THE CASE OF MTCA.4: MANAGING THE INTRODUCTION OF A NEW CRATE STANDARD AT LARGE SCALE FACILITIES AND BEYOND*

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Abstract

The demands on hardware for control and data acquisition at large-scale research organizations have increased considerably in recent years. In response, modular systems based on the new MTCA.4 standard, jointly developed by large Public Research Organizations and industrial electronics manufacturers, have pushed the boundary of system performance in terms of analog/digital data processing performance, remote management capabilities, timing stability, signal integrity, redundancy and maintainability. Whereas such public-private collaborations are not entirely new, novel instruments are in order to test the acceptance of the MTCA.4 standard beyond the physics community, identify gaps in the technology portfolio and align collaborative R&D programs accordingly. We describe the on-going implementation of a time-limited validation project as means towards this end, highlight the challenges encountered so far and present solutions for a sustainable division of labor along the industry value chain.

MTCA AT A GLANCE

MTCA (also known as µTCA or MicroTCA, an abbreviation of Micro Telecommunications Computing Architecture) has evolved as a standard in the telecommunications industry from ATCA (Advanced Telecommunications Computing Architecture), a larger predecessor now dominating most of the market for telecom switching equipment. MTCA.0 marked the base specification for a smaller derivative standard, and MTCA.1, MTCA.2 and MTCA.3 added features needed to build ruggedized systems especially for the industrial and military markets. MTCA.4, mainly championed by the physics research community, brought further improvements regarding connectivity and signal precision. Defining feature of this latest amendment is the disentanglement of interfering signal paths made possible by the separation of boards, as depicted in Fig. 1 below.

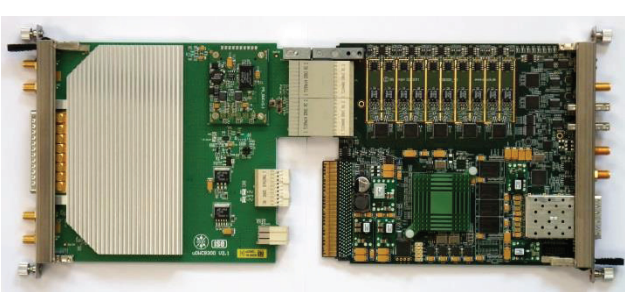

Figure 1: Pair of MTCA boards connected via Zone 3.

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MTCA ADVANCEMENTS ON THE CURRENT STATE-OF-THE-ART

The adoption of MTCA marks a departure from parallel bus topology, which has been deemed insufficient in the light of rapidly increasing demands regarding data throughput and low latency links [1]. MTCA offers an outstanding digital signal processing performance through serial bus topology while maintaining a high analog signal integrity through purely differential digital signal transmission. System scalability is ensured through a large variety of crate sizes and a wide range of board form factors, which allow users to start with small test systems and then migrate to larger and more powerful installations without changing the underlying technology.

MTCA was designed and maintained as an open and modular standard controlled by the PICMG (PCI Industrial Computer Manufacturers Group, a governing body of more than 200 organizations), which effectively inhibits vendor lock-in and greatly promotes product variety. A steadily growing number of research facilities and electronics manufacturers base their latest designs on MTCA, and a large spectrum of both general purpose and specialized boards has become commercially available as a result.

The extensive component redundancy options for failsafe operation as well as true *hot swap* capabilities to add or exchange components while the system is operational keep down-time to a minimum and further help to differentiate MTCA from other emerging competitors as well as existing legacy standards.

MTCA.4 as the latest addition to the evolving MTCA standard family adds value through a range of features and design measures that:

- enhance connectivity options through rear-side input/output channels in Rear Transfer Modules (RTMs), connecting to Advanced Mezzanine Cards (AMCs) in the front via Zone 3 connectors
- improve timing stability through radial clock lines for high-speed Analog Digital Converters (ADCs),
- provide enhanced shelf-management capabilities, e.g. to monitor and control power consumption, cooling conditions and mixed-vendor component compatibility.

JOINT MTCA.4 PORTFOLIO-BUILDING

Switching costs have been identified as a major barrier inhibiting the implementation of novel, superior standards [2]. The limited product variety that constrains every emerging standard in its early phases is arguably one of

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the most important cost drivers for early adopters, as work-arounds and intermediate solutions have to be found until fully functional hardware based on the new standard becomes widely available. MTCA in general and MTCA.4 in particular are no exception here. In view of the challenges that come with the operation of next generation particle accelerators and light sources, DESY has embarked on an ambitious program to design, build and test a wide range of high performance components exclusively based on the MTCA.4 standard, thereby closing many gaps in the portfolio, as Table 1 below illustrates.

Table 1: MTCA.4 Components Developed by DESY

Board	**Function**
DAMC2	Versatile data acquisition/ processing
DAMC-TCK7	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
DAMC-X2timer	Low jitter synchronisation system
DRTM-V2	2-channel vector modulator
DRTM-V2LF	2-channel vector modulator (low frequency version)
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
DRTM-DWC10	Ten channel high frequency down converter
DFMC-MD22	2-channel stepper motor driver

In parallel to board design, extensive research is underway to improve the performance of backplanes along various parameters [3]. Further efforts concern system-level integration of components and the mitigation of electromagnetic interference (EMI) inside the MTCA crates.

Apart from the obvious requirement to ensure the supply of high performance components for its own very demanding applications in beam diagnostics, data acquisition and machine controls, DESY also strives to make its newly developed designs available to other users in the research community and beyond through licensing for production to industrial partners. A broader spectrum of applications will result in larger production volumes for most of the boards and should also translate in faster debugging cycles, better support, secure long term supply and lower costs, as more firms enter this increasingly attractive market segment. Specialization patterns can already be observed, with *developer, manufacturer* and *system integrator* emerging as the primary roles. Vertical integration along this value chain remains an exception, but a growing number of bilateral collaborations between electronics companies as well as a few larger networks involving public research facilities have been established.

