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MICROTCA TECHNOLOGY LAB AT DESY: CURRENT CASES IN TECHNOLOGY TRANSFER*

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Abstract

MicroTCA-based LLRF systems for beam control and beam diagnostics are gaining traction in many facilities around the world. Over the past decade, a comprehensive portfolio of hardware solutions (boards, crates, backplanes) has become available to cater for demanding signal processing applications in state-of-the-art facilities like the European XFEL.

Gradually, industrial applications of MicroTCA also have become more common. In response to various requests, DESY has opened the *MicroTCA Technology Lab (A Helmholtz Innovation Lab)* in April 2018 as a service unit for research and industry with a focus on: customer-specific developments in MicroTCA (hardware, firmware, and software), high-end test and measurement services, electronic design consulting, and system integration.

We report on intermediate results and emerging projects after one year of operation, with transfer examples from the industrial automation and medical technology sectors as well as overlapping developments for the physics research community.

HELMHOLTZ INNOVATION LABS: TECHNOLOGY TRANSFER FROM LARGE RESEARCH FACILITIES

Large public research facilities are increasingly called upon to be active players in the field of technology transfer. In Germany, the Helmholtz Association has devised a portfolio of instruments to bridge the gap between basic research and market entry [1]. One of the recent additions to this portfolio is the *Helmholtz Innovation Lab*, a novel funding and support instrument to create “entrepreneurial enabling spaces” with a focus on disruptive technologies. DESY joined the first round of these Helmholtz Innovation Labs in 2016 with the *MicroTCA Technology Lab*, an organisational unit dedicated entirely to customers from research and industry that develop or deploy MicroTCA-based solutions.

Officially open since April 2018, the lab now also serves as a focal point for existing streams of longstanding MicroTCA-related activities at DESY, such as hardware and firmware licensing, training sessions and the annual MicroTCA Workshop.

THE MICROTCA STANDARD IN RESEARCH AND INDUSTRY

MicroTCA originated as an open, modular electronics standard in telecommunications and has been continuously improved to accommodate application scenarios in research (especially particle accelerators and plasma fusion reactors) and various industries, including transport, defence & aerospace, medical technology and industrial automation. It is jointly governed by members of the non-profit organization PICMG [2].

The impetus for DESY to evaluate, select and eventually contribute to the improvement of the standard came with the European XFEL, which required high-performance, failsafe electronics in a compact format along the beamline, as Fig. 1 illustrates.

Figure 1: MicroTCA installations at the European XFEL.

The MicroTCA standard comes with extensive remote diagnostics and remote management features as well as hot-swap and redundancy options. Originally developed to maximize up-time in telecom installations, these features were also embraced by the physics research community, where physical access to beamline installations is often restricted to a few days per month.

MicroTCA’s open, modular system approach spawned an eco-system of highly specialized suppliers, system integrators and developers, so that in principle, vendor lock-in situations cannot occur – an important argument for decision makers who are responsible for scientific installations with an expected lifetime of usually more than 20 years. The availability of standardized components that have been proven to work in major facilities around the world [3] allow new user groups to focus their development capacity on MicroTCA boards that are either not yet commercially available or so specific that they warrant a custom design. Buying all other parts “off the shelf” greatly reduces average project duration, development risk and total lifetime cost of systems. This effect is further amplified by MTCA.4, the latest version of the MicroTCA standard that introduced *Rear Transfer Modules (RTMs)* in addition to the existing *Advanced Mezzanine Cards (AMCs)* [4], which enable the separation of the development cycles for analogue (RTM) and digital (AMC) electronics and save costs compared to monolithic design approaches that attempt to accommodate both on the same board.

A wide variety of board formats and crate sizes has emerged over time, so that MicroTCA today is a highly scalable platform that allows developers to “start small”

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with a desktop system and roll out larger installations later, usually deploying the same type of boards all along. Recent product innovations include chassis with 1-2 height units (19”), which will allow for even more cost-efficient and compact configurations; housing, for example, complete LLRF systems and associated diagnostics in smaller facilities as well as beam control applications in medical accelerators.

