NEXT GENERATION ELECTRONICS BASED ON μTCA FOR BEAM-DIAGNOSTICS AT FLASH AND XFEL

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Abstract

Almost all accelerator-related diagnostic and steering systems require front-end electronic hardware and software for digitizing, synchronization, processing, controlling, and providing access to the control system. Increasingly high demands on resolution, bandwidth, stability, redundancy, low latency, real-time processing and distribution create the need for new technologies in order to fulfill those demands. For this reason, at the European XFEL and FLASH, the new TCA industry standard will be deployed. Over the last few years, significant achievements have been made in TCA (micro Telecommunication Computing Architecture) developments in collaboration with other research institutes and industry. In this paper, we give an overview of the required components of a typical TCA system for diagnostics applications. The FLASH bunch arrival-time monitor will be used as an example.

INTRODUCTION

The bunch arrival-time monitor as well as most of other diagnostic systems need a combination of electronics in order to convert and process signals measured and even control other subsystems. As the requirements for different applications are similar, following a standardized modular approach helps to reduce the number of developments, speeds up the process and allows better maintainance.

In order to allow standardization components, the decision on the hardware platform was needed. For XFEL and new systems at FLASH μTCA will be the standard platform. It allows installation of functional modules and the interconnection between them as well as related management and diagnostic functions.

Based on the hardware platform different universal modules (called: Advanced Mezzanine Cards, AMC) are needed to enable a system designer to exploit certain functionalities required for a diagnostic system. Main functions are: a central processing unit (CPU), Timing system integration, analog-to-digital conversion and processing, a multi purpose digital card which provide different standardized interfaces, and a controller board providing powerful signal interfacing and processing capabilities.

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HARDWARE PLATFORM

With increasing demands on bandwidth, availability, and remote control the current VME systems used at FLASH are limited. A transition from parallel buses to serial point-to-point connections combined with management function and redundancy in the system provides a solution. There are different extensions to VME and other platforms available or emerging on the market. For XFEL and new systems and partial replacements at FLASH μTCA was chosen to be the standard platform.

It emerged from the larger scale ATCA (Advanced Telecommunication Computing Architecture) system, which was invented by the telecommunication industry. Small mezzanine cards (AMCs) could be mounted on big ATCA cards (blades) as a modular system. μTCA crates allow to plug in those AMCs directly and offer therefore a smaller and cheaper scalable solution, while still offering high bandwidth connections, management and redundancy functions.

Furthermore the standard had been extended (known as MTCA.4) in order to provide additional possibilities common in physics applications. Within the standardizing consortium (PICMG, PCI Industrial Computing Manufacturers Group) a xTCA for Physics working group consisting of more than six labs like SLAC and DESY and 38 companies from industry was set up defining the extensions for μTCA and ATCA. Two major additions are the invention of so called rear transition modules (RTMs) and a special backplane assignment.

An important issue is the limited size of an AMC. For usual ADC applications three components (besides power supply and management) are required: signal conditioning, digitizing (ADC) and signal processing. It could be even extended with an DAC (digital-to-analog conversion) for feedback applications. A first step to increase the size of the modules is to use double size AMCs. Those are twice as high as a normal AMC. This was already defined by the original MTCA and AMC specifications. To increase the size even further and additionally allow more modularity, a connector had been defined connecting a double size AMC with an RTM of almost the same size from the back in the crate. In this way functional splitting of developments could be achieved like separating a standard ADC with processing from the specialized signal conditioning and conversion (see Fig. 1).

