NOVEL CRATE STANDARD MTCA.4 FOR INDUSTRY AND RESEARCH*

H. Schlarb, T. Walter#, K. Rehlich, F. Ludwig, DESY, Germany

Abstract

MTCA.4 is a novel electronic standard derived from the Telecommunication Computing Architecture (TCA) and championed by the xTCA for physics group, a network of physics research institutes and electronics manufacturers. Its main improvements over the preceding standards MTCA.0-MTCA.3 are enhanced rear I/O connectivity and provisions for improved precision timing. MTCA.4 was released as an official standard by the PCI Industrial Manufacturers Group (PICMG) in 2011. Although the standard is originally physics-driven, it holds promise for applications in many other fields with equally challenging requirements. With substantial funding from the Helmholtz Association for a two-year validation project, DESY currently develops novel, fully MTCA.4-compliant components to lower the barriers to adoption in a wide range of industrial and research use scenarios. Core activities of the project are: refinement, test and qualification of existing components; market research, market education (web information services, workshops); coordinated development of missing MTCA.4 components; further advancement of the standard beyond the current PICMG specification (e.g. Zone 3 pin assignment); investigation of measures to counteract electro-magnetic interferences and incompatibilities; training, support and consultancy. This paper summarizes intermediate results and lessons learned at project half-time.

THE ROAD TO MTCA.4

Explosive growth in the telecommunications industry during the late 1990ies led to the development of a multivendor switching computer platform named Advanced Telecommunications Computing Architecture (ATCA) which was primarily designed for high availability and scalability. ATCA marked a departure form parallel bus topologies and introduced a *switched fabric* type serial bus system, allowing for data throughput rates of 2.5 TBit/s [1]. ATCA was quickly complemented by a derivative standard named MicroTCA (also MTCA, µTCA), originally designed to accommodate some of the smaller ATCA ‘piggy-back’ boards and build more compact and economical systems (MTCA.0). Industrial process control engineers as well as defence contractors quickly realized the potential for their application domains and set out to specify ruggedization features to adapt the new standard to harsh environments (MTCA.1, 2 and 3). Meanwhile, the physics research community had picked up on the capabilities of both ATCA and MTCA and started participating in the further advancement of this standard family through an *xTCA for physics* interest group. One of the objectives is to build a Low-level Radio Frequency (LLRF) control system for particle accelerators and free electron lasers based on the MTCA standard, which required the addition of enhanced rear side input/output (I/O) connection capabilities as well as improvements regarding internal clock signal distribution to facilitate applications that require precision timing (MTCA.4).

DESY has currently taken on a coordinating role in the further development of MTCA.4 components as well as the further advancement of the standard and collaborates closely with MTCA interest groups at SLAC and CERN. Major accelerator facilities worldwide currently evaluate the deployment of MTCA.4-based LLRF systems for extensions or upgrades of existing as well as the initial equipment of new facilities.

MTCA.4 TECHNOLOGY ADVANTAGES

MTCA.4 has inherited many of the advantages of ATCA, including capabilities for remote monitoring, remote maintenance, hot-swap of components and facilities to duplicate critical components (hot stand-by). It also made the outstanding signal processing performance of ATCA systems more affordable and less demanding in terms of space requirements and energy consumption. In summary, it provides an attractive package for users in search of a small, powerful, precise, versatile, reliable and economical computing platform. MTCA was designed to be highly modular and flexible, as the remainder of this section will demonstrate.

Basic Setup

MTCA installations vary widely in their configurations, but they all share a common set of basic components:

- System Crate (incl. backplane)
- Power Supply
- Central Processing Unit (CPU)
- Memory Controller Hub (MCH)

Multivendor-capability is a defining feature of the MTCA standard, so these components are typically supplied by different companies that specialize in one component, respectively. Commercially available system crates and power supplies can currently be scaled up to accommodate a maximum of 12 slots of application-specific MTCA board pairs in one shelf.

Application-Specific Configurations

A viable MTCA installation will comprise further components for signal conditioning, digital/analog and analog/digital conversion, frequency up/down conversion,

*Work supported by Helmholtz Validation Fund HVF-0016
#thomas.walter@desy.de

ISBN 978-3-95450-122-9

Copyright © 2013 by JACoW — cc Creative Commons Attribution 3.0 (CC-BY-3.0)

data processing, clock generation and controlling of auxiliary devices. Many of these components were originally devised for extremely challenging tasks in high energy physics, which makes, in principle, a re-use in other settings feasible at least from a performance point of view. Responding to specific application scenarios (and associated requirements) outside the physics research community is therefore high on the agenda of a growing number of MTCA component suppliers [2]. At DESY, a number of novel components is currently under development, as Table 1 below illustrates.