MICROTCA TECHNOLOGY LAB: A NEW ENABLING SPACE FOR TECHNOLOGY TRANSFER

The comparatively smooth commissioning of an extremely large installation like the European XFEL sparked a lot of interest in MicroTCA as the underlying technology platform. Since 2012, DESY has made MicroTCA designs available before through extensive licensing and cooperation programs with industry partners, but scope and scale of the enquiries in recent years required a new approach. The concept of the MicroTCA Technology Lab now explicitly views technology transfer opportunities as “test cases” for sustainable business operations, possibly taking the form of a separate legal entity in the future.

Case 1: High-end Test and Measurement

Modern communication busses in embedded electronics require high-frequency measurement equipment for up to 20GHz that usually is beyond the reach of small and medium enterprises (SMEs). The prohibitive costs of these devices often force SMEs out and result in designs that claim compliance to applicable standards based on simulation results rather than measurements, which can be problematic when failsafe operation and certifications are firm requirements. Many MicroTCA board designs push layer stacks to the limit and feature high-performance FPGAs of the latest generations, so signal integrity issues rank prominently on the list of issues. As PCB routing, material choice and tacit knowledge “what works” become increasingly complex, an institution that bundles high-end equipment with design expertise and makes it affordable to SMEs is a valuable contribution in itself. In its first year of operation, the lab handled requests from:

- a *medical technology* developer who struggled with sporadic data loss in a medical imaging device,
- a leading manufacturer of *banknote printing machines* that sought advice on securing the signal integrity of a high-speed data connection between two boards,
- a major *industrial facility equipment* provider that needed support trouble-shooting a network-switched power supply for large cabinets.

From a lab development perspective, these cases are of limited commercial value, but often serve as “conversation starters” for high-value follow-on projects described in the following case studies.

Case 2: MTCA.4 Development

DESY has long been involved in the development efforts to complement the MicroTCA technology platform with the hardware, firmware and software needed to run accelerators. That first and foremost includes board designs for beam control and beam diagnostics. Signals up to 6GHz are usually sampled and processed directly; for higher frequencies a range of down-converter/ vector modulators exists. Solutions for triggering and timing, motor- and piezo control, as well as carrier cards to incorporate other form factors like FMC are also widely available. The MicroTCA Technology Lab frequently builds on this portfolio: These commercially available boards can serve as a starting point for derivate versions and more specialized solutions made to customer specification. One of the projects highlighting this fast and flexible approach included an industrial client who required a *laser-based measurement system for optical components*, feeding sensor signals directly into a MicroTCA crate.

The MicroTCA standard excels in application scenarios where large amounts of data have to be processed with high precision and speed, and this is where the lab tends to focus its advance research activities to showcase the capabilities of the standard. A fairly recent example is *high-resolution image processing* using GigE Vision® cameras that feed their data directly into the FPGA via an AMC card on the front side of the crate. Pilot applications in accelerator facilities include beam target protection and beam quality control – there they often complement MicroTCA installations that already exist along the beamlines (which helps to keep the costs down). Initial applications in industry focus on the visual inspection of fast-moving objects in automated quality control systems.

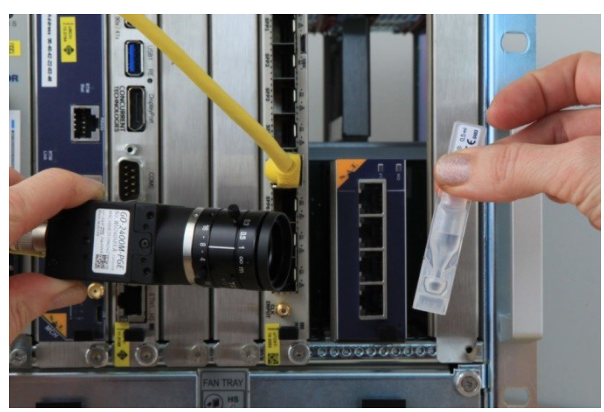

Figure 2: GigE Vision® on the MicroTCA platform: visual inspection of vials.