DESY has secured funding through its parent organization *Helmholtz Association* to function as a hub for such networking activities and actively promote the transfer of its MTCA.4 technology to industry in the course of a two-year *Helmholtz Validation Fund (HVF)* project, an 4m€ instrument devised to provide public-private bridge financing for emerging technologies en route to commercialization. It is the explicit goal of the HVF project "MTCA.4 for Industry" to identify and help remove the barriers to implementation for new users and foster widespread adoption, particularly through measures described in the following section.

FORMS OF CONTRIBUTIONS TO THE EMERGING MTCA.4 ECO-SYSTEM

Extensive communication with existing and potential users of MTCA systems revealed that system features, price/performance ratios and the availability of specific components are important, but do not account for all factors influencing the buying decision. Training and support measures as well as the opportunity for exchange with system experts and like-minded users are frequently included into the overall evaluation of an imminent system change situation. DESY has responded to this need with a range of "confidence-building measures" as quickly outlined below:

- **Website** [4]: information hub with comprehensive material for beginners, intermediate users and experts; updates on developments and events
- **Standardized licencing documents**: range of templates that are quickly customized to speed up negotiations between DESY and its licensors
- **Training sessions**: opportunity for MTCA users to learn basic system set-up, configuration and trouble shooting in the course of a two-day event conducted in collaboration with industry experts
- **MTCA Workshop**: Annual conference-style gathering of developers, users and suppliers of MTCA systems, including an industrial exhibition, pre-workshop tutorials and special-interest group meetings
- **Helpdesk**: Email-based bug tracking and user support facility, can be contacted with problem descriptions and help requests
- **Enhancement and extension of the MTCA.4 standard**: set of activities designed to eliminate 'blank spots' in the MTCA.4 specification and resolve current technical issues by providing guidance through recommendation documents jointly developed with interested parties in industry and research as well as basic system code.

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More recently, DESY has also begun to operate demonstration and test systems which can be used to run model applications in a controlled lab environment on site; a mobile version which can be temporarily shipped out to future collaborators for off-site testing is currently in preparation, see Fig. 2.

Figure 2: MTCA.4 crate in operation at DESY.

Representatives from other research facilities (including visiting students) as well as engineers from electronics companies regularly join the technical meetings at DESY to discuss the latest MTCA.4 developments and their implications for on-going research projects and industrial applications elsewhere.

MTCA INSTALLATIONS IN RESEARCH AND BEYOND – AN OUTLOOK

Applications at Large Scale Research Facilities

High frequency control systems for particle accelerators typically consist of a klystron driving a wave guide and its corresponding set of cavities, as Fig. 3 below illustrates.

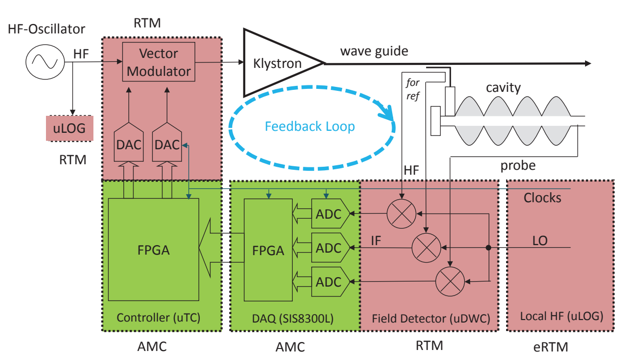

Figure 3: Typical accelerator control system layout based on MTCA.4 components

The challenge in terms of control system performance stems from the fact that multiple low-latency signals (<2µs] from sensors, clocks and reference sources have to be processed instantly with high precision to form an effective feedback loop. Adding the redundancy, hot-swap and remote maintainability requirements of present day accelerator facilities to the equation, it became clear that adapting the MTCA standard (designed with similar requirements from telecommunications operators in mind) to the needs of the physics research community (taking shape as MTCA.4) was easier than modifying the existing installations based on earlier standards.

With the first MTCA.4-based control systems now fully operational at DESY's FLASH facility, interest has picked up on the detector side of the particle accelerator community as well, as data acquisition is well into the gigasample/second region in many experiments, driving the specifications in terms of data throughput accordingly. MTCA.4 pilot installations have also emerged in plasma physics research, and application-ready platforms for use in other fields of science and smaller research units (such as university departments) are currently in preparation.

Applications in Industry

While MTCA.4 continues to make headway in research facilities worldwide, take-up by industry has been slower than originally predicted. Confirmed applications include high-speed quality inspection systems as an integral part of production process control applications in various industries. DESY's own effort to transfer MTCA.4 technology to industry within the HVF project has initially focused on a klystron protection system for use in high-power radio transmission installations, but market research has confirmed further potential in radar data processing, medical imaging and laser control systems. Further fields of application are currently investigated.

MANAGING MTCA.4 DISSEMINATION

At roughly half-time of DESY's HVF project, two key learnings have already emerged: First, educating a diverse range of research and engineering communities on the capabilities of the new standard requires an extensive presence at trade fairs, conferences and workshops. The resources needed for preparation, implementation and follow-up of these events are difficult to estimate, and often a surprising amount of engineering capacity is drained from the ongoing development work. Second, the management capacity needed to conduct contract negotiations in a public-private research collaboration setting tends to be underestimated, resulting in prolonged periods of legal uncertainty and difficulties to implement a joint work plan in time.

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