Table 1: MTCA.4 Validation Project HVF-0016 Components Currently Under Development at DESY

Board	Function
DAMC2	Versatile data acquisition/ processing
DAMC-TC7	Low-latency data processing
DAMC-DS800	8-channel 2.7GHz digitizer
DAMC-FMC20	2 slot FMC carrier (low pin)
DAMC-FMC25	2 slot FMC carrier (high pin)
DRTM-PZT4	4-channel piezo driver module
DRTM-V2	2-channel vector modulator
DRTM-AD84	8-channel ADC, 4-channel DAC
DRTM-DWC8VM1	8-channel down/ 1 channel up converter
DRTM-LOG1300	Multi-channel local oscillator, HF signal/ low-jitter clock fan out
DFMC-MD22	2-channel stepper motor driver

The components listed in Table 1 are primarily developed in the course of a two-year validation fund project to cater to the needs of beam line scientists at DESY, but the portfolio is constantly discussed, revised and updated with derivate versions where technically and economically feasible in order to accommodate the needs of fellow scientists at other accelerator facilities as well as those of potential users in unrelated settings and industries.

MTCA.4 INSTALLATIONS AT DESY AND THE EUROPEAN XFEL

The European XFEL research facility will produce "(…) ultra short X-ray flashes for photon science experiments with a peak brilliance that is a billion times higher than that of the best synchrotron X-ray radiation sources" [3]. The performance specifications for this facility, which is currently under construction in Northern Germany, required a fresh approach in view of the electronics for beam diagnostics and control, because of the heightened requirements in terms of accuracy, resolution, latency, quantity of signals, redundancy of components, radiation hardness and modularity (in view of maintainability and future upgrades). After extensive reviews, MTCA.4 became the standard of choice, and a gradual ramp-up and test of a complete LLRF system based solely on MTCA.4 in DESY's existing free electron laser facility FLASH was planned as an intermediate step.

As of November 2012, DESY has deployed the first fully functional LLRF system based on MTCA.4 inside the accelerator tunnel of the FLASH facility as depicted in Figure 1 below.

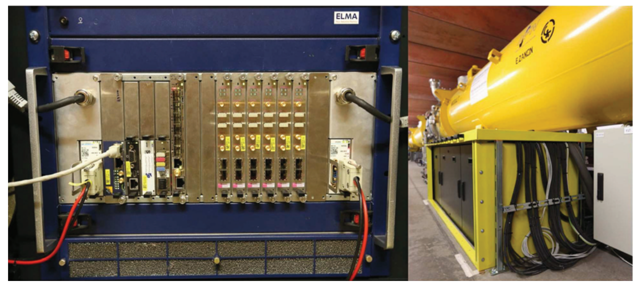

Figure 1: MTCA.4 crate with radiation shielding at DESY's free electron laser facility FLASH.

The new system MTCA.4 system duplicates the existing VME-based control system and is regularly used by beam line operators in parallel. The objective is to verify conformity to specification and check system availability under field conditions. Extensive monitoring is in place to gather data on the effects of thermal neutron and gamma x-ray radiation on the system. No critical faults have developed so far.

This small pilot installation will be complemented by further MTCA.4 based systems later in 2013 along the FLASH beam line. The findings will be used towards a refinement of the set-up in view of future applications on a much grander scale at the European XFEL facility, which has similar performance requirements, but many more process parameters to monitor and control at its 808 superconducting cavities and 25 RF stations [4].

TECHNICAL COORDINATION WITH INDUSTRY: THE CASE OF ZONE 3 PINS

Adopting MTCA.4 as a new standard comes with significant benefits, but also poses challenges in areas where developers and users are ahead of the official PICMG specification of the standard.

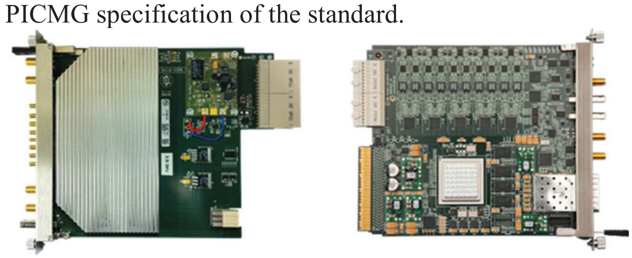

Figure 2: Pair of MTCA.4 boards (RTM left, AMC right)

Copyright © 2013 by JACoW — cc Creative Commons Attribution 3.0 (CC-BY-3.0)

A case in point is the connection between Advanced Mezzanine Cards (AMCs) and Rear Transfer Modules (RTMs), depicted in Figure 2 above.

AMCs and RTMs are plugged into the front side and the back side of an MTCA.4 crate, respectively. They are joined via a dedicated Zone 3 connector, depicted in close-up detail in Figure 3 below.

