate options
- many Commercial-of-the-Shelf COTS components

DECISION PROCESS

In order to reduce the software effort from the controls point of view and to be able to correlate the data from many subsystems, a common crate standard for XFEL is desirable.

To decide for a standard mainly three steps were taken :

- ATCA and μTCA where evaluated to understand this new technology and hardware from different vendors were bought to test the compatibility. In addition a Advanced Mezzanine Card (AMC) was developed to learn about this standard in detail.
- After this the controls group organized a workshop [] to compare different crate options like VME, CompactPCI and xTCA. The results of the evaluation process were presented and the various needs from the subsystems were gathered from our international collaborators.
- The results of the evaluation and the outcome of the workshop were presented in a XFEL seminar and approved by the XFEL management.

TELECOM COMPUTING ARCHITECTURE

ATCA

The Advanced Telecom Computing Architecture (ATCA) is the first member of this crate family standardized in 2003 as PICMG 3.0. ATCA is designed for high capacity for serial IO and high computing power. Every slot may have a power dissipation up to 300W. In ATCA only serial communication, but no parallel bus, is used with different protocol options:

- Ethernet, the most common choice
- Infiniband
- PCI Express
- Rapid-IO

The shelfs allow either

- Dual Star backplane allows to build a fabric with 2 to 14 slots in star topology.
- In full mesh configuration all slots can communicate with each other.

μTCA

μTCA was designed on the existing Advanced Mezzanine Card standard (AMC) from the more powerful ATCA standard and is consider as an extension to it.

It uses the edge connection of the AMC directly to a simplified back plane. The design goal was to provide a high performance platform which is more cost sensitive to be use in the Telecom and the industrial market. The modular design allows to build very simple and cheap system up to a complete redundant architecture. A standard μTCA system is build from a shelf with a five to fourteen slot back-plane plus a fan unit and a power module. These systems are already available in many different form factors like as desktop or 19" rack mount. As main management controller every system needs to have the MicroTCA Carrier Hub (MCH), which is connected via IPMB bus to all components. The main task of the MCH is to activate all components and ports and to monitor many parameters like temperature, voltages or fan speed. Via the MCH a complete remote control of the whole shelf is possible.

The most common high speed communication used in μTCA is PCI Express and Ethernet. In addition usually two SATA lanes are provided to connect a hard-disk AMC to a CPU.

CRATES AND BOARDS

CommercialOfTheShelf

CommercialOfTheShelf (COTS) components like shelfs (crates), CPU's, hard-disk carrier, graphic cards and standard industrial IO modules from different vendors are essential for a successful implementation into a control system.

- Shelf: There is already a great variety of shelf designs on the market. The range goes from SimpleμTCA costing about 1000,- Euro to a 14 slot 12 hight full mesh ATCA shelf with full redundancies for several thousand Euro.
- CPU : there is a big market for ATCA and μTCA CPUs mainly based on INTEL/AMD processors, but some PowerPC boards are available as well. SPARC based boards are around for ATCA systems.
- AMC blade carrier with or without additional on-board processor
- AMC hard-disk carrier
- Power Modules
- MicroTCA Carrier Hub (MCH)

Unfortunately the choice of industrial Input/Output cards is still limited. We tested :

- 8 channel fast ADC with 100MHz 14Bit
- AMC to IndustryPack IP adapter gives the access to many IP modules. A one IP card carrier is available, a three card carrier is coming soon.

In House Design

To understand the new ATCA technology it was decided to do an in-house design of an AMC board. This card is equipped with a powerful Virtex-5 FPGA for the PCI Express communication and local intelligence. The Rocket-IO lines are routed to a picky back connector and to the front panel plug to adapt various Input/Output. As Module Management Controller (MMC) an Atmel Atmega-128 was chosen and programmed.

The items, which were deeply investigated are:

- the serial PCI Express communication from the Linux and Solaris OS to the FPGA core. A driver was written to catch both types of PCI Express interrupts (Intx and MSI) from the AMC card.
- An Module Management Controller (MMC) implementation based on a Atmel micro controller was programmed with an in House version of IPMI code and tested against Open Source client programs.
- compatibility tests with different shelf's and CPUs were performed.
- Performance tests were done. A throughput of 500MB/s over PCI Express in DMA mode is achieved and to the Linux user space 380MB/s could be measured over 4 PCI Express Lanes with a payload of 128 bytes.
- The possibility of downloading FPGA code through the IPMC was evaluated.

Planned AMC Cards

- Timing board : for XFEL in every diagnostics shelf, a timing board with pico second stability is needed.
- Machine Protection System (MPS) : to protect XFEL against operator errors or device failures a MPS will be developed based on AMC technology.

REMOTE MONITORING

One of the most interesting features from controls point of view are the standardized remote monitoring and management capabilities of ATCA over the IPMI protocol. This will allow to read all parameter like fan speed, voltages, board IDs or configurations. The E-Keying facility guaranties, that only compatible AMCs are plugged into the right slots. Already a first version of a DOOCS[4] server was implemented to read the set-up of a shelf, create dynamical the appropriate properties and with these informations the display tool jDDD[5] is able to create displays of such a shelf on the fly. Over IPMI many parameters like fan speed or switching single board on/off may be done. A JTAC interface over IPMI for FPGA debugging and code download is foreseen in the PICMG standard. This is needed to maintain and debug the high number of FPGA's inside the tunnel.

CONCLUSION

After working with this new ATCA technology, the controls group is confident, that this standard is the right choice for the XFEL project. All relevant hardware and software parts are tested and understood and in house knowledge to design AMC cards have been developed. Many COTS parts are already available from industry, but still cheap industrial Input/Output AMC's are missing.

REFERENCES

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