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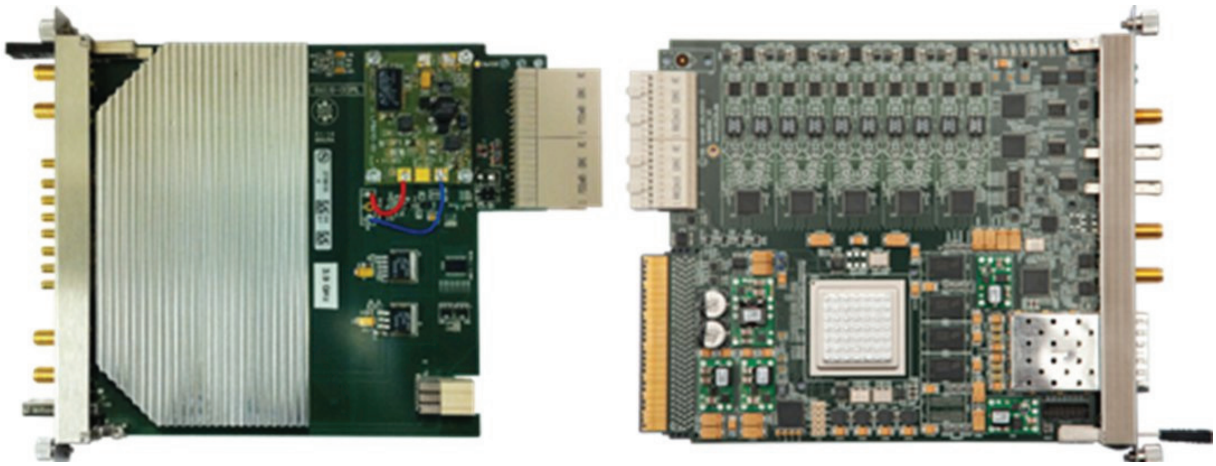

Figure 1: Analog-to-digital converter board SIS8300 with RTM.

On the other hand, assignments of certain connections on the backplane allows a standard combination of fast point-to-point connections and differential bus lines distributing clocks, triggers, interlocks and timing information. With those connections it is possible to concentrate or distribute measured and processed data within the crate with low latency and in high speed. The bus line allow an easy synchronization within the crate without any external connections.

COMMON MODULES

Connected to the previously mentioned MTCA.4 specification different AMC modules had been developed, are under construction or are planned. The following overview of modules are far from being complete, but should show the collection of universal cards with the possibility to add simple or complex specialized RTMs or mezzanines to them if needed.

μTCA Carrier Hub (MCH)

A μTCA Carrier Hub (MCH) is a central component in a μTCA crate. It provides different management features like controlling the cooling (fans) and power units, read out of voltage and temperature sensors of AMCs, electronic keying, alarms, and remote firmware updates of AMCs. Besides that it is a switch for PCIe and Gb Ethernet communication and distributes clocks. All functions could be accessed remotely via network.

Central Processing Unit (CPU)

A CPU in the crate is not required, but in most cases very useful to concentrate measured and preprocessed data, do further processing, transfer data over Ethernet connections, archiving on hard disks and so. Different CPU modules from different vendors are available. Also different operating systems are supported like Linux or Solaris.

Timing System

For diagnostic applications a synchronization to the related machine is in most cases important. This includes phase stable clocks and trigger information in order provide a sampling clock and start information for the ADCs for example. For XFEL and FLASH this will be provided along with much more detailed information by the XFEL Timing System. This is being developed in collaboration with the Stockholm University in Sweden. This AMC module provides a source for clock and trigger distribution on the backplane to other cards as well as front connectors to external hardware. For more information see [1].

Analog-to-Digital Conversion

One of the most important functions related to diagnostics is the conversion between analog and digital signals. The idea of splitting up the signal conversion and conditioning part from the ADC and processing was described earlier. One AMC implementing the ADC and processing part is the SIS8300 from Struck Innovative Systems (see right half of Fig. 1). It includes 10 channels of 125MSPS 16 bit ADCs, a FPGA, serial high speed links and DACs. The signal conversion and conditioning part will then be implemented as an RTM providing differential signals to the ADC board. The RTM shown on the right side of Fig. 1 implements a down converter for low level RF applications developed at DESY.