Figure 2 illustrates an example from the pharmaceutical industry, where vials in a production line have to be checked for correct content and possible impurities.

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Case 3: Turn-key System Configuration

Many MicroTCA-based application scenarios call for a *complete system design*, covering every aspect from the analysis of the initial requirements to the handover of a ready-to-use system. Major milestones along this path are the procurement and configuration of components, the design of missing elements (hardware, firmware, software) and their integration into a fully functional and tested installation. The engineering of interfaces to auxiliary and control systems as well as supporting activities like training, maintenance and upgrades are also increasingly inquired.

An example of an ongoing project of this scale is TARLA (Turkish Accelerator and Radiation Laboratory Ankara), for which *the low-level radiofrequency (LLRF)* system is currently in the commissioning phase at the DESY site in Hamburg/Germany, as Fig 3 illustrates.

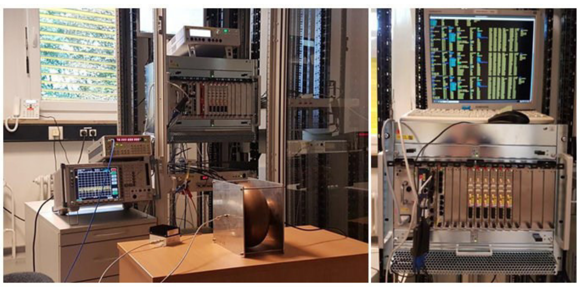

Figure 3: Commissioning and test of the MicroTCA.4-based LLRF system for TARLA.

The TARLA accelerator will house two superconducting modules with two TESLA-type cavities per module, as well as normal-conducting buncher cavities operating at 260 MHz and 1.3 GHz, respectively. TARLA will take over numerous design features of the radiation source *ELBE* (Electron Linac for beams with high Brilliance and low Emittance) at HZDR, another Helmholtz-Zentrum in Dresden-Rossendorf/Germany. Since DESY groups have been cooperating closely with HZDR on the design of ELBE, a large body of transferable knowledge exists that can be re-applied through the MicroTCA Technology Lab to other facilities worldwide.

Around this basic project set-up for a MicroTCA.4-based LLRF system, options for related system extensions using the same standard become increasingly viable. These options include *beam position monitoring, laser-synchronization systems* and *photon science applications*.

Further transfer opportunities for MicroTCA.4 exist in the field of medical accelerators for cancer treatments, as existing facilities continue to investigate new technology platforms to counteract emerging obsolescence problems. Furthermore, a stream of new proton beam facilities is coming online, inducing a double-digit market growth worldwide until at least 2024 [5]. LLRF systems for beamlines in research and therapy are remarkably similar along many characteristics, so that major components can in principle be transferred without larger development efforts.

PERSPECTIVES FOR LAB DEVELOPMENT

Helmholtz Innovation Labs are designed to reinforce existing technology transfer structures at the large-scale public research centers of the Helmholtz Association throughout Germany. In the case of DESY's MicroTCA Technology Lab, the mission is to facilitate new applications in research and industry with a view to establish self-sustaining operations long-term. A recurrent theme on this path is the re-use of proven concepts and existing hardware wherever possible in order to minimize development risks, shorten project cycles and establish an inter-project learning curve.

The cases highlighted in the previous section mark typical stages of a 'customer journey' where trust has to earned and a working relationship established with relatively small transactions in the beginning (Case 1) before larger projects (Case 2, Case 3) are even considered. On one hand, building business-like structures within the confines of a large public research organisation is possible, but has multiple legal, financial and logistical limitations which can be difficult and time-consuming to overcome. On the other hand, proximity to the DESY developer groups closest to the technology is vital for the delivery of large and technologically challenging projects.
Therefore, the current development plan for the lab attempts to achieve the best of both worlds - a small, agile lab structure that remains firmly embedded in DESY, and a larger structure that will form a business in a private company.

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