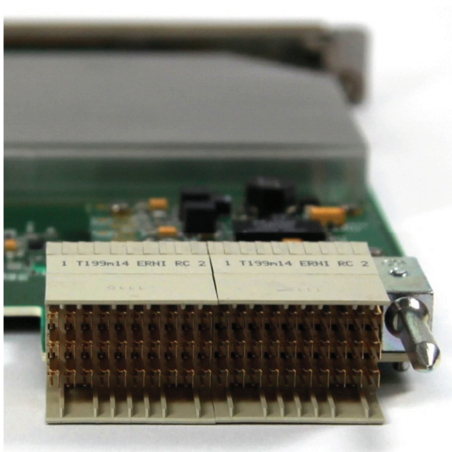

Figure 3: Close-up detail of Zone 3 connector

Pin assignment and signal levels were only partly laid down in the MTCA specifications by the PICMG in order to preserve the freedom of designers to utilize them at will in their applications. This was unproblematic in the early stages of MTCA adoption, as AMC and RTM boards usually came in fixed pairs from the same manufacturer. A higher degree of modularity soon emerged in response to market demands, with companies providing single boards that had, in principle, complementary functions to the matching boards of other manufacturers. However, the slightly different pin assignments the different manufacturers had chosen for the Zone 3 connector usually meant that these multi-vendor board pairs remained incompatible.

Particle accelerator facilities were among the first to take note and try to rectify the situation. Waiting for standard setting committees like PICMG to resolve the issue in the course of a standard revision was not an option because of already on-going board development projects that required an immediate answer to this problem. DESY initiated a series of meetings with leading accelerator facilities and MTCA component suppliers to review the situation and explore possible solutions. The discussion was structured by subdividing the field into two classes, analog and digital. Difficulties arose from the fact that very different types of boards (e.g. digitizers vs. beam position monitors) were to be covered by a single agreement. Small changes in the pin assignment sometimes affected the whole architecture of the boards to be matched, and a revised power-up management procedure had to be developed. These discussions on Zone 3 culminated after 1.5 years in a convention of like-minded developers at DESY's MTCA Workshop in December 2012, and a jointly developed pin assignment recommendation was published shortly thereafter [5].

VALIDATION FUND PROJECT HVF-0016 HALF-TIME: PRELIMINARY CAVEATS

DESY's role as a large research organization with a *non-profit* mission holds unique opportunities in view of the long-term development of an emerging standard like MTCA.4. The organization acts as an expert developer, lead user, market educator, support instance and exchange platform for many other market participants, constantly working to remove significant barriers to adoption like the Zone 3 incompatibilities described earlier in this paper. To sustain these substantial efforts, DESY has accessed a special bridge-finance instrument of its parent Helmholtz Association called the *Helmholtz Validation Fund*, which aims to develop technologies that have originated in science to a proof-of-concept stage and facilitate private sector investments en route to market at the same time. HVF-0016, the two-year Helmholtz Validation Fund project that supports DESY's MTCA.4 activities, now approaches half-time, so a few preliminary caveats from a technology transfer and industrial relations perspective can be shared at this point: First, the seemingly inevitable delays that afflict most large R&D projects tend to aggravate at the interface of public research and private development, as many contractual details are not standard practice and have to be negotiated between the parties involved for the very first time. Second, the proliferation of electronic design automation software has resulted in major productivity gains in many organizations; however, joining the outputs of two competing software packages may prove impossible and result in a costly abort-and-restart exercise. Last, some expert qualifications required to do advanced electronic development work may be in such short supply on the labour market that a good working relationship with the academic sector emerges as the only way forward.

REFERENCES

[1] R. Kuhlmann, R. *ATCA: Advanced Telecom Computing Architecture - Die Plattform der Zukunft für Telekommunikationssysteme.* (Poing: Franzis Verlag, 2007), 15.

[2] T. Holzapfel, "MTCA market development and progress". MTCA Workshop for Industry and Research Book of Abstracts, 11/12 December 2012, DESY: Hamburg.

[3] European XFEL GmbH, ANNUAL REPORT 2011 (2012) 128; http://www.xfel.eu/documents/annual_reports

[4] J. Branlard et al., "THE EUROPEAN XFEL LLRF SYSTEM", MOOAC0, Proceedings of IPAC2012, p55, New Orleans, Louisiana, USA.

[5] DESY, "Zone 3 Connector Pin Assignment Recommendation"; http://mtca.desy.de/resources/zone_3_recommenda tion/index_eng.html

Copyright © 2013 by JACoW — cc Creative Commons Attribution 3.0 (CC-BY-3.0)

ISBN 978-3-95450-122-9