Multi Purpose Digital Board

In numerous diagnostic applications special types of I/O or interfaces are required in order to control or read out special hardware. In this case a standard versatile digital AMC combined with a specialized RTM would provide a solution for that. In many cases the RTM is quite simple and could be developed with low cost in a short time. The digital AMC on the other hand could be used in many applications and a framework on the firmware and software

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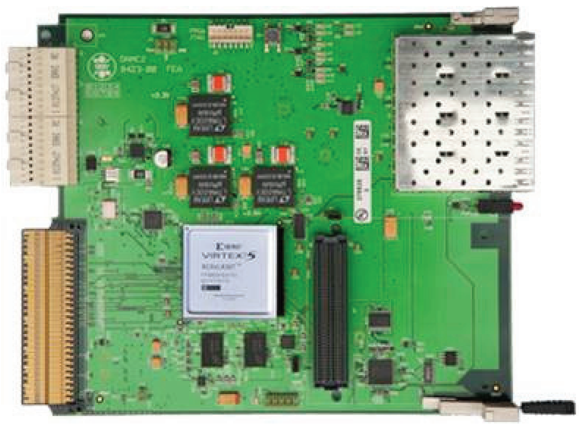

Figure 2: Universal digital DAMC2 board developed at FEA group at DESY.

level would also reduce development time and reduce errors.
Such a universal digital board had been developed at DESY and is know as DAMC2 (see Fig. 2). It provides an FPGA connected to the RTM connector, four SFP (Small Form-factor Pluggable) connectors, a FMC (FPGA Mezzanine Card) connector and the AMC connector to the backplane. The RTM connector offers 53 differential input or output lines for specialized applications on a RTM. The SFP connectors allow high speed communication to other boards or systems (eg. data concentration, real time feedback,...). The FMC connector allows mounting of FMC modules based on the VITA57 standard, which are available on the market, build by other labs or self made. They also offer a way of implementing specialized function on a standard board. ADCs are a good example of commercial available FMCs. Also the open hardware community is developing in the FMC direction. Further information on the DAMC2 could be found in [2].

Signal Processing and Controller

Another common application in diagnostics is the concentration of measured data and processing of that data. In some cases this output could even be used for high speed feedbacks. Such a board has to offer sophisticated computational power and numerous high speed inputs in order to concentrate measured data from other cards or systems. One board implementing this function was developed at the Technical University in Lodz, Poland. It implements a powerful FPGA along with a floating point digital signal processor (DSP). Data could be received or transmitted by six SFP modules, a RTM or the AMC backplane.

APPLICATION FOR THE BUNCH ARRIVAL-TIME MONITOR

As an example for an application in diagnostics using the new μTCA standard the bunch arrival-time monitor is presented. The system consists of on optical front end converting the arrival-time information into modulated laser pulses. Those laser pulses are transported in fibers to a RTM connected to the SIS8300 ADC card located in a μTCA crate. On the RTM they are converted to electrical signals, filtered and splitted before they are applied to the ADC inputs of the AMC board. Synchronized with the Timing System AMC card the signals are digitized and processed within the FPGA before they are transfered to the CPU and could be accessed by the control system. Besides transferring the data to the CPU, the arrival-time information is also transfered over low-latency high speed links on the backplane or SFP modules to the controller AMC board, where also data from other monitors and detectors arrive. In the controller all these inputs are combined and processed to provide amplitude and phase correction information to the low level RF controller AMC. This happens so fast, that corrections within a bunch train will be applied and the train stabilized in respect to the measurement data of the diagnostic systems.
Besides that, a DAMC2 board combined with a specialized RTM could be used to provide additional required functions in order to control the optical front end like laser diode drivers and temperature controllers.
Only parts of the mentioned subsystems had been tested, but as prototypes of all mentioned hardware has recently become available, a full demonstration of the system is planned by the end of this year.

CONCLUSION

New demands required changes in the technology towards a modular and scaleable standard with high speed point-to-point connections, remote management and redundancy. The μTCA standard had been chosen for the European XFEL and new developments at FLASH. Together with other labs and industry extensions had been developed in order to provide features common for physics applications. Many modules required in diagnostics are now available and very good performance had been demonstrated. Although we are currently far away from numbers of available cards line for VME, the community of developers and users of this technology is increasing. All test and evaluation so far showed, that μTCA is the right platform for large installations in industry and science.

This work is partly supported by IRUVX-PP an EU co-funded project under FP7 (Grant Agreement 211285)

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